Voltage Control with Pv-Inverter in Low Voltage Networks

D. Dharmendra, R. Kalidasan, A. Sunil Kumar, P Vivek

ABSTRACT: In some rural and sub-urban areas, the hosting capacity (HC) of low voltage networks is restricted by voltage limits. With local voltage control, photovoltaic generators can mitigate the voltage rise partly and, therefore, increase the HC. The two most common implementations of reactive power control have a similar effectiveness. High penetration levels of distributed (PV) generation on electrical distribution system show many opportunities and challenges for Egyptian Distribution Utilities. The sovereign purposiveness of this threshing was to augment the penetration level of the PV power production in three-phase LV grids, by using solar inverters with reactive power control inconvertibility, imposed by certain grid codes. This method, which is based on the grid voltage profile for location – dependent PF set premium could be cushioned to whole solar inverter. The main target was to mitigate unnecessary Q absorption.

Keywords: Hosting capacity, Photovoltaic generators, Reactive power control.

1 Introduction

Solar photovoltaic (PV) power is considered in most scenarios as an important energy resource for meeting the medium and long term renewable energy targets. Authors in [1] report growth of around 6 GW per year between 2011 and 2013 in Europe, and with five countries exceeding 1 GW despite the clear market decline in Europe, mainly in Germany and Italy. A very specific property of PV generation is its highly decentralized nature: according to [2], more than 70% of the installed PV capacity (more than 38 GW in 2014) is embedded in the low voltage (LV) network. In some areas, the local LV penetration reaches very high values (200 kWP/km²) and the hosting capacity (HC) of LV networks is locally exhausted triggering expensive network reinforcement measures. One of the main limitations towards the HC is the voltage rise caused by the PV infeed [3-5].

Currently, the voltage at remote nodes of feeders with a high penetration of PV generation, might exceed the planning limits of distribution system operators (DSO) which are set to allow them to comply with the +10% limit specified in the voltage quality standard. An alternative to the network reinforcement is local voltage control with PV inverters. Alongside the emergence of different local control concepts, the grid codes, standards and connection guidelines have been modified to allow DSOs to make use of them.

The main purpose of this paper was to increase the penetration attribution of PV power producing in three-phase LV network connected in Egyptian networks, by controlling of reactive power capability, which is generated from the solar inverter and P.F. in this paper the control of PV inverter is implemented using proportional plus integral (PI) controller to maintain the voltage at the PV bus.

2. Basic Concept

To increase the higher penetration levels to the power distribution systems, it may require a lot of efforts, to integrate dispersed generators. The optimum benefits from solar inverters installed on grid were to promote penetration levels more. The semiconductor switches are control of the Q quantity of inverter. When the active power injection is less than the inverter rated apparent power, the remaining capacity can be used for
supplying reactive power. New generation of solar inverters power factor (PF) is set at 0.9 PF, which keeps them at rated active power injection for network ancillary services. Reactive power can control the grid – connected inverters on LV distribution networks. In addition to this, if the solar irradiation decreases from 100% to 10%, the inverter can use the remaining capacity to provide the reactive power supply to compensate the voltage drop. Further, the grid voltage levels must be defined clearly as the power injections from the distributed generators, cause rise in the total voltage on the LV and MV grids which should be finite at ±10% and ±5% of the nominative grid voltage, consecutively. Thus, at a piece bond speck, it is required to measure these voltage changes that are triggered by the generators, where maximally permissible power injecting is specifiable.

3. Inverter Control

Fig. 1 shows that, at the network-side inverter, a back-to-back remitted; the phase angle of the current to the primate grid is defined. In the DC - DC converter is used for maximum power point tracking. Moreover, the grid side inverter is used to control both of the DC link voltage and the voltage at the point of common coupling (PCC). The three-phase voltage at the PCC is sensed and follows a phase locked loop (PLL) circuit to generate the transformation angle.

The actual three- phase currents at the PCC are converted from the abc to dq0 frames. The proportional plus integral (PI) controllers are used for this control action and produce the firing angles to the power electronic switches of the inverter.

The output voltage of inverter can also be adapted by applying a controller itself in the inverter. Most commonly used method for the inverter is the sinusoidal pulse width modulation (PWM) technique. By implementing this method, a constant DC input voltage is disposed into the inverter. Also an unflappable AC output voltage is accessed by regulating the on/off duration of the inverter units, PWM techniques.

The power commute Pact (within its boundary Pmin and Pmax) during the inverter is in general dealt by the executive control of the PV system with first imperative so that its boundary is the maximum possible reactive power preparation \( |Q|_{\text{max}} \) in Eq.(1).

\[
|Q|_{\text{max}}(t) = \sqrt{s_{\text{max}}^2 - p_{\text{act}}(t)} \quad \text{Eq.(1)}
\]
5. Simulation Model

Fig. 2 Simulation Block Diagram

Fig. 3 Sag voltage at each phase

Fig. 4 Input DC Voltage and Current from PV panel
Fig. 5: Compensated Inverter voltage

Fig. 6: MOSFET output at one phase

Fig. 7: MOSFET triggering pulse
6. Equations

The measurements of different values of the parameters for load flow calculations. It shows the values of voltage regulation for the grid voltage \(V_g\) and the load voltage \(V_L\) for each PV location of the grid. These data depend on the connection points of the inverters that are closest and faraway of the transformer, while neglects the power demands from the consumers. Eq. (2) estimates the voltage regulation \(\varepsilon\) values for each location.

\[
\varepsilon = \frac{V_g - V_L}{V_g} \quad \text{Eq.(2)}
\]

The load and line connecting at PF is 0.9, the active power by load is 10.5 kW, and the reactive power is 4.5 KVAR. When the load side injects a hc equal 0.156 KVAR, the load P.F is 0.948 and active power is 10.5 kW, and reactive power is 458 KVAR. The reactive power is increased due to voltage rise and the current is reduced. The line loss is estimated by Eq. (3).

\[
P_{\text{loss}} = 3I^2R = 3 \frac{p^2 + q^2}{V^2}R \quad \text{Eq.(3)}
\]

The reduction line of the values of current flow before and after is indicated in equations (4, 5)

\[
I_1 = \sqrt{\frac{p_1^2 + q_1^2}{V_1}} \quad \text{Eq. (4, 5)}
\]

\[
I_2 = \sqrt{\frac{p_2^2 + q_2^2}{V_2}}
\]

The reduction in the system current is given in Eq.(6)

\[
\frac{I_1 - I_2}{I_1} \quad \text{Eq. (6)}
\]

Where \(P_1\), \(Q_1\) and \(I_1\) are the values before control \(P_2\), \(Q_2\) and \(I_2\) are the values after control. The capacity of the system, is increased by 4.5%

7. Advantages and Disadvantages

Although the benefits of PV system were mentioned previously, the nature of solar power depend on the sun, when reduction or no power at some of the time, is caused by power fluctuation. Power production from PV power plants shows systematic patterns determined by apparent movement of the sun in the sky. This profile is disturbed by short-term variability driven by clouds. The PV power fluctuations are due to the variations in irradiance. The fluctuation is apparent. For some utilities, these fluctuations have a negative impact. The power is generated from a PV system designed to inject some or all output power into the grid. If any violation occurs, the utilities forward the owners to treat their PV systems. There are many of the technologies used for storage or delivery generated power to enhance PV systems.

8. Conclusion

With the ever-increasing PV penetration at the distribution systems, several problems can arise. One of the main problems is voltage fluctuation at the distribution network buses so this study has presented a new approach of location – P.F- P and Q-V droop characteristics method. It can be considered as standby solution, to control Q-V droop method imposed by certain grid codes. High penetration of grid installed PVs, and voltage support from the inverters close to the transformer is required. This method enhances the voltage profile of the grid and compensates line voltage drop in admissible limit especially at the end feeder without requiring any new infrastructure. Therefore, improvement of the voltage profile of the system buses can reduce the total losses of the network and saving consumed power by customers and increases the system capacity by 4.5%. In the future work, we will study the improvement of PV systems by smoothing its output power.

References
