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COUNTRY : Australia	PREF. SUBJECT : 2
REGISTRATION NUMBER : DLG1386	QUESTION N° : 2.9

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There are many suggestions and proposals on new technologies for the mass deployment of RES/DER in the distribution grid. Are there any cases of planning or actual implementations of such technologies such as MV STATCOMs and the integrated operation of smart inverters?

Australia has experienced amongst the highest uptake of rooftop solar PV in the world, with solar penetration exceeding 30% in some states. Despite the implementation of “smart inverter” standards (e.g. AS/NZS 4777.2:2020) that mandate Volt/Watt and Volt/VAR output, many networks experience voltage problems such as static and dynamic over voltages and high phase unbalance.

We are not aware of many deployments of MV STATCOMs to address these problems. However, since the problems are most severe on the LV networks, some Distribution Network companies are deploying LV STATCOMs to mitigate these problems. LV STATCOMs are typically connected in shunt with the network, towards the end of LV networks and they operate along Volt/VAR droop curves using the local voltage to determine their output reactive power.

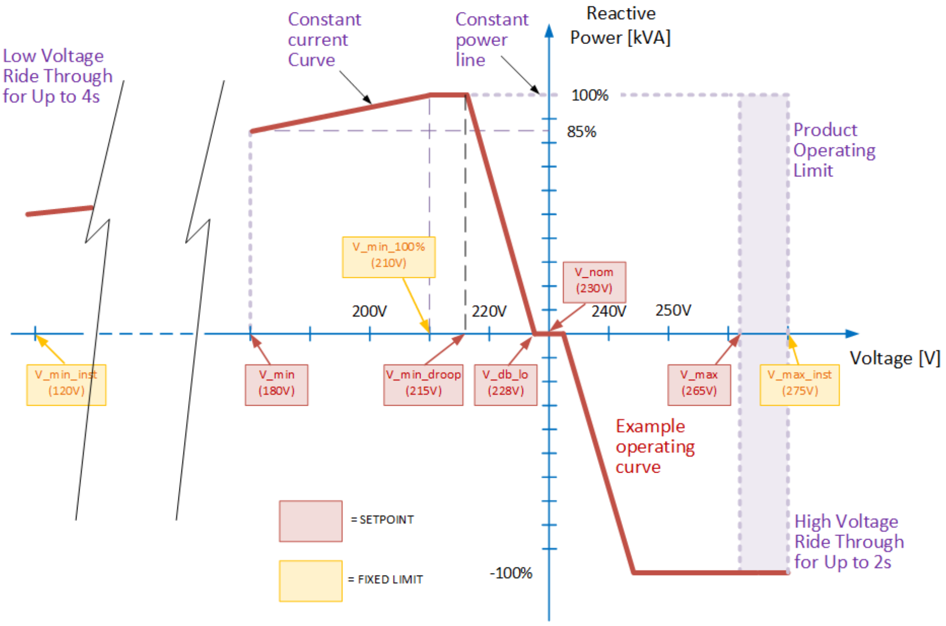


Figure 1: Typical LV STATCOM droop curve

When the local LV network voltage is high (e.g. during the middle of the day when solar output is high and local load is typically low) the LV STATCOM sinks (inductive) reactive power to reduce the network voltage. Conversely, when the voltage is low (e.g. during the evening when the local load is high and solar output is zero) the LV STATCOM sources (capacitive) reactive power to boost the network voltage.

The droop curve ensures inherently stable operation with other LV STATCOM units as well as with solar inverters, some of which are operating on volt/VAR and volt/watt curves themselves.

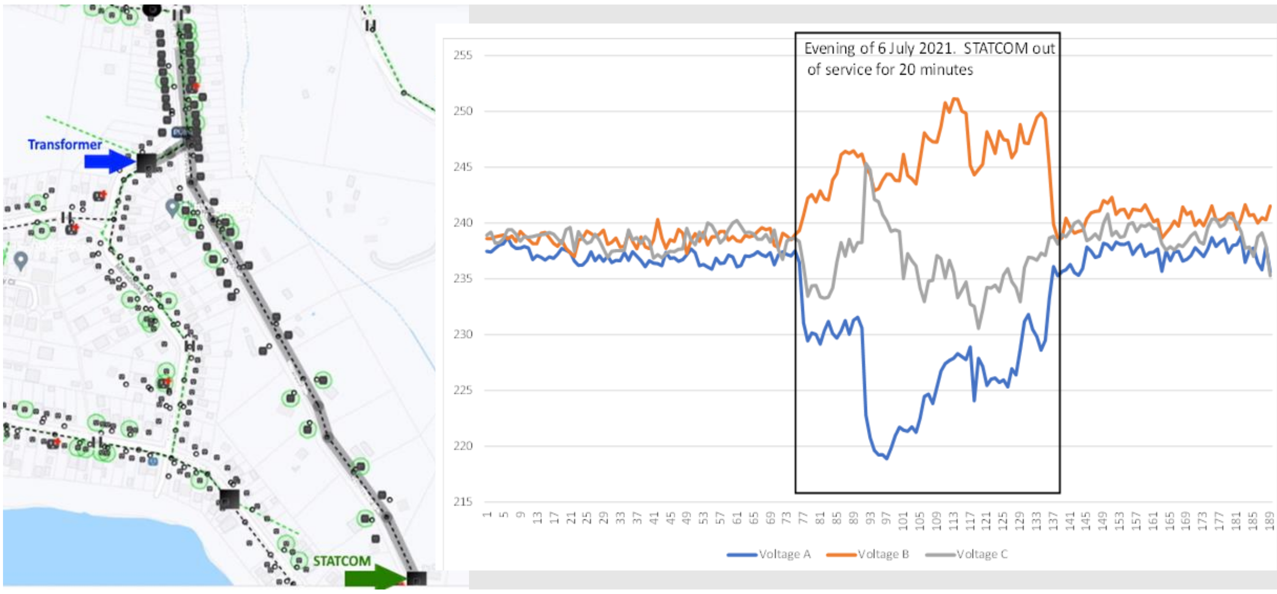
Units have been deployed by multiple Distribution Network companies in several states in Australia with promising results. For overhead LV networks, the STATCOM is mounted on an electricity pole using a “cherry picker” truck. Fig. 2 shows photos of a typical installation of LV STATCOMs. In this case, the units are installed as a set of three single phase units, coordinated to act together as a 4-wire three-phase unit. Independent, per phase operation is important to mitigate voltage unbalance.

Figure 2: A typical installation of a three-phase LV STATCOM

Since the units are connected in shunt, installation of the units can be done live, without the need for a planned power outage. Once field crews are trained and experienced with the installation, installation time for a three-phase set is typically in the order of two hours.

Field results from a LV STATCOM installation on the Ausgrid network are shown below. Ausgrid is the largest electricity distributor on Australia's east coast supplying Sydney and surrounding areas. The rated power of the three-phase STATCOMs installed was 30 kVAr (10 kVAr per phase).

The feeder of this LV distribution network is an urban long fringe distributor with a history of voltage regulation issues, with 61 households and 22 solar PV installations (about 36% of households). The distance from the transformer to the three-phase STATCOM is about 750 meters. In this case study, the load density is not high, but the distributor was running at the limit of its capacity. The layout of the LV distribution network and the three-phase RMS voltages while the STATCOM was switched OFF then ON after 20 minutes are presented in Fig. 3. As can be noticed, the system voltage becomes heavily unbalanced after the STATCOM is switched OFF. However, the three-phase voltage system becomes balanced again right after the STATCOM is switched ON again, and the average value is close to the set point (240 V).



(a) (b)

Fig. 3: a) layout of LV distribution network, b) three-phase RMS voltages when STATCOM was switched OFF for approximately 20 minutes on 06-Jul-2021.

Prior to the STATCOM installation, voltage complaints were received along this long radial distributor. The long length of mains and the low density of loads results in a large voltage phase separation for relatively small magnitude of out of balance phase currents. Re-balancing the services has helped in the past but eventually it just moves the issue to another phase and/or time period. Fig. 4 shows a longer time span of around 1 month with the STATCOM being placed out of service for just over a week. The area in red shows the period when the STATCOM was inactive with the voltages in excess of the standard. This caused solar PV inverters to trip and had a negative impact on solar energy yield and voltage profile.

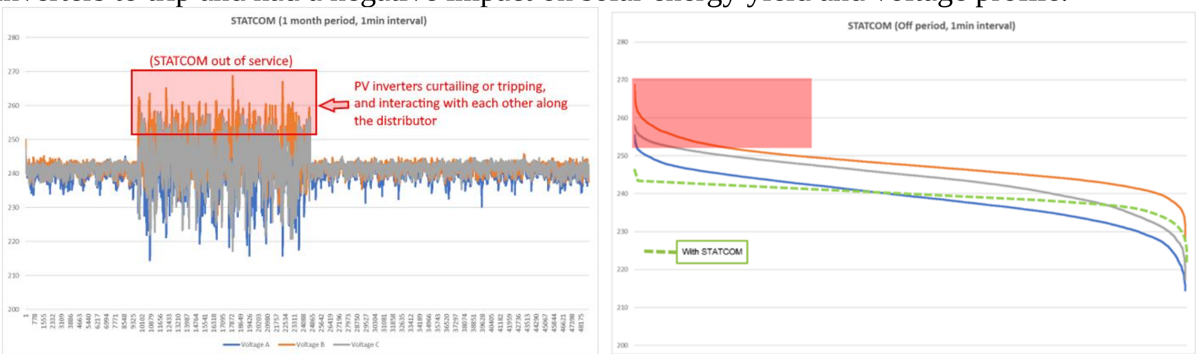


Fig. 4: Voltage plots with & without STATCOM operation showing PV inverters curtailing or tripping and interacting with each other along the distributor while STATCOM is out of service: a) three-phase RMS voltages; b) voltage distribution

The installed three-phase STATCOM addressed the network issue effectively and provided improved access to the LV distribution network for rooftop solar PV.

Typically a LV STATCOM installation has been found to be 3-5 times lower cost than a traditional augmentation, although this is highly dependent on the application (the particular LV network, local augmentation costs etc).

Similar results have been experienced at many other sites.

It is important to realise that the amount of voltage improvement or correction that the LV STATCOM can achieve on the grid depends on the power system inductance. The higher the power system inductance, the greater the voltage controllability. This means the STATCOM is particularly effective on weak grids with high inductance, such as overhead Open Wire networks. On the other hand, LV STATCOMs may not be effective on underground networks with low system inductance. Thus, to our knowledge LV STATCOMs have been deployed usually to support weak overhead networks. This has occurred across multiple states in Australia as well as in Europe and potentially elsewhere.