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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/411,317	10/13/2009	7602080	108144-200701/US (TGY010)	4944

64494 7590 09/23/2009
GREENBERG TRAURIG, LLP (SV)
IP DOCKETING
2450 COLORADO AVENUE
SUITE 400E
SANTA MONICA, CA 90404

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site <http://pair.uspto.gov> for additional applicants):

Ron HADAR, Cupertino, CA;
Shmuel ARDITI, Los Gatos, CA;

**SMA Solar Technology
America LLC v.
Tigo Energy Inc.
IPR2023-01184
Patent No. 8,823,218
Ex. 1015**



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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/411,317	03/25/2009	Ron HADAR	108144-200701/US (TGY010)	4944
64494 7590 09/15/2009 GREENBERG TRAURIG, LLP (SV) IP DOCKETING 2450 COLORADO AVENUE SUITE 400E SANTA MONICA, CA 90404			EXAMINER PALADINI, ALBERT WILLIAM	
			ART UNIT 2836	PAPER NUMBER
			NOTIFICATION DATE 09/15/2009	DELIVERY MODE ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

LAIPMAIL@GTLAW.COM
allenr@gtlaw.com
santosv@gtlaw.com

Response to Rule 312 Communication	Application No.	Applicant(s)
	12/411,317	HADAR ET AL.
	Examiner	Art Unit
	ALBERT W. PALADINI	2836

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

1. ☒ The amendment filed on 8/18/09 under 37 CFR 1.312 has been considered, and has been:

a) ☐ entered.

b) ☒ entered as directed to matters of form not affecting the scope of the invention.

c) ☐ disapproved because the amendment was filed after the payment of the issue fee.

Any amendment filed after the date the issue fee is paid must be accompanied by a petition under 37 CFR 1.313(c)(1) and the required fee to withdraw the application from issue.

d) ☐ disapproved. See explanation below.

e) ☐ entered in part. See explanation below.

/Albert W Paladini/
Primary Examiner, Art Unit 2836

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail** **Mail Stop ISSUE FEE**
Commissioner for Patents
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INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

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Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being electronically transmitted to the U.S. Patent and Trademark Office via EFS-Web on the date shown below.

Anne Collette	(Depositor's name)
/Anne Collette/	(Signature)
August 18, 2009	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/411,317	03/25/2009	Ron HADAR	108144-200701/US (TGY010)	4944

TITLE OF INVENTION:

SYSTEMS AND METHODS TO BALANCE SOLAR PANELS IN A MULTIPANEL SYSTEM

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	\$755	\$300	\$1055	11/09/2009

EXAMINER	ART UNIT	CLASS-SUBCLASS
PALADINI, ALBERT WILLIAM	2836	307-020000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

1 Greenberg Traurig, LLP

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Tigo Energy, Inc.

Los Gatos, CA

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are enclosed:

☒ Issue Fee

☒ Publication Fee (No small entity discount permitted)

☐ Advance Order - # of Copies _____

4b. Payment of Fee(s):

☐ A check in the amount of the fee(s) is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☒ The Director is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number 50-2638 (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

The Director of the USPTO is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature /John P. Ward/

Date August 18, 2009

Typed or printed name John P. Ward

Registration No. 40,216

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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Exhibit 1015

Page 4 of 275

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor:	Ron Hadar et al.	Examiner:	Albert William Paladini
Serial No.:	12/411,317	Group Art Unit:	2836
Filed:	March 25, 2009	Confirmation:	4944
Title:	SYSTEMS AND METHODS TO BALANCE SOLAR PANELS IN A MULTI-PANEL SYSTEM		

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AMENDMENT AFTER ALLOWANCE UNDER 37 CFR § 1.312

Sir:

Applicant respectfully requests the entry of the following amendments prior to the issuance of the above-referenced patent application.

IN THE CLAIMS

1. (Original) An apparatus, comprising:
a photovoltaic energy production unit to generate electricity; and
a management unit coupled between the photovoltaic energy production unit and a series connection of energy production units, the management unit having at least a first switch, the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit, the management unit to allow a second current larger than the first current to flow through the series connection of energy production units.
2. (Original) The apparatus of claim 1, wherein the management unit further comprises an energy storage unit connected to the photovoltaic energy production unit;
wherein, when the first switch is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current is equal to or larger than a sum of the first current and the third current; and
wherein, when the first switch is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy production units, and the management unit provides at least one path for the series connection of energy production units.
3. (Original) The apparatus of claim 2, wherein the energy storage unit comprises a capacitor coupled in parallel with the energy production unit; and when the first switch is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit.

4. (Currently Amended) The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode[[,]];
a second switch, wherein the management unit turns off the second switch when the first switch is turned on[[,]]; and
a synchronous rectifier.
5. (Original) The apparatus of claim 1, wherein the management unit further comprises a controller to control the first switch according to a duty cycle.
6. (Original) The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift, and a synchronization pulse.
7. (Currently Amended) The apparatus of claim 5, wherein the controller is configured to control the first switch based on one of:
at least one operating parameter associated with the energy production unit[[,]];
at least one operating parameter of a separate energy production unit[[,]]; and
a control signal received from a remote unit.
8. (Original) The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current, a voltage, and a temperature; and the duty cycle is based on a maximum power point of the energy production unit.
9. (Original) The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series, the second management unit having at least a second switch, the second photovoltaic energy

production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit, the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units.

10. (Original) The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel; and the management unit has no inductor and is integrated on the solar panel.
11. (Original) A method, comprising:
providing a management unit to couple a solar energy production unit to a series connection of energy production units, the management unit having a first switch and an energy storage unit coupled to the solar energy production unit; and
determining at least one parameter to control the first switch;
wherein, when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current; and
wherein, when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units, and the management unit provides at least one path for the series connection of energy production units.
12. (Original) The method of claim 11, wherein the determining comprises:
computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit.

13. (Original) The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises:
receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units; and
identifying a first voltage among the operating voltages;
wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit.
14. (Original) The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and
wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units.
15. (Original) The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected; and
undoing an adjustment to the duty cycle that causes the decrease.
16. (Original) The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected; and
in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit.

17. (Original) The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter; and
adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point.
18. (Original) The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:
receiving operating parameters of a plurality of solar energy production units connected in series;
identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter;
identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units;
identifying a second maximum power point voltage of the second solar energy production unit;
computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage; and
adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage.
19. (Original) The method of claim 12, further comprising:
adjusting the duty cycle to increase the first current.
20. (Original) The method of claim 12, further comprising:
adjusting the duty cycle to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units, the string including the solar energy production unit.

REMARKS

Applicant has amended the claims herein to correct grammatical and/or typographical errors. No new matter has been added.

Respectfully submitted,

Date: August 18, 2009

/John P. Ward/

John P. Ward

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor:	Ron Hadar et al.	Examiner:	Albert William Paladini
Serial No.:	12/411,317	Group Art Unit:	2836
Filed:	March 25, 2009	Confirmation:	4944
Title:	SYSTEMS AND METHODS TO BALANCE SOLAR PANELS IN A MULTI-PANEL SYSTEM		

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Alexandria, VA 22313-1450

COMMENTS ON STATEMENT OF REASONS FOR ALLOWANCE

Applicant respectfully provides the following comments on the Statement of Reasons for Allowance that was provided in the Notice of Allowability mailed in the subject application.

Applicant assumes that the allowed claims are to be interpreted based on the limitations recited in the claims rather than the paraphrases provided in the statement of reasons for allowance. Further, Applicant assumes that the statement of reasons for allowance is to be taken in light of the exact limitations recited in the allowed claims.

The allowed claims should not be interpreted to include the limitations that are not explicitly recited in the claims. The paraphrases in the statement of reasons for allowance should not be used in a way to narrow the scope of the allowed claims.

Respectfully submitted,

Date: August 18, 2009

/John P. Ward/

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Electronic Patent Application Fee Transmittal

Application Number:	12411317			
Filing Date:	25-Mar-2009			
Title of Invention:	SYSTEMS AND METHODS TO BALANCE SOLAR PANELS IN A MULTI-PANEL SYSTEM			
First Named Inventor/Applicant Name:	Ron HADAR			
Filer:	John Patrick Ward/Anne Collette			
Attorney Docket Number:	108144-200701/US (TGY010)			
Filed as Small Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl issue fee	2501	1	755	755
Publ. Fee- early, voluntary, or normal Exhibit 1015	1504	1	300	300

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				1055

Electronic Acknowledgement Receipt

EFS ID:	5911929
Application Number:	12411317
International Application Number:	
Confirmation Number:	4944
Title of Invention:	SYSTEMS AND METHODS TO BALANCE SOLAR PANELS IN A MULTI-PANEL SYSTEM
First Named Inventor/Applicant Name:	Ron HADAR
Customer Number:	64494
Filer:	John Patrick Ward/Anne Collette
Filer Authorized By:	John Patrick Ward
Attorney Docket Number:	108144-200701/US (TGY010)
Receipt Date:	18-AUG-2009
Filing Date:	25-MAR-2009
Time Stamp:	20:04:04
Application Type:	Utility under 35 USC 111(a)

Payment information:

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Payment Type	Deposit Account
Payment was successfully received in RAM	\$ 1055
RAM confirmation Number	4938
Deposit Account	502638
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1	Issue Fee Payment (PTO-85B)	108144-200701US_Issue_Fee.pdf	192227	no	1
			b27bd52eb0b998f304b1bffd9bb01cd2f87c1a1		
Warnings:					
Information:					
2		108144-200701US_Rule_312_Amendment.pdf	94425	yes	7
			a0c69b017ef3d5ca30f68f0fba89e77dc9a19a5c		
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Amendment after Notice of Allowance (Rule 312)		1	1	
	Claims		2	6	
	Applicant Arguments/Remarks Made in an Amendment		7	7	
Warnings:					
Information:					
3	Post Allowance Communication - Incoming	108144-200701US_Comments_on_Reasons_for_Allowance.pdf	81737	no	1
			233286db269c7e6099727364c99e898e464c5944		
Warnings:					
Information:					
4	Fee Worksheet (PTO-875)	fee-info.pdf	32038	no	2
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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

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Receipt date: 08/05/2009

12411317 - CAU: 2836

Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

Approved for use through 05/31/2009. OMB 0851-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12411317
	Filing Date	2009-03-25
	First Named Inventor	Ron Hadar
	Art Unit	2838
	Examiner Name	Albert William Paladini
	Attorney Docket Number	108144-200701/US (TGY010)

U.S. PATENTS Remove						
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1	4580090		1986-04-01	Bailey et al.	
	2	4604567		1986-08-05	Chetty	
	3	4873480		1989-10-10	Lafferty	
	4	5027051		1991-06-25	Lafferty	
	5	5504418		1996-04-02	Ashley	
	6	5747987		1998-05-05	Muljadi et al.	
	7	5932994		1999-08-03	Jo et al.	
	8	7394237		2008-07-01	Chou et al.	

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Receipt date: 08/05/2009 INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12411317	12411317 - GAU: 2836
	Filing Date		2009-03-25	
	First Named Inventor		Ron Hadar	
	Art Unit		2836	
	Examiner Name		Albert William Paladini	
	Attorney Docket Number		108144-200701/US (TGY010)	

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	1	0178757	EP		1986-04-23	TRW Inc.	☐
	2	2005069096	WO		2005-07-28	Koninklijke Philips Electronics	☐
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Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.					T ⁵
	1	ALONSO, R, et al., "A New Distributed Converter Interface for PV Panels," 20th European Photovoltaic Solar Energy Conference, Barcelona, Spain, pp. 2288-2291, June 6-10, 2005.					☐
	2	ALONSO, R, et al., "Experimental Results of Intelligent PV Module for Grid-Connected PV Systems," 21st European Photovoltaic Solar Energy Conference, Dresden, Germany, pp. 2297-2300, September 4-8, 2006.					☐
	3	BASSO, Tim, "IEEE Standard for Interconnecting Distributed Resources With the Electric Power System," IEEE PES Meeting, June 9, 2004.					☐

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ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AP/

Receipt date: 08/05/2009 INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12411317 12411317 - GAU: 2836
	Filing Date		2009-03-25
	First Named Inventor	Ron Hadar	
	Art Unit	2836	
	Examiner Name	Albert William Paladini	
	Attorney Docket Number	108144-200701/US (TGY010)	

4	Boostbuck.com, "The Four Boostbuck Topologies," located at http://www.boostbuck.com/TheFourTopologies.html , 2003.	☐
5	ENSLIN, Johan H.R., et al., "Integrated Photovoltaic Maximum Power Point Tracking Converter," IEEE Transactions on Industrial Electronics, vol. 44, no. 6, pp. 769-773, December 1997.	☐
6	GAUTAM, Nalin K. et al., "An Efficient Algorithm to Simulate the Electrical Performance of Solar Photovoltaic Arrays," Energy, Vol. 27, No. 4, pp. 347-361, 2002.	☐
7	International Patent Application PCT/US08/75127, International Search Report and Written Opinion (mailed April 28, 2008)	☐
8	LINARES, Leonor et al., "Improved Energy Capture in Series String Photovoltaics via Smart Distributed Power Electronics," 24th Annual IEEE Applied Power Electronics Conference and Exposition, pp. 904-910, February 15, 2009.	☐
9	NORDMANN, T. et al., "Performance of PV Systems Under Real Conditions," European Workshop on Life Cycle Analysis and Recycling of Solar Modules, The "Waste" Challenge, Brussels, Belgium, March 18-19, 2004.	☐
10	ROMAN, Eduardo, et al., "Intelligent PV Module for Grid-Connected PV Systems," IEEE Transactions on Industrial Electronics, vol. 53, no. 4, pp. 1066-1073, August 2006.	☐
11	WALKER, Jeffrey R. et al., "Cascaded DC-DC Converter Connection of Photovoltaic Modules," IEEE Transactions on Power Electronics, vol. 19, no. 4, pp. 1130-1139, July 2004.	☐

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	/Albert Paladini/	Date Considered	08/17/2009
---------------------------	-------------------	------------------------	------------

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

Notice of Allowability

Application No.

12/411,317

Examiner

ALBERT W. PALADINI

Applicant(s)

HADAR ET AL.

Art Unit

2836

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to application filed on 3/25/09.
2. ☒ The allowed claim(s) is/are 1-20.
3. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☐ All b) ☐ Some* c) ☐ None of the:
- ☐ Certified copies of the priority documents have been received.
 - ☐ Certified copies of the priority documents have been received in Application No. _____.
 - ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).
- * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.

THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
- (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
- 1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
- (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.
- Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

- | | |
|---|--|
| 1. ☒ Notice of References Cited (PTO-892) | 5. ☐ Notice of Informal Patent Application |
| 2. ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948) | 6. ☐ Interview Summary (PTO-413),
Paper No./Mail Date _____. |
| 3. ☒ Information Disclosure Statements (PTO/SB/08),
Paper No./Mail Date <u>3/25/09</u> | 7. ☐ Examiner's Amendment/Comment |
| 4. ☐ Examiner's Comment Regarding Requirement for Deposit
of Biological Material | 8. ☒ Examiner's Statement of Reasons for Allowance |
| | 9. ☐ Other _____. |

/Albert W Paladini/
Primary Examiner, Art Unit 2836

Reasons for Allowance

1. The following is an examiner's statement of reasons for allowance: None of the references cited or the art searched disclose or teach alone or in combination the apparatus including a photovoltaic energy production unit to generate electricity where a management unit is coupled between the photovoltaic energy production unit and a series connection of energy units, and the management unit has a first switch which connects the photovoltaic energy production unit to the series connection of energy units allowing a first current to flow. The references cited and the art searched do not also teach that the management unit allows a second current larger than the first current to flow through the series connection of energy production units as recited in claims 1 and 11.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Relevant Prior Art

2. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

Blanc (7,259,474) discloses a system for collecting power from power sources such as solar cells, where current from multiple solar panels is converted to alternating current through the use of multiple converters.

Art Unit: 2836

Lai (7,336,004) discloses topologies for using multiple energy sources, using photovoltaic energy arrays as one of the primary power sources.

McNamara (7,462,955) discloses electrical power distribution systems utilizing a variety of power sources including photovoltaic arrays.

Eckroad (7,518,266) discloses an electric power transmission system using a plurality of diverse distributed generation DC power sources including photovoltaic devices.

Nomoto (7,538,451) discloses a power system, and teaches using a solar cell control scheme for operation with the operating point set to a maximum point from the inherent current and voltage characteristics.

Yoshikawa (7,545,053) discloses a power supply system which includes some of a micro gas turbine, a fuel cell battery, a NAS battery, a lead battery, an aero generator, and a solar power generator.

3. Any inquiry concerning this communication or earlier communication from the examiner should be directed to Albert W. Paladini whose telephone number is 571-272-3748. The examiner can normally be reached from 7:00 AM to 3 PM on Monday, Tuesday, Thursday or Friday.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Mr. Rexford Barnie can be reached on 571-272-7492. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

/Albert W Paladini/
Primary Examiner, Art Unit 2836

7/24/09

Notice of References Cited	Application/Control No. 12/411,317		Applicant(s)/Patent Under Reexamination HADAR ET AL.	
	Examiner ALBERT W. PALADINI		Art Unit 2836	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-7,259,474	08-2007	Blanc, James Joseph	307/45
*	B	US-7,336,004	02-2008	Lai, Jih-Sheng	307/66
*	C	US-7,462,955	12-2008	McNamara et al.	307/64
*	D	US-7,518,266	04-2009	Eckroad, Steven Wallace	307/82
*	E	US-7,538,451	05-2009	Nomoto, Kazutoshi	307/66
*	F	US-7,545,053	06-2009	Yoshikawa et al.	307/19
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Search Notes 	Application/Control No. 12411317	Applicant(s)/Patent Under Reexamination HADAR ET AL.
	Examiner ALBERT W PALADINI	Art Unit 2836

SEARCHED			
Class	Subclass	Date	Examiner
307	19, 20, 64-66	7/20/09	awp
136	244, 243, 251, 206	7/21/09	awp

SEARCH NOTES		
Search Notes	Date	Examiner
EAST	7/20/09	awp

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner
307	20, 19	7/24/09	awp

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BIB DATA SHEET

CONFIRMATION NO. 4944

SERIAL NUMBER 12/411,317	FILING or 371(c) DATE 03/25/2009 RULE	CLASS 136	GROUP ART UNIT 2836	ATTORNEY DOCKET NO. 108144-200701/US (TGY010)		
APPLICANTS Ron HADAR, Cupertino, CA; Shmuel ARDITI, Los Gatos, CA; ** CONTINUING DATA ***** This appln claims benefit of 61/200,601 12/02/2008 ** FOREIGN APPLICATIONS ***** ** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** ** SMALL ENTITY ** 04/01/2009						
Foreign Priority claimed ☐ Yes ☒ No 35 USC 119(a-d) conditions met ☐ Yes ☐ No Verified and /ALBERT WILLIAM PALADINI/ Acknowledged Examiner's Signature		☐ Met after Allowance Initials	STATE OR COUNTRY CA	SHEETS DRAWINGS 8	TOTAL CLAIMS 20	INDEPENDENT CLAIMS 2
ADDRESS GREENBERG TRAUIG, LLP (SV) IP DOCKETING 2450 COLORADO AVENUE SUITE 400E SANTA MONICA, CA 90404 UNITED STATES						
TITLE Systems and Methods to Balance Solar Panels in a Multi-Panel System						
FILING FEE RECEIVED 462	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:			☐ All Fees		
				☐ 1.16 Fees (Filing)		
				☐ 1.17 Fees (Processing Ext. of time)		
				☐ 1.18 Fees (Issue)		
				☐ Other _____		
			☐ Credit			

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	105	("5245985") or ("6129844") or ("6184058") or ("4292136") or ("4301323") or ("4331829") or ("4341917") or ("4847669") or ("4909045") or ("5354385") or ("5417052") or ("5468521") or ("5504015") or ("5575855") or ("5601074") or ("5620531") or ("5658448") or ("5740677") or ("5842813") or ("5974803") or ("5981865") or ("6048621") or ("6051774") or ("6116034") or ("6399411") or ("6468433") or ("7459064") or ("20050109393") or ("20050172150") or ("20060000616") or ("20060060358") or ("20070272416") or ("20080087437") or ("5685362") or ("5871952") or ("5931157") or ("4243432") or ("4255208") or ("4262411") or ("4299445") or ("4313022") or ("4337997") or ("4342650") or ("4381978") or ("4412430") or ("4425216") or	USPAT; FPRS; EPO; JPO; DERWENT	OR	OFF	2009/07/20 09:39

		("4459343") or ("4481774") or ("4491487") or ("4497724")).PN.				
L2	4	1 and (solar adj panel)	USPAT; FPRS; EPO; JPO; DERWENT	OR	ON	2009/07/20 09:39
L3	24	1 and photovoltaic	USPAT; FPRS; EPO; JPO; DERWENT	OR	ON	2009/07/20 09:40
L4	28	2 or 3	USPAT; FPRS; EPO; JPO; DERWENT	OR	ON	2009/07/20 09:40
L5	179	(307/19,20).OCLS.	USPAT; FPRS; EPO; JPO; DERWENT	OR	OFF	2009/07/20 09:41
L6	4	5 and ((solar adj panel) or photovoltaic)	USPAT; FPRS; EPO; JPO; DERWENT	OR	ON	2009/07/20 09:42
L7	605	(photovoltaic or (solar cell)) with supplement with (energy or power)	USPAT; FPRS; EPO; JPO; DERWENT	OR	ON	2009/07/20 09:53
L8	24	((photovoltaic or (solar cell)) with supplement with (energy or power)) same switch	USPAT; FPRS; EPO; JPO; DERWENT	OR	ON	2009/07/20 09:54
L9	6	((photovoltaic or (solar adj cell)) with supplement with (energy or power)) same switch	USPAT; FPRS; EPO; JPO; DERWENT	OR	ON	2009/07/20 10:08

7/ 20/ 2009 10:10:12 AM

EAST Search History**EAST Search History (Prior Art)**

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	3100	(307/64-66,71). CCLS.	USPAT; FPRS; EPO; JPO; DERWENT	OR	OFF	2009/07/20 10:38
L2	149	1 and (photovoltaic or (solar adj cell) or (solar adj Panel))	USPAT; FPRS; EPO; JPO; DERWENT	OR	ON	2009/07/20 10:40

7/ 20/ 2009 10:40:22 AM

EAST Search History**EAST Search History (Prior Art)**

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	3100	(307/64-66,71). CCLS.	USPAT; FPRS; EPO; JPO; DERWENT	OR	OFF	2009/07/20 10:38
L2	149	1 and (photovoltaic or (solar adj cell) or (solar adj Panel))	USPAT; FPRS; EPO; JPO; DERWENT	OR	ON	2009/07/20 10:40
L3	86	2 and series	USPAT; FPRS; EPO; JPO; DERWENT	OR	ON	2009/07/20 10:56

7/ 20/ 2009 10:59:37 AM

Receipt date: 03/25/2009

Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

12411317 - GAI-2836

Approved for use through 01/31/2009. OMB 0651-0031

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number			
	Filing Date			
	First Named Inventor	Ron Hadar		
	Art Unit			
	Examiner Name	Not Assigned		
	Attorney Docket Number	108144-200701/US (TGY010)		

U.S.PATENTS						
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	5648731	A1	1997-07-15	Decker et al.	

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS						
Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20050172995	A1	2005-08-11	Rohrig et al.	

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS								
Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1	2005112551	WO	A2	2005-12-01	Hansung Engineering Co. LTD		☐

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NON-PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵

Receipt date: 03/25/2009 INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12411317 - GAU: 2836
	Filing Date		
	First Named Inventor	Ron Hadar	
	Art Unit		
	Examiner Name	Not Assigned	
	Attorney Docket Number	108144-200701/US (TGY010)	

	1		☐
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If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	/Albert Paladini/	Date Considered	07/20/2009
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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.



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NOTICE OF ALLOWANCE AND FEE(S) DUE

64494

7590

08/07/2009

GREENBERG TRAURIG, LLP (SV)
IP DOCKETING
2450 COLORADO AVENUE
SUITE 400E
SANTA MONICA, CA 90404

EXAMINER

PALADINI, ALBERT WILLIAM

ART UNIT

PAPER NUMBER

2836

DATE MAILED: 08/07/2009

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
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12/411,317

03/25/2009

Ron HADAR

108144-200701/US

4944

TITLE OF INVENTION: SYSTEMS AND METHODS TO BALANCE SOLAR PANELS IN A MULTI-PANEL SYSTEM (TGY010)

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
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nonprovisional

YES

\$755

\$300

\$0

\$1055

11/09/2009

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

**Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
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Alexandria, Virginia 22313-1450
or Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

64494 7590 08/07/2009

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I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
-----------------	-------------	----------------------	---------------------	------------------

12/411,317 03/25/2009 Ron HADAR 108144-200701/US 4944

TITLE OF INVENTION: SYSTEMS AND METHODS TO BALANCE SOLAR PANELS IN A MULTI-PANEL SYSTEM (TGY010)

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
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nonprovisional YES \$755 \$300 \$0 \$1055 11/09/2009

EXAMINER	ART UNIT	CLASS-SUBCLASS
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PALADINI, ALBERT WILLIAM 2836 307-020000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

- ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

- (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, 1 _____
(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed. 2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

- ☐ Issue Fee
☐ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

- ☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27. ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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Exhibit 1015

PTOL-85 (Rev. 03/05) Approved for use through 08/31/2010.

OMB 0651-0033

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/411,317	03/25/2009	Ron HADAR	108144-200701/US (TGY010)	4944
64494	7590	08/07/2009	EXAMINER	
PALADINI, ALBERT WILLIAM				
ART UNIT			PAPER NUMBER	
2836			DATE MAILED: 08/07/2009	

GREENBERG TRAURIG, LLP (SV)
IP DOCKETING
2450 COLORADO AVENUE
SUITE 400E
SANTA MONICA, CA 90404

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

Notice of Allowability

Application No.

12/411,317

Examiner

ALBERT W. PALADINI

Applicant(s)

HADAR ET AL.

Art Unit

2836

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to application filed on 3/25/09.
2. ☒ The allowed claim(s) is/are 1-20.
3. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☐ All b) ☐ Some* c) ☐ None of the:
- ☐ Certified copies of the priority documents have been received.
 - ☐ Certified copies of the priority documents have been received in Application No. _____.
 - ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.

THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
- (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
- 1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
- (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.
- Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

- ☒ Notice of References Cited (PTO-892)
- ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
- ☒ Information Disclosure Statements (PTO/SB/08),
Paper No./Mail Date 3/25/09
- ☐ Examiner's Comment Regarding Requirement for Deposit
of Biological Material
- ☐ Notice of Informal Patent Application
- ☐ Interview Summary (PTO-413),
Paper No./Mail Date _____
- ☐ Examiner's Amendment/Comment
- ☒ Examiner's Statement of Reasons for Allowance
- ☐ Other _____

/Albert W Paladini/
Primary Examiner, Art Unit 2836

Reasons for Allowance

1. The following is an examiner's statement of reasons for allowance: None of the references cited or the art searched disclose or teach alone or in combination the apparatus including a photovoltaic energy production unit to generate electricity where a management unit is coupled between the photovoltaic energy production unit and a series connection of energy units, and the management unit has a first switch which connects the photovoltaic energy production unit to the series connection of energy units allowing a first current to flow. The references cited and the art searched do not also teach that the management unit allows a second current larger than the first current to flow through the series connection of energy production units as recited in claims 1 and 11.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Relevant Prior Art

2. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

Blanc (7,259,474) discloses a system for collecting power from power sources such as solar cells, where current from multiple solar panels is converted to alternating current through the use of multiple converters.

Art Unit: 2836

Lai (7,336,004) discloses topologies for using multiple energy sources, using photovoltaic energy arrays as one of the primary power sources.

McNamara (7,462,955) discloses electrical power distribution systems utilizing a variety of power sources including photovoltaic arrays.

Eckroad (7,518,266) discloses an electric power transmission system using a plurality of diverse distributed generation DC power sources including photovoltaic devices.

Nomoto (7,538,451) discloses a power system, and teaches using a solar cell control scheme for operation with the operating point set to a maximum point from the inherent current and voltage characteristics.

Yoshikawa (7,545,053) discloses a power supply system which includes some of a micro gas turbine, a fuel cell battery, a NAS battery, a lead battery, an aero generator, and a solar power generator.

3. Any inquiry concerning this communication or earlier communication from the examiner should be directed to Albert W. Paladini whose telephone number is 571-272-3748. The examiner can normally be reached from 7:00 AM to 3 PM on Monday, Tuesday, Thursday or Friday.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Mr. Rexford Barnie can be reached on 571-272-7492. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

/Albert W Paladini/
Primary Examiner, Art Unit 2836

7/24/09

Notice of References Cited	Application/Control No. 12/411,317		Applicant(s)/Patent Under Reexamination HADAR ET AL.	
	Examiner ALBERT W. PALADINI		Art Unit 2836	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-7,259,474	08-2007	Blanc, James Joseph	307/45
*	B	US-7,336,004	02-2008	Lai, Jih-Sheng	307/66
*	C	US-7,462,955	12-2008	McNamara et al.	307/64
*	D	US-7,518,266	04-2009	Eckroad, Steven Wallace	307/82
*	E	US-7,538,451	05-2009	Nomoto, Kazutoshi	307/66
*	F	US-7,545,053	06-2009	Yoshikawa et al.	307/19
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
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	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12/411317	
	Filing Date			
	First Named Inventor	Ron Hadar		
	Art Unit	2836		
	Examiner Name	Not Assigned ALBERT PALADINI		
	Attorney Docket Number	108144-200701/US (TGY010)		

U.S. PATENTS								
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear		
Qw	1	5648731	A1	1997-07-15	Decker et al.			
If you wish to add additional U.S. Patent citation information please click the Add button.								
U.S. PATENT APPLICATION PUBLICATIONS								
Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear		
Qw	1	20050172995	A1	2005-08-11	Rohrig et al.			
If you wish to add additional U.S. Published Application citation information please click the Add button.								
FOREIGN PATENT DOCUMENTS								
Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T ⁵
Qw	1	2005112551	WO	A2	2005-12-01	Hansung Engineering Co. LTD		☐
If you wish to add additional Foreign Patent Document citation information please click the Add button.								
NON-PATENT LITERATURE DOCUMENTS								
Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.						T ⁵

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number		12/411317
Filing Date		
First Named Inventor	Ron Hadar	
Art Unit	2836	
Examiner Name	Not Assigned ALBERT PALADINI	
Attorney Docket Number	108144-200701/US (TGY010)	

1		☐
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EXAMINER SIGNATURE

Examiner Signature	<i>Albert W. Paladini</i>	Date Considered	7/20/09
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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.



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BIB DATA SHEET

CONFIRMATION NO. 4944

SERIAL NUMBER 12/411,317	FILING or 371(c) DATE 03/25/2009 RULE	CLASS ~~136~~ 307	GROUP ART UNIT 2836	ATTORNEY DOCKET NO. 108144-200701/US (TGY010)		
APPLICANTS Ron HADAR, Cupertino, CA; Shmuel ARDITI, Los Gatos, CA; ** CONTINUING DATA ***** This appln claims benefit of 61/200,601 12/02/2008 ** FOREIGN APPLICATIONS ***** ** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** ** SMALL ENTITY ** 04/01/2009						
Foreign Priority claimed ☐ Yes ☒ No 35 USC 119(a-d) conditions met ☐ Yes ☐ No Verified and /ALBERT WILLIAM PALADINI/ Acknowledged Examiner's Signature		☐ Met after Allowance Initials	STATE OR COUNTRY CA	SHEETS DRAWINGS 8	TOTAL CLAIMS 20	INDEPENDENT CLAIMS 2
ADDRESS GREENBERG TRAUIG, LLP (SV) IP DOCKETING 2450 COLORADO AVENUE SUITE 400E SANTA MONICA, CA 90404 UNITED STATES						
TITLE Systems and Methods to Balance Solar Panels in a Multi-Panel System						
FILING FEE RECEIVED 462	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:			☐ All Fees		
				☐ 1.16 Fees (Filing)		
				☐ 1.17 Fees (Processing Ext. of time)		
				☐ 1.18 Fees (Issue)		
				☐ Other _____		
				☐ Credit		

307/20

Search Notes 	Application/Control No. 12411317	Applicant(s)/Patent Under Reexamination HADAR ET AL.
	Examiner ALBERT W PALADINI	Art Unit 2836

SEARCHED			
Class	Subclass	Date	Examiner
307	19, 20, 64-66	7/20/09	awp
136	244, 243, 251, 206	7/21/09	awp

SEARCH NOTES			
Search Notes		Date	Examiner
EAST		7/20/09	awp

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner
307	20, 19	7/24/09	awp

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12411317
	Filing Date		2009-03-25
	First Named Inventor	Ron Hadar	
	Art Unit	2836	
	Examiner Name	Albert William Paladini	
	Attorney Docket Number	108144-200701/US (TGY010)	

U.S. PATENTS						Remove
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1	4580090		1986-04-01	Bailey et al.	
	2	4604567		1986-08-05	Chetty	
	3	4873480		1989-10-10	Lafferty	
	4	5027051		1991-06-25	Lafferty	
	5	5504418		1996-04-02	Ashley	
	6	5747967		1998-05-05	Muljadi et al.	
	7	5932994		1999-08-03	Jo et al.	
	8	7394237		2008-07-01	Chou et al.	

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Application Number	12411317
Filing Date	2009-03-25
First Named Inventor	Ron Hadar
Art Unit	2836
Examiner Name	Albert William Paladini
Attorney Docket Number	108144-200701/US (TGY010)

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Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear		
	1	20080036440		2008-02-14	Garmer			
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FOREIGN PATENT DOCUMENTS							Remove	
Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ² ;	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1	0178757	EP		1986-04-23	TRW Inc.		☐
	2	2005069096	WO		2005-07-28	Koninklijke Philips Electronics		☐
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NON-PATENT LITERATURE DOCUMENTS							Remove	
Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.						T ⁵
	1	ALONSO, R. et al., "A New Distributed Converter Interface for PV Panels," 20th European Photovoltaic Solar Energy Conference, Barcelona, Spain, pp. 2288-2291, June 6-10, 2005.						☐
	2	ALONSO, R. et al., "Experimental Results of Intelligent PV Module for Grid-Connected PV Systems," 21st European Photovoltaic Solar Energy Conference, Dresden, Germany, pp. 2297-2300, September 4-8, 2006.						☐
	3	BASSO, Tim, "IEEE Standard for Interring Connecting Distributed Resources With the Electric Power System," IEEE PES Meeting, June 9, 2004.						☐

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number	12411317
Filing Date	2009-03-25
First Named Inventor	Ron Hadar
Art Unit	2836
Examiner Name	Albert William Paladini
Attorney Docket Number	108144-200701/US (TGY010)

4	Boostbuck.com, "The Four Boostbuck Topologies," located at http://www.boostbuck.com/TheFourTopologies.html , 2003.	☐
5	ENSLIN, Johan H.R., et al., "Integrated Photovoltaic Maximum Power Point Tracking Converter," IEEE Transactions on Industrial Electronics, vol. 44, no. 6, pp. 769-773, December 1997.	☐
6	GAUTAM, Nalin K. et al., "An Efficient Algorithm to Simulate the Electrical Performance of Solar Photovoltaic Arrays," Energy, Vol. 27, No. 4, pp. 347-361, 2002.	☐
7	International Patent Application PCT/US08/75127, International Search Report and Written Opinion (mailed April 28, 2009)	☐
8	LINARES, Leonor et al., "Improved Energy Capture in Series String Photovoltaics via Smart Distributed Power Electronics," 24th Annual IEEE Applied Power Electronics Conference and Exposition, pp. 904-910, February 15, 2009.	☐
9	NORDMANN, T. et al., "Performance of PV Systems Under Real Conditions," European Workshop on Life Cycle Analysis and Recycling of Solar Modules, The "Waste" Challenge, Brussels, Belgium, March 18-19, 2004.	☐
10	ROMAN, Eduardo, et al., "Intelligent PV Module for Grid-Connectred PV Systems," IEEE Transactions on Industrial Electronics, vol. 53, no. 4, pp. 1066-1073, August 2006.	☐
11	WALKER, Jeffrey R. et al., "Cascaded DC-DC Converter Connection of Photovoltaic Modules," IEEE Transactions on Power Electronics, vol. 19, no. 4, pp. 1130-1139, July 2004.	☐

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EXAMINER SIGNATURE

Examiner Signature		Date Considered	
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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number	12411317
Filing Date	2009-03-25
First Named Inventor	Ron Hadar
Art Unit	2836
Examiner Name	Albert William Paladini
Attorney Docket Number	108144-200701/US (TGY010)

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/John P. Ward/	Date (YYYY-MM-DD)	2009-08-05
Name/Print	John P. Ward	Registration Number	40216

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

12

EUROPEAN PATENT APPLICATION

21 Application number: 85305606.7

51 Int. Cl.⁴: **G 05 D 25/02**

22 Date of filing: 07.08.85

30 Priority: 15.10.84 US 660811

43 Date of publication of application:
23.04.86 Bulletin 86/17

64 Designated Contracting States:
DE FR GB IT

71 Applicant: TRW INC.
23555 Euclid Avenue
Cleveland Ohio 44117(US)

72 Inventor: Reppucci, George Michael
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Los Angeles California 90045(US)

72 Inventor: Decker, Darwin Kent
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72 Inventor: Lepisto, Jack William
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74 Representative: Ailden, Thomas Stanley et al,
A.A. THORNTON & CO. Northumberland House 303-306
High Holborn
London WC1V 7LE(GB)

54 Solar array regulator.

57 Apparatus for regulating the voltage output of a solar cell array by selectively actuating individual cells that have been constructed to include a light control valve capable of being rendered opaque or transparent under electrical control. By automatically controlling selected cells in the array in this manner, the output characteristics of the array can be regulated to compensate for variations caused by temperature or other changes.

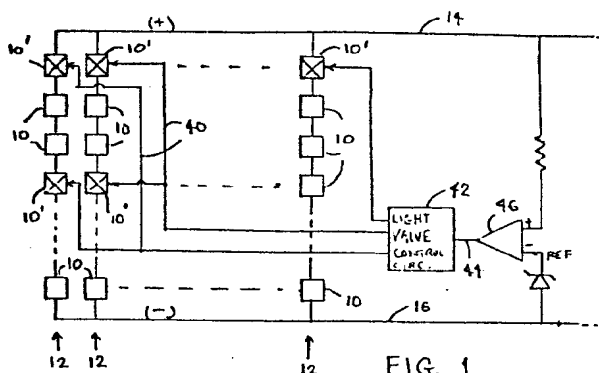


FIG. 1

EP 0 178 757 A2

SOLAR ARRAY REGULATORBACKGROUND OF THE INVENTION

This invention relates generally to solar cell arrays, and more particularly, to techniques for regulating the electrical output of an array in varying conditions. Arrays of semiconductor solar cells are frequently used as the principal power source in spacecraft and terrestrial application, to power battery charging circuits, or to power other electrical equipment directly.

Although solar cell arrays are an efficient and reliable power source, there are some commonly encountered conditions that vary the operating characteristics of such arrays. Variations in temperature can produce wide variations in the output voltage of a solar cell array, and some form of voltage regulation is therefore necessary. More specifically, the maximum or open-circuit voltage available from an array is significantly increased when the temperature of the cells making up the array is relatively low. When a spacecraft emerges from a shadow condition, as when eclipsed by the earth or some other body, the temperature of the array may be as low as approximately -176 degrees C. After exposure to direct sunlight for some minutes, the temperature may rise by as much as 200 degrees C. The voltage output from an array that has just emerged from shadow may be almost double the value obtained after the array reaches its equilibrium temperature in sunlight.

Unless the electrical load on the array can be increased during periods when the temperature is low, the output voltage must be regulated down to a

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lower value. The technique normally used is to bypass or short-circuit strings of cells by means of high-power switching transistors. If each string of cells in the array is shortened by appropriate
5 switching, the output of the array is reduced, but only at the expense of power dissipation in the switching transistors. Consequently, the power dissipation of the transistors is greatly increased during periods that the voltage is being regulated in
10 this manner.

It will be appreciated from the foregoing that there is a need for an alternative technique for regulating the electrical output of a solar cell array during conditions of increased voltage. This
15 need is especially accute in spacecraft power supply applications, but is also present in terrestrial applications in which arrays are subject to wide temperature fluctuations.

SUMMARY OF THE INVENTION

20 The present invention resides in the use of an electrically controlled optical device to regulate the output from a solar cell array having multiple solar cells. Basically, and in general terms, the apparatus of the invention comprises means for provid-
25 ing control signals indicative of a desired change in electrical output of the array, and electrically operated light valve means installed on selected cells of the array and operable by the control signals to control the amount of radiation reaching the
30 selected cells, and therefore the total electrical output of the array. The means for providing control signals includes means for monitoring the output voltage of the solar cell array, means for comparing

the monitored output voltage with a desired reference value and generating a difference signal, and control means responsive to the difference signal, to generate control signals to regulate the output of the
5 array.

More specifically, the light valve means may take the form of cover panels that include a liquid crystal element. The control signals are then effective to render the cover panels relatively opaque to
10 at least some portion of the solar radiation spectrum.

The control means of the invention may be constructed to provide a plurality of control signals, the number of which is dependent on the magnitude of the difference signal. For larger differences between the actual voltage and the desired reference voltage, a larger number of control signals will be generated, each being coupled to separate cells or groups of cells in the array. Alternatively,
15 the light valve means is responsive to an analog signal to provide varying degrees of opaqueness, and the control means then produces a single analog control signal, the magnitude of which determines the degree to which all of the light valve means are
20 rendered opaque.

Although liquid crystal displays provide the necessary characteristics to function as a light valve, other materials under development may prove to have superior characteristics. For example, a ceramic material referred to as PLZT (lead lanthanate zirconate titanate) has electrically controllable light
30 transmission properties.

It will be appreciated from the foregoing that the present invention represents a significant
35 advance in the field of solar cell arrays. In par-

particular, the invention provides an efficient technique for modulating the voltage output from a solar array without bypassing cells in the array. Other aspects and advantages of the invention will become
5 apparent from the following more detailed description, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a simplified schematic diagram
10 of a solar cell array, the voltage output of which is regulated in accordance with the invention;

FIG. 2 is a graph showing the current-versus-voltage characteristics of a solar cell array;
and

15 FIG. 3 shows the comparative current-versus-voltage characteristics of a typical solar cell having a liquid crystal display (LCD) light valve installed and either activated or inactivated.

DESCRIPTION OF THE PREFERRED EMBODIMENT

20 As shown in the drawings for purposes of illustration, the present invention is concerned with a novel technique for regulating the output voltage of an array of solar cells. A single solar cell is a diode of silicon or other semiconductor material,
25 having the property that an electrical current is generated as a result of the incidence of light on the cell. A single cell can generate an open-circuit voltage of about 0.5 volt, i.e. when no load is connected to the cell, and has a short-circuit current
30 of about 50 milliamperes (mA) or less, i.e. the current that flows when the output terminals of the cell

are connected together in a short-circuit condition. Because the electrical output of a single cell is of little practical application, cells are typically connected together in an array having multiple strings of series-connected cells. Each string has a combined voltage output of many times that of a single cell. Increased current output is provided by connecting multiple strings in parallel to form the array.

Such an array is shown in fragmentary and diagrammatic form in FIG. 1. Multiple cells, indicated by reference numeral 10, are connected in series strings 12, which are connected together in parallel between two output buses 14 and 16. A typical current-versus-voltage characteristic for an array is shown in FIG. 2. If the output buses are open-circuited, the output current is zero and the output voltage is the open-circuit voltage, which is indicated as approximately 38 volts. If the output buses are connected together, the output voltage is zero and the current generated is the short-circuit current, indicated as I_{sc} . At the short-circuit current condition, the load impedance is zero. If the load impedance is gradually increased, the output voltage also increases, but the current initially remains relatively constant, as indicated by the curve 20. As the voltage approaches its open-circuit value, the current begins to drop off rapidly.

The characteristic has a limiting operating point, indicated at 22, at which the output power, the product of current and voltage, will be at a maximum. When the array is not electrically loaded, the open-circuit output voltage will be generated. As electrical load is added to the array, the voltage will fall off slightly, and the current will in-

crease, providing increasing power output from the array. However, when the maximum power output point 22 is reached, further attempts to increase the load will result in significant reduction in the voltage and the output power. A typical, partly loaded condition is indicated by the load line 24.

The problem with which the invention is concerned arises because the current-voltage characteristic 20 changes significantly when the array is at a lower operating temperature, as when a spacecraft on which the array is installed has just emerged from a shadow. The characteristic for such a reduced temperature condition is shown at 20'. The curve 20' has the same general shape as curve 20, but the short-circuit current is reduced and the open-circuit voltage is increased. Typically, a single solar cell has a temperature coefficient of 2 millivolts (mv) per degree C, i.e., the voltage output of the cell changes by 2mv for each degree of temperature change. For a string of a hundred cells exposed to temperature differences of 200 degrees, the overall voltage variation can be as high as 40 volts, or a 100-percent variation. Unless the electrical load can be increased, some means must be provided to regulate this increased voltage down to the normal level. In the past, this has been done by selectively short-circuiting sub-strings of cells by means of high-power switching transistors, in which power must be dissipated.

In accordance with the invention, selected cells, indicated at 10', are provided with a light control valve, to "shadow" these cells from radiation and thereby reduce the total voltage generated by each series string 12. Electrically actuated light valves have been known for some time, but not applied

to the problem of solar array voltage regulation. United States Pat. No. 2,185,379 to Meyers et al. discloses an electrically controlled light valve proposed for use in a projection television system.

5 The use of electric fields to control a diffraction grating is disclosed in United States Pat. No. 3,813,142 to Buhrer. Moreover, the properties of liquid crystal cells for use as optical switches in a general sense is well known. There are many patents

10 and publications concerning liquid crystals and liquid crystal displays (LCDs). For example, United States Pat. No. 4,385,799 to Soref and United States Pat. No. 3,791,716 to Borel et al.

Each of the selected cells 10' includes a

15 cover panel having an electrically controllable element, by means of which the transmission of light to the cell is controlled. Basically, the controllable element must be able to render the cover panel relatively opaque to radiation over some portion of the

20 spectrum to which the cell is responsive.

One controllable element that satisfies this requirement is the liquid crystal display (LCD) element. As is well known, the application of an electric field to the liquid crystal element results in

25 an arrangement of the crystalline structure that renders the element relatively opaque and black in appearance. A suitable LCD element is liquid crystal Model No. CIN-6-ITC manufactured by UCE Inc., of Norwalk, Connecticut 06855.

30 FIG. 3 shows how the output characteristic of a solar cell is effected by activation of the electrically controllable element. Curve 30 shows the I-V characteristic when the LCD element is inactive and relatively transparent, and curve 32 shows

35 the same characteristic after activation of the ele-

ment to render it relatively opaque. The output current is reduced by about half and the voltage reduced by a lesser amount. A more ideal light valve element would effectively collapse the output characteristic
5 and produce zero output contribution to a string of cells.

Another possible material for use as a light valve is an optical ceramic material referred to as PLZT (lead lanthanate zirconate titanate). This and
10 related materials have been investigated for various applications, such as in aircraft cockpit windows and protective eye shields. These ceramic materials can be controlled to provide good reflectivity properties, suitable for reflecting incident radiation from
15 selected solar cells in an array.

In a practical application of the principles of the invention, each of the selected cells 10' is connected by control lines 40 to a control circuit 42. The control circuit 42 receives on line 44 a signal
20 indicative of the difference between the actual output voltage of the array and a reference voltage. The difference signal is provided by a difference amplifier 46 to which are connected two input lines 48 and 50 carrying signals indicative of the actual and
25 reference voltages, respectively. The function of the control circuit 42 is to produce control signals on lines 40 to "shadow" selected ones of the cells 10'. It will be appreciated that the nature of the control signals on lines 40 will depend on the nature
30 of the light control valve elements used in the cells 10'. If the control valves are binary in nature, that is either on or off, the control signals will also be binary and will be distributed in such a manner as to effect the desired reduction in output
35 from the array, by actuating an appropriate number of

the cells 10' in each array string 12. If the control valves are analog in nature, providing a continuously variable transmissivity of light, then the control signals on line 40 will also be analog signals, varying the transmissivity of all of the selected cells 10' by an appropriate amount to regulate the output voltage to its desired level.

One difficulty with selective shadowing of cells in an array, is that each shadowed cell that produces no output, or a reduced output, functions as an electrical load on the array. If a single cell in a string is selected for shadowing, the voltage across the cell can be high enough that significant power is dissipated in the cell in the form of heat. This creates a "hot spot" in the array, which can have a significant effect on the mechanical design of the array. The problem can be minimized by ensuring that cells selected for shadowing are spaced apart by no more than some minimum amount in each cell string.

It will be appreciated from the foregoing that the present invention represents a significant advance in the field of solar cell arrays. In particular, the invention provides a novel technique for regulating the electrical output of an array without using switching transistors to selectively short-circuit strings of cells. The advantages of the technique are that it uses a small number of additional parts, it is light in weight, and it consumes very little power to effect control of the array.

It will be also appreciated that, although a specific embodiment of the invention has been described in detail for purposes of illustration, various modifications may be made without departing from the spirit and scope of the invention. Accordingly, the invention is not to be limited except as by the appended claims.

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CLAIMS

1. Apparatus for regulating the electrical output of a solar cell array having multiple solar cells, the apparatus comprising:

means for providing control signals indicative of a desired change in electrical output of the array; and

electrically actuated light valve means installed on selected cells of the array and operable by the control signals to control the amount of radiation reaching the selected cells, and therefore the total electrical output of the array.

2. Apparatus as set forth in claim 1, wherein the means for providing control signals includes:

means for monitoring the output voltage of a solar cell array;

means for comparing the monitored output voltage with a desired reference value and generating a difference signal; and

control means responsive to the difference signal, to generate the control signals to regulate the output of the array.

3. Apparatus as set forth in claim 1, wherein:

the electrically actuated light valve means includes a cell cover panel having a liquid crystal element switchable between a relatively transparent condition and a relatively opaque condition.

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4. Apparatus as set forth in claim 2,
wherein:

the electrically actuated light valve means
includes a cover panel having a liquid crystal ele-
5 ment switchable between a relatively transparent con-
dition and a relatively opaque condition.

5. Apparatus as set forth in claim 1,
wherein:

the electrically actuated light valve means
includes a cover panel of an optical ceramic ma-
5 terial.

6. Apparatus as set forth in claim 2,
wherein:

the electrically actuated light valve means
includes a cover panel of an optical ceramic ma-
5 terial.

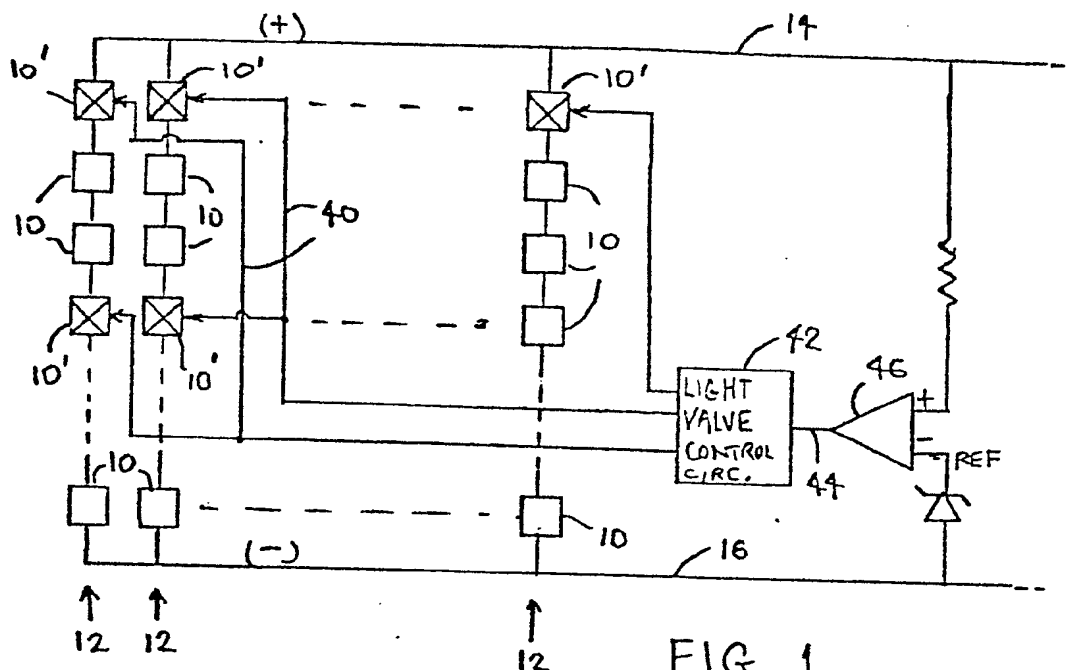


FIG. 1

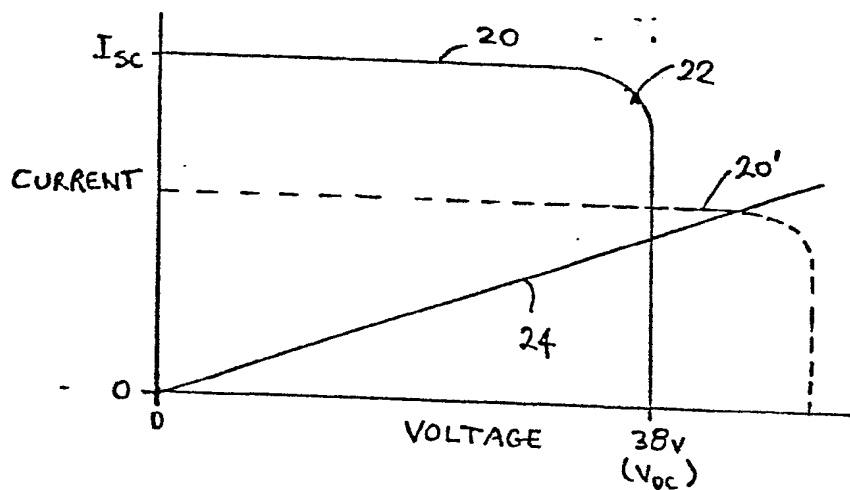


FIG. 2

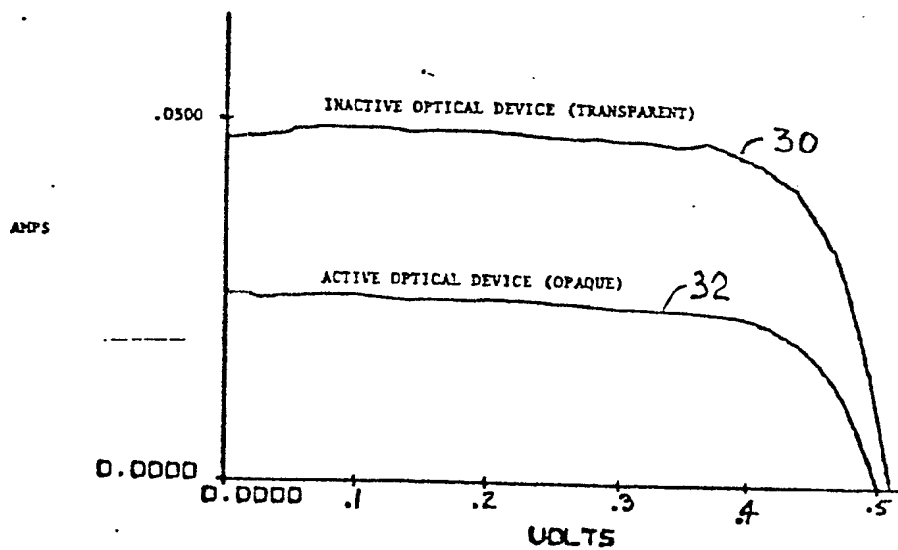


FIG. 3

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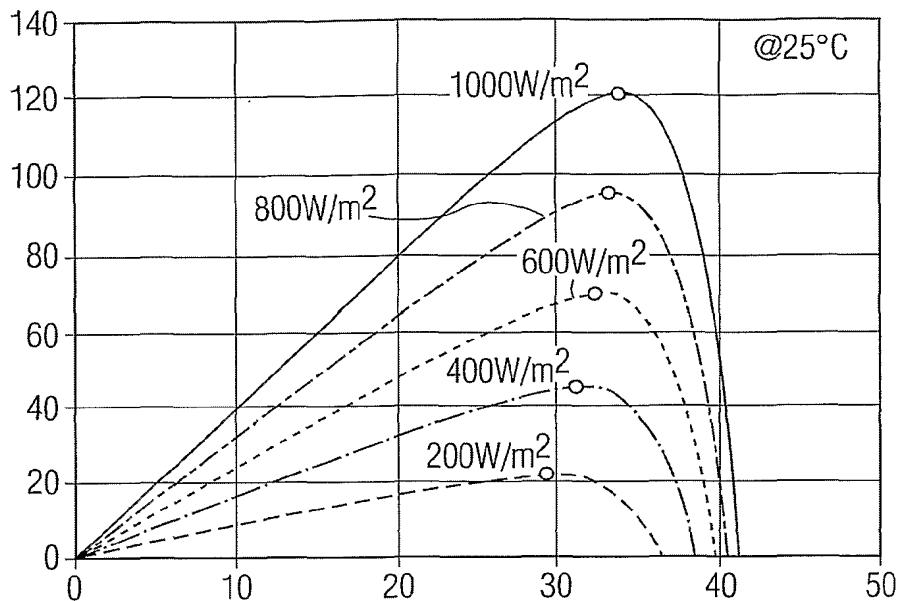
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a patent (Rule 4.17(ii)) for the following designations AE,
AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ,
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[Continued on next page]

(54) Title: SOLAR POWER SOURCE WITH MAXIMUM POWER-POINT TRACKING



(57) Abstract: A solar array power source is provided that automatically operates at its maximum power point despite changes in irradiance and array temperature.



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SOLAR POWER SOURCE WITH MAXIMUM POWER-POINT TRACKING

This invention relates to maximum power point tracking to enable the maximum extraction of power from solar cell apparatus.

5 With continuing increases in efficiency and decreases in cost of solar cell devices, their use for providing electrical power is becoming ever more practical. To facilitate the extraction of the maximum power output, it is desirable to perform maximum power point tracking (MPPT) for varying levels of irradiance. This can be better understood with reference to Figure 1, which shows output power versus output voltage curves for a typical photovoltaic
10 (PV) solar cell array operating at a number of different irradiance levels of light impinging on the array, at an array temperature of 25°C. Note that, for each different irradiance level, there is only one operating point on the respective curve where the output power from the solar array is at a maximum. This maximum power point is marked by a small circle on each of the curves.

15 One known type of maximum power point tracking employs an active searching algorithm. If changes in the irradiance level occur slowly or infrequently, a static approach may be employed whereby the power output at different operating points along a given curve for a fixed irradiance level is measured until the maximum power point is found. If a more dynamic approach is desired, to better track quickly changing irradiance levels, additional
20 computational speed and complexity is required.

Two other types of known maximum power point tracking, which are generally simpler and require less computational speed, utilize a fixed voltage or current approach:

- The fixed voltage approach measures the open-circuit voltage of a solar cell array and sets the operating voltage of the array at a fixed percentage of the measured
25 voltage. This, however, requires intermittent interruption of the power generation by the array to take the necessary measurement. Further, the relationship between the open-circuit voltage and the maximum power point is not perfectly linear.
- The fixed current approach measures the short-circuit current of a solar cell array and sets the operating current of the array at a fixed percentage of the measured
30 current. This is generally more accurate than the open-circuit voltage approach, but

only if there are not substantial variations in the temperature of the array. Also, this approach still requires intermittent interruption of the power generation.

It is desirable to have a maximum power point measurement approach which is accurate and can be implemented in a simple and low cost manner without adversely affecting operation of solar cell power generation.

In accordance with the invention, a solar cell power source includes a solar cell array having a characteristic maximum power point output current that varies substantially with changes of the irradiance of light impinging on the array, but does not vary substantially with temperature changes of the array over an operating temperature range of the array. A photo-detector device which produces an output signal that varies with changes in the irradiance of impinging light is disposed for detecting the irradiance of light impinging on the solar cell array. A load electrically connected to an output of the solar cell array has an input impedance which varies in response to the photo-detector output signal to effect drawing from the array that output current which is characteristic of the maximum power point of the array at the irradiance of the light impinging on the array. With this simple approach, the solar array can be automatically operated approximately at its maximum power point despite substantial changes in irradiance and temperature of the array.

The principle of the invention can be better understood by referring to Figures 2 and 3. Figure 2 illustrates output current versus output voltage curves for the solar cell array of Figure 1, when operating at a number of different array temperatures and at an irradiance level of 1000 Watts/m². The curves for the other irradiance levels shown in Figure 1 are similar, but are not included in Figure 2 to keep this figure simple. The maximum power point current for each of the irradiance levels can be determined from the plot of Figure 3. Note from Figure 2 that while the output voltage produced by the array at the maximum power point (indicated by the small circle on each curve) varies significantly with array temperature, the output current does not. In fact, the current at the maximum power point varies by less than 1% over the operating temperature range -25°C to +75°C. For all of the irradiance levels for which curves are shown in Figure 1, the current at the maximum power point varies by less than 2% over the operating temperature range -25°C to +75°C. In other words, the maximum power point can be maintained by measuring the solar irradiance of light impinging on the array and loading the output of the array to draw the corresponding characteristic current indicated on the current-voltage plot for the particular array in use. For the array having the characteristic

curves shown in Figure 2, the output current to be drawn to maintain the maximum power point at an irradiance level of 1000 Watts/m² would be approximately 3.5 amps, as indicated in Figure 3.

Figure 1 is a plot of the characteristic output power versus output voltage curves for a particular solar cell array.

Figure 2 is a plot of the characteristic output current versus output voltage curves for the solar cell array.

Figure 3 is a plot of the maximum power point current versus irradiance for the solar cell array.

Figure 4 is a block diagram of an exemplary embodiment of a solar power source in accordance with the invention.

Figures 5-8 are schematic diagrams illustrating exemplary embodiments of solar power sources in accordance with the invention.

Figure 4 schematically illustrates an exemplary embodiment of a solar cell power source in accordance with the invention. This embodiment includes a solar-array module M, a control circuit C and a load L. The module M includes an array S of solar cells and a photo-detector P arranged for receiving impinging light radiation. DC power produced by the array S is made available at output terminals 1,2 of the array. An output signal produced by the photo-detector P in response to the impinging light radiation is applied to an input of the control circuit C. The control circuit is also electrically connected to the load L. The load L includes input terminals 3,4 that are electrically connected to the output terminals of the array and output terminals 5,6 for providing power to a user apparatus. In operation, the control circuit controls an input impedance of the load L in response to light radiation impinging on the photo-detector P and the solar array S to draw maximum power from the array, in accordance with the invention.

In one particularly useful embodiment, the load L is an inverter for converting the DC power produced by the array to AC power provided at the output terminals 5,6. Figure 5 illustrates one such embodiment as including a solar-array module M, the inverter load L having a conventional boost converter input section B and a DC-to-AC converter section, and control circuitry. The control circuitry includes a maximum power point tracker (MPPT), a difference generator Σ , an error amplifier A, and a duty cycle ratio controller R.

The MPPT produces a reference current signal I_{ref} representative of the average or DC current that should be drawn from the solar array to achieve the maximum power point at the irradiance of the array. This is done by sensing the current through the photo-detector P to detect the irradiance level and producing a reference signal corresponding to the maximum power point current that is characteristic of the array at that level.

This can be achieved with relatively simple circuitry if a photo-diode having a current-irradiance characteristic that varies with temperature similarly with that of the solar cells in the array S is employed for the photo-detector P. In fact, for typical silicon solar array a silicon photo-diode may be utilized which produces a current that is proportional to the maximum power point current of the array itself over the operating temperature range. In this case, a trans-impedance amplifier which will produce an output voltage that is proportional to the current through the photo-detector may be used for the MPPT circuitry.

The difference generator Σ compares the magnitude of the reference current signal I_{ref} with a current signal I_{solar} representing the current from the solar array S. In the exemplary embodiment of Figure 5, the current from the solar array is measured by sensing the current passing through one of the inputs of the load L. Any difference between these magnitudes is applied to an input of an error amplifier A, which drives a duty cycle ratio unit R that controls the switching of a transistor Q in the boost converter input section B. The unit R produces a square-wave signal that switches the transistor on and off at a ratio of on time to off time that effects production of an average solar array current I_{solar} equal to the reference current I_{ref} , thereby drawing the maximum power from the solar array.

Figure 6 illustrates an embodiment that is similar to that of Figure 5, but which utilizes peak current control rather than average current control. In this embodiment, cyclical switching of the transistor Q is controlled by a peak current mode controller PK such that the current drawn from the solar array by the load L is equivalent to the DC maximum power point current required at the irradiance sensed by the photo-detector P. This is done by switching the transistor off, during each cycle, at that peak current which results in the desired average current. The MPPT produces a reference signal $I_{ref} (peak)$ representative of this peak current. Controller PK determines when this peak current is reached by comparing the peak magnitude of the sensed solar array current I_{solar} with $I_{ref} (peak)$.

Figure 7 illustrates an embodiment similar to that of Figure 5, but employing a MPPT including a microprocessor μP . In this embodiment, data representing the maximum power

point currents for the solar array at a variety of irradiance levels can be stored in one or more look-up tables. The reference current I_{ref} would be looked up by the microprocessor in response to a sensed array irradiance.

Figure 8 illustrates an embodiment where all of the control functions are included in a MPPT including a microprocessor. This embodiment could be used to replace any or all of the embodiments of Figures 5-7, and a variety of other embodiments. It could also store the characteristic data needed to operate a number of different solar arrays at their characteristic power point currents and to power a number of different loads, thereby providing a universal solar power source.

While exemplary embodiments of the invention are described, various modifications and changes can be made without departing from the spirit and scope of the invention. It is therefore to be understood that the invention includes all embodiments that fall within the scope of the appended claims.

Claims

What is claimed is:

1. A solar cell power source comprising:
 - 5 a. a solar cell array (S) having a characteristic maximum power point output current that varies substantially with changes in irradiance of light impinging on the array, but does not vary substantially with temperature changes of the array over an operating temperature range;
 - b. a photo-detector device (P) disposed for detecting the irradiance of light impinging on the solar cell array, said device producing an output signal that varies with changes of said
10 detected irradiance;
 - c. a load (L) electrically connected to an output of the solar cell array and which is controlled in response to the photo-detector output signal to effect drawing from said array that output current which is characteristic of the maximum power point of the array at the irradiance of the light impinging on the array.
- 15 2. A solar cell power source as in claim 1 where the load comprises an inverter for converting DC power produced by the solar cell array to AC power.
3. A solar cell power source comprising:
 - 20 a. a solar cell array (S) having a characteristic maximum power point output current that varies substantially with changes in irradiance of light impinging on the array, but does not vary substantially with temperature changes of the array over an operating temperature range;
 - b. photo-detector device (P) disposed for detecting the irradiance of light impinging on the solar cell array, said device producing an output current that varies with changes of said
25 detected irradiance;
 - c. a load (L) electrically connected to an output of the solar cell array and having an input impedance which varies in response to the photo-detector output current to effect drawing from said array that output current which is characteristic of the maximum power point of the array at the irradiance of the light impinging on the array.
- 30 4. A solar cell power source as in claim 3 where the photo-detector device output current varies linearly with changes of the detected irradiance.

5. A solar cell power source comprising:
- a. a solar cell array (S) having a characteristic maximum power point output current that varies substantially with changes in irradiance of light impinging on the array, but does not vary substantially with temperature changes of the array over an operating temperature range;
 - 5 b. a photo-detector device (P) disposed for detecting the irradiance of light impinging on the solar cell array, said device producing an output signal that varies with changes of said detected irradiance;
 - c. a load (L) electrically connected to an output of the solar cell array and having a controllable input impedance;
 - 10 d. control circuitry (C) coupled to the photo-detector and to the load for effecting variation of the input impedance in response to the photo-detector output signal to such that the load draws from the array that output current which is characteristic of the maximum power point of the array at the irradiance of the light impinging on the array.
- 15 6. A solar cell power source as in claim 5 where the control circuitry comprises:
- a. a maximum power point tracker (MPPT) responsive to the photo-detector output signal for producing a reference signal representative of the maximum power point current that should be drawn from the solar cell array at the detected irradiance;
 - b. circuitry for cyclically varying the controllable input impedance such that the output
 - 20 current drawn from the array by the load tracks the maximum power point current represented by the reference signal.
7. A solar cell power source as in claim 6 where the reference signal represents an average value of the maximum power point current.
- 25 8. A solar cell power source as in claim 6 where the reference signal represents a peak value of the maximum power point current.
9. A solar cell power source as in claim 6 where the maximum power point tracker comprises
- 30 a processor.

10. A solar cell power source as in claim 9 where data representative of the characteristic maximum power point output currents of the array for different irradiances is stored in at least one look-up table.

5 11. A solar cell power source as in claim 5 where the control circuitry comprises a processor.

12. A solar cell power source as in claim 11 where data representative of the characteristic maximum power point output currents of the array for different irradiances is stored in at least one look-up table.

10

1/4

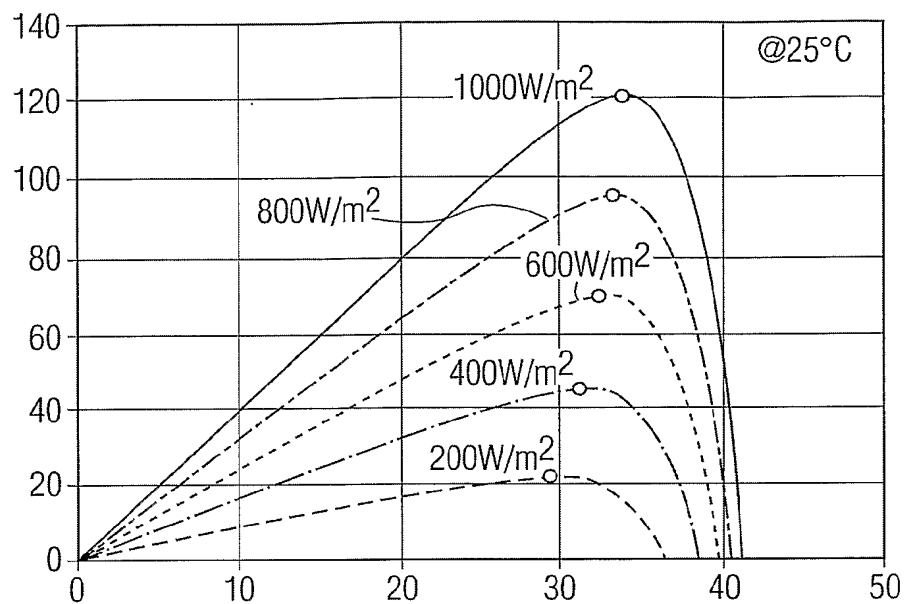


FIG. 1

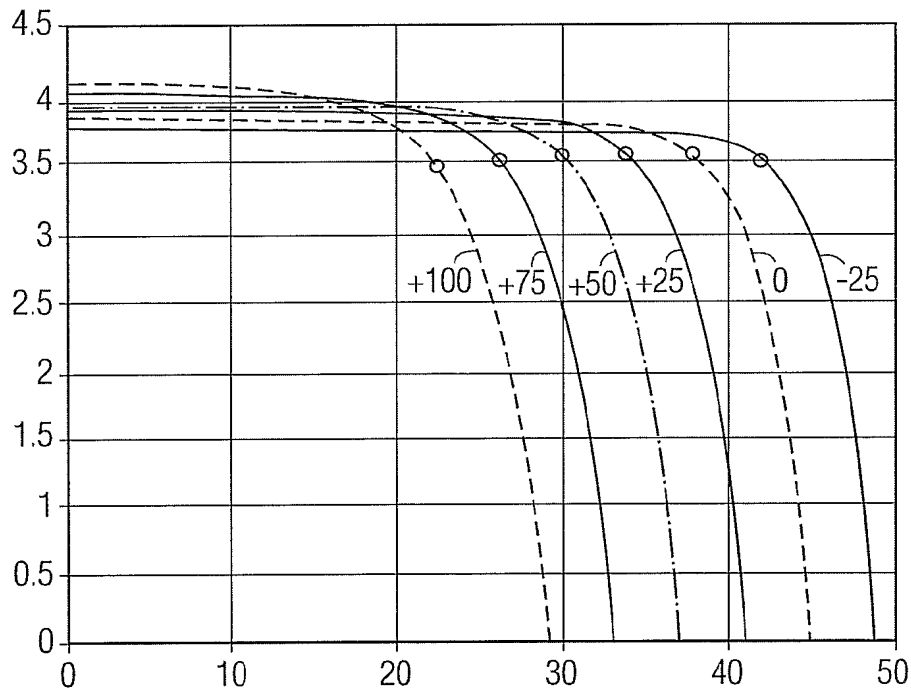


FIG. 2

2/4

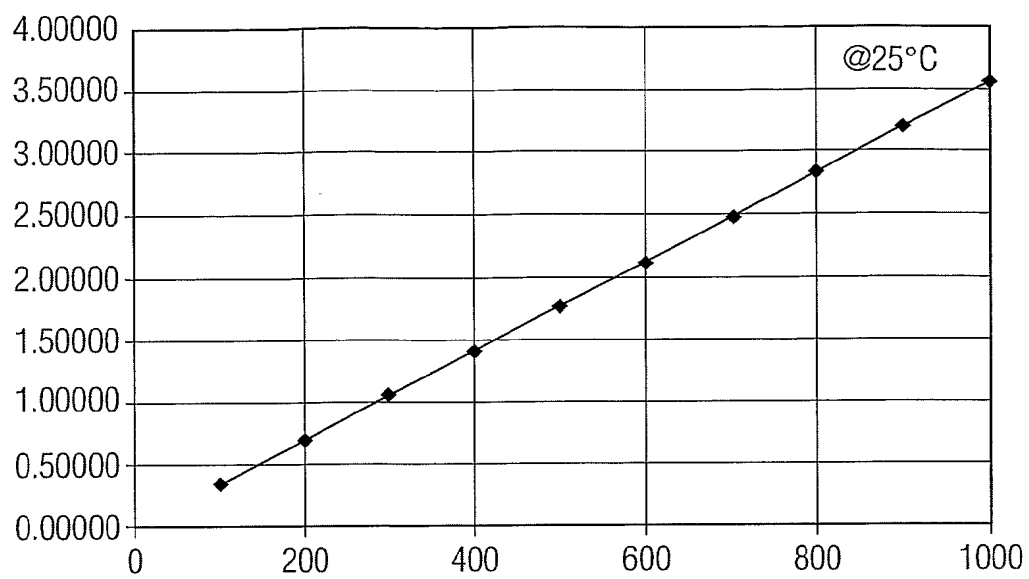


FIG. 3

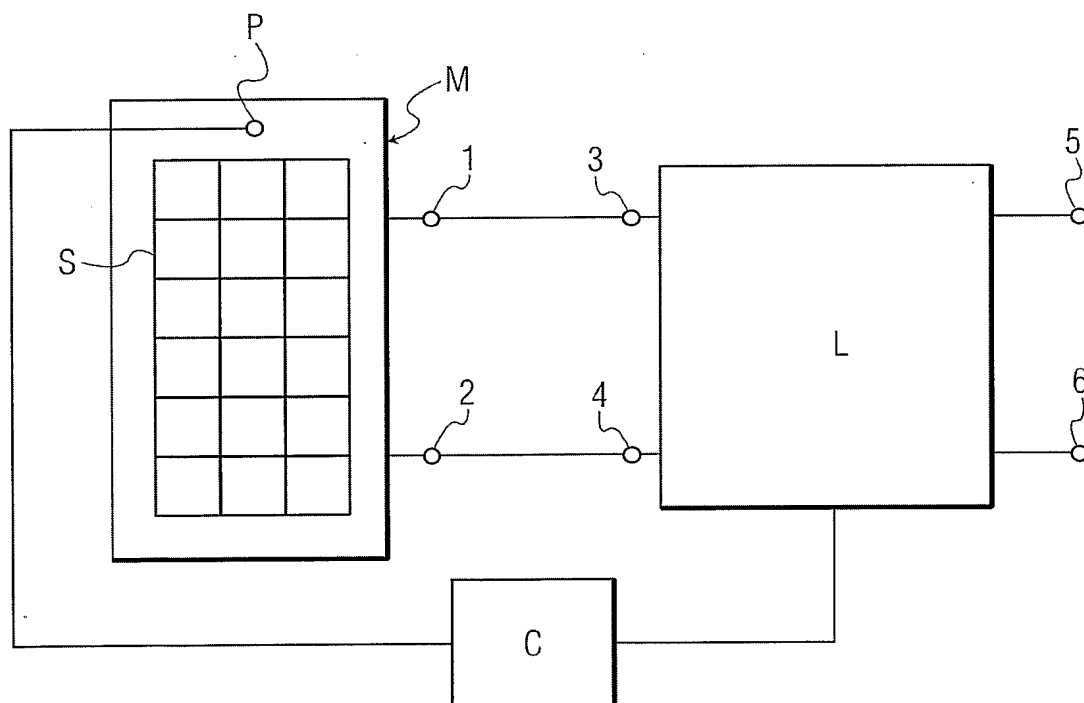


FIG. 4

3/4

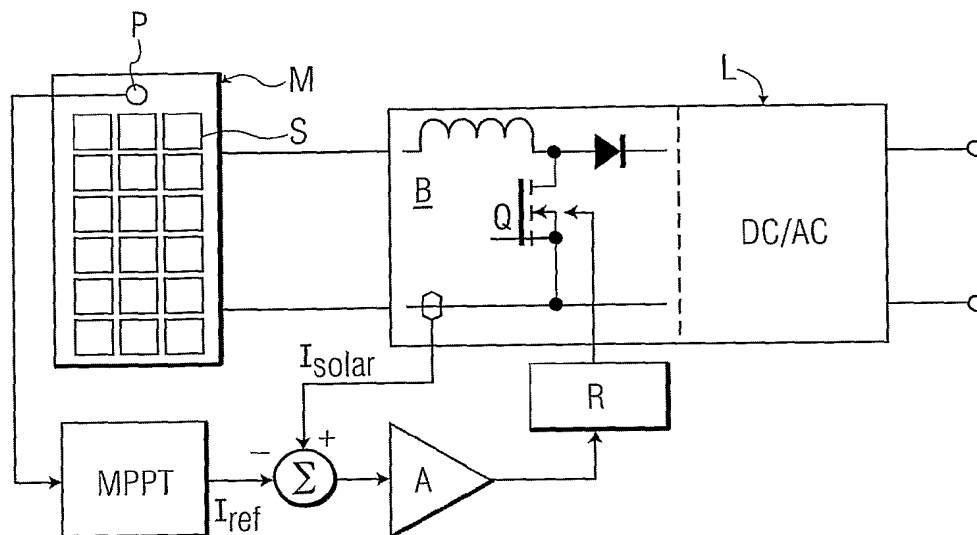


FIG. 5

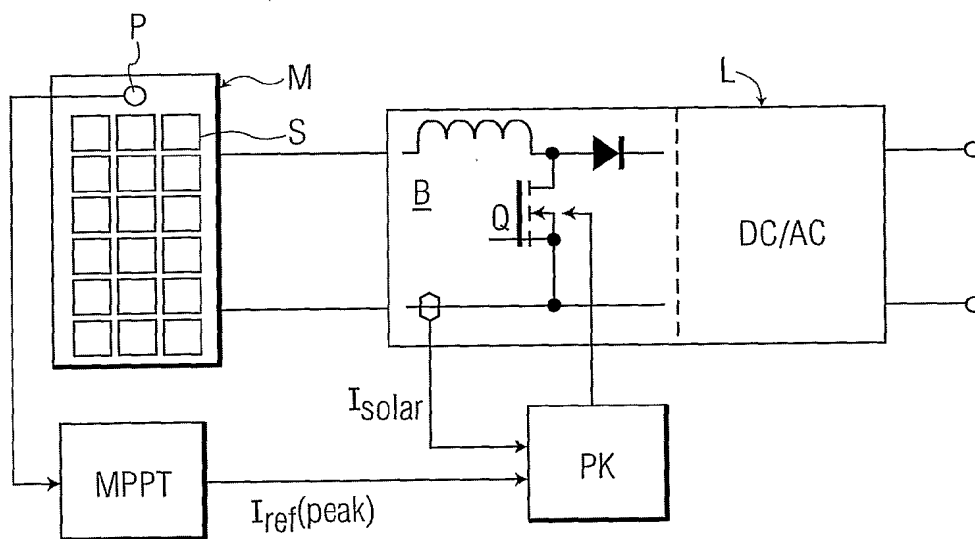


FIG. 6

4/4

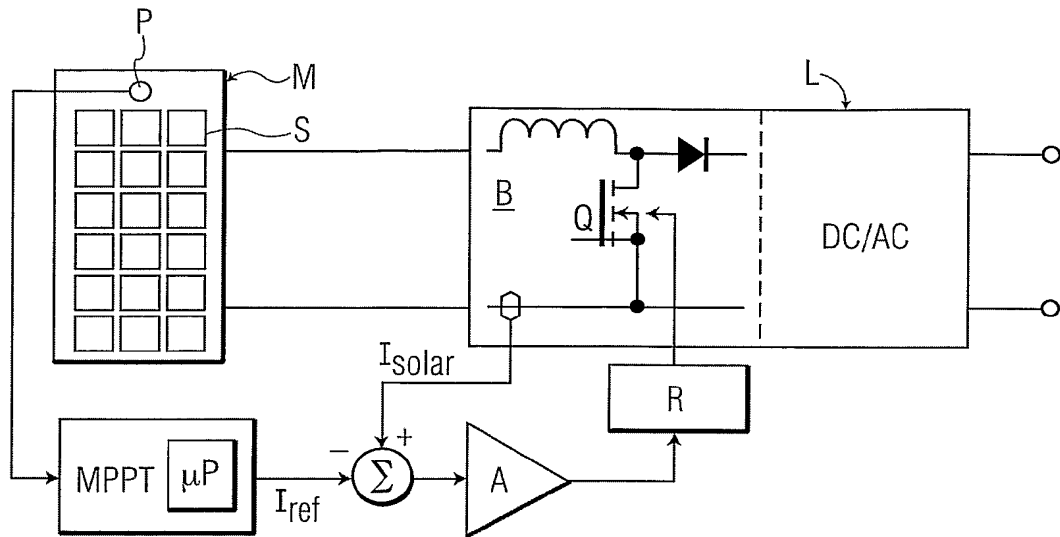


FIG. 7

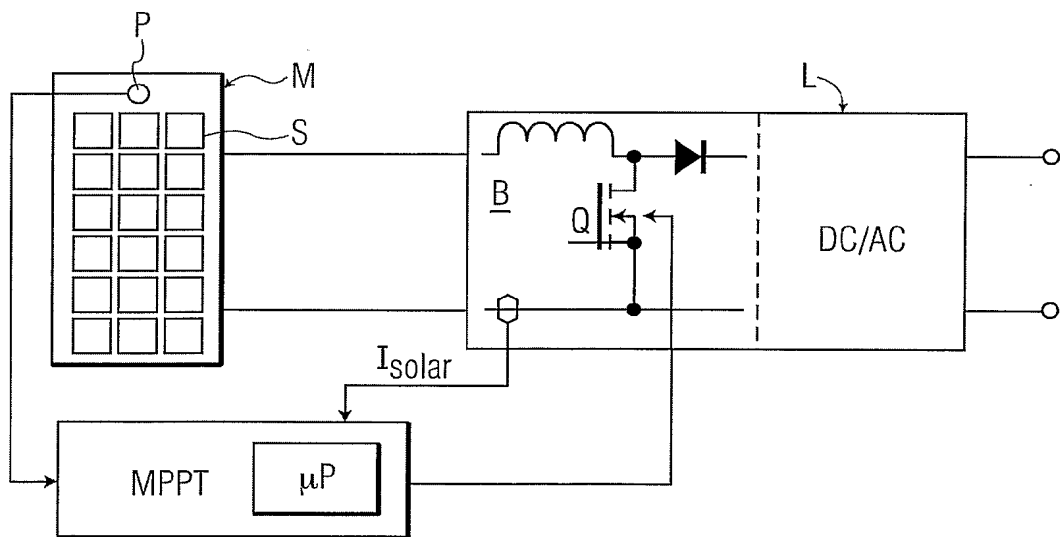


FIG. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB2005/050127

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G05F1/67 H01L31/042

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G05F H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 873 480 A (LAFFERTY ET AL) 10 October 1989 (1989-10-10) column 3, line 12 - column 6, line 16; figures 1,2	1-12
X	US 5 293 447 A (FANNEY ET AL) 8 March 1994 (1994-03-08) column 3, line 33 - column 7, line 27; figures 1-3,5	1-12
X	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 15, 6 April 2001 (2001-04-06) & JP 2000 347753 A (MITSUBISHI ELECTRIC CORP; KAKEI GAKUEN), 15 December 2000 (2000-12-15) abstract; figure 1	1-12

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *G* document member of the same patent family

Date of the actual completion of the international search

5 April 2005

Date of mailing of the international search report

21/04/2005

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Waters, D

INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/IB2005/050127

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 4873480	A	10-10-1989	NONE	
US 5293447	A	08-03-1994	NONE	
JP 2000347753	A	15-12-2000	NONE	

Form PCT/ISA/210 (patent family annex) (January 2004)

Electronic Acknowledgement Receipt

EFS ID:	5834927
Application Number:	12411317
International Application Number:	
Confirmation Number:	4944
Title of Invention:	SYSTEMS AND METHODS TO BALANCE SOLAR PANELS IN A MULTI-PANEL SYSTEM
First Named Inventor/Applicant Name:	Ron HADAR
Customer Number:	64494
Filer:	John Patrick Ward/Patricia Caldwell
Filer Authorized By:	John Patrick Ward
Attorney Docket Number:	108144-200701/US (TGY010)
Receipt Date:	05-AUG-2009
Filing Date:	25-MAR-2009
Time Stamp:	16:25:04
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Filed (SB/08)	108144-200701_IDS.pdf	609627 e4154af3d0e3a417ed8bd3a298775f33280bf995	no	5

Warnings:

Information:

EXHIBIT 1015

2	Foreign Reference	EP0178757.pdf	500288	no	13
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Warnings:					
Information:					
3	Foreign Reference	WO2005069096.pdf	562451	no	16
			15c7813ed32eebc659af1a8a5b67beb09bfa4925		
Warnings:					
Information:					
4	NPL Documents	gautameff2002.pdf	177477	no	15
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Warnings:					
Information:					
5	NPL Documents	Alonso_Distributed.pdf	316381	no	4
			bd912fa51bb4928ef3f81333f9c90b06de0bb7c6		
Warnings:					
Information:					
6	NPL Documents	Alonso_Experimental.pdf	248866	no	4
			5f6be18061d8ab4a0030ef3f285ad210e6b4a67f		
Warnings:					
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7	NPL Documents	Basso.pdf	1376968	no	56
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8	NPL Documents	Boostbuck.pdf	68958	no	3
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10	NPL Documents	PCTUS08_075127_ISR_WO.pdf	432332	no	12
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Exhibit 1015
Page 81 of 275

11	NPL Documents	Linares.pdf	1041332	no	7
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Information:					
12	NPL Documents	Nordmann.pdf	24716128	no	20
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14	NPL Documents	Walker.pdf	823250	no	10
			2984cf6c5be1dfa83611ebd822e2041f3757 a8d8		
Warnings:					
Information:					
Total Files Size (in bytes):			32092975		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PLUS Search Results for S/N 12411317, Searched Fri Jul 17 13:22:41 EDT 2009

The Patent Linguistics Utility System (PLUS) is a USPTO automated search system for U.S. Patents from 1971 to the present PLUS is a query-by-example search system which produces a list of patents that are most closely related linguistically to the application searched. This search was prepared by the staff of the Scientific and Technical Information Center, SIRA.

5245985 99	4497724 77
6129844 99	
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PLUS Search Results for S/N 12411317, Searched Thu Jul 16 10:33:11 EDT 2009

The Patent Linguistics Utility System (PLUS) is a USPTO automated search system for U.S. Patents from 1971 to the present PLUS is a query-by-example search system which produces a list of patents that are most closely related linguistically to the application searched. This search was prepared by the staff of the Scientific and Technical Information Center, SIRA.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/411,317	03/25/2009	Ron HADAR	108144-200701/US (TGY010)	4944
64494 7590 07/15/2009 GREENBERG TRAUIG, LLP (SV) IP DOCKETING 2450 COLORADO AVENUE SUITE 400E SANTA MONICA, CA 90404			EXAMINER PALADINI, ALBERT WILLIAM	
			ART UNIT 2836	PAPER NUMBER
			MAIL DATE 07/15/2009	DELIVERY MODE PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.



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GREENBERG TRAURIG, LLP (SV)
 IP DOCKETING
 2450 COLORADO AVENUE, SUITE 400E
 SANTA MONICA, CA 90407

In re Application of:

EGAN *et al.*

Serial No.: 12/411,317

Filed: March 25, 2009

Docket: 108144-200701/US (TGY010)

Title: **SYSTEMS AND METHODS TO
 BALANCE SOLAR PANELS IN A
 MULTI-PANEL SYSTEM**

DECISION ON PETITION TO
 MAKE SPECIAL FOR NEW
 APPLICATION UNDER 37
 C.F.R. § 1.102 & M.P.E.P. §
 708.02

This is a decision on the petition filed on march 25, 2009, to make the above-identified application special for accelerated examination procedure under 37 C.F.R. § 1.102(d).

The request, and the petition to make the application special are GRANTED.

The application is eligible for accelerated examination and the petition complies with the conditions for granting the application special status pursuant to the "Change to Practice for Petitions in Patent Applications to Make Special and for Accelerated Examination" published June 26, 2006, in the Federal Register. (71 Fed. Reg. 36323).

The prosecution of the instant application will be conducted expeditiously according to the following guidelines.

1. The application will be docketed to an examiner and taken up for action within two weeks of the date of this decision.
2. Restriction Practice:
 If the examiner determines that the claims are not directed to a single invention, a telephone request to elect one single invention will be made pursuant to MPEP 812.01. As a prerequisite to the grant of this petition, the applicant has agreed to make an oral election, by telephone, without traverse. If the applicant refuses to make an election without traverse, or the examiner cannot reach the applicant after a reasonable effort, the examiner will treat the first claimed invention (invention defined by claim 1) as having being constructively elected without traverse for examination.

3. Office action:

If it is determined that, after appropriate consultation, there is a potential rejection or any other issue to be addressed, the examiner will telephone the applicant and arrange an interview to discuss and resolve the issue. An Office action, other than a Notice of Allowance and Fee(s) Due (Notice of Allowance), will not be issued unless either: 1) an interview was conducted but did not result in agreed to action that places the application in condition for allowance, or, 2) a determination is made that an interview would be unlikely to result in the application being placed in condition for allowance, and 3) an internal conference has been held to review any rejection of any claim.

4. Time for Reply:

An Office action other than a Notice of Allowance or a final Office action will set a shortened statutory period of one month or thirty days, whichever is longer, for reply with no extension of time available under 37 CFR 1.136(a). Failure to timely file a reply within this non-extendible period for reply will result in the abandonment of the application.

5. Reply by Applicant:

A timely reply to an Office action other than the Notice of Allowance must be submitted electronically via EFS or EFS-web and limited to addressing the rejections, objections and requirement made. Any amendment that attempts to: 1) add claims which would result in more than three pending independent claims or more than twenty pending total claims; 2) present claims not encompassed by the pre-examination search or an updated accelerated examination support document; or 3) present claims that are directed a non-elected invention or an invention other than that previously claimed and examined in the application, will be treated as not fully responsive and will not be entered.

For any amendment to the claims (including any new claim) that is not encompassed by the accelerated examination support document, applicant must provide an updated accelerated examination support document that encompasses the amended or new claims at the time of filing of the amendment.

To proceed expeditiously with the examination, it is recommended that a reply with amendments made to any claim or with any new claim being added be accompanied by an updated accelerated examination support document or a statement explaining how the amended or new claim is supported by the original accelerated examination support document.

6. Information Disclosure Statement (IDS):

Any IDS filed during prosecution must be submitted electronically via EFS or EFS-web, accompanied by an updated accelerated examination support document, and be in compliance with 37 CFR 1.97 and 1.98.

7. Post-Allowance Processing:

To expedite processing of the allowed application into a patent, the applicant must: 1) pay the required fees within one month of the date of the Notice of Allowance, and 2) not

file any post allowance papers not required by the Office. In no event may the issue fee be paid and accepted later than three months from the date of the Notice of Allowance.

8. After-Final and Appeal Procedures:

To expedite prosecution, after receiving the final Office action, applicant must: 1) promptly file a notice of appeal, an appeal brief and appeal fees; and 2) not request a pre-appeal brief conference.

Any amendment, affidavit or other evidence filed after final Office action must comply with applicable rules and the requirements outlined in numbered paragraphs 5 and 6 above.

On appeal, the application will proceed according to normal appeal procedures. After appeal, the application will again be treated special.

9. Proceedings Outside the Normal Examination Process:

If the application becomes involved in a proceeding that is outside the normal examination process (e.g., a secrecy order, national security review, interference proceeding, petitions under 37 CFR 1.181, 182 or 183), the application will be treated special before and after such proceeding.

10. Final Disposition:

The twelve month goal of this accelerated examination procedure ends with a final disposition. The mailing of a final Office action, a Notice of Allowance, the filing of a Notice of Appeal, or the filing of a Request for Continued Examination (RCE) is the final disposition.

If, during prosecution, a paper is not filed electronically using EFS-web, a reply is filed but is not fully responsive, the application is involved in an appeal, or a proceeding outside normal examination process, the application will still be examined expeditiously, however, the final disposition may occur more than twelve months from the filing of the application.

Any inquiry regarding this decision should be directed to the undersigned at (571) 272-1594.



Clayton E. LaBalle, T-QAS
Technology Center 2800 - Semiconductors,
Electrical & Optical Systems & Components



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GREENBERG TRAURIG, LLP (SV)
IP DOCKETING
2450 COLORADO AVENUE, SUITE 400E
SANTA MONICA, CA 904047

In re Application of:

EGAN *et al.*

Serial No.: 12/411,317

Filed: March 25, 2009

Docket: 108144-200701/US (TGY010)

Title: **SYSTEMS AND METHODS TO
BALANCE SOLAR PANELS IN A
MULTI-PANEL SYSTEM**

:
:
: DECISION ON PETITION TO
: MAKE SPECIAL FOR NEW
: APPLICATION UNDER 37
: C.F.R. § 1.102 & M.P.E.P. §
: 708.02
:
:

This is a decision on the petition filed on march 25, 2009, to make the above-identified application special for accelerated examination procedure under 37 C.F.R. § 1.102(d).

The request, and the petition to make the application special are GRANTED.

The application is eligible for accelerated examination and the petition complies with the conditions for granting the application special status pursuant to the "Change to Practice for Petitions in Patent Applications to Make Special and for Accelerated Examination" published June 26, 2006, in the Federal Register. (71 Fed. Reg. 36323).

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For any amendment to the claims (including any new claim) that is not encompassed by the accelerated examination support document, applicant must provide an updated accelerated examination support document that encompasses the amended or new claims at the time of filing of the amendment.

To proceed expeditiously with the examination, it is recommended that a reply with amendments made to any claim or with any new claim being added be accompanied by an updated accelerated examination support document or a statement explaining how the amended or new claim is supported by the original accelerated examination support document.

6. Information Disclosure Statement (IDS):

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file any post allowance papers not required by the Office. In no event may the issue fee be paid and accepted later than three months from the date of the Notice of Allowance.

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On appeal, the application will proceed according to normal appeal procedures. After appeal, the application will again be treated special.

9. Proceedings Outside the Normal Examination Process:

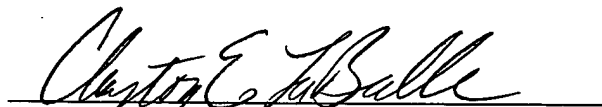
If the application becomes involved in a proceeding that is outside the normal examination process (e.g., a secrecy order, national security review, interference proceeding, petitions under 37 CFR 1.181, 182 or 183), the application will be treated special before and after such proceeding.

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Any inquiry regarding this decision should be directed to the undersigned at (571) 272-1594.


Clayton E. LaBalle, T-QAS
Technology Center 2800 - Semiconductors,
Electrical & Optical Systems & Components

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventors:	Ron Hadar et al.	Examiner:	Albert Paladini
Serial No.:	12/411,317	Group Art Unit:	2836
Filed:	March 25, 2009	Confirmation:	4944
Title:	Systems and Methods to Balance Solar Panels in a Multi-Panel System		

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

PRELIMINARY AMENDMENT

Sir:

Prior to the examination of the subject application, please kindly enter the following amendments and consider the following remarks/arguments:

Amendments to the Specification begin on page 2 of this paper; and

Remarks/Arguments begin on page 3 of this paper.

SPECIFICATION

Please replace paragraph [0001] of the specification with the following amended paragraph.

[0001] The present application claims the benefit of Provisional U.S. Application Serial No. 61/200,601, filed December 2, 2008 and entitled “Enhanced System and Method for Balancing Solar Panels in a Multi-Panel System,” the disclosure of which is hereby incorporated herein by reference. The present application also claims the benefit of Provisional U.S. Application Serial No. 61/200,279, filed November 26, 2008 and entitled “Enhanced System and Method for Balancing Solar Panels in a Multi-Panel System.”

REMARKS

Paragraph [0001] is amended to claim the benefit of Provisional U.S. Application Serial No. 61/200,279 ('279 Application), filed November 26, 2008.

"Accelerated Examination Support Document" is updated and filed herewith to identify the support in the '279 Application for the pending claims.

An updated Application Data Sheet is also filed herewith.

Respectfully submitted,

Date: June 15, 2009

/Lehua Wang/
Lehua Wang
Reg. No. 48,023

GREENBERG TRAURIG, LLP
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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ACCELERATED EXAMINATION SUPPORT DOCUMENT

Sir:

This accelerated examination support document is provided in support of the petition for accelerated examination.

CLAIMS

There are twenty claims currently pending in the application. The claims read as follows:

1. An apparatus, comprising:
a photovoltaic energy production unit to generate electricity; and
a management unit coupled between the photovoltaic energy production unit and a series connection of energy production units, the management unit having at least a first switch, the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit, the management unit to allow a second current larger than the first current to flow through the series connection of energy production units.
2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit connected to the photovoltaic energy production unit;
wherein, when the first switch is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current is equal to or larger than a sum of the first current and the third current; and
wherein, when the first switch is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy production units, and the management unit provides at least one path for the series connection of energy production units.

3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor coupled in parallel with the energy production unit; and when the first switch is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit.
4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode,
a second switch, wherein the management unit turns off the second switch when the first switch is turned on, and
a synchronous rectifier.
5. The apparatus of claim 1, wherein the management unit further comprises a controller to control the first switch according to a duty cycle.
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift, and a synchronization pulse.
7. The apparatus of claim 5, wherein the controller is configured to control the first switch based on one of:
at least one operating parameter associated with the energy production unit,
at least one operating parameter of a separate energy production unit, and
a control signal received from a remote unit.
8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current, a voltage, and a temperature; and the duty cycle is based on a maximum power point of the energy production unit.

9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series, the second management unit having at least a second switch, the second photovoltaic energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit, the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units.
10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel; and the management unit has no inductor and is integrated on the solar panel.
11. A method, comprising:
providing a management unit to couple a solar energy production unit to a series connection of energy production units, the management unit having a first switch and an energy storage unit coupled to the solar energy production unit; and
determining at least one parameter to control the first switch;
wherein, when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current; and
wherein, when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy

production units, and the management unit provides at least one path for the series connection of energy production units.

12. The method of claim 11, wherein the determining comprises:
computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit.
13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises:
receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units; and
identifying a first voltage among the operating voltages;
wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit.
14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and
wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units.
15. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected; and

undoing an adjustment to the duty cycle that causes the decrease.

16. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected; and
in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit.
17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter; and
adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point.
18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:
receiving operating parameters of a plurality of solar energy production units connected in series;
identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter;
identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units;
identifying a second maximum power point voltage of the second solar energy production unit;

computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage; and
adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage.

19. The method of claim 12, further comprising:
adjusting the duty cycle to increase the first current.
20. The method of claim 12, further comprising:
adjusting the duty cycle to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units, the string including the solar energy production unit.

REFERENCES DEEMED MOST CLOSELY RELATED

An Information Disclosure Statement in compliance with 37 C.F.R. §1.98 has been filed herewith citing each of the following references deemed most closely related to the subject matter of the claim.

Lee et al. WO 2005/112551 (Lee)

Rohrig et al. US2005/0172995 (Rohrig)

Decker et al. US5648731 (Decker)

IDENTIFICATION OF LIMITATIONS DISCLOSED BY REFERENCES**Lee: WO 2005/112551**

Lee discloses a photovoltaic power system monitoring system (*Abstract, lines 1-3*). With respect to the claims listed below, relevant portions of Lee showing the features related to the claim limitations are identified below within the parentheses near the corresponding claim limitations.

1. An apparatus (*Fig. 1*), comprising:
a photovoltaic energy production unit (“solar cells PV1, PV2”, *Fig. 1*) to generate electricity; and
a management unit coupled between the photovoltaic energy production unit and a series connection of energy production units (“solar cells PV1, PV2”, *Fig. 1*), the management unit having at least a first switch (“switches SW1 and SW2”, *Fig. 1*), the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit (*not disclosed*), the management unit to allow a second current larger than the first current to flow through the series connection of energy production units (*Fig. 1*).
2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit (“capacitor C1 or C2”, “inductor L”, *Fig. 1*) connected to the photovoltaic energy production unit;
wherein, when the first switch (“switch SW1 or SW2”, *Fig. 1*) is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second

current is equal to or larger than a sum of the first current and the third current;
and

wherein, when the first switch (“switch SW1 or SW2”, *Fig. 1*) is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy production units (*not disclosed*), and the management unit provides at least one path for the series connection of energy production units.

3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor (“Capacitor C1 or C2”, *Fig. 1*) coupled in parallel with the energy production unit (“solar cell PV1 or PV2”, *Fig. 1*); and when the first switch is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit.
4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode (“Diode near switch SW1 or SW2”, *Fig. 1*),
a second switch, wherein the management unit turns off the second switch when the first switch is turned on (*not disclosed*), and
a synchronous rectifier (*not disclosed*).
5. The apparatus of claim 1, wherein the management unit further comprises a controller to control the first switch according to a duty cycle (*Par. [34], page 4*).
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift, and a synchronization pulse (*Fig. 2*).

7. The apparatus of claim 5, wherein the controller is configured to control the first switch based on one of:
at least one operating parameter associated with the energy production unit (*not disclosed*),
at least one operating parameter of a separate energy production unit (*not disclosed*), and
a control signal (*Fig. 1*) received from a remote unit.
8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current, a voltage, and a temperature; and the duty cycle is based on a maximum power point of the energy production unit (*not disclosed*).
9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series, the second management unit having at least a second switch (“switches SW1 and SW2”, *Fig. 1*), the second photovoltaic energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit (*not disclosed*), the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units (*Fig. 1*).
10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel (“solar cells PV1, PV2”, *Fig. 1*); and the management unit has no inductor and is integrated on the solar panel.

11. A method, comprising:
- providing a management unit to couple a solar energy production unit to a series connection of energy production units (“solar cells PV1, PV2”, *Fig. 1*), the management unit having a first switch (“switches SW1 and SW2”, *Fig. 1*) and an energy storage unit (“capacitor C1 or C2”, “inductor L”, *Fig. 1*) coupled to the solar energy production unit; and
- determining at least one parameter to control the first switch (*Pars. [34-48], pages 4-5*);
- wherein, when the first switch (“switch SW1 or SW2”, *Fig. 1*) is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current; and
- wherein, when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected (*not disclosed*) from the series connection of energy production units, and the management unit provides at least one path for the series connection of energy production units (*Fig. 1*).
12. The method of claim 11, wherein the determining comprises:
- computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit (*not disclosed*).
13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises:
- receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units (*Par. [50], page 5*); and
- identifying a first voltage among the operating voltages (*not disclosed*);

wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit (*not disclosed*).

14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units (*not disclosed*).
15. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*not disclosed*); and
undoing an adjustment to the duty cycle that causes the decrease (*not disclosed*).
16. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*not disclosed*); and
in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit (*not disclosed*).
17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter; and

adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point (*not disclosed*).

18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:

receiving operating parameters of a plurality of solar energy production units connected in series;

identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter (*not disclosed*);

identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units (*not disclosed*);

identifying a second maximum power point voltage of the second solar energy production unit (*not disclosed*);

computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage (*not disclosed*); and

adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage (*not disclosed*).

19. The method of claim 12, further comprising:

adjusting the duty cycle to increase the first current (*not disclosed*).

20. The method of claim 12, further comprising:

adjusting the duty cycle to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units, the string including the solar energy production unit (*not disclosed*).

Rohrig: US2005/0172995

Rohrig discloses a distributed power system (*Figs. 2 and 3*). With respect to the claims listed below, relevant portions of Rohrig showing the features related to the claim limitations are identified below within the parentheses near the corresponding claim limitations.

1. An apparatus, comprising:
a photovoltaic energy production unit (“generators G1, G2, G3”, *Fig. 2*; “generator G”, *Fig. 3*) to generate electricity; and
a management unit (“generator control unit (GCU)”, *Figs. 2 and 3*) coupled between (*not disclosed*) the photovoltaic energy production unit and a series connection of energy production units, the management unit having at least a first switch (*not disclosed*), the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit (*not disclosed*), the management unit to allow a second current larger than the first current to flow through the series connection of energy production units (*Figs. 2 and 3*; *Pars. [0052-0054]*).
2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit (*not disclosed*) connected to the photovoltaic energy production unit; wherein, when the first switch is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current is equal to or larger than a sum of the first current and the third current (*not disclosed*); and wherein, when the first switch is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy

production units (*not disclosed*), and the management unit provides at least one path for the series connection of energy production units.

3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor coupled in parallel with the energy production unit (*not disclosed*); and when the first switch is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit (*Figs. 2 and 3*).
4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode (*not disclosed*),
a second switch, wherein the management unit turns off the second switch when the first switch is turned on (*not disclosed*), and
a synchronous rectifier (*not disclosed*).
5. The apparatus of claim 1, wherein the management unit further comprises a controller to control the first switch according to a duty cycle (*not disclosed*).
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift, and a synchronization pulse (*not disclosed*).
7. The apparatus of claim 5, wherein the controller is configured to control the first switch (*not disclosed*) based on one of:
at least one operating parameter associated with the energy production unit,
at least one operating parameter of a separate energy production unit, and
a control signal received from a remote unit.

8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current, a voltage, and a temperature; and the duty cycle (*not disclosed*) is based on a maximum power point of the energy production unit.
9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series (*not disclosed*), the second management unit having at least a second switch, the second photovoltaic energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit (*not disclosed*), the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units.
10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel (“photovoltaic system”, *abstract*); and the management unit has no inductor and is integrated on the solar panel.
11. A method, comprising:
providing a management unit (“generator control unit (GCU)”, *Figs. 2 and 3*) to couple a solar energy production unit to a series connection of energy production units (*not disclosed*), the management unit having a first switch (*not disclosed*) and an energy storage unit (*not disclosed*) coupled to the solar energy production unit;
and

determining at least one parameter to control the first switch (*not disclosed*);
wherein, when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current (*not disclosed*); and
wherein, when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected (*not disclosed*) from the series connection of energy production units, and the management unit provides at least one path for the series connection of energy production units (*Figs. 2 and 3; Pars. [0052-0054]*).

12. The method of claim 11, wherein the determining comprises:
computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit (*not disclosed*).
13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises:
receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units; and
identifying a first voltage among the operating voltages;
wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit (*not disclosed*).
14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and

wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units (*not disclosed*).

15. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*not disclosed*); and
undoing an adjustment to the duty cycle that causes the decrease (*not disclosed*).
16. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*not disclosed*); and
in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit (*not disclosed*).
17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter (*not disclosed*); and
adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point (*not disclosed*).

18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:
- receiving operating parameters of a plurality of solar energy production units connected in series (*Par. [0052]*);
 - identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter (*Par. [0052]*);
 - identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units (*not disclosed*);
 - identifying a second maximum power point voltage of the second solar energy production unit (*Par. [0052]*);
 - computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage (*not disclosed*); and
 - adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage (*not disclosed*).
19. The method of claim 12, further comprising:
- adjusting the duty cycle to increase the first current (*not disclosed*).
20. The method of claim 12, further comprising:
- adjusting the duty cycle (*not disclosed*) to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units, the string including the solar energy production unit.

Decker: US5648731

Decker discloses a solar electrical system (*Fig. 1*). With respect to the claims listed below, relevant portions of Decker showing the features related to the claim limitations are identified below within the parentheses near the corresponding claim limitations.

1. An apparatus, comprising:
a photovoltaic energy production unit (“solar array panel 3”, *Fig. 1*) to generate electricity; and
a management unit (“array regulator module 5”, *Fig. 1*) coupled between the photovoltaic energy production unit and a series connection of energy production units (*not disclosed*), the management unit having at least a first switch (“switch S1”, *Fig. 2*), the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units (*not disclosed*) via the first switch of the management unit, the management unit to allow a second current (“ I_{out} ”, *Col. 4, lines 16-19*) larger than the first current to flow through the series connection of energy production units.
2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit (“capacitor C1”, *Fig. 2*) connected to the photovoltaic energy production unit;
wherein, when the first switch (“switch S1”, *Fig. 2*) is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current is equal to or larger than a sum of the first current and the third current (*not disclosed*); and
wherein, when the first switch (“switch S1”, *Fig. 2*) is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series

connection of energy production units, and the management unit provides at least one path (“diode D1”, *Fig. 2*) for the series connection of energy production units.

3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor (“capacitor C1”, *Fig. 2*) coupled in parallel with the energy production unit (“solar array panel 3”, *Fig. 1*); and when the first switch is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit (*Not disclosed*).
4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode (“diode D1”, *Fig. 2*),
a second switch, wherein the management unit turns off the second switch when the first switch is turned on (*not disclosed*), and
a synchronous rectifier (*not disclosed*).
5. The apparatus of claim 1, wherein the management unit further comprises a controller (“circuit 34”, *Fig. 2*) to control the first switch according to a duty cycle (*Col. 7, lines 36-40*).
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift, and a synchronization pulse (*not disclosed*).
7. The apparatus of claim 5, wherein the controller is configured to control the first switch based on one of:
at least one operating parameter associated with the energy production unit (*Col. 10, lines 49-65; Col. 11, lines 6-20*),
at least one operating parameter of a separate energy production unit (*not disclosed*), and

a control signal received from a remote unit (*Fig. 2*).

8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current, a voltage (*Col. 10, lines 49-65*), and a temperature; and the duty cycle is based on a maximum power point of the energy production unit (*Col. 11, lines 6-20*).
9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series (*not disclosed*), the second management unit having at least a second switch, the second photovoltaic energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit, the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units.
10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel ("solar array panel 3", *Fig. 1*); and the management unit has no inductor and is integrated on the solar panel.
11. A method, comprising:
providing a management unit ("array regulator module 5", *Fig. 1*) to couple a solar energy production unit ("solar array panel 3", *Fig. 1*) to a series connection of energy production units (*not disclosed*), the management unit having a first switch

(“switch S1”, *Fig. 2*) and an energy storage unit (“capacitor C1”, *Fig. 2*) coupled to the solar energy production unit; and
determining at least one parameter to control the first switch (*Col. 10, lines 49-65; Col. 11, lines 6-20*);
wherein, when the first switch (“switch S1”, *Fig. 2*) is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current (*not disclosed*); and
wherein, when the first switch (“switch S1”, *Fig. 2*) is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units, and the management unit provides at least one path (“diode D1”, *Fig. 2*) for the series connection of energy production units.

12. The method of claim 11, wherein the determining comprises:
computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit (*Col. 11, lines 6-20*).
13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises:
receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units; and
identifying a first voltage among the operating voltages;
wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit (*not disclosed*).

14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units (*not disclosed*).
15. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*not disclosed*); and
undoing an adjustment to the duty cycle that causes the decrease (*not disclosed*).
16. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*not disclosed*); and
in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit (*not disclosed*).
17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter; and
adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point (*Col. 11, lines 6-20*).

18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:
- receiving operating parameters of a plurality of solar energy production units connected in series;
- identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter (*Col. 11, lines 6-20*);
- identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units (*not disclosed*);
- identifying a second maximum power point voltage of the second solar energy production unit;
- computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage (*not disclosed*); and
- adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage (*not disclosed*).
19. The method of claim 12, further comprising:
- adjusting the duty cycle to increase the first current (*Col. 7, lines 23-31*).
20. The method of claim 12, further comprising:
- adjusting the duty cycle to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units (*Col. 10, lines 49-65*), the string including the solar energy production unit.

DETAILED EXPLANATION OF PATENTABILITY

All of the references identified above (Lee, Rohrig and Decker) fail to at least teach or suggest “the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit” of claim 1.

Rohrig addresses the problem of different solar generators connected in series having different currents at their respective maximum power points (MPP) by introducing bypasses (see, e.g., Figs. 2 and 3; Pars. [0052-0054], Rohrig). In Rohrig, the current in the string is the lowest MPP current of the MPP currents of the solar generators. Such an approach is different from “the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit” recited in claim 1.

Decker does not address the problem of different solar generators connected in series having different currents at their respective maximum power points (MPP). In Decker, different solar array panels 3 are connected in parallel to the main power bus 37 (see, e.g., Fig. 1; Col. 4, lines 4-5 and 23-25; Decker). Decker discloses a switch S1, which is part of the buck regulator 7. A buck regulator is typically used to as a step-down converter (e.g., to reduce the output voltage of the solar panel). In Deck, the buck regulator is also used to set the solar panel at the maximum power point (see, e.g., Col. 10, lines 49-65; Col. 11, lines 6-20; Decker). Decker does not show “the photovoltaic energy production unit to generate a first current to provide electricity *to the series connection of energy production units* via the first switch of the management unit” recited in claim 1.

Lee discloses a circuit that can set the operating voltage of two solar cells connected in series based on the off duty cycles of the switches in the circuit (see, e.g., Fig. 1; Pars. [34-48], pages 4-5). Lee does not show “the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit” recited in claim 1.

Thus, claim 1 and its dependent claims are seen to patentably distinguish over each of these references alone or in combination.

All of the references identified above (Lee, Rohrig and Decker) fail to at least teach or suggest “when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units” and “when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units” of claim 11.

Rohrig addresses the problem of different solar generators connected in series having different currents at their respective maximum power points (MPP) by introducing bypasses (see, e.g., Figs. 2 and 3; Pars. [0052-0054], Rohrig). In Rohrig, the current in the string is the lowest MPP current of the MPP currents of the solar generators. Rohrig does not disclose a first switch such that “when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units” and “when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units”, as recited in claim 11.

Decker does not address the problem of different solar generators connected in series having different currents at their respective maximum power points (MPP). In Decker, different solar array panels 3 are connected in parallel to the main power bus 37 (see, e.g., Fig. 1; Col. 4, lines 4-5 and 23-25; Decker). Decker discloses a switch S1, which is part of the buck regulator 7. A buck regulator is typically used to as a step-down converter (e.g., to reduce the output voltage of the solar panel). In Deck, the buck regulator is used to set the solar panel at the maximum power point (see, e.g., Col. 10, lines 49-65; Col. 11, lines 6-20; Decker). Deck does not show “when the first switch is turned on, the solar energy production unit provides a first current to *the series connection of energy production units*” and “when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from *the series connection of energy production units*”, as recited in claim 11.

Lee discloses a circuit that can set the operating voltage of two solar cells connected in series based on the off duty cycles of the switches in the circuit (see, e.g., Fig. 1; Pars. [34-48], pages 4-5). The switches SW1 and SW2 of Lee are used to connect/disconnect the inductor L.

Lee does not disclose a first switch such that “when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units” and “when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units”, as recited in claim 11.

Thus, claim 11 and its dependent claims are seen to patentably distinguish over each of these references alone or in combination.

Further, all of the references identified above fail to at least teach or suggest “receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units; and identifying a first voltage among the operating voltages; wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit” of claim 13. Thus, claim 13 and its dependent claims are seen to patentably distinguish over each of these references alone or in combination.

Further, all of the references identified above fail to at least teach or suggest “when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units” of claim 14. Thus, claim 14 and its dependent claims are seen to patentably distinguish over each of these references alone or in combination.

Further, all of the references identified above fail to at least teach or suggest “adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected” of claims 15 and 16. Thus, claims 15 and 16 are seen to patentably distinguish over each of these references alone or in combination.

Further, all of the references identified above fail to at least teach or suggest “identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units; identifying a second maximum power point voltage of the second solar energy production unit; computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage; and adjusting the duty cycle to drive an

operating voltage of the first solar energy production unit towards the target voltage” of claim 18. Thus, claim 18 is seen to patentably distinguish over each of these references alone or in combination.

CONCISE STATEMENT OF UTILITY

The invention as claimed by claim 1 has utility at least in that it provides photovoltaic devices that can be connected in series without affecting the efficiency of each other.

The invention as claimed by claim 11 has utility at least in that it provides a process for a solar system having multiple photovoltaic devices connected in series without affecting the efficiency of each other.

IDENTIFICATION OF REFERENCES DISQUALIFIED

AS PRIOR ART UNDER 35 U.S.C. §103(C)

None of the cited references are disqualified as prior art under 35 U.S.C. §103(c).

SHOWING OF SUPPORT UNDER 35 U.S.C. §112, FIRST PARAGRAPH

The pending claims does not invoke 35 U.S.C. §112, sixth paragraph. There are no means- (or step-) plus-function claim elements.

The present application claims priority to provisional U.S. Patent Application Serial No. 61/200,601, filed on December 2, 2008, and provisional U.S. Patent Application Serial No. 61/200,279, filed on November 26, 2008.

Support in the present application:

With respect to the claims listed below, at least some of the relevant portions of the present application, which provide the support under 35 U.S.C. §112, first paragraph, are identified below within the parentheses near the corresponding claim limitations.

1. An apparatus, comprising:
a photovoltaic energy production unit (“solar module 102”, *Fig. 1*) to generate electricity;
and
a management unit (“LMU 101”, *Fig. 1*) coupled between the photovoltaic energy production unit (“solar module 102”, *Fig. 1*) and a series connection of energy production units (“serial power bus 103”, *Fig. 1*), the management unit having at least a first switch (“switch Q1 106”, *Fig. 1*), the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit (*Fig. 1*), the management unit to allow a second current larger than the first current to flow through the series connection of energy production units (*Fig. 1*; *Par. [0005, 0048]*).
2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit (“capacitor C1 105”, *Fig. 1*) connected to the photovoltaic energy production unit;
wherein, when the first switch is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current is equal to or larger than a sum of the first current and the third current (*Fig. 1*; *Par. [0007]*); and
wherein, when the first switch is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy production units (*Fig. 1*; *Par. [0007]*), and the management unit provides at least one path (“diode D1 107”, *Fig. 1*; “switch Q2 108”, *Fig. 2*) for the series connection of energy production units.

3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor (“capacitor C1 105”, *Fig. 1*) coupled in parallel with the energy production unit (“solar module 102”, *Fig. 1*); and when the first switch (“switch Q1 106”, *Fig. 1*) is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit (*Fig. 1; Par. [0008]*).
4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode (“diode D1 107”, *Fig. 1*),
a second switch, wherein the management unit turns off the second switch when the first switch is turned on (“switch Q2 108”, *Fig. 2; Pars. [0009, 0044]*), and
a synchronous rectifier (“switch Q2 108”, *Fig. 3; Pars. [0009, 0044]*).
5. The apparatus of claim 1, wherein the management unit further comprises a controller (“controller 109”, *Fig. 1*) to control the first switch according to a duty cycle (“duty cycle 104a”, *Fig. 1*).
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift (“duty cycle 104b”, *Fig. 1*), and a synchronization pulse (“duty cycle 104c”, *Fig. 1*).
7. The apparatus of claim 5, wherein the controller is configured to control the first switch based on one of:
at least one operating parameter associated with the energy production unit (*Par. [0105]*),
at least one operating parameter of a separate energy production unit (*Par. [0091]*), and
a control signal received from a remote unit (*Par. [0042]*).

8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current (*Pars. [0054, 0059]*), a voltage (*Pars. [0059, 0069, 0090]*), and a temperature (*Pars. [0069, 0098]*); and the duty cycle is based on a maximum power point of the energy production unit (*Pars. [0098, 0101]*).
9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series (*Fig. 4*), the second management unit having at least a second switch, the second photovoltaic energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit, the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units (*Figs. 1-3; Par. [0012]*).
10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel (*Fig. 5; Par. [0063]*); and the management unit has no inductor (*Figs. 1-3; Par. [0006]*) and is integrated on the solar panel (*Fig. 5; Par. [0006]*).
11. A method, comprising:
providing a management unit ("LMU 101", *Fig. 1*) to couple a solar energy production ("solar module 102", *Fig. 1*) unit to a series connection of energy production units ("serial power bus 103", *Fig. 1*), the management unit having a first switch ("switch Q1 106", *Fig. 1*) and an energy storage unit ("capacitor C1 105", *Fig. 1*) coupled to the solar energy production unit; and

determining at least one parameter to control the first switch (*Par. [0091]*);
wherein, when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current (*Fig. 1*); and
wherein, when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units (*Fig. 1*), , and the management unit provides at least one path (“diode D1 107”, *Fig. 1*; “switch Q2 108”, *Fig. 2*) for the series connection of energy production units (*Par. [0013]*).

12. The method of claim 11, wherein the determining comprises:
computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit (*Par. [0091]*).
13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises:
receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units (*Par. [0090]*); and
identifying a first voltage among the operating voltages (*Par. [0090]*);
wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit (*Par. [0091]*).
14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and

wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units (*Par. [0091]*).

15. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (“operation 427”, *Fig. 7; Par. [0096]*); and
undoing an adjustment to the duty cycle that causes the decrease (“operation 429”, *Fig. 7; Par. [0096]*).
16. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (“operation 427”, *Fig. 7; Par. [0097]*); and
in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit (“operation 431”, *Fig. 7; Par. [0097]*).
17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter (*Par. [0098]*); and
adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point (*Par. [0098]*).

18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:
- receiving operating parameters of a plurality of solar energy production units connected in series (“operation 441”, *Fig. 8*);
- identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter (“operation 443”, *Fig. 8*);
- identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units (“operation 445”, *Fig. 8*);
- identifying a second maximum power point voltage of the second solar energy production unit (“operation 447”, *Fig. 8*);
- computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage (“operation 449”, *Fig. 8*); and
- adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage (“operation 451”, *Fig. 8*).
19. The method of claim 12, further comprising:
- adjusting the duty cycle to increase the first current (*Par. [0105]*).
20. The method of claim 12, further comprising:
- adjusting the duty cycle to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units, the string including the solar energy production unit (*Par. [0105]*).

Support in provisional U.S. Patent Application Serial No. 61/200,601, filed on December 2,

2008:

With respect to the claims listed below, at least some of the relevant portions of the provisional U.S. Patent Application Serial No. 61/200,601, filed on December 2, 2008, which provide the support under 35 U.S.C. §112, first paragraph, are identified below within the parentheses near the corresponding claim limitations.

1. An apparatus, comprising:
a photovoltaic energy production unit (“solar module 102”, *Fig. 1*) to generate electricity;
and
a management unit (“LMU 101”, *Fig. 1*) coupled between the photovoltaic energy production unit and a series connection of energy production units (“serial power bus 103”, *Fig. 1*), the management unit having at least a first switch (“switch Q1 106”, *Fig. 1*), the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit (*Fig. 1*), the management unit to allow a second current larger than the first current to flow through the series connection of energy production units (*Fig. 1; lines 18-20, page 2*).
2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit (“capacitor C1 105”, *Fig. 1*) connected to the photovoltaic energy production unit;
wherein, when the first switch is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current is equal to or larger than a sum of the first current and the third current (*Fig. 1*); and

wherein, when the first switch is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy production units (*Fig. 1*), and the management unit provides at least one path (“diode D1 107”, “switch Q2 108”, *Fig. 1*) for the series connection of energy production units .

3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor (“capacitor C1 105”, *Fig. 1*) coupled in parallel with the energy production unit (“solar module 102”, *Fig. 1*); and when the first switch (“switch Q1 106”, *Fig. 1*) is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit (*Fig. 1*).
4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode (“diode D1 107”, *Fig. 1*),
a second switch (“switch Q2 108”, *Fig. 1*), wherein the management unit turns off the second switch when the first switch is turned on, and
a synchronous rectifier (*lines 7-8, page 2*).
5. The apparatus of claim 1, wherein the management unit further comprises a controller (“SCMC 109”, *Fig. 1*) to control the first switch according to a duty cycle (“duty cycle 104a”, *Fig. 1*).
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift (“phase 104b”, *Fig. 1*), and a synchronization pulse (“sync pulse 104c”, *Fig. 1*).

7. The apparatus of claim 5, wherein the controller is configured to control the first switch based on one of:
at least one operating parameter associated with the energy production unit (*lines 4-5, page 5*),
at least one operating parameter of a separate energy production unit (*lines 6-12, page 4*),
and
a control signal received from a remote unit (*lines 2-4, page 2*).
8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current (*line 26, page 2*), a voltage (*lines 4-5, page 5*), and a temperature (*line 21, page 4*); and the duty cycle is based on a maximum power point of the energy production unit (*lines 21-26, page 4*).
9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series (*Fig. 2*), the second management unit having at least a second switch, the second photovoltaic energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit, the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units (*Fig. 1; lines 18-20, page 2*).

10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel (*lines 16-18, page 2*); and the management unit has no inductor (*Fig. 1*) and is integrated on the solar panel (*lines 20-22, page 1; lines 16-18, page 2*).
11. A method, comprising:
providing a management unit (“LMU 101”, *Fig. 1*) to couple a solar energy production unit (“solar module 102”, *Fig. 1*) to a series connection of energy production units (“serial power bus 103”, *Fig. 1*), the management unit having a first switch (“switch Q1 106”, *Fig. 1*) and an energy storage unit (“capacitor C1 105”, *Fig. 1*) coupled to the solar energy production unit; and
determining at least one parameter to control the first switch (*lines 6-12, page 4*);
wherein, when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current (*Fig. 1*); and
wherein, when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units (*Fig. 1*), and the management unit provides at least one path (“diode D1 107”, “switch Q2 108”, *Fig. 1*) for the series connection of energy production units.
12. The method of claim 11, wherein the determining comprises:
computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit (*lines 4-5, page 5*).

13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises: receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units (*line 8, page 4*); and identifying a first voltage among the operating voltages (*line 10-12, page 4*); wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit (*line 10-12, page 4*).
14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units (*lines 10-12, page 4*).
15. The method of claim 14, further comprising: adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*lines 13-14, page 4*); and undoing an adjustment to the duty cycle that causes the decrease (*lines 14-15, page 4*).
16. The method of claim 14, further comprising: adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*lines 17-18, page 4*); and

in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit (*lines 18-20, page 4*).

17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter (*lines 21-24, page 4*); and
adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point (*lines 24-26, page 4*).
18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:
receiving operating parameters of a plurality of solar energy production units connected in series (*lines 15-16, page 7*);
identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter (*lines 18-20, page 7*);
identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units (*line 17, page 7*);
identifying a second maximum power point voltage of the second solar energy production unit (*lines 18-20, page 7*);
computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage (*lines 21-25, page 7*); and
adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage (*lines 26-28, page 7*).
19. The method of claim 12, further comprising:

adjusting the duty cycle to increase the first current (*lines 4-6, page 5*).

20. The method of claim 12, further comprising:

adjusting the duty cycle to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units, the string including the solar energy production unit (*lines 4-7, page 5*).

Support in provisional U.S. Patent Application Serial No. 61/200,279, filed on November 26,

2008:

With respect to the claims listed below, at least some of the relevant portions of the provisional U.S. Patent Application Serial No. 61/200,279, filed on November 26, 2008, which provide the support under 35 U.S.C. §112, first paragraph, are identified below within the parentheses near the corresponding claim limitations.

1. An apparatus, comprising:

a photovoltaic energy production unit (“solar module 102”, *Fig. 1*) to generate electricity;
and

a management unit (“LMU 101”, *Fig. 1*) coupled between the photovoltaic energy production unit and a series connection of energy production units (“serial power bus 103”, *Fig. 1*), the management unit having at least a first switch (“switch Q1 106”, *Fig. 1*), the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit (*Fig. 1*), the management unit to allow a second current larger than the first current to flow through the series connection of energy production units (*Fig. 1; lines 18-20, page 2*).

2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit (“capacitor C1 105”, *Fig. 1*) connected to the photovoltaic energy production unit;
wherein, when the first switch is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current is equal to or larger than a sum of the first current and the third current (*Fig. 1*); and
wherein, when the first switch is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy production units (*Fig. 1*), and the management unit provides at least one path (“diode D1 107”, “switch Q2 108”, *Fig. 1*) for the series connection of energy production units .
3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor (“capacitor C1 105”, *Fig. 1*) coupled in parallel with the energy production unit (“solar module 102”, *Fig. 1*); and when the first switch (“switch Q1 106”, *Fig. 1*) is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit (*Fig. 1*).
4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode (“diode D1 107”, *Fig. 1*),
a second switch (“switch Q2 108”, *Fig. 1*), wherein the management unit turns off the second switch when the first switch is turned on, and
a synchronous rectifier (*lines 7-8, page 2*).

5. The apparatus of claim 1, wherein the management unit further comprises a controller (“SCMC 109”, *Fig. 1*) to control the first switch according to a duty cycle (“duty cycle 104a”, *Fig. 1*).
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift (“phase 104b”, *Fig. 1*), and a synchronization pulse (“sync pulse 104c”, *Fig. 1*).
7. The apparatus of claim 5, wherein the controller is configured to control the first switch based on one of:
at least one operating parameter associated with the energy production unit (*lines 4-5, page 5*),
at least one operating parameter of a separate energy production unit (*lines 6-12, page 4*),
and
a control signal received from a remote unit (*lines 2-4, page 2*).
8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current (*line 26, page 2*), a voltage (*lines 4-5, page 5*), and a temperature (*line 21, page 4*); and the duty cycle is based on a maximum power point of the energy production unit (*lines 21-26, page 4*).
9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series (*Fig. 2*), the second management unit having at least a second switch, the second photovoltaic

energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit, the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units (*Fig. 1; lines 18-20, page 2*).

10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel (*lines 16-18, page 2*); and the management unit has no inductor (*Fig. 1*) and is integrated on the solar panel (*lines 20-22, page 1; lines 16-18, page 2*).
11. A method, comprising:
providing a management unit ("LMU 101", *Fig. 1*) to couple a solar energy production unit ("solar module 102", *Fig. 1*) to a series connection of energy production units ("serial power bus 103", *Fig. 1*), the management unit having a first switch ("switch Q1 106", *Fig. 1*) and an energy storage unit ("capacitor C1 105", *Fig. 1*) coupled to the solar energy production unit; and
determining at least one parameter to control the first switch (*lines 6-12, page 4*);
wherein, when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current (*Fig. 1*); and
wherein, when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units (*Fig. 1*), and the management unit provides at least one path ("diode D1 107", "switch Q2 108", *Fig. 1*) for the series connection of energy production units.

12. The method of claim 11, wherein the determining comprises:
computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit (*lines 4-5, page 5*).
13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises:
receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units (*line 8, page 4*); and
identifying a first voltage among the operating voltages (*line 10-12, page 4*);
wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit (*line 10-12, page 4*).
14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and
wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units (*lines 10-12, page 4*).
15. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*lines 13-14, page 4*); and
undoing an adjustment to the duty cycle that causes the decrease (*lines 14-15, page 4*).
16. The method of claim 14, further comprising:

adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*lines 17-18, page 4*); and
in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit (*lines 18-20, page 4*).

17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter (*lines 21-24, page 4*); and
adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point (*lines 24-26, page 4*).
18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:
receiving operating parameters of a plurality of solar energy production units connected in series (*lines 12-13, page 7*);
identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter (*lines 15-17, page 7*);
identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units (*line 14, page 7*);
identifying a second maximum power point voltage of the second solar energy production unit (*lines 15-17, page 7*);
computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage (*lines 18-22, page 7*); and
adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage (*lines 23-25, page 7*).

19. The method of claim 12, further comprising:
adjusting the duty cycle to increase the first current (*lines 4-6, page 5*).
20. The method of claim 12, further comprising:
adjusting the duty cycle to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units, the string including the solar energy production unit (*lines 4-7, page 5*).

Respectfully submitted,

Date: June 15, 2009

/Lehua Wang/
Lehua Wang
Reg. No. 48,023

GREENBERG TRAURIG, LLP
CUSTOMER NUMBER **64494**
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	108144-200701/US (TGY010)
		Application Number	
Title of Invention	Systems and Methods to Balance Solar Panels in a Multi-Panel System		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2

- ☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Applicant Information:

Applicant 1						Remove	
Applicant Authority		☒ Inventor		☐ Legal Representative under 35 U.S.C. 117		☐ Party of Interest under 35 U.S.C. 118	
Prefix	Given Name	Middle Name		Family Name		Suffix	
	Ron			HADAR			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service							
City	Cupertino	State/Province	CA	Country of Residenceⁱ		US	
Citizenship under 37 CFR 1.41(b)ⁱ		IL					
Mailing Address of Applicant:							
Address 1		10337 Tula Lane					
Address 2							
City	Cupertino	State/Province		CA			
Postal Code		95014		Countryⁱ	US		
Applicant 2						Remove	
Applicant Authority		☒ Inventor		☐ Legal Representative under 35 U.S.C. 117		☐ Party of Interest under 35 U.S.C. 118	
Prefix	Given Name	Middle Name		Family Name		Suffix	
	Shmuel			ARDITI			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service							
City	Los Gatos	State/Province	CA	Country of Residenceⁱ		US	
Citizenship under 37 CFR 1.41(b)ⁱ		US					
Mailing Address of Applicant:							
Address 1		104 Las Uvas					
Address 2							
City	Los Gatos	State/Province		CA			
Postal Code		95032		Countryⁱ	US		
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button. Add							

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

- ☐ An Address is being provided for the correspondence Information of this application.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	108144-200701/US (TGY010)	
		Application Number		
Title of Invention	Systems and Methods to Balance Solar Panels in a Multi-Panel System			
Customer Number	64494			
Email Address	wangl@gtlaw.com	Add Email	Remove Email	
Email Address	svip@gtlaw.com	Add Email	Remove Email	

Application Information:

Title of the Invention	Systems and Methods to Balance Solar Panels in a Multi-Panel System		
Attorney Docket Number	108144-200701/US (TGY010)	Small Entity Status Claimed	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)		Suggested Figure for Publication (if any)	

Publication Information:

☐	Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐	Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

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Customer Number	64494		

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Prior Application Status	Pending	Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	non provisional of	61200601	2008-12-02
Prior Application Status	Pending	Remove	

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	108144-200701/US (TGY010)	
		Application Number		
Title of Invention	Systems and Methods to Balance Solar Panels in a Multi-Panel System			
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	
	non provisional of	61200279	2008-11-26	
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.				Add

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			Remove
Application Number	Country ⁱ	Parent Filing Date (YYYY-MM-DD)	Priority Claimed
			☒ Yes ☐ No
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Assignee Information:

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Assignee 1			Remove
If the Assignee is an Organization check here. ☒			
Organization Name	Tigo Energy, Inc.		
Mailing Address Information:			
Address 1	170 Knowles Drive		
Address 2	Suite 203		
City	Los Gatos	State/Province	CA
Country ⁱ	US	Postal Code	95032
Phone Number		Fax Number	
Email Address			
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Signature:

A signature of the applicant or representative is required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature.					
Signature	/Lehua Wang/			Date (YYYY-MM-DD)	2009-06-15
First Name	Lehua	Last Name	Wang	Registration Number	48023

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	108144-200701/US (TGY010)
		Application Number	
Title of Invention	Systems and Methods to Balance Solar Panels in a Multi-Panel System		

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
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Electronic Acknowledgement Receipt

EFS ID:	5519369
Application Number:	12411317
International Application Number:	
Confirmation Number:	4944
Title of Invention:	Systems and Methods to Balance Solar Panels in a Multi-Panel System
First Named Inventor/Applicant Name:	Ron HADAR
Customer Number:	64494
Filer:	John Patrick Ward/Anne Collette
Filer Authorized By:	John Patrick Ward
Attorney Docket Number:	108144-200701/US (TGY010)
Receipt Date:	15-JUN-2009
Filing Date:	25-MAR-2009
Time Stamp:	21:08:57
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		108144-200701US_Prelim_Amendment.pdf	88793 82d40f0e8748e2ada33946af387a7d90b675b8de	yes	3

Multipart Description/PDF files in .zip description					
Document Description			Start	End	
Preliminary Amendment			1	1	
Specification			2	2	
Applicant Arguments/Remarks Made in an Amendment			3	3	
Warnings:					
Information:					
2	Examination support document	108144-200701US_AESD.pdf	237862	no	49
			2924b06a0c6e48c054d7e4b053697ec505f a4dfb		
Warnings:					
Information:					
3	Application Data Sheet	108144-200701US_ADS.pdf	1192589	no	5
			86257172708574b47a0431b2ac58744fe46 a6872		
Warnings:					
Information:					
Total Files Size (in bytes):			1519244		
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 12/411,317		Filing Date 03/25/2009		☐ To be Mailed	
APPLICATION AS FILED – PART I										
(Column 1)			(Column 2)			SMALL ENTITY ☒ OR		OTHER THAN SMALL ENTITY		
FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)	OR	RATE (\$)	FEE (\$)	OR	RATE (\$)	FEE (\$)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X \$	=		X \$	=		X \$	=
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X \$	=		X \$	=		X \$	=
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).									
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))										
* If the difference in column 1 is less than zero, enter "0" in column 2.										
APPLICATION AS AMENDED – PART II										
(Column 1)			(Column 2)			SMALL ENTITY OR		OTHER THAN SMALL ENTITY		
AMENDMENT	06/15/2009	CLAIMS REMAINING AFTER AMENDMENT	MINUS	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)
Total (37 CFR 1.16(i))	* 20	Minus	** 20	=	0	X \$26 =	0	OR	X \$ =	
Independent (37 CFR 1.16(h))	* 2	Minus	*** 3	=	0	X \$110 =	0	OR	X \$ =	
☐ Application Size Fee (37 CFR 1.16(s))										
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))										
						TOTAL ADD'L FEE	0	OR	TOTAL ADD'L FEE	
(Column 1)			(Column 2)			SMALL ENTITY OR		OTHER THAN SMALL ENTITY		
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT	MINUS	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	OR	RATE (\$)	ADDITIONAL FEE (\$)
Total (37 CFR 1.16(i))	*	Minus	**	=		X \$ =		OR	X \$ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=		X \$ =		OR	X \$ =	
☐ Application Size Fee (37 CFR 1.16(s))										
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))										
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.										

Legal Instrument Examiner:
/Ruth Graden/

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
12/411,317	03/25/2009	1795	462	108144-200701/US (TGY010)	20	2

CONFIRMATION NO. 4944

64494
GREENBERG TRAURIG, LLP (SV)
IP DOCKETING
2450 COLORADO AVENUE
SUITE 400E
SANTA MONICA, CA 90404

FILING RECEIPT



Date Mailed: 04/01/2009

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Ron HADAR, Cupertino, CA;
Shmuel ARDITI, Los Gatos, CA;

Assignment For Published Patent Application

TIGO ENERGY, INC., Los Gatos, CA

Power of Attorney: The patent practitioners associated with Customer Number 64494

Domestic Priority data as claimed by applicant

This appln claims benefit of 61/200,601 12/02/2008

Foreign Applications

If Required, Foreign Filing License Granted: 04/01/2009

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/411,317**

Projected Publication Date: 06/03/2010

Non-Publication Request: No

Early Publication Request: No

**** SMALL ENTITY ****

Title

Systems and Methods to Balance Solar Panels in a Multi-Panel System

Preliminary Class

136

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PETITION TO MAKE SPECIAL UNDER ACCELERATED EXAMINATION PROGRAM

Attorney Docket Number	108144-200701/US (TGY010)	First Named Inventor	Ron Hadar
Application Number (if Known)			
Title of Invention	Systems and Methods to Balance Solar Panels in a Multi-Panel System		

APPLICANT HEREBY PETITIONS TO MAKE THE ABOVE-IDENTIFIED APPLICATION SPECIAL UNDER THE REVISED ACCELERATED EXAMINATION PROGRAM. See Instruction sheet on page 3.

1.	Claims of the application: a. The application must contain three (3) or fewer independent claims and twenty (20) or fewer total claims. The application may not contain any multiple dependent claims. b. Applicant hereby agrees not to separately argue the patentability of any dependent claim during any appeal in the application. Specifically, the applicant agrees that the dependent claims will be grouped together with and not argued separately from the independent claim from which they depend in any appeal brief filed in the application (37 CFR 41.37(c)(1)(vii)). c. The claims must be directed to a single invention.
2.	Interviews: Applicant hereby agrees to have (if requested by examiner): a. An interview (including an interview before a first Office action) to discuss the prior art and any potential rejections or objections with the intention of clarifying and possibly resolving all issues with respect to patentability at that time, and b. A telephonic interview to make an election without traverse if the Office determines that the claims are not obviously directed to a single invention.
3.	Preexamination Search Statement and Accelerated Examination Support Document: With this petition, applicant is providing: a preexamination search statement, in compliance with the requirements set forth in item 8 of the instruction sheet, and an “accelerated examination support document” that includes: a. An information disclosure statement in compliance with 37 CFR 1.98 citing each reference deemed most closely related to the subject matter of each of the claims; b. For each reference cited, an identification of all the limitations of the claims that are disclosed by the reference specifying where the limitation is disclosed in the cited reference; c. A detailed explanation of how each of the claims are patentable over the references cited with the particularity required by 37 CFR 1.111(b) and (c); d. A concise statement of the utility of the invention as defined in each of the independent claims (unless the application is a design application); e. An identification of any cited references that may be disqualified as prior art under 35 U.S.C. 103(c) as amended by the CREATE act; and f. A showing of where each limitation of the claims finds support under the first paragraph of 35 U.S.C. 112 in the written description of the specification. If applicable, the showing must also identify: (1) each means- (or step-) plus-function claim element that invokes consideration under 35 U.S.C. 112, ¶6; and (2) the structure, material, or acts that correspond to any means- (or step-) plus-function claim element that invokes consideration under 35 U.S.C. 112, ¶6. If the application claims the benefit of one or more applications under title 35, United States Code, the showing must also include where each limitation of the claims finds support under the first paragraph of 35 U.S.C. 112 in each such application in which such support exists.

PETITION TO MAKE SPECIAL UNDER ACCELERATED EXAMINATION PROGRAM (Continued)

Attorney Docket Number	108144-200701/US (TGY010)	First Named Inventor	Ron Hadar
Attachments:			
a.		Accelerated Examination Support Document (see item 3 above).	
b.		A statement, in compliance with the requirements set forth in item 8 of the instruction sheet, detailing the preexamination search which was conducted.	
c.		Information Disclosure Statement.	
d.	☐	Other (e.g., a statement that the claimed subject matter is directed to environmental quality, energy, or countering terrorism (37 CFR 1.102(c)(2)). 	
Fees: The following fees must be filed electronically via EFS or EFS-Web:			
a.	The basic filing fee, search fee, examination fee, and application size fee (if required) under 37 CFR 1.16.		
b.	Petition fee under 37 CFR 1.17(h) - unless the petition is filed with a showing under 37 CFR 1.102(c)(2).		
Signature:			
Click Remove if you wish to remove this signatory			Remove
Signature	/LEHUA WANG/	Date	2009-03-25
Name (Print/Typed)	Lehua Wang	Registration Number	48023
Click Add if you wish to add additional signatory			Add
<i>Note: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature.</i>			

Instruction Sheet Petition to Make Special Under the Accelerated Examination

A grantable petition must meet the following conditions:

1. The petition to make special under the accelerated examination program must be filed with the application and accompanied by the fee set forth in 37 CFR 1.17(h) or a statement that the claimed subject matter is directed to environmental quality, energy, or countering terrorism.
2. The application must be a non-reissue utility or design application filed under 35 U.S.C. 111(a).
3. The application must be **filed electronically** using the Office electronic filing system (EFS) or EFS-Web.
4. The application must be complete under 37 CFR 1.51 and in condition for examination on filing. For example, the application must be filed together with the basic filing fee, search fee, examination fee, and application size fee (if applicable), and an oath or declaration under 37 CFR 1.63.
5. The application must contain three (3) or fewer independent claims and twenty (20) or fewer total claims. The application may not contain any multiple dependent claims. The petition must include a statement that **applicant will agree not to separately argue the patentability of any dependent claim during any appeal** in the application. Specifically, the applicant is agreeing that the dependent claims will be grouped together with and not argued separately from the independent claim from which they depend in any appeal brief filed in the application (37 CFR 41.37(c)(1)(vii)).
6. The claims must be directed to a **single invention**. The petition must include a statement that applicant will agree to have a telephonic interview to make an election without traverse in a telephonic interview if the Office determines that all the claims are not directed to a single invention.
7. The petition must include a statement that **applicant will agree** to have an interview (including an interview before a first Office action) to discuss the prior art and any potential rejections or objections with the intention of clarifying and possibly resolving all issues with respect to patentability at that time.
8. At the time of filing, applicant must provide a statement that a **preexamination search was conducted**, including an identification of the field of search by United States class and subclass and the date of the search, where applicable, and, for database searches, the search logic or chemical structure or sequence used as a query, the name of the file or files searched and the database service, and the date of the search.
 - a. This preexamination search must involve U.S. patents and patent application publications, foreign patent documents, and nonpatent literature, unless the applicant can justify with reasonable certainty that no references more pertinent than those already identified are likely to be found in the eliminated source and includes such a justification with this statement.
 - b. This preexamination search must be directed to the claimed invention and encompass all of the features of the independent claims, giving the claims the broadest reasonable interpretation.
 - c. The preexamination search must also encompass the disclosed features that may be claimed, in that an amendment to the claims (including any new claim) that is not encompassed by the preexamination search will be treated as non-responsive and will not be entered.
 - d. A search report from a foreign patent office will not be accepted unless the search report satisfies the requirements set forth above.
 - e. Any statement in support of a petition to make special must be based on a good faith belief that the preexamination search was conducted in compliance with these requirements. See 37 CFR 1.56 and 10.18.
9. At the time of filing, applicant must provide in support of the petition an **accelerated examination support document that includes:**
 - a. An **information disclosure statement** in compliance with 37 CFR 1.98 citing each reference deemed most closely related to the
 - subject matter of each of the claims;
 - b. For each reference cited, an **identification of all the limitations of the claims** that are disclosed by the reference specifying where the limitation is disclosed in the cited reference;
 - c. A **detailed explanation of how each of the claims are patentable** over the references cited with the particularity required by 37 CFR 1.111(b) and (c);
 - d. A concise **statement of the utility** of the invention as defined in each of the independent claims (unless the application is a design application);
 - e. An identification of any cited references that may be disqualified as prior art under 35 U.S.C. 103(c) as amended by the CREATE act; and
 - f. A **showing of where each limitation of the claims finds support under the first paragraph of 35 U.S.C. 112** in the written description of the specification. If applicable, the showing must also identify: (1) each means- (or step-) plus-function claim element that invokes consideration under 35 U.S.C. 112, ¶6; and (2) the structure, material, or acts that correspond to any means- (or step-) plus-function claim element that invokes consideration under 35 U.S.C. 112, ¶6. If the application claims the benefit of one or more applications under title 35, United States Code, the showing must also include where each limitation of the claims finds support under the first paragraph of 35 U.S.C. 112 in each such application in which such support exists.

For more information, see notice "Changes to Practice for Petitions in Patent Applications to Make Special and for Accelerated Examination" available on the USPTO web site at <http://www.uspto.gov/web/office/s/pac/dapp/ogsheet.html>

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number			
	Filing Date			
	First Named Inventor	Ron Hadar		
	Art Unit			
	Examiner Name	Not Assigned		
	Attorney Docket Number	108144-200701/US (TGY010)		

U.S.PATENTS						
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	5648731	A1	1997-07-15	Decker et al.	

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS						
Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20050172995	A1	2005-08-11	Rohrig et al.	

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS								
Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1	2005112551	WO	A2	2005-12-01	Hansung Engineering Co. LTD		☐

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		
	Filing Date		
	First Named Inventor	Ron Hadar	
	Art Unit		
	Examiner Name	Not Assigned	
	Attorney Docket Number	108144-200701/US (TGY010)	

	1		☐
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If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature		Date Considered	
--------------------	--	-----------------	--

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number	
Filing Date	
First Named Inventor	Ron Hadar
Art Unit	
Examiner Name	Not Assigned
Attorney Docket Number	108144-200701/US (TGY010)

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/LEHUA WANG/	Date (YYYY-MM-DD)	2009-03-25
Name/Print	Lehua Wang	Registration Number	48023

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

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2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Patent Application Fee Transmittal

Application Number:				
Filing Date:				
Title of Invention:	Systems and Methods to Balance Solar Panels in a Multi-Panel System			
First Named Inventor/Applicant Name:	Ron HADAR			
Filer:	John Patrick Ward/Anne Collette			
Attorney Docket Number:	108144-200701/US (TGY010)			
Filed as Small Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Utility filing Fee (Electronic filing)	4011	1	82	82
Utility Search Fee	2111	1	270	270
Utility Examination Fee	2311	1	110	110
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Petition fee- 37 CFR 1.17(h) (Group III)	1464	1	130	130

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				592

Electronic Acknowledgement Receipt

EFS ID:	5036557
Application Number:	12411317
International Application Number:	
Confirmation Number:	4944
Title of Invention:	Systems and Methods to Balance Solar Panels in a Multi-Panel System
First Named Inventor/Applicant Name:	Ron HADAR
Customer Number:	64494
Filer:	John Patrick Ward/Anne Collette
Filer Authorized By:	John Patrick Ward
Attorney Docket Number:	108144-200701/US (TGY010)
Receipt Date:	25-MAR-2009
Filing Date:	
Time Stamp:	20:26:03
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$592
RAM confirmation Number	14741
Deposit Account	502638
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Charge any Additional Fees required under 37 C.F.R. Section 1.16 (National application filing, search, and examination fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		108144-200701US_Application.pdf	171933 62ae117c8ad626ace99fab61872264f6f6afa188	yes	28
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Specification		1	22	
	Claims		23	27	
	Abstract		28	28	
Warnings:					
Information:					
2	Drawings-only black and white line drawings	108144-200701US_Drawings.pdf	80914 557d65eb8bab1891af431b6aec7bcc52bc72677f	no	8
Warnings:					
Information:					
3	Oath or Declaration filed	108144-200701US_Declaration.pdf	1289302 a6d41b8c94b57fea444392aae44c6a34d35889f	no	2
Warnings:					
Information:					
4	Statement of preexamination search	108144-200701US_Search.pdf	123866 9b65d4e2a07c1698ba07bb3d1cae5244c8277275	no	5
Warnings:					
Information:					
5	Examination support document	108144-200701US_Support.pdf	224473 d63d1fb8b51826ce29f61734ea0c59256a095dfa	no	43
Warnings:					
Information:					
6	Foreign Reference	WO2005112551.pdf	775077 7503544a0210f80581f854689d4e004d3c7283f3	no	17
Warnings:					

Information:					
7	Application Data Sheet	108144-200701US_ADS.pdf	1134015 b3c8000fea7a91698d9d8b4b0fea5ec0092db955	no	4
Warnings:					
Information:					
8	Petition for 12-month Accelerated Exam	108144-200701US_Petition.pdf	1127182 528f2c9a8394cd74994c26a8574984d859c89daa	no	4
Warnings:					
Information:					
9		108144-200701US_IDS.pdf	764640 d591421a694f1d554f2bfecced2b98ec82ddb94	yes	4
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Information Disclosure Statement (IDS) Filed (SB/08)		1	2	
	Information Disclosure Statement Letter		3	4	
Warnings:					
Information:					
10	Fee Worksheet (PTO-06)	fee-info.pdf	36602 c76ba61e6074fe2082c347f9be655a5422e6a27a	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			5728004		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

UNITED STATES PATENT APPLICATION
FOR
SYSTEMS AND METHODS TO BALANCE SOLAR PANELS IN A MULTI-PANEL SYSTEM

INVENTORS:

**RON HADAR
SHMUEL ARDITI**

PREPARED BY:

GREENBERG TRAURIG, LLP

PHONE: (650) 328-8500

FAX: (650) 328-8508

SYSTEMS AND METHODS TO BALANCE SOLAR PANELS IN A MULTI-PANEL SYSTEM

RELATED APPLICATIONS

[0001] The present application claims the benefit of Provisional U.S. Patent Application Serial No. 61/200,601, filed December 2, 2008 and entitled “Enhanced System and Method for Balancing Solar Panels in a Multi-Panel System,” the disclosure of which is hereby incorporated herein by reference.

FIELD OF THE TECHNOLOGY

[0002] At least some embodiments of the disclosure relate to photovoltaic systems in general, and more particularly but not limited to, improving the energy production performance of photovoltaic systems.

BACKGROUND

[0003] Solar system installers take a large guard band (or safety margin) to make sure the voltages don’t cross the 600V or 1000V limits in the United States and the European Union, respectively. That limitation inhibits them from installing more solar panel modules, often referred to as “modules” or “panels,” in series to reduce the cost of combiner boxes or string inverters. When solar modules are connected in series or in mesh configurations, there can be a problem in which weaker modules not only produce less energy but also affect other modules’ capabilities to deliver energy in the same string or wiring section.

SUMMARY OF THE DESCRIPTION

[0004] Systems and methods to balance currents among a plurality of photovoltaic units connected in series are described herein. Some embodiments are summarized in this section.

[0005] In one aspect, an apparatus includes: a photovoltaic energy production unit to generate electricity; and a management unit coupled between the photovoltaic energy production unit and a series connection of energy production units. The management unit has at least a first switch, via which the photovoltaic energy production unit generating a first current is to provide electricity to the series connection of energy production units. The management unit is configured to allow a second current, larger than the first current, to flow through the series connection of energy production units.

[0006] In one embodiment, the energy production unit is at least one solar cell of a solar panel; and the management unit has no inductor and is integrated on the solar panel. For example, the energy production unit may be a subset of photovoltaic cells in a string on a solar panel, or the entire set of photovoltaic cells of a solar panel.

[0007] In one embodiment, the management unit further includes an energy storage unit connected to the photovoltaic energy production unit. When the first switch is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current in the series connection is equal to or larger than a sum of the first current and the third current. When the first switch is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy production units, and the management unit provides at least one path for the series connection of energy production units.

[0008] In one embodiment, the energy storage unit includes a capacitor coupled in parallel with the energy production unit. When the first switch is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit.

[0009] In one embodiment, the at least one path includes at least one of: a diode, a second switch that is turned off when the first switch is turned on, and a synchronous rectifier.

[0010] In one embodiment, the management unit further includes a controller to control the first switch according to a duty cycle and/or at least one of: a phase shift, and a synchronization pulse. The controller may be configured to control the first switch based on one of: at least one operating parameter (e.g., current, voltage, and temperature) associated with the energy

production unit, at least one operating parameter (e.g., current, voltage, and temperature) of a separate energy production unit, and a control signal received from a remote unit (e.g., duty cycle, phase, voltage, power).

[0011] In one embodiment, the duty cycle is determined based on a maximum power point of the energy production unit, based on a maximum current of the energy production unit, based on a voltage ratio relative to the strongest unit on the string, based on a power ratio relative to the strongest unit on the string, based on a maximum power point voltage ratio relative to the strongest unit on the string, and/or based on a maximum power point power ratio relative to the strongest unit on the string.

[0012] In one embodiment, the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further includes: a second management unit and a second photovoltaic energy production unit. The second management unit is connected to the first management unit in series. The second management unit has at least a second switch. The second photovoltaic energy production unit is to provide electricity to the series connection of energy production units via the second switch of the second management unit. The second management unit is to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units.

[0013] In another aspect, a method includes: providing a management unit having a first switch to couple a solar energy production unit to a series connection of energy production units; and determining at least one parameter to control the first switch. The management unit has an energy storage unit coupled to the solar energy production unit. When the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units, the energy storage unit provides a second current, and a third current in the series connection of energy production units is equal to or larger than a sum of the first current and the second current. When the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units, and the management unit provides at least one path for the series connection of energy production units.

[0014] In one embodiment, the determining of the parameter includes computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit.

[0015] In one embodiment, the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further includes: receiving operating voltages of a plurality of solar energy production units that are connected in series via a plurality of management units respectively; and identifying a first voltage among the operating voltages. The duty cycle is then computed according to a function of the first voltage and the operating voltage of the solar energy production unit.

[0016] In one embodiment, the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units.

[0017] In one embodiment, the method further includes: adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected; and undoing an adjustment to the duty cycle that causes the decrease.

[0018] In another embodiment, the method further includes: adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected; and in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit. In one embodiment, the duty cycle for the second solar energy production unit is decreased until the operating voltage of the second solar energy production unit is maximized.

[0019] In one embodiment, the method further includes: identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter; and adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point.

[0020] In one embodiment, the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further includes: receiving operating parameters of a plurality of solar energy production units connected in series;

identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter; identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units; identifying a second maximum power point voltage of the second solar energy production unit; computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage; and adjusting the duty cycle to drive an operating voltage of the first solar energy production unit to the target voltage.

[0021] In one embodiment, the method further includes adjusting the duty cycle to increase the first current.

[0022] In one embodiment, the method further includes adjusting the duty cycle to change an operating voltage of the solar energy production unit to increase an output power of an entire string of solar energy production units.

[0023] The disclosure includes methods and apparatuses which perform these methods, including data processing systems which perform these methods, and computer readable media containing instructions which when executed on data processing systems cause the systems to perform these methods.

[0024] Other features will be apparent from the accompanying drawings and from the detailed description which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The embodiments are illustrated by way of example and not limitation in the figures of the accompanying drawings in which like references indicate similar elements.

[0026] **Figures 1 – 3** illustrate local management units according to some embodiments.

[0027] **Figure 4** illustrates a photovoltaic system according to one embodiment.

[0028] **Figure 5** illustrates a solar panel according to one embodiment.

[0029] **Figures 6 – 8** show methods to improve performance of a photovoltaic system according to some embodiments.

DETAILED DESCRIPTION

[0030] The following description and drawings are illustrative and are not to be construed as limiting. Numerous specific details are described to provide a thorough understanding.

However, in certain instances, well known or conventional details are not described in order to avoid obscuring the description. References to one or an embodiment in the present disclosure are not necessarily references to the same embodiment; and, such references mean at least one.

[0031] When solar modules are connected in series or mesh configuration, there can be a problem in which weaker modules not only produce less energy but also affect other modules in the same string or wiring section. By measuring one can determine that a few modules are weaker than the others in most commercially installed strings. Thus, the string is generating less power than the sum available at each module if modules were operated separately.

[0032] At least one embodiment of the present disclosure provides methods and systems to switch on and off weak modules in the string in a way that the current on the string bus from the good modules won't be affected by the weak modules.

[0033] **Figures 1 – 3** illustrate local management units according to some embodiments. In **Figures 1 – 3**, local management units (101) are used to switch on and off the solar module (102) periodically to improve the energy production performance of the photovoltaic systems connected, at least in part, in series.

[0034] In **Figure 1**, a management unit (101) is local to the solar module (102) and can be used to periodically couple the solar module (102) to the serial power bus (103) via the switch Q1 (106), to improve the total power output for the string of solar modules connected to the serial power bus in series.

[0035] The local management unit (LMU) (101) may include a solar module controller to control the operation of the solar module (102) and/or a link module unit to provide connectivity to the serial power bus (103) for energy delivery and/or for data communications.

[0036] In one embodiment, the command to control the operation of the switch Q1 (106) is sent to the local management unit (101) over the photovoltaic (PV) string bus (power line) (103). Alternatively, separate network connections can be used to transmit the data and/or commands to/from the local management unit (101).

[0037] In **Figures 1 and 2**, the inputs (104a, 104b, 104c) to the local management unit (101) are illustrated separately. However, the inputs (104a, 104b, 104c) are not necessarily communicated to local management unit (101) via separate connections. In one embodiment, the inputs are received in the local management unit via the serial power bus (103).

[0038] In **Figure 1**, the solar module (102) is connected in parallel to the capacitor C1 (105) of the local management unit (101). The diode D1 (107) of the local management unit (101) is connected in series in the serial power bus (103) which may or may not be part of an overall mesh configuration of solar modules. The switch Q1 (106) of the local management unit can selectively connect or disconnect the solar module (102) and the capacitor C1 (105) from a parallel connection with the diode D1 (107) and thus connect or disconnect the solar module (102) from the serial power bus (103).

[0039] In **Figure 1**, a controller (109) of the local management unit (101) controls the operation of the switch (106) according to the parameters, such as duty cycle (104a), phase (104b) and synchronization pulse (104c).

[0040] In one embodiment, the controller (109) receives the parameters (104a, 104b, 104c) from a remote management unit via the serial power bus (103) or a separate data communication connection (e.g., a separate data bus or a wireless connection). In some embodiment, the controller (109) may communicate with other local management units connected on the serial power bus (103) to obtain operating parameters of the solar modules attached to the serial power bus (103) and thus compute the parameters (e.g., 104a and 104b) based on the received operating parameters. In some embodiment, the controller (109) may determine the parameter (e.g., 104a and 104b) based on the operating parameters of the solar module (102) and/or measurements obtained by the controller (109), without communicating with other local management units of other solar modules, or a remote system management unit.

[0041] In **Figure 2**, a system (100) has a local management unit (101) coupled to the solar module (102). The local management unit (101) is connected between the solar module (102) and the string bus (103) to improve the total power output for the whole string on the serial power bus (103). Commands to the local management unit (101) can be sent over the photovoltaic (PV) string bus (power line) (103). To make the figure more clear, the inputs (104a, 104b, 104c) to the controller (109) of the local management unit (101) were drawn separately, which does not necessarily indicate that the inputs (104a, 104b, 104c) are provided

via separate connections and/or from outside the local management unit (101). For example, in some embodiments, the controller (109) may compute the parameters (104a, 104b, 104c) based on measurements obtained at the local management unit (101), with or without data communications over the serial power bus (103) (or a separate data communication connection with other management units).

[0042] In **Figure 2**, the local management unit (101) is connected in one side to the solar module (102) in parallel and on the other side in series to a string of other modules, which may or may not be part of an overall mesh configuration. The local management unit (101) may receive, among others, three inputs or types of input data, including a) requested duty cycle (104a), which can be expressed as a percentage (e.g., from 0 to 100%) of time the solar module (102) is to be connected to the serial power bus (103) via the switch Q1 (106), b) a phase shift (104b) in degrees (e.g., from 0 degree to 180 degree) and c) a timing or synchronization pulse (104c). These inputs (e.g., 104a, 104b and 104c) can be supplied as discrete signals, or can be supplied as data on a network, or composite signals sent through the power lines or wirelessly, and in yet other cases, as a combination of any of these input types.

[0043] In **Figure 2**, the local management unit (101) periodically connects and disconnects the solar module (102) to and from the string that forms the serial power bus (103). The duty cycle (104a) and the phase (104b) of the operation of the switch Q1 (106) can be computed in a number of ways to improve the performance of the system, which will be discussed further below.

[0044] In **Figure 2**, the local management unit (101) includes a capacitor C1 (105) and a switch Q1 (106), as well as a diode D1 (107). In **Figure 2**, the diode D1 (107) is supplemented with an additional switch Q2 (108), which acts as a synchronous rectifier to increase efficiency. In one embodiment, the additional switch Q2 (108) is open (turned off) when the switch Q1 (106) is closed (turned on) to attach the solar module (102) (and the capacitor C1 (105)) to the serial power bus (103).

[0045] In some cases, a filter (not shown), including a serial coil and a parallel capacitor, is also used. The filter may be placed at the local management unit or placed just before the fuse box or inverter, or be part of either one of those.

[0046] In **Figure 2**, the controller (109) is used to process the input signals (e.g., 104a, 104b, 104c) and drive the switches Q1 (106) and Q2 (108). In one embodiment, the controller (109) is

a small single chip micro controller (SCMC). For example, the controller (109) may be implemented using Application-Specific Integrated Circuit (ASIC) or Field-Programmable Gate Array (FPGA). The controller (109) can even be implemented in discrete, functionally equivalent circuitry, or in other cases a combination of SCMC and discrete circuitry.

[0047] In one embodiment, the controller (109) is coupled to the solar module (102) in parallel to obtain power for processing; and the controller (109) is coupled to the serial power bus (103) to obtain signals transmitted from other management units coupled to the serial power bus (103).

[0048] By switching the module (102) (or groups of cells, or a cell) on and off to the string periodically, the local management unit (101) may lower the voltage reflected to the string bus (103) (e.g., a lower average voltage contributed to the string bus) and can cause the current reflected to the string bus (103) to be higher, nearer the level it would be if the module was not weak, generating a higher total power output.

[0049] In one embodiment, it is preferable to use different phases to operate the switches in different local management units on a string to minimize voltage variance on the string.

[0050] In **Figure 3**, the local management unit (101) provides two connectors (112 and 114) for serial connections with other local management unit (101) to form a serial power bus (103). The controller (109) controls the states of the switches Q1 (106) and Q2 (108).

[0051] In **Figure 3**, when the controller (109) turns on the switch (106), the panel voltage and the capacitor C1 (105) are connected in parallel to the connectors (112 and 114). The output voltage between the connectors (112 and 114) is substantially the same as the output panel voltage.

[0052] In **Figure 3**, during the period the switch (106) is turned off (open), the controller (109) turns on (closes) the switch (108) to provide a path around the diode D1 (107) to improve efficiency.

[0053] In **Figure 3**, when the switch (106) is turned off (open), the panel voltage charges the capacitor C1 (105), such that when the switch (106) is turned on, both the solar panel and the capacitor (105) provides currents going through the connectors (112 and 114), allowing a current larger than the current of the solar panel to flow in the string (the serial power bus (103)). When the switch (106) is turned off (open), the diode D1 (107) also provides a path between the

connectors (112 and 114) to sustain the current in the string, even if the switch (108) is off for some reasons.

[0054] In one embodiment, the controller (109) is connected (not shown in **Figure 3**) to the panel voltage to obtain the power for controlling the switches Q1 (106) and Q2 (108). In one embodiment, the controller (109) is further connected (not shown in **Figure 3**) to at least one of the connectors to transmit and/or receive information from the string. In one embodiment, the controller (109) includes sensors (not shown in **Figure 3**) to measure operating parameters of the solar panel, such as panel voltage, panel current, temperature, light intensity, etc.

[0055] **Figure 4** illustrates a photovoltaic system (200) according to one embodiment. In **Figure 4**, the photovoltaic system 200 is built from a few components, including photovoltaic modules (201a, 201b, ..., 201n), local management unit units (202a, 202b, ..., 202n), an inverter (203), and a system management unit (204).

[0056] In one embodiment, the system management unit (204) is part of the inverter (203), the combiner box (206), a local management unit, or a stand-alone unit. The solar modules (201a, 201b, ..., 201n) are connected in parallel to the local management unit units (202a, 202b, ..., 202n) respectively, which are connected in series to form a string bus (205), which eventually is connected to an inverter (203) and the management unit (204).

[0057] In **Figure 4**, the string bus (205) can be connected to the inverter (203) directly or as part of a mesh network or combiner boxes or fuse boxes (not shown). An isolated local management unit can be used as a combiner box (206) to adjust all voltages before connecting to the inverter (206); or, a single or multi-string inverter can be used. To limit the changes in the voltage of the bus, the management unit (204) may assign a different phase for each of the local management units (202a, 202b, ..., 202n). In one embodiment, at any given time, a maximum of a predetermined number of solar modules (e.g., one single solar module) are disconnected from the string bus (205).

[0058] In one embodiment, beyond the module connection the local management units can have the signal inputs, including but not limited to duty cycle (104a), phase (104b) and synchronization pulse (104c) (e.g., to keep the local management units synchronized). In one embodiment, the phase (104b) and the synchronization pulse (104c) are used to further improve performance, but the local management unit (101) can work without them.

[0059] In one embodiment, the local management unit may provide output signals. For example, the local management unit (101) may measure current and voltage at the module side and optionally measure current and voltage in the string side. The local management unit (101) may provide other suitable signals, including but not limited to measurements of light, temperature (both ambient and module), etc.

[0060] In one embodiment, the output signals from the local management unit (101) are transmitted over the power line (e.g., via power line communication (PLC)), or transmitted wirelessly.

[0061] In one embodiment, the system management unit (204) receives sensor inputs from light sensor(s), temperature sensor(s), one or more each for ambient, solar module or both, to control the photovoltaic system (200). In one embodiment, the signals may also include synchronization signals. For example, a management unit can send synchronization signals periodically to set the timing values, etc.

[0062] Using the described methods the local management unit can be a very non-expensive and reliable device that can easily increase the throughput of a photovoltaic solar system by a few (e.g., signal or low double digits) percentage points. These varied controls also allow installers using this kind of system to control the VOC (open circuit voltage) by, for example by shutting off some or all modules. For example, by using the local management units of the system, a few modules can be disconnected from a string if a string is getting to the regulatory voltage limit, thus more modules can be installed in a string.

[0063] In some embodiments, local management units can also be used within the solar panel to control the connection of solar cells attached to strings of cells within the solar panel.

[0064] **Figure 5** illustrates a solar panel according to one embodiment. In one embodiment, the solar panel (300) has a few strings of solar cells (e.g., three solar cell strings per module). In **Figure 5**, a local management unit (101) can be applied to a group of cells (301) within a string of an individual solar panel (300), or in some cases to each cell (301) in a solar panel (300).

[0065] In **Figure 5**, a group of solar cells (301) that are attached to a local management unit (101) may be connected to each other in series, in parallel, or in a mesh configure. A number of local management units (101) connect the groups of the solar cells (301) in a string to provide output for the solar panel (300).

[0066] Some embodiments of the disclosure includes methods to determine the duty cycles and/or phases for local management units connected to a string or mesh of solar modules.

[0067] In some embodiments, the duty cycle of all local management units in a string or mesh can be changed, to increase or decrease the string voltage. The duty cycles may be adjusted to avoid exceeding the maximum voltage allowed. For example, the maximum voltage may be limited by the combiner box (206), the inverter (203), or any other load connected to the string bus (205), or limited by any regulations applicable to that system. In some embodiments, the duty cycles are adjusted to align the voltage of multiple strings.

[0068] In some embodiments, the duty cycle of one local management unit (101) in a string can be changed to cause higher current in that local management unit (101) and overall higher power harvesting.

[0069] In one embodiment, the duty cycles are computed for the solar modules that are connected to a string via the corresponding local management units. The duty cycles can be calculated based on the measured current and voltages of the solar modules and/or the temperatures.

[0070] After an initial set of duty cycles is applied to the solar modules, the duty cycles can be further fine tuned and/or re-adjusted to changes, such as shifting shading etc., one step a time, to improve power performance (e.g., to increase power output, to increase voltage, to increase current, etc.). In one embodiment, target voltages are computed for the solar modules, and the duty cycles are adjusted to drive the module voltage towards the target voltages.

[0071] The methods to compute the duty cycles of the solar modules can also be used to compute the duty cycles of the groups of solar cells within a solar module.

[0072] **Figures 6 – 8** show methods to improve performance of a photovoltaic system according to some embodiments.

[0073] In **Figure 6**, at least one operating parameter of a solar energy production unit coupled to a string via a management unit is received (401) and used to identify (403) a duty cycle for the management unit to connect the solar energy production unit to string. The solar energy production unit may be a solar module, a group of solar cells within a solar module, or a single solar cell in a string in a solar module. The duty cycle is adjusted (405) to optimize the performance of the solar energy production unit and/or the string.

[0074] For example, the duty cycle can be adjusted to increase the current in the string and/or the solar energy production unit, to increase the output power of the string and/or the solar energy production unit, to increase the voltage of the solar energy production unit, etc.

[0075] In **Figure 7**, the operating voltages of a plurality of solar panels connected in series are received (421) and used to identify (423) a second solar panel having the highest operating voltage (highest output power) in the string.

[0076] In **Figure 7**, a duty cycle of a first solar panel is computed (425) based on a ratio in operating voltage between the first and second solar panels. Alternatively, the duty cycle can be computed based on a ratio in output power between the first and second solar panels.

Alternatively, the duty cycle can be computed based on a ratio between the first and second solar panels in estimated/computed maximum power point voltage. Alternatively, the duty cycle can be computed based on a ratio between the first and second solar panels in estimated/computed maximum power point power.

[0077] The duty cycle of the first solar panel is adjusted (427) to improve the performance of the first solar energy production unit and/or the string, until a decrease in the operating voltage of the second solar panel is detected. For example, the duty cycle of the first solar panel can be adjusted to increase the total output power of the string, to increase the current of the string, to increase the current of the first solar panel, to drive the voltage of the first solar panel towards a target voltage, such as its maximum power point voltage estimated based on its current operating parameters, such as temperature or a voltage calculated using its estimated maximum power point voltage.

[0078] In **Figure 7**, in response to the detected decrease in the operating voltage of the second solar panel which had the highest operating voltage, the adjustment in the duty cycle of the first solar panel that causes the decrease is undone/reversed (429).

[0079] In **Figure 7**, the duty cycle of the second solar panel is optionally decreased (431) to increase the operating voltage of the second solar panel. In some embodiments, the strongest solar panel (or strong panels within a threshold from the strongest panel) is not switched off line (e.g., to have a predetermined duty cycle of 100%).

[0080] In one embodiment, the duty cycle of the second solar panel is repeatedly decreased (429) until it is determined (431) that the decrease (429) in the duty cycle of the second solar panel cannot increase the voltage of the second solar panel.

[0081] In **Figure 8**, operating parameters of a plurality of solar panels connected in a string are received (441) and used to identify (443) a first maximum power point voltage of a first solar panel. A second solar panel having the highest operating voltage (or output power) in the string is identified. A second maximum power point voltage of the second solar panel is identified (447) based on the received operating parameters and used to compute (449) a target voltage for the first solar energy production unit. In one embodiment, the target voltage is a function of the first and second maximum power point voltages and the highest operating voltage identified (445) in the second solar panel in the string. The duty cycle of the first solar energy production unit is adjusted to drive the operating voltage of the first solar panel towards the target voltage.

[0082] Alternatively, the target voltage may be set as the first maximum power point voltage of the first solar panel.

[0083] In one embodiment, to adjust voltage a same factor is applied to all modules in that string. For example, in a case of a first module A1 that is producing only 80%, and the voltage of the whole string needs to be 5% lower, the duty cycle of A1 is 80% multiplied the duty cycle applied to the whole string (which is Y in this example) so module A1 then has $Y \times 0.8$ as duty cycle.

[0084] In some embodiments, the system management unit (204) and/or the local management units (e.g., 202a, 202b, ..., 202n) are used solely or in combination to determine the parameters to control the operations of the switches.

[0085] For example, in one embodiment, a system management unit (204) is the “brain” of the system, which decides on the duty cycle and phase parameters.

[0086] For example, in another embodiment, each local management unit broadcasts information to the other local management units on the string to allow the individual local management units to decide their own duty cycle and phase parameters.

[0087] In some embodiment, a local management unit may instruct one or more other local management units to adjust duty cycle and phase parameters. For example, the local management units on a string bus (205) may elect one local management unit to compute the duty cycle and phase parameters for other local management units on the string.

[0088] For example, in some embodiment, the system management unit (204) may determine one or more global parameters (e.g., a global duty cycle, the maximum power on the string, the

maximum voltage on the string, etc.), based on which individual local management units adjust their own duty cycles.

[0089] In some embodiments, a local management unit may determine its own duty cycles without relying upon communicating with other management units. For example, the local management unit may adjust its duty cycle for connecting its solar module to the string to operate the solar module at the maximum power point.

[0090] In one embodiment, module voltage are measured by the local management units in the same string at substantially/approximately the same time and used to identify the strongest solar module. A strongest solar module provides the most power in the string. Since the modules are connected in series, the solar module having the highest module voltage in the string can be identified as the strongest solar module. In some embodiment, the operating voltage and current of the solar module are measured to determine the power of the solar module.

[0091] In one embodiment, after the highest module voltage V_m in the string is identified, the duty cycle for each module can be computed as a function of a ratio between the module voltage V of the module and the highest module voltage V_m . For example, the duty cycle for a module can be computed as $1 - ((V_m - V)/V_m) = V/V_m$.

[0092] In one embodiment, the system management (204) may identify the highest module voltage from the module voltages received from the local management units (202a, 202b, ..., 202n), and compute the duty cycles for the corresponding local management units (202a, 202b, ..., 202n).

[0093] In one embodiment, the local management units (202a, 202b, ..., 202n) may report their module voltages on the string bus (205) to allow individual local management units (202a, 202b, ..., 202n) to identify the highest module voltage and compute the duty cycles, without relying upon the system management unit (204).

[0094] In one embodiment, one of the local management units (202a, 202b, ..., 202n) may identify the highest module voltage and/or compute the duty cycles for the other local management units (202a, 202b, ..., 202n).

[0095] In one embodiment, the duty cycles are determined and/or adjusted periodically.

[0096] In one embodiment, after the duty cycles for the solar modules on the string are set based on the module voltage ratio relative to the highest module voltage in the string, the duty cycles can be fine tuned to increase the power performance. The duty cycles can be fine tuned

one step a time, until a decrease of voltage of the module with the highest power is detected. In response to the detected decrease, the last change that caused the decrease can be reversed (undone). The fine tuning of the duty cycles can be used to reach the peak performance point (e.g., for maximum power point tracking).

[0097] In one embodiment, after the strongest module is identified, the duty cycles of the solar modules on the string are adjusted until the module with the highest power in the string decrease its voltage. Since decreasing the duty cycle of a solar module decreases the time period the module is connected to the string and thus increases its voltage, the duty cycle of the module with the highest power in the string can be decreased to increase its voltage, in response to the decrease in its voltage caused by the adjustment to the duty cycles of other solar modules on the string. For example, the duty cycle of the module with the highest power in the string can be decreased until its voltage is maximized.

[0098] In one embodiment, the local management unit measures module and ambient temperatures for some methods to determine the duty cycles. For example, the operating parameters measured at the local management units (e.g., 202a, 202b, ..., 202n), such as module temperature, can be used compute the estimated voltages of the solar modules at their maximum power points. For example, a formula presented by Nalin K. Gautam and N.D. Kaushika in “An efficient algorithm to simulate the electrical performance of solar photovoltaic arrays”, *Energy*, Volume 27, Issue 4, April 2002, pages 347-261, can be used to compute the voltage V_{mp} of a solar module at the maximum power point. Other formulae can also be used. Once the maximum power point voltage V_{mp} of a solar module is computed or estimated, the duty cycle of the solar module connected to a string can be adjusted to drive the module voltage to the computed/estimated maximum power point voltage V_{mp} , since decreasing the duty cycle of a solar module normally increases its voltage.

[0099] In one embodiment, a local management unit may adjust the duty cycle of the solar module connected to the local management unit to change the module voltage to the computed/estimated maximum power point voltage V_{mp} , without having to communicating with other management units.

[00100] In one embodiment, a local management unit (or a system management unit) may adjust the duty cycle of the solar module connected to the local management unit to perform maximum power point tracking.

[00101] In one embodiment, after identifying the strongest module and computing/ estimating the maximum power point voltage V_{mpm} of the strongest module, the duty cycle for each module on a string can be computed as a function of a ratio between the maximum power point voltage V_{mp} of the module and the maximum power point voltage V_{mpm} of the strongest module. For example, the duty cycle for a module can be computed as $1 - ((V_{mpm} - V_{mp})/V_{mpm}) = V_{mp}/V_{mpm}$. The duty cycle can be periodically updated, based on the current operating parameters measured, and/or fine tuned until a decrease in the voltage of the strongest module is detected.

[00102] Alternatively, a target voltage for each module on the string can be computed as a function of a ratio between the maximum power point voltage V_{mp} of the module and the maximum power point voltage V_{mpm} of the strongest module. For example, the target voltage for a module can be computed as $V_m \times V_{mp}/V_{mpm}$, where V_m is the measured voltage of the strongest module. The duty cycle of the module can be changed to drive the module voltage of the module towards the target voltage.

[00103] In one embodiment, after identifying the strongest module and computing/ estimating the maximum power point power P_{mpm} of the strongest module, the duty cycle for each module on a string can be computed as a function of a ratio between the maximum power point power P_{mp} of the module and the maximum power point power P_{mpm} of the strongest module. For example, the duty cycle for a module can be computed as $1 - ((P_{mpm} - P_{mp})/P_{mpm}) = P_{mp}/P_{mpm}$. The duty cycle can be periodically updated, based on the current operating parameters measured, and/or fine tuned until a decrease in the voltage of the strongest module is detected, since decreasing the duty cycle normally increases the module voltage.

[00104] In one embodiment, a target voltage for each module on the string can be computed as a function of a ratio between the maximum power point power P_{mp} of the module and the maximum power point power P_{mpm} of the strongest module. For example, the target voltage for a module can be computed as $V_m \times P_{mp}/P_{mpm}$, where V_m is the measured voltage of the strongest module. The duty cycle of the module can be changed to drive the module voltage of the module towards the target voltage, since decreasing the duty cycle normally increases the module voltage.

[00105] In one embodiment, the duty cycle for each local management unit is changed to increase the current of the solar module attached to the local management unit (e.g., based on the measurement of the voltage and current of the solar module), until the maximum current is

achieved. This method assumes that string maximum power can be achieved with some accuracy by driving each local management unit to maximum current. In one embodiment, the voltages and currents of the solar modules are measured for tuning the duty cycles for maximum power point tracking for the string. The measurements of the voltages and currents of the solar modules also enable the local management units to additionally serve as a module level monitoring system.

[00106] The duty cycles can be adjusted by the system management unit (e.g., 204) based on the measurements reported by the local management units (e.g., 202a, 202b, ..., 202n), or adjusted directly by the corresponding local management units (e.g., 202a, 202b, ..., 202n).

[00107] In one embodiment, during the process of setting and/or tuning the duty cycles, the maximum power point tracking operation by the inverter (203) is frozen (temporarily stopped). Light intensity at the solar modules is monitored for changes. When the light intensity at the solar modules stabilizes, the voltage and current of the solar modules are measured for the determination of the duty cycles. Then normal operation resumes (e.g., unfreezing of maximum power point tracking operation).

[00108] In one embodiment, the local management units measure the voltages and currents of the solar modules to determine the power of the solar modules. After identifying the highest power P_m of the solar module on the string, the duty cycles of the solar modules on the string are determined by the power ratio relative to the highest power P_m . For example, if a module produces 20 percent less power, it will be disconnected from the string bus about 20 percent of the time. For example, if a module produces power P , its duty cycle can be set to $1 - ((P_m - P)/P_m) = P/P_m$.

[00109] In one embodiment, a predetermined threshold is used to select the weak modules to apply duty cycles. For example, in one embodiment, when a module produces power less than a predetermined percent of highest power P_m , a duty cycle is calculated and applied to the solar module. If the module is above the threshold, the module is not disconnected (and thus having a duty cycle of 100%). The threshold may be based on the power, or based on the module voltage.

[00110] In one embodiment, the system management unit (204) finds the duty cycles for the local management units (202a, 202b, ..., 202n) and transmits data and/or signals representing the duty cycles to the local management units (202a, 202b, ..., 202n) via wires or wireless

connections. Alternatively, the local management units (202a, 202b, ..., 202n) may communicate with each other to obtain the parameters to calculate the duty cycles.

[00111] In one embodiment, the system management unit (204) knows all the different duty cycles indicated for the local management units (202a, 202b, ..., 202n).

[00112] In one embodiment, during power fine tuning, the system management unit (204) sends the appropriate data/signal to the appropriate local management units (202a, 202b, ..., 202n), and then the system management unit (204) calculates the total power of the string and corrects the duty cycle to produce maximum power. Once maximum power is achieved, the duty cycles for the local management units (202a, 202b, ..., 202n) may be saved in a database and serve as a starting point for the corresponding local management units (202a, 202b, ..., 202n) at the same time of day on the next day. Alternatively, a local management may store the duty cycle in its memory for the next day.

[00113] The stored duty cycles can be used when there is a fixed shade on the modules, such as a chimney, a tree, etc., which will be the same shade on any day at the same time.

Alternatively, historical data may not be saved, but may be recalculated from scratch on each run, for example every 30 minutes.

[00114] In one embodiment, the light intensity at the solar modules is monitored for changes. The duty cycles are calculated when the light intensity does not change significantly. If there are changes in sun light radiation at the solar modules, the system will wait until the environment stabilizes before applying or adjusting the duty cycles.

[00115] In one embodiment, the system management unit (204) can communicate with the inverter as well. When the environment is not stable (e.g., when the sun light radiation is changing), the inverter may stop maximum power point tracking. In such a situation, the inverter can be set up for its load, instead of tracking for maximum power point. Instead of using the inverter to perform maximum power point tracking, the system management unit (204) and the local management units (202a, 202b, ..., 202n) are used to set the operating parameters and balance the string.

[00116] Alternatively, when the environment is not stable but measurements and calculation are done faster than the MPPT is working, there may be no need to stop the MPPT on the inverter. Alternatively, when the environment is not stable, measurements can be taken few times for the same radiation until a stable result is achieved.

[00117] Many variations may be applied to the systems and methods, without departing from the spirit of the invention. For example, additional components may be added, or components may be replaced. For example, rather than using a capacitor as primary energy store, an inductor may be used, or a combination of inductor and capacitor. Also, the balance between hardware and firmware in the micro controllers or processors can be changed, without departing from the spirit of the invention. In some cases, only some problematic modules may have a local management unit, for example in a shaded or partially shaded or otherwise different situation. In yet other cases, local management units of strong modules may be virtually shut off. The methods for determining the duty cycles for the solar modules can also be used to determine the duty cycles of groups of cells connected via local management units in a string within a solar panel/module.

[00118] In the foregoing specification, the disclosure has been described with reference to specific exemplary embodiments thereof. It will be evident that various modifications may be made thereto without departing from the broader spirit and scope as set forth in the following claims. The specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense.

CLAIMS

What is claimed is:

1. An apparatus, comprising:
a photovoltaic energy production unit to generate electricity; and
a management unit coupled between the photovoltaic energy production unit and a series connection of energy production units, the management unit having at least a first switch, the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit, the management unit to allow a second current larger than the first current to flow through the series connection of energy production units.
2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit connected to the photovoltaic energy production unit;
wherein, when the first switch is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current is equal to or larger than a sum of the first current and the third current; and
wherein, when the first switch is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy production units, and the management unit provides at least one path for the series connection of energy production units.
3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor coupled in parallel with the energy production unit; and when the first switch is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit.

4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode,
a second switch, wherein the management unit turns off the second switch when the first switch is turned on, and
a synchronous rectifier.
5. The apparatus of claim 1, wherein the management unit further comprises a controller to control the first switch according to a duty cycle.
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift, and a synchronization pulse.
7. The apparatus of claim 5, wherein the controller is configured to control the first switch based on one of:
at least one operating parameter associated with the energy production unit,
at least one operating parameter of a separate energy production unit, and
a control signal received from a remote unit.
8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current, a voltage, and a temperature; and the duty cycle is based on a maximum power point of the energy production unit.
9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series, the second management unit having at least a second switch, the second photovoltaic energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit, the second

management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units.

10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel; and the management unit has no inductor and is integrated on the solar panel.
11. A method, comprising:
providing a management unit to couple a solar energy production unit to a series connection of energy production units, the management unit having a first switch and an energy storage unit coupled to the solar energy production unit; and
determining at least one parameter to control the first switch;
wherein, when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current; and
wherein, when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units, and the management unit provides at least one path for the series connection of energy production units.
12. The method of claim 11, wherein the determining comprises:
computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit.
13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises:
receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units; and

- identifying a first voltage among the operating voltages;
wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit.
14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and
wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units.
15. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected; and
undoing an adjustment to the duty cycle that causes the decrease.
16. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected; and
in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit.
17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter; and
adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point.

18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:
receiving operating parameters of a plurality of solar energy production units connected in series;
identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter;
identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units;
identifying a second maximum power point voltage of the second solar energy production unit;
computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage; and
adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage.
19. The method of claim 12, further comprising:
adjusting the duty cycle to increase the first current.
20. The method of claim 12, further comprising:
adjusting the duty cycle to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units, the string including the solar energy production unit.

ABSTRACT

Systems and methods to balance currents among a plurality of photovoltaic units connected in series. In aspect, a management unit is coupled between a photovoltaic energy production unit and a string of energy production units. The management unit has an energy storage element (e.g., a capacitor) connected to the photovoltaic energy production unit. The management unit further has a switch to selectively couple to the energy storage element and the photovoltaic energy production unit to the string. The management unit allows the current in the string to be larger than the current in the photovoltaic energy production unit.

Title: Systems and Methods to Balance Solar Panels in a Multi-Panel System

Inventors: Ron Hadar; Shmuel Arditi

Filing Date: March 25, 2009

Sheet: 1 of 8

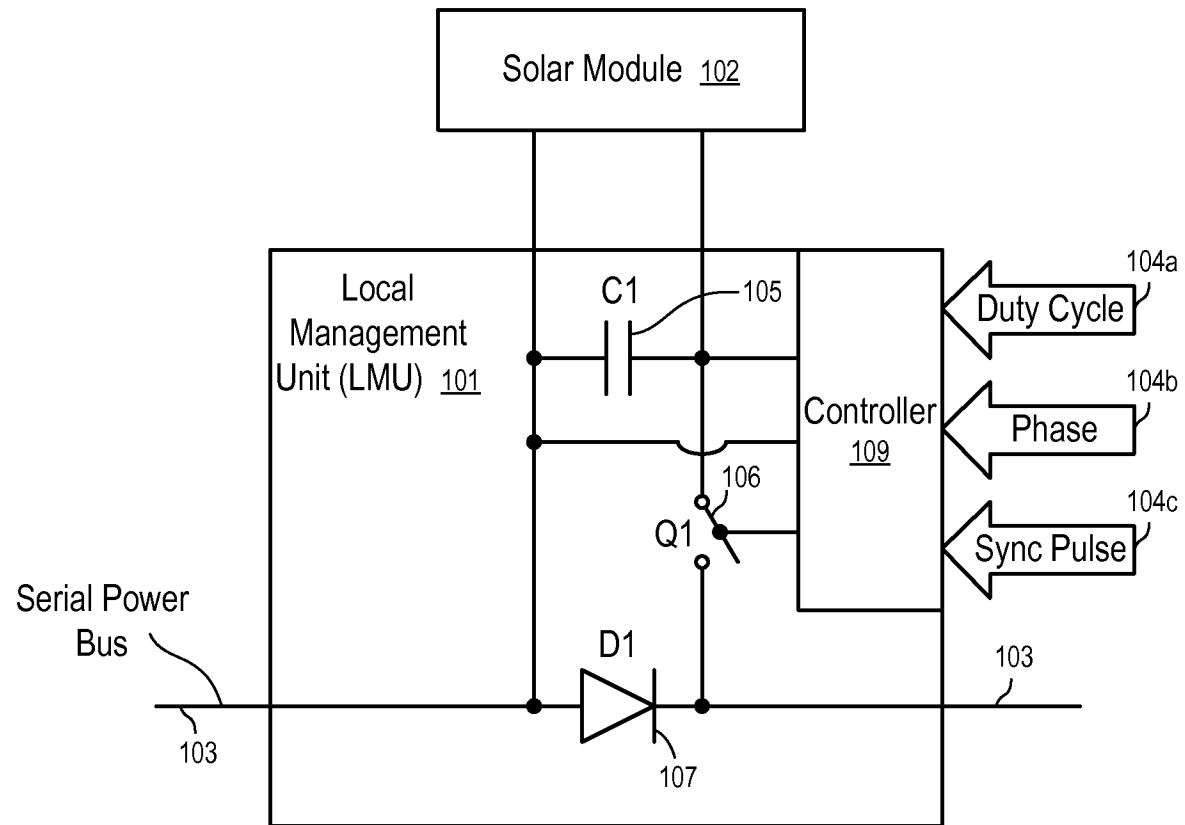


FIG. 1

Title: Systems and Methods to Balance Solar Panels in a Multi-Panel System

Inventors: Ron Hadar; Shmuel Arditi

Filing Date: March 25, 2009

Sheet: 2 of 8

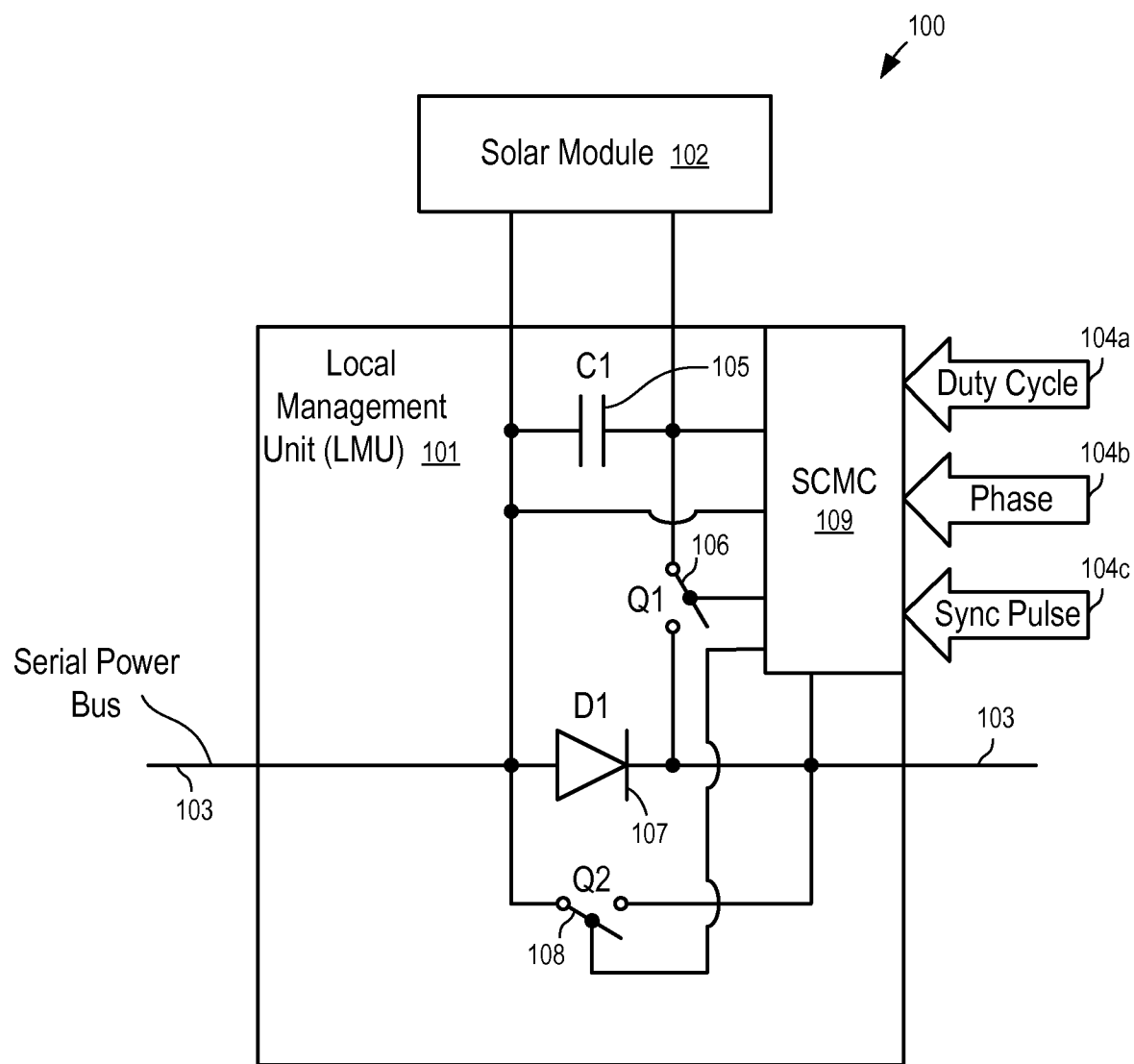


FIG. 2

Title: Systems and Methods to Balance Solar Panels in a Multi-Panel System

Inventors: Ron Hadar; Shmuel Arditi

Filing Date: March 25, 2009

Sheet: 3 of 8

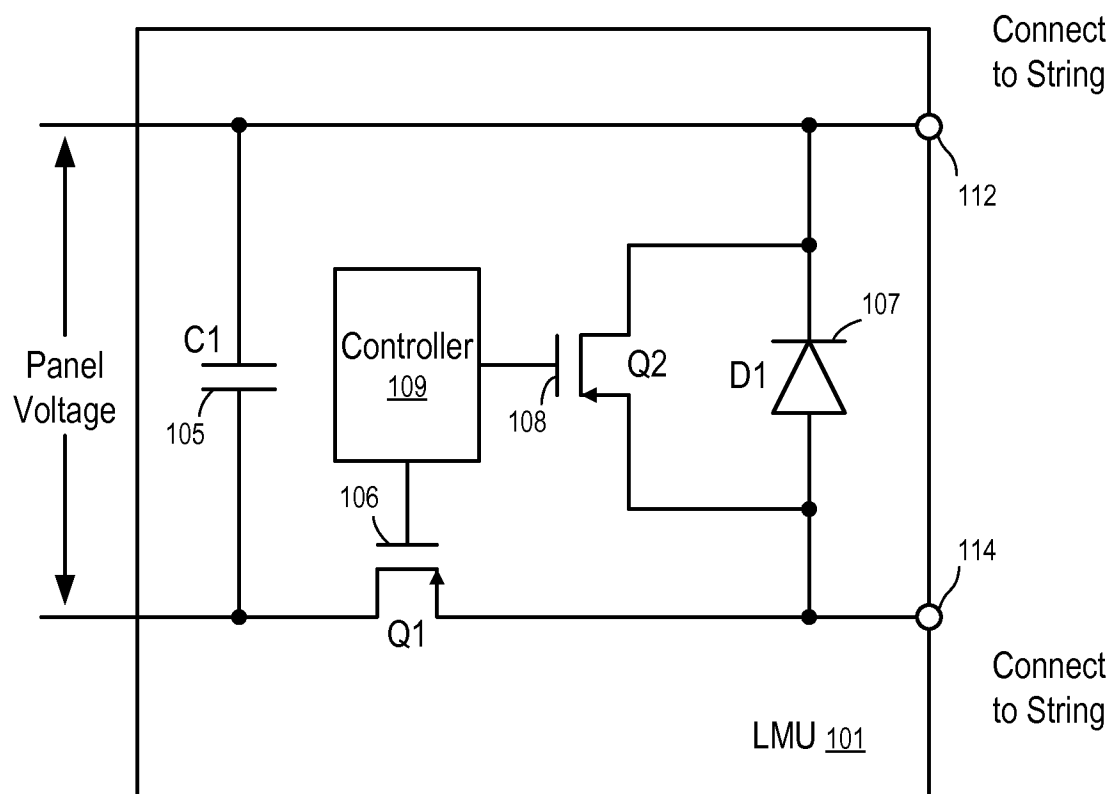


FIG. 3

Title: Systems and Methods to Balance Solar Panels in a Multi-Panel System

Inventors: Ron Hadar; Shmuel Arditi

Filing Date: March 25, 2009

Sheet: 4 of 8

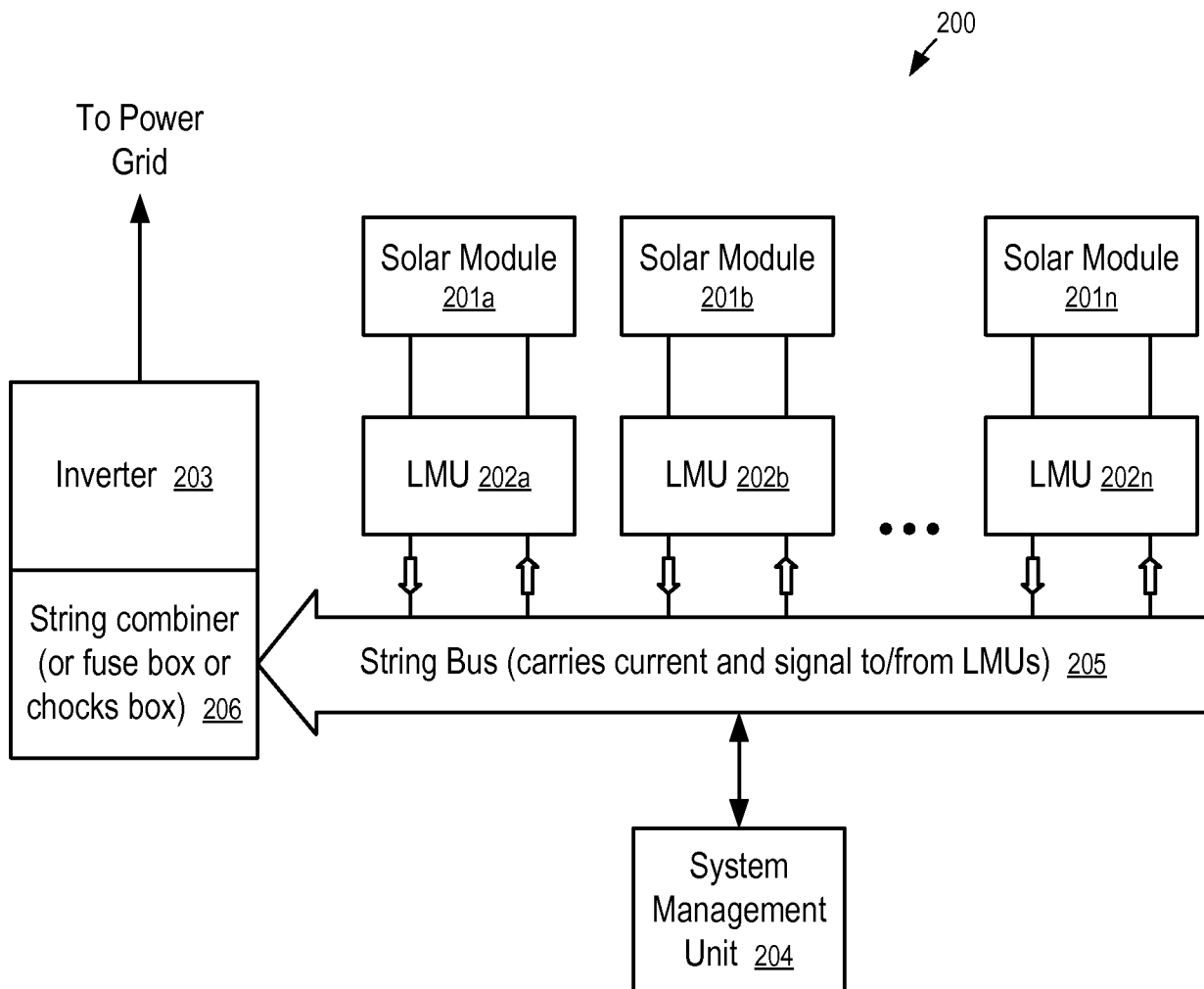


FIG. 4

Title: Systems and Methods to Balance Solar Panels in a Multi-Panel System

Inventors: Ron Hadar; Shmuel Arditi

Filing Date: March 25, 2009

Sheet: 5 of 8

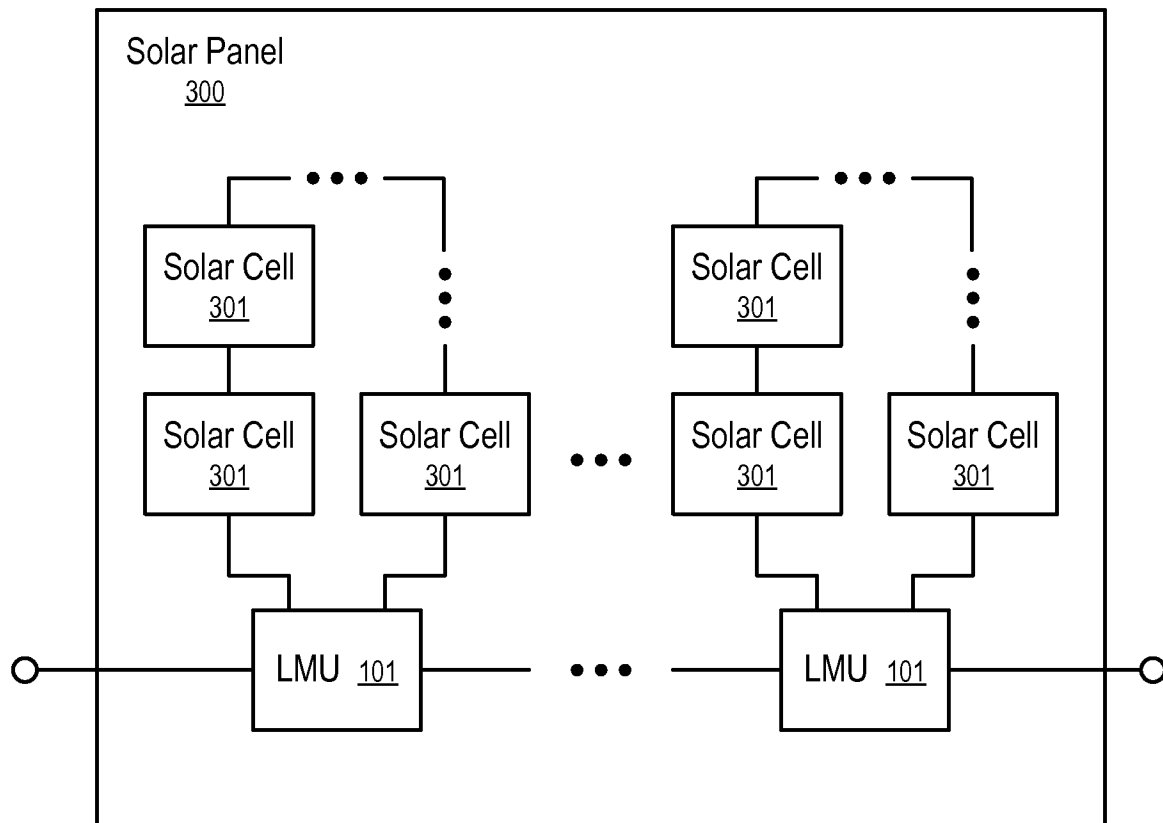


FIG. 5

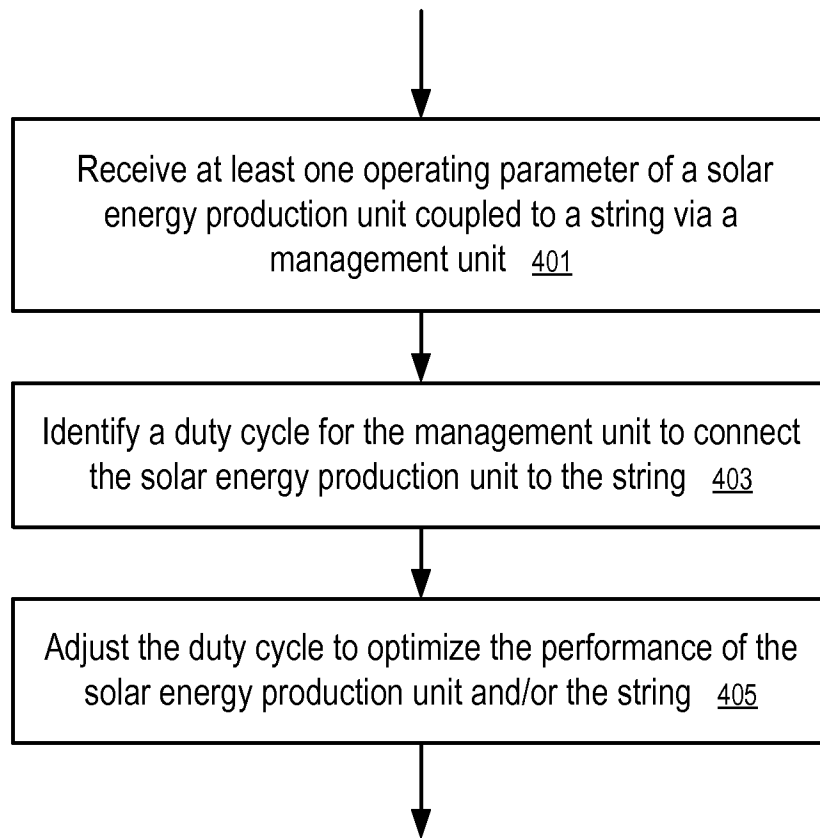


FIG. 6

Title: Systems and Methods to Balance Solar Panels in a Multi-Panel System

Inventors: Ron Hadar; Shmuel Arditi

Filing Date: March 25, 2009

Sheet: 7 of 8

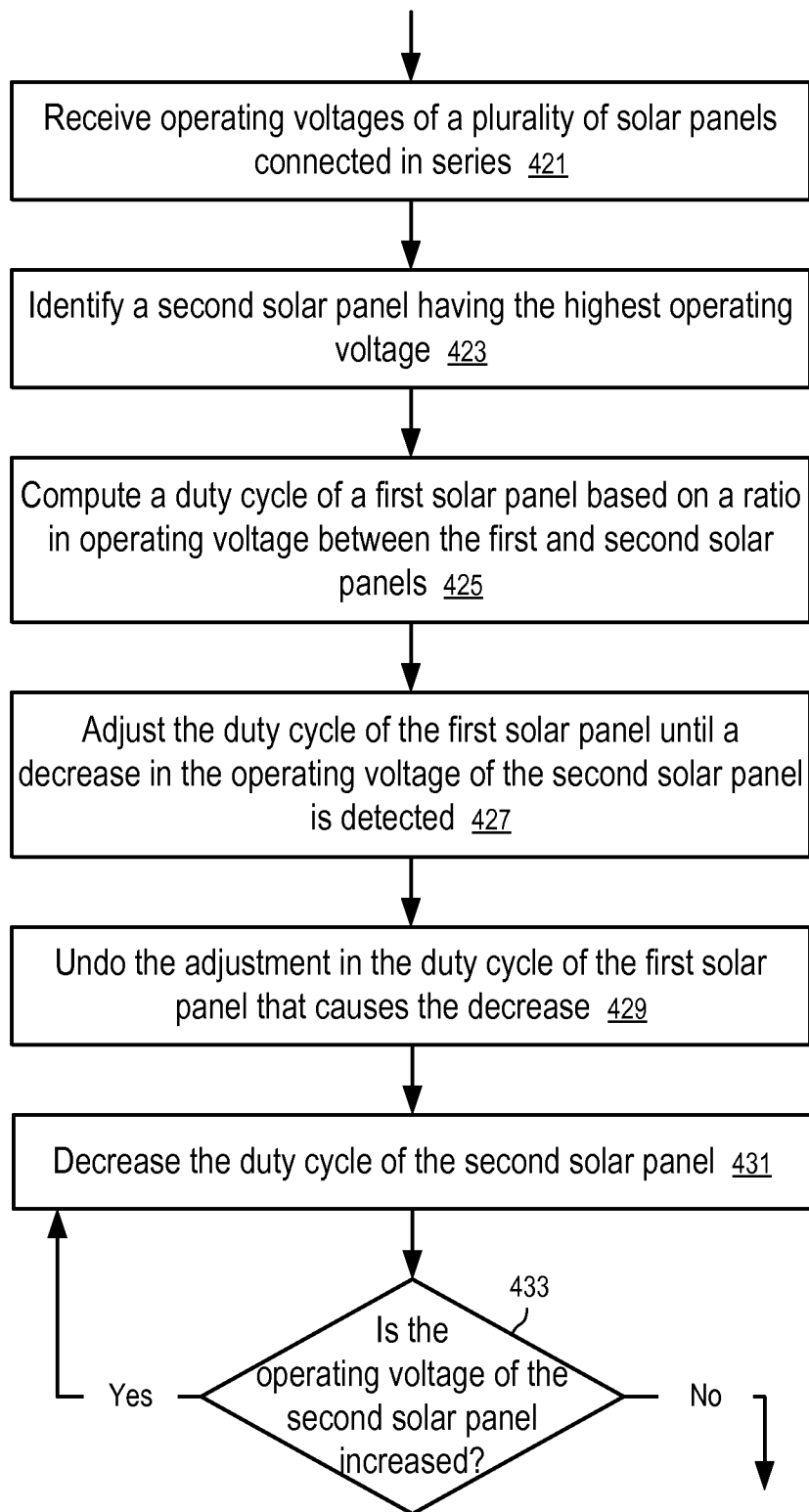


FIG. 7

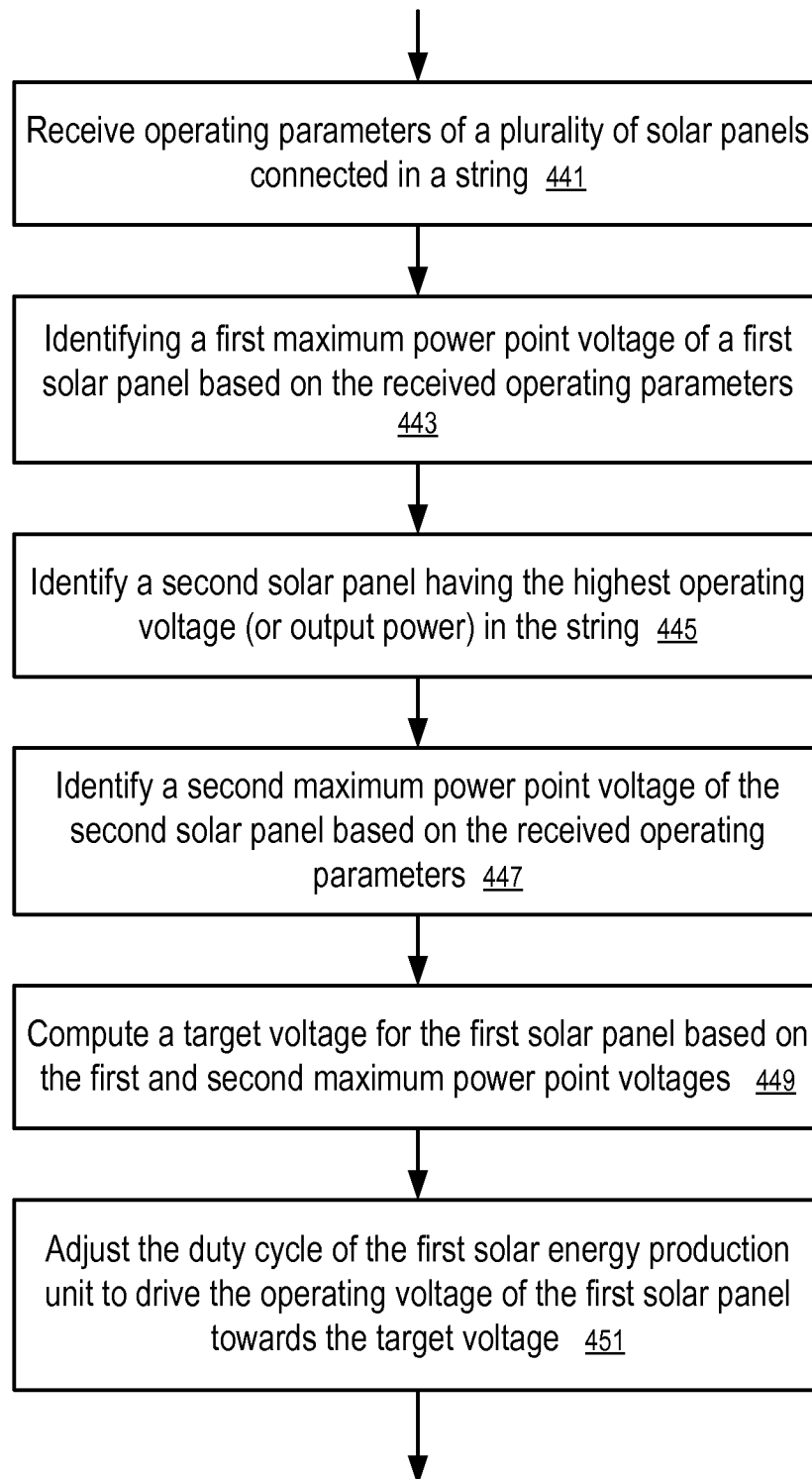


FIG. 8

Patent

Attorney Docket No. 108144-200701/US (TGY010)

UNITED STATES PATENT APPLICATION
COMBINED DECLARATION AND POWER OF ATTORNEY

I hereby declare that:

Each Inventor's residence, mailing address and citizenship are as stated below next to their name.

I believe the inventor(s) named below to be the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**SYSTEMS AND METHODS TO BALANCE SOLAR PANELS IN A MULTI-PANEL
SYSTEM**

the specification of which

☒ is attached hereto, or

☐ was filed on _____ as U.S. Application No. _____ or
PCT International Application No. _____, and
was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b) of any foreign application(s) for patent, inventor's or plant breeder's rights certificate(s), or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent, inventor's or plant breeder's rights certificate(s), or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached?	
				YES	NO
			☐	☐	☒

I hereby appoint practitioners associated with the Customer Number 64494 as my/our attorney(s) or agent(s) to prosecute this application and to transact all business in the United States Patent

Patent

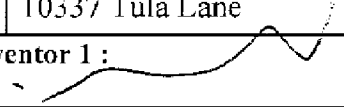
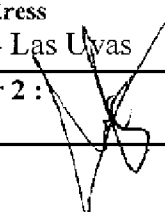
Attorney Docket No. 108144-200701/US (TGY010)

and Trademark Office and before competent International Authorities including the World Intellectual Property Organization, connected herewith.

I hereby authorize them to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/organization who/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct Greenberg Traurig, LLP to the contrary.

Please direct all correspondence in this case to Greenberg Traurig LLP according to the address associated with the Customer Number 64494, telephone (650) 328-8500, facsimile (650) 328-8508.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Full Name of Inventor	Family Name ARDITI	First Given Name Shmuel	Second Given Name
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Signature of Inventor 2 : 			Date: <i>March 20, 2009</i>

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventors:	Ron Hadar, et al.	Examiner:	Not Assigned
Serial No.:	Not Assigned	Group Art Unit:	Not Assigned
Filed:	Herewith	Confirmation:	Not Assigned
Title:	Systems and Methods to Balance Solar Panels in a Multi-Panel System		

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

PRE-EXAMINATION SEARCH DOCUMENT

Sir/Madam:

This pre-examination search statement is provided in support of the petition for accelerated examination filed herewith.

A pre-examination search was conducted involving U.S. patents and patent application publications, foreign patent documents and non-patent literature as indicated below. The results of the search are provided on an Information Disclosure Statement filed concurrently herewith.

PRE-EXAMINATION SEARCH*US Field of Search*

Class	Subclass	Date Searched
136	243, 244, 293	January 20-21, 2009
323	222, 285, 299 906	January 20-21, 2009

Database Searches

Database Service: Free Patents Online (<http://www.freepatentsonline.com/>)

Files Searched: U.S. Patents, U.S. Patent Applications, EP Documents, Abstracts of Japan,
WIPO (PCT)

Date Conducted: January 20-21, 2009

Search Logic:

1. (solar or photovoltaic) and (multi-panel or multipanel)
2. (solar or photovoltaic) and (“management unit” or LMU)
3. (solar or photovoltaic) and (panel or module) and controller and “duty cycle”
4. (solar or photovoltaic) and (panel or module) and controller and string
5. (solar or photovoltaic) and “temperature” and “duty cycle”
6. (solar or photovoltaic) and “light intensity” and “duty cycle”
7. (Vmp or (voltage and “maximum power point”)) and “duty cycle”

8. (“Maximum Power Point Tracking” or MPPT) and “duty cycle”

Database Service: EPO (<http://ep.espacenet.com/>)

Files Searched: Worldwide

Date Conducted: January 20-21, 2009

Search Logic:

1. (solar or photovoltaic) and (multi-panel or multipanel)
2. (solar or photovoltaic) and (“management unit” or LMU)
3. (solar or photovoltaic) and controller and “duty cycle”
4. (solar or photovoltaic) and controller and string
5. (solar or photovoltaic) and temperature and “duty cycle”
6. (solar or photovoltaic) and “light intensity” and “duty cycle”
7. (Vmp or (voltage and “maximum power point”)) and “duty cycle”
8. (“Maximum Power Point Tracking” or MPPT) and “duty cycle”

Database Service: Google (<http://www.google.com/>)

Files Searched: Web, Scholar

Date Conducted: January 20-21, 2009

Search Logic:

1. (solar OR photovoltaic) AND (multi-panel OR multipanel)
2. (solar OR photovoltaic) AND (“management unit” OR LMU)
3. (solar OR photovoltaic) AND (panel OR module) AND controller AND “duty cycle”

4. (solar OR photovoltaic) AND (panel OR module) AND controller AND string
5. (solar OR photovoltaic) AND “temperature” AND “duty cycle”
6. (solar OR photovoltaic) AND “light intensity” AND “duty cycle”
7. (Vmp OR (voltage AND “maximum power point”)) AND “duty cycle”
8. (“Maximum Power Point Tracking” OR MPPT) AND “duty cycle”

Database Service: Google Patent Search (<http://www.google.com/patents>)

Files Searched: U.S. Patents, U.S. Patent Applications

Date Conducted: January 20-21, 2009

Search Logic:

1. (solar OR photovoltaic) AND (multi-panel OR multipanel)
2. (solar OR photovoltaic) AND (“management unit” OR LMU)
3. (solar OR photovoltaic) AND (panel OR module) AND controller AND “duty cycle”
4. (solar OR photovoltaic) AND (panel OR module) AND controller AND string
5. (solar OR photovoltaic) AND “temperature” AND “duty cycle”
6. (solar OR photovoltaic) AND “light intensity” AND “duty cycle”
7. (Vmp OR (voltage AND “maximum power point”)) AND “duty cycle”
8. (“Maximum Power Point Tracking” OR MPPT) AND “duty cycle”

SEARCH DIRECTED TO THE INVENTION

The pre-examination search was directed to the claimed invention, encompassing all the features of the claims and giving the claims their broadest reasonable interpretation.

SEARCH DIRECTED TO THE DISCLOSURE

No disclosed features that are unclaimed at this time are currently seen as features that may be claimed later.

SEARCH REPORT FROM A FOREIGN PATENT OFFICE

No search report from a foreign patent office is provided here as the pre-examination search.

STATEMENT OF GOOD FAITH

All statements above in support of the petition to make special are based on a good faith belief that the search was conducted in compliance with the requirements of this rule.

Respectfully submitted,

Date: March 25, 2009

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventors:	Ron Hadar, et al.	Examiner:	Not Assigned
Serial No.:	Not Assigned	Group Art Unit:	Not Assigned
Filed:	Herewith	Confirmation:	Not Assigned
Title:	Systems and Methods to Balance Solar Panels in a Multi-Panel System		

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

ACCELERATED EXAMINATION SUPPORT DOCUMENT

Sir/Madam:

This accelerated examination support document is provided in support of the petition for accelerated examination filed herewith.

CLAIMS

There are twenty claims currently pending in the application. The claims read as follows:

1. An apparatus, comprising:
a photovoltaic energy production unit to generate electricity; and
a management unit coupled between the photovoltaic energy production unit and a series connection of energy production units, the management unit having at least a first switch, the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit, the management unit to allow a second current larger than the first current to flow through the series connection of energy production units.
2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit connected to the photovoltaic energy production unit;
wherein, when the first switch is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current is equal to or larger than a sum of the first current and the third current; and
wherein, when the first switch is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy production units, and the management unit provides at least one path for the series connection of energy production units.

3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor coupled in parallel with the energy production unit; and when the first switch is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit.
4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode,
a second switch, wherein the management unit turns off the second switch when the first switch is turned on, and
a synchronous rectifier.
5. The apparatus of claim 1, wherein the management unit further comprises a controller to control the first switch according to a duty cycle.
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift, and a synchronization pulse.
7. The apparatus of claim 5, wherein the controller is configured to control the first switch based on one of:
at least one operating parameter associated with the energy production unit,
at least one operating parameter of a separate energy production unit, and
a control signal received from a remote unit.
8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current, a voltage, and a temperature; and the duty cycle is based on a maximum power point of the energy production unit.

9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series, the second management unit having at least a second switch, the second photovoltaic energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit, the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units.
10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel; and the management unit has no inductor and is integrated on the solar panel.
11. A method, comprising:
providing a management unit to couple a solar energy production unit to a series connection of energy production units, the management unit having a first switch and an energy storage unit coupled to the solar energy production unit; and
determining at least one parameter to control the first switch;
wherein, when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current; and
wherein, when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy

production units, and the management unit provides at least one path for the series connection of energy production units.

12. The method of claim 11, wherein the determining comprises:
computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit.
13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises:
receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units; and
identifying a first voltage among the operating voltages;
wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit.
14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and
wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units.
15. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected; and

undoing an adjustment to the duty cycle that causes the decrease.

16. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected; and
in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit.
17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter; and
adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point.
18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:
receiving operating parameters of a plurality of solar energy production units connected in series;
identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter;
identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units;
identifying a second maximum power point voltage of the second solar energy production unit;

computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage; and
adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage.

19. The method of claim 12, further comprising:
adjusting the duty cycle to increase the first current.
20. The method of claim 12, further comprising:
adjusting the duty cycle to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units, the string including the solar energy production unit.

REFERENCES DEEMED MOST CLOSELY RELATED

An Information Disclosure Statement in compliance with 37 C.F.R. §1.98 has been filed herewith citing each of the following references deemed most closely related to the subject matter of the claim.

Lee et al. WO 2005/112551 (Lee)

Rohrig et al. US2005/0172995 (Rohrig)

Decker et al. US5648731 (Decker)

IDENTIFICATION OF LIMITATIONS DISCLOSED BY REFERENCES

Lee: WO 2005/112551

Lee discloses a photovoltaic power system monitoring system (*Abstract, lines 1-3*). With respect to the claims listed below, relevant portions of Lee showing the features related to the claim limitations are identified below within the parentheses near the corresponding claim limitations.

1. An apparatus (*Fig. 1*), comprising:
a photovoltaic energy production unit (“solar cells PV1, PV2”, *Fig. 1*) to generate electricity; and
a management unit coupled between the photovoltaic energy production unit and a series connection of energy production units (“solar cells PV1, PV2”, *Fig. 1*), the management unit having at least a first switch (“switches SW1 and SW2”, *Fig. 1*), the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit (*not disclosed*), the management unit to allow a second current larger than the first current to flow through the series connection of energy production units (*Fig. 1*).
2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit (“capacitor C1 or C2”, “inductor L”, *Fig. 1*) connected to the photovoltaic energy production unit;
wherein, when the first switch (“switch SW1 or SW2”, *Fig. 1*) is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second

current is equal to or larger than a sum of the first current and the third current;
and

wherein, when the first switch (“switch SW1 or SW2”, *Fig. 1*) is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy production units (*not disclosed*), and the management unit provides at least one path for the series connection of energy production units.

3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor (“Capacitor C1 or C2”, *Fig. 1*) coupled in parallel with the energy production unit (“solar cell PV1 or PV2”, *Fig. 1*); and when the first switch is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit.
4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode (“Diode near switch SW1 or SW2”, *Fig. 1*),
a second switch, wherein the management unit turns off the second switch when the first switch is turned on (*not disclosed*), and
a synchronous rectifier (*not disclosed*).
5. The apparatus of claim 1, wherein the management unit further comprises a controller to control the first switch according to a duty cycle (*Par. [34], page 4*).
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift, and a synchronization pulse (*Fig. 2*).

7. The apparatus of claim 5, wherein the controller is configured to control the first switch based on one of:
at least one operating parameter associated with the energy production unit (*not disclosed*),
at least one operating parameter of a separate energy production unit (*not disclosed*), and
a control signal (*Fig. 1*) received from a remote unit.
8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current, a voltage, and a temperature; and the duty cycle is based on a maximum power point of the energy production unit (*not disclosed*).
9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series, the second management unit having at least a second switch (“switches SW1 and SW2”, *Fig. 1*), the second photovoltaic energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit (*not disclosed*), the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units (*Fig. 1*).
10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel (“solar cells PV1, PV2”, *Fig. 1*); and the management unit has no inductor and is integrated on the solar panel.

11. A method, comprising:
- providing a management unit to couple a solar energy production unit to a series connection of energy production units (“solar cells PV1, PV2”, *Fig. 1*), the management unit having a first switch (“switches SW1 and SW2”, *Fig. 1*) and an energy storage unit (“capacitor C1 or C2”, “inductor L”, *Fig. 1*) coupled to the solar energy production unit; and
- determining at least one parameter to control the first switch (*Pars. [34-48], pages 4-5*);
- wherein, when the first switch (“switch SW1 or SW2”, *Fig. 1*) is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current; and
- wherein, when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected (*not disclosed*) from the series connection of energy production units, and the management unit provides at least one path for the series connection of energy production units (*Fig. 1*).
12. The method of claim 11, wherein the determining comprises:
- computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit (*not disclosed*).
13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises:
- receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units (*Par. [50], page 5*); and
- identifying a first voltage among the operating voltages (*not disclosed*);

wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit (*not disclosed*).

14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and
wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units (*not disclosed*).
15. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*not disclosed*); and
undoing an adjustment to the duty cycle that causes the decrease (*not disclosed*).
16. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*not disclosed*); and
in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit (*not disclosed*).
17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter; and

adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point (*not disclosed*).

18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:

receiving operating parameters of a plurality of solar energy production units connected in series;

identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter (*not disclosed*);

identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units (*not disclosed*);

identifying a second maximum power point voltage of the second solar energy production unit (*not disclosed*);

computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage (*not disclosed*); and

adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage (*not disclosed*).

19. The method of claim 12, further comprising:

adjusting the duty cycle to increase the first current (*not disclosed*).

20. The method of claim 12, further comprising:

adjusting the duty cycle to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units, the string including the solar energy production unit (*not disclosed*).

Rohrig: US2005/0172995

Rohrig discloses a distributed power system (*Figs. 2 and 3*). With respect to the claims listed below, relevant portions of Rohrig showing the features related to the claim limitations are identified below within the parentheses near the corresponding claim limitations.

1. An apparatus, comprising:
a photovoltaic energy production unit (“generators G1, G2, G3”, *Fig. 2*; “generator G”, *Fig. 3*) to generate electricity; and
a management unit (“generator control unit (GCU)”, *Figs. 2 and 3*) coupled between (*not disclosed*) the photovoltaic energy production unit and a series connection of energy production units, the management unit having at least a first switch (*not disclosed*), the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit (*not disclosed*), the management unit to allow a second current larger than the first current to flow through the series connection of energy production units (*Figs. 2 and 3*; *Pars. [0052-0054]*).
2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit (*not disclosed*) connected to the photovoltaic energy production unit; wherein, when the first switch is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current is equal to or larger than a sum of the first current and the third current (*not disclosed*); and wherein, when the first switch is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy

production units (*not disclosed*), and the management unit provides at least one path for the series connection of energy production units.

3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor coupled in parallel with the energy production unit (*not disclosed*); and when the first switch is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit (*Figs. 2 and 3*).
4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode (*not disclosed*),
a second switch, wherein the management unit turns off the second switch when the first switch is turned on (*not disclosed*), and
a synchronous rectifier (*not disclosed*).
5. The apparatus of claim 1, wherein the management unit further comprises a controller to control the first switch according to a duty cycle (*not disclosed*).
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift, and a synchronization pulse (*not disclosed*).
7. The apparatus of claim 5, wherein the controller is configured to control the first switch (*not disclosed*) based on one of:
at least one operating parameter associated with the energy production unit,
at least one operating parameter of a separate energy production unit, and
a control signal received from a remote unit.

8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current, a voltage, and a temperature; and the duty cycle (*not disclosed*) is based on a maximum power point of the energy production unit.
9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series (*not disclosed*), the second management unit having at least a second switch, the second photovoltaic energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit (*not disclosed*), the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units.
10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel (“photovoltaic system”, *abstract*); and the management unit has no inductor and is integrated on the solar panel.
11. A method, comprising:
providing a management unit (“generator control unit (GCU)”, *Figs. 2 and 3*) to couple a solar energy production unit to a series connection of energy production units (*not disclosed*), the management unit having a first switch (*not disclosed*) and an energy storage unit (*not disclosed*) coupled to the solar energy production unit;
and

determining at least one parameter to control the first switch (*not disclosed*);
wherein, when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current (*not disclosed*); and
wherein, when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected (*not disclosed*) from the series connection of energy production units, and the management unit provides at least one path for the series connection of energy production units (*Figs. 2 and 3; Pars. [0052-0054]*).

12. The method of claim 11, wherein the determining comprises:
computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit (*not disclosed*).
13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises:
receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units; and
identifying a first voltage among the operating voltages;
wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit (*not disclosed*).
14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and

wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units (*not disclosed*).

15. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*not disclosed*); and
undoing an adjustment to the duty cycle that causes the decrease (*not disclosed*).
16. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*not disclosed*); and
in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit (*not disclosed*).
17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter (*not disclosed*); and
adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point (*not disclosed*).

18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:
- receiving operating parameters of a plurality of solar energy production units connected in series (*Par. [0052]*);
- identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter (*Par. [0052]*);
- identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units (*not disclosed*);
- identifying a second maximum power point voltage of the second solar energy production unit (*Par. [0052]*);
- computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage (*not disclosed*); and
- adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage (*not disclosed*).
19. The method of claim 12, further comprising:
- adjusting the duty cycle to increase the first current (*not disclosed*).
20. The method of claim 12, further comprising:
- adjusting the duty cycle (*not disclosed*) to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units, the string including the solar energy production unit.

Decker: US5648731

Decker discloses a solar electrical system (*Fig. 1*). With respect to the claims listed below, relevant portions of Decker showing the features related to the claim limitations are identified below within the parentheses near the corresponding claim limitations.

1. An apparatus, comprising:
a photovoltaic energy production unit (“solar array panel 3”, *Fig. 1*) to generate electricity; and
a management unit (“array regulator module 5”, *Fig. 1*) coupled between the photovoltaic energy production unit and a series connection of energy production units (*not disclosed*), the management unit having at least a first switch (“switch S1”, *Fig. 2*), the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units (*not disclosed*) via the first switch of the management unit, the management unit to allow a second current (“ I_{out} ”, *Col. 4, lines 16-19*) larger than the first current to flow through the series connection of energy production units.
2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit (“capacitor C1”, *Fig. 2*) connected to the photovoltaic energy production unit;
wherein, when the first switch (“switch S1”, *Fig. 2*) is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current is equal to or larger than a sum of the first current and the third current (*not disclosed*); and
wherein, when the first switch (“switch S1”, *Fig. 2*) is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series

connection of energy production units, and the management unit provides at least one path (“diode D1”, *Fig. 2*) for the series connection of energy production units.

3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor (“capacitor C1”, *Fig. 2*) coupled in parallel with the energy production unit (“solar array panel 3”, *Fig. 1*); and when the first switch is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit (*Not disclosed*).
4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode (“diode D1”, *Fig. 2*),
a second switch, wherein the management unit turns off the second switch when the first switch is turned on (*not disclosed*), and
a synchronous rectifier (*not disclosed*).
5. The apparatus of claim 1, wherein the management unit further comprises a controller (“circuit 34”, *Fig. 2*) to control the first switch according to a duty cycle (*Col. 7, lines 36-40*).
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift, and a synchronization pulse (*not disclosed*).
7. The apparatus of claim 5, wherein the controller is configured to control the first switch based on one of:
at least one operating parameter associated with the energy production unit (*Col. 10, lines 49-65; Col. 11, lines 6-20*),
at least one operating parameter of a separate energy production unit (*not disclosed*), and

a control signal received from a remote unit (*Fig. 2*).

8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current, a voltage (*Col. 10, lines 49-65*), and a temperature; and the duty cycle is based on a maximum power point of the energy production unit (*Col. 11, lines 6-20*).
9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series (*not disclosed*), the second management unit having at least a second switch, the second photovoltaic energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit, the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units.
10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel ("solar array panel 3", *Fig. 1*); and the management unit has no inductor and is integrated on the solar panel.
11. A method, comprising:
providing a management unit ("array regulator module 5", *Fig. 1*) to couple a solar energy production unit ("solar array panel 3", *Fig. 1*) to a series connection of energy production units (*not disclosed*), the management unit having a first switch

(“switch S1”, *Fig. 2*) and an energy storage unit (“capacitor C1”, *Fig. 2*) coupled to the solar energy production unit; and
determining at least one parameter to control the first switch (*Col. 10, lines 49-65; Col. 11, lines 6-20*);
wherein, when the first switch (“switch S1”, *Fig. 2*) is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current (*not disclosed*); and
wherein, when the first switch (“switch S1”, *Fig. 2*) is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units, and the management unit provides at least one path (“diode D1”, *Fig. 2*) for the series connection of energy production units.

12. The method of claim 11, wherein the determining comprises:
computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit (*Col. 11, lines 6-20*).
13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises:
receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units; and
identifying a first voltage among the operating voltages;
wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit (*not disclosed*).

14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and
wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units (*not disclosed*).
15. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*not disclosed*); and
undoing an adjustment to the duty cycle that causes the decrease (*not disclosed*).
16. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*not disclosed*); and
in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit (*not disclosed*).
17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter; and
adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point (*Col. 11, lines 6-20*).

18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:
- receiving operating parameters of a plurality of solar energy production units connected in series;
- identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter (*Col. 11, lines 6-20*);
- identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units (*not disclosed*);
- identifying a second maximum power point voltage of the second solar energy production unit;
- computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage (*not disclosed*); and
- adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage (*not disclosed*).
19. The method of claim 12, further comprising:
- adjusting the duty cycle to increase the first current (*Col. 7, lines 23-31*).
20. The method of claim 12, further comprising:
- adjusting the duty cycle to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units (*Col. 10, lines 49-65*), the string including the solar energy production unit.

DETAILED EXPLANATION OF PATENTABILITY

All of the references identified above (Lee, Rohrig and Decker) fail to at least teach or suggest “the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit” of claim 1.

Rohrig addresses the problem of different solar generators connected in series having different currents at their respective maximum power points (MPP) by introducing bypasses (see, e.g., Figs. 2 and 3; Pars. [0052-0054], Rohrig). In Rohrig, the current in the string is the lowest MPP current of the MPP currents of the solar generators. Such an approach is different from “the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit” recited in claim 1.

Decker does not address the problem of different solar generators connected in series having different currents at their respective maximum power points (MPP). In Decker, different solar array panels 3 are connected in parallel to the main power bus 37 (see, e.g., Fig. 1; Col. 4, lines 4-5 and 23-25; Decker). Decker discloses a switch S1, which is part of the buck regulator 7. A buck regulator is typically used to as a step-down converter (e.g., to reduce the output voltage of the solar panel). In Deck, the buck regulator is also used to set the solar panel at the maximum power point (see, e.g., Col. 10, lines 49-65; Col. 11, lines 6-20; Decker). Decker does not show “the photovoltaic energy production unit to generate a first current to provide electricity *to the series connection of energy production units* via the first switch of the management unit” recited in claim 1.

Lee discloses a circuit that can set the operating voltage of two solar cells connected in series based on the off duty cycles of the switches in the circuit (see, e.g., Fig. 1; Pars. [34-48], pages 4-5). Lee does not show “the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit” recited in claim 1.

Thus, claim 1 and its dependent claims are seen to patentably distinguish over each of these references alone or in combination.

All of the references identified above (Lee, Rohrig and Decker) fail to at least teach or suggest “when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units” and “when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units” of claim 11.

Rohrig addresses the problem of different solar generators connected in series having different currents at their respective maximum power points (MPP) by introducing bypasses (see, e.g., Figs. 2 and 3; Pars. [0052-0054], Rohrig). In Rohrig, the current in the string is the lowest MPP current of the MPP currents of the solar generators. Rohrig does not disclose a first switch such that “when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units” and “when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units”, as recited in claim 11.

Decker does not address the problem of different solar generators connected in series having different currents at their respective maximum power points (MPP). In Decker, different solar array panels 3 are connected in parallel to the main power bus 37 (see, e.g., Fig. 1; Col. 4, lines 4-5 and 23-25; Decker). Decker discloses a switch S1, which is part of the buck regulator 7. A buck regulator is typically used to as a step-down converter (e.g., to reduce the output voltage of the solar panel). In Deck, the buck regulator is used to set the solar panel at the maximum power point (see, e.g., Col. 10, lines 49-65; Col. 11, lines 6-20; Decker). Deck does not show “when the first switch is turned on, the solar energy production unit provides a first current to *the series connection of energy production units*” and “when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from *the series connection of energy production units*”, as recited in claim 11.

Lee discloses a circuit that can set the operating voltage of two solar cells connected in series based on the off duty cycles of the switches in the circuit (see, e.g., Fig. 1; Pars. [34-48], pages 4-5). The switches SW1 and SW2 of Lee are used to connect/disconnect the inductor L.

Lee does not disclose a first switch such that “when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units” and “when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units”, as recited in claim 11.

Thus, claim 11 and its dependent claims are seen to patentably distinguish over each of these references alone or in combination.

Further, all of the references identified above fail to at least teach or suggest “receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units; and identifying a first voltage among the operating voltages; wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit” of claim 13. Thus, claim 13 and its dependent claims are seen to patentably distinguish over each of these references alone or in combination.

Further, all of the references identified above fail to at least teach or suggest “when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units” of claim 14. Thus, claim 14 and its dependent claims are seen to patentably distinguish over each of these references alone or in combination.

Further, all of the references identified above fail to at least teach or suggest “adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected” of claims 15 and 16. Thus, claims 15 and 16 are seen to patentably distinguish over each of these references alone or in combination.

Further, all of the references identified above fail to at least teach or suggest “identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units; identifying a second maximum power point voltage of the second solar energy production unit; computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage; and adjusting the duty cycle to drive an

operating voltage of the first solar energy production unit towards the target voltage” of claim 18. Thus, claim 18 is seen to patentably distinguish over each of these references alone or in combination.

CONCISE STATEMENT OF UTILITY

The invention as claimed by claim 1 has utility at least in that it provides photovoltaic devices that can be connected in series without affecting the efficiency of each other.

The invention as claimed by claim 11 has utility at least in that it provides a process for a solar system having multiple photovoltaic devices connected in series without affecting the efficiency of each other.

IDENTIFICATION OF REFERENCES DISQUALIFIED

AS PRIOR ART UNDER 35 U.S.C. §103(C)

None of the cited references are disqualified as prior art under 35 U.S.C. §103(c).

SHOWING OF SUPPORT UNDER 35 U.S.C. §112, FIRST PARAGRAPH

The pending claims does not invoke 35 U.S.C. §112, sixth paragraph. There are no means- (or step-) plus-function claim elements.

The present application claims priority to provisional U.S. Patent Application Serial No. 61/200,601, filed on December 2, 2008.

Support in the present application:

With respect to the claims listed below, at least some of the relevant portions of the present application, which provide the support under 35 U.S.C. §112, first paragraph, are identified below within the parentheses near the corresponding claim limitations.

1. An apparatus, comprising:
a photovoltaic energy production unit (“solar module 102”, *Fig. 1*) to generate electricity;
and
a management unit (“LMU 101”, *Fig. 1*) coupled between the photovoltaic energy production unit (“solar module 102”, *Fig. 1*) and a series connection of energy production units (“serial power bus 103”, *Fig. 1*), the management unit having at least a first switch (“switch Q1 106”, *Fig. 1*), the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit (*Fig. 1*), the management unit to allow a second current larger than the first current to flow through the series connection of energy production units (*Fig. 1*; *Par. [0005, 0048]*).
2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit (“capacitor C1 105”, *Fig. 1*) connected to the photovoltaic energy production unit;
wherein, when the first switch is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current is equal to or larger than a sum of the first current and the third current (*Fig. 1*; *Par. [0007]*); and
wherein, when the first switch is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy production units (*Fig. 1*; *Par. [0007]*), and the management unit provides at least one path (“diode D1 107”, *Fig. 1*; “switch Q2 108”, *Fig. 2*) for the series connection of energy production units.

3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor (“capacitor C1 105”, *Fig. 1*) coupled in parallel with the energy production unit (“solar module 102”, *Fig. 1*); and when the first switch (“switch Q1 106”, *Fig. 1*) is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit (*Fig. 1; Par. [0008]*).
4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode (“diode D1 107”, *Fig. 1*),
a second switch, wherein the management unit turns off the second switch when the first switch is turned on (“switch Q2 108”, *Fig. 2; Pars. [0009, 0044]*), and
a synchronous rectifier (“switch Q2 108”, *Fig. 3; Pars. [0009, 0044]*).
5. The apparatus of claim 1, wherein the management unit further comprises a controller (“controller 109”, *Fig. 1*) to control the first switch according to a duty cycle (“duty cycle 104a”, *Fig. 1*).
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift (“duty cycle 104b”, *Fig. 1*), and a synchronization pulse (“duty cycle 104c”, *Fig. 1*).
7. The apparatus of claim 5, wherein the controller is configured to control the first switch based on one of:
at least one operating parameter associated with the energy production unit (*Par. [0105]*),
at least one operating parameter of a separate energy production unit (*Par. [0091]*), and
a control signal received from a remote unit (*Par. [0042]*).

8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current (*Pars. [0054, 0059]*), a voltage (*Pars. [0059, 0069, 0090]*), and a temperature (*Pars. [0069, 0098]*); and the duty cycle is based on a maximum power point of the energy production unit (*Pars. [0098, 0101]*).
9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series (*Fig. 4*), the second management unit having at least a second switch, the second photovoltaic energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit, the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units (*Figs. 1-3; Par. [0012]*).
10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel (*Fig. 5; Par. [0063]*); and the management unit has no inductor (*Figs. 1-3; Par. [0006]*) and is integrated on the solar panel (*Fig. 5; Par. [0006]*).
11. A method, comprising:
providing a management unit ("LMU 101", *Fig. 1*) to couple a solar energy production ("solar module 102", *Fig. 1*) unit to a series connection of energy production units ("serial power bus 103", *Fig. 1*), the management unit having a first switch ("switch Q1 106", *Fig. 1*) and an energy storage unit ("capacitor C1 105", *Fig. 1*) coupled to the solar energy production unit; and

determining at least one parameter to control the first switch (*Par. [0091]*);
wherein, when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current (*Fig. 1*); and
wherein, when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units (*Fig. 1*), , and the management unit provides at least one path (“diode D1 107”, *Fig. 1*; “switch Q2 108”, *Fig. 2*) for the series connection of energy production units (*Par. [0013]*).

12. The method of claim 11, wherein the determining comprises:
computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit (*Par. [0091]*).
13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises:
receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units (*Par. [0090]*); and
identifying a first voltage among the operating voltages (*Par. [0090]*);
wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit (*Par. [0091]*).
14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and

wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units (*Par. [0091]*).

15. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (“operation 427”, *Fig. 7; Par. [0096]*); and
undoing an adjustment to the duty cycle that causes the decrease (“operation 429”, *Fig. 7; Par. [0096]*).
16. The method of claim 14, further comprising:
adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (“operation 427”, *Fig. 7; Par. [0097]*); and
in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit (“operation 431”, *Fig. 7; Par. [0097]*).
17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter (*Par. [0098]*); and
adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point (*Par. [0098]*).

18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:
- receiving operating parameters of a plurality of solar energy production units connected in series (“operation 441”, *Fig. 8*);
- identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter (“operation 443”, *Fig. 8*);
- identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units (“operation 445”, *Fig. 8*);
- identifying a second maximum power point voltage of the second solar energy production unit (“operation 447”, *Fig. 8*);
- computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage (“operation 449”, *Fig. 8*); and
- adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage (“operation 451”, *Fig. 8*).
19. The method of claim 12, further comprising:
- adjusting the duty cycle to increase the first current (*Par. [0105]*).
20. The method of claim 12, further comprising:
- adjusting the duty cycle to change an operating voltage of the solar energy production unit to increase an output power of a string of solar energy production units, the string including the solar energy production unit (*Par. [0105]*).

Support in provisional U.S. Patent Application Serial No. 61/200,601, filed on December 2,

2008:

With respect to the claims listed below, at least some of the relevant portions of the provisional U.S. Patent Application Serial No. 61/200,601, filed on December 2, 2008, which provide the support under 35 U.S.C. §112, first paragraph, are identified below within the parentheses near the corresponding claim limitations.

1. An apparatus, comprising:
a photovoltaic energy production unit (“solar module 102”, *Fig. 1*) to generate electricity;
and
a management unit (“LMU 101”, *Fig. 1*) coupled between the photovoltaic energy production unit and a series connection of energy production units (“serial power bus 103”, *Fig. 1*), the management unit having at least a first switch (“switch Q1 106”, *Fig. 1*), the photovoltaic energy production unit to generate a first current to provide electricity to the series connection of energy production units via the first switch of the management unit (*Fig. 1*), the management unit to allow a second current larger than the first current to flow through the series connection of energy production units (*Fig. 1; lines 18-20, page 2*).
2. The apparatus of claim 1, wherein the management unit further comprises an energy storage unit (“capacitor C1 105”, *Fig. 1*) connected to the photovoltaic energy production unit;
wherein, when the first switch is turned on, the energy production unit provides the first current to the series connection of energy production units, the energy storage unit provides a third current, and the second current is equal to or larger than a sum of the first current and the third current (*Fig. 1*); and

wherein, when the first switch is turned off, the energy production unit and the energy storage unit are electronically disconnected from the series connection of energy production units (*Fig. 1*), and the management unit provides at least one path (“diode D1 107”, “switch Q2 108”, *Fig. 1*) for the series connection of energy production units .

3. The apparatus of claim 2, wherein the energy storage unit comprises a capacitor (“capacitor C1 105”, *Fig. 1*) coupled in parallel with the energy production unit (“solar module 102”, *Fig. 1*); and when the first switch (“switch Q1 106”, *Fig. 1*) is turned on, an output voltage of the local management unit is substantially equal to an output voltage of the energy production unit (*Fig. 1*).
4. The apparatus of claim 3, wherein the at least one path includes at least one of:
a diode (“diode D1 107”, *Fig. 1*),
a second switch (“switch Q2 108”, *Fig. 1*), wherein the management unit turns off the second switch when the first switch is turned on, and
a synchronous rectifier (*lines 7-8, page 2*).
5. The apparatus of claim 1, wherein the management unit further comprises a controller (“SCMC 109”, *Fig. 1*) to control the first switch according to a duty cycle (“duty cycle 104a”, *Fig. 1*).
6. The apparatus of claim 5, wherein the controller is to further control the first switch according to at least one of: a phase shift (“phase 104b”, *Fig. 1*), and a synchronization pulse (“sync pulse 104c”, *Fig. 1*).

7. The apparatus of claim 5, wherein the controller is configured to control the first switch based on one of:
at least one operating parameter associated with the energy production unit (*lines 4-5, page 5*),
at least one operating parameter of a separate energy production unit (*lines 6-12, page 4*),
and
a control signal received from a remote unit (*lines 2-4, page 2*).
8. The apparatus of claim 5, wherein the at least one operating parameter associated with the energy production unit includes one of: a current (*line 26, page 2*), a voltage (*lines 4-5, page 5*), and a temperature (*line 21, page 4*); and the duty cycle is based on a maximum power point of the energy production unit (*lines 21-26, page 4*).
9. The apparatus of claim 1, wherein the management unit is a first management unit and the photovoltaic energy production unit is a first photovoltaic energy production unit; and the apparatus further comprises:
a second management unit and a second photovoltaic energy production unit, the second management unit connected to the first management unit in series (*Fig. 2*), the second management unit having at least a second switch, the second photovoltaic energy production unit to provide electricity to the series connection of energy production units via the second switch of the second management unit, the second management unit to allow the second current, larger than a current from the second photovoltaic energy production unit, to flow through the series connection of energy production units (*Fig. 1; lines 18-20, page 2*).

10. The apparatus of claim 1, wherein the energy production unit is at least one solar cell of a solar panel (*lines 16-18, page 2*); and the management unit has no inductor (*Fig. 1*) and is integrated on the solar panel (*lines 20-22, page 1; lines 16-18, page 2*).
11. A method, comprising:
providing a management unit (“LMU 101”, *Fig. 1*) to couple a solar energy production unit (“solar module 102”, *Fig. 1*) to a series connection of energy production units (“serial power bus 103”, *Fig. 1*), the management unit having a first switch (“switch Q1 106”, *Fig. 1*) and an energy storage unit (“capacitor C1 105”, *Fig. 1*) coupled to the solar energy production unit; and
determining at least one parameter to control the first switch (*lines 6-12, page 4*);
wherein, when the first switch is turned on, the solar energy production unit provides a first current to the series connection of energy production units and the energy storage unit provides a second current, a third current in the series connection of energy production units being equal to or larger than a sum of the first current and the second current (*Fig. 1*); and
wherein, when the first switch is turned off, the solar energy production unit and the energy storage unit are disconnected from the series connection of energy production units (*Fig. 1*), and the management unit provides at least one path (“diode D1 107”, “switch Q2 108”, *Fig. 1*) for the series connection of energy production units.
12. The method of claim 11, wherein the determining comprises:
computing a duty cycle to control the first switch based on at least one operating parameter of the solar energy production unit (*lines 4-5, page 5*).

13. The method of claim 12, wherein the at least one operating parameter includes an operating voltage of the solar energy production unit; and the method further comprises: receiving operating voltages of a plurality of solar energy production units connected in series via a plurality of management units (*line 8, page 4*); and identifying a first voltage among the operating voltages (*line 10-12, page 4*); wherein the duty cycle is computed according to a function of the first voltage and the operating voltage of the solar energy production unit (*line 10-12, page 4*).
14. The method of claim 13, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and wherein, when a second solar energy production unit of the plurality of solar energy production units provides a highest power among the plurality of solar energy production units, the first voltage is an operating voltage of the second solar energy production unit, and the duty cycle is based at least in part on a ratio between the operating voltages of the first and second solar energy production units (*lines 10-12, page 4*).
15. The method of claim 14, further comprising: adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*lines 13-14, page 4*); and undoing an adjustment to the duty cycle that causes the decrease (*lines 14-15, page 4*).
16. The method of claim 14, further comprising: adjusting the duty cycle until a decrease in the operating voltage of the second solar energy production unit is detected (*lines 17-18, page 4*); and

in response to the decrease, decreasing a duty cycle for a local management unit coupled to the second solar energy production unit to increase the operating voltage of the second solar energy production unit (*lines 18-20, page 4*).

17. The method of claim 12, further comprising:
identifying a voltage of the solar energy production unit at a maximum power point based on the at least one operating parameter (*lines 21-24, page 4*); and
adjusting the duty cycle to change an operating voltage of the solar energy production unit towards the voltage at the maximum power point (*lines 24-26, page 4*).
18. The method of claim 12, wherein the solar energy production unit is a first solar energy production unit of the plurality of solar energy production units; and the method further comprises:
receiving operating parameters of a plurality of solar energy production units connected in series (*lines 15-16, page 7*);
identifying a first maximum power point voltage of the first solar energy production unit based on the at least one operating parameter (*lines 18-20, page 7*);
identifying a second solar energy production unit having an operating voltage highest among the plurality of solar energy production units (*line 17, page 7*);
identifying a second maximum power point voltage of the second solar energy production unit (*lines 18-20, page 7*);
computing a target voltage based on the first maximum power point voltage and the second maximum power point voltage (*lines 21-25, page 7*); and
adjusting the duty cycle to drive an operating voltage of the first solar energy production unit towards the target voltage (*lines 26-28, page 7*).

19. The method of claim 12, further comprising:
adjusting the duty cycle to increase the first current (*lines 4-6, page 5*).
20. The method of claim 12, further comprising:
adjusting the duty cycle to change an operating voltage of the solar energy production
unit to increase an output power of a string of solar energy production units, the
string including the solar energy production unit (*lines 4-7, page 5*).

Respectfully submitted,

Date: March 25, 2009

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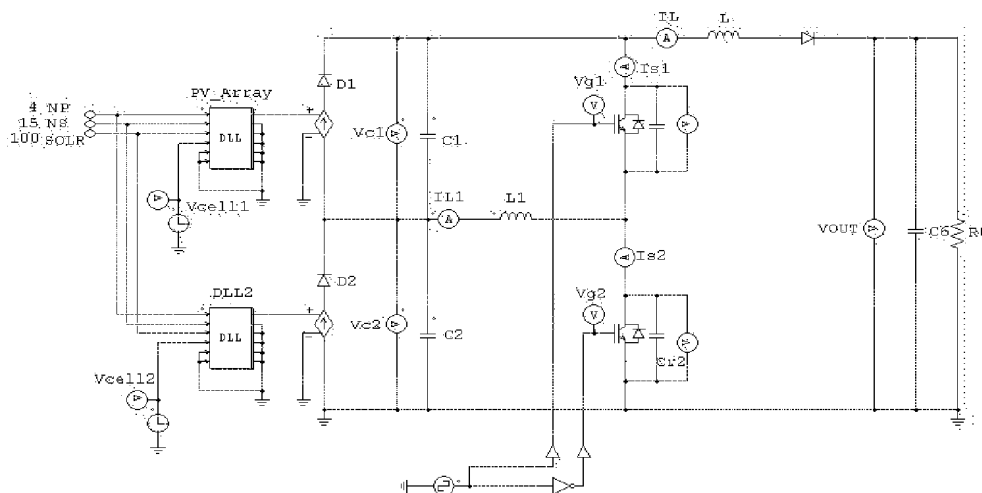
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[Continued on next page]

(54) Title: METHOD FOR COMPENSATING FOR PARTIAL SHADE IN PHOTOVOLTAIC POWER SYSTEM



(57) Abstract: There is provided a method for compensating for partial shade using a photovoltaic power system, in which a plurality of serial-connected arrays of solar cell modules are connected in parallel, the arrays are connected to a converter, and a final power is outputted from the converter. The method includes the steps of: connecting an auxiliary power source to each solar cell module; if a low solar radiation is detected by an MPPT controller, supplying a necessary power through the auxiliary power source at a time, thereby maintaining constant voltage and preventing a temporarily shutdown; connecting in parallel the solar cell modules of the serial- connected arrays in multi-stages; and varying an operating voltage ratio of the solar cell module by controlling an off duty cycle of each chopper at the MPPT controller, thereby generating maximum output from the serial-connected array of each solar cell module.



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Description

METHOD FOR COMPENSATING FOR PARTIAL SHADE IN PHOTOVOLTAIC POWER SYSTEM

Technical Field

- [1] The present invention relates to a method for compensating for a partial shade in a photovoltaic power system, and more particularly, to a method for compensating for a partial shade in a photovoltaic power system, in which a constant voltage can be maintained by supplying an insufficient voltage of a solar cell module in a low solar radiation, a temporary shutdown of the system can be prevented, and a maximum power can be generated at a serial-connected array of each solar cell module.

[2]

Background Art

- [3] Korea established an alternative energy resource development/usage/ distribution promotion policy for promoting an expanded distribution of new regeneration energy and supported its development of technology.
- [4] Since a solar photovoltaic power generation utilizes a natural energy, many researches on it have been made for a long time. In recent years, home power generators are available.
- [5] In such a photovoltaic power generation system, a plurality of solar cell modules are connected in serial/parallel fashion and are connected to a power conversion device. The reason is that since a solar cell module alone has a low output voltage of below 30 V, a serial connection of the module and a boost converter are required for boosting the low output voltage to an input voltage of a grid-tie inverter. A final power is obtained by connecting the serial-connected arrays in parallel.
- [6] In an output characteristic of each module, however, an operating point of the solar cell module array is changed depending on solar radiation, temperature, load variation, etc. Accordingly, in the solar cell, a maximum power point tracking (MPPT) control method capable of always providing a maximum output should be applied to the converter. Several MPPT control algorithms have been studied. There are an analog MPPT algorithm and a digital MPPT algorithm using a microprocessor. In view of a control object, the MPPT control algorithms are also classified into an MPPT control algorithm using a constant voltage control method, a P&O (Perturbation and Observation Method) MPPT control algorithm, an Inc Cond (Incremental Conductance) MPPT algorithm, and a current feedback algorithm. Although the conventional MPPT control algorithms operate well in a high solar radiation, the MPPT control does not operate well in a low solar radiation. Thus, an amount of power generation is reduced.

Accordingly, a lot of improved algorithms have been studied.

- [7] Also, in an installation of the photovoltaic power system, considering that the solar cells are used in places such as general home or places where the installation area is small, generation power is greatly reduced when the solar cells are connected in series, because solar radiation is different depending on the shade of the adjacent buildings or the installation place. In order to partially solve this problem, bypass diodes are connected to the solar cells. Also, in order to increase the generation efficiency, MPPT control algorithm is installed in each module, or a temporary voltage reduction is compensated using hardware.

[8]

Disclosure of Invention

Technical Problem

- [9] In order to solve problems of an installation situation and temporary reduction of power generation, the present invention provides a system that can always supply maximum power by applying choppers to each module in multi-stage and controlling power generation of each serial-connected array. Also, the present invention provides an improved method using an auxiliary circuit to which a digital controller and a switching topology are applied. By configuring simulation and small-capacity circuit, efficiency of the compensation for partial shade and low solar radiation can be increased.

- [10] An object of the present invention is to maintain constant voltage and prevent temporary shutdown by connecting an auxiliary power source to an output terminal of each solar cell module and supplying necessary power through the auxiliary power source when a low solar radiation is detected by an MPPT controller.

- [11] Another object of the present invention is to provide generate maximum output from the serial-connected array of each solar cell module by connecting in parallel the solar cell modules of the serial-connected arrays in multi-stages and varying an operating voltage ratio of the solar cell module by controlling an off duty cycle of each chopper at the MPPT controller.

[12]

Technical Solution

- [13] According to an aspect of the present invention, there is provided a method for compensating for partial shade using a photovoltaic power system, in which a plurality of serial-connected arrays of solar cell modules are connected in parallel, the arrays are connected to a converter, and a final power is outputted from the converter, the method comprising the steps of: connecting an auxiliary power source to each solar cell module; if a low solar radiation is detected by an MPPT controller, supplying a

necessary power through the auxiliary power source at a time, thereby maintaining constant voltage and preventing a temporarily shutdown; connecting in parallel the solar cell modules of the serial-connected arrays in multi-stages; and varying an operating voltage ratio of the solar cell module by controlling an off duty cycle of each chopper at the MPPT controller, thereby generating maximum output from the serial-connected array of each solar cell module.

[14] The auxiliary power source includes: a switch for performing a switching operation according to a control of the MPPT controller; and a capacitor or small-capacity battery for discharging charged voltage according to the switching of the switch.

[15] The MPPT controller sets a reference voltage (V_{ref}) as a lowest operating voltage of an MPPT control range of the serial-connected array, increases the reference voltage (V_{ref}) and detects an output voltage ($V(k)$) of the serial-connected array. If the output voltage ($V(k)$) is greater than the reference voltage, the MPPT controller does not operate the switch. If the output voltage ($V(k)$) decreases due to an amount of the solar radiation or a change of load after the reference voltage (V_{ref}) increases to the maximum, the MPPT controller decreases the reference voltage (V_{ref}).

[16] The MPPT controller alternately switches each chopper.

[17]

Advantageous Effects

[18] In the method for compensating for the partial shade in the photovoltaic power system, multi-stage choppers are applied to every solar cell module, and maximum power is always supplied at the serial-connected array by controlling power generation of the serial-connection array of each module. A maximum power point is obtained by connecting multi-stage choppers in parallel. Therefore, it is possible to compensate for the partial shade and obtaining constant output by controlling maximum power point even when the partial shade occurs.

[19]

Brief Description of the Drawings

[20] FIG. 1 is a circuit diagram of a generation control circuit according to an embodiment of the present invention;

[21] FIG. 2 illustrates a switching sequence and a reactor current waveform in a generation control circuit according to an embodiment of the present invention;

[22] FIG. 3 is a flowchart illustrating a method for compensating for a partial shade in a photovoltaic power system according to an embodiment of the present invention;

[23] FIG. 4 is a circuit diagram of a power point control circuit according to an embodiment of the present invention;

[24] FIG. 5 is a current waveform of an inductor and each part in a power point control

circuit according to an embodiment of the present invention;

- [25] FIG. 6 is a circuit diagram of a photovoltaic power system to which a method for compensating for a partial shade is applied;
- [26] FIG. 7 is an operation waveform of each part in a rapid change of a solar radiation in a photovoltaic power system according to an embodiment of the present invention;
- [27] FIG. 8 is a test circuit of a photovoltaic power system according to an embodiment of the present invention; and
- [28] FIG. 9 is a graph illustrating an output characteristic before and after a control of each solar cell in a photovoltaic power system according to an embodiment of the present invention.
- [29]

Best Mode for Carrying Out the Invention

- [30] Hereinafter, the preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings.
- [31] In the embodiments of the present invention, multi-stage chopper is applied to each solar cell module, and a power generation in a serial-connected array of each module is controlled, such that a maximum power is always supplied from the serial-connected array. Also, using an MPPT controller, a maximum output voltage is always supplied. In this manner, by solving a problem that an output of an entire array is reduced in a low solar radiation or a partial shade is solved, a maximum power point can be obtained. Thus, a compensation for the partial shade is possible and a constant output can be obtained by the control of the maximum power point even at the partial shade. However, the present invention is not limited to the above-described system, but it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention.
- [32] First, a shape-compensation MPPT technique will be described below.
- [33] FIG. 1 is a circuit diagram of a generation control circuit in which two solar cells are connected in series. The generation control circuit is provided for solving a problem of a power-generation unbalanced state. FIG. 2 illustrates a switching sequence of switches SW1 and SW2 and reactor current waveform. Here, the switching sequence controls to alternately operate the switches SW1 and SW2, instead of turning off them at the same time.
- [34] Meanwhile, an off duty cycle of the switches SW1 and SW2 can be obtained by Equation 1 below.
- [35] (Equation 1)
- [36]

$$\overline{D_1} \cdot \overline{D_2}$$

[37] A relationship between the off duty cycle and an operating voltage of each solar cell can be expressed as Equations 2 to 6 below.

[38] (Equation 2)

[39]

$$\left\{ \begin{array}{l} V_1 = -L \frac{di_L}{dt} \\ V_2 = L \frac{di_L}{dt} \end{array} \right. \Rightarrow \left\{ \begin{array}{l} V_1 = -L \frac{\Delta i_L}{T_{2OFF}} \\ V_2 = L \frac{\Delta i_L}{T_{1OFF}} \end{array} \right.$$

[40] (Equation 3)

[41]

$$L\Delta i_L = V_1 T_{2OFF} = V_2 T_{1OFF}$$

[42] (Equation 4)

[43]

$$V_1 \frac{T_{2OFF}}{T_S} = V_2 \frac{T_{1OFF}}{T_S}$$

[44] (Equation 5)

[45]

$$\therefore V_1 \overline{D_2} = V_2 \overline{D_1}$$

[46] (Equation 6)

[47]

$$V_1 : V_2 = \overline{D_1} : \overline{D_2}$$

[48] It can be seen from Equations 2 to 6 that a ratio (V1:V2) of the operating voltage in each solar cell can be freely set by changing the off duty cycle of each switch.

[49] Unlike the conventional method, when a low solar radiation is detected in a state that the MPPT control is not performed, an auxiliary power source configured with a switch and a capacitor is operated. A large-capacity super capacitor or a small-capacity battery can be used as the capacitor of the auxiliary power source. By charging as an input voltage using the voltage charged in the capacitor or the battery, an insufficient voltage is supplemented for a predetermined time, such that a temporary power generation is possible.

[50] At this point, after a reference voltage Vref is set as a lowest operating voltage of the MPPT control range and is increased, an output voltage V(k) is detected. When the output voltage V(k) is greater than the reference voltage Vref, the switches of the auxiliary power source do not operate. Instead, when the output voltage V(k) decreases

due to an amount of the solar radiation or a change of load after the reference voltage V_{ref} increases to the maximum, the reference voltage V_{ref} is reduced.

[51] In other words, the power $P(k)$ and $P(k-1)$ detected by the algorithm are compared with each other. If the two powers are identical to each other, the MPPT is not executed. When two powers are different, the power is reduced while following an array voltage, and an operation of reducing the reference voltage is executed. During this process, the reference voltage is maintained for a predetermined time, but the meaning of the increase/decrease value of the reference voltage V_{ref} is different, although it is similar to the conventional P&O MPPT.

[52] FIG. 3 is a flowchart illustrating a method for compensating for a partial shade in a photovoltaic power system according to an embodiment of the present invention.

[53] FIG. 4 is a circuit diagram of a power point control circuit using PSIM according to an embodiment of the present invention. In FIG. 4, `ms_user6.dll` is a solar cell model to which a characteristic of a solar cell is applied, `ms_user7.dll` is applied for making an environment where solar radiation varied with time, and `ms_user8.dll` is an algorithm program.

[54] FIG. 5 is a current waveform of an inductor and each part in the power point control circuit according to an embodiment of the present invention. It can be seen that characteristic identical to ideal waveform is obtained.

[55] FIG. 6 is a circuit diagram of a photovoltaic power system to which a method for compensating for a partial shade is applied. In FIG. 6, there is shown a circuit for applying an improved IncCon control method.

[56] FIG. 7 is an operation waveform of each part in a rapid change of a solar radiation in a photovoltaic power system according to an embodiment of the present invention. Compared with the conventional control method, an error in a fast following speed, an actual power and a generated power is reduced.

[57] FIG. 8 is a test circuit of the photovoltaic power system according to an embodiment of the present invention. A solar cell used in the test is GMG01531, a characteristic of the solar cell is a rated maximum output of 53 W, an open circuit voltage of 21.7 V, a short circuit voltage of 3.25 V, a maximum operating voltage of 17.4 V, and a maximum operating current of 3.05 A.

[58] FIG. 9 is a graph illustrating an output characteristic before and after a control of each solar cell in a photovoltaic power system according to an embodiment of the present invention. Due to a partial shade at PV2 before the control, a current flows through bypass diode, causing the power generation to be reduced. However, due to the power point control operation, the amounts of power generation PV1 and PV2 are identical to each other.

[59] In order to solve the problem of the conventional MPPT control algorithm in that

power generation is impossible at a low solar radiation and a response speed is slow at a rapid change of solar radiation, an improved MPPT control algorithm is proposed. This method is implemented with a simple structure. A low solar radiation is detected and the switches of the auxiliary power source connected to the output terminal of the solar cell is operated. In this manner, an insufficient power is temporarily supplied, thereby maintaining a constant voltage and preventing a temporary shutdown of the system.

[60] Also, in order to solve a problem in that an output of an entire array is greatly lowered when a partial shade occurs in the serial/parallel connection of the system, a maximum power point is obtained by connecting multi-stage choppers in parallel. Therefore, it is possible to compensate for the partial shade and obtaining constant output by controlling maximum power point even when the partial shade occurs.

[61] It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention. Thus, it is intended that the present invention covers the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

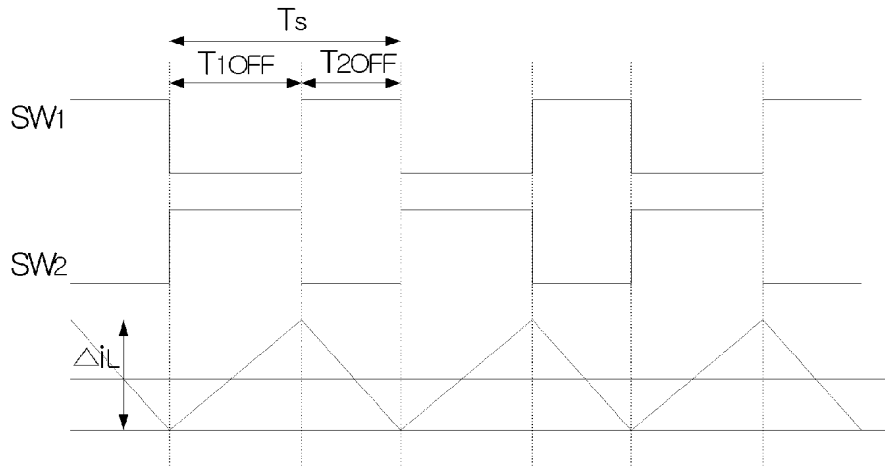
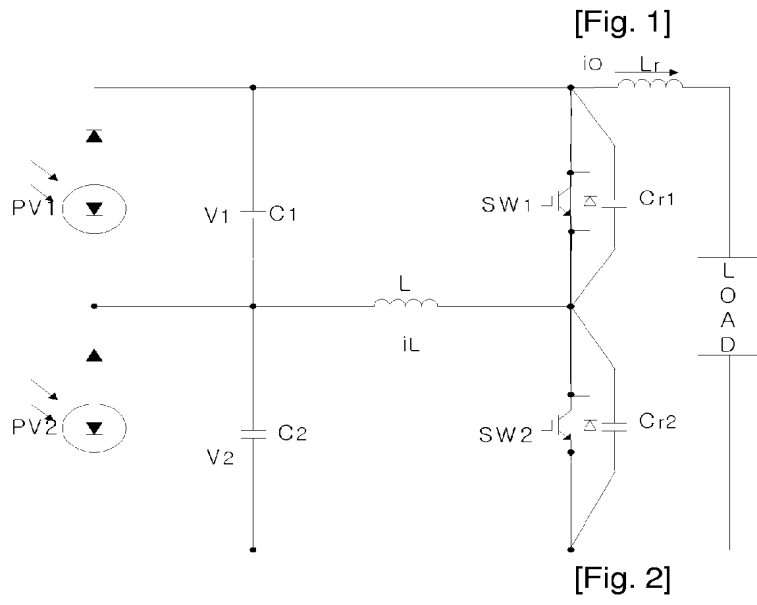
[62]

Industrial Applicability

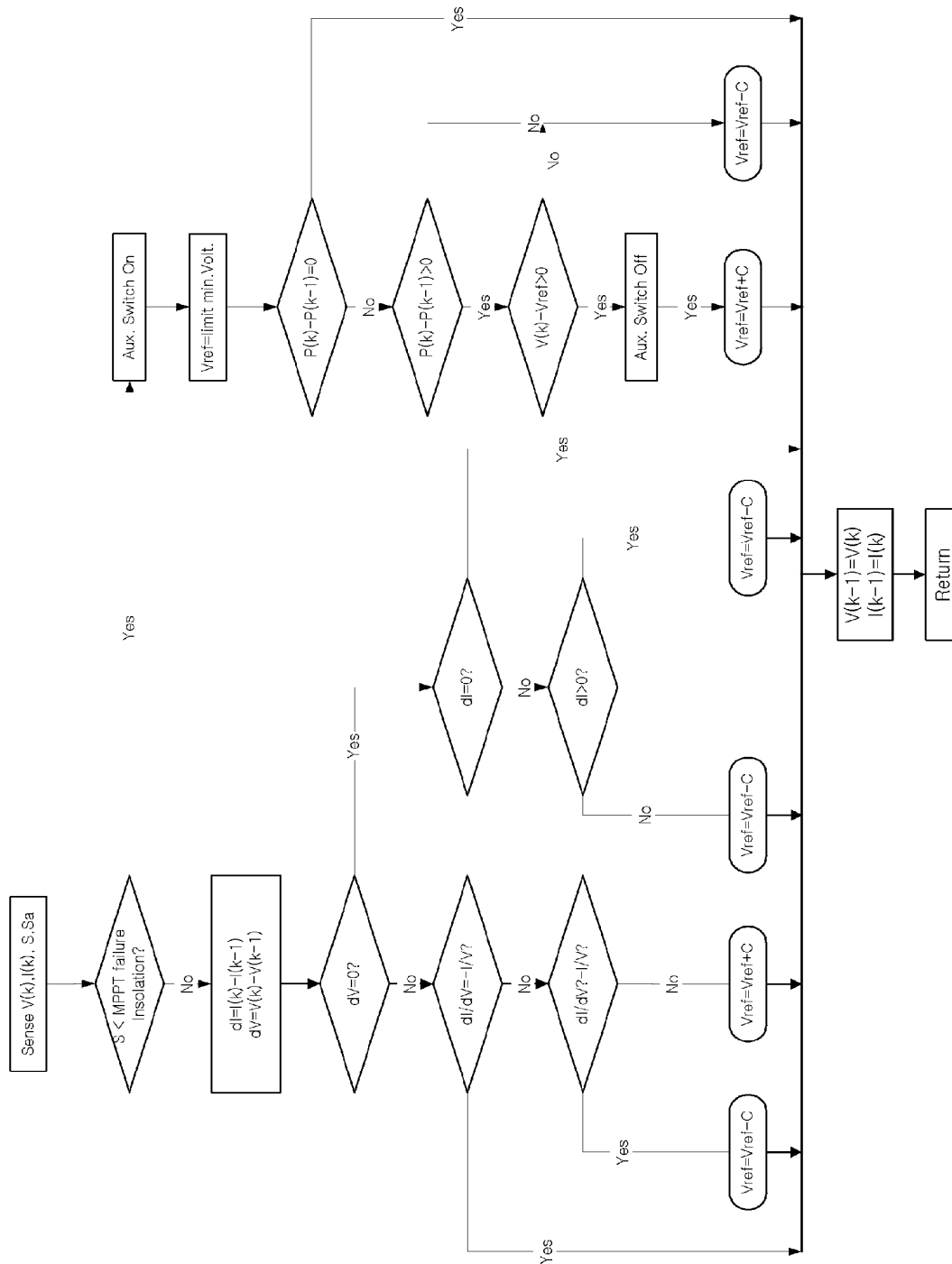
[63] In the method for compensating for the partial shade in the photovoltaic power system, multi-stage choppers are applied to every solar cell module, and maximum power is always supplied at the serial-connected array by controlling power generation of the serial-connection array of each module. A maximum power point is obtained by connecting multi-stage choppers in parallel. Therefore, it is possible to compensate for the partial shade and obtaining constant output by controlling maximum power point even when the partial shade occurs.

Claims

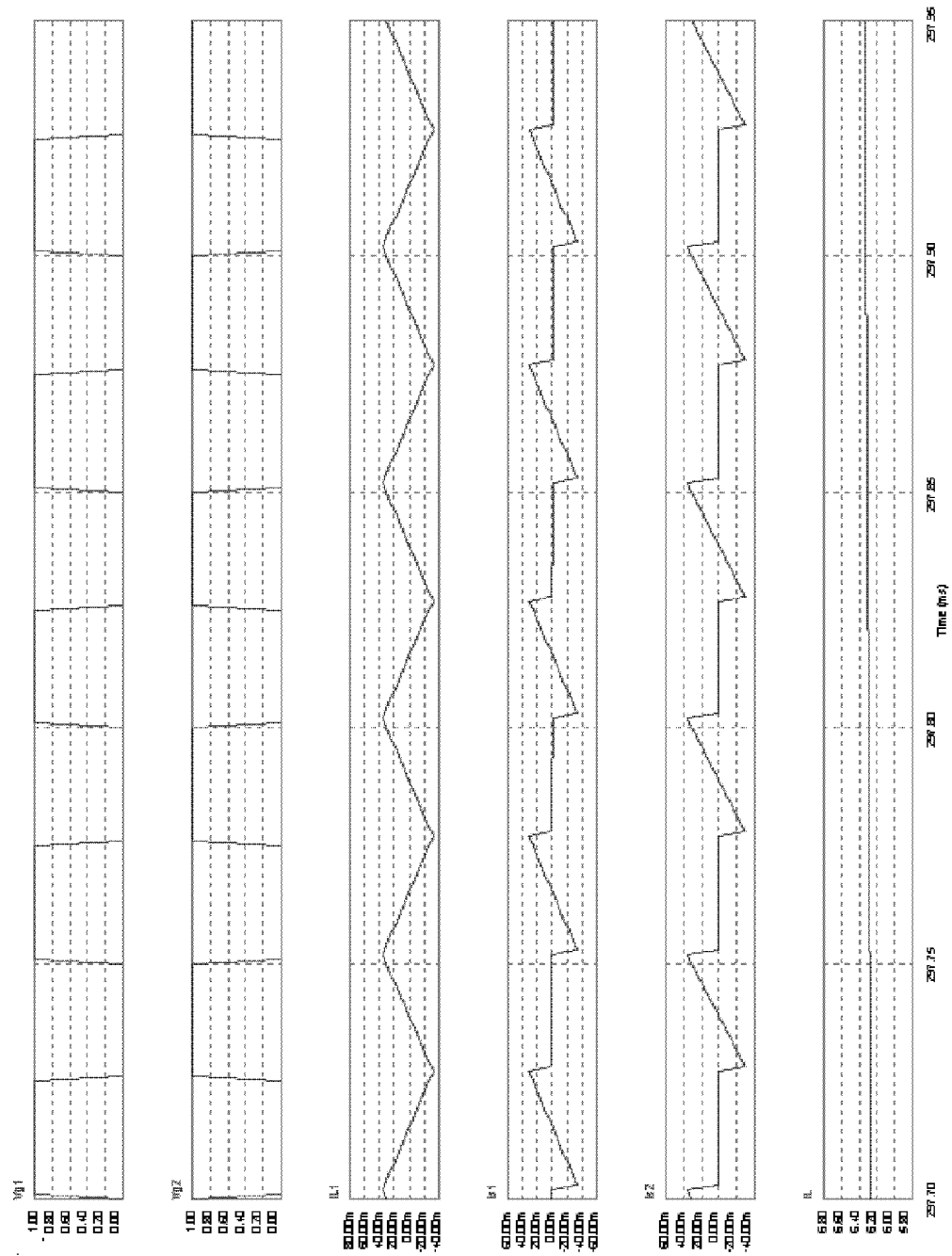
- [1] A method for compensating for partial shade using a photovoltaic power system, in which a plurality of serial-connected arrays of solar cell modules are connected in parallel, the arrays are connected to a converter, and a final power is outputted from the converter, the method comprising the steps of:
connecting an auxiliary power source to each solar cell module;
if a low solar radiation is detected by an MPPT controller, supplying a necessary power through the auxiliary power source at a time, thereby maintaining constant voltage and preventing a temporarily shutdown;
connecting in parallel the solar cell modules of the serial-connected arrays in multi-stages; and
varying an operating voltage ratio of the solar cell module by controlling an off duty cycle of each chopper at the MPPT controller, thereby generating maximum output from the serial-connected array of each solar cell module.
- [2] The method of claim 1, wherein the auxiliary power source includes:
a switch for performing a switching operation according to a control of the MPPT controller; and
a capacitor or small-capacity battery for discharging charged voltage according to the switching of the switch.
- [3] The method of claim 1, wherein the MPPT controller sets a reference voltage (V_{ref}) as a lowest operating voltage of an MPPT control range of the serial-connected array, increases the reference voltage (V_{ref}) and detects an output voltage ($V(k)$) of the serial-connected array,
if the output voltage ($V(k)$) is greater than the reference voltage, the MPPT controller does not operate the switch, and
if the output voltage ($V(k)$) decreases due to an amount of the solar radiation or a change of load after the reference voltage (V_{ref}) increases to the maximum, the MPPT controller decreases the reference voltage (V_{ref}).
- [4] The method of claim 1, wherein the MPPT controller alternately switches each chopper.



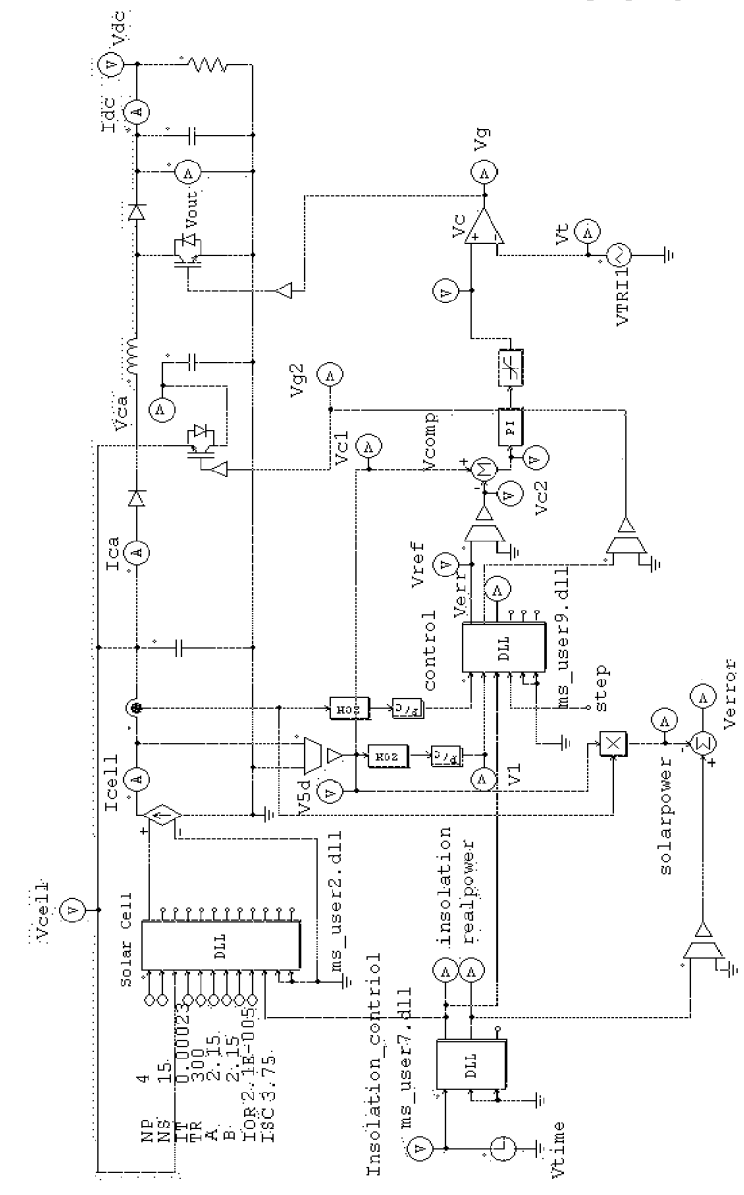
[Fig. 4]



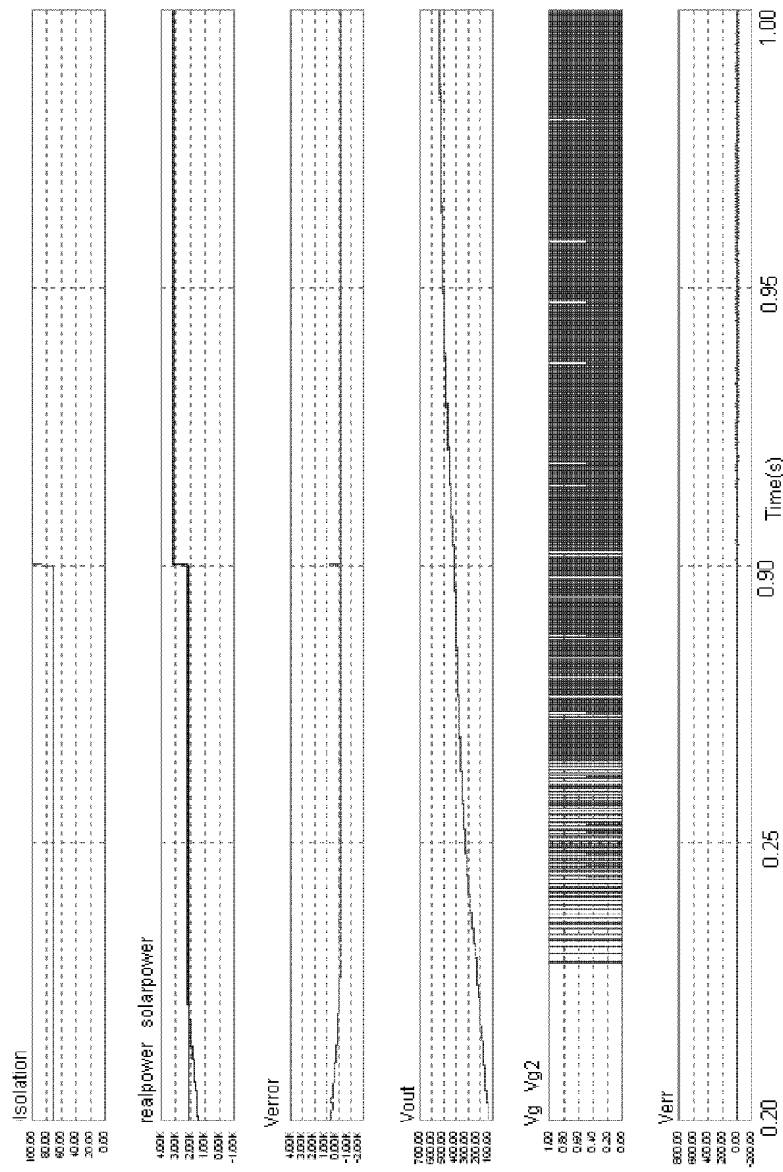
[Fig. 5]



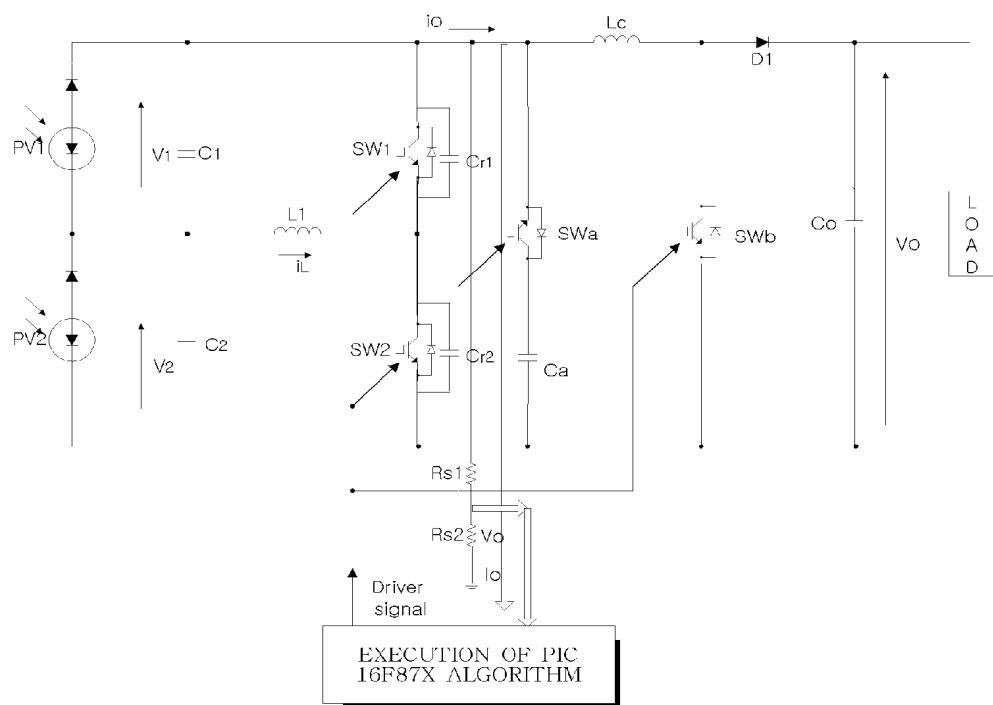
[Fig. 6]



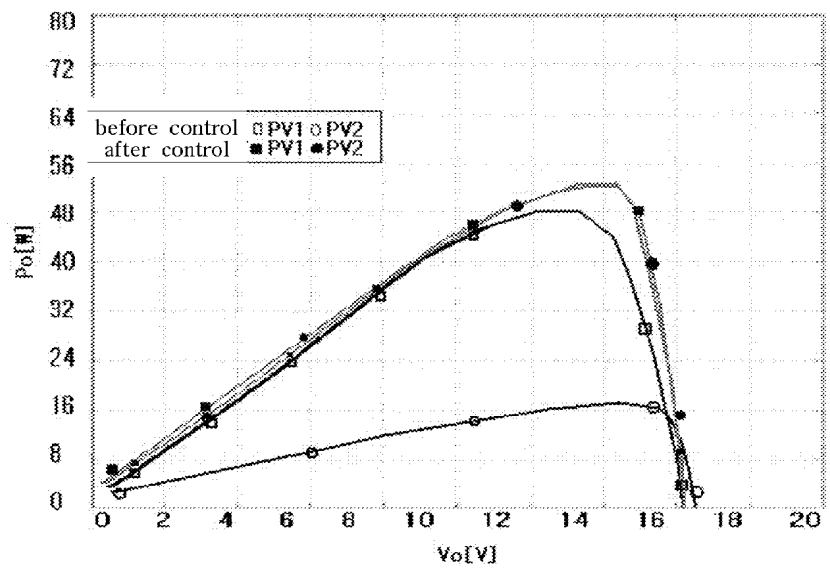
[Fig. 7]



[Fig. 8]



[Fig. 9]



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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	108144-200701/US (TGY010)
		Application Number	
Title of Invention	Systems and Methods to Balance Solar Panels in a Multi-Panel System		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Applicant Information:

Applicant 1						Remove	
Applicant Authority		☒ Inventor		☐ Legal Representative under 35 U.S.C. 117		☐ Party of Interest under 35 U.S.C. 118	
Prefix	Given Name	Middle Name		Family Name		Suffix	
	Ron			HADAR			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service							
City	Cupertino	State/Province	CA	Country of Residenceⁱ		US	
Citizenship under 37 CFR 1.41(b)ⁱ		IL					
Mailing Address of Applicant:							
Address 1		10337 Tula Lane					
Address 2							
City	Cupertino	State/Province		CA			
Postal Code		95014		Countryⁱ	US		
Applicant 2						Remove	
Applicant Authority		☒ Inventor		☐ Legal Representative under 35 U.S.C. 117		☐ Party of Interest under 35 U.S.C. 118	
Prefix	Given Name	Middle Name		Family Name		Suffix	
	Shmuel			ARDITI			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service							
City	Los Gatos	State/Province	CA	Country of Residenceⁱ		US	
Citizenship under 37 CFR 1.41(b)ⁱ		US					
Mailing Address of Applicant:							
Address 1		104 Las Uvas					
Address 2							
City	Los Gatos	State/Province		CA			
Postal Code		95032		Countryⁱ	US		
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button. Add							

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ An Address is being provided for the correspondence Information of this application.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	108144-200701/US (TGY010)	
		Application Number		
Title of Invention	Systems and Methods to Balance Solar Panels in a Multi-Panel System			
Customer Number	64494			
Email Address	wangl@gtlaw.com	Add Email	Remove Email	
Email Address	svip@gtlaw.com	Add Email	Remove Email	

Application Information:

Title of the Invention	Systems and Methods to Balance Solar Panels in a Multi-Panel System		
Attorney Docket Number	108144-200701/US (TGY010)	Small Entity Status Claimed	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)		Suggested Figure for Publication (if any)	

Publication Information:

☐	Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐	Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Enter either Customer Number or complete the Representative Name section below. If both sections are completed the Customer Number will be used for the Representative Information during processing.			
Please Select One:	☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number	64494		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78(a)(2) or CFR 1.78(a)(4), and need not otherwise be made part of the specification.			
Prior Application Status	Pending	Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	non provisional of	61200601	2008-12-02
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.			Add

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	108144-200701/US (TGY010)
		Application Number	
Title of Invention	Systems and Methods to Balance Solar Panels in a Multi-Panel System		

Foreign Priority Information:

This section allows for the applicant to claim benefit of foreign priority and to identify any prior foreign application for which priority is not claimed. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(a).			
			Remove
Application Number	Country ⁱ	Parent Filing Date (YYYY-MM-DD)	Priority Claimed
			☒ Yes ☐ No
Additional Foreign Priority Data may be generated within this form by selecting the Add button.			Add

Assignee Information:

Providing this information in the application data sheet does not substitute for compliance with any requirement of part 3 of Title 37 of the CFR to have an assignment recorded in the Office.			
			Remove
Assignee 1			
If the Assignee is an Organization check here. ☒			
Organization Name	Tigo Energy, Inc.		
Mailing Address Information:			
Address 1	170 Knowles Drive		
Address 2	Suite 203		
City	Los Gatos	State/Province	CA
Country ⁱ	US	Postal Code	95032
Phone Number		Fax Number	
Email Address			
Additional Assignee Data may be generated within this form by selecting the Add button.			Add

Signature:

A signature of the applicant or representative is required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature.					
Signature	/LEHUA WANG/			Date (YYYY-MM-DD)	2009-03-25
First Name	Lehua	Last Name	Wang	Registration Number	48023

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Filing Date: 03/25/09

Approved for use through 7/31/2006. OMB 0651-0032

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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number

12/411,317**APPLICATION AS FILED – PART I**

(Column 1)

(Column 2)

SMALL ENTITY

OR

OTHER THAN
SMALL ENTITY

FOR	NUMBER FILED	NUMBER EXTRA
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A
SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A
TOTAL CLAIMS (37 CFR 1.16(i))	20 minus 20 =	0
¹ (37 CFR 1.16(h))	2 minus 3 =	0
APPLICATION SIZE FEE (37 CFR 1.16(s))		
22-Aug		

RATE (\$)	FEE (\$)
N/A	82
N/A	270
N/A	110
X\$ 25	0
X\$100	0
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TOTAL	462

RATE (\$)	FEE (\$)
N/A	
N/A	
N/A	
X\$50	
X\$210	
370	
TOTAL	0

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II

(Column 1)

(Column 2)

(Column 3)

SMALL ENTITY

OR

OTHER THAN
SMALL ENTITY

AMENDMENT A		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
	Total (37 CFR 1.16(i))	*	Minus	**	=
	Independent (37 CFR 1.16(h))	*	Minus	***	=
	Application Size Fee (37 CFR 1.16(s))				
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))				

RATE (\$)	ADDI- TIONAL FEE (\$)
X =	
X =	
N/A	
TOTAL ADD'T FEE	

RATE (\$)	ADDI- TIONAL FEE (\$)
X =	
X =	
N/A	
TOTAL ADD'T FEE	

(Column 1)

(Column 2)

(Column 3)

OR

AMENDMENT B		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
	Total (37 CFR 1.16(i))	*	Minus	**	=
	Independent (37 CFR 1.16(h))	*	Minus	***	=
	Application Size Fee (37 CFR 1.16(s))				
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))				

RATE (\$)	ADDI- TIONAL FEE (\$)
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X =	
N/A	
TOTAL ADD'T FEE	

RATE (\$)	ADDI- TIONAL FEE (\$)
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X =	
N/A	
TOTAL ADD'T FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

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