A more efficient alternative to PV inverter Volt-VAR and Volt-Watt settings

Background

Distributed Energy Resource (DER) is the most cost-effective method of generating power from renewable sources. In addition to cost, DER has many benefits compared to large scale renewable generation. The generation is located at the point of use reducing energy loses. Being distributed, it is more resilient to equipment failures and natural disasters. DER generation on the LV and MV networks will increase the grid voltage. Distribution utilities are required to maintain grid voltages within statutory limits of 230VAC +10% and -6% for all customers. To mitigate the voltage rise, distribution utilities either limit the export generation or implement some form of VAR management. The most preferred method is the use the Volt-VAR and Volt-Watt functions of smart inverters.

Volt-VAR and Volt-Watt characteristics

Figure 1 shows a typical smart inverter Volt-VAR characteristic. As the voltage rises or falls beyond the acceptable voltage limits the generator will start to generate leading VARs to raise the voltage or lagging VARs to reduce the voltage. VARs are generated by sacrificing real power output. For example, when the voltage rises above 240V the inverter will generate at 0.8PF lagging.

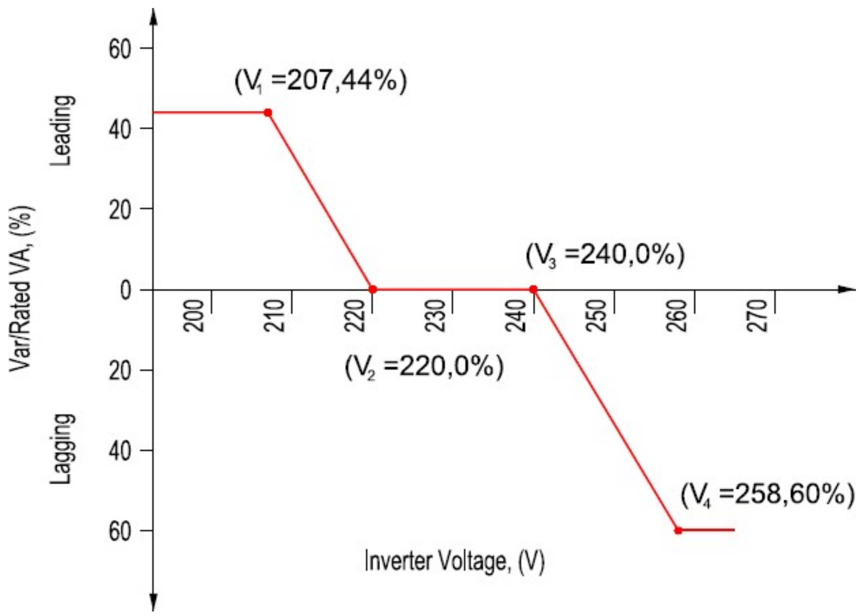

Figure 1 – Typical Volt-VAR characteristic for a PV inverter

A Volt-Watt characteristic is shown in Figure 2. As the voltage exceeds a predetermined limit the power output of the inverter is ramped down to 20% output limit.

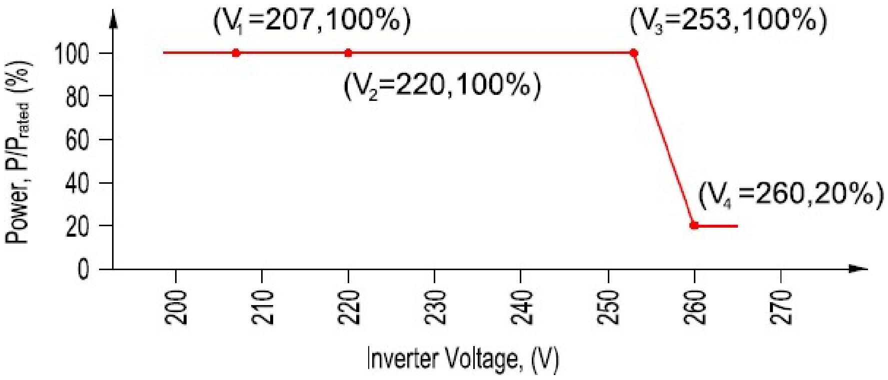

Figure 2 – Typical Volt-Watt characteristic

These two characteristics of smart inverters are used widely to control excessive voltage rise on the grid.

eleXsys Characteristics

The eleXsys is a 4 quadrant inverter which has been designed to generate leading or lagging VARs at full rating. A 30kVA eleXsys is 97% efficient with internal real losses of 900W at full output. eleXsys needs 900W of real power to generate 30kVAR of either leading or lagging VARs.

DER efficiency

The implementation of Volt-VAR and Volt-Watt to reduce voltage rise on the grid can seriously affect the real power output or efficiency of a DER generator. Once the voltage rises above the acceptable voltage limit, the inverter will start to generate VARs to reduce voltage. The VAR generation reduces the real power output of the inverter, thus reducing the system efficiency of the DER. The loss of efficiency can be demonstrated by a simple 100KVA DER installation with voltage rise due to a high hosting capacity. Figure 3 shows the loss of real power generation with a Volt-VAR for a 100kVA PV installation. Figure 3 shows the output for the voltage range 220-240VAC. The PV inverter will produce 100kW of real power at a PF of 1.0.

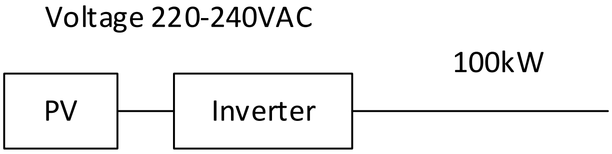

Figure 3 – Normal operation of PV installation

As the hosting capacity of the network increases the voltage for customers towards the end of any feeder will increase. Using the Volt-VAR curve in Figure 1, if the voltage increases above 240VAC the inverter will begin to reduce real power output and increase lagging/absorbing VARs to reduce voltage. Figure 4 shows the output power when the voltage reaches 258VAC. Once the voltage increases to 258VAC, a 100kVA inverter will be producing 80kW of real power and 60 kVARs. The real power output that a customer uses has been reduced to 80kW a reduction of 20kW or 20% of output power. According to Figure 1 the power factor is 0.8.

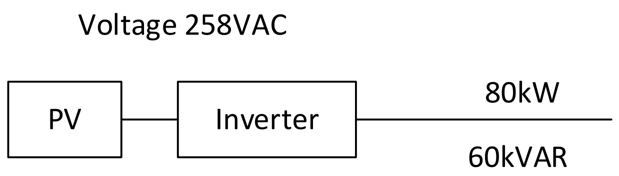

Figure 4 – Output curtailed due to voltage rise

An alternative to the loss of 20% of the PV generation is to add an eleXsys which would supply the VARs and allow the PV inverter to stay within its unity PF range of 220-240VAC. Figure 5 shows the Kw and kVAR contributions for each of the devices. The PV inverter will produce its 100kW of real power at unity PF and 2kW of this output would supply the losses of the eleXsys which would produce the 60kVAR required by the Volt-VAR curve of Figure 1. The real power output of the installation is now 98kW instead of the 80kW without an eleXsys.

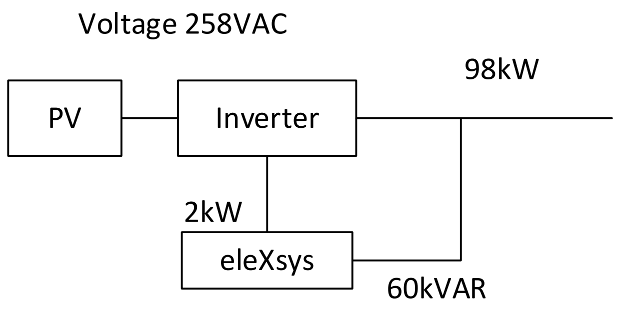

Figure 5 – Power contributions with eleXsys

Volt-Watt settings

As the voltage increases further to 260VAC the inverter would be required to reduce real power output to 20kW and 63kVARs until the voltage reduced to 258VAC.

eleXsys Configuration

The eleXsys would be configured with a Volt-VAR curve as shown in Figure 6 below. The eleXsys curve is designed so that the eleXsys produces all of the VARs while the PV inverter stays within the unity power factor voltage range. If the grid voltage continues to rise above 258VAC then the Volt-VAR curve of the PV inverter will activate and the PV inverter will start to generate VARs to regulate the voltage.

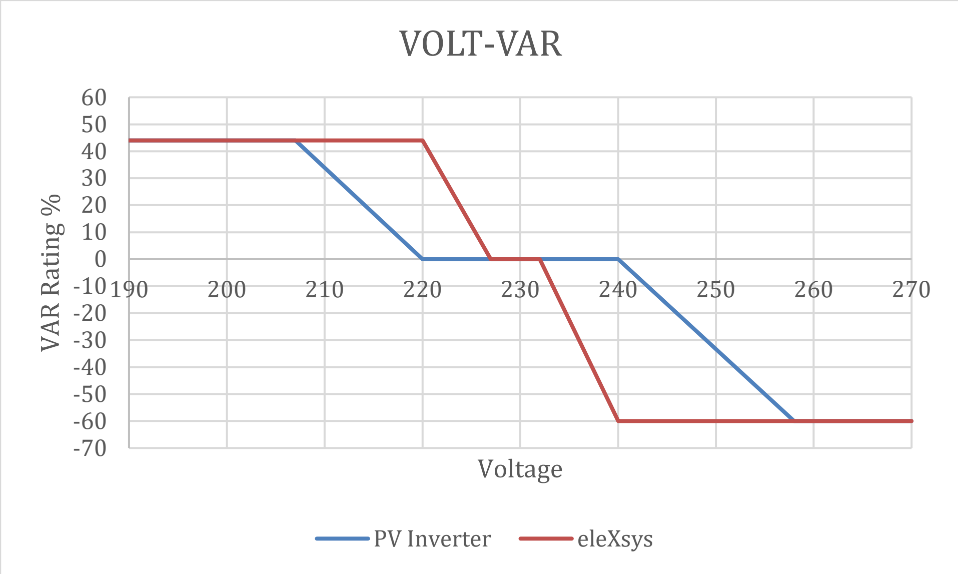

Figure 6 – eleXsys Volt-Var coordination

Economic benefits of eleXsys

As the hosting capacity of the network increases, the voltage will rise for all customers on the network. The voltage rise will not be uniform for all customers (see White Paper on Equity Issues with Smart Inverters). Customers who are further away from the substation or the distribution transformer will experience more voltage rise than customers close to the substation or distribution transformer. So, customers close to the substation or distribution will experience less curtailment of real power. Some jurisdictions are also specifying a power factor of 0.8 for all new installations.

The economic loss for a customer can be calculated by equation 1 below

$ Loss pa = average hours curtailed per day * 365 * Tariff rate in cents * kwhs/kW generation * PV kVA

For a 100kVA PV system being curtailed to 0.8PF for 4hrs per day in Brisbane and on a customer tariff of 20 cents per kWhs, the loss of revenue is $4800 per annum. On a fixed 0.8PF the loss of revenue would be double to$9600.

Conclusions

As the hosting capacity of DER increases into the future, DER real energy output will decrease due to use of Volt-VAR implementation in smart inverters and the voltage rise on the utility networks. The use of eleXsys technology to supply the VARs in place of PV inverters allows more real power to be generated for a customer and the community increasing the efficiency of DER.