

ISOLATION ELECTRONICS FOR POWER SYSTEM GRID INTERCONNECTION

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Assignee: Not applicable

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FIELD OF THE INVENTION

The invention relates to the safe interconnection of solar energy systems to an electricity grid. The main objective of this invention is to implement multiple anti-islanding procedures by implementing an electrical interconnection system for a solar power generator connected to a power grid network. The anti-islanding may additionally be isolated indirectly to a buildings using the power grid network supply. However, it is not restricted this case and may be used for any other related anti-islanding safety purposes. In example embodiments, the invention relates to improvements in grid interconnectivity of a photovoltaic generator allowing multiple isolation means of the said generator for safe disconnection from the grid. Such devices may be used to isolate the solar system for safety procedures under the occurrence of various events such as a grid black out, a fire in a building, or for other automated shut down procedures for scheduled or ad-hoc servicing of electrical installations.

BACKGROUND OF THE INVENTION

Photovoltaic (PV) generators are becoming more prevalent for generation of power. PV generators are DC energy systems, where the incidence of sunlight on a semiconductor material leads to a flow of charge through a closed circuit. This flowing charge may provide electrical power for a building or can be injected into a power transmission network. A PV generator system is typically comprised of an array of individual PV modules which are manufactured to cover a large area. The incident sunlight on the area of coverage of the solar module is converted into electrical power. The solar PV module holds a plurality of individual solar cells, and these cells are wired together so as to establish a particular power output with characteristic voltage and current from the individual electrical component. Such PV modules are use to cover a particular area so as to increase a power systems output. Stringing of these modules together is performed to connect the whole system for electricity generation.

Today two kinds of systems are most commonly constructed. Solar farms are power stations which utilize a large amount of outdoor area over empty land. A solar power system is installed by placing mounting poles into the ground or otherwise installing a mechanical system to support the solar PV modules. These modules are strung then and connected through electrical gear to establish an electrical power output which may be introduced into a electrical grid. Another type of system distinct from the solar farm is a rooftop based system. In this case, a solar power system is installed on a framing support system on top of a building. Here again the individual PV modules are strung into an array to aggregate the output of the power system.

The stringing of the solar PV modules used both series and parallel connections. Thus, an array of solar panels will include a number of strings in series, and a number of parallel strings. These stringing arrangements determine the voltage and current of the entire PV array. For reference, we cite the Handbook of Photovoltaic Science and Engineering by A. Luque and S. Hegedus which includes details of solar PV systems stringing procedures and on the electrical characteristics of the PV module components.

In the case the solar PV system is installed on a building, a different standard for electrical safety is required. This is because in urban environments, the close proximity of the solar PV system to other electrical gear, and the occurrence of a high population density lead to a higher probability of hazards occurrence, and a higher and more prominent risk implication posed for the electrical installations. Safe isolation of the systems is a manner by which risk of electrical shock is mitigated. The electrical gear must be safely isolated so that in the event a grid power source is disconnected, the additional incoming power source from the PV system. Moreover, other occurrences such as a security breach, fire, or blackout or shut down of the buildings load can be vents which will lead to an automatic shut down of the generator. This will reduce the likelihood that a electrical worker or other individual can be subject to a voltage from the generator.

Islanding refers to the state where a generator continues to create power even when a power distribution network is not powered from an independent electric utility. For example, a power blackout may occur, while a solar energy generator continues to perform and generate power and a voltage at the connection. In this instance, the generator is said to create an island. This situation can be dangerous for utility workers or others, and can also damage hardware at the network. For example, a utility network may assume that a power blackout has occurred while no voltage is present on a distribution board to be worked on.

This worker may then receive an electrical shock since the islanding of a generator leads to an additional power source or voltage at the distribution board, even though a blackout has occurred.

With intentional islanding, the generator will continue to generate power even during a blackout or shut down servicing event. If the generator is a solar energy system, there will be power so long as sunlight is incident on the photovoltaic or thermal converters. In this case, the supply line from the generator becomes an island surrounded by a “sea” of unpowered conductors. This could be utilized for power backup for example. If the intentional islanding is wanted, the generator may disconnect from the grid and is forced to power a local electric load for example.

When islanding is determined to be unsafe, an automatic anti-islanding shut down mechanism can be used. This can be done by using a de-synchronization method from the grid. Synchronizers are electrical components which will detect the waveform of a power distribution network, and will then provide an output signal which conforms to the AC power grid. The solar energy system is equipped with an inverter which will take a DC power input and release an AC power output. These inverters may also be implemented with an internal synchronizer such that the connection apparatus for the solar energy generator can include an output at the inverter which is synchronized. Thus, an inverter/synchronizer instrument will then be able to perform an anti-islanding operation for a safe shut down procedure. This can effectively isolate the generator from the power grid. The de-synchronization can be set to occur when the supply is disrupted, or when the grid goes outside of preset voltage parameters as well, to prevent islanding.

In consideration of the safety protocols enabled with the invention utilizing various electrical components, similar ratings of the auto cut-off switch, circuit breakers or other components, including the pilot cable or replacement means of signalling the auto cut-off of solar power generator may be used, or may be inter-changeable. When similar ratings of the auto cut-off switch, circuit breakers or other components are not available, electrical gear with a higher rating may be used with an over-current and earth fault setting to ensure electrical safety. An additional synchronizing relay cut off pilot cable with one or multiple relays depending on the number of strings in the solar system is used on top of a solar power inverters automatic AC disconnectors interlocking with each other for added electrical safety for anti-islanding.

It is noted that common anti-islanding measures alone would be sufficient for any Grid-tie PV Systems installed behind the building Main Switchboard where isolation of Main Circuit

Breakers is possible to serve as additional step for Anti-islanding. However, if the Grid-tie PV Power System is installed directly onto the grid network, additional isolating switches would be recommended for the cut off of Solar Power to the Grid (at the building outgoing connection to the power grid). Additional safety features to the inverter synchronising switches provide additional levels of isolation, and may be implemented such as to create an automated system shut down due to a plurality of events occurring. In highly populated urban environments, added electrical and fire safety measures should be implemented to ensure risks for firemen and energy grid servicemen, as well as the public, so that risks in the case of an emergency or a power system shut down are minimised. With this in mind, this paper describes a variety of interconnection methods for direct connection of a solar energy system to a grid power distribution network, whereby various isolation and interlocking means are implemented to cause dual isolation, or isolation using more than one means for automated disconnection and anti-islanding.

DESCRIPTION OF THE DRAWINGS

Fig. 1 is the simplified electrical connection drawing for a grid interconnection whereby the connection point of the solar photovoltaic gear including the solar panels and inverters is at the service cables of the grid connecting the building.

Fig. 2 is the simplified electrical connection drawing for a grid interconnection whereby the connection point of the solar photovoltaic gear including the solar panels and inverters is at an over ground electrical box nearby to the building.

Fig. 3 is the simplified electrical connection drawing for a grid interconnection whereby the connection point of the solar photovoltaic gear including the solar panels and inverters is at the substation of the grid connecting nearby to the building.

Fig. 4 is the simplified electrical connection drawing for a grid interconnection whereby the connection point of the solar photovoltaic gear including the solar panels and inverters is at the substation of the grid while the voltage of the generator runs through a step-up transformer.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

As a measure to safeguard from a system fault, such a power system shut downs, and islanding of generators, additional anti-islanding procedures are produced using the electrical apparatus described below. The electrical apparatus described enhance safety and the manner in which an anti-islanding of a generator may be forced on. A common feature of the embodiment is the added anti-islanding resulting from the multiple interlock mechanisms created. Those interlocks, moreover, may be implemented assuming a variety of connections points of a solar energy generator to the power grid distribution network. These mechanisms are based on de-synchronization resulting from a sense signal, which will detect a specific even. A plurality of events maybe sensed, while an isolation mechanism may be added per event.

The implementation of this isolation method is engineered so as to account for the interconnections point at the grid. Four cases of the connection instruments are described; however, the common embodiment of the invention may be implemented in other circumstances where a connection point at the grid is determined. The sense signal is described in what follows as a signal line interconnection which may then interact at the common breaker point. A plurality of such breakers is added for safe isolation so as to cause an interlocking mechanism. These implement a communication base since an added interlock is employed through an additional electrical installation enabled to reference a variety of signals through a pilot line or the like thereof.

The selection method to choose which connection point will be used, and thus which interconnection isolation system to install, is various. Generally the connection point will be chosen to reduce cost. Thus, preferably the shortest distance to the connection point from the solar energy generator will be used as a merit. Other considerations on the connection method to use include commercial terms such as who owns a service cable, which may be a building owner or another external firm such as the power grid operator. The consideration of installations cost may also affect the method to be used. When installing electrical gear with a transformer, a cost is included for this element that may mean a low tension connection point is preferred. No limitation on the use of any system as described herein.

In the first scenario, it is assumed a power grid operator or a building owns a service cable which is accessible nearby to the building. The building receives 400V 3 Phase LT supply from the power grid. The service cable has the full capacity to carry the solar power generated from the solar energy system installed on a to the power grid low tension network

for distribution. In this case, connections system apparatus described above referencing to Fig. 1 may be employed.

As a second scenario, consider that an over ground electrical box is available close to the building. It may be required that a connection point be made at the over ground box due to a mismatch in the voltage at the buildings service cable, or due to inaccessibility. In this case an additional over ground electrical box may be installed and electrical connection may be made to the existing over ground box. The existing over ground electrical box has the full capacity to carry the solar power generated from the Building roof by Retailer back to the power grid low tension network for distribution. Alternatively, a similar working electrical connection can be implemented at the low tension sub-station operated by the power grid. In this third scenario, there is a low tension connection capacity in the adjacent power grid substation to allow solar power to be injected to the power grid low tension network for distribution. In this case the electrical apparatus described in Fig. 3 may be employed. The methods in scenario 2 and 3 may also be implemented in the event that the building where the solar power is generated receives a low tension supply from the power grid, but the service cable is under the rated capacity required to carry the solar power generated into the power grid. However, there is a low tension connection capacity in the power grid high tension sub-station to allow solar power to be injected to the Network.

In the event that a connection is to be made to a high tension power supply, a larger voltage input is required. In these cases, a step up and step down controller may be installed at proper points of conversion within the multiple interlocking electrical apparatus described. In this case, the electrical system described in Fig. 4 may be employed.

An industrial control system such as the protocol supervisory control and data acquisition(SCADA) communication method may be utilized for signalling as an alternative to the pilot cable lines described below. In this communication method, communication is used to send utility status information to an inverter, while the inverter can interpret to determine whether an island has been formed in the power system network. Communication-based methods include various methods such as a direct transfer trip (DTT) method, a power line carrier communication (PLCC) method, or integration of inverters into utility SCADA. In DTT, the utility's breaker or other isolation device is tied to a transmitter that sends the breaker's status to the DG. In PLCC, a form of direct transfer trip (DTT) may be employed in which the communication channel is the power line itself. In what follows, descriptions of additional anti-islanding methods are described based on implementing a signal connection pilot line. These however are implied to be implemented with various methods including the direct

transfer trip, power line carrier communication, and supervisory control and data acquisition methods mentioned here.

While we present a physical connection assumed to be a wire connection, it is also possible to implement the signal sense channels using a variety of other apparatus. For example, it is proposed below that the signal line may also be implemented optionally as a communications channel using a local telecommunications network. In this case, one or more communications accounts may be implemented to interlock the isolation means employed at the specified points of the electrical system. In this case, one or more SIM card may be installed along with a signal generation apparatus at the connection point to provide communications to implement a signal within the isolation apparatus for anti-islanding. Such SIM cards may be implemented along with other solar energy generators at the inverter output so as to limit the events where an island may form should two generators detect each other through the network during a system shut down. Moreover, the SCADA system, or a pulse signal travelling through existing wire may be implemented to perform such signalling.

Passive anti-islanding protection can be incorporated in the form of an under and over voltage protection, as well as an under and over voltage frequency protection. Here, is the voltage goes outside the range settings as a minimum voltage (V_{min}) or a maximum voltage (V_{max}), or its frequency goes outside the range of a minimum frequency (f_{min}) to a maximum frequency (f_{max}), the disconnection device in the protection system of the inverter will operate within a set time interval for disconnection. For example, on detection of an event which will cause isolation for more than 2 seconds interval, the anti-islanding of the inverter function will be implemented.

For a specific case we may follow certain values. These values must be determined based on the voltages and frequencies normally utilized for a particular power grid. Anti-islanding may results when V_{min} lies in the range 200-230 V for a single-phase system or 350-400 V for a three-phase system, when V_{max} lie in the range 230-270 V for a single-phase system or 400-470 V for a three-phase system, when f_{min} lies in the range of 45-50 Hz, and when f_{max} lies in the range 50-55 Hz, The limits V_{max} , V_{min} , f_{max} and f_{min} can also be set manually, or are programmable, and may be selected to correspond with the values that a power network requires.

In addition to the incorporation of at least one passive anti islanding method, active anti-islanding protection may also be implemented. Examples of such methods include shifting the frequency of the inverter away from nominal conditions in the absence of a reference

frequency (frequency shift), allowing the frequency of the inverter to be inherently unstable in the absence of a reference frequency (frequency instability), periodically varying the output power of the inverter (power variation) and monitoring for sudden changes in the impedance of the grid by periodically injecting a current pulse (current injection). Active anti-islanding protection is put in place in addition to the passive anti-islanding protection to prevent a situation where islanding may occur due to multiple inverters providing a frequency and voltage reference among each another. The disconnection device in the protection system of the inverter can operate based on a time lapse in a power supply detected on the grid. For example, an inverter may be set to disconnect upon detection of a disruption to the power supply from the grid for a 2 second interval, or similar.

The following interconnection mechanism is implemented while the generator is to be connected at a buildings service cable labelled 120. The service cable capacity will be installed or otherwise verified to be able to accept the full capacity to transmit the solar power generated by the generator to the grid network. This service cable will be connected back to the substation of the power network, and so is able to carry power into the electricity network. Fig. 1 demonstrates an interconnection of a solar power generator to the power grid distribution network. In this case the incoming line from the solar energy system 100 enters a solar sub-board 101 with breakers 110 and 111. The solar sub-board 101 connections 115 enter an additional connection board 104 housing breakers 112, 113 and 114. This connection board 104 holds an additional auto cut off switch 109 at the incoming line 115.

100 is a solar energy system comprised of an array or arrays of photovoltaic modules, and the array based on strings of solar panels and solar inverters. The inverters are grid tie inverters and the system is configured to include dual pole complete wave alternating current isolator(s), or similar. 101 is a sub-board for solar system interconnections. 102 is a building main switchboard. 103 is an additional synchronizing relay cut off pilot cable with one or multiple relays depending on the number of strings in the solar system 100.

104 is an additional connection board housing breakers and auto cut of switch 108. 105 is the original service cable to the building. 106 is a suggested location for a grid grade revenue meter complete with a telephone line to measure output from the Solar Power Supply 100. 108 is an automatic cut of switch.

109 are the outgoing line or lines of the solar system to the solar sub-board 101. There may be more than one string of units incoming to the solar sub-board at 101. 110 is a single

incoming breaker or multiple breakers installed within the solar sub-board 101. 111 is an outgoing breaker installed within the solar sub-board 101.

112 is a grid incoming breaker housed within the additional connection board 104. 113 is a outgoing breaker housed within the additional connection board 104. 114 is an incoming breaker for the solar generation connection. 115 is a connection line feeding power from the solar sub-board 101 through the additional connection board 104 into the power grid. 120 is a power grid incoming service cable.

122 is an incoming breaker housed within the main switchboard 102. 123 is a single or multiple number of outgoing breakers housed within the main switchboard 102. 156 is a suggested location for a grid grade revenue meter complete with a telephone line for building incoming supply. 199 is the plurality of building outgoing supply lines (N total units).

All the solar generators 100 inverters shall be of grid tie type incorporated with automatic AC disconnectors for isolation of the solar power supply in the absence of a grid AC supply from the power grid via a new grid service cable 120. An additional connection board 104 is installed as an interconnection point for the grid power supply 112 to the main switchboard 102. The original service cable 105 connecting the power grid supply 120 to the main switchboard 102 is routed to connect onto the grid incoming breaker 112 of the additional connection board 104. A new service cable 125 is installed from the outgoing breaker 113 of the additional connection board 104 to the main switchboard 102. New power cable(s) 109 are installed from the outgoing breaker(s) 110 from the solar power system 100 (subjected to the numbers of solar panel strings) to the solar sub-board 101 and connected to the additional connection board 104. A new pilot cable 103 is to be installed having an interlocking cut-off of the auto cut-off switch breaker 108 on the additional connection board 104 together with all the built-in automatic AC Disconnectors on solar generators inverters 100 to cause additional isolation of the solar power supply 100 in the absence of a alternating current supply sensed on the power grid.

Once all the synchronising relays of the solar inverters detect that there is a power grid failure or shut-down, both the auto cut-off switch breaker 108 on the additional connection board 104 and the automatic AC disconnectors on solar generators inverters installed in the solar energy system 100 shall cut-off, thus, isolating the solar power supply 100 from feeding into the power grid network. On the other hand, once one of the synchronising relays of the solar inverters detect that the grid supply 120 is resumed, both the auto cut-off switch breaker 108 on the additional connection board 104 together and the automatic AC

disconnectors on the solar generators 100 inverters shall switch back after the solar power supply is synchronised with the power grid AC supply, connecting the solar power supply back into the power grid network.

The electrical interconnections systems described are designed to cause automated shut down due to a power grid black out or due to planned servicing events where shut down occurs at the building or at the grid sub-station. In the event of a fire emergency, the grid power supply will shut down when isolation has adapted its signal from this alarm. In this event, the solar energy interconnections apparatus described will also turn off the solar power supply 10 to the power grid. Additional alarms may be incorporated into the additional connection board 104 so that multiple channels may be utilized to create an automated isolation of the solar energy system 100 from the power grid network. I.e. if automatic cut-off fails, any electrical worker can also isolate the Solar Power Supply from the grid upon hearing the alarm. By manual turn off solar power supply incoming breaker 114 on the additional connection board, the solar power supply 100 wil cut off from the grid network.

200 is a solar energy system comprised of an array or arrays of photovoltaic modules, and the array based on strings of solar panels and solar inverters. The inverters are grid tie inverters and the system is configured to include dual pole complete wave alternating current isolator(s) or similar. 201 is a solar sub-board taking in one or more than one strings from the solar energy system 200. The solar sub-board 201 includes an incoming breaker 210 and an outgoing breaker 211. 202 is a building main switchboard or more than one main switchboard.

203 is an additional synchronizing relay cut-off pilot cable with one or multiple relays depending on the number of strings in the solar system 200. 204 is an additional over ground electrical box for connection of the solar energy system sub board 201 through to an existing power grid over ground electrical box 288. 205 is a solar power service cable supplying power to the existing over ground box 288 from the additional connection over ground electrical box 204. 206 is a suggested location for a grid grade revenue meter complete with a telephone line for Solar Power Supply. 208 is an automatic cut off switch.

209 is a single or more than one incoming supply line from the solar energy system 200 to the solar sub-board 201. 210 is an incoming breaker or multiple breakers installed in the solar sub-board 201. 211 is the outgoing breaker of the solar sub-board 201. 214 is an incoming breaker at the additional over ground electrical box 204. 215 is the conductor cable taking power from the solar sub-board 201 and supplying power through the additional over

ground electrical box 204 into the power grid. 222 is an incoming breaker at the main switchboard 202. 223 is an outgoing breaker at the main switchboard 202. 225 is the conductor supplying power through the over ground electrical bog 288 to the main switchboard 202.

231 is an incoming breaker in the over ground electrical box 288 for supply from the power grid 299 connecting to the incoming line 205 to the additional over ground electrical box 204 for solar power feed. 232 is an incoming breaker for the over ground electrical box 288 at the grid incoming supply 299. 233 is an outgoing breaker for the over ground electrical box 288.

256 is a suggested location for a grid grade revenue meter complete with a telephone line for to measure power flowing to the building incoming supply 277. 277 is the outgoing or more than one outgoing supply lines to building(s). 288 is an over ground electrical box connected to the power grid incoming line 299. 299 is an incoming line from the power grid supply network, for example it may be a low tension voltage service cable supplying power to the grid over ground electrical box 288.

All the solar generators 200 inverters shall be of grid tie type incorporated with automatic AC disconnectors for isolation of solar power supply in the absence of power grid AC supply via grid incoming service cable 299. An additional connection over ground electrical box 204 is installed adjacent to the power grid low tension over ground electrical box 288, connecting into the same via new service cable 205 to feed into the power grid low tension over ground electrical box 288. A new service cable 205 is to be installed, connecting the solar power supply from the additional connection over ground electrical box 204 to the power grid over ground box 288 onto the additional incoming breaker 231 of the power grid over ground box 288. A new service cable 215 is installed from the outgoing breaker 211 of the solar sub-board 201 to the additional connection over ground electrical box 204. A new pilot cable 203 to be installed to having interlocking cut-off of the auto cut-off switch breaker 208 on the additional connection over ground electrical box 204 together with all the built-in automatic AC Disconnectors in the solar generators inverters 200 as additional isolation of solar power supply in the absence of an AC supply from the power grid 299.

Once the synchronising relay of the solar inverters detect a power grid main failure or shut-down, both the auto cut-off switch breaker on the additional connection over ground electrical box together and the built-in automatic AC disconnectors in the solar generators 200 inverters shall cut-off, isolating the solar power supply from feeding into the grid network via the power grid over ground electrical box 288. On the other hand, once the synchronising

relay of the solar inverters' sense that the power grid low tension supply is resumed, both the auto cut-off switch breaker on the additional connection over ground electrical box 204 and the built-in automatic AC disconnectors in the solar generators 200 inverters shall switch back after the solar power supply is synchronised with power grid AC supply, connecting the solar power supply back into the power grid network.

The above are applicable for a power grid blackout or a planned servicing of the power grid. In the event of a fire emergency, by switching off the grid AC supply from the additional cut-off breaker on the power grid over ground electrical box shall also turn off the solar power supply to the power grid. Additional alarms may be incorporated into the additional connection board 204 so that multiple channels may be utilized to create an isolation of the solar energy system 100 from the power grid network. I.e. if automatic cut-off fails, any Licensed Electrical Worker can also isolate the solar power supply 200 from the grid upon sensing the alarm. By manual turn off of solar power supply incoming breaker 214 on the additional over ground box, or the solar power supply incoming breaker 231 on the existing grid over ground electrical box 288, the solar power supply 200 will cut off from the grid network.

300 is a solar energy system comprised of an array or arrays of photovoltaic modules, and the array based on strings of solar panels and solar inverters. The inverters are grid tie inverters and the system is configured to include dual pole complete wave alternating current isolator(s) or similar. 301 is a solar sub-board taking in one or more than one strings from the solar energy system 300. The solar sub-board 301 includes an incoming breaker 310 and an outgoing breaker 311.

302 are a building main switchboard or more than one main switchboard. 303 is an additional synchronizing relay cut off pilot cable with one or multiple relays depending on the number of strings in the solar system 300. 304 is an additional sub connection board for connection of the solar energy system sub-board 301 through to an existing power grid low tension switchboard 388 at the power grid sub-station 388.

305 is a solar power service cable supplying power to the existing power grid low tension switchboard 388 from the additional sub connection board 304. 306 is a suggested location for a grid grade revenue meter complete with a telephone line for measuring the output of the Solar Power Supply 300. 308 is an automatic cut off switch. 309 is a single or more than one incoming supply line from the solar energy system 300 to the solar sub-board 101. 310

is an incoming breaker of the solar sub-board 301. 311 is the outgoing breaker or multiple breakers installed in the solar sub-board 301.

314 is an incoming breaker at the additional sub connection board 304. 315 is the conductor cable taking power from the solar sub-board 301 supplying power through the additional sub connection board 304 into the power grid. 322 is an incoming breaker at the main switchboard 302.

323 is an outgoing breaker at the main switchboard 302. 325 is the conductor supplying power through the existing power grid low tension switchboard 388 to the building main switchboard 302. 331 is a new incoming breaker for the existing grid power grid low tension low tension switchboard 388 in the power grid sub-station connecting to the solar incoming line 305 and to the additional sub connection board 304.

332 is an incoming breaker for the existing power grid low tension switchboard 388 connected to the grid incoming supply 399 in the power grid sub-station. 333 is an outgoing breaker in the existing grid power low tension switchboard 388. 356 is a suggested location for a grid grade revenue meter complete with a telephone line for measuring the incoming power supply 325 for the building. 377 is the outgoing or more than one outgoing supply lines to building(s). 388 is an existing low tension switchboard at the power grid sub-station. 399 is an incoming service cable from the power grid supply network supplying power to the existing power grid low tension switchboard 388.

All the solar generators inverters 300 shall be of grid tie type incorporated with an automatic AC disconnecter for isolation of the solar power supply in the absence of AC supply from the power grid via grid incoming service cable 399. An additional connection board 304 is to be installed within the power grid sub-station connect onto the additional cut off breaker 331 on the existing low tension main board 388 via a new service cable 305. A new power cable 315 is installed from the solar power outgoing breaker 311 of the solar sub-board 301 to the additional connection board 304.

A new pilot cable 303 is to be installed having an interlocking cut-off of the auto cut-off switch breaker 308 on the additional connection board 304 together with all the built-in automatic AC disconnectors in the solar generators 300 inverters for additional isolation of the solar power supply 300 in the absence of power grid AC supply via the grid service cable 399. Once the synchronising relay of the solar inverters 300 detect that there is a power grid main failure or shut-down, both the auto cut-off switch breaker 308 on the additional

connection board 304 together with the automatic AC Disconnectors installed in the solar generators inverters 300 shall cut-off, isolating the solar power supply from feeding into the power grid network via the existing low tension switchboard 388.

On the other hand, once the synchronising relay of the solar inverters sense that the power grid low tension supply is resumed, both the auto cut-off switch breaker 308 on the additional connection board 304 together and the built-in automatic AC disconnectors in the solar generators 300 inverters shall switch back after the solar power supply is synchronised with the AC supply of the power grid via the existing low tension main board 388, connecting the solar power supply back into the power grid network via grid service cable 399.

The above are applicable for a power grid blackout or a planned servicing by the grid by implementing the above electrical apparatus. In the event of a fire emergency, by switching off the power grid supply shall also isolate the solar power supply to the grid and the other buildings. Additional alarms may be incorporated into the additional connection board 304 so that multiple channels may be utilized to create an automatic isolation of the solar energy system 100 from the power grid network. I.e. if automatic cut-off fails, any electrical worker can also isolate the solar power supply from the grid upon sensing the alarm. By manually turn off solar power supply incoming breaker 314 on the additional connection board or the additional cut off breaker 331 on the existing low tension main board 388, will cut-off the solar power supply from the grid network.

400 is a solar energy system comprised of an array or arrays of photovoltaic modules, and the array based on strings of solar panels and solar inverters. The inverters are grid tie inverters and the system is configured to include dual pole complete wave alternating current isolator(s) or similar. 401 is a solar sub-board taking in one or more than one strings from the solar energy system 400. The solar sub-board 401 includes an incoming breaker 410 and an outgoing breaker 411.

402 is a building main switchboard or more than one main switchboard. 403 is an additional synchronizing relay cut off pilot cable with one or multiple relays depending on the number of strings in the solar system 400. 404 is an additional sub connection board for connection of the solar energy system sub-board 401 through to an existing high tension power switchgear component 488 in the power grid sub-station after a step-up of the voltage via the power transformer 467.

405 is a solar power low tension service cable supplying power to the existing high tension switchgear 488 through power transformer 467 from the additional sub connection board 404. 406 is a suggested location for a grid grade revenue meter complete with a telephone line. 407 is a solar power high tension service cable supplying power to the existing HT switchgear 488 through power transformer 467 from the additional sub connection board 404.

408 is an automatic cut off switch. 409 is a single or more than one incoming supply line from the solar energy system 400 to the solar sub-board 401. 410 is an incoming breaker of the solar sub-board 401. 411 is the outgoing breaker of the solar sub-board 401.

414 is an incoming breaker at the additional sub connection board 404. 415 is the conductor cable taking power from the solar sub board 401 and supply through the additional sub connection board 404 into the existing high tension switchgear 488. 416 is a low tension outgoing breaker at the additional sub connection board 404. 422 is an incoming breaker at the building main switchboard 402. 423 is an outgoing breaker at the building main switchboard 402.

425 is the conductor supplying power through the existing high tension high tension switchgear to the building main switchboard 402 after step-down by power transformer 466. 431 is a new incoming breaker in the existing high tension switchgear 488 connecting to the additional sub connection board 404 via solar incoming high tension service cables 407 through step-up power transformer 467 and low tension service cable 405. 432 is an incoming breaker in the existing high tension switchgear 488 connected to the grid incoming supply 499. 433 is an outgoing breaker in the existing high tension switchgear 488 in power grid sub-station.

456 is a suggested location for a grid grade revenue meter complete with a telephone line for building incoming supply for measuring the incoming power supply to the building. 466 is a step-down transformer converting the voltage from the existing high tension switchgear 488 for the incoming supply to the building low tension main switchboard 402. 467 is a step-up transformer converting the voltage from the additional sub connection board 404 at the incoming supply to the existing high tension switchgear 488 in power grid sub-station.

477 is the outgoing or more than one outgoing supply lines to building(s). 488 is an existing high tension power switchgear component in the power grid sub-station. 499 is a high

tension incoming service cable from the power grid supply network supplying power to the existing high tension switchgear 488.

All the solar generators inverters 400 shall be of grid tie type incorporated with automatic AC disconnectors for isolation of the solar power supply 400 in the absence of an AC supply on the existing power grid high tension switchgear 488. An additional connection board 404 is installed within the power grid sub-station feeding solar power from the outgoing breaker 416 through the low tension service cable 405 into a step-up power transformer 467, and subsequently through a new high tension service cable 407 which is connected onto the additional cut off breaker 407 of the existing power grid high tension switchgear 488. A new power cable 415 is installed from the solar power outgoing breaker 411 of the solar sub-board 401 to the additional connection board 404.

A new pilot cable 403 is installed having an interlocking cut-off at the auto cut-off switch breaker on the additional connection board 404 together with all the built-in automatic AC disconnectors in the solar generators inverters 400 as an additional isolation mechanism of the solar power supply 400 in the absence of an AC supply from the existing power grid high tension switchgear 488.

Once the synchronising relay of the solar inverters' detect a main failure on the existing power grid high tension switchgear 488, or a shut-down of the power grid supply, both the auto cut-off switch breaker 408 on the additional connection board 404 together and the built-in automatic AC Disconnectors in solar generators 400 inverters shall cut-off, isolating the solar power supply from feeding into the power grid network via the existing power grid high tension switchgear 488.

On the other hand, once the synchronising relay of the solar inverters detect that the power supply of the power grid exists again, the existing power grid high tension switchgear 488 is resumed. Both the auto cut-off switch breaker on the additional connection board 404 together and the built-in automatic AC disconnectors in the solar generators 400 inverters shall switch back after the solar power supply is synchronised with the AC supply of the power grid via the existing power grid high tension switchgear 488 connecting the solar power supply 400 back into the power grid network.

The above are applicable for a power grid blackout or a planned servicing by the power grid. In the event of a fire emergency, by switching off the grid power supply shall also turn off the solar power supply to the power grid and other buildings connected on the network.

Additional alarms may be incorporated into the additional connection board 404 so that multiple channels may be utilized to create an automated isolation of the solar energy system 400 from the power grid network. I.e. if automatic cut-off fails, any electrical worker can also isolate the Solar Power Supply from the grid upon detecting the alarm. By manually turn off solar power supply incoming breaker 416 on the additional connection board or the additional cut off breaker 407 on the existing high tension switchgear 488, will cut-off the solar power supply from the grid network.

CLAIMS

1. A grid interconnection system for photovoltaic (PV) generators comprising:
at least one automatic switch breaker disposed on an electrical connection between
a grid supply point and the output of at least one PV generator; and
a pilot cable connection for connection of a pilot cable to an automatic AC disconnect on an
inverter of the at least one PV generator, wherein the pilot cable connection is disposed such
that a waveform of a grid supply is detectable irrespective of the state of the at least one
automatic switch breaker;
wherein the at least one automatic switch breaker is configured to cut the electrical connection
between the at least one PV generator and the grid supply point based on the detected
waveform; and
wherein the pilot cable is connected to respective synchronizing relays of the at least one PV
generators.
2. The system as claimed in claim 1, further comprising at least one manual switch breaker
disposed between the grid supply point and the at least one PV generator, for manual cutting
of the electrical connection between the at least one PV generator and the grid supply point.
3. The system as claimed in claims 1 or 2, wherein the grid supply point comprises a power
grid cable connection.
4. The system as claimed in claims 1 or 2, wherein the grid supply point comprises an over
ground electrical box connection.
5. The system as claimed in claims 1 or 2, wherein the grid supply point comprises a low
tension main board connection.
6. The system as claimed in claims 1 or 2, wherein the grid supply point comprises a high
tension power switchgear component connection.
7. The system as claimed in claim 6, further comprising a transformer disposed between the
high tension power switchgear component connection and the automatic switch breaker.
8. The system as claimed in any one of the preceding claims, configured such that when a
power grid failure or shut-down is detected based on the waveform, the automatic switch
breaker and the automatic AC disconnect cut the connection between the at least one PV
generator and the grid supply point.
9. The system as claimed in any one of the preceding claims, configured such that when
resumption of grid supply is detected based on the waveform, the automatic switch breaker and

the automatic AC disconnect close the connection between the at least one PV generator and the grid supply point.

10. A grid interconnection method for photovoltaic (PV) generators, the method comprising: providing at least one automatic switch breaker disposed on an electrical connection between a grid supply point and the output of at least one PV generator; providing a pilot cable connection for connection of a pilot cable to an automatic AC disconnect on an inverter of the at least one PV generator, wherein the pilot cable connection is disposed such that a waveform of a grid supply is detectable irrespective of the state of the at least one automatic switch breaker; wherein the at least one automatic switch breaker is configured to cut the electrical connection between the at least one PV generator and the grid supply point based on the detected waveform; and comprising connecting the pilot cable to respective synchronizing relays of the at least one PV generators.

11. The method as claimed in claim 10, further comprising providing at least one manual switch breaker disposed between the grid supply point and the at least one PV generator, for manual cutting of the electrical connection between the at least one PV generator and the grid supply point.

12. The method as claimed in claims 10 or 11, wherein the grid supply point comprises a power grid cable connection.

13. The method as claimed in claims 10 or 11, wherein the grid supply point comprises an over ground electrical box connection.

14. The method as claimed in claims 10 or 11, wherein the grid supply point comprises a low tension main board connection.

15. The method as claimed in claims 10 or 11, wherein the grid supply point comprises a high tension power switchgear component connection.

16. The method as claimed in claim 15, further comprising providing a transformer disposed between the high tension power switchgear component connection and the automatic switch breaker.

17. The method as claimed in any one of claims 10 to 16, comprising, when a power grid failure or shut-down is detected based on the waveform, using the automatic switch breaker and the automatic AC disconnect to cut the connection between the at least one PV generator and the grid supply point.

18. The method as claimed in any one of claims 10 to 17, comprising, resumption of grid supply is detected based on the waveform, using the automatic switch breaker and the automatic AC disconnect to close the connection between the at least one PV generator and the grid supply point.