

Impact of embedded renewable generation on voltage quality

Converting energy from a photo-voltaic source requires power electronics, and from modern wind turbines, almost always. These power electronics are a non-linear interface between the utility network and the renewable energy source and injects current at points in the network designed for voltage drops.

Voltage quality at end-users need to remain of sufficient quality to sustain normal operation of their electrical equipment. Sufficient voltage quality is defined by different power quality standards. Power quality (PQ) parameters of concern are:

- Voltage magnitude regulation.
- Voltage symmetry between different phases, mostly known as voltage unbalance.
- Voltage total harmonic distortion and individual voltage harmonics.
- Voltage flicker.

Observe the simplified single-line diagram in Figure 1, used below to discuss how each of the above PQ parameters are affected by grid-integrated sources of renewable energy.

Energy flow at the fundamental frequency is transported to PCC₂ by the fundamental frequency voltage (V_1) and current (I_1). At PCC₁ the fundamental frequency voltage (V_2') is less than V_1 as caused by the voltage drop across the impedance (Z) between PCC₁ and PCC₂.

Power systems were designed to cater for this voltage drop by both sufficient fault level (sufficient low network impedance) to allow acceptable regulation in voltage magnitude at any PCC or Point of Connection to end-users.

Renewable energy is injected at points in a network designed for voltage drops, injecting current against the normal direction of fundamental frequency current. This can be a concern to voltage magnitude regulation at points in the network where the ability to actively control voltage magnitude, does not exist. A grid code will normally address how users that inject energy has to locally control their impact on voltage magnitude in order to realise acceptable voltage magnitude regulation all over.

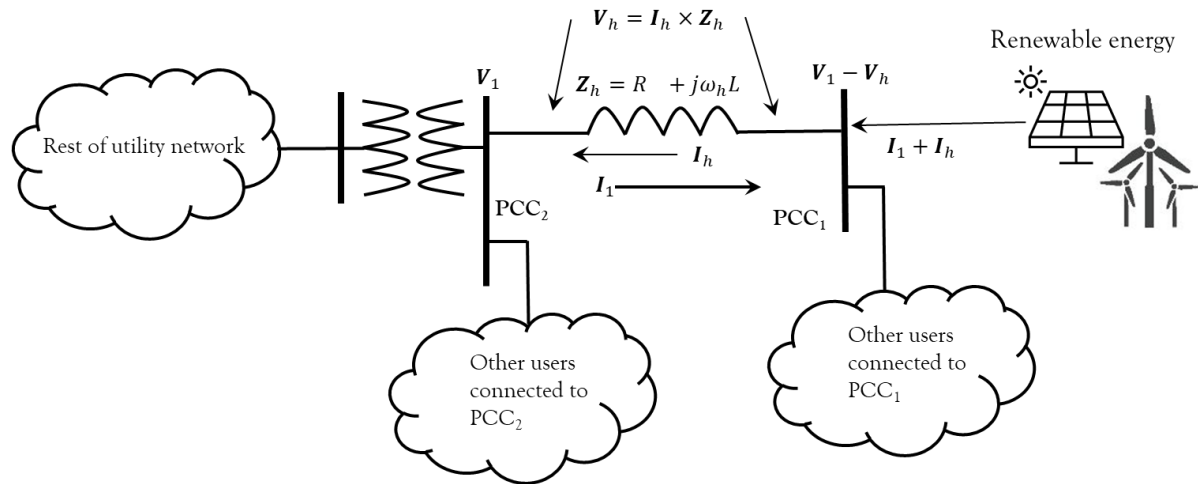


Figure 1: Distribution network with integrated PV

At the upstream Point of Coupling (PCC₁), assume that a perfectly sinusoidal voltage waveform exists, delivered to PCC₁ by the upstream utility network having sufficient fault level to be not affected by the penetration of harmonic currents contributed by users at any point in that network.

The injection of harmonic currents that flows through a supply network harmonic impedance (Z_h) will cause the voltage total harmonic distortion to increase at PCC₂ as shown in Figure 1.

Power electronic interface (grid-connected inverters) not only injects fundamental frequency currents, but also harmonic currents (I_h). The resulting voltage drop (V_h) across the impedance Z_h cause the PCC₂ voltage ($V'_2 \pm V_h$) to be harmonically distorted (not a sinusoidal voltage waveform anymore). Without the source of renewable energy connected to the grid, and without users consuming harmonic currents, the voltage at PCC₂ would only have been affected by a fundamental frequency voltage drop, remaining perfectly sinusoidal (if V_1 was perfectly sinusoidal).

Different source of harmonic currents located all over the distribution network all inject harmonic currents. It can collectively result in voltage total harmonic distortion at some points of the network to increase beyond levels regarded acceptable by the power quality standard pertaining.

Due to the non-linear interaction between these sources of distortion located at different points in the network, harmonic filtering by passive filters could not be performing well and why an active harmonic filter that can adapt to a change in filtering requirement, is most effective.

If the harmonics are injected by mostly single-phase inverters, voltage unbalance will be affected at a PCC and careful consideration is needed to where they are located to contain voltage unbalance (and magnitude). Those who are further away should normally be rated lower than those near the PCC.

Three-phase grid-connected inverters can also cause unbalance to increase under certain conditions.

When the renewable energy source is fluctuating such as when wind speed changes across the blades of a wind turbine, then voltage amplitude modulation (voltage flicker) can be a consequence of renewable energy injection. Fluctuating currents into the system impedance can cause a modulation of the voltage amplitude. If the modulation frequency is around 8.8 Hz and the voltage flicker penetrate into low voltage networks, humans can be affected when voltage flicker is transferred by lighting to realise a variation in lumens production.

By using active voltage conditioning solutions, the above concerns on voltage magnitude regulation, voltage unbalance, voltage total harmonic distortion and voltage flicker can be contained at any point in the network where end-users are affected.