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(54) PHOTOVOLTAIC AC INVERTER MOUNT AND INTERCONNECT

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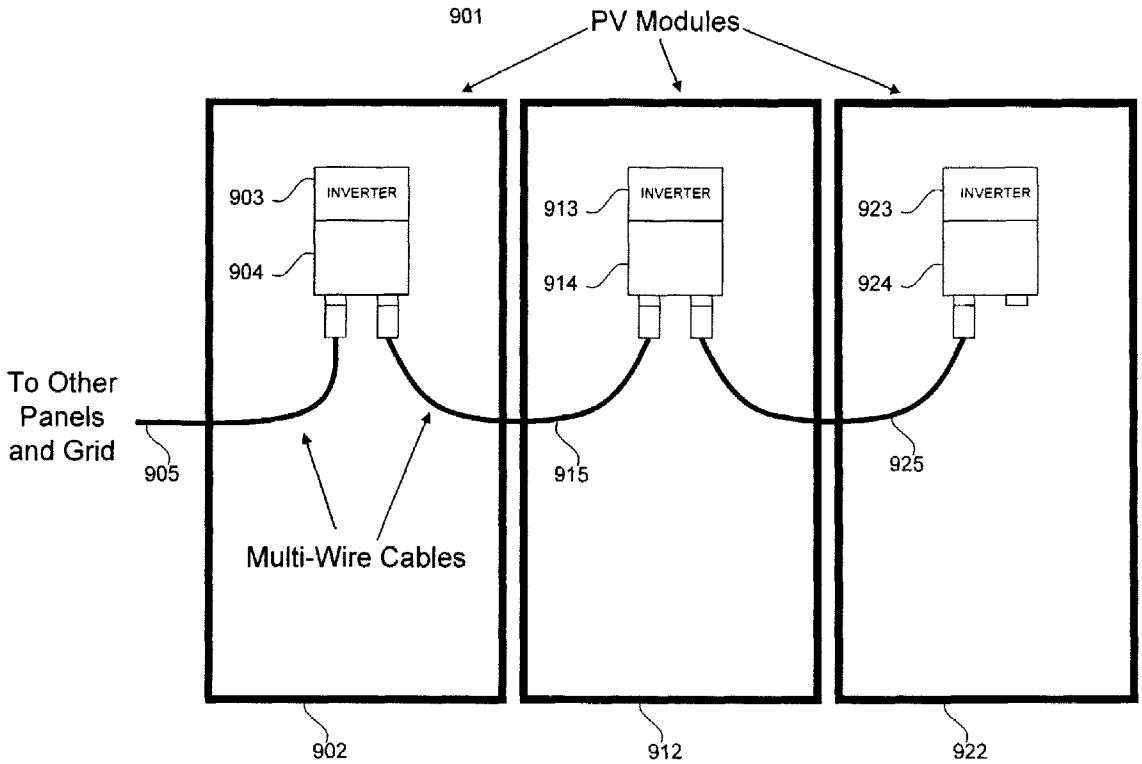
(52) **U.S. Cl.** **136/251**

(57) **ABSTRACT**

A replaceable photovoltaic inverter is mounted on each of a plurality of photovoltaic module for the conversion of direct current, produced by the photovoltaic cells, to alternating current. The inverter is coupled to a mounting bracket on the photovoltaic module such that is can be easily replaced. Replacement of an individual photovoltaic module inverter can occur during continuous operation of the photovoltaic module system with minimal impact on overall power production. The inverter is also mounted apart from the photovoltaic module to facilitate heat transfer generated by operation of the inverter.



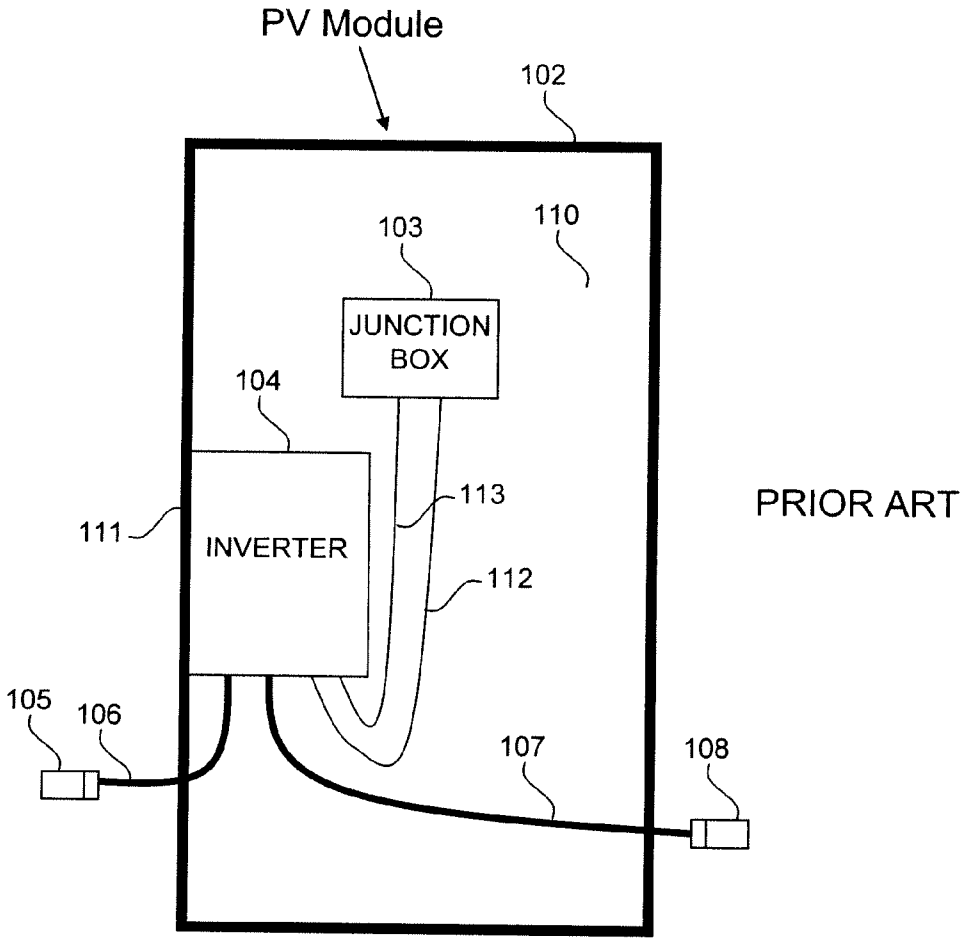

PV Module
102
103
110
JUNCTION BOX
104
113
111
INVERTER
112
PRIOR ART
105
106
107
108

FIG. 1

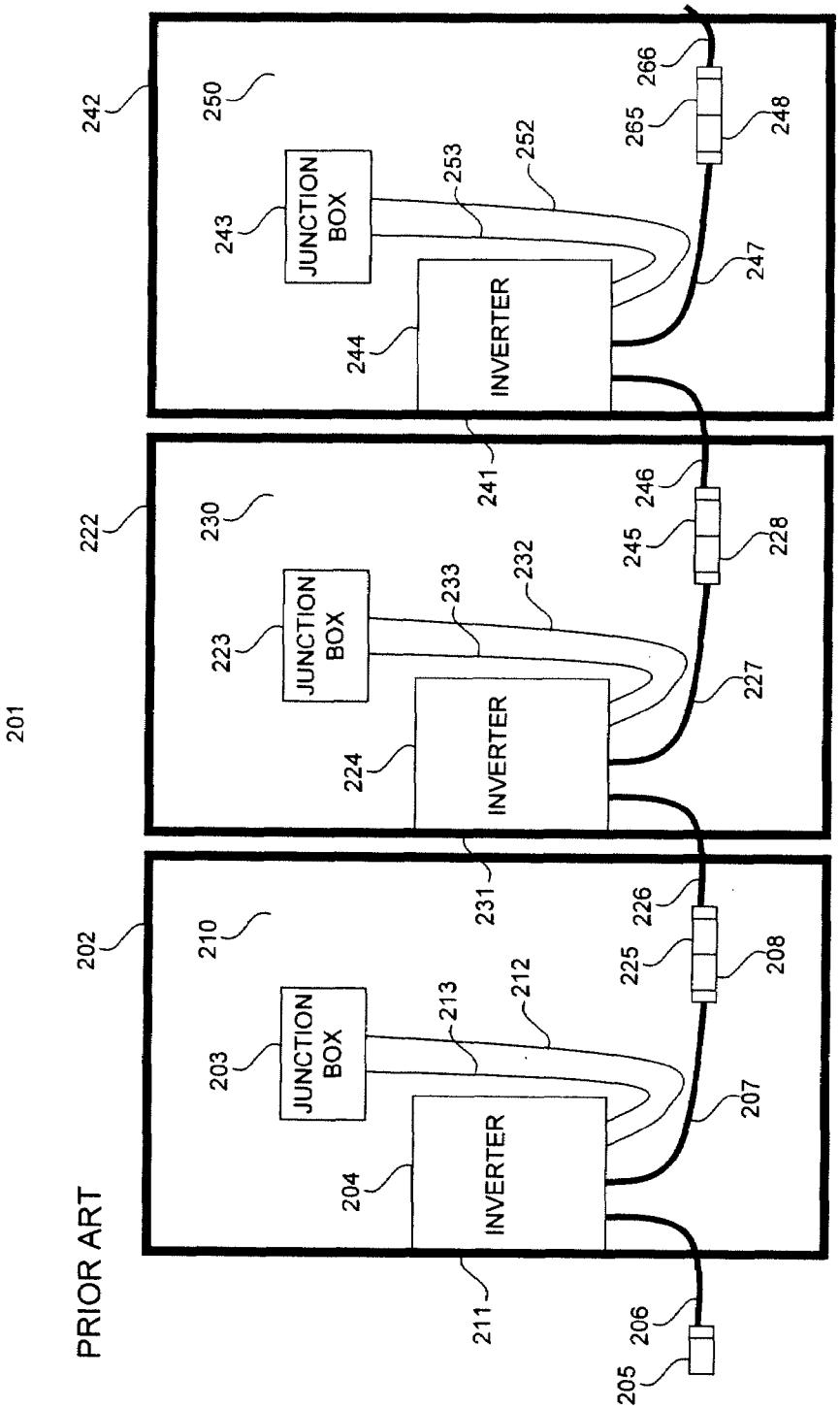

PRIOR ART
201
202
210
203
JUNCTION BOX
213
212
204
INVERTER
211
206
205
207
226
225
208
231
222
230
223
JUNCTION BOX
233
232
224
INVERTER
227
246
245
228
241
242
250
243
JUNCTION BOX
253
252
244
INVERTER
247
266
265
248

FIG. 2

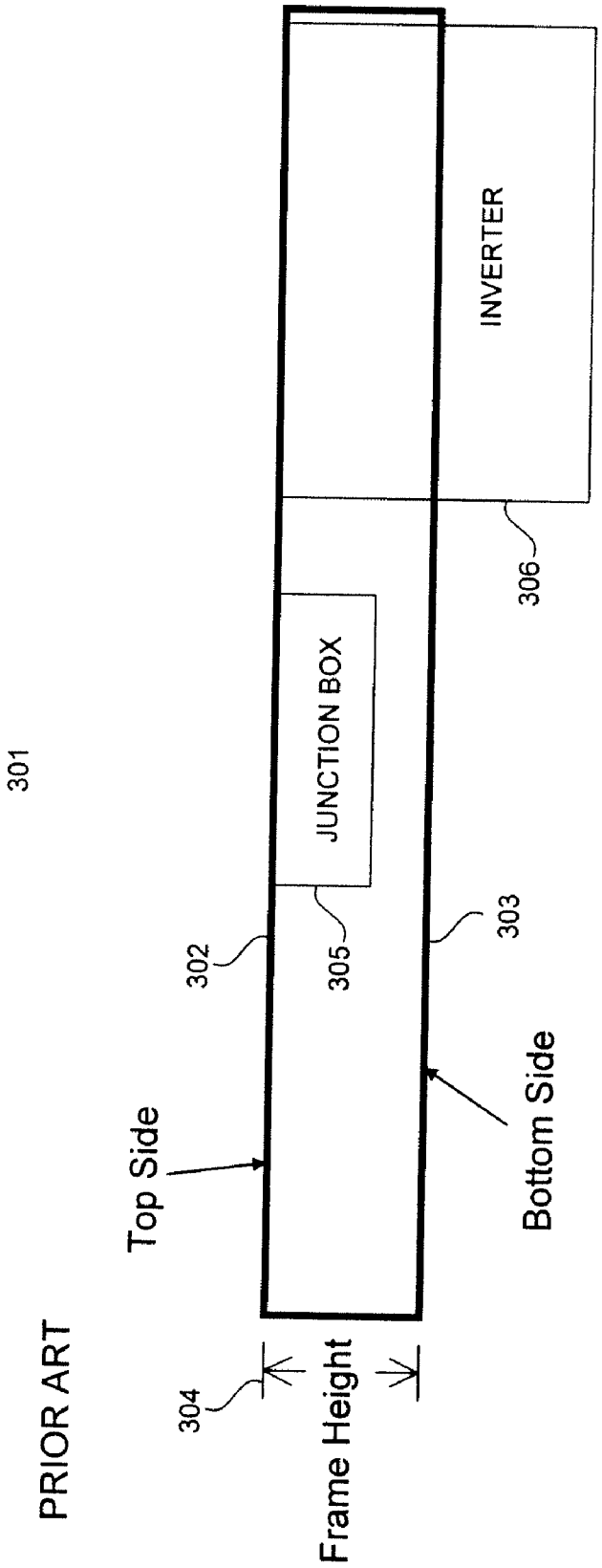

PRIOR ART
301
Top Side
302
304
Frame Height
305
JUNCTION BOX
303
Bottom Side
306
INVERTER

FIG. 3

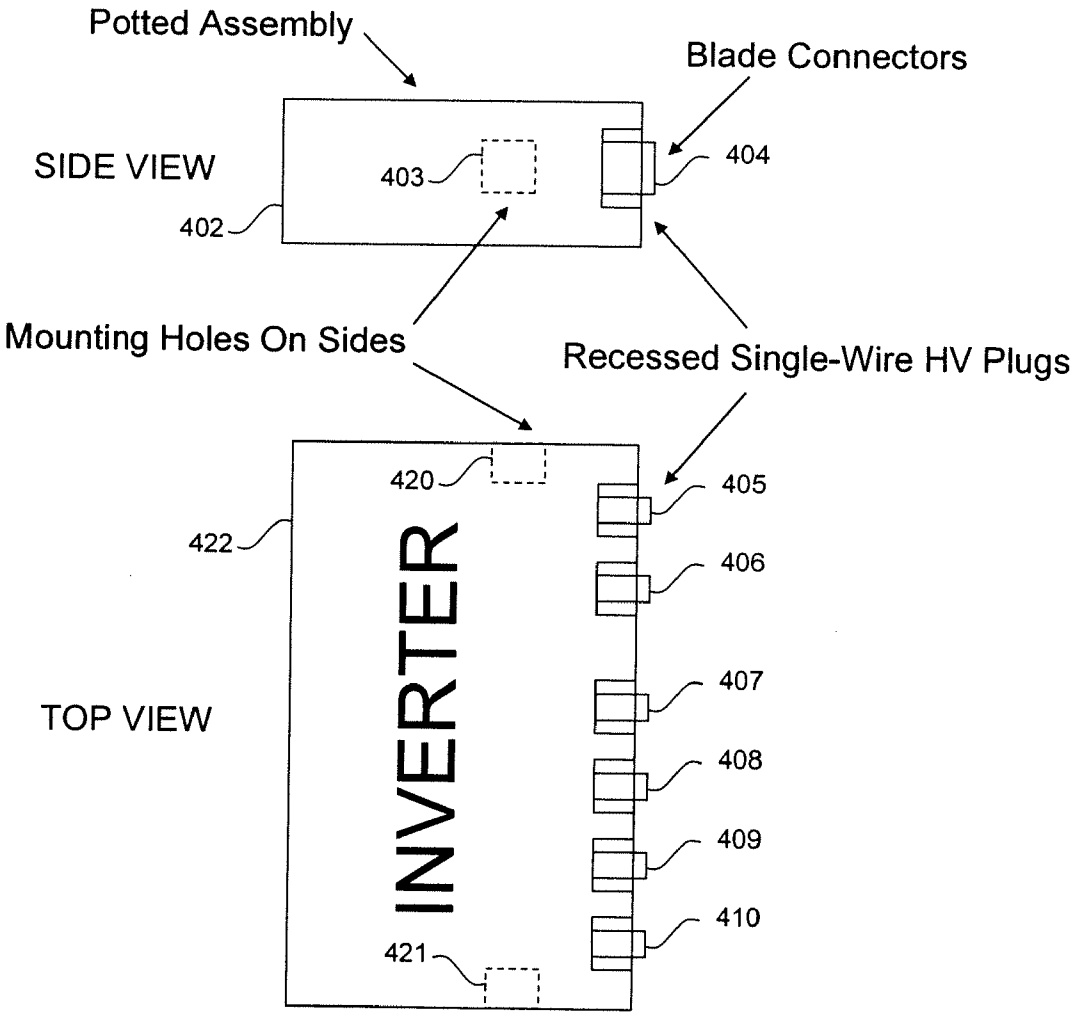

Potted Assembly
Blade Connectors
SIDE VIEW
403
404
402
Mounting Holes On Sides
Recessed Single-Wire HV Plugs
420
405
422
406
INVERTER
TOP VIEW
407
408
409
410
421

FIG. 4

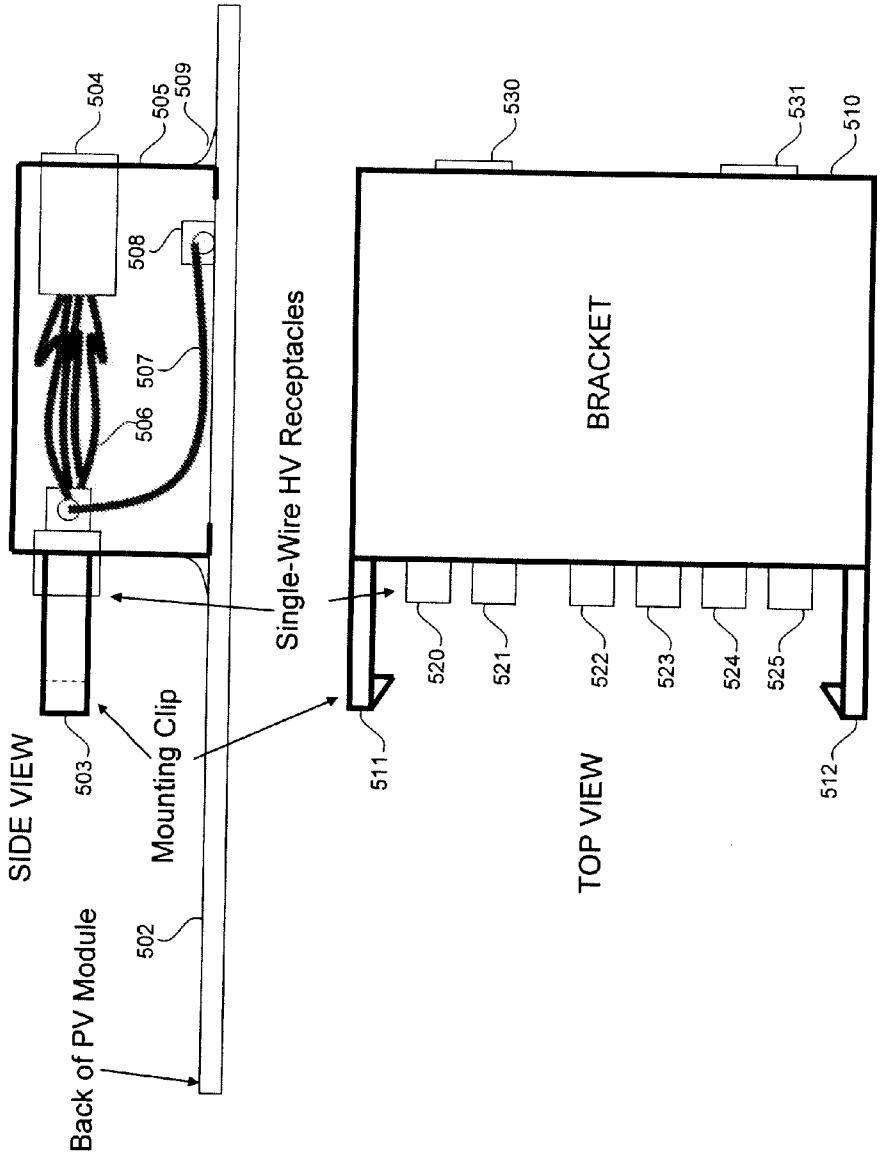

SIDE VIEW
Back of PV Module
502
503
Mounting Clip
504
505
506
507
508
509
Single-Wire HV Receptacles
TOP VIEW
BRACKET
510
511
512
520
521
522
523
524
525
530
531

FIG. 5

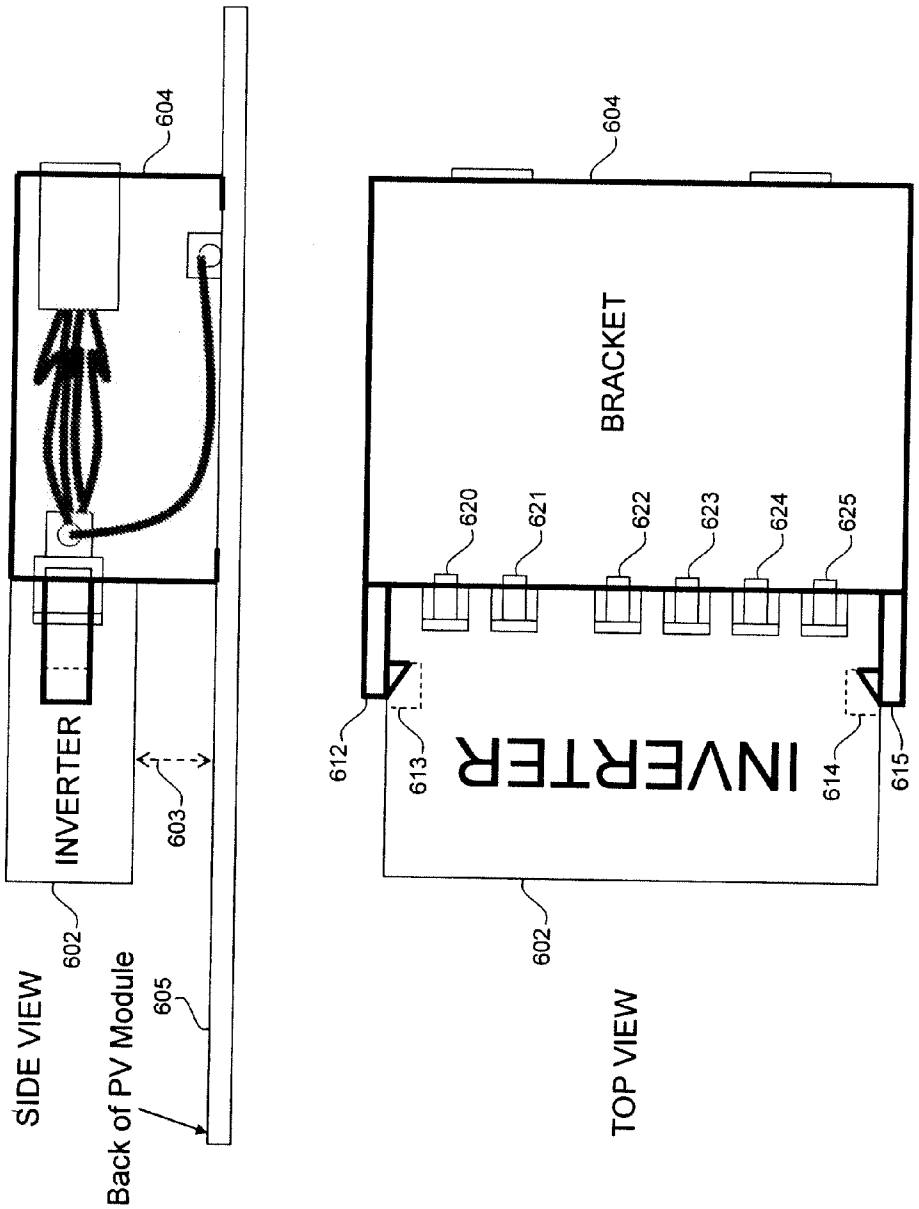

SIDE VIEW
INVERTER
602
603
604
605
Back of PV Module
TOP VIEW
INVERTER
BRACKET
602
604
612
613
614
615
620
621
622
623
624
625

FIG. 6

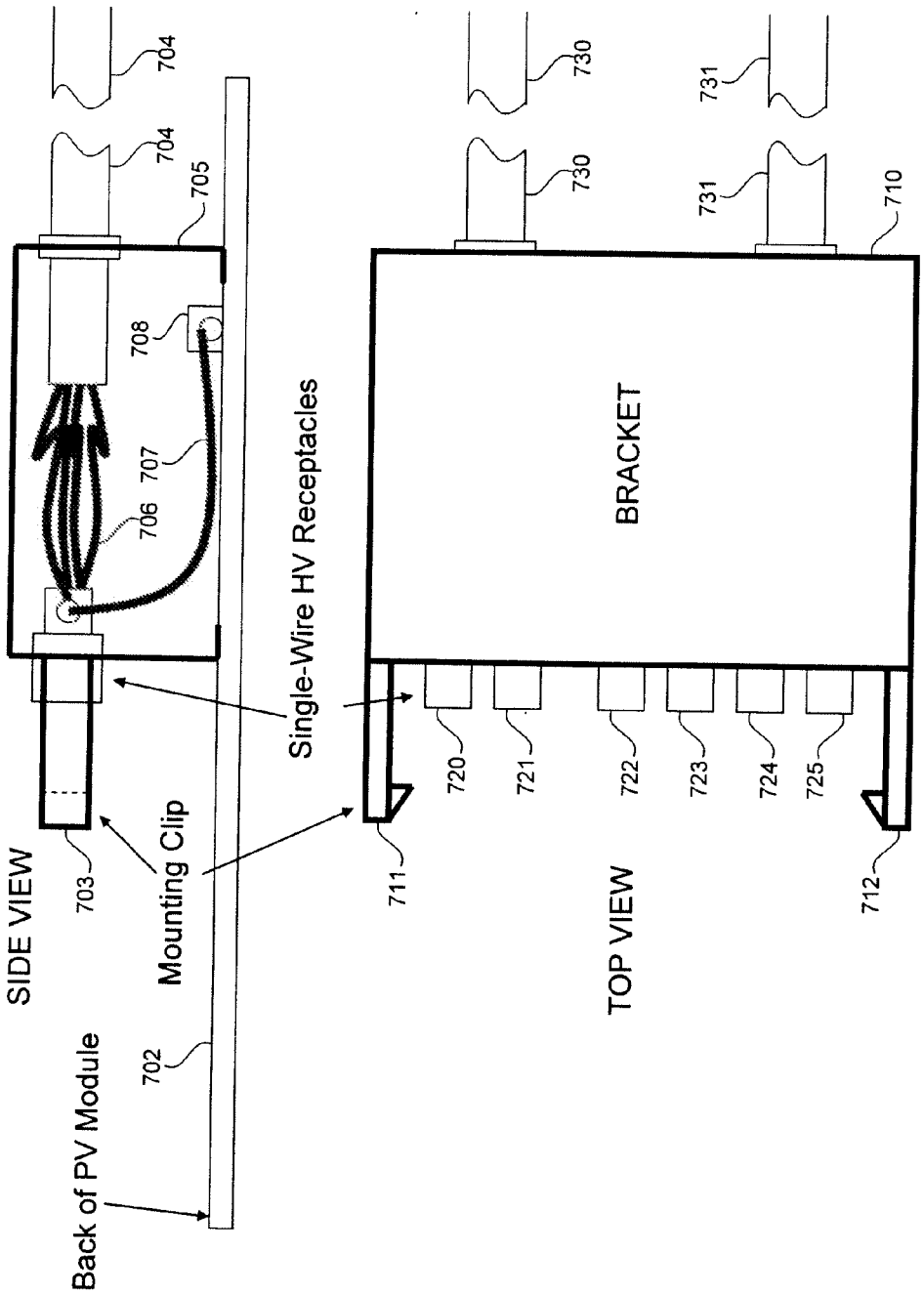

SIDE VIEW
Back of PV Module
Mounting Clip
Single-Wire HV Receptacles
TOP VIEW
BRACKET
702
703
704
704
705
706
707
708
710
711
712
720
721
722
723
724
725
730
730
731
731

FIG. 7

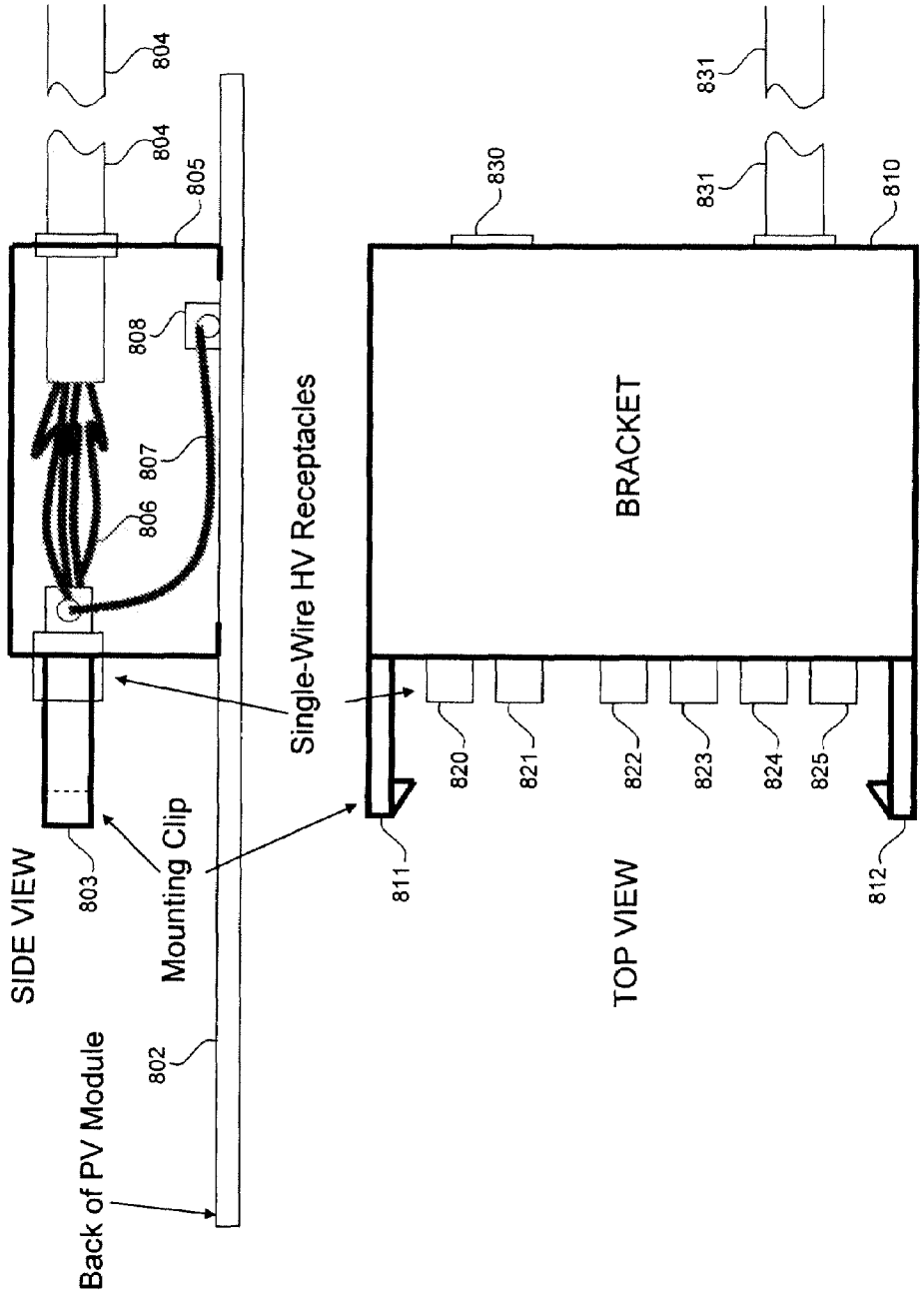

SIDE VIEW
Back of PV Module
802
803
Mounting Clip
806
807
808
805
804
804
Single-Wire HV Receptacles
TOP VIEW
BRACKET
811
812
820
821
822
823
824
825
830
831
831
810

FIG. 8

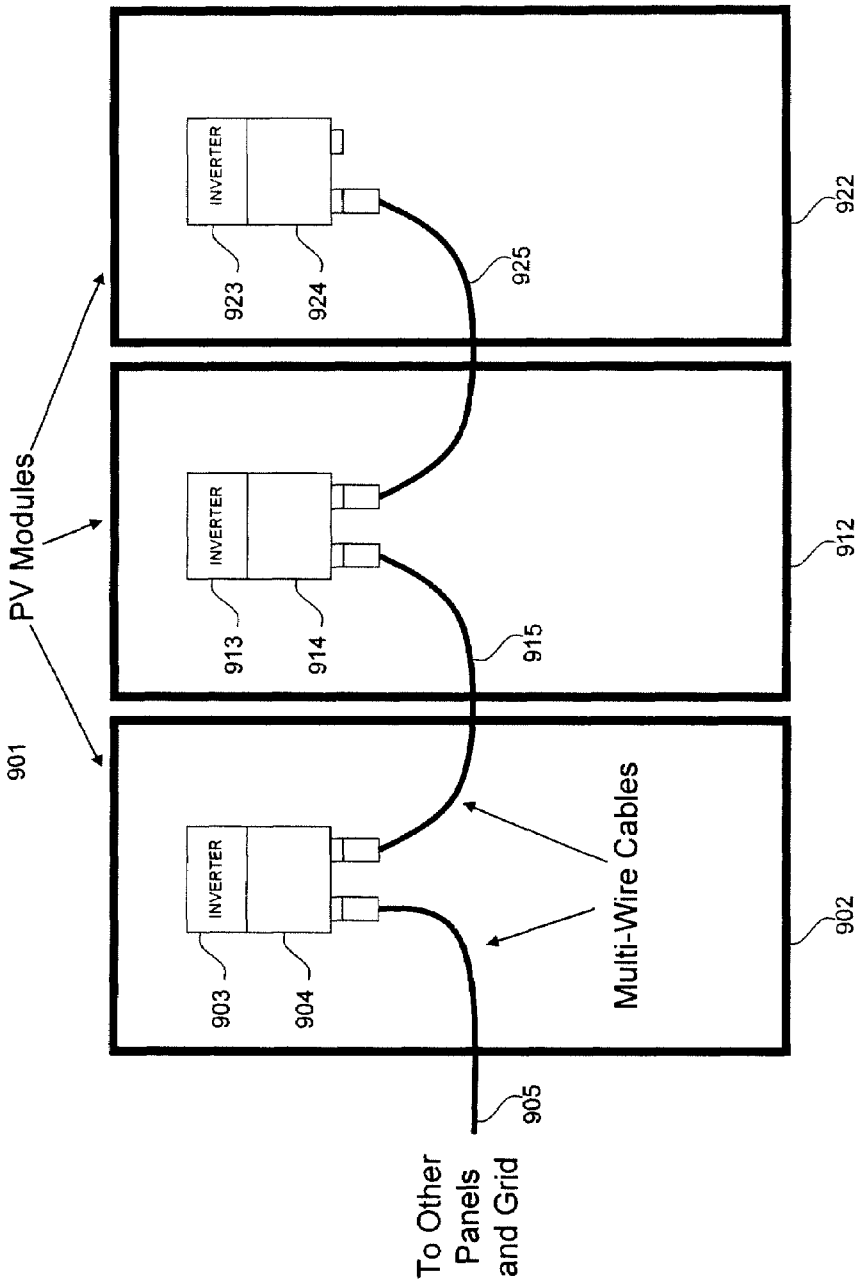

PV Modules
901
INVERTER
903
904
INVERTER
913
914
INVERTER
923
924
Multi-Wire Cables
915
925
902
912
922
905
To Other Panels and Grid

FIG. 9

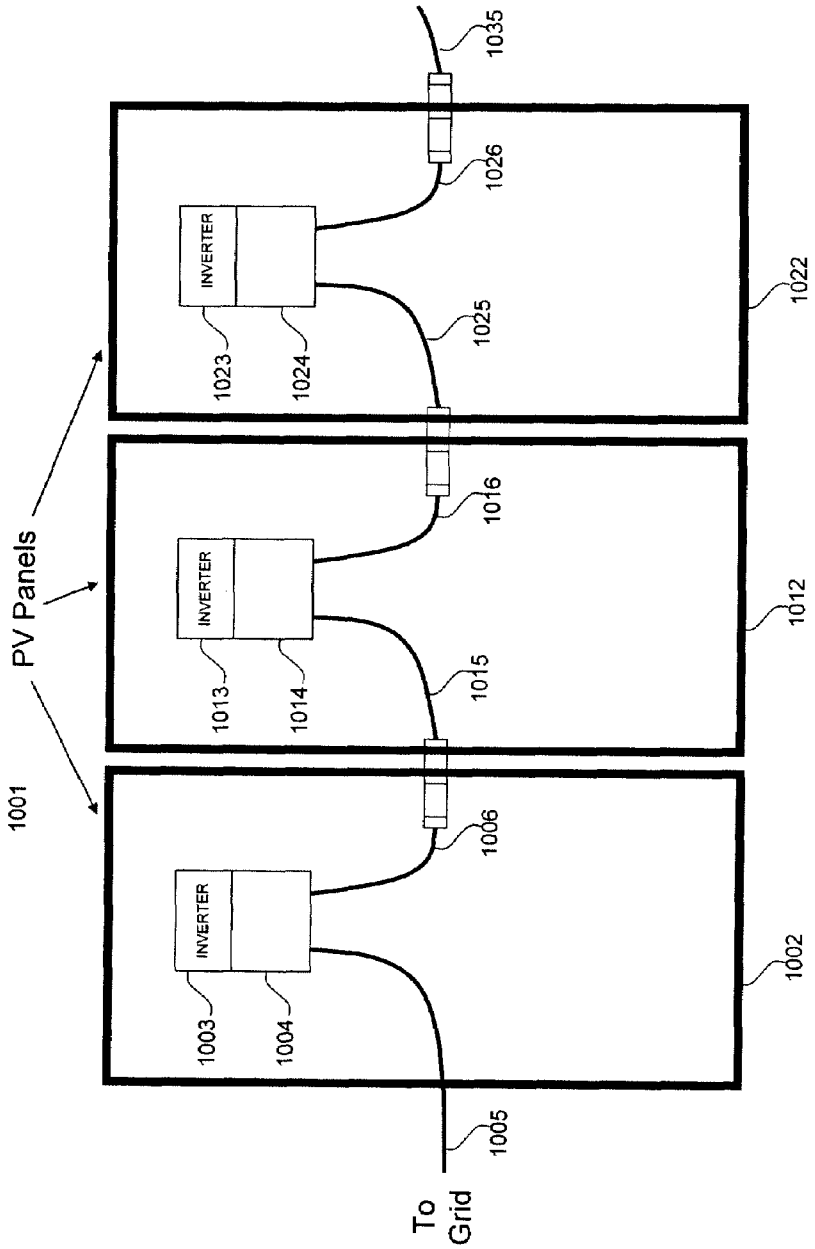

PV Panels
1001
INVERTER
1003
1004
1006
1002
INVERTER
1013
1014
1015
1016
1012
INVERTER
1023
1024
1025
1026
1022
1035
1005
To Grid

FIG. 10

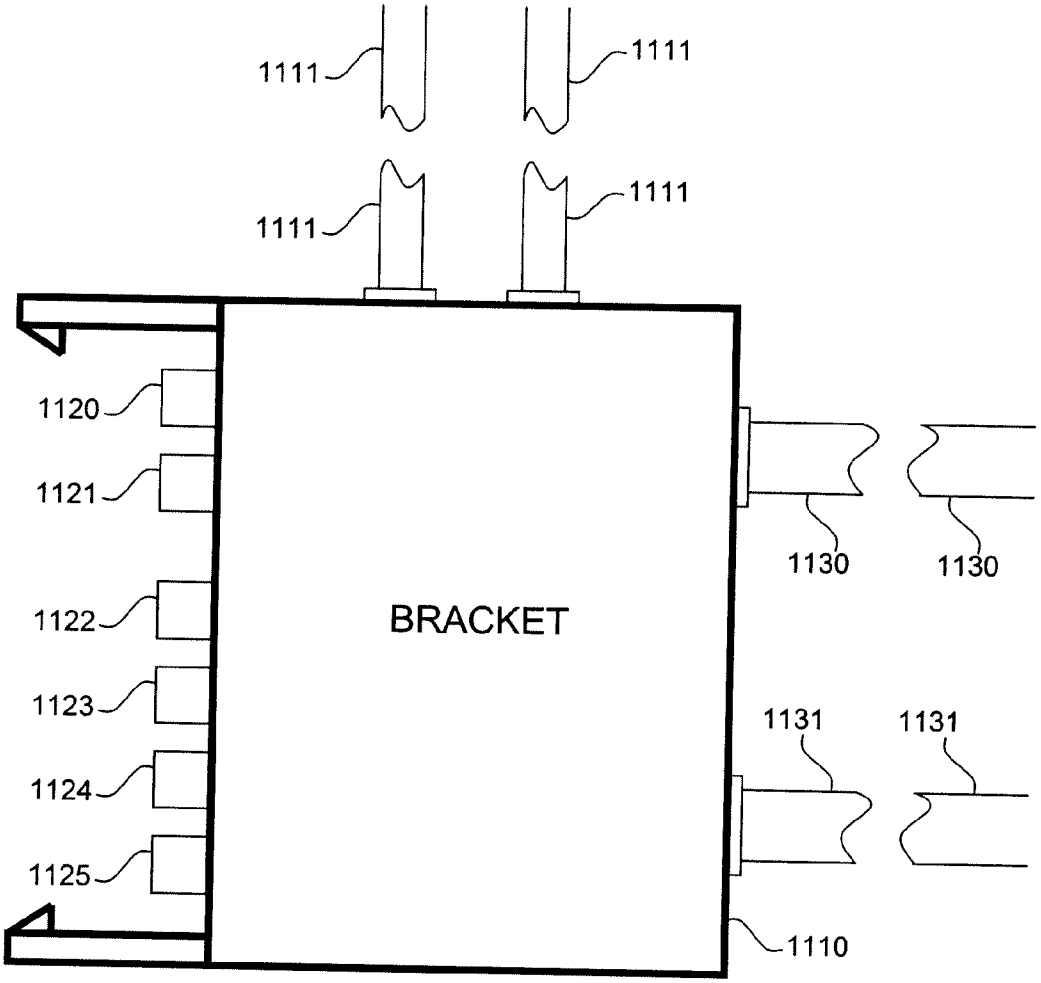

1111
1111
1111
1111
1120
1121
1122
1123
1124
1125
BRACKET
1130
1130
1131
1131
1110

FIG. 11

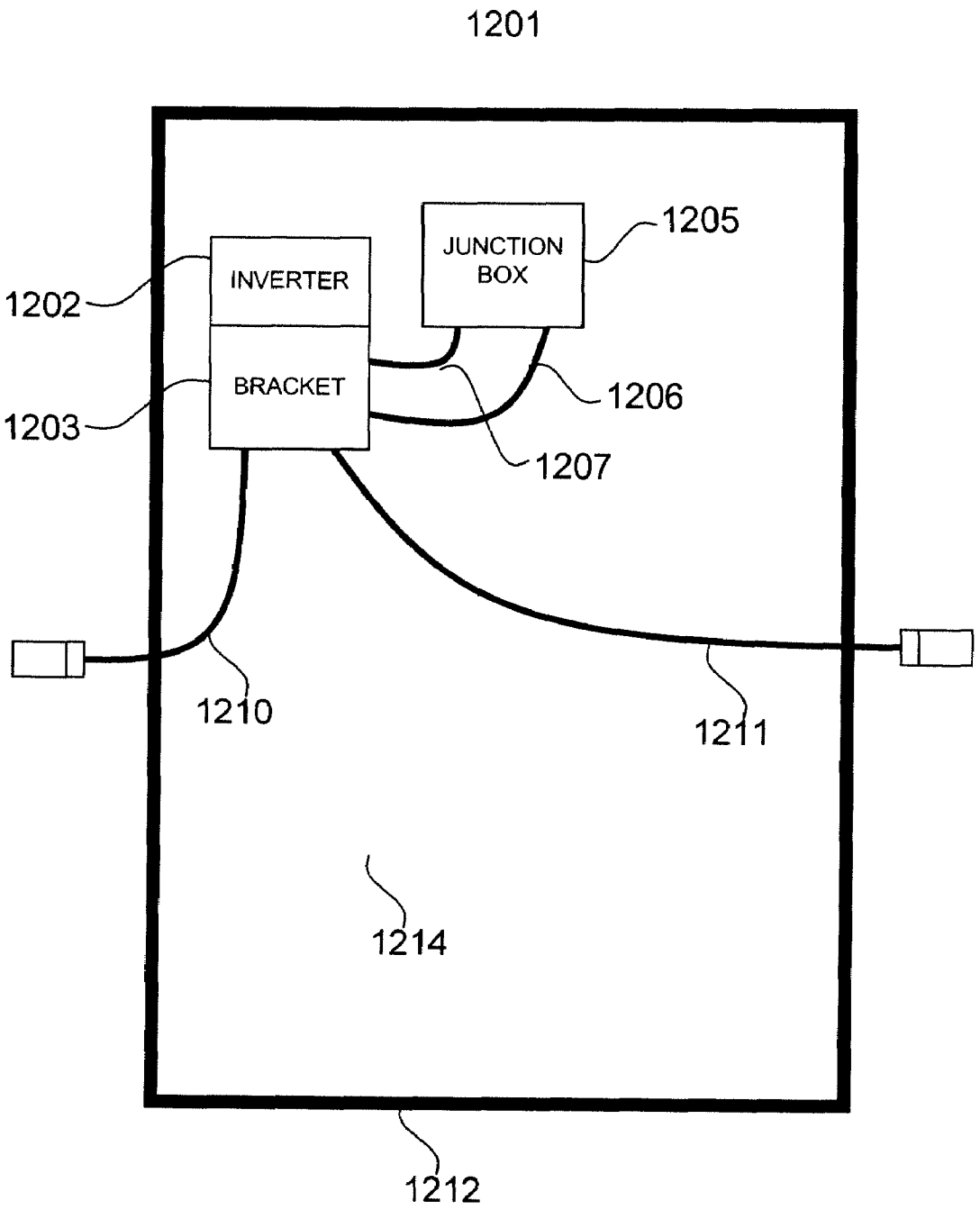

1201
INVERTER
JUNCTION BOX
BRACKET
1202
1203
1205
1206
1207
1210
1211
1214
1212

FIG. 12

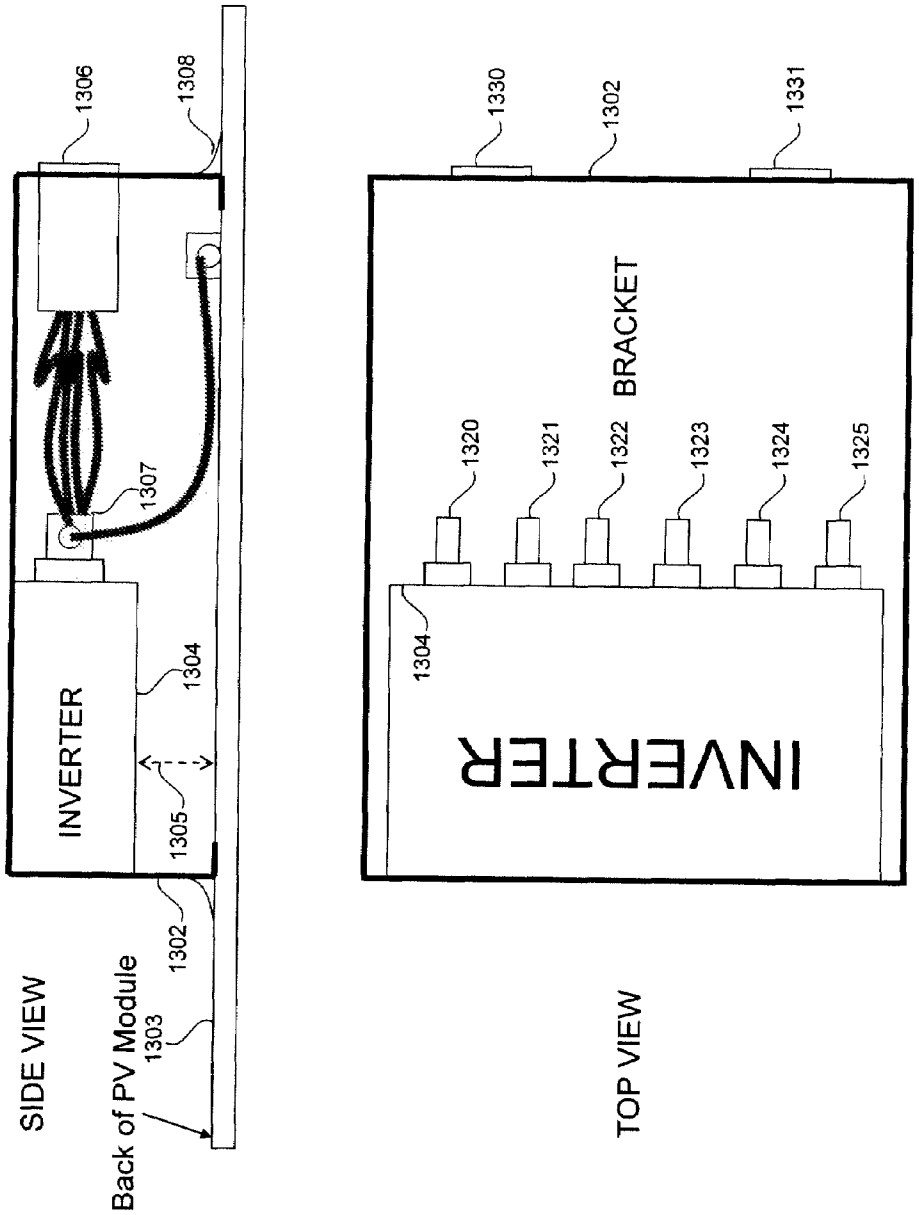

SIDE VIEW
INVERTER
1306
1308
1307
1304
1305
1302
1303
Back of PV Module
TOP VIEW
INVERTER
BRACKET
1330
1302
1331
1320
1321
1322
1323
1324
1325
1304

FIG. 13

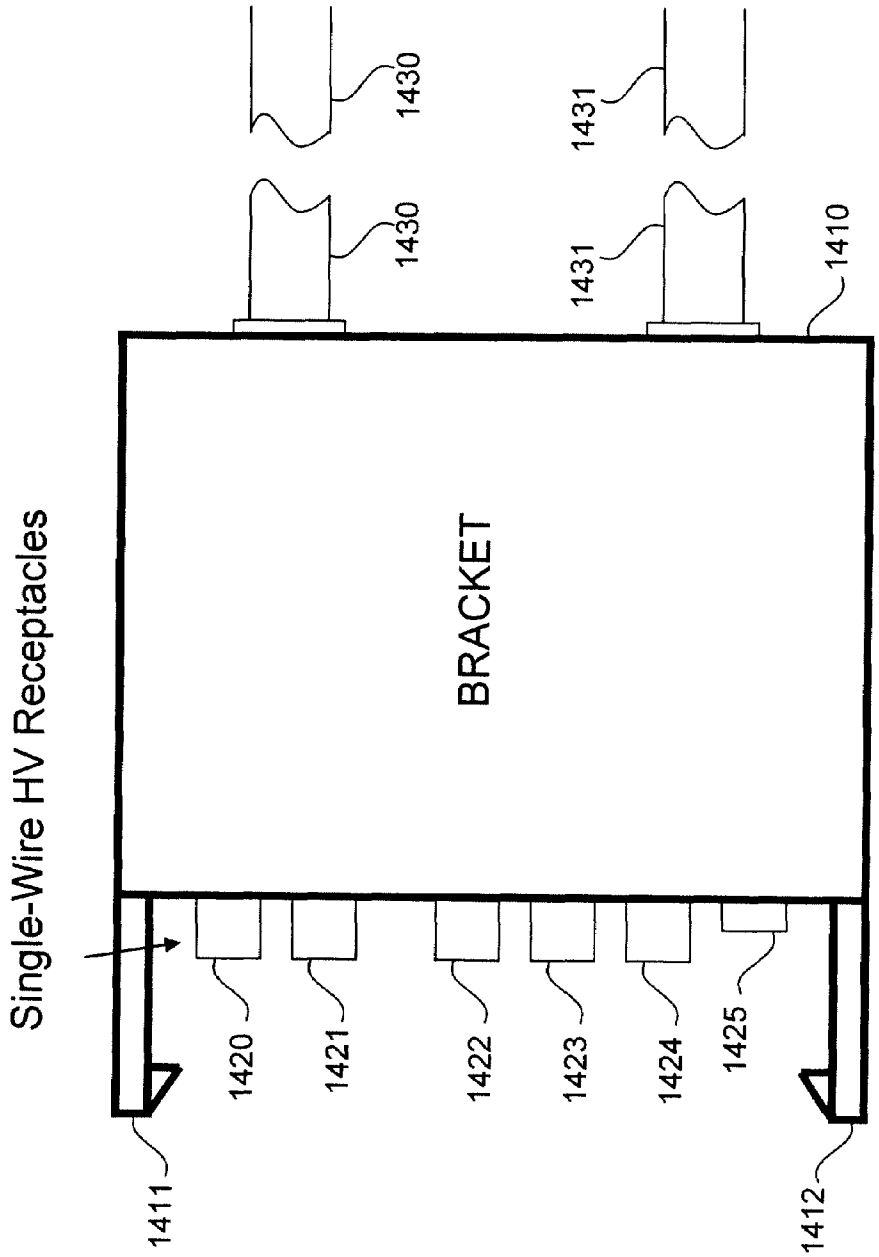

Single-Wire HV Receptacles
BRACKET
1411
1420
1421
1422
1423
1424
1425
1412
1430
1430
1431
1431
1410

FIG. 14

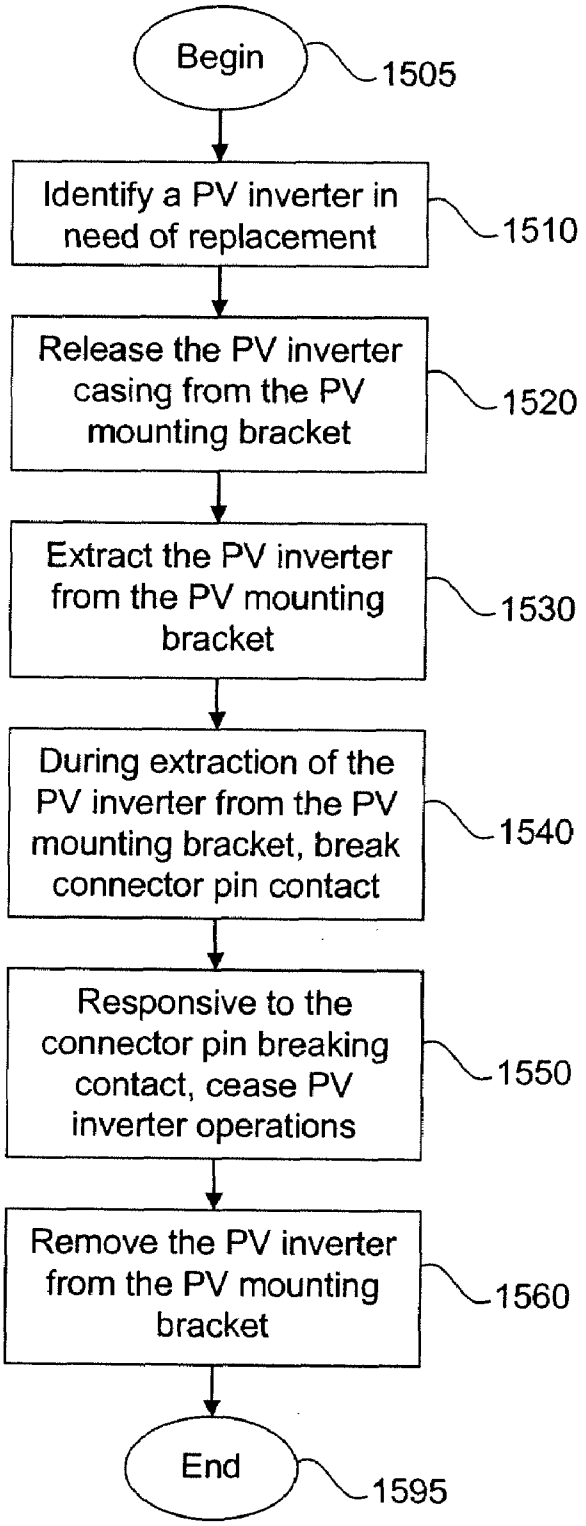

Begin
1505
Identify a PV inverter in need of replacement
1510
Release the PV inverter casing from the PV mounting bracket
1520
Extract the PV inverter from the PV mounting bracket
1530
During extraction of the PV inverter from the PV mounting bracket, break connector pin contact
1540
Responsive to the connector pin breaking contact, cease PV inverter operations
1550
Remove the PV inverter from the PV mounting bracket
1560
End
1595

FIG. 15

PHOTOVOLTAIC AC INVERTER MOUNT AND INTERCONNECT

RELATED APPLICATION

[0001] The present application relates to and claims the benefit of priority to U.S. Provisional Patent Application No. 60/938,663 filed May 17, 2007, which is hereby incorporated by reference in its entirety for all purposes as if fully set forth herein. The present application is further related to co-pending U.S. Patent Application Ser. No. LAR003 entitled, "Photovoltaic Module-Mounted AC Inverter" and U.S. Patent Application Ser. No. LAR002 entitled "Distributed Inverter and Intelligent Gateway", both of which are hereby incorporated by this reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The invention relates to electrical current power conversion and, more particularly, to a mount for an inverter configured to convert photovoltaic module output power into alternating current.

[0004] 2. Relevant Background

[0005] An inverter is a device that converts direct current ("DC") into alternating current ("AC"). Inverters can be designed to supply power from photovoltaic ("PV") modules to a utility power grid, also referred to herein as the "grid." This process places several special constraints on the power conversion process. Existing photovoltaic inverters generally fall into the category of centralized inverters wherein a single inverter performs power conversion of the DC supplied by a group of PV modules into the desired AC grid.

[0006] Another category of inverters is known as distributed inverters. A distributed inverter uses multiple inverters to generate the desired AC power from a number of PV modules. When the inverter is mounted on the PV module, the assembly comprising the PV module and inverter is termed an AC module. Previous attempts at development and marketing of AC modules have met with little success. One reason for this failure has been that the sales volume was too low to achieve any kind of economies of scale. Additionally, the components used in the distributed inverters associated with AC modules were off-the-shelf and, in many cases, were not optimized for the rigors of supplying AC power to the grid. The reliability levels of existing off-the-shelf components used in the inverters limits their lifetime to between five and ten years. Additionally, there can be up to 1000 components in an inverter resulting in significant cost per unit of energy. Furthermore, the complexity and system requirements of such an inverter result in a cumbersome package that is difficult to attach to a PV module.

[0007] Referring now to FIG. **1**, the back-side **110** of a PV module **102** including a PV module-mounted inverter **104** as known in the prior art is shown. A junction box **103**, normally a component of the PV module **102**, is permanently attached to the PV module **102** frame via an adhesive. The junction box **103** encloses and protects the DC connections from the module **102**, including bypass diodes used to shunt current around disabled or non-producing PV cells within the module. The PV module **102** DC outputs typically leave the junction box **103** via single-wire cables **112**, **113** and connect to an inverter **104**. The inverter **104** is mounted to the frame of PV module **102** near an edge **111** of the PV module. The weight and size of the inverter may vary, and in many instances further measures are needed to improve support to the inverter **104** including mounting it at a corner of the frame, adding metal brackets to the frame or even mounting the inverter on the members that ultimately support the PV module **102**. Cables **106**,**107** from the inverter connect the PV module **102** to the AC grid and to other PV module-mounted inverters via connectors **105**, **108**. The cables **106**, **107** are connected together, according to one system of implementation and as described in related application Ser. No. _____ in parallel within the inverter **104** so that all voltages on the pins of the first connector **105** also appear on the corresponding pins of the second connector **108**. The cables **106**, **107** and connectors **105**, **108** are typically designed to support single-phase, single pole or single-phase, two-pole AC grid interconnection, and each requires a minimum of three conductors. The connectors are defined to allow for chains of inverters to be developed in which the AC grid connection is accessible to all inverters by simply connecting the connector **108** of one inverter **104** to another connector **105** of an adjacent PV module-mounted inverter in a system. The inverter **104** typically has a metallic enclosure, requiring that an equipment grounding conductor be brought through cables **106**, **107** for electrical code mandated safety ground.

[0008] Referring to FIG. **2**, an array **201** of PV modules **202**, **222**, **242** including PV module-mounted inverters **204**, **224**, **244** as known in the prior art is shown. In the configuration shown, connector **205** is connected to the grid. As referred to herein the grid will be recognized by on skilled in the art of electrical generation and local electric grid systems. This grid includes not only the ability to use the power produced by the PV modules locally, for example to power a commercial enterprise or residence, but also to sell back excess or unused power to a community electric grid. The AC grid voltage appears at connector the **208** and is passed to the inverter **224** of the PV module **222** via another connector **225**, which is mated with a receiving connector **208**. Similarly, the same AC voltage is now available at a similar inverter **244** via the mating of a like connector **228** to another receiving connector **245**. This sequence can continue until the maximum current rating of all cables **206**, **207**, **226**, **227**, **246**, **247** and **266** has been exhausted.

[0009] FIG. **3** is a side end view of a PV module **301** including a PV module-mounted inverter **306** as is known in the prior art. The height of the frame **304** of the module typically measures about one inch. The junction box **305** and inverter **306** are generally attached to the top side **302** of the module **301**. The height of junction box **305** typically remains below the frame height and therefore does not protrude below the lower edge of the frame **303**. However, existing inverter designs are considerably taller than the frame height **304** due to their complexity and protrude below the module frame. Since PV modules are typically stacked frame-to-frame, a tall inverter impedes pre-assembly of the inverter to the PV module prior to shipment and severely impacts the ability to service a PV module or inverter in the field should one fail after installation.

[0010] Additionally, existing designs of PV module-mounted inverters present significant reliability problems. Inverters occasionally fail. When such an event occurs the PV module to which it is attached is no longer contributing in the production of electricity for the system. The identification of that singular PV module failure, however, is extremely difficult as there is no outright indication that a PV module has failed. Generally the only indication of a PV module failure is

a decrease in power production. This is compounded with the fact that each PV module and its installation in a system represents a significant capital outlay. A failure of an inverter, should it be identified, results in the replacement of the entire PV module. To do such a repair, under the systems and inverters currently used in the prior art, the entire PV system must be taken off line. Not only is the replacement of the entire PV system costly, but the loss in power production of at least a significant portion of the entire PV system while a single module is replaced is inefficient.

[0011] The weight, size, metallic enclosure and relatively low efficiency of the existing inverter designs result in a more complex mounting arrangement and a considerable increase in cost over a centralized inverter approach. But a centralized inverter is also not an optimal solution. Yet, the benefits of maximum power-point tracking optimization normally achieved by having an inverter at each PV module easily can be lost by a lack of power efficiency. Also the lifetime of an inverter is less than that of a PV module; therefore, any inverter mounted onto a PV module in a distributed model will need replacement at some point during the life of the PV module. Finally, existing inverters are difficult to replace due to their weight, anchoring schemes and wiring.

[0012] An efficient inverter that creates little heat, is lightweight in construction, is easily replaced and minimizes exposed wiring remains a challenge. Compounding this challenge is that such an invention should also minimize system cost and easily fit within the depth of the PV module frame. These and other deficiencies of the prior art are addressed by embodiments of the present invention.

SUMMARY OF THE INVENTION

[0013] According to one embodiment of the present invention, a replaceable PV module-mounted AC inverter is designed to be inserted into an inverter mounting bracket. The inverter mounting bracket is attached to the back of a PV module via adhesive of some other means. The inverter and inverter mounting bracket are made of non-conducting materials to remove electrical code requirements for equipment grounding conductors. The inverter is coupled to the bracket via locking mounting clips on the inverter mounting bracket that lock into inverter mounting recesses. No tools are required to insert the inverter into the bracket and only a simple blade screwdriver is required to release the clips for removal and replacement of the inverter.

[0014] According to one embodiment of the present invention, the inverter is spaced from the back surface of the PV module to minimize heating of the PV module by the inverter and to provide for convective air flow surrounding the inverter to dissipate heat generation. Furthermore, the inverter can be replaced while the PV module and indeed the entire PV module system remains operational. According to one embodiment of the present invention, by virtue of the joining mechanism of the inverter to the PV module bracket, an inverter can safely be removed from the bracket/interconnect with minimal fear of an arc and without disrupting the production of power from the remaining PV modules.

[0015] There are, according to one embodiment, two inverter mounting bracket AC connections to support daisy-chain connections between multiple AC modules. The AC connections can be made using bracket mounted connectors or by using cables affixed to the bracket. Finally, AC connections can be a combination of one affixed cable and one bracket-mounted connector.

[0016] The inverter mounting bracket DC connections, according to one embodiment of the present invention, can be implemented inside the bracket by mounting the bracket on top of the DC connections of a PV module. Additional external single-wire cables can be added to accommodate connection to an existing junction box mounted on a PV module.

[0017] For applications requiring permanent inverter installation without the capability of field replacement of the inverter, the inverter can be completely enclosed by the bracket to result in a very reliable and low-cost bracket implementation. By removing the interface between the bracket and the inverter, the reliability of the PV module is enhanced at the cost of the flexibility to replace an inverter in the field.

[0018] The features and advantages described in this disclosure and in the following detailed description are not all-inclusive. Many additional features and advantages will be apparent to one of ordinary skill in the relevant art in view of the drawings, specification, and claims hereof Moreover, it should be noted that the language used in the specification has been principally selected for readability and instructional purposes and may not have been selected to delineate or circumscribe the inventive subject matter; reference to the claims is necessary to determine such inventive subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The aforementioned and other features and objects of the present invention and the manner of attaining them will become more apparent, and the invention itself will be best understood, by reference to the following description of a preferred embodiment taken in conjunction with the accompanying drawings, wherein:

[0020] FIG. **1** is a layout diagram of the back-side of an AC module as is known in the prior art;

[0021] FIG. **2** is a layout diagram of the back side of an AC PV module system as is known in the prior art;

[0022] FIG. **3** is a side end view schematic of an AC module as is known in the prior art;

[0023] FIG. **4** is a mechanical drawing of an inverter according to one embodiment of the present invention;

[0024] FIG. **5** is a mechanical drawing of an inverter mounting bracket according to one embodiment of the present invention;

[0025] FIG. **6** is a mechanical drawing of an inverter inserted into an inverter mounting bracket according to one embodiment of the present invention;

[0026] FIG. **7** is a mechanical drawing of a an inverter mounting bracket according to one embodiment of the present invention;

[0027] FIG. **8** is a mechanical drawing of a an inverter mounting bracket according to one embodiment of the present invention;

[0028] FIG. **9** is a layout drawing of the placement of inverters, inverter mounting brackets, associated AC cables and PV modules according to one embodiment of the present invention;

[0029] FIG. **10** is layout drawing of the placement of inverters, inverter mounting brackets, associated AC cables and PV panels according to one embodiment of the present invention;

[0030] FIG. **11** is a mechanical drawing of a an inverter mounting bracket according to another embodiment of the present invention;

[0031] FIG. **12** is a layout drawing of the placement of an inverter mounting bracket, inverter and associated AC and

DC cables on the back of a PV module with a junction box according to one embodiment of the present invention;

[0032] FIG. **13** is a mechanical drawing of an inverter mounting bracket with an enclosed inverter according to one embodiment of the present invention;

[0033] FIG. **14** is a mechanical drawing of an inverter mounting bracket with a recessed pin to enable power-on replacement of the inverter, according to one embodiment of the present invention; and

[0034] FIG. **15** is a flowchart showing one method embodiment for removing a PV inverter from a fully operational PV module.

[0035] The Figures depict embodiments of the present invention for purposes of illustration only. One skilled in the art will readily recognize from the following discussion that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles of the invention described herein.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0036] Specific embodiments of the present invention are hereafter described in detail with reference to the accompanying Figures. Like elements in the various Figures are identified by like reference numerals for consistency. Although the invention has been described and illustrated with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example and that numerous changes in the combination and arrangement of parts can be resorted to by those skilled in the art without departing from the spirit and scope of the invention.

[0037] Referring now to FIG. **4**, a mechanical drawing including a side **402** and top view **422** of a removable PV module-mounted power element according to a one embodiment of the present invention is shown. According to one embodiment of the present invention the power element **422** can be an inverter capable of converting DC power to AC power. In another embodiment of the present invention the power module is a DC conditioner capable of modifying the DC characteristics including, but not limited to voltage. While the present invention is hereafter described in terms of an inverter, one skilled in the art will recognize that the power element **422** can possess multiple functionalities without departing from the spirit of the invention.

[0038] Referring again to FIG. **4**, a potted assembly inverter **422** in a non-conductive enclosure is shown with metallic blade connectors **404**, **405**, **406**, **407**, **408**, **409**, **410** to bring AC and DC wiring connections out of the enclosure **402**. The blade connectors **404**, **405**, **406**, **407**, **408**, **409**, **410** are designed to support high voltage and high current operation consistent with a single PV module output power. Recessed mounting holes **403**, **420**, **421** are used in conjunction with a mounting clip to secure the inverter in the mounting bracket using a single installation motion. The dimensions and aspect ratio of the inverter **422** may be adjusted to support differing power requirements based on PV module design. The inverter is lightweight—generally less than 16 ounces—and does not significantly load the PV module to which it is attached.

[0039] FIG. **5** shows, according to another embodiment of the present invention, a mechanical drawing of a side **505** and top view **510** of an inverter mounting bracket mounted on the back of a PV module **502**. The bracket is attached to the back of a PV module **502** by an adhesive **509** that is placed between bracket **505** and PV module **502** prior to assembly. The bracket **505** is molded from a non-conductive material, such as a composite plastic or the like, to minimize cost. Mounting clips **503**, **511**, **512** are used to lock the inverter in place once the inverter is inserted into the electrical high-voltage receptacles **520**, **521**, **522**, **523**, **524**, **525** of the bracket **505**. DC wiring connections **507** from the inverter receptacles to the PV module are made by wire or bus-bar means. Connectors **504**, **530**, **531** are used to make all AC connections to the inverter via wires **506** to the inverter receptacles. The connectors **504** can be discrete or can be molded into the body of bracket **505**. Inverter receptacles **520**, **521**, **522**, **523**, **524**, **525** may be recessed into the bracket to improve protection against weather, sunlight, ultraviolet radiation and other environmental features.

[0040] FIG. **6** shows a side and top view of an inverter **602** inserted into an inverter mounting bracket **604** according to an embodiment of the present invention. The high voltage pins **620**, **621**, **622**, **623**, **624**, **625** of the inverter are inserted into the bracket **604** receptacles. The inverter is locked into place to eliminate disengagement via vibration or accidental means via locking clips **612**, **615** that engage inverter mounting holes **613**, **614**. The design of the inverter **602** and inverter mounting bracket **604** results in spacing **603** of the inverter **602** from the back surface of PV module **605** thereby reducing heating of PV module **605** by heat generated in the inverter **602**. It is well known that the conversion of DC power to AC power by an inverter produces as a by product, heat. In a centralized type of system configuration in which DC power transported away from the PV modules for conversion, heat production by the inverter is of little concern. However in system in which an inverter is coupled to each PV module the generation of heat can significantly reduce the efficiency of each photovoltaic cell. To better understand the implications of heat generated by an inverter consider how a PV module operates.

[0041] PV modules operate as current sources derived from a photoexcited semiconductor junction. The maximum available power from the PV cell is defined by the product of its output voltage and current. The current is due to generated photocarriers and, at low output voltages, will be proportional to the incident illumination on the PV cell and is termed the photocurrent. The PV cell behaves as if it has a photocurrent source in parallel with a non-illuminated junction diode. The output voltage is defined by the diode circuit effects implicit in the semiconductor junction and ultimately limits the maximum useful output voltage to a point where the diode current begins to increase significantly. Diode current is a strong function of operating temperature and results in a reduced PV cell voltage for a given output current as temperature rises. PV module output power therefore decreases with temperature. This effect requires that the PV module temperature be kept as low as possible by mitigating any related heat sources as much as possible.

[0042] Previous designs neglect to consider this important aspect of power production. According to one embodiment of the present invention, a replaceable inverter **602** is mounted physically apart from the PV module. By maximizing surface area of the inverter open to surrounding air currents the heat produced by each inverter can be dissipated away from the inverter by way of convection to the atmosphere and not to the PV module.

[0043] No tools are required to insert the inverter and only a simple blade screwdriver is required to release the clips for removal and replacement.

[0044] Shown in FIG. **7** is a mechanical drawing, according to another embodiment of the present invention, of a side **703** and top view **710** of an inverter mounting bracket capable of being mounted on the back of a PV module **702**. The bracket is identical in design to the embodiment shown in FIG. **5** with the exception of the method of AC connections. AC connections shown in FIG. **7** are made using multi-conductor cables **704**, **730**, **731** that are affixed to mounting bracket **710**. The cables **704**, **730**, **731** are directly connected via internal wires **706** to bracket inverter receptacles **720**, **721**, **722**, **723**, **724**, **725**.

[0045] FIG. **8** shows another embodiment of an inverter mounting bracket that can be mounted on the back of a PV module **802**. The first AC connection shown in FIG. **8** is made using multi-conductor cable, **804** or **831**, that is affixed to the mounting bracket **810**. A cable **831** is directly connected via internal wires **806** to bracket inverter receptacles **820**, **821**, **822**, **823**, **824**, **825**. The second AC connection is made via the bracket **810** mounted connector **830** and is connected to the inverter receptacles **820**, **821**, **822**, **823**, **824**, **825** via additional wiring **806**. The connector **830** may be discrete or molded into the body of bracket **810**.

[0046] FIG. **9** is a layout drawing, according to one embodiment of the present invention, showing the backside of an array **901** of PV modules **902**, **912**, **922** with inverter mounting brackets **904**, **914**, **924** attached at the DC connection location of each module. Inverters **903**, **913**, **923** are inserted into inverter mounting brackets **904**, **914**, **924**, respectively. Multi-wire AC connecting cables **915**, **925** are shown connecting the inverters. A multi-wire AC connecting cable **905** is shown connecting the inverters on the PV modules in the drawing and the AC grid (not shown).

[0047] FIG. **10** is also a layout drawing, according to another embodiment of the present invention, showing the backside of an array **1001** of PV modules **1002**, **1012**, **1022** with inverter mounting brackets **1004**, **1014**, **1024** attached at the DC connection location on PV modules **1002**, **1012**, **1022**. The inverters **1003**, **1013**, **1023**, according to the embodiment shown in FIG. **7**, are inserted into inverter mounting brackets **1004**, **1014**, **1024**, respectively. Multi-wire AC connecting cables **1006**, **1015** are connected together via connectors at the end of each bracket affixed cable. Additional multi-wire AC connecting cables **1016**, **1025**, **1026**, **1035** are connected together via connectors at the end of each bracket affixed cable. The assembly is thereafter connected to the AC grid.

[0048] FIG. **11** shows a mechanical drawing of a top view of an inverter mounting bracket **1110** capable of being mounted on the back of a PV module. Bracket **1110** is similar in design to the embodiment shown in FIG. **7** with the exception of the design of the DC connections. In this embodiment, the DC connections are made using single-wire cables **1111**, **1112** that are affixed to mounting bracket **1110**. Cables **1111**, **1112** are directly connected via their internal wires to bracket inverter receptacles **1120**, **1121**, **1122**, **1123**, **1124**, **1125**. The DC cables **1111**, **1112** may be placed in other locations than those shown in FIG. **11**.

[0049] Likewise, FIG. **12** presents a layout drawing showing the backside **1214** of a PV module **1212** with inverter mounting bracket **1203** attached according to one embodiment of the present invention. An inverter **1202** is shown inserted into the top of inverter mounting bracket **1203**. AC cables **1210**, **1211** are shown leaving the bottom of bracket **1203**. Single-wire DC cables **1206**, **1207** connect the junction box **1205** to the inverter mounting bracket **1203**. This allows the inverter to be used with existing manufactured PV modules **1212** that have junction boxes **1205** pre-assembled without any modifications to PV modules **1212**.

[0050] According to another embodiment of the present invention and as shown in FIG. **13**, a bracket **1302** is attached to the back of PV module **1303** by an adhesive **1308** that is placed between bracket **1302** and PV module **1303**. The bracket **1302** is molded from a non-conductive material, such as a composite plastic or the like, to minimize cost. The inverter **1304** is completely enclosed within bracket **1302**. Inverter connections **1320**, **1321**, **1322**, **1323**, **1324**, **1325** are connected to AC connectors **1306**, **1330**, **1331** and the PV module by internal wiring. Cables **730**, **731** of the inverter mounting bracket **710** shown in FIG. **7** may be substituted for the connectors **1306**, **1330**, **1331** shown in FIG. **13**. Likewise, the cable of the inverter mounting bracket **810** shown in FIG. **8** may be substituted for the connector **1331** shown in FIG. **13**.

[0051] FIG. **14** is a mechanical drawing according to another embodiment of the present invention showing a top view of an inverter mounting bracket **1410** mounted on the back of a PV module. The bracket **1410** is identical in design to the embodiment of FIG. **5** with the exception of the method of placement of the inverter connection receptacles. An inverter connection receptacle **1425** is shown partially recessed into the bracket. When the inverter is removed from the bracket **1410**, the associated connector pin on the inverter is disconnected from receptacle **1410** prior to the inverter pins connected to receptacles **1420**, **1421**, **1422**, **1423**, **1424** being disengaged. A detection circuit is implemented in the inverter to determine that the connection to the receptacle **1410** has been broken and thereby disables all power currents into and out of the inverter. As a result, no arc is formed at the receptacles **1420**, **1421**, **1422**, **1423**, **1424** when the inverter is removed. Similarly, power current flow into and out of the inverter is not enabled until after a complete connection has been made on the receptacle **1425** after the power connections have been established on receiving receptacles **1420**, **1421**, **1422**, **1423**, **1424**. Since the connections have been established prior to the enabling of current, no arc can occur at the connection **1420**, **1421**, **1422**, **1423**, **1424**. The recessed receptacle **1410** and associated detection circuitry implements a hot-swap function in which the inverter can be removed and replaced while voltages remain active on all the AC and DC connections to the inverter without creating a potentially hazardous arc.

[0052] Similarly the connector pin **425** upon replacement of the inverter prevents operations of the inverter prior to the connection of the receptacles **1420**, **1421**, **1422**, **1423**, **1424**. As the inverter is mated with the inverter bracket, each receptacle of the inverter mates with a corresponding connection of the inverter bracket. Subsequent to the connections being made the connection pin **1425** establishes contact with a corresponding component of the inverter bracket signifying that operation of the inverter can safely begin. In one embodiment the connection pin is a recessed pin/receptacle combination over which a simple continuity circuit can be attached while in another the pin is a telescoping pin coupled to a switch that signifies whether a complete connection or extraction of the inverter.

[0053] FIG. **15** is a flowchart illustrating methods of implementing an exemplary process for replacing a PV inverter associated with a PV module. In the following description, it will be understood that some blocks of the flowchart illustration, and combinations of blocks in the flowchart illustra-

tions, can be implemented by computer program instructions while other blocks represent physical methodology. When implemented by a computer, these computer program instructions may be loaded onto a computer or other programmable apparatus to produce a machine such that the instructions that execute on the computer or other programmable apparatus create means for implementing the functions specified in the flowchart block or blocks. These computer program instructions may also be stored in a computer-readable memory that can direct a computer or other programmable apparatus to function in a particular manner such that the instructions stored in the computer-readable memory produce an article of manufacture including instruction means that implement the function specified in the flowchart block or blocks. The computer program instructions may also be loaded onto a computer or other programmable apparatus to cause a series of operational steps to be performed in the computer or on the other programmable apparatus to produce a computer implemented process such that the instructions that execute on the computer or other programmable apparatus provide steps for implementing the functions specified in the flowchart block or blocks.

[0054] Accordingly, blocks of the flowchart illustrations support combinations of means for performing the specified functions and combinations of steps for performing the specified functions. It will also be understood that each block of the flowchart illustrations, and combinations of blocks in the flowchart illustrations, can be implemented by various means including a computer, robotics, or via human implementation. Indeed many of the steps illustrated in FIG. **15** can comprise multiple steps that are not listed herein as they would be well known to one skilled in the art. Furthermore the steps listed and discussed below are one example of a process for replacing a PV inverter associated with a PV module according to the present invention.

[0055] FIG. **15** begins **1505** with the identification **1510** of a PV inverter in need of replacement. The identification of an inverter can be due to failure of the inverter, periodic or preventive maintenance or for other reasons known to one skilled in the art. The determination of what PV inverter in a PV system needs to be replaced is not trivial and is not the subject of this invention. Upon identification **1510** the PV inverter is released **1520** from its mounting bracket. Upon release of any physical restraints holding the PV to the inverter bracket the PV inverter can be extracted **1530** from the bracket. Note that during this process, and according to one embodiment of the present invention, the PV system remains operational and indeed the PV module to which the PV inverter is associated continues to provide DC power to the PV inverter.

[0056] As the PV inverter is removed from the inverter bracket but prior to the connectors mating the PV module to the PV inverter from breaking contact, a connector pin indicates **1540** to the inverter that a secure connection between the inverter bracket and the PV inverter has been compromised. Responsive to the connector pin breaking contact, the PV inverter ceases operation **1550**. As one skilled in art will recognize the termination of operation of the PV inverter can be accomplished by a number of methodologies. According to one embodiment a detection circuit is included in the PV inverter to ensure that a positive connection exists between the PV module (inverter bracket) and the PV inverter prior to converting the DC power to AC power. The process ends **1595** with the inverter being safely removed **1560** from an operation PV module without any electrical arc or danger to the technician.

[0057] While there have been described above the principles of the present invention in conjunction with a PV module AC inverter mount and interconnect, it is to be clearly understood that the foregoing description is made only by way of example and not as a limitation to the scope of the invention. Particularly, it is recognized that the teachings of the foregoing disclosure will suggest other modifications to those persons skilled in the relevant art. Such modifications may involve other features that are already known per se and which may be used instead of or in addition to features already described herein. Although claims have been formulated in this application to particular combinations of features, it should be understood that the scope of the disclosure herein also includes any novel feature or any novel combination of features disclosed either explicitly or implicitly or any generalization or modification thereof which would be apparent to persons skilled in the relevant art, whether or not such relates to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same technical problems as confronted by the present invention. The Applicant hereby reserves the right to formulate new claims to such features and/or combinations of such features during the prosecution of the present application or of any further application derived therefrom.

We claim:

1. A system for mounting a photovoltaic power element, the system comprising;

a bracket affixed to a photovoltaic module having a plurality of photovoltaic cells wherein the bracket includes a first mounting interface wherein direct current leads from the plurality of photovoltaic cells conveying direct current are coupled to the first mounting interface; and

a replaceable power element casing housing the photovoltaic power element having a second mounting interface mated with the first interface such that power conveyed from the plurality of photovoltaic cells is modified by the photovoltaic power element and conveyed back to the bracket via the first and second mounting interface.

2. The system of claim **1** wherein the photovoltaic power element is a direct current conditioner.

3. The system of claim **1** wherein the photovoltaic power element is an inverter

4. The system of claim **3** wherein the first mounting interface is positioned on the bracket such that the replaceable power element casing is suspended apart from the photovoltaic module.

5. The system of claim **3** wherein the replaceable power element casing includes supplemental surface area fixtures to facilitate heat transfer.

6. The system of claim **3** wherein the first mounting interface and the second mounting interface include a plurality of interconnects.

7. The system of claim **6** wherein a subset of the plurality of interconnects convey direct current from the bracket to the photovoltaic inverter.

8. The system of claim **6** wherein a subset of the plurality of interconnects convey alternating current from the photovoltaic power element to the bracket.

9. The system of claim **3** wherein replacement of the photovoltaic power element occurs during continuous operation of the photovoltaic module.

10. The system of claim **3** wherein the photovoltaic power element converts direct current of the plurality of photovoltaic cells into three-phase alternating current.

11. The system of claim **3** wherein the photovoltaic power element converts direct current of the plurality of photovoltaic cells into single-phase alternating current.

12. The system of claim **1** wherein the first and second mounting interface masks any electrical arc during replacement of the replaceable power element casing.

13. The system of claim **1** wherein the bracket includes connections capable of linking in parallel the photovoltaic module with other brackets of other photovoltaic modules.

14. The system of claim **1** wherein mating of the first mounting interface to the second mounting interface creates a substantially weather tight seal.

15. A mounting fixture for a attaching a photovoltaic power element to a bracket fixed to a photovoltaic module, the mounting fixture comprising;

a first interface housed in the bracket and coupled to direct current leads from photovoltaic cells of the photovoltaic module and to multi-wire cables linking the photovoltaic module to other photovoltaic modules; and

a second interface housed in a replaceable photovoltaic power element casing and coupled to the photovoltaic power element configured to mate with the first interface so as to mount the photovoltaic inverter to the bracket.

16. The mounting fixture of claim **15** wherein the bracket is affixed to the photovoltaic module.

17. The mounting fixture of claim **15** wherein the photovoltaic power element casing includes supplemental surface area fixtures to facilitate heat transfer.

18. The mounting fixture of claim **15** wherein the photovoltaic power element casing is suspended apart from the photovoltaic module.

19. The mounting fixture of claim **15** wherein the replaceable photovoltaic power element is an inverter.

20. The mounting fixture of claim **19** wherein replacement of the replaceable photovoltaic power element occurs during continuous operation of the photovoltaic module.

21. A method for removing a photovoltaic power element in a photovoltaic system, the method comprising;

identifying from among a plurality of operational photovoltaic modules within the photovoltaic system at least one photovoltaic module having an power element bracket wherein the bracket includes a mounting interface coupling the photovoltaic power element to the power element bracket and herein the mounting interface includes a plurality of connectors for conveyance of electrical power between the photovoltaic module and the photovoltaic power element;

releasing the photovoltaic power element from the power element bracket; and

extracting the photovoltaic power element from the power element bracket wherein prior to the plurality of connectors breaking contact, a connector pin connection is broken, and responsive to the connector pin connection being broken the photovoltaic power element ceases operation.

22. The method of claim **21** wherein the photovoltaic power element is an inverter.

23. The method of claim **22** wherein power production of each photovoltaic module within photovoltaic system produces continual power during the extraction of the photovoltaic power element including at the at least one photovoltaic module.

24. The method of claim **22** further comprising replacing the photovoltaic power element with another photovoltaic power element during continuous operation of the at least one photovoltaic module wherein the another photovoltaic power element begins operation subsequent to the connector pin being connected subsequent to the plurality of connectors interfacing the power element bracket to the photovoltaic power element mating.

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