

# Implications of Reactive Power Control on the design of PV Systems

November 2015

The electricity distribution utilities in Queensland recently introduced a requirement for most PV systems<sup>1</sup> to incorporate Reactive Power Control (RPC) functionality. Other distribution utilities in Australia will no doubt follow suit over the 12 months, so it is critical for PV system designers and installers to understand the implications of RPC on system design and performance.

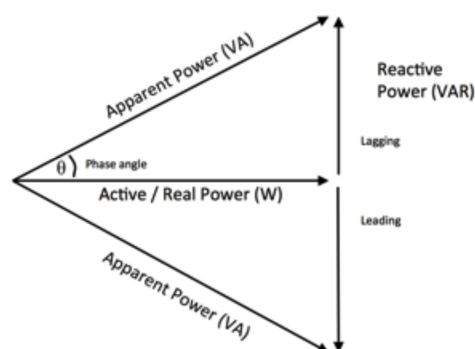
Reactive Power Control requirements affect the design of all PV systems in a similar way – whether they be based on microinverters, conventional string inverters, or DC optimisers. In this paper we will summarise the key points that are critical for PV system designers and installers to understand when working with RPC.

## Terminology

Prior to looking at some worked examples of relative power calculations it might be useful to review the common AC circuit terminology as it relates to reactive power calculations.

- Active power / Real Power / True Power is measured in Watts (W)
- Apparent Power is measured in Volt Amps (VA)
- Reactive power is measured in Volt Amps Reactive (VAR)

The relationship between active, apparent and reactive power is understood with the use of the ‘power triangle’:



Power factor is defined as the ratio of the active power flowing to the load to the apparent power, and is expressed as a value between 0 and 1. The power factor can be leading or lagging, depending on whether the load is predominantly capacitive or inductive. Most residential installations would typically have a power factor of around 0.9 lagging, however commercial/industrial installations can often have power factors lower than this – in the range of 0.7 to 0.9.

### **Why do we need Reactive Power Control on grid connect inverters?**

All AC loads which contain inductance or capacitance require both active power (measured in Watts - W) and reactive power (measured in Volt Amps Reactive - VAR) in order to operate. In the past, when all grid connected inverters were set to operate at unity (1.0) power factor, PV systems would supply the active power requirements of an installation only, leaving the utility to supply the reactive power component required by the load. In most cases utilities do not get paid for supplying reactive power, so some would say it was inevitable that once the enabling inverter technology arrived, utilities would change their connection requirements to require PV systems to meet both the active and reactive power requirements of an installation.

A further reason for the introduction of reactive power requirements is that PV systems which supply both active and reactive power in the approximate proportions required by the loads they are supplying, do not have the effect of pushing up the AC voltage in the same way that systems which only supply active power do. RPC systems, therefore, have less of an effect on the network - meaning that more and/or larger PV systems may be able to be connected to the existing electricity distribution network without it having to be modified or upgraded.

Reactive Power Control can be implemented in several ways - inverters can either set to supply a specific ratio of active to reactive power, or set to dynamically match the reactive power requirements of the load as these change over time. Currently, utilities in Australia only require inverters to be set to a fixed power factor - usually in the range of 0.8 to 0.95 lagging.

### **Inverter Sizing**

The detailed electrical theory behind reactive power control makes for great lunchtime conversation for the engineers at AC Solar Warehouse, but for most PV system designers it is the implications for design, rather than the theory behind RPC which is most important to understand. The implications for designers will be summarised here, but feel free to contact AC Solar Warehouse if you're interested in understanding the theory behind this explanation.

Inverter apparent power capacity is measured in Volt Amps (VA). Historically, when inverters operated at unity power factor, the apparent power rating of an inverter (VA) was equal in value to the active power rating (W) so these terms were often used interchangeably. In the world of reactive power control, however, this is no longer the case, so the relationship between apparent power (inverter capacity) and active power needs to be clearly understood. Thankfully, it is a relatively simple relationship as shown in the following formula:

$$\text{Apparent Power (VA)} \times \text{Power Factor} = \text{Active Power (W)}$$

For example:

An inverter rated at 5kVA set to operate at 0.9 power factor will have an active power rating of  $5 \times 0.9 = 4.5\text{kW}$ . Similarly, a microinverter rated at 260VA and set to operate at 0.9 power factor will have an active power rating of  $260 \times 0.9 = 234\text{W}$ .

Note that when RPC is implemented, utilities always refer to system size in terms of the inverter apparent power capacity measured in kVA. System connection approvals issued by distribution utilities will specify inverter capacity in kVA at a given power factor, as opposed to kW.

### Installer Tip #1

When working with RPC, the inverter size in VA needs to be calculated correctly to ensure that the inverter will be capable of supplying the desired amount of active power (W)

### Array sizing

One of the most critical issues to understand with RPC, is that the output of an array of PV modules is unaffected by the reactive power control setting. Twenty modules on a north facing roof will produce exactly the same amount of energy (kWh) on a given day whether the inverter is set to unity, 0.9 or 0.8 power factor. What is important is that the inverter is sized appropriately so that this energy from the modules can be fully utilised. For example, if a system designer chooses to design a system where the inverter size matches the peak rating of the array (i.e. no array oversizing) then the inverter capacity would be calculated as follows:

$$\text{Inverter capacity (VA)} = \text{Peak power rating of the array} / \text{power factor}$$

For a string system design requiring a  $5\text{kW}_p$  array and operating at 0.9 power factor...

$$\text{Inverter capacity} = 5\text{kW}_p / 0.9$$

$$\text{Minimum required inverter capacity} = 5.55\text{kVA}$$

And for a microinverter system design using  $250\text{W}_p$  modules...

$$\text{Inverter capacity} = 250\text{W}_p / 0.9$$

$$\text{Minimum required inverter capacity} = 278\text{VA}$$

If a system designer chooses to oversize the array to the full extent allowed under the Clean Energy Council System Design Guidelines<sup>ii</sup> then the minimum inverter capacity would be calculated as follows:

$$\text{Minimum inverter capacity (VA)} = [\text{Peak power rating of the array} \times 0.75] / \text{power factor}$$

For a string system design requiring a  $5\text{kW}_p$  array and operating at 0.9 power factor...

$$\text{Minimum inverter capacity} = [5\text{kW}_p \times 0.75] / 0.9$$

$$\text{Minimum required inverter capacity} = 4.17\text{kVA}$$

And for a microinverter system design using  $250\text{W}_p$  modules...

$$\text{Minimum inverter capacity} = [250\text{W}_p \times 0.75] / 0.9$$

$$\text{Minimum required inverter capacity} = 208\text{VA}$$

The array oversizing ratio should be carefully checked on RPC system designs as it is based on the nominal active power rating of the inverter (W) when adjusted for the power factor at which the system is being operated. The array cannot have a peak rating of more than 133% of the nominal AC active power rating of the inverter.

For example, a  $5.5\text{kW}_p$  array on a  $5\text{kVA}$  string inverter set to 0.9 PF would have an array oversizing ratio of:

$$\text{Nominal AC active power rating of the inverter} = 5\text{kVA} \times 0.9 = 4.5\text{kW}$$

$$\text{Array oversizing ratio} = \text{array capacity} / \text{inverter capacity} = 5.5\text{kW}_p / 4.5\text{kW} = 122\%$$

And for a microinverter system design using  $250\text{W}_p$  modules on a  $220\text{VA}$  microinverter the array oversizing ratio would be:

$$\text{Nominal AC active power rating of the inverter} = 220\text{VA} \times 0.9 = 198\text{W}$$



$$\text{Array oversizing ratio} = \text{array capacity} / \text{inverter capacity} = 250\text{W}_p / 198\text{W} = 126\%$$

## Installer Tip #2

The array oversizing ratio should be carefully checked on RPC system designs because if the array is oversized to suit a system designed to operate at unity power factor, and the inverter is then set to operate at a power factor of 0.9 or 0.8, there is a serious risk that the array oversizing ratio will exceed the maximum allowable under the CEC guidelines. This has serious legal implications because when signing forms to claim small-scale technology certificates (STCs) the designer must certify that the system is designed in accordance with the CEC design guidelines.

## Microinverter RPC Systems

Enphase Energy S-Series microinverters are currently the only microinverters available on the Australian market that provide RPC functionality. There are two models available and their ratings at various power factor settings are shown in the following table.

	<table border="1"><thead><tr><th>Power Factor</th><th>Peak rating</th><th>Recommended module size</th></tr></thead><tbody><tr><td>1.0</td><td>230</td><td>250W – 270W</td></tr><tr><td>0.9</td><td>207</td><td>230W – 260W</td></tr><tr><td>0.8</td><td>184</td><td>200W – 240W</td></tr></tbody></table>	Power Factor	Peak rating	Recommended module size	1.0	230	250W – 270W	0.9	207	230W – 260W	0.8	184	200W – 240W
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The engineers at AC Solar Warehouse are well versed in RPC system design and are very happy to assist system designers in the selection of appropriate modules and inverters for specific system designs.

For further information or assistance with the design of microinverter systems, contact Australia's leading AC Solar wholesaler, AC Solar Warehouse.

**Email:** [sales@acsolarwarehouse.com](mailto:sales@acsolarwarehouse.com)

**Phone:** 1300 55 44 67

<sup>i</sup> As of October 1 2015 Reactive Power Control is required on most residential and small commercial grid connected PV systems in Queensland larger than 3kVA in the Energex distribution area and 2kVA in the Ergon area. Specific requirements can be obtained from Ergon Energy and Energex or by contacting AC Solar Warehouse.

<sup>ii</sup> Section 9.4 of the "Clean Energy Council Grid-Connected Solar PV Systems (No Battery Storage), Design Guidelines for Accredited Installers, January 2013" requires that the nominal AC power output (in this case taking into account the power factor setting of the inverter) cannot be less than 75% of the array peak power. Please refer to these guidelines for further details.