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solar grid interactive sinewave inverter

Introduction

Power Solutions Australia Grid Interactive Inverters provide a means of directly connecting dc renewable sources such as solar photovoltaic arrays and small wind turbines to the electricity grid. Grid connection ensures that all renewable energy generated can be utilised. Solar Grid Battery systems described elsewhere allow local loads to be supported when grid power is lost while allowing power in excess of local loads to be exported to the grid.

Power Solutions Australia Interactive Inverters are fully bi-directional. DC power can be inverted to produce full mains quality supply. However when connected to an AC supply source the inverter can fully and smoothly control its power flow from full inversion to full rectification.

The Solar Grid Interactive inverter uses similar hardware and software as our remote area power system solar panels to be directly connected to the dc side of the inverter. Provided the grid supply is present and in tolerance the inverter starts when solar power becomes available. It controls the voltage presented to the panels to optimise power output and supplies AC power to the network. When the array output falls below the level required to meet inverter losses the inverter shuts down until insolation rises sufficiently to justify restarting the inverter.

The inverter automatically synchronises with the network; no additional controls are required. The inverter will shut down if the network supply fails either to short circuit or an open circuit or if the voltage or frequency of the network falls out of tolerance.

An alpha numeric LCD display allows inverter variables to be displayed and allows suitably qualified technicians to adjust operating parameters to optimise system performance.

Hardware and software provide electronic protection against most types of abuse. The inverter is fully self-resetting against all recoverable fault conditions, for example if the generator fails to start and the load persists the inverter shuts down before damage to the batteries occurs. If renewable inputs recharge the battery to a reasonable level the system will then restart automatically.

Data logging operates continuously in the inverter to record power, voltage temperature and current variables. Most variables are averaged over 15 minute periods but minimum and

maximum values of selected variables during each 15 minute period are also recorded. Data covering up to 8 days of testing is stored in non-volatile memory in the inverter.

A single day of data or all stored data can be retrieved over a serial link or remotely via a modem or via sat phone. The oldest day's data is automatically cleared and overwritten as each new day of logged data is added. There is no need to clear logged data from the inverter. Remote monitoring and analysis of data allows performance to be monitored and problems anticipated. Remote diagnosis allows remote units to be fixed in a single visit and allows expert staff to assist with systems anywhere in the world.

An IBM compatible PC program is provided which converts logged data from the inverter into spreadsheet format and extracts event records. This records the times when units start, start and stop the generator or change mode as well as other events associated with inverter operation including protective actions. The data can be graphically displayed by copying it into a pre-prepared spreadsheet.

Inverter Self Test

The inverter performs a self-check as it starts up. During the self test all the LED indicators on a module flash. Only if no faults are detected will the inverter start. Normal operation is indicated by steady illumination of the top green indicator light.

A flashing green indicator at the top indicates the self-test has detected a fault and the inverter will be not able to start. If the top green indicator is flashing record the pattern of indicators that are illuminated and advise your supplier.

Initial Starting of System

This procedure only needs to be followed when the inverter has been fully shut down and the DC circuit breaker has been opened.

- Turn on the Mains and Auxiliary circuit breakers and any other isolators external to the inverter connecting the inverter to the mains supply. The keep alive supply will charge the main capacitors if ac supply is present.
- Close the dc circuit breaker.
- Turn the inverter on/off switch to on. If there is insolation present the inverter will start its self test sequence, all indicator lights will flash as the inverter does its self test
- When the self-test is completed the top indicator light will be on and steady indicating the inverter is available to start.

Provided the ac grid supply is present, the array volts are sufficient and there is sufficient array power available the inverter will start and synchronise to the grid.

The inverter will load the array gradually by increasing power out until the array voltage reaches the initial target voltage. Provided power output is sufficient the inverter will automatically adjust the array voltage to maximise power output.

Shutting the System Down

- Turn of the inverter on/off to off.
- Turn off the AC circuit breaker to isolate the grid supply.
- Turn off the array circuit breakers to remove the dc supply.
- If working on the dc input side of the array circuit breakers isolate the solar array input to the inverter.
- If working inside the inverter wait for the input capacitors to discharge before working on the system.

Maximum Power Point Tracking

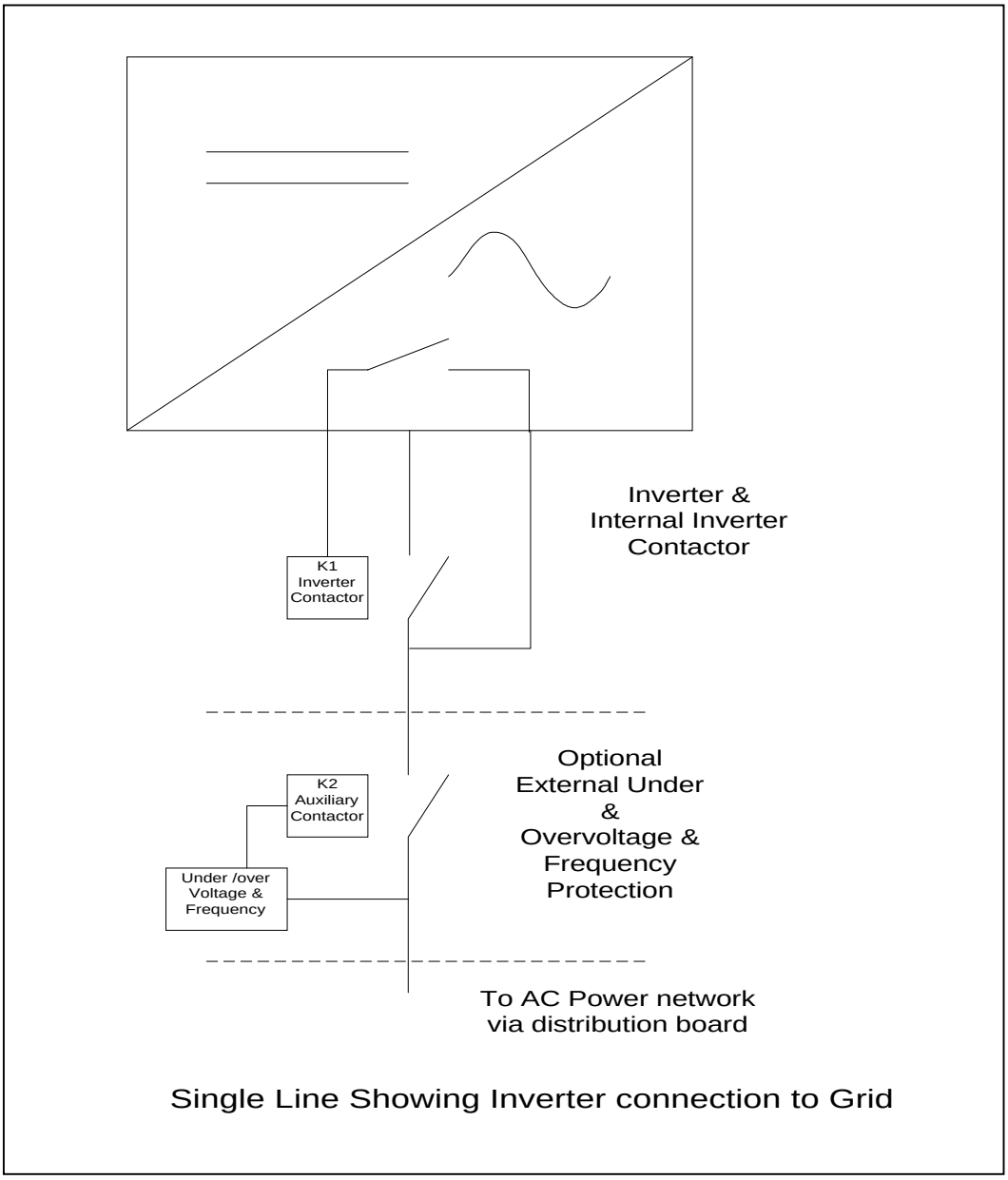
The inverter uses a maximum power point tracking algorithm to keep the voltage on the solar panels close to the optimum value to achieve maximum ac power output.

Keep alive supply

An optional keep-alive supply allows the electronics to operate 24 hours per day to allow data to be retrieved at any time. Even without this supply logged data is maintained in battery-backed memory, a time of day clock is maintained, and parameter settings are stored in non-volatile EEPROM

SOLAR Grid Tied Inverters Isolation & Safety

Electricity utilities are particularly concerned about the possibility of distributed generation maintaining or re-establishing the supply while staff are working on the network or after accidents that leave wires lying on the ground or accessible to the public. The design and connection arrangements for PSA grid tied inverters protect the system from back feeding if supply is interrupted, from accidental re-energisation and allow safe working on the inverter and ac network. These features are implemented as follows, and are illustrated in the diagram below.



Single Line Showing Inverter connection to Grid

Connection Direct & Via Optional Isolating Contactor

Inverters include an internal ac coil contactor with its supply drawn from the mains. The contactor coil is controlled from the inverter software via a pilot relay. When the inverter senses and synchronises to an external ac supply it closes the pilot relay. Without external supply the main contactor cannot change. Sensing of the external supply is via an input to a voltage transformer.

Without an external supply the solar interactive inverter software will not allow the inverter to start operation hence even a fault connecting the sense input direct to the inverter output will not cause the inverter to start.

It is important to recognise that the ac contactor does not prevent the inverter operating as an island and continuing to supply an external load if connection to the grid is lost. While the inverter powers the load the contactor will remain energised. The inverter must initiate disconnection as described below.

Safety when working on inverter

The inverter should be connected to the supply via a standard circuit breaker on a distribution switchboard, as is any normal load. Opening this circuit breaker isolates the inverter from the mains and the inverter will shut down. The inverter can be turned off using the on/off switch.

Safety when working on Switch Boards & Sub Circuits

The inverter should be fed from its own individual sub circuit of a distribution switchboard. Opening the inverter circuit breaker on the board will always cause the inverter to shut down.

A notice with words similar to "Circuit breaker X feeds a potential source of supply. Open circuit breaker X as well as the main incoming supply to isolate this board. Always check that the board is isolated using a voltmeter or voltage detector", or other wording as described in the Draft Guidelines or to the requirements of the local supply authority.

Safety from Island Operation & Detecting Grid Disconnection

The inverter disconnects from the grid when the ac voltage or frequency on the inverter terminals goes out of tolerance, when it senses the inability to control power and when it detects the absence of the normal fluctuations in power associated with connection to the grid.

The normal mode of failure for the grid is for supply to be interrupted at a significant distance (physically and electrically), leaving the inverter attempting to back feed large loads such as an entire building or street. The inverter current limits, its output voltage collapses and it disconnects and shuts down within 30ms.

If the inverter is isolated more locally, leaving a load within its capabilities, then it will attempt to import or export power to maintain the desired voltage on the array. To do this it will change frequency and phase until the frequency drifts out of the normal inverter frequency tolerance. With typical values of 49.3 and 50.5 Hz this will occur within 1 to 2 seconds, disconnecting the mains input and shutting down.

In some situations the connected load may closely balance the solar input and disconnection may take longer. The optional isolating contactor will drop out. Extensions to software to periodically perturb the power output can reduce the probability of forming an inland but these changes can only be effective if there is only a small number of inverters in any local island that happens to form. Once multiple inverters are present the frequency of the island will be insufficiently perturbed for any individual inverter to detect that it is isolated from the main grid.

In all situations the frequency and voltage applied to any loads remaining connected will remain in tolerance until disconnection from the grid takes place. The inverter frequency and voltage tolerance values are digitally set internal to the inverter.

Once the grid is disconnected the internal contactor opens and it cannot re-close because the grid supply, required to energise its coil, is no longer available. The optional external isolating contactor will also open and the inverter cannot connect to the grid until supply is restored from the grid side.

Safety from reconnection

Once the grid is disconnected the internal contactor will be open and it cannot reconnect because the grid supply required to energise its coil is no longer available. The optional external isolating contactor will be open and cannot connect to the grid until supply is restored from the grid side.

When the mains supply is restored the inverter will detect it. Provided mains supply remains in frequency and voltage tolerance continuously for at least 60 seconds the inverter will restart and resynchronise.

Safety when working on network

The automatic disconnection of the system from the network on loss of network supply as described above ensures that the external network will be de-energised and remain de-energised after network supply is lost. Network supply must be present and in tolerance before reconnection can take place.

Safety from miss synchronisation

The inverter automatically synchronises when mains is present and in tolerance. It adjusts its voltage phase and frequency to match the network before closing its contactor to parallel. Even if it synchronised 180 degree out of phase the current limiting characteristic will limit the maximum current well below the level of disturbance created by direct on line starting a typical induction motor of a similar rating. Three phase inverters will not connect unless the correct phase rotation is present and all phases are in voltage and phase angle tolerance.

Inverter Parameter Settings & Stability

The inverter disconnects and (will not reconnect) if the frequency or voltage of the external supply is out of a voltage tolerance or frequency tolerance for a period of 200ms.

For inverters connected to a large grid typical frequency settings are 49.3Hz and 50.5Hz for a 50Hz grid and 59.0 and 60.6Hz for a 60Hz grid. The frequency is measured digitally using high-resolution counters. The resolution is better than 0.01Hz and the accuracy is better than 0.02Hz. The reference is the microprocessor crystal clock which results in a maximum change over the temperature range 0 to 70C of less than +-0.03Hz from nominal.

Voltage tolerance it typically set at +-40V from nominal with an uncertainty of 10V i.e. on a 240V system the disconnect voltage could lie between 190V and 210V. The inverter will shut down if the voltage remains more than 30V above nominal for longer than 1 second. The uncertainty in the voltage tolerance is improved to about 5V after the system has been operating for 10 minutes at less than 10% of rating.

Inverter & Software Failure Modes

The inverter is largely software driven. Software must be operational for a sine output voltage to be generated. There is no hardware fault that could result in a sustained uncontrolled ac voltage output. Should the software lockup, the most likely result is saturation of the primary of the 50Hz power transformer. The transformer isolates all dc supply circuits from the ac output. Hardware will trip off the power electronics and in the worst case the transformer will be left connected to the ac output with its primary open circuit.

Within half a second a hardware watchdog timer will restart the inverter software if any of the three main task priorities cease execution.

Electrical noise, which may disturb operation, is most likely to invoke the watchdog timer and automatically reset and restart the microprocessor. Hardware faults will cause loss of control of some function and result in tripping via hardware and software.

Conclusion

The PSA Grid Connected Inverter provides a high level of protection against back feeding of the network when grid supply is lost or when local supplies are isolated. An optional external isolating contactor can provide a second level of protection from re-energising the external network. Normal safety, isolating and checking procedures should be followed when working on any mains circuit.

Notes on Conformance with ESAA Draft Grid Connection Guidelines.

3.4 PSA grid connected inverters is an accepted inverter in that they have been accepted for connection and in is in operation connected to networks, operated by Energy Australia, Northern Rivers, Citipower, Advance Energy, Great Southern.

3.7 Includes anti-island features in line with guidelines.

4.3 Conforms, provides voltage support for transient voltage disturbances before returning to unit power factor operation.

4.4 The inverter is a voltage source inverter but meets harmonic current limits for both types as in 4.4.2 and 4.4.3.

4.5 Present product includes RFI suppression and has been tested to AS 2064 to meet C tick requirements.

4.6 Equipment conforms.

4.7 Frequency tolerance and voltage tolerance settings described are programmable and can bet set to meet requirements of 4.7.

Includes frequency shifting and will disconnect within limits and conditions specified in 4.7.

Unit will be submitted for conformance with guidelines in late July.

4.8 Software self testing and design features mean that the fundamental failure modes are all fail safe.

All settings are digital and are referred to crystal oscillator reference and analog to digital converter reference voltage

Routine functional testing is not required. An annual physical inspection is recommended.

Replacement of main electrolytic capacitors every 5 to 10 years may be needed.

4.9 Unit uses 50Hz isolating transformer to prevent dc current injection.

4.10 Not applicable part of inverter installation

4.11 Not applicable part of inverter installation

4.12 Not applicable part of inverter installation

4.13 Conforms

Installation recommendations conform to paras 4.10, 4.11, and 4.12.