UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

HOYMILES USA, INC.,

Petitioner,

v.

CYBOENERGY, INC.,

Patent Owner.

CASE: IPR2024-01106

U.S. PATENT NO. 8,786,133

Declaration of Mladen Kezunovic

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I, Dr. Mladen Kezunovic, declare as follows:

I. INTRODUCTION

[001] I, Dr. Mladen Kezunovic, a citizen of the United States of America, have been retained by K&L Gates, counsel for Petitioner Hoymiles Power Electronics USA, Inc. ("Hoymiles") to provide expert testimony in the inter partes review of U.S. Patent No. 8,786,133 ("'133 Patent").

II. QUALIFICATIONS

[002] My qualifications are discussed below. A copy of my CV is attached as Appendix 1.

[003] I graduated from the University of Sarajevo, Sarajevo, Bosnia, in 1974 with a Bachelor of Science degree in Electrical Engineering.

[004] I received my Master of Science in Electrical Engineering from the University of Kansas in 1977, and was awarded my Ph.D. in Electrical Engineering, also from the University of Kansas, in 1980.

[005] I currently serve in a variety of academic and professional roles. In the academic realm, I have worked at Texas A&M University ("TAMU") 1986-1987 as a Visiting Associate Professor, and then a Visiting Scientist and Adjunct Associate Professor during 1987-1992, and in 1992 I became a tenure track Associate Professor and the director of TAMU's Power Systems Control and Protection Laboratory. I became a tenured professor at TAMU in 1996, and currently teach

there. From 2012 until 2019 I also served as director of TAMU's Smart Grid Center. From 1997 until 2006 I served as the director of TAMU's Electric Power and Power Electronics Institute.

[006] In the professional realm, I have been a site director for the Power Systems Engineering Research Center, originally a part of the National Science Foundation I/UCRC, since 2000.

[007] I am the President, CEO, and Principal consultant of Test Laboratories International, Inc., d.b.a. XpertPower Associates, a company I started in 1992.

[008] I have been a registered professional engineer in the state of Texas under the Texas Board of Professional Engineers since 1993. My license number is 76824.

[009] Prior to my current professional employments, I was an engineer and project leader at Energoinvest Company from 1980 until 1987, and prior to that role I was a systems engineer in the Industry Systems division of Westinghouse Electric Corporation from 1979 until 1980.

[010] I am an active member of The Institute of Electrical and Electronic Engineers (IEEE) since 1980 and have held a variety of roles in IEEE since 1990.

[011] A list of my publications is attached as Appendix 2. I have not testified or been deposed in any litigation matter within the last four years.

[012] Based on the above qualifications I am considered an expert in the field of power system protection and control, interfacing of renewables (including solar

panels and other solar sources) to power grid and data analytics for fault analysis and power system operation. The subject matter of the ’133 patent is squarely within my expertise.

[013] I have been retained by Petitioner’s counsel to determine whether the claims of the ’133 Patent are valid, and I am being paid $400 per hour to review the patent at issue, various prior art references, and to provide the opinions set forth in this declaration. I have no connection with CyboEnergy, Inc. and do not have a stake, financial or otherwise, in whether the claims of the ’133 Patent are affirmed or canceled.

[014] I have read and am familiar with the ’133 Patent, its prosecution history, and the prior art references as detailed in the petition.

III. SUMMARY OF OPINIONS

[015] I was asked to provide opinions on whether claims 15–24 of the ’133 Patent are anticipated by and/or obvious in view of prior art. In preparing this Declaration, I reviewed the references that are cited in Appendix 2.

[016] In my opinion, claims 15–24 of the ’133 Patent recite obvious combinations of prior art elements of DC to AC inverters, particularly the kind used in solar power systems. Independent claims 15 and 19 are directed to inverters that i) have more than one DC input and that ii) connect in a “daisy chain,” such that the AC output of one inverter connects to an AC input port of the next inverter.

[017] Inverters having multiple DC inputs were known in the prior art before the invention of the '133 Patent, as demonstrated *e.g.* in U.S. Patent Publication No. 2005/0105224 ("Nishi") and U.S. Patent Publication No. 2009/0020151 ("Fornage"). Likewise, the idea of connecting multiple inverters in a "daisy chain" was also known in the prior art, as demonstrated *e.g.* in U.S. Patent Publication No. 2002/0038667 ("Kondo").

[018] In my opinion, it would have been obvious to combine Kondo's teaching of daisy chaining multiple inverters with either Fornage or Nishi's teaching of multi-input, shared inverters. A person of ordinary skill would be motivated to do this to enhance the scalability of Kondo's system, while reducing component count and cost. A person of ordinary skill would further be motivated by the understanding that the resulting combination would be able to perform maximum power point tracking (MPPT) on each of the DC input sources individually.

[019] It would also have been obvious to start with the multi-input inverter of Fornage or Nishi and add Kondo's teaching of daisy-chaining additional inverters. A person of ordinary skill would be motivated to do this because daisy chaining inverters was known to be a simple way to increase the scale of an inverter system. A person of ordinary skill would further be motivated by the understanding that the resulting combination would be capable of detecting and mitigating overcurrent on the combined AC connection, as taught by Kondo.

[020] Claims 16–18 and 20–24 depend on claims 15 and 19 and are obvious for similar reasons.

IV. MATERIALS CONSIDERED

[021] In forming my opinions, I relied upon my education and experience in the relevant field, and I considered the viewpoint of a person having ordinary skill in the relevant art, as of July 16, 2009 (the earliest claimed priority date listed on the '133 Patent).

[022] A list of documents that I considered in forming my opinions is attached as Appendix 2.

V. LEGAL PRINCIPLES

[023] I am not an attorney, and I offer no opinions regarding the law. My understanding of the relevant legal principles is informed by counsel. Below is a summary of these legal principles that I have applied in reaching my opinions.

A. Anticipation (35 U.S.C. § 102)

[024] I understand that a prior art reference anticipates a patent claim if that single reference discloses all limitations of that claim, either expressly or inherently. I understand that, in order for a prior art reference to anticipate a patent claim, the descriptions in that reference and the words in the claim need not be identical so long as all of the limitations of the claim are present in the single reference such that a person of ordinary skill in the art, after looking at the reference, would be able to make and use the claimed invention.

[025] Moreover, I understand that a prior art reference need not explicitly describe each limitation of the claimed invention if the limitations are necessarily present in the reference.

B. Obviousness (35 U.S.C. § 103(a))

[026] I understand that an asserted claim that is not anticipated is still invalid if, at the time of the alleged invention, the subject matter of the claim would have been obvious to one of ordinary skill in the art in light of the teachings of the prior art.

[027] I understand that obviousness often involves combining more than one prior art reference. I understand that the following factors must be evaluated to determine whether an asserted claim is obvious:

- the scope and content of the prior art;
- the difference or differences, if any, between each asserted claim and the prior art;
- the level of ordinary skill in the art at the time the invention was made; and
- additional secondary considerations, if any, indicating that the invention was obvious or not obvious.

[028] I understand that care must be taken not to rely on "hindsight" analysis, *i.e.* using the teachings of the patent as a roadmap to combine prior art references or otherwise to find a claim obvious. Instead, the obviousness analysis must be guided

by the prior art references and the then-existing knowledge, skill, and creativity of a person of ordinary skill in the art.

[029] I understand that a claim is not obvious simply because each element existed somewhere in the prior art. I understand there must be a reason why one of ordinary skill would have combined elements from different prior art references. I understand the motivation to combine could be prompted by any need, design consideration, or problem known in the field at the time of the alleged invention. I understand that the reason to combine an element from the prior art may derive from the fact that it is well known or commonly used in the art. I also understand that the reason to combine references may come from the background knowledge possessed by a person having ordinary skill in the art.

VI. PERSON OF ORDINARY SKILL IN THE ART

[030] In my opinion, a person of ordinary skill in the art ("POSITA") of the technology claimed by the '133 Patent is a person having a bachelor's degree in electrical engineering and five years of experience designing grid connected photovoltaic systems.

[031] The technology claimed in the '133 Patent is not complex, and the '133 Patent itself provides little description of any circuitry for implementing the claims. Indeed, the systems and methods claimed by the '133 Patent are depicted as an arrangement of literal "black boxes," *e.g.* in Figure 5, which shows a number of "Power

Inverter[s]" daisy chained together in parallel and having multiple DC inputs. The "Power Inverter[s]" themselves are depicted *e.g.* in Figure 9, schematically, as a collection of black box components (*e.g.*, DC-DC Boost Converter 183, DC-AC Inverter 186, *etc.*). *See also* '133 Patent 6:44–46 ("FIG. 9 is a bock diagram illustrating a smart dual-input power inverter that inverts the DC power from two DC sources to single phase AC power"); 6:46-7:17 (describing components of FIG. 9). The '133 Patent describes these components in terms of their functionality, rather than their circuit structure. For example, in describing "DC-AC Inverter 186," the '133 Patent states that "[t]he total combined DC power is inverted to AC power with voltage larger than 240V AC by the DC-AC inverter 168." *Id.* at 6:56–58.

[032] The '133 Patent does not contain any actual board-level circuit diagrams, which would identify components such as Application Specific Integrated Circuits (ASICs), transformers, capacitors, sensors, and the like. Given the conceptual, high level at which the systems and methods of the '133 Patent are described, I conclude that the appropriate level of skill in the art is not particularly high.

VII. THE '133 PATENT

[033] The '133 Patent relates to DC-AC inverters for use in photovoltaic (PV) systems, *i.e.* systems that convert solar energy into electrical power. The '133 Patent states that "[t]he subject of this patent relates to direct current (DC) to alternating current (AC) power inverters that invert DC power from single or multiple DC

power sources to single-phase or three-phase AC power, where the DC power source includes but is not limited to photovoltaic (PV) solar modules, fuel cells, batteries, and other DC power generators." '133 Patent, 1:7–13.

[034] An inverter is an electronic device that changes an electrical signal from direct current (DC) to alternating current (AC). In a DC circuit, the electrical current moves in one direction along the wire. In an AC circuit, the direction of current alternates such that, if one were to measure the magnitude of power flow at a point along the wire, the measurement would typically take the form of a sine wave. That is, the magnitude of the current flow increases first from zero to some maximum in a positive direction, drops back to zero, and then increases to some maximum in the negative direction. The voltage of an AC signal is also generally a sine wave, out of phase with the current waveform.

[035] One of the qualities of alternating current is that AC electrical power experiences lower losses when transmitted across long distance transmission lines, operating at high voltage and relatively low current. This is why AC is preferred over DC for transmitting electrical power over long distances, and it is why electrical power supplied through a local electrical utility "grid" is AC.

[036] A photovoltaic solar module ("PV module") (also called a solar cell or a solar module) is a device that converts solar radiation (*i.e.*, sunlight) into electrical energy. PV modules are sometimes provided in assemblies called "solar panels," which

themselves might be referred to as the PV modules. As explained in the '133 Patent, these PV modules generate DC electrical power. However, for that electrical power to be usable by household appliances or by the larger grid, it must first be converted into AC. Hence the need for an inverter—a device that transforms the DC signal into AC.

[037] The claims of the '133 Patent relate to systems (and methods) for inverters. For example, Claim 15 recites a "plurality of power inverters," each having a "single DC-AC inverter" with "at least two DC power input ports." Each inverter also has "an AC power input port" and "an AC power output port," where the plurality of inverters are connected in a "daisy chain" such that the AC output port of one inverter connects to the AC input port of the next inverter, except for the AC power input port of the first power inverter being left open and the AC power output port of the last inverter connecting to a "power service panel" of a grid.

[038] With respect to "daisy chain," the '133 Patent notes:

> Although we say the power inverters daisy chain, where the output port of each power inverter is connected to the input port of the next power inverter, the actual connection of the inverters is pass-through. That means, the generated AC power from each power inverter is added in parallel on to the AC powerline.

'133 Patent, 3: 61–66. Based on this language, a POSITA would understand that, when the '133 Patent refers to a "daisy chain," it is simply referring to an

arrangement of inverters wherein the AC output port of each inverter connects to an AC input port of the next inverter in the chain.[1]

[039] Claim 19, which is also an independent claim, recites "[a] method of making a DC to AC power conversion system incrementally scalable." Similar to Claim 15, Claim 19 recites "a plurality of DC to AC power inverters," each having a single DC-AC inverter, at least two DC input ports, and AC input and output ports. Although Claim 19 itself does not recite daisy chaining the multiple inverters, this is recited in Claim 22, which depends on Claim 19.

[040] FIG. 5 of the '133 patent illustrates an exemplary inverter architecture of Claims 15 and 19.

[1] I note that the term "daisy chain" could sometimes be used in the art to refer to systems of electrical components that were connected *either* in series or in parallel. However, because the '133 Patent specifically describes its daisy chained inverters as connected in parallel, I have selected prior art that similarly teaches connecting inverters in parallel (*i.e.*, Kondo).

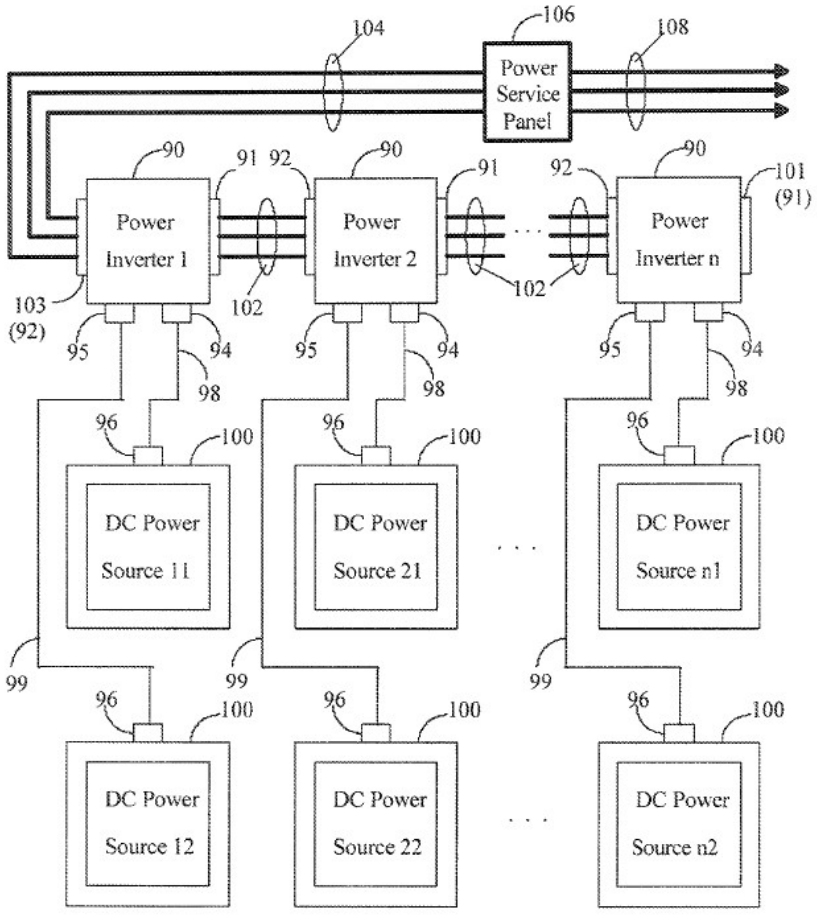


Fig. 5

[041] One aspect of solar inverters that is relevant to my opinions is "maximum power point tracking" or "MPPT." MPPT relies on "Ohm's Law," which describes the mathematical relationship between voltage, current, and resistance. Ohm's Law states that V=IR, where V is voltage (electrical potential), I is current (the flow of electrical charge), and R is resistance.

[042] This behavior of electricity, particularly in DC, is often analogized to the behavior of water. Voltage (or potential) is a measure of the pushing force that causes charge to flow in a wire. By analogy, voltage is like the height of water stored in an

elevated water tank, or the downward slope of a water pipe or a river. Current (or the rate of flow) is the measure of the amount of charge moving in a conductor, analogous to the amount of water flowing in a river, or over a waterfall. Resistance refers to the forces that tend to resist the flow of electricity, like rocks in a river or blockages in a water pipe. Ohm's law means that where there is more resistance, more force (or voltage) will be required to push the same amount of current. Electrical power, the rate of electrical energy transferred per unit time, is the product of voltage and current. That is, P=IV.

[043] The voltage and current output from a PV module can be plotted on an I-V curve for a given load (*i.e.*, a given resistance). Below is an example I-V curve for a typical PV module under different illumination conditions, taken from another of Patent Owner's patents[2].

[2] U.S. Patent No. 9,331,489

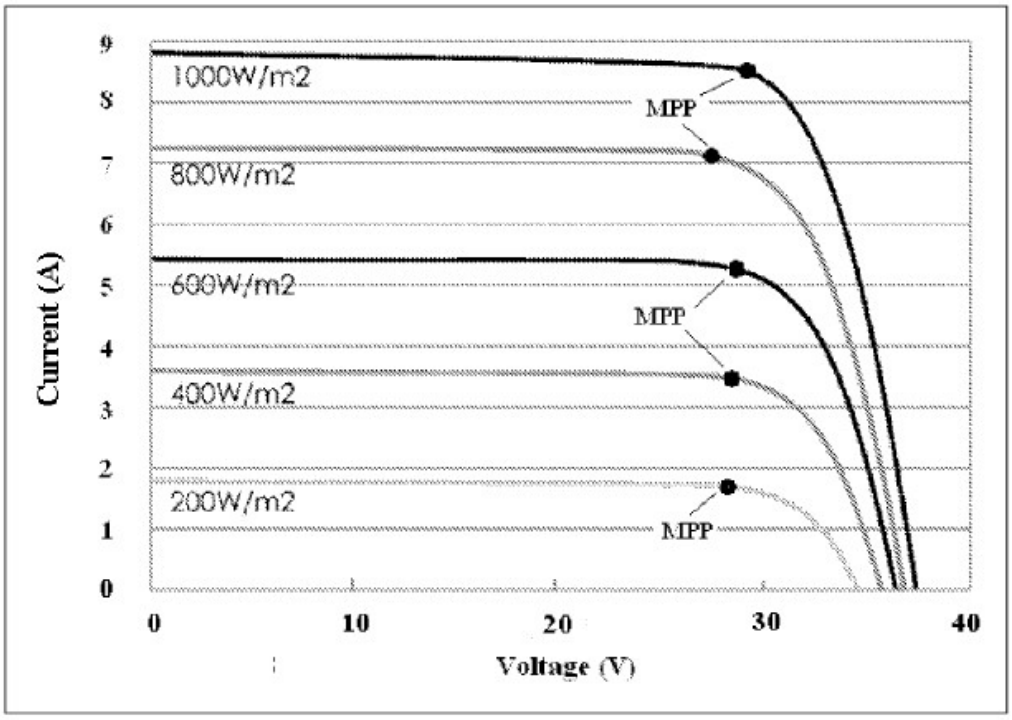


Fig. 1 (Prior Art)

[044] For each set of conditions, "MPP" refers to the "maximum power point," *i.e.* the point at which power generation is maximized. I note that the MPP typically occurs around the "elbow" of the I-V curve before the current begins to drop precipitously.

[045] I further note that the maximum power point changes based on the illumination of the panel. Although not depicted in the graph above, the MPP of a PV module can also change based on the age of the panel, temperature, or other environmental factors.

[046] Maximum power point tracking refers to a process of evaluating the PV module's I-V curve on a continuous or sampled basis to determine the optimal load

voltage that will maximize output power. Specifically, a "bias voltage" is presented to the output terminals of a PV module, equal to the output voltage of the module at the maximum power point. This was known in the prior art, as described by U.S. Patent Publication No. US2009/0000654 ("Rotzoll '654). *See* Rotzoll '654, [0008]. Similarly, U.S. Patent Publication No. 2009/0020151 ("Fornage") states that "[t]he cell should be biased at the Maximum Power Point (MPP) in order to extract the maximum power." *See* Fornage, [0007].

[047] Accordingly, solar inverters will often have bias voltage or impedance matching circuits that present the ideal bias voltage to the PV module. This function is generally provided by a DC-DC converter, which is also taught by the '133 Patent. *See* '133 Patent, 5:57–63 ("The MFA microcontroller preforms real-time control and optimization functions for the smart and scalable power inverter, in which Model-Free Adaptive (MFA) controllers are used to control the DC-DC boost converter, and MFA optimizers provide maximum power point tracking (MPPT) to allow the power inverter to achieve optimal power production.").

[048] Although Claims 15–24 of the '133 Patent do not recite either maximum power point tracking or the use of a DC-DC converter, these features will be relevant to my opinions regarding the motivation to combine certain prior art references.

VIII. OVERVIEW OF THE PRIOR ART

[049] The systems and methods of claims 15–24 of the '133 Patent were obvious in view of the state of the art as of July 16, 2009. These claims combine two well-known inverter architectures: i) shared inverters, *i.e.* inverters having multiple DC inputs; and ii) inverters connected in a "daisy chain."

[050] The 2005 IEEE paper by Kjaer, Pederson, and Blaabjerg, A REVIEW OF SINGLE-PHASE GRID-CONNECTED INVERTERS FOR PHOTOVOLTAIC MODULES, (2005) ("Kjaer") explains various solar inverter topologies that were known in the prior art. As illustrated in Figure 3(a) of Kjaer, reproduced below, early solar systems used a single central inverter. PV modules (*i.e.*, solar panels) would be connected in series and in parallel, and their combined DC output would be fed to the single inverter. Later, there were developed "string inverters," where a string of PV modules (themselves connected in series) would then connect to the inverter. This is shown in Figure 3(b). "Multi-string" inverters, shown in Figure 3(c), used multiple strings of PV modules, each connected to their own DC-DC converters. The outputs of those DC-DC converters would be fed to a single DC-AC inverter, which has multiple DC input ports and can produce 1 or 3 phase AC power. Finally, Kjaer discloses "AC-Modules," where each connected PV module has its own inverter.

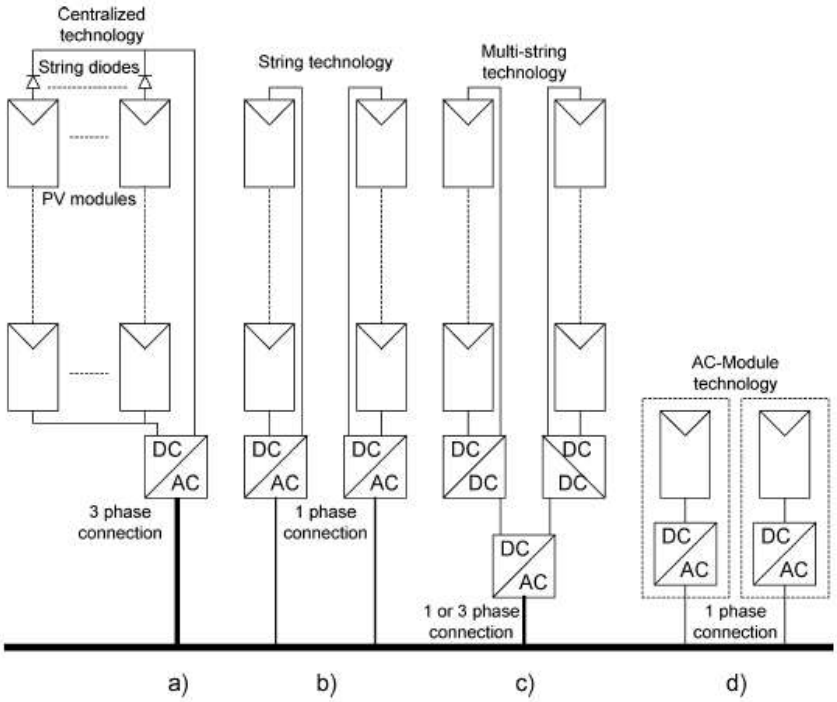


Fig. 3. Historical overview of PV inverters. (a) Past centralized technology. (b) Present string technology. (c) Present and future multi-string technology. (d) Present and future ac-module and ac cell technologies.

[051] Kjaer describes two advantages of multi-string topology: individual control and scalability/flexibility. Kjaer states:

> The multi-string inverter depicted in Fig. 3(c) is the further development of the string inverter, where several strings are interfaced with their own dc-dc converter to a common dc-ac inverter [7], [28]. This is beneficial, compared with the centralized system since every string can be controlled individually. Thus, the operator may start his/her own PV power plant with a few modules. Further enlargements are easily achieved since a new string with dc-dc converter can be plugged into the existing platform. A flexible design with high efficiency is hereby achieved.

Kjaer, pg. 1296.

[052] Because a multi-string inverter has multiple DC inputs, the user can start with one string of solar panels and add additional strings later as needed. When Kjaer refers to individual control, it is referencing the ability to bias each string differently

so that each string operates at its Maximum Power Point, increasing the overall efficiency. This is accomplished by providing a DC-DC converter for each connected panel or string, as I explain above.

[053] The ability to perform MPPT on each string individually is advantageous because each string may be of a different size, different type, or may experience its own unique sunlight conditions (*e.g.*, due to different panel location, shading, angle of incline toward the sun, or dirt on the solar panels). Therefore, each string may have a different optimal bias voltage. By operating each string at its maximum power point, overall power production can be maximized. The alternative would be to operate all strings at some average power point, which would be less optimal. *See e.g.* Rotzoll '654, [0008] ("Due to the nature of residential rooftops, the string design results in MPPT performance at the levels of the least power producing modules in the photovoltaic (PV) array. This degrades the AC power harvest for the entire array.").

[054] Another advantage of multi-input (*i.e.*, multi-string) inverters is the reduction in overall component cost, compared to an AC module configuration like the one shown in Fig. 3(d) of Kjaer. This is because there is no need for each string to have its own inverter. This was a significant consideration to operators of PV generating facilities near the time of the invention. *See* Kjaer, 1292 ("The cost of the grid-connected inverter is, therefore, becoming more visible in the total system price. A

cost reduction per inverter watt is, therefore, important to make PV-generated power more attractive [4]."); *see also* Rotzoll '118, [0006] ("there can be up to 1000 components in an inverter resulting in significant cost per unit energy").

[055] Thus, the multi-string inverter topology was known to be advantageous over alternatives such as AC modules (which were expensive because of the number of inverters needed) and centralized inverters (which jeopardize system reliability by having a single point of failure and which cannot perform MPPT on each connected panel).

[056] For these reasons, it is my opinion that a person of ordinary skill would have been motivated to incorporate a multi-input inverter topology—like that disclosed in Kjaer, Nishi, and Fornage—into the daisy chained inverter systems disclosed by Kondo.

A. Fornage

[057] Figure 5 of Fornage shows an inverter 300 with multiple DC inputs, each of which has its own DC-DC boost converter 508. The outputs of these DC-DC boost converters are provided to a single DC-AC inverter 510. I have reproduced Figure 5 below.

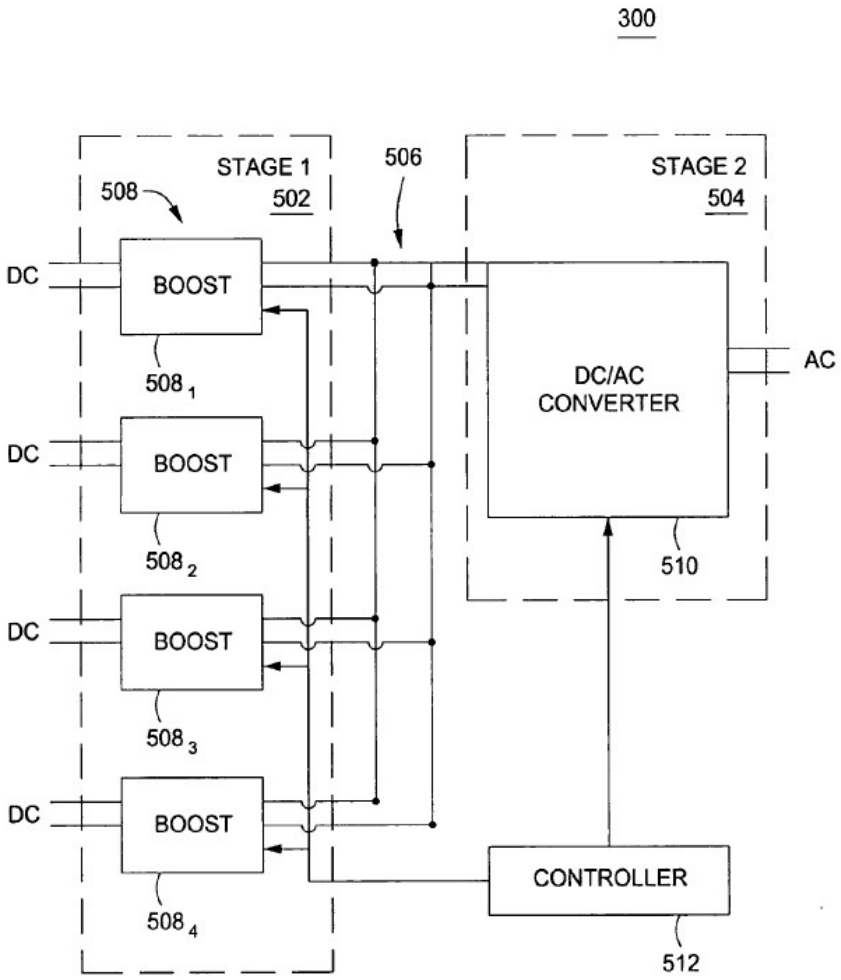


FIG. 5

[058] Fornage also discloses connecting DC inputs to DC sources such as solar panels. *See* Fornage, [0017].

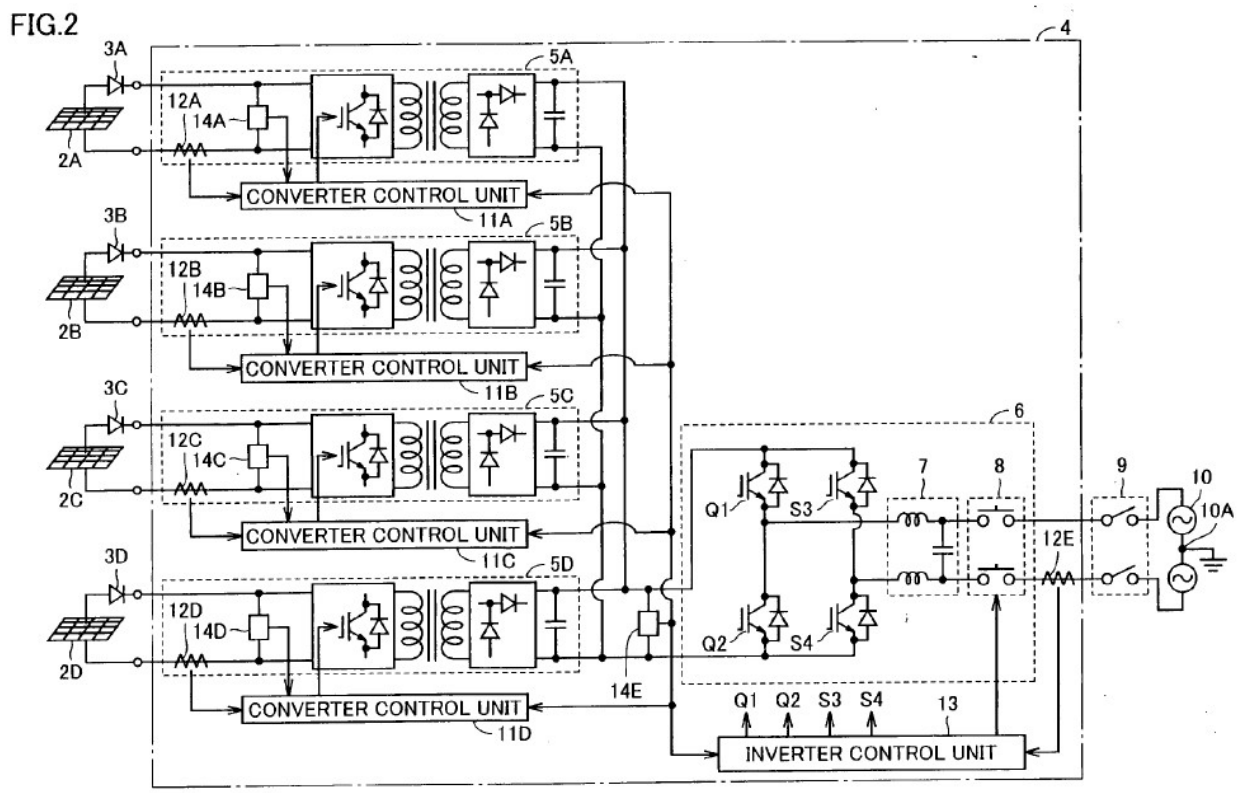
[059] Fornage teaches that one advantage of having a single inverter with multiple DC inputs is that each connected solar panel (or segments of a panel, like rows of individual solar cells) can be biased individually at its maximum power point. *See* Fornage, [0033] ("A controller 512 provides an individual control signal to each boost circuit 508 to ensure that the rows of cells coupled thereto operates at the row's

MPP. The boost circuits 508 are coupled by a DC bus 506, which . . . couples the combined DC outputs of the boost circuits, 508 to the DC/AC converter switching to convert DC to AC.").

B. Nishi

[060] Figure 2 of Nishi discloses an inverter 4 with multiple DC inputs, each connected to a solar panel 2_A–2_D. Each DC input is supplied to a respective DC-DC converter 5_A–5_D, the outputs of which are provided to a common DC bus. This DC bus is connected to a single DC-AC inverter 6. The AC output of the inverter is provided to a utility grid 10. I have reproduced Figure 2 below.

FIG.2



[061] Like Fornage, Nishi recognizes that one advantage of having a single inverter with multiple DC inputs is the ability to run each connected solar panel individually to maximize power production. *See* Nishi, [0077] ("Here, converter control units 11A-11D each calculate an output power of respective solar cell arrays 2A-2D based on corresponding input voltage detection value and input current detection value, and control respective converters 5A-5D so that the output power of respective solar cell arrays 2A-2D becomes maximum."), [0029] ("it is desirable that the inverter . . . can address a plurality of DC power sources with different output voltage ranges in order to perform efficient power generation").

[062] Nishi teaches that another advantage of a multi-input inverter system is the ability to combine DC power generated by different types of DC sources, not just PV modules, using a single inverter. *See* Nishi, [0115] ("a dispersed power-source system of a hybrid type can easily be structured with low costs and without reduction of efficiency"). Nishi calls these "hybrid systems" and provides an example illustration at Figure 6. *See* Nishi, [0108]–[0109]. In these hybrid systems, a single DC-AC inverter 6 can take DC power from connected solar panels 2_A–2_D and connected fuel cell 16. *See* Nishi, [0110]. A fuel cell is a device that converts energy from a chemical reaction (*e.g.*, oxidizing hydrogen) into DC electricity.

[063] Thus, it was well known in the art that a solar inverter could have multiple DC inputs, thereby receiving DC power from multiple individually connected PV

modules. Moreover, it was understood that such arrangements were advantageous because they could be scaled easily, allowed for maximum power point tracking on individual solar panels, and allowed for integration with non-solar DC sources.

C. Kondo

[064] Figures 1 and 2 of Kondo disclose a system of multiple inverters connected in a "daisy chain," with the AC output port of each inverter connecting to an AC input port of the next inverter. In this way, the AC output port of any given inverter outputs the combined power of that inverter plus the AC power received from the upstream inverter. I have reproduced Figures 1 and 2 below.

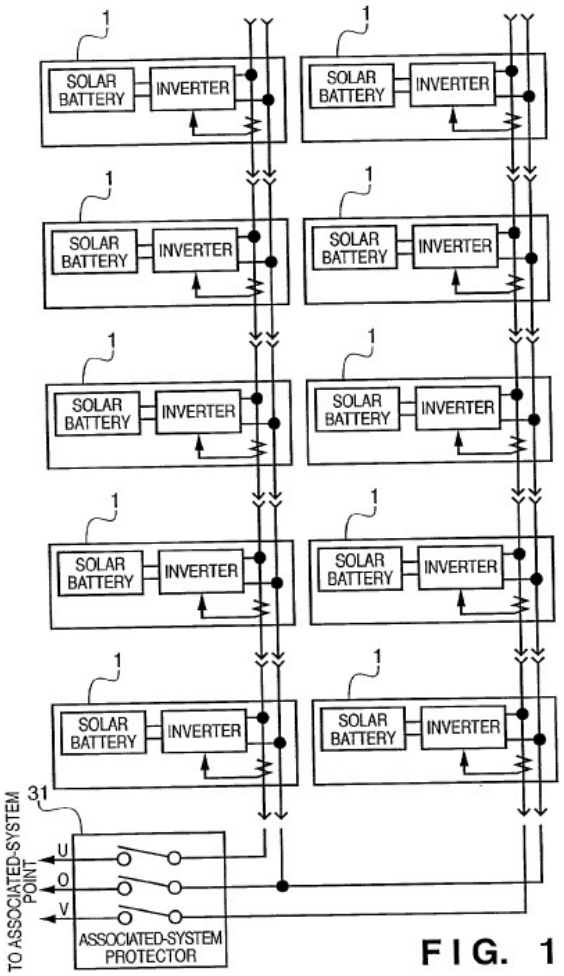


FIG. 1

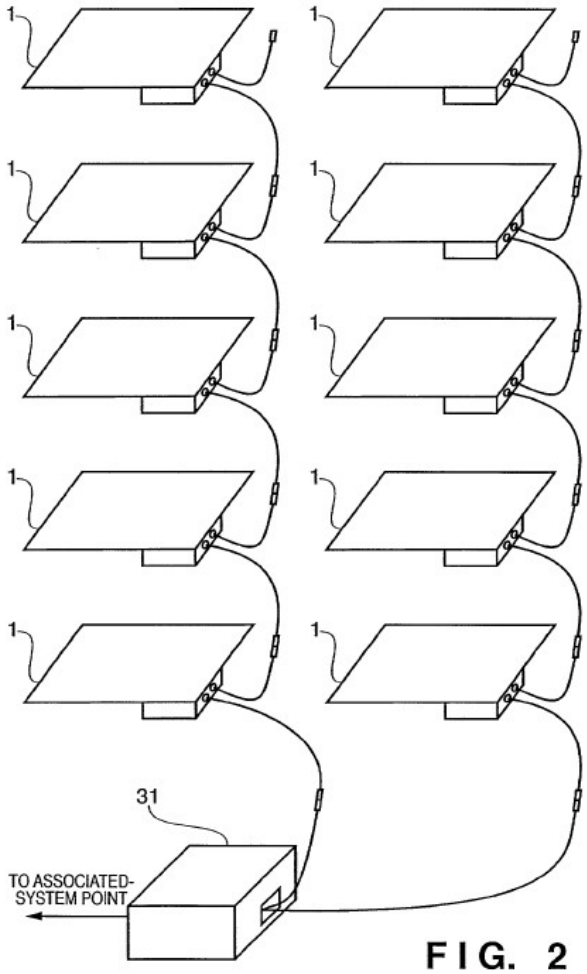
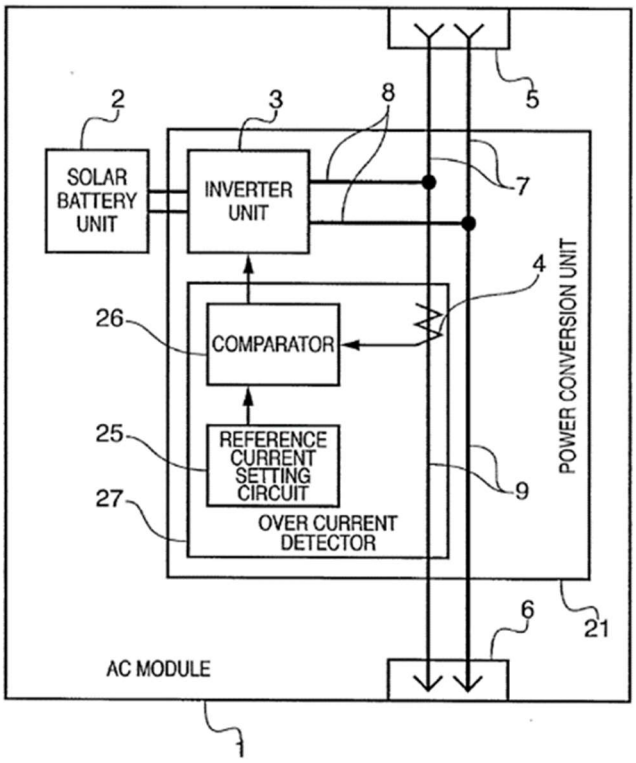


FIG. 2

[065] Figure 3 of Kondo provides a detailed view of an individual "AC module" 1. Kondo's AC module includes a solar battery unit 2 (*i.e.*, a PV module or solar cell) and a power conversion unit 21. I have reproduced Figure 3 below.

FIG. 3



[066] Kondo explains, "[p]referably used as the solar battery unit 2 is one employing amorphous silicon, or polycrystalline silicon or crystalline silicon in its photoelectronic transducer." Kondo, [0031]; *see also* [0002] (referring to "power generated by a solar battery"). Thus, a POSITA would understand that these "solar batterie units" are photovoltaic cells, *i.e.* silicon semiconductor devices that generate DC electrical power from solar energy.

[067] Kondo discloses that power conversion unit 21 includes a DC-AC inverter (depicted in Fig. 3 as "inverter unit" 3). *See* Kondo, [0033]. The inverter unit is described in detail at paragraphs [0034]–[0040] and Figure 5 of Kondo.

[068] Returning to Figure 3 of Kondo, AC module 1 includes an AC input port 5 and an AC output port 6. According to Kondo, "[t]he converted AC power is collected together with AC power, which is inputted from an input connector 5, and then outputted to an output connector 6." Kondo, [0033]. Kondo further explains:

> The DC power generated by the solar battery unit 2 is converted to AC power by the inverter unit 3, sent through the current path 8, collected together with the power, which is generated by other AC modules 1 and inputted from the input connector 5, then sent through the current path 9, and outputted to the output 6.

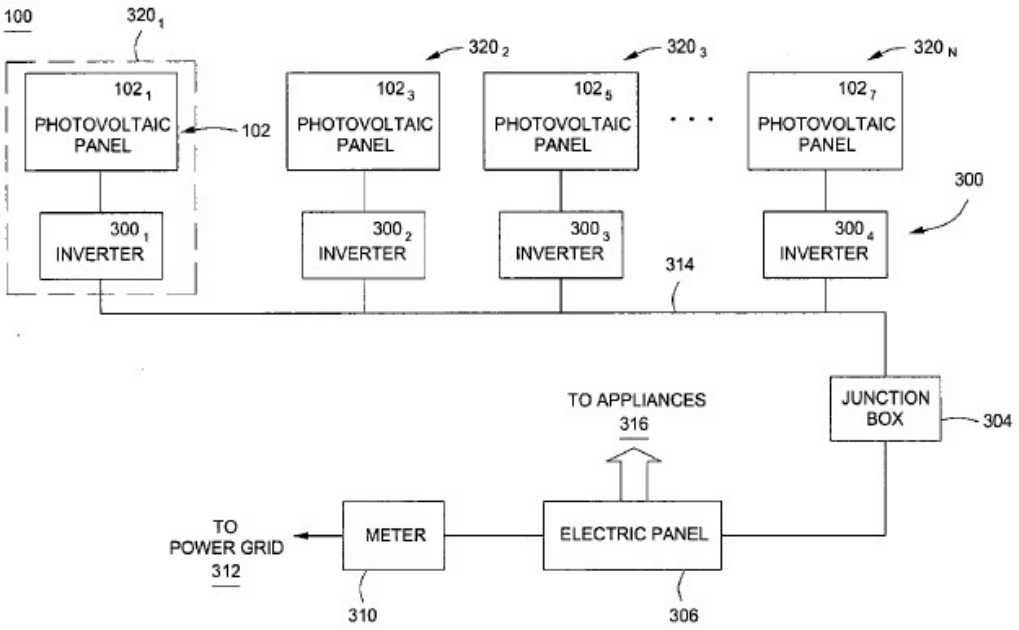
Kondo, [0051]. This means what I explain above. Kondo's inverters combine i) the AC power that was received from the DC inputs and inverted by the DC-AC inverter unit, with ii) the AC power received from upstream inverters via the AC input port. The combined AC power is then output through AC output port 6.

[069] Kondo also discloses that, in the daisy chain arrangement, the first inverter in the chain would have nothing connected to its AC input port. *See* Kondo, [0048] ("As shown in Fig. 1, the input connector 5 of the AC module 1, which is connected at the end of the cascade connection, is unconnected. Therefore, a receptacle that does not allow easy contact with the electrically activated portion is used for the input connector 5"). In addition, Kondo discloses that the AC output port of the last

inverter in the chain connects to a "commercial-use power system," *i.e.* a power grid. *See* Kondo, [0026] ("An associated-system protector 31, comprising a switch and a system abnormality detector, is provided between the AC module 1 and a commercial-use power system").

[070] Kondo describes several advantages to daisy chaining inverters through connected AC input and output ports. First, Kondo notes that the number of inverters in the system can easily be increased. *See* Kondo, [0025] ("Connecting the input connector with the output connector of the AC module 1 as shown in FIGS. 1 and 2 enables to increase the number of parallel connection [*sic*] of the AC module 1").

[071] One alternative to daisy chaining inverters would be connecting the multiple inverters to a common AC bus. This is illustrated, for example, in Figure 3 of Fornage, which I have reproduced below.



[072] Kondo describes a disadvantage of this kind of AC bus arrangement: there is a risk that too much current will be supplied to the bus, especially under unexpectedly bright illumination conditions. *See* Kondo, [0004] ("an improvident increase of the number of connections causes the current in a connector or current path of the AC module to exceed the rated current"). In prior art AC bus systems, this meant the entire system of inverters would have to be shut off from the grid. *See* Kondo, [0026] ("When the associated-system protector 31 detects a voltage increase of the system, a frequency abnormality, a power failure or the like, it turns off the switch to disconnect the photovoltaic power generation apparatus from the system").

[073] Kondo teaches that its daisy chain arrangement directly addresses this problem. Each of Kondo's AC modules includes an overcurrent detector (27 in Fig. 3) which senses the current level on current path 9 using current detector 4. *See* Kondo, [0042]–[0046]. When the current through one of Kondo's AC modules exceeds a set value, the inverter unit 3 in that module is shut off. *See* Kondo, [0046]. However, the remaining inverters continue to operate and continue to supply power to the grid. *See* Kondo, [0056]–[0057].

[074] This presents a significant advantage over prior art systems. The key element is that—rather than connecting each inverter to an external AC bus—Kondo routes the combined AC current through each inverter. This means every inverter in the chain has the ability to sample the total amount of current accumulated. The system

can then selectively shut down only the inverters that contribute excess current, above the system's threshold.

[075] I note that Kondo does not use the term "daisy chain." Kondo instead describes its inverters as being connected "in parallel" or "in a cascade." *See* Kondo, Abstract, Cl. 8. In my opinion, a POSITA would understand this to be a "daisy chain" connection, at least as that term is used in the '133 Patent. Being connected "in parallel" means that Kondo's inverters operate at the same voltage, and the current (and power) supplied by all inverters is combined. This is how the '133 Patent describes its "daisy chain" connections:

> Although we say the power inverters daisy chain, where the output port of each power inverter is connected to the input port of the next power inverter, the actual connection of the inverters is pass-through. That means, the generated AC power from each power inverter is added in parallel onto the AC powerline.

'133 Patent, 3:61–66.

[076] Therefore, if the '133 Patent teaches daisy chaining multiple inverters, then so does Kondo. Both describe inverters that are connected one after another, such that the AC output port of each inverter connects to the AC input port of the next inverter. And both describe their inverters as connected electrically in parallel, such that total power is equal to the sum of the power generated by each individual inverter.

[077] Thus, the two critical elements of the challenged claims—multiple DC input ports and daisy chaining multiple inverters—are conventional elements that were well known in the prior art. These elements could be combined in a predictable manner to increase the reliability of solar inverter systems, reduce their cost, and achieve higher power efficiency, all with a high chance for improved system performance.

IX. CLAIM CONSTRUCTION

[078] I understand that claims in an IPR are given their ordinary and customary meaning as understood by one of ordinary skill in the art considering the specification and prosecution history.

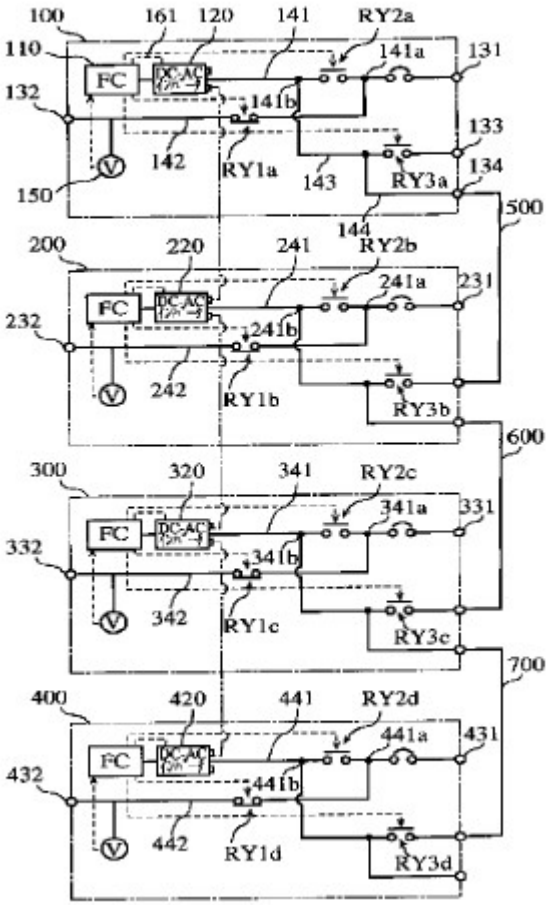
[079] I note that the terms of the ’133 Patent have not yet been construed by any Court. In the District Court litigation between Petitioner and Patent Owner, the parties have only just begun the claim construction process. I have been informed that Patent Owner contends the terms of the ’133 Patent should be assigned their plain and ordinary meaning. For purposes of this Declaration, that is how I have construed the terms of challenged claims.

X. FILE HISTORY OF THE ’133 PATENT

[080] I have reviewed the file history of the ’133 Patent, which I understand is the record of negotiation between the patentee and the Patent Office.

[081] I understand that the initial versions of Claims 15 and 19 were rejected over Japanese Patent Publication No. JP09275637, which is referred to in the file history as both "Ishizawa" and "Aoki." I will refer to this reference as "Aoki." While I have not reviewed an English translation of that reference, there appears to be a copy of the original Japanese document in the file history, which includes a figure showing an inverter apparatus. I have reproduced that figure (Fig. 1) below.

【図１】



[082] The Examiner noted that Aoki discloses a plurality of inverters, each with a DC input port. *See* Office Action, June 12, 2013, pp. 3–4. Aoki's DC sources are the

fuel cells marked "FC," and each is connected to a DC-AC inverter (120, 220, *etc.*, marked "DC-AC"). The Examiner also noted that each of Aoki's inverters includes an AC input port and an AC output port. The AC input ports are "respective input ports 333[3]," and the AC output ports are "respective output ports 134." *See id*.

[083] Based on Figure 1 of Aoki, I agree with the Examiner that 134 and the corresponding terminals in the other devices are AC output ports. This is evident because of the connections to the DC-AC inverters. I further agree that 133 and the corresponding terminals in the other devices are AC input ports. This is evident because each of these terminals connects to the AC output port of the previous inverter in the chain. For example, AC output port 134 of device 100 is connected to the terminal on device 200 that corresponds to terminal 133 on device 100. Thus, Aoki's inverters are connected in a daisy chain in the same way as those of the '133 Patent.

[084] The Examiner further noted that connecting a power generation system to the grid through a power service panel was generally known in the art and would have been obvious to incorporate into a system of solar inverters.

> Official Notice is taken that both the concept and advantages of providing a power service panel connection from a supplemental utility grid co-generation system and providing power to the utility grid are well known and expected in the art. It would have been obvious to have

[3] This appears to be a clerical error by the Examiner as I believe he meant to identify input ports 133, rather than 333.

> included the power service panel in Aoki as these panels are known to provide known and desirable power connections from a co-generation system for use on the utility grid.

Office Action, June 12, 2013, p. 4.

[085] I agree with the Examiner's analysis. It was well known in the prior art to connect solar power generation systems to the commercial electric grid through a service panel. This was done, *e.g.* in typical home solar power setups because it allowed the home to receive solar power through the service panel, in the same way that it received power from the grid. An advantage of this setup was that the service panel could include circuit breakers that would disconnect household circuits when the current drawn by those circuits got too high. Moreover, excess solar power could be sold to the grid, often for payment or credit from the utility company.[4] Therefore, it would have been obvious to incorporate this feature into, *e.g.*, the system of Aoki.

[086] The Examiner further noted that outputting either single-phase or three-phase AC was well known in the art.

> Official Notice is taken that both the concept and advantages of providing for single or three phases power in power inversion systems are well known and expected in the art. It would have been obvious to have included the desirable number of phases (single or three) in Aoki's inverter system as the number of phases are known to be readily chosen depending on the needs of the connected grid/load.

Office Action, June 12, 2013, p. 5.

[4] This kind of arrangement is described *e.g.* in paragraph [0027] at Fornage.

[087] I agree with the Examiner's analysis. Both single-phase and three-phase power, and their advantages, have been known for over a century. In a single-phase system, power is transmitted on a single conductor, and the current and voltage waveforms are a single sine wave. In a three-phase system, three wires are used, and the voltage and current waveforms are shifted 120 degrees relative to one another. Single-phase has generally been used in homes whereas three-phase has generally been used in industrial/commercial environments. I agree with the Examiner that it would have been obvious to a POSITA to configure an inverter system to output either single-phase or three-phase AC, depending on whether the inverter is for residential or commercial purposes.

[088] Returning to the file history, the applicant responded to the rejection in view of Aoki by amending the claims that would eventually be issued as Claims 15 and 19. Specifically, the applicant amended these claims to recite "a plurality of power inverters, each of said power inverters having at least two DC power input ports." Response to Office Action, August 15, 2013, p. 11 (amended Claim 21). The applicant then argued that Aoki's inverters each have only a single DC input port:

> Ishizawa et al. is directed to a system in which a number of fuel cells are operated in parallel. Although the system of Ishizawa et al. includes a plurality of power inverters, or owner inverter is provided for each fuel cell. Nowhere in Ishizawa et al. is there any teaching or suggestion as to how a single power inverter might have multiple DC input ports.

Response to Office Action, August 15, 2013, p. 15.

[089] The Examiner appears to have been convinced by this argument because the claims were deemed allowable as amended. The Examiner stated in the reasons for allowance:

> Claims 26-32 in the application are deemed to be directed to an nonobvious improvement over the prior art of record, particularly Erickson, JR. et al. US 2012/0025618; Stren US 2010/0237703; Dennis et al. US 2011/0273022; Rotzoll et al. US 2008/0283118; and Bower et al. US 2003/0111103 teach systems for providing AC power to a grid from a plurality of sources/converters.
>
> The primary reason for allowance of the claims is the inclusion of the particular port configuration further comprising both an AC input port coupled to the single DC-AC inverter and the AC output port coupled to the single DC-AC inverter.

Notice of Allowance, April 4, 2014.

[090] With due respect to the Patent Office, the Examiner appears to have misstated the reasons for allowance. The Examiner states that the claims are allowable because the prior art fails to teach "both an AC input port coupled to the single DC-AC inverter and the AC output port coupled to the single DC-AC inverter." But these are the exact features that the Examiner found to be taught by Aoki (*i.e.* 133 and 134 in Figure 1 of Aoki).[5] Rather, it appears the Examiner granted allowance of the

[5] The Examiner also cited Rotzoll '118 as one of the prior art references considered during prosecution. Figure 2 of Rotzoll '118 plainly also discloses each inverter having AC input and output ports, as well as daisy chaining multiple inverters. *See* Rotzoll '118, Fig. 2, [0008]; *see also* [0015] ("There are, according to one embodiment, two inverter mounting bracket AC connections to support daisy-chain connections between multiple AC modules").

claims based on the inclusion of "each of said power inverters having at least two DC power input ports."

[091] I agree that Figure 1 of Aoki does not appear to show each DC-AC inverter having two or more DC input ports. However, as I explain above, this feature was already well known in the art, for example as taught by Fornage and Nishi. For the reasons below, it would have been obvious to combine the elements of daisy chaining multiple inverters and connecting multiple DC inputs to each inverter.

XI. INVALIDITY OPINIONS

A. Ground 1: Kondo and Nishi

[092] In my opinion, Claims 15–16, 18–20, and 22–24 of the '133 Patent are unpatentable because they are obvious over the combination of Kondo and Nishi. In this combination, I am using Kondo as the starting point and showing how it would have been obvious to modify Kondo based on the teachings of Nishi.

[093] Kondo describes a system of daisy chained solar inverters, wherein each inverter has an AC power input port and an AC power output port. In my opinion, it would have been obvious to modify Kondo's inverters so that each can accept DC input from more than one connected DC source, as taught by Nishi. A POSITA would be motivated to make this change because they would see it as providing improved scalability, improved reliability, improved efficiency, and reduced component cost.

[094] Below, I discuss the elements of the challenged claims and how they are taught by Kondo and Nishi.

Cl. 15, Pre(1): A scalable DC to AC power inversion system for providing AC power to a power grid

Cl. 19, Pre: A method of making a DC to AC power conversion system incrementally scalable, comprising:

[095] Kondo discloses a DC to AC power inversion system, *i.e.* a system that converts DC to AC. In Kondo, "power conversion unit 21 converts DC power supplied from the solar battery unit 2 to 50/60 Hz and 100V AC power." Kondo, [0033].

[096] Kondo's system is also scalable because additional AC modules can be added to the system, as shown in Figures 1 and 2. Kondo also explicitly states that "AC module, integrating a solar battery and an inverter, can easily be connected with other plural AC modules in parallel by way of cascade connections." Kondo, Abstract.

[097] Kondo's system also supplies AC power to a power grid, which Kondo refers to as the "commercial use power system." *See* Kondo, [0026]. This is illustrated in Figure 1 of Kondo, which shows that the arrangement of inverters connects "to associated system point." *See* Kondo, Fig. 1; *see also* [0002] (referring generally to "suppl[ying] a commercial-use power system with AC power obtained by an inverter performing DC/AC conversion of power generated by a solar battery"). I also note

that the Examiner concluded it would have been obvious to connect a power generation system to the grid through a power service panel, for this was well known in the art.

Cl. 15, Pre(2): from a plurality of individual DC power sources each having a DC power output port, comprising:

Cl. 19(a)(1): providing a plurality of DC power sources

[098] Kondo discloses receiving DC power from a plurality of DC power sources. In Figures 1, 3, and 4 of Kondo, these DC power sources are shown to be "solar batteries." Kondo further explains, "[p]referably used as the solar battery unit 2 is one employing amorphous silicon, or polycrystalline silicon or crystalline silicon in its photoelectronic transducer." Kondo, [0031]; *see also* [0002] (referring to "power generated by a solar battery"). Thus, a POSITA would understand that these "solar batteries" are photovoltaic cells, *i.e.* a silicon semiconductor device that converts solar energy into DC electrical energy.

[099] A POSITA would recognize that Kondo's solar batteries must have some sort of output port, in order for electrical energy to be transmitted from the battery to the inverter. Kondo states that "DC power is outputted from an electrode (not shown) of the solar battery unit 2." Kondo, [0031]. This electrode would connect to "DC input terminal 18" of Kondo's power inverter 3, as shown in Figure 5. *See also* Kondo, [0036]. Thus, Kondo discloses a plurality of individual DC power sources (*i.e.*, solar batteries) each having a DC power output port (*i.e.*, electrode).

Cl. 15(a)(1): a plurality of power inverters, each of said power inverters including a single DC-AC inverter,

Cl. 19(a)(2): and a plurality of DC to AC power inverters, said DC to AC power inverters each having a single DC-AC inverter,

[100] Kondo's power inversion system includes a plurality of "inverters," as depicted in Figure 1. These inverters are also depicted in Figure 3 as the "power conversion unit" 21. *See* Kondo, [0033] ("The power conversion unit 21 converts DC power supplied from the solar battery unit 2 to 50/60 Hz and 100V AC power").

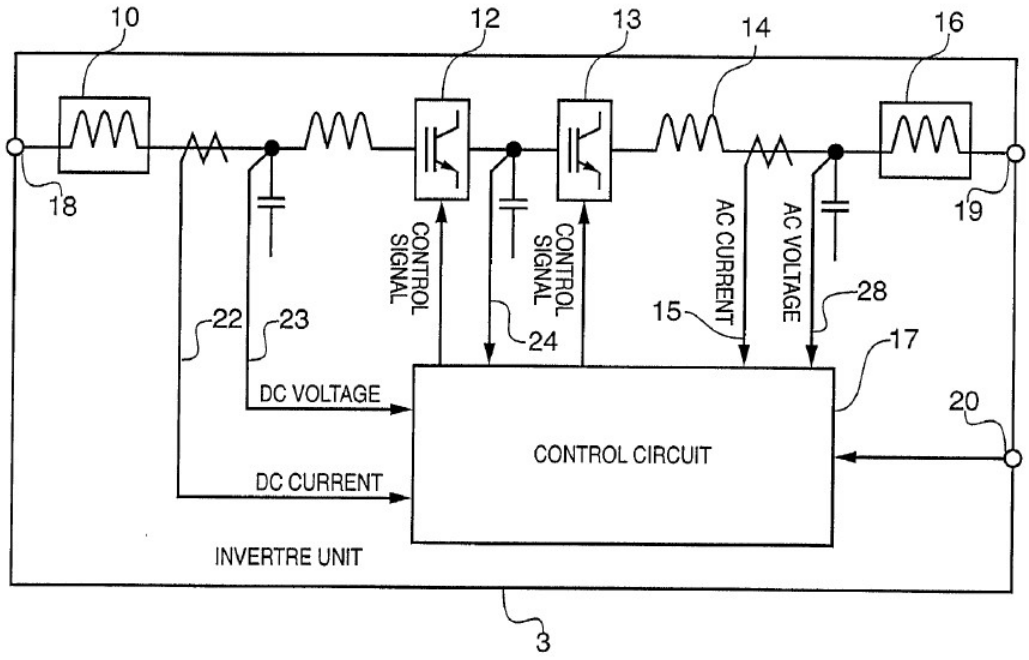
[101] Kondo further discloses that each inverter includes a single DC-AC inverter, depicted as "inverter unit" 3 in Figure 3. *See* Kondo, [0033] ("The power conversion unit 21 comprises an inverter unit 3, an over current detector 27, and current paths 7, 8, and 9"). The inverter unit is shown in more detail in Figure 5 of Kondo.

Cl. 15(a)(2): at least two DC power input ports coupled to the single DC-AC inverter,

Cl. 19(a)(4): and at least two DC input ports coupled to the single DC-AC inverter;

[102] The inverters used in Kondo's DC to AC power inversion system each have a single DC power input port. For example, Figure 3 of Kondo depicts a single solar battery unit 2, which provides electrical energy to power conversion unit 21 / inverter unit 3 at a single point. Likewise, Figure 5—which provides a more detailed view of inverter unit 3—shows a single "DC input terminal 18." *See* Kondo, [0036]. I have reproduced Figure 5 of Kondo below.

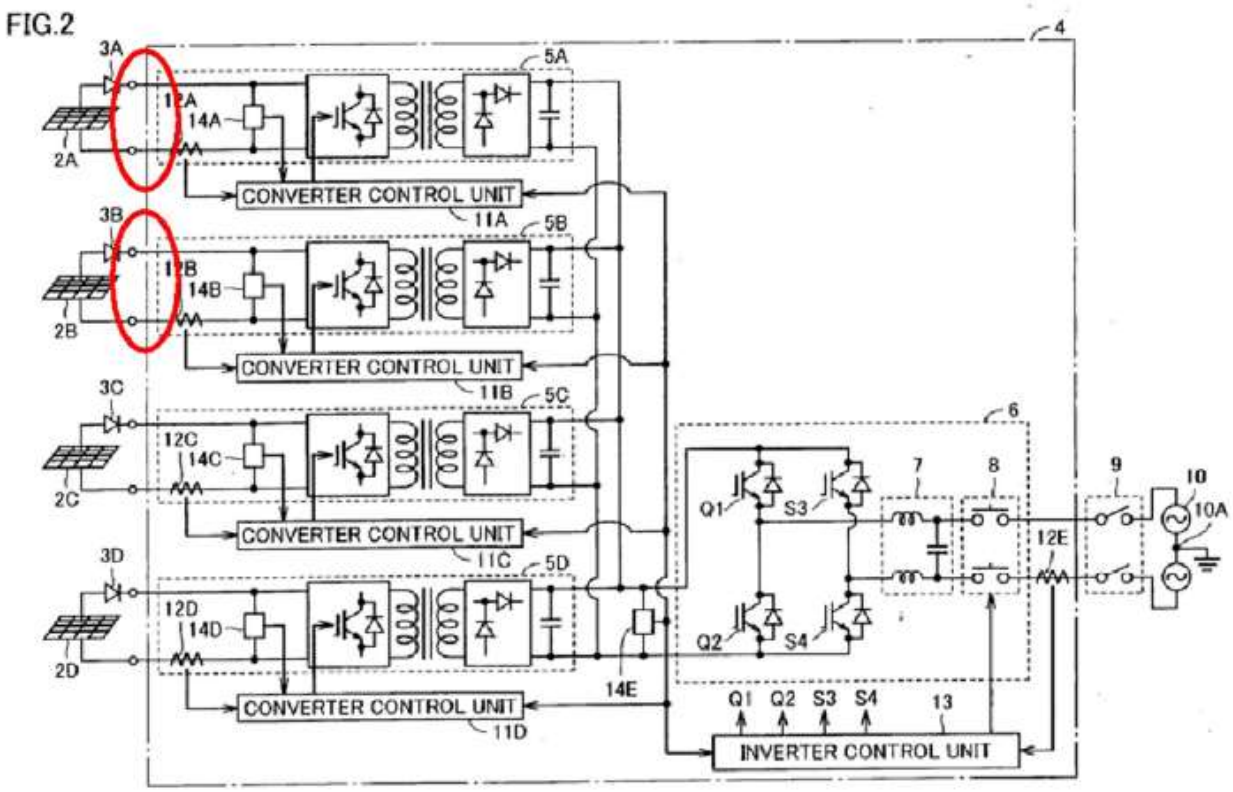
FIG. 5



[103] Figure 5 of Kondo shows that, in Kondo's inverter unit, DC power is received through input port 18 and then supplied to a boost circuit 12. *See* Kondo, [0036]. Kondo describes how "[t]he DC voltage, about 25V, which is imputed to the DC input terminal 18, is converted to 160V DC voltage by the booster circuit 12 which includes a boost chopper." Kondo, [0036]. Kondo further describes how "[a]t this stage, the control circuit 17 performs the well-known optimum operation point tracking control based on DC current 22 and DC voltage 23." Kondo, [0036]. Kondo's reference to "optimum operation point tracking" is synonymous with the concept of maximum power point tracking ("MPPT") that I discussed previously.

[104] Nishi discloses an "inverter apparatus" 4, which is described in paragraphs [0038], [0068], and [0070]. According to Nishi, this inverter apparatus includes a

single DC-AC inverter 6, which is depicted in Figure 2 and described at paragraphs [0038] and [0067]. Figure 2 of Nishi shows that the inverter apparatus has four DC power input ports, each of which takes DC input from a connected solar cell array 2_A–2_D. *See* Nishi, [0060]–[0063] (describing solar cell arrays). Below, I have reproduced Figure 2 of Nishi and highlighted two of these DC input ports in red.



[105] Paragraph [0063] of Nishi confirms that these solar cell arrays "each output a DC voltage." Further, each of the DC input ports connects to a DC-DC converter (depicted in Figure 2 as 5_A–5_D), the outputs of which are combined on a DC bus. The bus provides the combined DC power to inverter 6. *See* Nishi, [0067] ("Inverter

6 receives a DC power, which is a combined DC power of every DC power outputted from each of converters 5A-5D").

[106] It would have been obvious to incorporate Nishi's teachings of providing multiple DC inputs to a single inverter into Kondo's system for daisy chaining multiple inverters. A POSITA would have been motivated to incorporate Nishi's multi-input inverter into Kondo because it permits each inverter to optimize the DC power output of more than one connected string of PV modules, thereby increasing efficiency and reliability of the system while offering scalability, and because it reduces component cost by allowing multiple DC sources to share a single inverter.

[107] Nishi describes as much where it states, in regard to Figures 1 and 2:

> "converter control units 11A–11D each calculate an output power of respective solar cell arrays 2A–2D based on corresponding input voltage detection value and input current detection value, and control respective converters 5A–5D so that the output of respective solar cell arrays 2A–2D becomes maximum."

Nishi, [0077]. This is advantageous because each string may have different sunlight conditions, and maximizing input power on each individual string (*i.e.*, by operating each string at a different voltage) maximizes the overall power. *See* Nishi, [0061]–[0063] (describing how different solar arrays receiving different amounts of sunlight will have different output voltage) and [0065] (stating that parallel DC-DC converters can adjust solar cell output voltage of all cells to maximize power).

[108] A POSITA would further be motivated to add multiple DC inputs to Kondo's inverters, as taught by Nishi, because this would enable incorporation of other kinds of DC power sources, such as fuel cells. Nishi discloses as much in Figure 6, which shows an inverter receiving DC inputs from solar panels 2_A–2_D as well as from fuel cell 16. *See* Nishi, [0110]. Nishi further notes that "it is highly advantageous to structure a dispersed-power-source system of a hybrid type that is higher in efficiency and lower in costs." Nishi, [0035]; *see also* [0047] (emphasizing the advantages of receiving power from different kinds of power sources).

[109] Incorporating Nishi's multi-input inverter into the system of Kondo would be a simple substitution of one known element for another, yielding predictable results. Kondo already discloses one DC input (18 in Figure 5), a DC-DC boost converter ("boost circuit 12"), and a controller ("control circuit 17") for performing MPPT. *See* Kondo, [0036] ("At this stage, the control circuit 17 performs the well-known optimum operation point tracking control based on DC current 22 and DC voltage 23"). Modifying Kondo based on Nishi would simply involve providing additional DC inputs and additional boost circuits controlled by Kondo's existing controller. The total DC output of the boost circuits could be combined on a DC bus, as taught by Nishi, and then provided to Kondo's DC-AC inverter. It would not be difficult for a POSITA to do this in view of Nishi's disclosure. The wiring is elementary and would simply involve replicating Kondo's components (*e.g.*, input port 18 and boost

circuit 12), connecting the outputs from the boost circuits to a common DC bus, and then connecting that bus to Kondo's DC-AC inverter 13.

[110] Alternatively, the POSITA could simply substitute Nishi's inverter 4 for Kondo's power conversion unit, while retaining Kondo's AC input and output ports. This would retain Kondo's flexibility and ability to detect overcurrent conditions. Indeed, if the goal was to increase the number of DC inputs, a POSITA would recognize the risk of overcurrent conditions (as taught by Kondo) and would therefore be motivated to keep Kondo's daisy chain arrangement, under which each inverter in the daisy chain can detect and address overcurrent.

Cl. 15(a)(3): an AC power input port, and an AC power output port coupled to the single DC-AC inverter,

Cl. 19(a)(3): an AC input port coupled to the single DC-AC inverter, an AC output port coupled to the single DC-AC inverter,

[111] Kondo's power inverters each have an AC power input port 5 and an AC power output port 6, both of which are coupled to the inverter unit 3. This is depicted in Figure 3 of Kondo, where current paths 8 and 9 connect the AC input and output ports respectively to the inverter. *See* Kondo, [0051] ("The DC power generated by the solar battery unit 2 is converted to AC power by the inverter unit 3, sent through the current path 8, collected together with the power, which is generated by other AC modules 1 and inputted from the input connector 5, then sent through the current path 9, and outputted to the output connector 6"); *see also* [0033] ("The converted

AC power is collected together with AC power, which is inputted from an input connector 5, and then outputted to an output connector 6").

Cl. 15(a)(4): each of said DC power input ports having one DC power source connected thereto;

Cl. 19(b): connecting at least one of said DC power sources, respectively, to each of said DC input ports; and

[112] As I explain above, both Kondo and Nishi disclose DC power input ports (terminal 18 in Figure 5 of Kondo, or the connections shown above in Figure 2 of Nishi) that are connected to DC sources, which would be Kondo's solar battery unit 2 (*see* Kondo Fig. 3) and Nishi's solar cell arrays 2_A–2_D (or fuel cell 16).

Cl. 15(b)(1): said AC power output port of each power inverter being connected in a daisy chain to the AC power input port of the next power inverter,

Cl. 22(a): The method of claim 19 further comprising daisy-chaining at least two of said DC to AC power inverters, said AC power output port of each DC to AC power inverter being connected in a daisy-chain to the AC power input port of the next DC to AC power inverter,

[113] As I explain above, Kondo discloses a system of daisy chained inverters, wherein the output port of each inverter is connected to the AC input port of the next inverter. This is illustrated in Figures 1 and 2 of Kondo.

Cl. 15(b)(2): except for the AC power input port of the first power inverter being left open,

Cl. 22(b): except for the AC power input port of the first DC to AC power inverter being left open,

[114] As I explain above, Kondo discloses that the AC power input port of the first inverter in the daisy chain is left open. This is depicted in Figure 2 of Kondo, where the uppermost left-hand inverter has its AC input port left open. Kondo also describes this feature explicitly at paragraph [0048], saying "the input connector 5 of the AC module 1, which is connected at the end of the cascade connection, is unconnected."

> **Cl. 15(b)(3):** **and the AC power output port of the last power inverter being connected to a power service panel of the power grid;**
>
> **Cl. 19(c):** **providing AC power to the power grid.**
>
> **Cl. 22(c):** **and the AC power output port of the last DC to AC power inverter being connected to a power service panel of the power grid.**

[115] Kondo discloses that the AC power output port of the last inverter is connected to a power service panel of a power grid. Specifically, Figures 1 and 2 of Kondo show the last power inverter is connected to an "associated system point" through an "associated system protector" 31, which is depicted as a breaker panel including breaker switches like the kind that would be present in a utility customer's service panel. A POSITA would understand that Kondo's "associated system point" is a power grid, what Kondo refers to as the "commercial use power system." *See* Kondo, [0026]. A POSITA would further understand that the associated system protector 31 is a service panel, particularly in view of Kondo's teaching that "associated system protector 31, comprising a switch and a system abnormality detector, is provided

between the AC module 1 and a commercial-use power system." This is describing a service panel.

[116] To the extent Kondo does not explicitly disclose connecting the AC output port of the last inverter to a power service panel of a power grid, I agree with the Examiner's observation that this would be obvious in view of a POSITA's general knowledge in the art.

[117] Alternatively, it would be obvious to incorporate this element into Kondo based on the teachings of Nishi. Figure 2 of Nishi shows that inverter 4 is connected to "commercial power system" 10 via a "breaker" 9. *See* Kondo, [0097] ("The AC power outputted from inverter 6 is supplied to commercial power system 10 and household loads, which are not shown, via leakage breaker 9"). A POSITA would understand that the breaker 9 is a utility customer's service panel, which includes circuit breakers that can isolate the customer's home from the grid.

[118] Finally, to the extent neither Nishi nor Kondo disclose this element, it would have been obvious in view of, *e.g.*, Fornage. Figure 3 of Fornage explicitly discloses an "electric panel" 306, which is connected to "power grid" 312. Fornage also describes the advantage of this arrangement, which is enabling the owner of the photovoltaic system to sell excess electricity to the utility or at least offset the cost of power from the utility. *See* Fornage, [0005], [0027]. Fornage's teachings of the

advantages of this arrangement would motivate a POSITA to incorporate this claim element into the combination of Kondo and Nishi.

Cl. 15(c): whereby said system is incrementally scalable by adding or subtracting DC power sources and daisy-chained inverters.

[119] Kondo's system of daisy chained inverters is incrementally scalable by adding or subtracting DC power sources and daisy chained inverters. Kondo states that its arrangement of inverters "enables to increase the number of parallel-connected AC modules by sequentially repeating cascade connection" (Kondo, [0003]) and "enables easy parallel connection of plural AC modules by way of cascade connection." Kondo, [0004]. Although paragraphs [0003] and [0004] of Kondo are discussing other patent applications, Kondo makes clear that its own system of inverters is a similar "cascade connection" arrangement. *See* Kondo, Cl. 8 ("wherein the solar battery devices are connected in a cascade"), Cl. 9 ("said solar battery devices are cascaded"), [0048] ("AC module 1, which is connected at the end of the cascade connection"). Thus, Kondo's reference to "increas[ing] the number of parallel-connected AC modules" applies just as well to Kondo's system. Moreover, a POSITA would recognize that the easy way Kondo's inverters can be connected in parallel through connected AC input and output ports (as illustrated in Figures 1 and 2) means the system is incrementally scalable because inverters can be added or subtracted easily. Indeed, this is the whole reason Kondo teaches the inclusion of an

overcurrent limitation functionality—to reduce the risk associated with adding too many inverters to the system.

[120] Additionally, Nishi's system is incrementally scalable by adding or subtracting DC power sources to/from the shared inverter:

> Thus, inverter apparatus 4 in the dispersed-power-source system includes a plurality of converters having different input voltage ranges, and therefore it can transform a DC power outputted from each of a plurality of DC power sources having different output voltage ranges into a commercial AC power, without providing a booster circuit at a front stage or imposing limit on a number of solar cell modules to be connected for constituting an solar cell array.

Nishi, [0068]; *see also* [0003] (referring to a "plurality of DC sources"), [0043] (referring to a "plurality of converters," each connected to a DC source). A POSITA would understand from these disclosures that Nishi contemplates an arbitrary number of DC sources, wherein DC sources can be added or subtracted.

[121] In my opinion, it would have been obvious to take Kondo's already scalable system (*i.e.*, able to add/subtract inverters) and enhance it with the ability to add or subtract DC power sources to/from a single inverter. A POSITA would be motivated to do this, understanding that the resulting system would be able to perform MPP tracking on the individual DC sources connected to each inverter, thereby reducing component cost (because fewer inverters are required) and achieving higher efficiency and reliability (because of MPP tracking and avoiding single point of failure). It would also permit different kinds of DC sources (*e.g.*, photovoltaic panels

and fuel cells) to share a single inverter, which is an advantage taught by paragraph [0115] of Nishi.

> **Cl. 16: The system of claim 15, in which the output of each of the said power inverters is single phase AC.**
>
> **Cl. 20: The method of claim 19, in which the output of each of said power inverters is single phase AC.**

[122] Kondo's inverters output single phase AC. *See* Kondo, [0025] ("each AC module 1 has a 100V single-phase output").

> **Cl. 18: The system of claim 15 further comprising a first DC power source connected to one of said DC power input ports of one of said power inverters and a second DC power source, different in kind from said first DC power source, connected to another of said DC power input ports of said one power inverter.**
>
> **Cl. 24: The method of claim 19 further comprising: a) connecting a first DC power source to one of said DC power input ports of one of said power inverters; and b) connecting a second DC power source, different in kind from said first DC power source, to another of said DC power input ports of said one power inverter.**

[123] Nishi discloses an inverter that is connected to multiple DC power sources that are "different in kind." For example, Nishi observes that different DC power sources of inverter 4 will have higher or lower output voltage. *See* Nishi, [0063] ("solar cell arrays 2A, 2B and solar cell arrays 2C, 2D are different in output voltage range and output power range"). Nishi teaches that this kind of arrangement is advantageous because it allows for maximum power point tracking on each individual DC source, thereby maximizing overall power production and reducing

component costs as compared to having one inverter for each DC source. *See* Nishi, [0072]–[0079]; *see also* [0077] ("control units 11A-11D each control the pulse width of PFM control signal so that the output power of respective solar cell arrays 2A-2D becomes maximum").

[124] A POSITA would have been motivated to incorporate into Kondo the ability to take DC inputs from different kinds of sources because it enables the system to maximize power generation even when different solar panels are experiencing different illumination conditions, thereby improving efficiency. A POSITA would also recognize the benefit of reducing component cost by having multiple DC sources (including different kinds of DC sources) share a single inverter.

[125] In addition, Nishi teaches providing DC power to an inverter from both solar and non-solar sources. *See* Nishi, [0047] ("the inverter apparatus . . . can be applied to a home power generation system that transforms a DC power from a plurality of DC power sources constituted of solar batteries, fuel cells, generators or the like"). This is depicted in Figure 6 of Nishi, which shows the inverter 4A receiving DC power from solar panels 2_A–2_D and from fuel cell 16. *See also* Nishi, [0108] ("In a second embodiment, a dispersed-power-source system of the hybrid type in which solar cell arrays and fuel cells are used as DC power sources is shown").

[126] As I describe above, a POSITA would have been motivated to modify Kondo's inverters to have multiple DC inputs, as taught by Nishi, to gain the

advantage of being able to optimize power generation from a collection of solar panels operating under different sunlight conditions. A POSITA would have further recognized the advantages of being able to connect both solar and non-solar DC sources to a single inverter. Nishi teaches the advantages of this kind of "hybrid" system. *See* Nishi, [0115] ("a dispersed-power-source system of a hybrid type can easily be structured with low costs and without reduction of efficiency"). Nishi teaches that providing an inverter, capable of accepting inputs from different kinds of sources, would have been a simple modification within the level of ordinary skill. Specifically, Nishi teaches that the only modification required to the arrangement of Figure 1 would be connecting the fuel cell to a DC-DC converter with different input voltage range. *See* Nishi, [0066], [0111], [0112] (30–60V for the fuel cell vs. 80–320V or 50–160V for solar panels).

Cl. 23: The method of claim 19 where the providing of AC power includes producing a total AC power that is the summation of the AC power supplied by each said DC to AC power inverter.

[127] In Kondo's daisy chain arrangement of inverters, the power of all connected inverters is summed and then provided to the grid. A POSITA would understand as much based on the fact that Kondo's inverters are connected electrically in parallel. *See* Kondo, Abstract. As I explain above, being connected "in parallel" means that Kondo's inverters operate at the same voltage, and the power supplied by all inverters is combined. Kondo also specifically states:

> The DC power generated by the solar battery unit 2 is converted to AC power by the inverter unit 3, sent through the current path 8, collected together with the power, which is generated by other AC modules 1 and inputted from the input connector 5, then sent through the current path 9, and outputted to the output connector 6.

Kondo, [0051]; *see also* [0053] (referring to "collected current values of the AC modules 1 connected in common phase"), [0053] (referring to current added by each module contributing 0.9A). This means that the combined output of all inverters is summed on "current path" 9, which is depicted in Figure 3 of Kondo and which I have highlighted below in Figure 1 of Kondo.

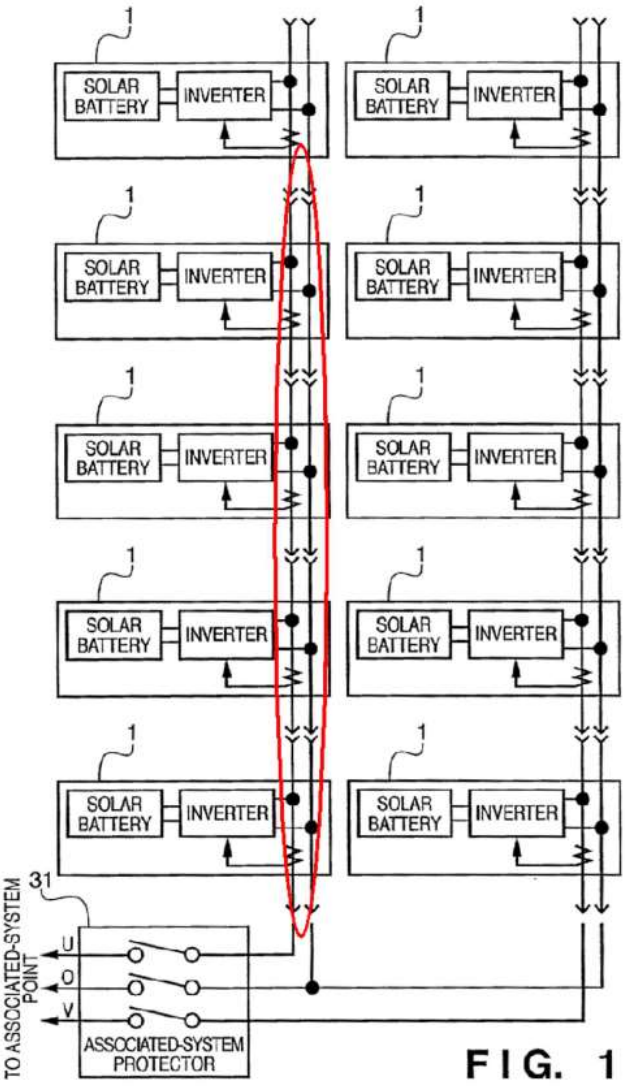


FIG. 1

[128] Indeed, Kondo teaches there is a risk of too much current accumulating on the current path, and it addresses this problem by teaching the capability for each inverter to detect overcurrent and shut itself off, while allowing other inverters to continue operating. *See* Kondo, [0069] ("it is possible to prevent over current flow in the current path 9 and the output connector 6. Even if a sudden increase is found in the insolation, the output power of the AC module 1 is suppressed from the one

closest to the associated-system point, and other AC modules 1 can continue their operation").

B. Ground 2: Kondo and Fornage

[129] In my opinion, Claims 15–16, 18–20, and 22–24 of the '133 Patent are unpatentable because they are obvious over the combination of Kondo and Fornage. In this combination, I am once again using Kondo as the starting point and showing how it would have been obvious to modify Kondo based on the teachings of Fornage.

[130] In my analysis that follows, I will not repeat my analysis regarding Kondo's disclosures that I set forth above under Ground 1. With respect to claim elements 15 Pre(1) and 19 Pre; 15 Pre(2) and 19(a)(1); 15(a)(1) and 19(a)(2); 15(a)(3) and 19(a)(3); 15(a)(4) and 19(b); 15(b)(1) and 22(a); 15(b)(2) and 22(b); 15(b)(3), 19(c), and 22(c); 15(c); 16 and 20; and 23; my opinion is that these claim elements are disclosed in Kondo for the reasons set forth above under Ground 1. Below, I will make specific observations about Fornage, how it applies to specific claim elements, and why it would have been obvious to combine with Kondo.

Cl. 15(a)(2): at least two DC power input ports coupled to the single DC-AC inverter,

Cl. 19(a)(4): and at least two DC input ports coupled to the single DC-AC inverter;

[131] In my opinion, Fornage discloses multiple DC input ports connected to a single inverter. For example, Figure 5 of Fornage shows multiple inputs labeled "DC," each of which is connected to a DC-DC boost circuit 508. *See* Fornage,

[0033]. The DC outputs of those boost circuits are combined on a DC bus 506 and provided to "DC/AC Converter" 510. *See id*.

[132] Figure 3 of Fornage discloses an arrangement of parallel connected inverters 300_n, each of which may have multiple DC inputs as shown in Figure 5. *See* Fornage, [0032] ("Fig. 5 is a block diagram of an exemplary embodiment of a dual stage inverter 500 that may be used as an inverter 300 within a power generator 320 in accordance with the present invention").

[133] It would have been obvious to incorporate Fornage's teaching of providing multiple DC inputs to a single inverter into Kondo's arrangement of daisy chaining multiple inverters through their AC inputs and outputs. This would involve simply modifying Kondo's DC-AC inverters to accept DC input from multiple sources. A POSITA would have been motivated to incorporate Fornage's multi-input inverter into Kondo because it enables a plurality of connected solar panels to be operated at their respective maximum power points, thereby increasing efficiency and reliability because if offers MPP tracking on each solar panel and reduces single point of failure if there was just one inverter, and because it reduces component cost by allowing multiple DC sources to share a single inverter.

[134] Fornage notes for example that different solar panels may experience different sunlight conditions. *See* Fornage, [0018] ("The shaded-areas 106_1 and 106_2 are subjected to a shadow from a neighboring panel and are exposed to less light; thus,

the shaded areas 1061 and 1062 may produce less DC than the areas exposed to direct sun"). This means different solar panels will have different maximum power points, depending on the amount of illumination. *See* Fornage, [0018] ("the cells in the lit-area 1041 have a different MPP as compared to the MPP of the cells in the shaded area 1061"). Fornage addresses this problem by performing MPP tracking on each connected solar panel individually, or on each panel segment such as a row of cells, so that the "maximum amount of power can be extracted from the panel when fully illuminated or when shaded." Fornage, [0018]. Similar to Nishi, Fornage accomplishes this by connecting each DC input to a DC-DC boost circuit, controlled by a shared controller. *See* Fornage, [0033] ("A Controller 512 provides an individual control signal to each boost circuit 508 to ensure that the rows of cells coupled thereto operates [sic] at the row's MPP").

[135] A POSITA would further recognize another advantage of Fornage is flexibility and scalability. That is, the user can add solar panels without having to add inverters. *See* Fornage, [0025] (characterizing Fornage's system as "scalable and flexible to fit any user's needs"). Kondo also recognizes the advantage of flexibility and scalability, stating that its system of daisy chained inverters "enables to increase the number of parallel-connected AC modules by sequentially repeating cascade connection." Kondo, [0003]; *see also* [0004] ("enables easy parallel connection of plural AC modules by way of cascade connection"). A POSITA would see Kondo's

teachings about the advantages of scalability and would therefore be motivated to combine Kondo's system of daisy-chained inverters with Fornage's multi-input inverters, thereby allowing for scalability in terms of additional inverters and additional solar panels.

[136] Incorporating Fornage's multi-input inverter into the system of Kondo would be a simple substitution of one known element for another, yielding predictable results. Kondo already discloses one DC input (18 in Figure 5), a DC-DC boost converter ("boost circuit 12"), and a controller ("control circuit 17") for performing MPPT. *See* Kondo, [0036] ("At this stage, the control circuit 17 performs the well-known optimum operation point tracking control based on DC current 22 and DC voltage 23"). Modifying Kondo based on Fornage would simply involve providing additional DC inputs and additional boost circuits controlled by Kondo's existing controller. The total DC output of the boost circuits could be combined on a DC bus, as taught by Fornage (*see* Fornage, [0033]), and then provided to Kondo's DC-AC inverter. It would not be difficult for a POSITA to do this in view of Fornage's disclosure. The wiring is elementary and would simply involve replicating Kondo's components (e.g., input port 18 and boost circuit 12), connecting the outputs from the boost circuits to a common DC bus, and then connecting that bus to Kondo's DC-AC inverter 13.

Cl. 15(a)(4): each of said DC power input ports having one DC power source connected thereto;

Cl. 19(b): connecting at least one of said DC power sources, respectively, to each of said DC input ports; and

[137] As I set forth above in my opinions regarding Ground 1, Kondo already teaches connecting at least one DC power source to each DC input port. Fornage also teaches this element. *See* Fornage, [0034] ("The boost circuit 508 receives DC from a DC source, such as, rows 404, columns 406, solar cell 402, portions thereof and the like"), Fig. 3 (showing each inverter 300 connected to a photovoltaic panel 102).

Cl. 15(b)(3): and the AC power output port of the last power inverter being connected to a power service panel of the power grid;

Cl. 19(c): providing AC power to the power grid.

Cl. 22(c): and the AC power output port of the last DC to AC power inverter being connected to a power service panel of the power grid.

[138] As I set forth above in my opinions regarding Ground 1, Kondo already teaches these elements where it discloses connection to a "commercial-use power system" through a system protector 31, as shown in Figure 1 and described in paragraph [0026] of Kondo.

[139] To the extent Kondo does not explicitly disclose connecting the AC output port of the last inverter to a power service panel of a power grid, it would be obvious to incorporate this element into Kondo based on the teachings of Fornage. Figure 3 of Fornage shows connection to "power grid" 312 via an "electric panel" 306. A

POSITA would understand that it is advantageous to connect a PV system to the grid through a service panel because this enables the PV system to be used to power household appliances ("appliances" 316, in Figure 3 of Fornage) and enables the user to sell power back to the utility. *See* Fornage, [0027] ("the owner of the system 100 can be compensated for supplying electricity to the grid 312").

Cl. 15(c): whereby said system is incrementally scalable by adding or subtracting DC power sources and daisy-chained inverters.

[140] As I set forth above in my opinions regarding Ground 1, Kondo already teaches a system that is incrementally scalable by adding or subtracting DC power sources and daisy-chained inverters.

[141] Additionally, Fornage's system is incrementally scalable by adding or subtracting DC power sources to/from the shared inverter. Figure 3 of Fornage shows a system where any number of inverters *n* are coupled together in parallel along an AC bus 314. *See* Fornage, [0025] ("The inverters 3001, 3002…300n couple the output AC to an AC bus 314"), [0026] ("Using such an AC bus 314 and discrete power generators 320N, the system 100 is scalable and flexible to fit any user's needs").

[142] Thus, Fornage discloses a "scalable and flexible" system by which an arbitrary number of inverters can be added or subtracted from an AC bus. Fornage also discloses that any of its inverters can be a multi-input inverter, as depicted in

Figure 5. *See* Fornage, [0032]. Fornage also discloses that its inverters can have any number of boost circuits 508. *See* Fornage, [0033] ("The first stage [of inverter 500] comprises a plurality of boost circuits 508, which include 5081, 5082…508n"), [0034] ("In this embodiment, the boost circuits 5081, 5082…508n share a single DC/AC converter 510"). A POSITA would understand that Fornage teaches an arbitrary number of DC sources may be connected to the inverter of Figure 5, meaning DC sources can be added or subtracted. *See* Fornage, [0023] ("system 100 may include any number of the photovoltaic panels 102").

[143] In my opinion, it would have been obvious to take Kondo's already scalable system (*i.e.*, able to add/subtract inverters) and enhance it with the ability to add or subtract DC power sources to/from a single inverter. A POSITA would be motivated to do this, understanding that the resulting system would be able to perform MPP tracking on the individual DC sources connected to each inverter, thereby reducing component cost (because fewer inverters are required) and achieving higher efficiency and reliability. It would also permit different kinds of DC sources to share a single inverter.

> **Cl. 18: The system of claim 15 further comprising a first DC power source connected to one of said DC power input ports of one of said power inverters and a second DC power source, different in kind from said first DC power source, connected to another of said DC power input ports of said one power inverter.**
>
> **Cl. 24: The method of claim 19 further comprising: a) connecting a first DC power source to one of said DC power input**

ports of one of said power inverters; and b) connecting a second DC power source, different in kind from said first DC power source, to another of said DC power input ports of said one power inverter.

[144] Fornage discloses an inverter that is connected to multiple DC power sources that are "different in kind." For example, Fornage discloses that the DC power "may be generated by a DC source, such as rows 404, columns 406, solar cell 402, portions thereof and the like." Fornage, [0036]; *see also* [0023] ("The plurality of photovoltaic panels . . . may be of any size or shape"). Fornage further discloses that different solar panels may experience different sunlight conditions. *See* Fornage, [0018] ("The shaded-areas 1061 and 1062 are subjected to a shadow from a neighboring panel and are exposed to less light; thus, the shaded areas 1061 and 1062 may produce less DC than the areas exposed to direct sun"). This means different solar panels will have different maximum power points, depending on the amount of illumination. *See* Fornage, [0018] ("the cells in the lit-area 1041 have a different MPP as compared to the MPP of the cells in the shaded area 1061").

[145] Moreover, Fornage discloses that its system can operate each DC input at its specific MPP. *See* Fornage, [0031] (describing "operating each row at the row's MPP"). A POSITA would understand that such a system allows for the introduction of different kinds of DC inputs.

[146] A POSITA would have been motivated to incorporate into Kondo the ability to take DC inputs from different kinds of sources because it enables the system to

maximize power generation even when different solar panels are experiencing different illumination conditions, thereby increasing efficiency and reliability. A POSITA would also recognize the benefit of reducing component cost by having multiple DC sources (including different kinds of DC sources) share a single inverter.

C. Ground 3: Fornage and Kondo

[147] In my opinion, Claims 15–16, 18–20, and 22–24 of the '133 Patent are unpatentable because they are obvious over the combination of Fornage and Kondo. In this combination, I am using Fornage as the starting point and showing how it would have been obvious to modify Fornage based on the teachings of Kondo. Specifically, a POSITA starting with Fornage's parallel arrangement of multi-input inverters would have found it obvious to daisy chain those inverters together through AC input and output ports as taught by Kondo. A POSITA would have been motivated to do this because of Kondo's ability to detect and mitigate overcurrent conditions, which is a risk associated with combining AC outputs on Fornage's AC bus 314.

Cl. 15, Pre(1): A scalable DC to AC power inversion system for providing AC power to a power grid

Cl. 19, Pre: A method of making a DC to AC power conversion system incrementally scalable, comprising:

[148] As I discuss above in Ground 2 with respect to claim element 15(c), Fornage discloses an incrementally scalable system. Fornage contemplates connecting an

arbitrary number of inverters in parallel on an AC bus (as shown in Figure 3), as well as an arbitrary number of DC sources to each inverter (as shown in Figure 5). *See also* Fornage, [0025] (stating that its system is "scalable and flexible to fit any user's needs"). Fornage also discloses that it's system supplies power to the grid. *See* Fornage [0026]–[0027].

Cl. 15, Pre(2): from a plurality of individual DC power sources each having a DC power output port, comprising:

Cl. 19(a)(1): providing a plurality of DC power sources

[149] As I explain above, Fornage's system includes a plurality of DC power sources, namely the photovoltaic panels 102n depicted in Figure 3. Fornage teaches that these photovoltaic panels would be connected to the DC inputs depicted in Figure 5. *See* Fornage, [0023]–[0024]. A POSITA would understand each of those photovoltaic panels would have some DC output port capable of being plugged into the inverter's DC inputs.

[150] I also note that Kondo explicitly discloses that its photovoltaic panels ("solar batteries") have an "electrode" that provides DC output. *See* Kondo, [0031]. To the extent Fornage does not disclose an explicit structure that provides DC power out of the solar panels, it would have been obvious to incorporate Kondo's electrode to allow power to be obtained from the solar panels.

Cl. 15(a)(1): a plurality of power inverters, each of said power inverters including a single DC-AC inverter,

Cl. 19(a)(2): and a plurality of DC to AC power inverters, said DC to AC power inverters each having a single DC-AC inverter,

[151] Figure 3 of Fornage discloses a plurality of power inverters 300n, which are described in [0022] and [0024]–[0025]. Each of Fornage's power inverters 300n includes a single DC-AC inverter, which is shown in Figure 5 as "DC/AC Converter" 510. *See* Fornage, [0032] (explaining that Fig. 5 depicts a two-stage inverter that can be used as one of the inverters 300 of Fig. 3). [0033] ("The second stage 504 comprises a DC/AC converter 510"), [0034] (describing how DC/AC Converter 510 converts DC to AC).

[152] I also note that the '133 Patent speaks of "inverters" broadly as devices that convert AC to DC. *See* '133 Patent, 1:7–10 ("The subject of this patent relates to direct current (DC) to alternating current (AC) power inverters that invert DC power from single or multiple DC power sources to single-phase or three-phase AC power"). Therefore, a POSITA would understand Fornage's inverters to be "inverters" as in the '133 Patent.

Cl. 15(a)(2): at least two DC power input ports coupled to the single DC-AC inverter,

Cl. 19(a)(4): and at least two DC input ports coupled to the single DC-AC inverter;

[153] Fornage's power inverters contain at least two DC input ports coupled to the single DC-AC inverter. For example, Figure 5 of Fornage depicts four DC input

ports, each coupled to a boost circuits 508. The outputs of these boost converters are connected via DC bus 506 to the DC/AC Converter 510.

Cl. 15(a)(3): an AC power input port, and an AC power output port coupled to the single DC-AC inverter,

Cl. 19(a)(3): an AC input port coupled to the single DC-AC inverter, an AC output port coupled to the single DC-AC inverter,

[154] Figure 3 of Fornage shows multiple inverters connected in parallel, where each inverter's AC power output is combined on an AC bus 314. *See* Fornage, [0025] ("The inverters 3001, 3002 . . . 300n couple the output AC to an AC bus 314"). This arrangement necessarily requires that each of Fornage's inverters includes at least an AC output port. This is shown in Figure 5, where the AC output port is labeled "AC."

[155] In my opinion, it would have been obvious to modify Fornage's system, as shown in Figure 3 and 5, so that the inverters have AC input and output ports and are connected in a daisy chain, as taught by Kondo. As I explain above, Kondo discloses a system of daisy chained inverters where each inverter's AC output port is connected to an AC input port of the next inverter in the chain. The modification to Fornage would simply be adding an AC input port to each inverter, and then connecting those inverters by their AC input and output ports. This is conceptually the same as taking Fornage's external AC bus 314 and routing it *through* each of the inverters.

[156] There are several scalability reasons why a POSITA would be motivated to make this modification. First, providing AC input and output ports would have been a straightforward way to permit the user to scale the system by plugging additional inverters into the chain, as taught by Kondo. *See* Kondo Figs. 1–2; *see also* Abstract ("can easily be connected with other plural AC modules in parallel by way of cascade connections"). This would advance Fornage's interest in a system that is "scalable and flexible to fit any user's needs." Fornage, [0025].

[157] Additionally, a POSITA would recognize that one of the disadvantages of Fornage's system is the risk of over current (*i.e.*, exceeding the current rating of AC bus 314), which can occur when too many inverters are connected in a string. Fornage is susceptible to over current problems because it allows for an arbitrary number of inverters 300n to be used (as shown in Figure 3) and for an arbitrary number of DC sources to be connected to each inverter (as shown in Figure 5). A POSITA would therefore be motivated to modify Fornage based on the teachings of Kondo, which teaches a solution to the over current problem.

[158] Specifically, a POSITA would be motivated to adopt Kondo's solution to the over current problem, which is to route the combined AC bus *through* each connected inverter as shown in Figure 1 of Kondo. In that way, each individual inverter can measure the total current accumulated up to that point in the chain, and can shut itself off—while allowing other inverters to continue operation—in order

to prevent over current. *See* Kondo, [0042]–[0046]; *see also* [0046] ("When the output of the current detector 4 is larger than the set value, the comparator 26 supplies an inverter halt signal to the signal input terminal 20 of the inverter unit 3"), [0057] ("Unlike the configuration where the associated-system protector 31 detects an over current and disconnects the switch therein, even in a case where a sudden increase is found in the insolation, AC module 1 other than the one closest to the associated-system point can continue their operation because power conversion of the AC module 1 is halted sequentially from the one closest to the associated-system point").

[159] This system has a number of advantages. It permits the user to install many inverters without the risk of over current, even under changing sunlight conditions. Additionally, as Kondo points out, this system allows the photovoltaic generation system to stay connected to the grid, with some subset of the inverters producing a total power associated with a current near the maximum rating of the system. Only some inverters need be shut down, since only those inverters are adding excess current. So, the entire system stays connected, and keeps producing power, under a variety of illumination conditions. *See* Kondo, [0057]. This presents an advantage over prior art systems where the entire solar generation system would be disconnected from the grid in the event of an over current. *See id*.

[160] I would emphasize here again that replacing Fornage's Fig. 3 external bus configuration with Kondo's internal bus arrangement would also further Fornage's interest in a system that is "scalable and flexible to fit any user's needs." Fornage, [0025]. Kondo's daisy chain arrangement with current monitoring enables inverters to be added without concern that the system will be shut down entirely in the event of overcurrent. Scaling Kondo's system is also straightforward as additional inverters can simply be plugged into inverters already connected to the grid. Also, recall that Fornage expresses a general interest in efficiency and maximizing power generation, which would be furthered by the modification in view of Kondo. *See* Fornage, [0020]. Modifying Fornage based on Kondo's configuration results in more power generation and less down-time because it keeps the system connected to the grid and operating at near-maximum current.

[161] Finally, modifying Fornage in view of Kondo as I have proposed would be simple, predictable, and well within the level of skill of the POSITA. Kondo provides the blueprint for this modification in Figures 1–3. The only changes to Fornage's inverters would be adding Kondo's AC input port and over current detector. Fornage's inverters could then use their existing controller 512 to initiate the "halt signal" referenced in Kondo.

Cl. 15(a)(4): each of said DC power input ports having one DC power source connected thereto;

Cl. 19(b): connecting at least one of said DC power sources, respectively, to each of said DC input ports; and

[162] As I explain above, Fornage shows four DC input ports (labeled "DC" in Figure 5), each of which is connected to a DC power source such as the photovoltaic panels 102 shown in Figure 3. *See also* Fornage, [0034] ("boost circuit 508 receives DC from a DC source, such as rows 404, columns 406, solar cell 402, portions thereof and the like").

Cl. 15(b)(1): said AC power output port of each power inverter being connected in a daisy chain to the AC power input port of the next power inverter,

Cl. 22(a): The method of claim 19 further comprising daisy-chaining at least two of said DC to AC power inverters, said AC power output port of each DC to AC power inverter being connected in a daisy-chain to the AC power input port of the next DC to AC power inverter,

[163] As I explain above, Kondo discloses a daisy chain arrangement of inverters, wherein each inverter's AC output port connects to the AC input port of the next inverter in the chain. This arrangement is illustrated in Figure 1–3 of Kondo. For the reasons above, it would have been obvious to modify Fornage's parallel arrangement of inverters shown in Figure 3 based on Kondo's daisy chain arrangement in order to route the AC bus through each of the inverters. This would allow each inverter to measure the total current accumulated on the bus and sense/correct any over current conditions.

Cl. 15(b)(2): except for the AC power input port of the first power inverter being left open,

Cl. 22(b): except for the AC power input port of the first DC to AC power inverter being left open,

[164] In my opinion, Kondo discloses that the AC power input port of the first inverter in the chain is left open. *See* Kondo, [0048] ("the input connector 5 of the AC module 1, which is connected at the end of the cascade connection, is unconnected"). I explain above why it would have been obvious to a POSITA to incorporate Kondo's daisy chain arrangement into Fornage's parallel arrangement of inverters. Therefore, it would have also been obvious to a POSITA to incorporate Kondo's teaching of leaving the AC input port of the first inverter open.

Cl. 15(b)(3): and the AC power output port of the last power inverter being connected to a power service panel of the power grid;

Cl. 19(c): providing AC power to the power grid.

Cl. 22(c): and the AC power output port of the last DC to AC power inverter being connected to a power service panel of the power grid.

[165] As I explain above in Ground 2, Fornage discloses the AC output port of the last inverter being connected to a power service panel of a power grid. Figure 3 of Fornage shows the last inverter in the chain, 300_4, is connected to "power grid" 312 through "electric panel" 306. *See also* Fornage, [0027] (noting the advantage of being able to sell surplus power to the grid). I also agree with the Examiner that connecting a photovoltaic power generation system to an electric grid through a

service panel was generally known in the art and would have been obvious to incorporate into any solar power generation system.

Cl. 15(c): whereby said system is incrementally scalable by adding or subtracting DC power sources and daisy-chained inverters.

[166] As I explain above in Ground 2, Fornage already discloses that its system is "scalable and flexible." *See* Fornage, [0025]. Fornage discloses a system wherein solar panels may be added or removed from the multiple DC inputs, as shown in Figure 5. *See* Fornage, [0017] ("Although three panels are shown, the photovoltaic panel system 100 may include any number of panels 102"). In addition, inverters can be added or removed from the AC bus 314, as shown in Figure 3. *See* Fornage, [0032] ("system 100 may include any number of inverters 300"). Further, the addition of Kondo's over current protection scheme enhances the flexibility and scalability of Fornage's system because it guards against a problem that can occur if too many inverters are connected.

Cl. 16: The system of claim 15, in which the output of each of the said power inverters is single phase AC.

Cl. 20: The method of claim 19, in which the output of each of said power inverters is single phase AC.

[167] Fornage discloses that its inverters will output whatever phase AC is used by the connected AC grid. *See* Fornage, [0024] ("The inverters 300 of the present invention may produce current that is in-phase with the AC grid current and generate such current with low distortion"). Kondo explicitly says that its inverters output

single phase AC. *See* Kondo, [0025]. A POSITA would understand that if the grid supplies single phase AC, then the photovoltaic system would also supply single phase AC.

[168] Rotzoll '654, which I will discuss further below in Ground 4, teaches that "[r]esidential systems commonly utilize single phase AC, while commercial systems most often use three phase AC." Rotzoll '654, [0007]. Accordingly, if a POSITA was configuring the system of Fornage to interface with residential loads, they would know to configure Fornage to output single phase AC. Likewise, if interfacing with commercial loads, the POSITA would know to use three phase AC. Both were known in the art and were well within the level of ordinary skill.

[169] Figure 3 of Kjaer also shows a multi-input inverter of the kind taught by Fornage, wherein the output can be single or three phase AC.

[170] I also agree with the Examiner that single and three phase AC were well known in the art, and it would have been obvious to a POSITA to configure a system to generate either, depending on the needs of the connected grid or load.

> **Cl. 18: The system of claim 15 further comprising a first DC power source connected to one of said DC power input ports of one of said power inverters and a second DC power source, different in kind from said first DC power source, connected to another of said DC power input ports of said one power inverter.**
>
> **Cl. 24: The method of claim 19 further comprising: a) connecting a first DC power source to one of said DC power input ports of one of said power inverters; and b) connecting a second DC power source, different in kind from said first DC power**

source, to another of said DC power input ports of said one power inverter.

[171] Fornage discloses that its inverter can connect to different kinds of DC sources. For example, Fornage says that photovoltaic cells have different maximum power points because certain solar cells will receive more or less sunlight than others. *See* Fornage, [0018] ("The shaded-areas 1061 and 1062 are subject to a shadow from a neighboring panel and are exposed to less light; thus, the shaded areas 1061 and 1062 may produce less DC than the areas exposed to direct sun"). Fornage also discloses that DC power "may be generated by a DC source, such as rows 404, columns 406, solar cell 402, portions thereof and the like." Fornage, [0036]; *see also* [0023] ("The plurality of photovoltaic panels . . . may be of any size or shape").

[172] Moreover, Fornage discloses that its system can operate each DC input at its specific MPP. *See* Fornage, [0031] (describing "operating each row at the row's MPP"). A POSITA would understand that such a system allows for the introduction of different kinds of DC inputs.

Cl. 23: The method of claim 19 where the providing of AC power includes producing a total AC power that is the summation of the AC power supplied by each said DC to AC power inverter.

[173] Fornage already discloses that the AC power outputs of all inverters are summed on AC bus 314, where the combined AC power is fed to a junction box 304. *See* Fornage, [0026] (The junction box 304 generally connects together the outputs

from all the inverters 3001, 3002…300n to form a single AC feed to the electric panel 106). This summation of power is a necessary consequence of Kirchoff's current law, which requires that the current be added together in a parallel circuit system. The same result would occur if Fornage's system were modified based on Kondo, as I have described. The only difference is that current is accumulated on an internal bus rather than an external bus.

D. Nishi and Kondo

[174] In my opinions regarding Ground 3, I focus on the combination of Fornage's multiple DC input inverter with Kondo's daisy chained inverters. In my opinion, any other multiple DC input inverter could be combined with Kondo in the same manner as Fornage. For example, Nishi, discussed above in Ground 1, also discloses an inverter with multiple DC inputs. It would have been just as obvious to combine Nishi and Kondo, using Nishi as the starting point. The motivation would be the same, *i.e.* providing Kondo's method for detecting and stopping an over current condition that might occur in Nishi's system.

E. Opinions Regarding Claims 17 and 21

[175] Claims 17 and 21 depend on Claims 15 and 19 respectively and both recite "the output of each of said power inverters is three-phase AC." In my opinion, these claims are obvious for the same reasons as Claims 16 and 20. As the Examiner indicated in the file history, the phase of an AC output can be either single or three

phase, and both were well known in the art. For example, Figure 3 of Kjaer discloses a multi-input inverter that could output one or three phase AC power. In addition, Rotzoll '654 confirms that single and three phase AC were commonly used in residential and commercial systems respectively. *See* Rotzoll '654, [0007] ("Residential systems commonly utilize single phase AC, while commercial systems most often use three phase AC").

[176] Figure 6 of Rotzoll '654 discloses a multi-string, multi-input inverter system, similar to that of Nishi and Fornage. In Rotzoll '654's system, a "distributed inverter" 620 connects to multiple PV modules 602–604 and 612–614 through "DC wiring" 605, 606, 615, and 616. *See also* Rotzoll '654, [0063]–[0064]. The AC output of inverter 624 is connected to other inverters through AC wiring 625 (*i.e.*, an AC bus like that of Fornage). *See* Rotzoll '654, [0066].

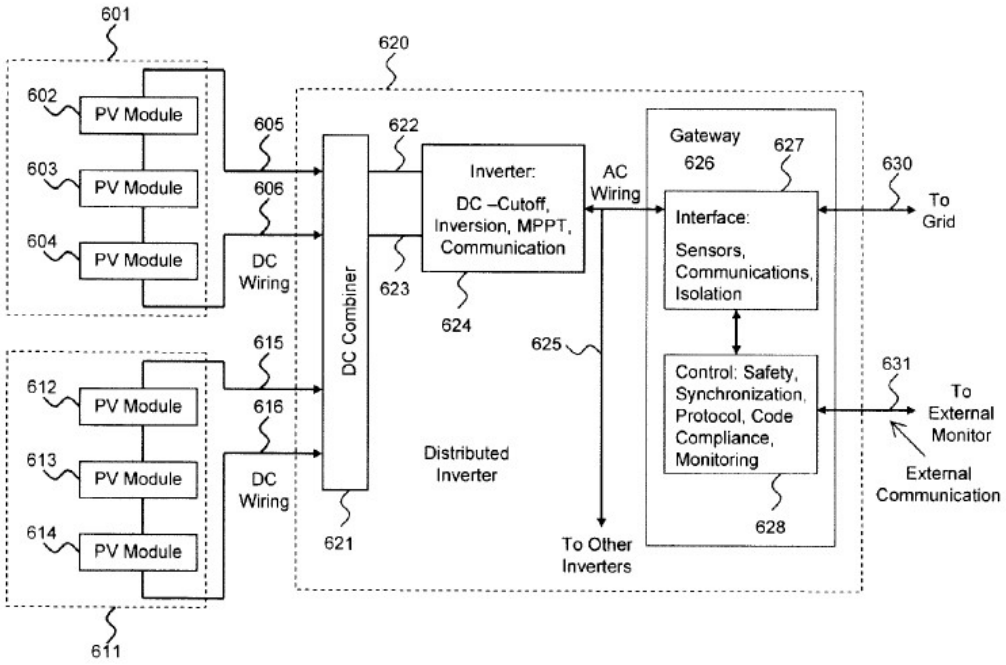


FIG. 6

[177] Rotzoll ’654 repeatedly emphasizes that its inverters can produce AC output power with any appropriate phase. *See* Rotzoll ’654, [0071] (“Without loss of generality, the output of the microinverters can be single-phase AC, split-phase AC or multi-phase AC”), [0045] (“The AC power may be generated in single-phase or multi-phase form”).

[178] In my opinion, the person of ordinary skill would understand, in light of these disclosures, that solar inverters of the sort disclosed in Rotzoll ’654 could output three phase power as an alternative to single phase power. It would have therefore been obvious to modify or configure any of the prior art combinations discussed above, including the ones in Grounds 1–3, to output three phase AC instead of single

phase AC. A POSITA would have been motivated to make this change if the system were being designed for an industrial or commercial setting, as these commonly used three phase AC. *See* Rotzoll '654, [0007].

[179] This would have been an easy modification, having predictable results, and would have been well within the level of ordinary skill in the art. As Kjaer demonstrates, it was known to provide solar inverters that could output either single or three phase AC. Therefore, a POSITA could have easily modified any of the combinations described in Grounds 1–3 to use a three phase inverter instead of a single phase inverter.

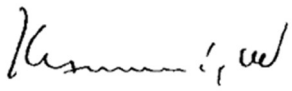
F. Secondary Considerations of Nonobviousness

[180] I understand the Patent Owner has not yet submitted any evidence of secondary considerations of nonobviousness in the District Court litigation between the parties.

[181] I understand that Patent Owner raised certain arguments relating to secondary considerations in a response to *ex parte* re-examination of the '133 Patent. *See* App. No. 90/019,341, May 17, 2024 Patent Owner's Statement, at 6-11. I have reviewed the evidence put forward by the Patent Owner as allegedly showing long felt need in the art, industry praise, and copying by others. However, none of this changes my opinion that Claims 15-23 of the '133 Patent were obvious in view of the prior art.

[182] I reserve the right to supplement my opinions if the Patent Owner provides additional exhibits or arguments related to secondary considerations.

I declare that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.



June 27, 2024

Date

Mladen Kezunovic

APPENDIX 1

Dr. Mladen Kezunovic, P.E.
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CURRENT	
Texas A&M University (TAMU), Department of ECEN, College Station, TX	
University Distinghuished Professor	2024-Present
Regents Professor	2016-Present
Director, Smart Grid Center	2012-2019
Eugene E. Webb Professor	2000-Present
Professor, Tenured	1996-Present
Director, Power Systems Control and Protection Laboratory	1992-Present
National Science Foundation I/UCRC	
Site Director, Power Systems Engineering Research Center (PSERC)	2000-Present
Test Laboratories International, Inc. d.b.a. XpertPower Associates	
President& CEO, Principal Consultant	1992-Present
Texas Board of Professional Engineers	
Registered Professional Engineer, License No. 76824	1993-Present
EDUCATION	
University of Kansas, Lawrence, KS	
Ph.D., Electrical Engineering	Jun 1980
M.Sc., Electrical Engineering	Oct 1977
University of Sarajevo, Sarajevo, Bosnia	
Diploma of Engineering (B.Sc.), Electrical Engineering	Oct 1974
EXPERTISE	
Protective Relaying, Automated Power System Disturbance Analysis, Computational Intelligence and Data Analytics, Distributed Eenergy Resources, Smart Grids	
HONORS/AWARDS	
Academic	
Tsinghua University, China	
Guest Professor in State Key Laboratory of Simulation of Power System and Generation Equipment	2018-2021
Texas A&M University at Qatar, Qatar	
Eminent Scholar	2015-2016
National Council for Scientific and Technological Development (CNPq), Brazil	

Special Visiting Scholar, Science without Borders	2015-2017
Texas A&M University, College Station, TX	
University Distinghuished Professor	2024
Association of Former Students Distinguished Achievement Award for Research	2018
Regents Professor	2016
Faculty Service Award, Department of ECEN	2010
Eugene E. Webb Professor	2000
E.D. Brockett Professor	1999
Texas Engineering Experiment Station, Senior Fellow	1998
Texas Engineering Experiment Station, Fellow	1997
Texas Engineering Experiment Station, Fellow	1993
The King Saud University, Saudi Arabia	
ARAMCO Chair in Electrical Power	2010
South China University of Technology, China	
Honorary Title, Guest Professor	2005
University of Kansas, Lawrence, KS	
Final Ph.D. Exam Honors	1980
Dissertation Fellowship	1980
Comprehensive Ph.D. Exam Honors	1979
Fulbright Foundation, U.S. Department of State, USA	
Foreign Student Graduate Scholarship	1976-1977
Professional	
National Academy of Engineering	
Member	2022-present
Department of Energy	
Electricity Advisory Committee (appointed by the Secretary of Energy), two terms	2017-2021
National Institute of Standards and Technology	
Smart Grid Interoperability Panel 2.0 Director, Board of Directors, Reappointed	2013
Smart Grid Interoperability Panel 1.0 Governing Board of Directors, Elected	2009-2013
The Institute of Electrical and Electronic Engineers	
IEEE PES Fellow Evaluation Committee, Chair	2017-2019
IEEE PES Fellow Evaluation Committee Member	2015-2017
IEEE PES Prize Paper Award, "Advancements in Centralized Protection and Control Within a Substation"	2017
IEEE Life Fellow	2017
IEEE PES Technical Committee, WG Recognition Award "Understanding, Prediction, Mitigation and Restoration of Cascading Failures"	2015
Power Systems Relaying Committee (PSRC), Service Award for 25 Years	2012
IEEE, Educational Activities Board Standards Education Award	2011

Power Systems Analysis, Computing and Economics Committee, Chairman Certificate of Appreciation, TF on "Fault Analysis"	2011
The IEEE Standards Association, Outstanding contribution to development of IEEE Standard C37.239-2010	2010
Power Systems Relaying Committee (PSRC), Service Award for 20 Years	2007
Power Analysis, Computing and Economics Committee, Recognition Award "Working Group on New Technologies and Practical Applications"	2006
Power Systems Relaying Committee, Chairman Certificate of Appreciation "WG on Application of Intelligent Systems to Power System Protection"	2000
IEEE Fellow for contribution to "the development and implementation of systems for automated fault analysis"	1999
PSRC, WG Recognition Award "IEEE standard 37.111-1991"	1993
International Council on Large Electric Systems-CIGRE	
CIGRÉ Medal in recognition of an oustanding contribution to the development of CIGRÉ, CIGRÉ-Paris	2024
Dale Douglass Award for Technical Achievements, US CIGRÉ National Committee	2021
Philip Sporn Award for cumulative career contributions to the advancement of the concept of system integration in the theory, design and/or operation of large, high voltage electric systems in the United States, US CIGRÉ National Committee	2019
Distinguished member, CIGRÉ-Paris	2018
Fellow and Honorary Member, CIGRÉ-Paris	2014
Technical Committee Award for "remarkable technical contribution to the study committee B5, protection and automation", CIGRÉ-Paris	2012
Atwood Associate Award given to an individual who has made notable contributions to CIGRE over an extended period, U.S. CIGRÉ National Committee	2008
Best Paper Recognition Award, CIGRÉ General Session, U.S. National Committee,	2004
Best Paper Recognition Award, CIGRÉ General Session, U.S. National Committee,	1998
Best Paper Recognition Award, CIGRÉ General Session, U.S. National Committee	1996
EXPERIENCE	
Academic	
Texas A&M University (TAMU), Department of ECEN, College Station, TX	
Director, Smart Grid Center	Aug 2012-Sep 2019
Deputy Director, Electrical Vehicles-Transportation and Electricity Convergence (EV-TEC) Center	2008-2013
Leader, Smart Energy Campus Initiative	Aug 2009-Present
Leader, Smart Grid Center Initiative	Jan 2012-Aug 2012
Site-Director, NSF I/UCRC PHEV/EBV-TEC	Mar 2009-Aug 2010
Director, Electric Power and Power Electronics Institute	Jun 1997-Dec 2006
Coordinator, Electric Power and Power Electronics Program	Jun 1997-Dec 2006
Eugene E. Webb endowed Professor	Jan 2000-Present
Site Director, NSF I/UCRC PSERC	Sep 2000-Present
Tenured Professor	Sep 1996-Present
Tenured Associate Professor	Sep 1994-Aug 1996
Director, Power System Control and Protection Laboratory	Jan 1992-Present
Associate Professor	Jan 1992-May 1994
Adjunct Associate Professor	Sep 1991-Dec 1991

Visiting Associate Scientist	Jun 1989-Aug 1991
Visiting Associate Professor	Aug 1986-May 1989
Graduate Student Advisor, 31 Ph.D., 24 M.Sc., 8 M.E.	Sep 1989-Present
The University of Hong Kong, Hong Kong	
Visiting Professor, Dept. of Electrical and Electronic Engineering	Sep 2007-Dec 2007
TxCEE (six Texas Universities), Texas	
Leader, Texas Consortium for Electric Energy	Dec 2004-Dec 2007
Washington State University, Pullman, WA	
Visiting Associate Professor, Department of Electrical Engineering	Aug 1986-May 1987
The University of Sarajevo, Sarajevo, Bosnia	
Associate Professor (equivalent title from industry)	Apr 1986-May 1987
Assistant Professor, School of Electrical Engineering	Oct 1974-April 1986
Industry	
Test Laboratories International, Inc. d.b.a. XpertPower Associates, College Station, TX	
President& CEO, Principal Consultant	1992-Present
Domestic clients: ISO New England; AVO Multi-Amp Corporation; Bonneville Power Administration; CenterPoint Energy; Commonwealth Edison; Decision Systems International; Duke Power; Electric Power Research Institute; Entergy Services, Inc.; First Energy; GE Corporate Research; Florida Power & Light Company; Hewlett-Packard; Harza Engineering; Holland&Knight Law Firm, Illinois Power; Industrial Economics, Inc.; K&L Gates LLP law firm; MICON Inc.; New York Power Authority; Oncor; Quanta Technologies; Quarles law firm; Reliant Energy HL&P; Southern California; Shook-Hardy-Bacon Law Firm; Edison; TECHRON, Inc.; Test Laboratories International, Inc.; Texas Engineering Experiment Station, The World Bank Group; Toshiba America, Inc; University of Kentucky; Western Area Power Administration; Wisconsin Power & Light. *International clients:* BC Hydro (Canada); CEPEL (Brazil); CHESFE (Brazil); CEATI (Alberta, Canada); CEPEL (Brazil); DuServe (Dubai); Electricite de France (France); Electrix (New Zealand); Electropaulo Metropolitana (Brazil); Elia (Belgium); Energoinvest Company (Bosnia); ESKOM (South Africa); Government of China (China); Hydro Québec (Canada); Institute Nikola Tesla, Serbia; King Saud University (Saudi Arabia); RTE (France); Statnett (Norway); Saudi Electric (Saudi Arabia)	
INESC-TEC Portugal	
Consultant (Sabbatical leave), Department of Power System Studies	Jan 2024-Jul 2024
Electricité de France, Research Center, Clamart, France	
Consultant (Sabbatical leave), Department FCR	Sept 1999-Jun 2000
Energoinvest Company, Sarajevo, Bosnia	
Project Leader, Institute for Control & Computer Sciences	Mar 1982-Aug 1987
Systems Engineer, Institute for Computer & Information Systems	Oct 1980-Feb 1982
Westinghouse Electric Corporation, Pittsburgh, USA	

Systems Engineer, Industry Systems Division	May 1979-Sept 1980
STUDENTS	
31 Former Ph.D. graduate students: Qinghua Chen (Tsinghua University); Payman Dehghanian (George Washington University); Tatjana Djokic; Yimai Dong (Siemens); Papiya Dutta (India); Ahad Esmaeilian (Audubon); Zhixiong Gong (China); Ashok Gopalakrishnan (Siemens); Yufan Guan (China); Yong Guo (BroadCom); Mohammad Khoshjahan (Plus Power); Sead Kreso (University of Sarajevo); Slobodan Levi (England); Yuan Liao (University of Kentucky); Saeed Lotfifard (Washington State University); Xu Luo (Southern Cal Edison); Biljana Matic-Cuka (USA); Satish Natti (GridAxon); Chenzong Pang (Wichita State University); Jinfeng Ren (Entergy); Cheng Qian; Veselin Skendzic (Schweitzer Eng.); Milad Soleimani (Guidehouse); Hongbiao Song (Bechtel); Slavko Vasilic (Bloom Energy); Yang Wu (Alstom Grid); Xingjun Xu (CAISO); Qin Yan (Changsha University of Science and Technology); Bei Zhang (G.E.); Nan Zhang (Energy Exemplar); Ce Zheng (Siemens) **24 Former M.Sc. graduate students:** Siva Kumar Akkiraju (India); Zarko Djekic (Australia); Sasa Jakovljevic (Real Time Utility Engrs.); Fang Ji (Texas Instruments); Maja Knezev (Australia); Eun Hui Ko (KEPCO); Amela Kreho (USA); Rodrigo Martinez-Lagunes (ABB); Jasna Mrkic (Eriksson); Chris Nail (Sandia); Padmanaban Namasivayam (India); Bogdan Naodovic (Intel); Levi Portillo (Texas New Mexico Power); Xiaoxia Qi; Zhifang Ren; Igor Rikalo (i2); Dragan Ristanovic (Bechtel); Christoph Seidl (Austria); Emina Soljanin (Rutgers); Predrag Spasojevic (Rutgers); Jianyong Sun; Milos Todorovic (GE); Nitin Ved (Microsoft); Young Su Kim (KEPCO) **8 Former M.E. graduate students:** Noah Badayos; Mohsen Ghvam; Chenyan Guo; Nien-Tzu Hsia; Anisha Jonas; Mahesh Rajani; Steven Sauer, Christof Seidl **2 Ph.D. candidates:** Rashid Baembitov; Taif Mohamed Mohamed; **1 M.Sc. candidate:** Abinash Karmacharya	
SERVICE	
Texas A&M University	
Member, Faculty Advisory Committee, ECEN	2022-2024
Member, Distinguished Speaker Seminar Committee, ECEN	2021-2022
Member, Faculty Professional Recognition & External Awards Committee	2020-2021
Member, Distinguished Speaker Seminar Committee, ECEN	2019-2020
Hiring Committee	2016-2018
Member, ECE Tenure and Promotion Committee	2012-2014
Member, Energy Action Plan 2015 Advisory Committee	2011-2013
Member, Entrepreneurship Committee, Texas A&M University	2010-2012
Member, Council for Built Environment, Texas A&M University	2010-2012
Member, Council of Principal Investigators, Texas A&M University	2009-2012
Chair, Strategic Planning Committee, ECE	1996-2005
Member, Council of Principal Investigators, Texas A&M University	1996-2002
NIST, Smart Grid Interoperability Panel	
Director, Board of Directors, SGIP 2.0	2013
Member, Testing and Certification Committee	2010-2013
Member, Governing Board, SGIP 1.0	2009-2013
Chair, GB WG on Communication, Marketing and Education	2009-2013
Member, Priority Action Plan 13	2009-2013
Member, Domain Expert Working Group for T&D	2009-2013
National Research Council	

Review Panel, NIST Physical Measurement Laboratory	2015-2016
The Institute of Electrical and Electronic Engineers (IEEE)	
Power Systems Relaying Committee	
Member, Power Systems Relaying Committee	1995-2020
Member, Line Protection Subcommittee	1993-2015
Relay Input Sources Subcommittee	1995-1997
Systems Protection Subcommittee	1997-2010
Relay Practices Subcommittee	1994-2008
Chair, WG on "Intelligent System Applications to Protection Engineering"	1994-1999
Chair, WG on "Digital Simulator Performance Requirements for Relay Testing"	1993-1997
Member of 28 working groups	1990-Present
Transmission&Distribution Committee	
Member, Working Group on "Modeling and Analysis of System Transients Using Digital Programs", General Systems Subcommittee	1994-2000
Member, Working Group on "Application of Intelligent Methods to Transmission and Distribution Problems", General Systems Subcommittee	1994-1999
Member, Task Force on "Protection and Control Modeling" Working Group on "Modeling and Analysis of System Transients Using Digital Programs", General Systems Subcommittee	1994-1998
Power Systems Analysis, Computing and Economics Committee	
Member, Subcommittee on Intelligent System Applications	1997-Present
Vice Chair, Task Force on "Fault Analysis", Working Group on "Practical Applications of Intelligent System Technologies", Subcommittee on Intelligent System Applications	2000-2011
Chair, Task Force on "Fault Analysis", Working Group on "Practical Applications of Intelligent System Technologies", Subcommittee on Intelligent System Applications	1997-2000
International Council on Large Electric Systems (CIGRE)	
Convener, U.S. Representative, Working Group B5.82, Education, Qualification and Continuing Professional Development of Engineers in Protection, Automation and Control, Study Committee B5 (Protection)	2023-present
US Representative, SC B5 (first four years as secondary, and last two years as primary)	2018-2024
U.S. Representative, Joint Working Group C4C2.62/IEEE "Review of Advancements in Synchrophasor Measurement Applications"	2021-present
U.S. Representative, Working Group C2.18 "Wide Area Monitoring Protection and Control Systems – Decision Support for System Operators,"	2020-2023
Convener, U.S. Representative, Working Group B5.62, Life Cycle Testing of Synchrophasor Based Systems used for Protection, Monitoring and Control, Study Committee B5 (Protection)	2017-2021
Member, U. S. National Committee	1988-Present
Convener, U.S. Representative, Working Group B5.10, "Education, Qualification and Continuing Professional Development of Engineers in Protection and Control," Study Committee B5 (Protection)	2010-2014
Convener, U.S. Representative, Working Group B5.20, "New Trends for Automated Fault and Disturbance Analysis," Study Committee B5 (Protection)	2005-2009

Convener, Task Force on "Tools for Protective Relay Engineering," Study Committee B5 (Protection)	1999-2005
Corresponding Member, U.S. Representative, Working Group on "Analysis and Guidelines for Testing Numerical Protection Schemes," Study Committee B5 (Protection)	1996-2000
Convener, Task Force on "Practical Intelligent System Applications to Protection and Substation Monitoring and Control," Study Committee 34 (Protection)	1997-1999
Editorial Boards	
Member, Editorial Advisory Panel, Electric Power Systems Research Journal, Switzerland	1990-2015
Reviewer	
The National Research Council, Switzerland	2021
IEEE Transactions in Instrumentation and Measurements	2016-present
IEEE Transactions on Smart Grids	2010-present
Science Foundation of Serbia	2010-Present
Science Foundation of Ireland	Sep 2010
Indiana Economic Development Fund	Feb 2007
DOE Distributed Energy Resources Program	Nov 2003
National Science Foundation	1995-Present
Canadian Electrical Association	2000-Present
IEE Proceedings Generation, Trans& Distribution, England	1996-Present
IEEE Power Engineering Society, Trans. on Power Systems	1994-Present
IEEE Power Engineering Society, Trans. on Power Delivery	1990-Present
Journal on Engineering Intelligent Systems, England	1996-Present
Journal on Electric Power and Energy Systems, Elsevier Science	1996-Present
IEEE Walter Fee Outstanding Young Engineer Award	1988, 1989, 1990, 1991
Center for Energy & Mineral Resources, Texas A&M University	1991
Conferences/Workshops	
Chair, SGSMA Board of Directors, "The Fourth IEEE Conference on Smart Grid Synchronized Measurements and Analytics", (SGSMA), Washington DC, USA	May 2024
Chair, Joint US-European Workshop "Flexible Electric Grid Critical Infrastructure for Resilient Society," Philadelphia, PA, USA	April, 2023
Chair**,** Joint US European NSF Workshop, Grid at the Edge, Hybrid, Split, Croatia	May 2022
Chair, SGSMA Board "The Third IEEE Conference on Smart Grid Synchronized Measurements and Analytics", (SGSMA), Split, Croatia	May 2022
Chair, Executive Committee "The Second IEEE Conference on Smart Grid Synchronized Measurements and Analytics", (SGSMA), Online	May 2021
Chair**,** NSF/PSerc Workshop, Grid at the Edge, Online	Mar 2021
Chair, PSerc/NSF Forum, Grid at the Edge, Online	Oct 2020
Chair, "The First IEEE Conference on Smart Grid Synchronized Measurements and Analytics" (SGSMA), College Station, TX, USA	May 2019
Honorary Chair, "Innovative Smart Grid Technologies (ISGT)", Sarajevo, Bosnia	Oct 2018

Chair, NSF-PSerc Executive Forum, "Physical and Cyber Infrastructure to Support the Future Grid: Unresolved Research Problems and Technology Requirements for the Next 10 Years", Washington DC, USA	May 2015
Member, Technical Program Committee, "IEEE Innovative Smart Grid Technologies (ISGT)", Washington DC, USA	Jan 2013, Feb 2014, Feb 2015
Chair, NSF Workshop on "Energy Cyber-Physical Systems"	Dec 2013
Chair, Annual Smart Grid Workshop, Texas A&M University	2013-2019
Chair, Technical Program Committee, First IEEE International, Conference on Electrical Vehicles (IEVC 2012)	Mar 2012
Chair, Third Workshop titled "The Role of PHEV in Interfacing Electricity and Transportation Networks," College Station, TX	Oct 2010
Chair, Workshop titled "Smart Electricity Grids: Impact and role of Information Technology," 43th Annual Hawaii International Conference on System Sciences (HICCS 43), Hawaii, USA	Jan 2010
Chair, Second EV-TEC Workshop titled "The Role of PHEV in Interfacing Electricity and Transportation Networks," Austin, TX, USA	Jul 2009
Chair, PSerc Executive Forum Titled "Smart Grid Deployment Strategies and Business Opportunities," Austin, TX, USA	Mar 2009
Chair, First EV-TEC Workshop titled "The Role of PHEV in Interfacing Electricity and Transportation Networks," Austin, TX, USA	Aug 2008
Chair, Second Sino-American Workshop on "Electric Energy for the 21st Century: The China-US Research and Development Needs," Washington DC	Dec 2007
Member, Technical Program Committee, "International Conference on Intelligent System Applications to Power Systems," Kaohsiung, Taiwan	Nov 2007
Chair, First Sino-American Workshop on "Responsive Power Systems," Guangzhou, China	Oct 2006
Member, Technical Steering Committee, International Conference on Intelligent System Applications to Power Systems, Washington, DC	Nov 2005
Chair, Organizing Committee, "The First Texas Electric Energy Forum," College Station, Texas, USA	Nov 2004
Member, Technical Program Committee, International Conference on Intelligent System Applications to Power Systems, Lemnos, Greece	Aug 2003
Chair, NSF Sponsored Symposium "Modernizing the National Electric Power Grid," New Orleans, Louisiana, USA	Nov 2002
Member, Technical Program Committee, International Conference on Power Systems Protection, Ljubljana, Slovenia	Oct 2002
Member, Technical Program Committee, International Conference on Power System Transients, Rio de Janeiro, Brazil	Jun 2001
Member, Technical Program Committee, International Conference on Intelligent System Applications to Power Systems, Budapest, Hungary	Jul 2001
Member, Technical Program Committee, International Conference on Digital Power System Transients, Budapest, Hungary	Jun 1999
Chair, Technical Program Committee, Third International Conference on Digital Power System Simulators, Västerås, Sweden	May 1999
Chair, Technical Program Committee, Second International Conference on Digital Power System Simulators, Montreal, Canada	May 1997
Member, Technical Program Committee, International Conference on Power System Transients, Seattle, Washington	June 1997
Member, Technical Program Committee, International Conference on Power System Protection, Ljubljana, Slovenia	Oct 1996

First IEEE International Conference on Digital Power System Simulators, College Station, Texas, USA: • Technical Program Committee (TPC) Chairman • TPC Liaison to the Steering Committee • Local Organizing Committee Chairman	Apr 1995
RESEARCH	
Total project funding raised is $43,740,628.00 (TAMU portion is $22,537,989.00)	
"Detection, Characterization, and Mitigation of Disruptive Events (DECODE) by Combining Machine Learning/Artificial Intelligence on Synchrophasors and Physics-based Analysis" • Principal Investigator, PSerc • Total Project Funding: $220,000.00 (TAMU portion is $80,000.00) PI: Mladen Kezunovic, (ECE, TAMU); Co-PIs: Vijay Vittal (ASU) and Mani Venkatasubramanian (WSU)	Jul 22-Jun 24
"Travel Grant: Joint US-European Workshop on Flexible Electric Grid Critical Infrastructure for Resilient Society," • Principal Investigator, NSF • Total Project Funding is $44,950.00 PI: Mladen Kezunovic, (ECE, TAMU)	Apr 2023-Mar 2024
"Travel Grant for Joint US-European Workshop on "Grid at the Edge: towards the zero-carbon power grid with improved visibility, safety and reliability" • Principal Investigator, NSF • Total Project Funding is $19,700.00 PI: Mladen Kezunovic, (ECE, TAMU)	Apr 2022-Mar 2023
"SCC-IRG Track1: Advanced Learning for Energy Risk Tracking (ALERT) • Principal Investigator, National Science Foundation • Total Project Funding is $1,498,793.00 (TAMU Portion is $422,810.00) PI: Mladen Kezunovic, (ECE, TAMU); Co-PIs: Zoran Obradovic (Temple University), Alex Brown (Texas A&M University), Paul Pavlou (University of Houston), and Roger Enriquez (The University of Texas-San Antonio)	Jan 2022-Aug 2026
"Predictive Outage Management" • Principal Investigator, Lawrence Livermore National Laboratory • Total Project Funding is $67,869.00 (TAMU Portion is $67,869.00) PI: Mladen Kezunovic, (ECE, TAMU)	Jun 2020-Dec 2021
"SCC-PG: Advanced Learning for Energy Risk Tracking (ALERT)" • Principal Investigator, NSF • Total Project Funding is $150,000 PI: Mladen Kezunovic, (ECE, TAMU); Co-PIs: Zoran Obradovic (Temple University), Alex Brown (Texas A&M University), Paul Pavlou (University of Houston), and Rob Tillyer (The University of Texas-San Antonio)	Oct 2020-Sept 2021
"Travel Grant for Workshop on Electricity Grid at the "Edge" • Principal Investigator, NSF • Total Project Funding is $49,984.00 PI: Mladen Kezunovic, (ECE, TAMU)	Feb 2020-Jan 2022
"Predictive Outage and Asset Management" • Principal Investigator, CenterPoint Energy and United Cooperative • Total Project Funding is $160,000.00 (TAMU portion is $160,000.00)	Jan 2020-Dec 2023

PI: Mladen Kezunovic, (ECE, TAMU)	
"Big Data Synchrophasor Monitoring and Analytics for Resiliency Tracking (BDSMART)" • Principal Investigator, DOE • Total Project Funding is $1,696,560 (TAMU portion is $946,325.00) PI: Mladen Kezunovic, (ECE, TAMU), Co-PIs: Zoran Obradovic, (Temple University Philadelphia, PA); Yi Hu, (Quanta Technology), Rachna Handa, (OsiSoft)	Sep 2019-Aug 2022
"US-India Collaborative for Smart Distribution System with Storage (UI-ASSIST)" • TAMU Principal Investigator, DOE • Total project funding is $7,500,000.00 (TAMU portion is $1,179,998.00) PI: Noel Schulz, Anurag K Srivastava (Washington State University, Director, Smart Grid Demonstration and Research Investigation Lab (SGDRIL)), Co-PIs: Mladen Kezunovic (ECE, TAMU), Anuradha Annaswamy (MIT), Rob Hovsapian (Idaho National Laboratory), Kevin Davies (Hawaii National Energy Institute), Ahmed Saber (ETAP), Devendra Vishwakarma (GE Energy Solutions), Mani Venkata (Alstom Grid Inc). Washington State University is the Lead Institution and MIT is a collaborator.	Oct 2017- Sept 2022
"Timing Intrusion Management Ensuring Resiliency-TIMER" • Principal Investigator, DOE • Total project funding is $4,429,451.00 (TAMU portion is $2,999,501.00) Co-PIs: A. Sprintson and J.-C. (Steve) Liu, J. Lusher, Texas A&M University; E. Schellenberg, M. Papic, Idaho Power Company; B. Johnson, C. Bonebrake, S. Pal, Pacific Northwest National Lab; K. Martin, I. Singh, EPG	Oct 2016-Mar 2021
"Smart Grids Big Data Spoke" • Principal Investigator, NSF • Total project funding is $1,000,000.00 (TAMU portion is $666,999.00) Co-PIs: P.R. Kumar and L. Xie, D. Da Silva, Texas A&M University; S. Grijalva, Georgia Tech; Z. Obradovic, Temple University	Oct 2016-Aug 2022
"Vegetation Management Risk Model" • Principal Investigator, CenterPoint Energy Total project funding is $102,000.00 (TAMU portion is $102,000.00)	Feb 2016-Jan 2018
"Integration of Solar Generation and Electrical Vehicles into The Smart Grid" • Principal Investigator, Qatar National Research Fund • Total project funding is $788,933.00 (TAMU portion is $788,933.00) Co-PIs: Mohamed Trabelsi and Haitham Abu-Rub, Texas A&M University at Qatar	Feb 2016-Jan 2019
"Detection, Classification, and Mitigation of Cybersecurity Attacks on Synchrophasor Systems"	Jan 2016-Dec 2018

• Principal Investigator, TEES • Total project funding is $50,000.00 (TAMU portion is $50,000.00) Co-PIs: Jyh-Charn (Steve) Liu, Dilma Da Silva and Guofei Gu, Texas A&M University at College Station	
"High Impact Project Title: Life-cycle Management of Mission-Critical Systems Through Certification, Commissioning, In-Service Maintenance, Remote Testing, and Risk Assessment" • Principal Investigator, PSerc • Total project funding is $1,200.000.00 (TAMU portion is $321,750.00) Co-PIs: Sakis Meliopoulos, Georgia Tech, David Bakken and Anurag Srivastava, Washington State University, and Tom Overbye, University of Illinois-Urbana Champaign	July 2015-Aug 2018
"Energy Cyberphysical Systems: Experimental Open Source Ecosystem for Synchrophasor Research" • Principal Investigator, TAMU-TEES Seed Grant • Total project funding is $100,000 (TAMU portion is $100,000.00) Co-PIs: Chanan Singh, P.R. Kumar, Erick Moreno-Centeno, Alex Sprintson, Radu Stoleru, Le Xie, Texas A&M University	Sep 2014-Aug 2016
"Development of Advanced Open-Source PMU/PDC Lab and Applications with Synchronized Data Obtained from Simulation and Actual Power Network" • Principal Investigator, TAMU-CAPES • Total project funding is $50,000.00 (TAMU portion is $50,000.00) Co-PIs: G. Taranto (COPPE/Federal University of Rio de Janeiro, Brazil)	Sep 2014-Aug 2016
"The Use of Big Data for Outage management in Distribution Systems" • Principal Investigator, NSF through University of Tennessee Total project funding is $75,238.00 (TAMU portion is $75,238.00)	Jan 2014-Dec 2014
"Systematic Integration of Large Data Sets for Improved Decision-Making" • Principal Investigator, PSerc Consortium • Total project funding is $210,000.00 (TAMU portion is $140,000.00) Co-PIs: Le Xie, Texas A&M University and Santiago Grijalva, Georgia Tech	Jun 2013-Aug 2015
"NSF CORBI: The Electricity and Transportation Infrastructure Convergence Using EVs" • Principal Investigator**,** PSerc and EV-TEC • Total project funding is $160,000.00 (TAMU portion is $80,000.00) Co-PIs: Ross Baldick, UT Austin and Sakis Meliopoulos, Georgia Tech	Aug 2012-Sep 2015
"Robust Adaptive Topology Control" • Principal Investigator • Total project funding is $4,910,031 (TAMU portion is $2,693,019) Co-PIs: Shmuel Oren, Berkeley; Kory Hardeman, Arizona State University; Erick Moreno-Centeno, Texas A&M; Alex Sprintson, Texas A&M; Garng Huang, Texas A&M, Jeff Stewart, LLNL; John Stoval, ORNL; Russell Robertson, GPA; DeJim Lowe, TVA; Sami Ayyorgun, Telcordia	Jan 2012-Jun 2015

"*The Next Generation EMS Design"* • Principal Investigator, PSerc Consortium • Total project funding is $150,000 (TAMU portion is $80,000) Co-PIs: Anjan Bose, Washington State University	Jun 2011-Aug 2013
"Data Mining to Characterize Signatures of Impending Events or Performance from PMU Measurements" • Co-Principal Investigator, PSerc Consortium • Total project funding is $220,000 (TAMU portion is $70,000) PI: Vijay Vittal, Co-PI: J. Zhang, Arizona State University	Jun 2011-Aug 2013
"A Real-time Monitoring, Control & Health Management System to Improve Grid Reliability and Efficiency" • Co-Principal Investigator, DOE • Total project funding is $4,123,923 (TAMU portion is $1,250,000) PIs: James Stoupis, Mirrasoul Mousavi, ABB	Apr 2011-Sep 2013
"Smart Grid Education for Students and Professionals" • Principal Investigator, PSerc Consortium/DOE • Total project funding is $140,000 (TAMU portion is $65,000) Co-PIs: Sakis Meliopoulos, Georgia Tech; Vijay Vittal, Arizona State University; Mani Venkatasubramanian, Washington State University; Alex Sprintson, TAMU	Mar 2011-Jun 2014
"Hierarchical Coordinated Protection of the Smart Grid with High Penetration of Renewable Resources" • Principal Investigator, PSerc Consortium/DOE • Total project funding is $210,000 (TAMU portion is $210,000)	Mar 2011-Jun 2014
"The Impact of PHEV/BEV Charging on Utility Distribution Systems" • Principal Investigator, EV-TEC Consortium • Total project funding is $80,000 (TAMU portion is $80,000)	Jan 2011-Dec 2012
"PHEV/BEV Data Hub" • Principal Investigator, EV-TEC Consortium • Total project funding is $80,000 (TAMU portion is $80,000) Co-PI: Le Xie, Texas A&M University	Jan 2011-Dec 2012
"Verifying Interoperability and Application Performance of PMUs and PMU-enabled IEDs at the Device and System level" • Principal Investigator, PSerc Consortium • Total project funding is $190,000 (TAMU portion is $130,000) Co-PIs: Ali Abur Northwestern University; Alex Sprintson, Texas A&M University	Jun 2010-Aug 2012
"The Smart Grid Needs: Model and Data Interoperability and Unified Generalized State Estimator" • Principal Investigator, PSerc Consortium • Total project funding is $135,000 (TAMU portion is $65,000) Co-PI: Santiago Grijalva, GaTech	Jun 2010-Aug 2012

"Optimized Fault Location for Distribution Systems" • Principal Investigator, ABB • Total project funding was $237,915 (TAMU portion is $237,915)	Mar 2009-Apr 2011
"PHEVs as Dynamically Configurable Dispersed Energy Storage" • Principal Investigator, PSerc Consortium • Total project funding was $220,000 (TAMU portion was $80,000) Co-PIs: Ross Baldick, UT Austin; Ivan Damnjanovic, TAMU	Jun 2009-Aug 2011
"Communication Requirements & Integration Options for Smart Grid Deployment" • Co-Principal Investigator, PSerc Consortium • Total project funding was $160,000 (TAMU portion was $60,000) PI: Ward Jewell, Wichita State University	Jun 2009-Aug 2011
"Impact of Wind Generation on Protection Systems" • Principal Investigator, Vestas • Total project funding was $75,000 (TAMU portion was $75,000)	Aug 2010-Aug 2011
"Information Technology for the 21st Century Smart Grid" • Principal Investigator, State of Texas & The Center for the Commercialization of Electrical Technologies • Total project funding was $500,000 (TAMU portion was $207,300) Co-PIs: Mack Grady, Surya Santoso**,** UT Austin; Wei-jen Lee, UT Arlington	Aug 2008-Aug 2009
"The 21st Century Substation Design" • Principal Investigator, NSF & PSerc Consortium • Total project funding was $150,000 (TAMU portion was $90,000) Co-PI: George Karady, Arizona State University	Jun 2008-Aug 2010
"Integration of Asset and Outage Management Tasks for Distribution Applications" • Principal Investigator, NSF & PSerc Consortium • Total project funding was $155,000 (TAMU portion was $75,000) Co-PI: Ward Jewell, Wichita State University	Jun 2007-Aug 2009
"Multiple Uses of Substation Data – Phase II" • Principal Investigator, EPRI • Total project funding was $570,019 (TAMU portion was $570,019)	May 2005-Dec 2009
"Synchronized Sampling Uses for Real Time Monitoring and Control" • Principal Investigator, DOE-CERTS • Total project funding was $300,000 (TAMU portion was $300,000)	Sept 2006-Sept 2009
"Intelligent Alarm Processors" • Principal Investigator, ERCOT • Total project funding was $100,000 (TAMU portion was $100,000)	Dec 2006-Mar 2008

"SGER: Integrated Solutions for Ubiquitous Use of Electricity and Cyber Services" • Principal Investigator, NSF • Total project funding was $75,000.00 (TAMU portion was $75,000)	Aug 2006-Feb 2008
"Integration of Substation IED Information into EMS Functionality" • Principal Investigator, NSF and PSerc Consortium • Total project funding was $120,000.00 (TAMU portion was $60,000.00) Co-PI: Tom Overbye, University of Illinois	Jun 2006-Aug 2008
"Detection, Prevention, and Mitigation of Cascading Events - Prototype Implementation" • Co-Principal Investigator, NSF and PSerc Consortium • PI: Mani Venkatasubramanian, Washington State University and Vijay Vittal, Arizona State University Total project funding was $236,000.00 (TAMU portion was $50,000)	Jun 2006-Aug 2008
"Electricity Systems for the 21st Century: The China-US Research and Development Needs" • Principal Investigator, Second Sino-American Workshop, TAMU Total project funding was $10,000.00 (TAMU portion was $10,000)	May 2007-Dec 2007
"Responsive Power Systems" • Principal Investigator, First Sino-American Workshop On, Guangzhou, China (TAMU and ABB) Total project funding was $20,000.00 (TAMU portion was $20,000)	Sept 2006-Sept 2007
"Integration of Substation IED Information into EMS Functionality" • Principal Investigator, DOE-CTC Total project funding was $230,000.00 (TAMU portion was $230,000)	Jan 2006-Mar 2007
"Digital Protection System Using Optical Instrument Transformers and Digital Relays Interconnected by an IEC 61850-9.2 Digital Process Bus" • Principal Investigator, NSF and PSerc Consortium • Co-PI: George Karady, Arizona State University Total project funding was $130,000.00 (TAMU portion was $65,000)	Jun 2005-Jun 2007
"Transient Testing of Protection Relays: Study of Benefits and Methodology" • Principal Investigator, NSF and PSerc Consortium • Co-PIs: Sakis Meliopoulos, GaTech and Ward Jewell, Wichita State University Total project funding was $160,000.00. (TAMU portion was $60,000)	Jun 2005-Jun 2007
"REU Site: Electrical Engineering Research Applications in Homeland Security" • Co- Principal Investigator, NSF • Co-PIs: H.F. Taylor, A.L. Narasimha Reddy, K.L. Butler-Purry, E. Serpedin, L. Kish, P.R. Hemmer, T. Zourntos, D. Kundur Total project funding was $200,365.00 (TAMU portion was $200,365.00)	May 2004-Apr 2007

"Automated Topology Analysis Using Substation Data" • Principal Investigator, ABB Corporate Research Total project funding was $217,000.00 (TAMU portion was $217,000.00)	Feb 2004-Mar2007
"Role of Substation Automation in Real Time Control" • Principal Investigator, DOE CERTS Total project funding was $230,000.00 (TAMU portion was $230,000.00)	Sep 2004-Aug 2006
"TAMU Participation in the NSF I/UCRC: Power Systems Engineering Research Center (PSERC)" • Principal Investigator, NSF Total project funding was $275,000.00 (TAMU portion was $275,000.00)	Sep 2000-Sep 2006
"Performance Assessment of Advanced Digital Measurement and Protection System" • Co-Principal Investigator, NSF and PSERC Consortium • PI: Dr. George Karady, Arizona State University Total project funding was $130,000.00 (TAMU portion was $65,000.00)	Jan 2004-Dec 2005
"Multiple Uses of Substation Data" • Principal Investigator, EPRI Total project funding was $40,079.00 (TAMU portion was $40,079.00)	May 2004-Apr 2005
"Enhanced Reliability of Power System Operation Using Advanced Algorithms and IEDs for On-Line Monitoring" • Principal Investigator, NSF and PSERC Consortium • Co-PIs: A. Abur, Texas A&M University, R. Shoureshi, Colorado School of Mines, S. Meliopoulos, Georgia Institute of Technology Total project funding was $262,800.00 (TAMU portion was $262,800.00)	Jun 2002-Jun 2005
"Microgrid Protection and Control" • Co- Principal Investigator, NSF and PSERC Consortium • PI: Dr. R. Lasseter, University of Wisconsin Total project funding was $150,000.00 (TAMU portion was $30,000.00)	Jun 2002-Jun 2005
"Detection, Prevention, and Mitigation of Cascading Events" • Co-Principal Investigator, NSF and PSERC Consortium • PI: V.V. Vittal, Iowa State University, Co-PI: M. Venkatasubramanian, Washington State University Total project funding was $240,000 (TAMU portion was $75,000.00)	Jun 2002-Jun 2005
"Automated Integration of Condition Monitoring with an Optimized Maintenance Schedule for Circuit Breakers and Power Transformers" • Co-Principal Investigator, NSF and PSERC Consortium • PI: J. McCalley, Iowa State University, • Co-PI: C. Singh, Texas A&M University, V. Honavar, Iowa State University Total project funding was $255,000.00, TAMU part (M. Kezunovic) $63,750.00, TAMU Part (C. Singh) $63,750.00	Jun 2002-Jun 2005

"Smart Sensor Development for Power Transmission and Distribution" • Co-Principal Investigator, NSF and PSERC Consortium • PI: M. Simoes, Colorado School of Mines, • Co-PI: R. Shoureshi, Colorado School of Mines Total project funding was $165,000.00 (TAMU portion was $30,000.00)	Jun 2002-Jun 2005
"Substation Data Uses for Improved Local and EMS Functions" • Principal Investigator, DOE CERTS Total project funding was $94,524.00 (TAMU portion was $95,524.00)	Sep 2003-Aug 2004
"Workshop: Modernizing the National Electric Power Grid" • Principal Investigator, NSF Total project funding was $28,000.00 (TAMU portion was $28,000.00)	Dec 2002-Nov 2003
"Data Integration and Information Exchange: Impact on Future Substation and EMS Applications and Related Implementation Requirements" • Principal Investigator, EPRI • Co-PI: A. Abur Total project funding was $150,690.00 (TAMU portion was $150,690.00)	May 2002-Dec 2003
"Automated Circuit Breaker Monitoring" • Principal Investigator, Reliant Energy HL&P Total project funding was $140,000.00 (TAMU portion was $140,000.00)	Sep 2000-Dec 2002
"Accurate Fault Location in Transmission and Distribution Networks Using Modeling, Simulation and Limited Field Recorded Data" • Principal Investigator, NSF and PSERC Consortium • Co-PIs: A. Abur Total project funding was $109,075.00 (TAMU portion was $109,075.00)	Sep 2000-Aug 2002
"Improved State Estimation via Advanced Substation Monitoring" • Co-Principal Investigator, NSF and PSERC Consortium • PI: A. Abur Total project funding was $76,000.00 (TAMU portion was $76,000.00)	Sep 2000-Aug 2002
"Power System Monitoring Using Wireless Substation and System-Wide Communications" • Principal Investigator, NSF and PSERC Consortium • Co-PIs: Dr. C. Georghiades Total project funding was $76,000.00 (TAMU portion was $76,000.00)	Sep 2000-Aug 2002
"Self-Evolving Agents for Monitoring, Control and Protection of Large Complex Dynamic Systems" • Co-Principal Investigator, ARO/EPRI • PI: Dr. G. Huang Total project funding was $546,980.00 (TAMU portion was $546,000.00)	Jan 1999-Jun 2002
"Planning Grant for TAMU's Participation in PSERC" • Principal Investigator, NSF	Jan 2000-Jun 2001

Total project funding was $10,000.00 (TAMU portion was $10,000.00)	
"Multidisciplinary Education Using Curriculum Re-Engineering, Industry Partnership and Simulation Technology" • Principal Investigator, NSF, EPRI, and eight industry sponsors • Co-PIs: Drs. A. Abur, G. Huang-TAMU and Drs. A. Bose, M. Venkatasubramanian, K. Tomsovic-Washington State University Total project funding was $812,828.00 (TAMU portion was $812,828.00)	May 1997-Apr 2001
"Advanced Tools for Power Quality Assessment" • Co-Principal Investigator, THECB, Reliant Energy HL&P, TU Electric • PI: A. Abur Total project funding was $216,865.00 (TAMU portion was $216,865.00)	Jan 1998-Aug 2000
"New Methodology for Distance Relay Testing" • Principal Investigator, Entergy Services Total project funding was $20,000.00 (TAMU portion was $20,000.00)	Dec 1999-Jul 2000
"Study of the Theoretical Basis for Different Behavior of Protective Relays under Various Test Conditions" • Principal Investigator, Electricite de France Total project funding was $20,000.00 (TAMU portion was $20,000.00)	Feb 1999-Jun 2000
"New Approaches for Preventing Wide-Area Power System Outages" • Principal Investigator, TAMU's Energy Resources Program Total project funding was $24,960.00 (TAMU portion was $24,960.00)	May 1998-Jun 1999
"Center for Power System Technology, Engineering, Application and Manufacturing" • Principal Investigator, Strategic Research Initiative Pre-Award, Texas A&M University Engineering Dean's Office • Co-PIs: Dr. G. Huang, Dr. A. Abur Total project funding was $15,000.00 (TAMU portion was $15,000.00)	Jun 1996-Dec 1998
"Research Experience for Undergraduates" • Principal Investigator, NSF • Supplement to NSF Grant MERIT 2000 Total project funding was $5,000.00 (TAMU portion was $5,000.00)	Jun 1998-Dec 1998
"Automated Classification of DFR Files Using Expert System and Signal Processing" • Principal Investigator, TU Electric Total project funding was $287,476.00 (TAMU portion was $287,476.00)	Jul 1996-Dec 1998
"Fault Location Using Synchronized Sampling" • Principal Investigator, Western Area Power Administration (WAPA) Total project funding was $61,600.00 (TAMU portion was $61,600.00)	Sept 1996-Dec 1998

"Acquisition of Advanced Instrumentation and Test Equipment for Research, Education, and Training in Electric Power Quality" • Principal Investigator, NSF • Co-PI: Dr. P. Enjeti Total project funding was $251,743.00 (TAMU portion was $251,743.00)	Sept 1995-Dec 1997
"Second International Conference on Digital Power System Simulators" • Principal Investigator, NSF Total project funding was $5,000.00 (TAMU portion was $5,000.00)	Aug 1996-Aug 1997
"An Expert System for Monitoring of a Generating Plant" • Principal Investigator, Houston Lighting and Power Company (HL&P) Total project funding was $129,546.00 (TAMU portion was $5,000.00)	Jun 1994-Dec 1996
"Research and Review of Literature for Fault Locators" • Principal Investigator, Western Area Power Administration Total project funding was $10,000.00 (TAMU portion was $10,000.00)	Jul 1995-Jul 1996
"New Real-Time Digital Simulator for Relay Testing" • Principal Investigator, Commonwealth Edison Company Total project funding was $446,089.00 (TAMU portion was $446,089.00)	Aug 1994-Feb 1996
"Protective Relay Workstation: Applications of a Digital Simulator-Phase II" • Principal Investigator, Electric Power Research Institute (EPRI), FPL Co., HL&P Co., DOE-Western Area Power Administration Total project funding was $816,138.00 (TAMU portion was $816,138.00)	Jul 1992-Sept 1995
"First International Conference on Digital Power System Simulators" • Principal Investigator, Travel Grant, NSF Total project funding was $5,000.00 (TAMU portion was $5,000.00)	May 1994-May 1995
"A Real Time Digital Simulator for Relay Testing" • Principal Investigator, Department of Energy (DOE)-Western Area Power Administration Total project funding was $627,860.00 (TAMU portion was $627,860.00)	Oct 1990-Sept 1994
"Evaluation of Dynamic and Transient Testing Using AVO Multi-Amp Pulsar Test System" • Principal Investigator, AVO Multi-Amp Corporation Total project funding was $19,507.00 (TAMU portion was $19,507.00)	Dec 1991-Nov 1993
"Synchronized Sampling for Electric Utility Applications-Phase II" • Principal Investigator, NASA Total project funding was $10,000.00 (TAMU portion was $10,000.00)	Jun 1993-Dec 1993
"Dynamic Testing and Evaluation of New Distance Relays" • Principal Investigator, Tennessee Valley Authority, TAMU Total project funding was $49,882.00 (TAMU portion was $49,882.00)	Oct 1990-Dec 1992

"Synchronized Sampling for Electric Utility Applications Using ACTS" • Principal Investigator, NASA • Co-PIs: Dr. A. D. Patton Total project funding was $30,688.00 (TAMU portion was $30, 688.00)	Jun 1992-Dec 1992
"Expert System for DFR Analysis" • Principal Investigator, , HL&P Co., TAMU • Total project funding was $27,240.00 (TAMU portion was $27, 240.00)	Jan 1990-Aug 1992
"Protective Relay Workstation: Applications of a Digital Simulator-Phase I" • Principal Investigator, EPRI, HL&P Co., Pacific Gas & Electric Co., FPL Co., TAMU • Total project funding was $543,254.00 (TAMU portion was $543,254.00)	Dec 1989-Jun 1992
"Development of Dynamic Testing Using Multi-Amp EPOCH Test System" • Principal Investigator, Multi-Amp Corporation • Total project funding was $18,364.00 (TAMU portion was $18,364.00)	Aug 1990-Feb 1991
"Dynamic Testing Tools for Protection Relays" • Principal Investigator, Houston Lighting & Power Co., U.S.A. • Total project funding was $25,000.00 (TAMU portion was $25,000.00)	Oct 1988-Oct 1989
"Evaluation of High Impedance Fault Detection Techniques" • Senior Research Staff, Electric Power Institute, Texas A&M University, U.S.A. PI: Dr. B. Don Russell	Jun 1988-Sept 1988
"Preliminary Design of a Power System Automation Laboratory" • Technical Consultant, Electric Power Institute, Texas A&M University, U.S.A. PI: Dr. B. Don Russell	Sept 1987-May 1988
At Other Universities in the USA ($20,000.00)	
"Application of Traveling Wave Fault Locators to Tapped DC Lines" • Principal Investigator (with Dr. R. A. Baker), Electric Power Research Institute, U.S.A. • Total funding was $20,000.00. Resigned to work for Energoinvest Company	May 1987-Aug 1987
In Bosnia (former Yugoslavia) ($2,000,000.00)	
Principal Investigator. "Integrated Substation Control and Protection System," Science Foundation of Energoinvest Company, Sarajevo. ($1,300,000.00).	Mar 1982-Aug 1987
Principal Investigator. "New Methods and Tools for Protective Relaying Equipment and System Testing," Science Foundation of Energoinvest Company, Sarajevo. ($200,000.00).	Nov 1985-Dec1986

Principal Investigator. (with Dr. J. T. Cain). "Analysis Synthesis and Evaluation of Digital Algorithms for Protective Relaying of Electric Power Systems," National Science Foundation, U.S.A. ($100,000.00).	Jan 1984-Dec 1986
Principal Investigator. "New Methods and Techniques for Transmission Line Protection," Science Foundation of Republic BiH, Bosnia. ($100,000.00).	Jun 1984-Jun 1986
Principal Investigator. "Microprocessor-Based Distance Relay," Science Foundation of Republic BiH, Bosnia. ($100,000.00).	Jun 1984-Jun 1985
Principal Investigator. "New Methods and Technologies for Protective Relaying Systems in H.V. Substations," Science Foundation of Energoinvest Company, Sarajevo. ($50,000.00).	Jun 1983-Jun 1985
Principal Investigator. "Application of Microprocessors to Control and Protection of Electric Power Systems," Science Foundation of Republic BiH, Bosnia. ($50,000.00).	Jun 1981-Jun 1983
Principal Investigator. "Feasibility Study of an Integrated Control and Protection System for H.V. Substation Applications," Energoinvest-IRCA, Sarajevo. ($100,000.00).	Oct 1980-Apr 1981
Note**:** *The equivalent dollar value of all of the projects funded in Bosnia (former Yugoslavia) in local currency was over $2,000,000.00*.	

PUBLICATIONS (Note: *Graduate students)

Books

1. M. Kezunovic, et al "Faut Location, The Models, Methods, and Solutions," Wiley Encyclopedia of Electrical and Electronic Engineering (ISBN 9780471346081), 2022
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3. M. Kezunovic, et al “Grid at the Edge: Challenges and Opportunities,” NSF/PSerc Workshop, Final Report, NSF Grant #1940990, June 2021
4. M. Kezunovic, et.al., “Life-Cycle Management of Mission-Critical Systems through Certification, Commissioning, In-Service Maintenance, Remote Testing, and Risk Assessment” PSerc Report #18-13, September 2018.
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13. M. Kezunovic, L. Xie, M. Chen, et al., "Assess Cross-disciplinary Impacts on Plug-in Hybrid Electric Vehicles/Battery Electric Vehicles Using Maximal Information Coefficient", EV-TEC Report #2, April 2013.
14. M. Kezunovic, "The Role of PHEV/BEV in Outage/Asset and Demand Side Management", EV-TEC Report #1, April 2013.
15. M. Kezunovic, "How the Use of Data from New Sensors Enhances Reliability," Sub-Report of DOE project "A Real-time Monitoring, Control & Health Management System to Improve Grid Reliability and Efficiency", March 2013.
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Patents & Copyrights

"Data Highway Access Control System," U.S. Patent No. 4,379,294	Apr 1983
"RISC-Based Open-Loop Simulator for Relay Testing – Hardware Design," U.S. Copyright, Reg. No: TX 4-273-793	May 1996
"Design Document for RISC-Based Two Terminal Open-Loop Relay Testing Software," U.S. Copyright, Reg. No: TX 4-275-950	May 1996
"RISC-Based Open-Loop Simulator for Relay Testing – Hardware Installation Manual and I/O System Design Documentation," U.S. Copyright, Reg. No: TX 4-275-951	May 1996
"Digital Simulator for Real-Time and Open-Loop Relay Testing – Installation Manual," U.S. Copyright, Reg. No: TX 4-275-952	May 1996
"Digital Simulator for Real-Time and Open-Loop Relay Testing – Software Documentation," U.S. Copyright, Reg. No: TX 4-286-737	May 1996
"RISC-Based Two Terminal Open-Loop Simulator Application Software-User's Manual," U.S. Copyright, Reg. No: TX 4-298-403	May 1996

"Expert System Installation at STP Substation-User Manual and Design Documentation," U.S. Copyright, Reg. No: TX 4-294-172	May 1996
"Real-Time Simulator Doc.," U.S. Copyright, Reg. No: TX 4-280-248	May 1996

LECTURES

Invited Lectures&Keynotes

1. "Risk management of future large-scale electrification" Invited talk, Tesla Days, Institute Nikola Tesla, Belgrade, Serbia, June 2024
2. "Risk management of future large-scale electrification" Invited talk, NESC-TEC Forum, Porto, Portugal, May 2024.
3. "The Role of ML and AI in Managing Forced Outages in Power Systems", Invited talk, INESC TEC Technical meeting, Porto, Portugal, May 2024
4. "Ph.D. Research: Opportunity of a lifetime", Invited talk, INESC-TEC Research Group, Porto, Portugal, May 2024
5. Big Data Analytics for Predicting Risk of Outages, and Managing and Mitigating Impacts using Distributed Energy Resources," Keynote, IEEE IAS Global Conference on Renewable Energy and Hydrogen Technologies-GlobConHT-2023, Male, Maldives, March 2023
6. "Big Data Analytics for Predicting, Managing and Mitigating Outages," Keynote, 7th Asia Conference on Power and Electrical Engineering (Virtual Conference), ACPEE, April 2022
7. "Big Data and Machine Learning/Artificial Intelligence: Predicting, Managing and Mitigating Risk of Forced Outages," Keynote, 13th Conference on Electricity Distribution with regional participation, Kopaonik, Srbija, October 2022
8. "Big Data Analytics for Predicting, Managing and Mitigating Outages," Keynote, the Workshop on Communication Networks and Power Systems (WCNPS), Brazil, November 2021
9. "Big Data Analytics for Predicting, Managing and Mitigating Outages," Distinghuished Lecture, Shanghai Tech, China, November 2021
10. "Big Data Analytics for Predicting, Managing and Mitigating Outages," Keynote, The 9th International Conference on Advanced Power System Automation and Protection, Jejy, Korea, October 2021
11. "Resilience and Flexible Electricity Grids," Keynote, 2019 IEEE 3rd International Electrical and Energy Conference, Beijing, China, September 2019
12. "The Role of Big Data Analytics in Predicting Power System Outages," Keynote, Deregulated Electricity Market Issues in South-East Europe conf., Heraklion, Greece, September 2019
13. "Resilience in Flexible Electricity Grids," Invited lecture, Qatar Environment and Energy Institute, March 2019
14. "Multidisciplinary Research in Partnership with Industry," Invited Panelist, Energy Leaders Summit, BIXPO 2018, Gwangju, Korea, October 1, 2018.
15. "Big Data: WHY, WHEN and HOW?", Keynote, ISGT Europe, Sarajevo, Bosnia and Herzegovina, October 2018.
16. "Resiliency in Flexible Electricity Grids," Invited talk, Tsinghua University, Beijing, China, July 2018.

17. “Resiliency in Flexible Electricity Grids,” Keynote, EnergyCon, Limasol Cyprus, June 2018.
18. “Big Data Uses in Smart Grids; Challenges and Opportunities,” IEEE DLP Invited Lecture, Nicosia, Cyprus, June 2018.
19. “Big Data Analytics for Improved Electric Grid Resiliency,” Keynote, Int. Conf. on Energy Internet and Energy System Integration, Beijing, China, November 2017.
20. “Synchrophasor Technology: Benefits and Pitfalls,” Invited Lecture, BioBio Energy Conf., Concepcion, Chile, Oct. 2017.
21. “Big Data Paradigm for Risk-Based Predictive Asset and Outage Management,” Keynote, 2nd International Symposium on Smart grid Methods, Tools and Technologies, Weihai, China, July 2017
22. “Big Data Paradigm for Risk-Based Predictive Asset and Outage Management,” Invited Lecture, Tsinghua University, Beijing, China, June 2017
23. “Big Data Uses in Smart Grids: Challenges and Opportunities,” Invited Lecture, The University of Edinburgh, Edinburgh, Scotland, June 2017
24. “Big Data Uses in Smart Grids: Challenges and Opportunities,” Invited Lecture, Sctrathclyde University, Glasgow, Scotland, June 2017
25. “Big Data Uses in Smart Grids: Challenges and Opportunities,” Keynote, PowerTech Conference, Manchester, England, 2017
26. “Synchrophasor Technology: Benefits and Pitfalls,” Invited Lecture, Serbian CIGRE Meeting, Zlatibor, Serbia, June 2017
27. “Big Data: WHAT, WHY, WHEN and HOW,” The University of Donja Gorica, Podgorica, Monte Negro, November 2016.
28. “Predictive Asset and Outage Management,” Keynote, MEDPOWER conf. in Belgrade, Serbia, November 2016.
29. “Synchrophasor Technology: Benefits and Pitfalls,” The University of Novi Sad, Serbia, November 2016.
30. “Life Cycle Management Tools for Synchrophasor Systems: Why We Need Them and What They Should Entail,” IFAC Workshop on Control of Transmission and Distribution Smart Grids, Prague, the Czech Republic, October 2016.
31. “Automated Fault and Disturbance Analysis in Smart Grids and respective Modelling, Simulation and Validation,” IEEE DLP Invited Lecture, The University of Dortmund, Germany, October 2016.
32. “Big Data: WHAT, WHY, WHEN and HOW,” Invited talk, The University of Novi Sad, Serbia, April 2016.
33. “Big Data: WHAT, WHY, WHEN and HOW,” EU ADVANTAGE Project Meeting in Novi Sad, Serbia, April 2016.
34. “Big Data: WHAT, WHY, WHEN and HOW,” Invited talk, The University of Sarajevo, Bosnia, April 2016.

35. “Synchrophasor Technology: Benefits and Pitfalls,” Invited talk, The State Utility Company of Bosnia, Sarajevo, Bosnia, April 2016.

36. “Synchrophasor Technology: Benefits and Pitfalls,” TAMUQ Eminent Scholar Lecture, Doha, Qatar, November 2015.

37. “Flexible Load: WHY, WHEN and HOW,” QEERI, Invited Lecture, Doha, Qatar, November 2015.

38. “Life-cycle Management of Synchrophasor Systems Through Certification, Commissioning, In-Service Maintenance, Remote Testing, and Risk Assessment,” CEPEL, Brazil, Invited Lecture, Rio de Janeiro, Brazil, October 2015.

39. “Big Data: WHAT, WHY, WHEN and HOW,” University of Sarajevo, IEEE DLP Invited Lecture, Sarajevo, Bosnia, October 2015.

40. “Energy Cyber-Physical Systems: What’s Next,” Keynote, ICAT 2015, Sarajevo, Bosnia, October 2015.

41. “Understanding Cascading Phenomenon: Methodologies and Industry Practice for Analysis of Cascading Failures,” IEEE PES GM 2015 Tutorial, Denver, CO, July 2015.

42. “Big Data: What, why, when and how,” Keynote, POWERENG 2015 – 5th International Conference on Power Engineering, Energy and Electrical Drives, Riga, Latvia, May. 2015.

43. “System in the Loop: The Next Generation of Cyber-Physical Testbeds,” Invited Lecture, Tenth Carnegie Mellon Conference on the Electricity Industry, Pittsburgh, PA, USA, Mar. 2015.

44. “TEES Smart Grid Center – Overview,” Invited Lecture, Smart Grid and Renewable Energy Workshop, Qatar, Mar. 2015

45. “Big Data: What, why, when and how,” Keynote, IEEE MedPower Conference, Athens, Greece, Nov. 2014.

46. “Big Data: What, why, when and how,” Keynote, IEEE Frontiers of Power Systems Conference, Oklahoma State University, Stillwater, Nov 2014.

47. “Big Data: What, why, when and how,” Invited Lecture, Shermco Industries SIMS Conference, Houston, September 2014.

48. “Flexible Load: why, when and how,” IEEE Distinguished Lecture, The University of Rome La Sapienza, Rome, Italy, May 2014.

49. “Flexible Load: why, when and how,” IEEE Distinguished Lecture, The University of Split, Split, Croatia, May 2014.

50. “Flexible Load: why, when and how,” IEEE Distinguished Lecture, The University of Ljubljana, Ljubljana, Slovenia, May 2014.

51. “Robust Power System Operation: Needs and Solutions,” Keynote, IEEE EnergyCon, Dubrovnik, Croatia, May, 2014.

52. “The Lay of the Land: Energy Cyber-physical systems,” Invited Lecture, Tsinghua University, Beijing, China, April 2014.

53. “EMS-NEXT,” Invited Lecture, New York ISO, February 2014.

54. “Energy Cyberphysical Systems: The Lay of the Land,” Invited Lecture, NSF Workshop on Energy Cyberphysical Systems, Arlington, VA, December 16, 2013.

55. “Synchrophasor Technology: Benefits and Pitfalls,” Invited Lecture, COPPE Workshop, Federal University of Rio de Janeiro, Brazil, December 4, 2013.

56. “Smart Grid: Opportunities and Challenges,” Invited Lecture, Xi’an Jiao Tong University, China, October 8, 2013.

57. “Smart Uses of Data in Smart Grids,” Keynote, ISGC&E, Jeju Island. Korea, July 2013.

58. “Smart Uses of Smart Grid Data,” Keynote, IEEE EURUCON 2013, Zagreb, Croatia, July 2013.

59. “Temporal and Spatial Properties and Uses of Power System Data,” Invited Lecture, University of Washington, Seattle, Washington, April 2013.

60. “Smart Grid Goals: Transition from Legacy to New Solutions,” Distinguished Speaker Invitation, The National University of Taiwan, Taipei, Taiwan, November 2012.

61. “Smart Grid Goals: Opportunities for Innovation,” Invited lecture, Jangtze Delta Region Institute of Tsinghua University, Zhejiang, China, Oct 2012.

62. Series of three invited lectures at the North China Electric Power University, “Data Uses in Smart grids”, “Spatial and Temporal Properties of Smart Grid Data”, “A Fast Stability Classification Scheme Based on Classification and Regression Trees,” Beijing, China, Oct 2012.

63. “Smart Grid Applications in the World and in Alberta,” Distinguished Speaker Invitation, Calgary IEEE Section, Canada, September 2012.

64. “Translational Knowledge: From Collecting Data to Making Decision in a Smart Grid,” Invited Lecture, The Istanbul Technical University, Turkey, June 2012.

65. “Temporal and Spatial Characteristics of Power System Data,” Invited Lecture, Los Alamos National Lab Workshop, Santa Fe, March 2012

66. “The 21st Century Smart grid: Current Developments, Future Opportunities, and Challenges,” Invited Lecture, IEEE Section, Calgary, Canada, March 2012

67. “Technical Program – International Electric Vehicle Conference (IEVC),” Invited lecture, 2012 IEEE International Electric Vehicle Conference (IEVC), Greenville, SC, March 2012.

68. “EV-TEC: Transportation and Electricity Convergence,” Electric Vehicle Workshop, University of New South Wales, Sydney, November 2011

69. “Future Challenges and Opportunities in Smart Grid Automation and Protection,” APAP Conf., Beijing, China, October 2011.

70. “Smart Grid Integration, Interoperability, and Methodologies,” Joint Critical Infrastructure Partnership Symposium, Houston, August 2011.

71. “Multiple Uses of Substation Data,” REE, Madrid, Spain, June 2011.

72. “Interoperability: Blessing with a Curse,” i-PC Grid Workshop, San Francisco, March/April 2011.

73. "The Smart Grid Data "Explosion: Translational Knowledge Challenge," Los Alamos National Lab, December 2010

74. "The Smart grid: Opportunities and Challenges," The University of Cyprus, Cyprus, Nov 2010.

75. "The Smart Grid: Opportunities and Challenges," Invited Plenary Talk, Modern Electric Power Systems Symposium, Wroclaw, Poland, September 2010.

76. "PHEV/BEVs Transportation and Electricity Convergence," Public Utility Commission, Austin, Texas, May 2010.

77. "New Role of Smart grid Testing: Smart Risk Mitigation," i-PCGRID Conference, San Francisco, March 2010.

78. "The Smart Grid: Opportunities and Challenges," The King Saudi University, Saudi Arabia, February, 2010.

79. "Interoperability: Synchronized Sapling Framework for Monitoring Application," i-PC Grid Workshop, San Francisco, March 2009.

80. "The Smart Grid Solutions for Monitoring, Control and Protection in the Transmission Grid," IEEE Lecture, The National Technical University of Athens, Athens, Greece, October 2008.

81. "Automated Fault Analysis," IEEE Lecture, UAE Section, Abu Dhabi, UAE, March 2008.

82. "Asset Management Improvements: Condition-Based Maintenance and Risk Based Maintenance Scheduling," IEEE Lecture, UAE section, Al Alain, UAE, March 2008.

83. "Uses of Operational and Non-operational Data," Egyptian Electricity Company, Cairo, Egypt, March 2008.

84. "Automated Fault Analysis," IEEE Distinguished Lecture, IEEE Vancouver Section, BC, Canada, February 2008.

85. "The Temporal and Spatial Properties of Power System Field Recorded Data," Arizona State University, Phoenix, AZ, USA, February 2008.

86. "Synchronized Sampling Applications for the 21st Century Power Systems," Series of five Invited lectures at Electric Power Research Institute, Xi'an Jiao Tong University, Shanghai Jiao Tong University, Tsinghua University, and Zhejiang University, People's Republic of China, November 2007.

87. "The Electricity System of the 21st Century," China Light and Power, Hong Kong, October 2007.

88. "The Temporal and Spatial Properties of Power System Field Recorded Data," Invited Lecture, The University of New South Wales, Sydney, Australia, May 2007.

89. "The Electricity System of the 21st Century," Invited Lecture, The University of Adelaide, Australia, May 2007.

90. "The Temporal and Spatial Aspects of Power System Field-Related Data," Invited lecture, Georgia Institute of Technology, October 2006.

91. "The Temporal and Spatial Considerations of Monitoring, Control, and Protection of Power Systems," a series of two lectures at the University of Novi Sad and Belgrade, and the Electric Utility Company of Serbia-EPS, February 2006.

92. "The Electricity Systems of the 21st Century," a series of two lectures at University of Auckland and University of Canterbury, New Zealand, November 2005.

93. "New Research Areas in Protection and Control," a series of six lectures given at the following universities in China: Tsinghua, Dalian, North China Power, Xi'an JiaoTong, Shanghai JiaTong, South China Institute of Technology, August 2005.

94. "New Research Areas in Protection and Control," Central Research Institute of Electric Power Industry (CRIEPI), Japan, August 2005.

95. "New Research Areas in Protection and Control," The University of Hong Kong, Hong Kong, August 2005.

96. "Integrating Data and Sharing Information from IEDs," Electric Utility Company of Serbia-EPS, Belgrade, Serbia, January 2005.

97. "Future of Communications in the Utilities," Electric Utility Company of Serbia-EPS, Belgrade, Serbia, March 2004.

98. "New Communication Technologies and Standards," Workshop Electric Utility Company of Province of Vojvodina, Novi Sad, Serbia, March 2004.

99. "Overview of PSerc Research: T&D Technology Research Stem," Workshop on Electricity interconnection AIT, Bangkok, Thailand, January 2004.

100. "New Communication Technologies and Standards," Elektrotehnicki Fakultet, Sarajevo, Bosnia and Hercegovina, December 2003.

101. "Advanced Substation Automation Applications," ABB Corporate Research Center, Bern, Switzerland, July 2003.

102. "Neural-Fuzzy Pattern Recognition Algorithm for Classifying the Events in Power System Networks," Temple University, Philadelphia, March 2003.

103. "Research Issues Related to Future Trends in Protective Relaying, Substation Automation, Testing and Related Standardization," Hong Kong Polytechnic University, Hong Kong, November 2002.

104. "Power System Control and Protection: Research Status and Future Trends," IEEE Section, University of Belgrade, Serbia, July 2002.

105. "Protective Relay Performance Characteristics and Behavior," Invited Speaker, IEEE Section, Paris, France, March 2000.

106. "Protective Relay Testing Methodology and Tools," Invited Speaker, IEEE Section, Paris, France, March 2000.

107. "Technical Activities in the Power Systems Relaying Committee of IEEE," Invited Speaker, IEEE Section, Paris, France, November 1999.

108. "Automated Fault Analysis," Invited Speaker, IEEE Section, Paris, France, November 1999.

109. "Advancements in Protective Relaying, Monitoring and Testing," Invited Speaker, IEEE Section, Amarillo, April 1999.

110. "Relay Assistant Software for Transient Testing of Protective Relays," AVO International Technical Conference, Invited Paper, Dallas, September 1998.

111. "Future Uses of Digital Simulators in the Protective Relaying Research," Invited Presentation, IEEE Section, Monterrey, Mexico, May 1996.

112. "Design Testing of Distance Relays," AVO International Technical Conference, Invited Paper, Dallas, Texas, August 1995.

113. "Recent Trends in the Power Industry in the USA," Texas A&M Center in Mexico D.F., Mexico, May 1995.

114. "Digital Simulators Research and Development at Texas A&M University," Instituto de InvestigacionesElectricas, Cuernavaca, Mexico, May 1995.

115. "New Approaches to Automated Fault Analysis for Operators in Control Centers," Siemens-Empros Power Systems Control, Minneapolis, Minnesota, March 1995.

116. "Development of Digital Simulators for Relay Testing," Nanjing Electric Power Automation Equipment General Factory, Nanjing, The People's Republic of China, October 1994.

117. "New Research Directions in Protective Relaying," Hauzhong University of Science and Technology, Wuhan, The People's Republic of China, October 1994.

118. "Advanced Research Topics in Protective Relaying," Tianjin University, Tianjin, The People's Republic of China, October 1994.

119. "New Approaches to Monitoring of Power Systems," Electricite de France, Paris, France, September 1994.

120. "New Digital Simulator Designs," Electricite de France, Paris, France, September 1994.

121. "Advances in Digital Simulator Developments," Red Electrica de Espana, Madrid, Spain, May 1994.

122. "Intelligent System Applications to Fault Analysis," Red Electrica de Espana, Madrid, Spain, May 1994.

123. "Digital Simulators for Relay Testing," CEPEL Electric Power Research Institute, Rio de Janeiro, Brazil, November 1993.

124. "Intelligent System Applications to Fault Analysis," CEPEL-Electric Power Research Institute, Rio de Janeiro, Brazil, November 1993.

125. "Applications of Synchronized Sampling," CEPEL-Electric Power Research Institute, Rio de Janeiro, Brazil, November 1993.

126. "New Designs of Digital Simulators for Relay Testing," GEC Alstom Measurements, Stafford, England, August 1993.

127. "Digital Simulators for Relay Testing," ABB Power T&D Company, Coral Springs, Florida, June 1993.

128. "Digital Simulator Requirements," IEEE Power Engineering Society, Protective Relaying Committee, Vancouver, British Columbia, Canada, May 1993.

129. "Advanced Research in Control and Protection," ABB Transmission Technology Institute, Raleigh, North Carolina, May 1993.

130. "Digital Simulators for Relay Testing," Commonwealth Edison, Chicago, Illinois, April 1992.

131. "Transient Testing of Protection Relays," Multi-Amp Users Conference, Invited Paper, Dallas, Texas, August 1991.

132. "Expert System Applications to Monitoring, Control and Protection," ABB Research Center, Baden, Switzerland, August 1990.

133. "Integrated/Coordinated Substation Systems," ABB Research Center, Baden, Switzerland, August 1990.

134. "Expert System Applications to Control and Protection," IEEE PSRC, WG on Expert Systems, Montreal, Canada, May 1990.

135. "TAMU R&D Activities in Protective Relaying," IREQ, Montreal, Canada, May 1990.

136. "TAMU R&D Activities in Protective Relaying," Ontario Hydro, Toronto, Canada, May 1990.

137. "DYNA-TEST Simulator Application to Relay Testing," Multi-Amp Users Conference, Invited Paper, Dallas, Texas, September 1989.

138. "Integrated Control and Protection for Electric Power Systems," IEEE Invited Lecture, Pittsburgh Section, University of Virginia, January 1989.

139. "New Trends in Microprocessor Applications to Control and Protection," series of 3-day presentations given at Mitsubishi, Toshiba and CRIEPI, Japan 1988.

140. "Integrated Solution for Relaying, Local and Remote Control in H.V. Substations," Invited Paper, YU CIGRE, Croatia, November 1988.

141. "Microprocessor Applications to Control and Protection," CEPEL, Brazil, July 1985.

142. "Microprocessor-Based Relaying Equipment," Energoinvest Company, Electric Power Institute, Bosnia, 1985.

143. "Application of Microprocessors to Protective Relaying," ISKRA Company, Slovenia, 1982.

144. "Integrated Control and Protection Systems," Institute Mihailo Pupin, Yugoslavia, 1981.

145. "Microprocessor Applications to Control and Protection," Energoinvest Company, Institute for Control and Computer Sciences, Bosnia, 1980.

Short Courses/Seminars/Tutorials/Webinars

1. The Big Data Analytics: An Incremental Improvement or a Transformational Change," Smart Grid Center Webinar, July 2020
2. "The Role of Big Data Analytics in Predicting Power System Outages", PSerc Webinar, February, 2020

3. “Big Data Analytics for Outage and Asset Management”, Short Course, Oct 2019
4. “Improving the Grid Resilience”, Short Course, Ocxt 2019
5. “Big Data uses in the utility industry,” Tutorial, CIGRE Symposium Grid of the Future, Philadelphia, Oct, 2016.
6. “Wide Area Protection, Communication and Control in Energy Systems,” Tutorial, IEEE PES Conference on Innovative Smart Grid Technologies, Washington, DC, USA, Feb. 2015.
7. "Multiple Uses of Substation IED Data for Future Grid Applications," Grid of the Future Symposium, Houston, Texas, October 2014.
8. “Energy Management System: Transition from Legacy to Future Design,” Independent System Operator, New England, June 2013.
9. “Synchrophasor Technology: Benefits and Pitfalls,” IEEE Region 5, Austin, March 2013.
10. “Tomorrow’s Smart Grid: The Business Value of Interoperability”, Seminar sponsored by Electrix, New Zealand, Oct 2012.
11. “PMU Laboratory, Commissioning and Filed Testing,” WAMS Short Course, University of Sannio, Benevento, Italy, November 2010.
12. “Protective Relaying Seminar: New Developments in Protective Relaying,” IEEE Iowa Illinois Section, October 2010.
13. “Smart Grid: Intelligent Transmission and Distribution,” Q1 Productions Industry Seminar, Miami, March, 2010.
14. “Integration of Asset and Outage Management Tasks for Distribution Applications,” PSerc Tele-seminar, April 2010.
15. “Automated Fault Analysis,” The King Saud University, Saudi Arabia, March 2010.
16. “Integration of Operational and Non-operational Data for Improved EMS Monitoring,” PSerc Tele-seminar, November 2008.
17. “Distribution Automation,” Dubai World Central, Dubai, UAE, March 2008.
18. “Automated Fault Analysis and Fault Location,” South China University of Technology, Guangzhou, People's Republic of China, November 2007.
19. “Automated Fault Analysis and Fault Location,” The University of Adelaide, Australia, May 2007.
20. “Uses of Operational and Non-operational Data,” Research Seminar, Texas A&M University Qatar, Qatar, March 2007
21. “Uses of Operational and Non-operational Data,” Research Seminar, UAE IEEE Section, Abu Dhabi, March 2007
22. “Real-Time Monitoring of Cascading Events,” PSERC Tele-Seminar, March 28, 2006.
23. “Automated Fault Analysis,” Electrix, New Zealand, November 2005.
24. “Use of Operational and Non-Operational Data in Utilities,” Electrix, New Zealand, November 2005.
25. “Uses of Substation Data for Improved Operation and Maintenance,” PSerc Tele-Seminary, October 5, 2005.
26. “Wide Area Disturbance Monitoring and Protection Schemes”, Decision Systems International, Seminar for Korea Power Exchange, San Francisco, October 2005.
27. M. Kezunovic, S. Meliopoulos, “PSerc Tutorial on Dynamic Disturbances Recorders,” Duke Power, Atlanta, July 2004.
28. “Evaluating Protecive Relay Operation Through Testing,” PSerc Tele-Seminar, April 6, 2004
29. “New Research and Developments in Utility Communications,” Brain Gain Program Elektrotehnicki Fakultet, Sarajevo, Bosnia and Hercegovina, December 2003.
30. “Management of Relaying and Control Assets,” Short Course, EPRI, November 2003
31. “R&D in T&D,” Invited Seminar, Electrix, New Zealand, October 2003.
32. “Current Research Issues in Protective Relaying,” Invited Seminar, CRIEPI, Japan, November 2002.
33. “The Research Agenda in Protective Relaying and Control,” TM T&D Company, Japan, November 2002.
34. “Application of Artificial Intelligence in Fault Analysis,” Invited Tutorial, IEEE T&D Conference, Japan, November 2002.

35. M. Kezunovic, A. Bartylak, R. Zivanovic, "Automated Fault Analysis and Fault Location," Invited Tutorial, ESKOM, South Africa, June 2002.
36. M. Kezunovic, C.C. Liu, S. McArthur, "Fault Analysis Tutorial," IEEE PES Winter Meeting, New York, January 2002.
37. "Advanced Engineering Tools for Protection Engineers," Invited Seminar, Electrix, New Zealand, December 2000.
38. M. Kezunovic, A. Abur, C.C. Liu, S. McArthur and L. Smith, "Fault Analysis Tutorial", IEEE PES Summer Meeting, Seattle, July 2000.
39. M. Kezunovic, A. Abur, G. Huang, "Protective Relay Testing Using EMTP and Digital Simulators," Short Course, Texas A&M University, May 2000.
40. M. Kezunovic, A. Abur, "MatLab for Power Engineers," Short Course, Entergy Services, New Orleans, August 1999.
41. "Protective Relay Testing Using EMTP and Digital Simulators," Short Course, Texas A&M University, College Station, May 1999.
42. M. Kezunovic, A. Abur, "Selected Advanced Topics in Digital Simulators, Protective Relay Testing, Substation Equipment Design and Fault Analysis," Short Course, Universidade Federal de Pernambuco, Recife, Brazil, August 1998.
43. M. Kezunovic, A. Abur, "Protective Relay Testing Using EMTP and Digital Simulators," Short Course, Texas A&M University, College Station, June 1998.
44. "Real-Time Simulators and Modeling of Electric Transmission System," Short Course, Harza Engineering, Chicago, May 1997.
45. "Recent Developments in Protective Relaying," Short Course, ESKOM, Johannesburg, South Africa, November 1996.
46. "New Trends in Protective Relaying," 15-week course recorded on a videotape, Continuing Education Program, Washington State University, 1986-87.
47. "Digital Algorithms for Protective Relaying," Energoinvest Company, Factory for Relaying, 5-day Short Course, Bosnia, 1985.
48. "Digital Communication Techniques for EMS Applications," Energoinvest Company, Institute for Computer and Information Systems, Bosnia, 5-day seminar, 1981.

VISITING SCHOLARS

Dr. Jie Zhao, PostDoc, USA	2019-2020
Dr. Kleber Melo de Silva, Federal University of Brazilia, Brazil	2019-2020
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Dr. Jonatas Boas Leite, São Paulo State University, Brazil	2016-2017
Dr. Xiaochen Du, PostDoc, China	2015
Dr. Vuk Malbasa, University of Novi Sad, Serbia	2012-2013
Dr. Gurunath Gurala, PostDoc, GE Global Research, India	2012/2013
Dr. Peter Imris, PostDoc, Poland	2012/2013
Dr. Huifang Wang, Zhejiang University, China	2012/2013
Mr. Andre A. P. Biscaro, Sao Paulo State University, Brazil	2011/2012
Dr. Yan Liu, North China Electric Power University, China	2010/2011
Mr. Ozgur Gonen, Texas A&M University	2009
Dr. Neso Mijuskovic, Transmission System Operator of Serbia	Fall 08
Mr. Deng Xianda, Tsinghua University, China	2008
Ms. Dina Khalifa, Cairo University, Egypt	2007/2008
Ms. Biljana Matic, University of Novi Sad, Serbia	2007
Dr. Soon-Ryul Nam, Myongji University, Korea	2007/2008

Mr. Rodrigo A.F. Pereira, Sao Paulo State University, Brazil	2005/2006
Dr. P. Zhang, Shanghai Jiaotong University, China	2005/2006
Dr. F. Gul Bagriyanik, Istanbul Technical University, Turkey	2001/2002
Dr. S. Luo, Tianjin University, China	2000-2002
Dr. J.B. Lee, Wonkwang University, Korea	1998/1999
Dr. B. Kasztenny, The Wroclaw Technical University, Poland	1997-1999
Dr. Lj. Kojović, Energoinvest Company, Bosnia	6/89-8/89; 4/90-9/90; 4/91-2/93
Dr. M. Aganagić, Energoinvest Company, Bosnia	1992/1993
Dr. B. Peruničić, University of Sarajevo, Bosnia	Summer, Fall 1992

APPENDIX 2

MATERIALS CONSIDERED

A. U.S. Patent No. 8,786,133

B. U.S. Patent No. 8,786,133 File History

C. U.S. Patent No. 9,331,489

D. U.S. Patent Publication No. 2009/0020151 ("Fornage")

E. Kjaer et al., A Review of Single-Phase Grid-Connected Inverters for Photovoltaic Modules, IEEE Transactions on Industry Applications, Vol. 41, No. 5, September/October 2005

F. U.S. Patent Publication No. 2002/0038667 ("Kondo")

G. U.S. Patent Publication No. 2005/0105224 ("Nishi")

H. U.S. Patent Publication No. 2008/0283118 ("Rotzoll '118")

I. U.S. Patent Publication No. 2009/0000654 ("Rotzoll '654")

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