Ingeteam Export Power Control

As distributed photovoltaic (PV) levels increase, technical limitations begin to appear due to the line impedance of the network. The limitations are due to the rise in local grid voltage that occurs as increasing numbers of uncontrolled distributed PV generators simultaneously push the maximum power of their PV arrays into the grid. As a result, inverter grid protection disconnect tripping can occur depending on local average grid voltage, the load profile of the local area, the line impedances in the network and the level of sunshine at the time. Inverter tripping en masse contributes to grid instability and loss of customer PV production, both highly undesirable.

The only option available to network operators to resolve this situation is to restrict the amount of new PV power being installed. Many network operators now require PV connection applications to include detailed design specifications to be submitted that demonstrate a grid voltage rise of no more than 1%, others place a cap on system inverter size, phase balance becomes mandatory above 5kW in some areas, network upgrades may be required as part of the approval to connect, and so on. Different network operators have different challenges and therefore different solutions have evolved in their connection approval processes.

In Europe similar issues have occurred for some years and new technologies have been developed to prevent the associated issues of voltage rise with high level PV penetration. These technologies are strongly supported with Eu government incentives (specifically in Germany) to encourage their deployment. Called “Self Consumption”, the concept is for the PV energy to be consumed onsite and to not be exported. This strategy ensures that distributed PV systems are not simultaneously pushing the maximum power from their PV arrays into the grid during moments of high sunshine and low network load. Guidelines have been developed in Europe to provide inverter manufacturers with recommended technical parameters for self consumption systems.

In Australia, although no government incentives are available for Self Consumption, the rising cost of retail electricity together with the decreasing cost of solar power systems continues to build a compelling case to install PV. The financial reality is that whilst the attractive Gross and Parity NET feed in tariffs that once encouraged export of PV energy no longer exists, self-consumption of PV energy is now a steadily growing driver for PV uptake. The deal breaker for new PV connection approvals however, is often network capacity to take more distributed PV energy in conjunction with limited published knowledge and equipment availability to facilitate Self Consumption.

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The Ingeteam range of LITE PV inverters have been designed and manufactured in Spain to comply with European guidelines for Self Consumption. The Ingeteam technology, called Export Power Control offers a host of options that enables PV system owners to retain their PV energy on site and not interfere with grid quality.

How It Works

The solution is described below. A bi-directional Wattmeter is inserted into the electrical circuit between the grid connection point and the site loads and PV system as per below diagram. The Wattmeter communicates with the inverter via RS485 protocols.

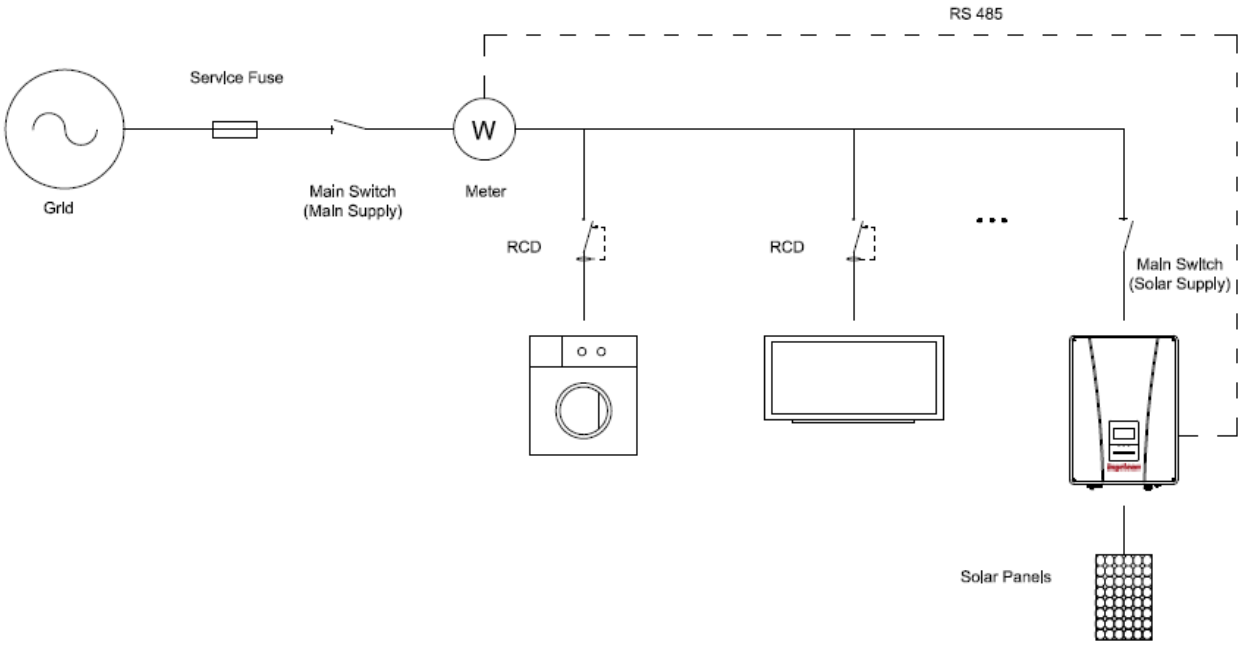

Fig.1 Ingeteam Export Power Control

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Power Balance Menu Settings

The Ingeteam LITE inverters have a password protected menu setting for Export Power Control that is labeled "Power Balance". This setting may be programmed by the installer for the desired export power. The setting is not accessible by the system owner. There are three possibilities for Power Balance:

1. Zero Power Balance in which the PV system **matches** the site load requirements. In this mode no PV energy is exported. PV power ramps up and down to match loads while achieving zero export.
2. Negative Power Balance in which the inverter allows a **limited export** amount of PV power (if available).
3. Positive Power Balance in which the inverter always requires a **limited import** amount of grid power to be maintained to the site loads regardless of how much PV power is available.

The Ingeteam LITE inverter setting for Power Balance is a numerical quantity displayed in Watts. A negative value setting indicates Negative Power Balance, a positive number indicates Positive Power Balance and a zero setting indicates Zero Power Balance. Fig. 3 shows the menu screen for the Power Balance setting with a Zero Balance value of zero Watts.

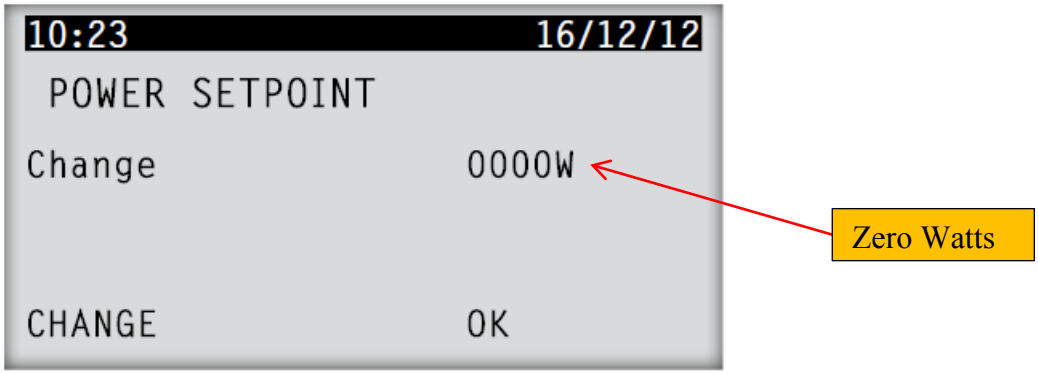

Fig.3 Ingeteam LITE inverter Power Balance setting

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As a failsafe in the event that a fault occurs to the system Wattmeter or the communications to the Wattmeter, the inverter output is disabled so that independent of site load conditions it is not possible for export power to occur. This fault condition is indicated to the system owner via the main operating display screen below in Fig. 4 in which the Wattmeter symbol in the circuit diagram blinks.

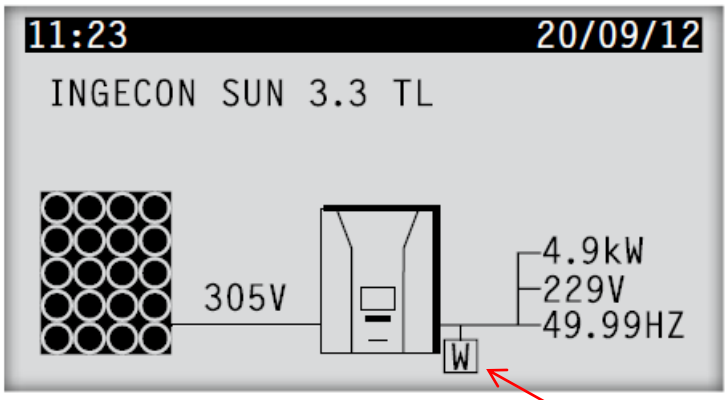

Fig.4 Wattmeter communications fault

Practical Application.

A PV inverter exports power by increasing the AC voltage at its output terminals against the line impedance between the inverter and the grid source. In an uncontrolled PV system, the inverter always drives towards exporting the maximum possible power from the PV array into the grid. A technique known as Maximum Power Point Tracking (MPPT) is used to achieve this and results in the inverter pushing its AC output voltage high enough to produce the current required to maximise PV array output. If the line impedance between the inverter and the grid is high, the inverter will proportionally increase its AC output higher in an attempt to overcome the voltage drop over the line impedance so as to achieve the required MPPT export current. This is a highly dynamic electrical process dependent on the instantaneous grid voltage, solar irradiance and site loads. The only constant in the process is line impedance.

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When a site load is introduced, according to the electrical fundamentals, AC voltage rise is limited on site to the value that is required to enable the required current flow across the sites internal line impedance between the inverter and the loads. The inverter MPPT is designed to generate the specific inverter outwards current for maximum PV array output, whether it is exported to the grid or consumed by site loads is of no consequence to an uncontrolled inverter. As a result, depending on the ratio between load power and the available PV power, voltage rise at the sites grid connection point may or may not be increased. In the event that all PV power is self-consumed, the site grid connection point AC voltage will not rise at all. If some PV power is exported to the grid, some voltage rise will occur at the grid connection point. By setting the Ingeteam LITE inverter Power Balance to the required value, the sites export power is controlled and therefore the sites grid connection point AC voltage rise is controlled.

System Loop Response

The speed with which the export power control system responds to load variations is called the Loop Response. As site loads vary or switch on and off the PV power must be controlled as quickly as practical so as to maintain the Power Balance setting. For example, if the inverter was set for **Zero Balance** and a site load consisting of a 2.4kW hot water element was operating whilst a PV system of 5kW size had 4kW of MPPT power available, then the inverter would be throttled back by 1.6kW to meet the required load match condition.

However when the thermostat switches off the hot water element, the inverter must throttle back the entire 4kW of available PV power. The EPC system, just like any feedback control system, takes time to adjust to the changed load conditions. The time taken is called the Loop Response and is dependent primarily by the communications method and quality between the Wattmeter and the inverter (like the Ping time on a computer network). European guidelines request a maximum Loop Response time of two seconds. Ingeteam EPC is guaranteed to be no more than 1.5 seconds so as to easily comply with Eu requirements.

The below graph in Fig. 2 illustrates the Loop Response time for the Ingeteam Export Power Control (EPC) system. The vertical axis is power and the horizontal axis is time. The green trace is the load power that changes level or switches on and off. The yellow trace is the inverter output power that varies in response to the load changes. The graph's horizontal divisions are set at 3 seconds each.

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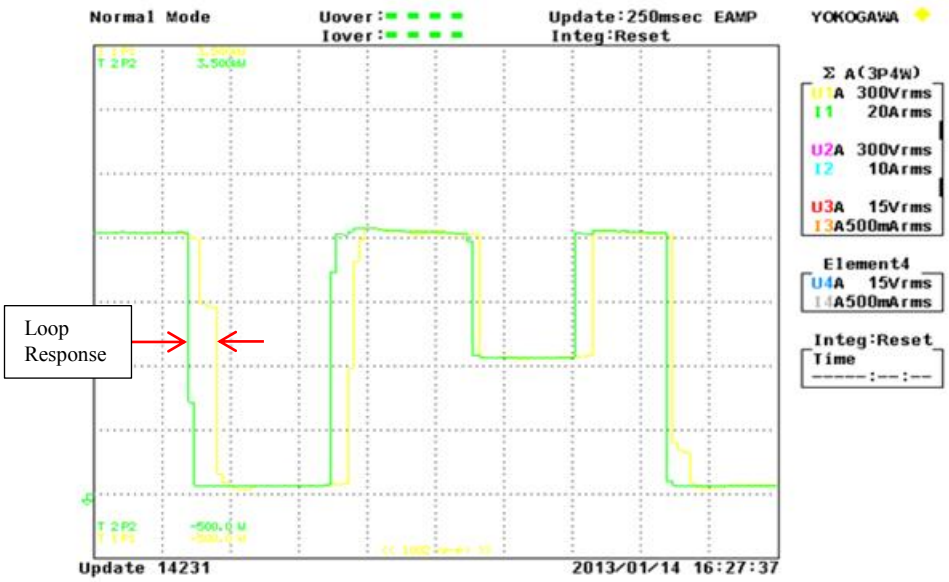

Fig. 2 Loop Response performance

The Loop Response is the measured horizontal gap between the green and yellow traces as load changes occur. The red arrows show a Loop Response time of approximately 1.3 seconds.

Conclusion

Ingeteam Export Power Control enables a PV system to be installed and controlled in such a way that the solar energy is primarily directed towards the sites loads without negatively impacting on grid voltage. Inverter settings can be installer configured to enable a wide variety of export modes ranging from negative (export) to zero (load match) to positive (import). In general terms the resultant effect to the grid network of the Ingeteam EPC system is to turn a PV system into little more than an electrical appliance in reverse, with its switching characteristics determined by the Loop Response and the site grid point connection AC voltage rise determined by the installer configured Power Balance setting. A network operator therefore can control grid quality in high PV penetration nodes and localities by approving new or retrofit PV connection applications based on their required Ingeteam EPC Power Balance setting.

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