Coordinated droop based reactive power control for distribution grid voltage regulation with PV systems

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The German Grid Codes (GGC) proposes a standard active power dependent (APD) characteristic, Q(P), to support the voltage profile via a PV system's reactive power as shown in Fig. 1 , where P and P_{max} show the feed-in and the maximum active power of the generator unit, respectively [1]. The GGC standard Q(P) characteristic requires the PV system to operate in an under-exited mode when the feed-in active power goes beyond a threshold of 50% of P_{max} in order to alleviate the possible voltage rise. In the GGC standard characteristic, the required reactive power of each PV system is determined based on its feed-in power and independent of its location in the grid. According to the GGC, the distribution system operators (DSO) can use a different characteristic from the standard characteristic depending upon the grid configuration, however, it is not clarified how to define such a characteristic and it is devolved to the DSO. Moreover, since the standard characteristic does not consider the voltage profile, its employment can cause unnecessary reactive power consumption. Considering large number of PV systems in grids, unnecessary reactive power consumption boosts the total line losses. Moreover, large amount consumption of reactive power by PV systems may also jeopardize the stability of the network in the case of contingencies in conventional power plants, which supply reactive power [2].

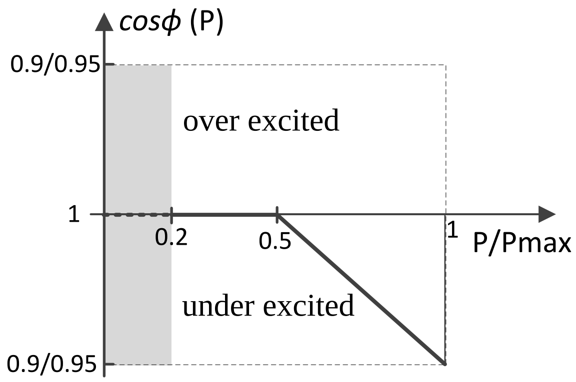

Fig. 1: Standard characteristic curve for *cosφ* (P)

Therefore, it is a matter of need to develop an APD method that can provide a coordinated, systematic characteristic for each PV system along a feeder. The voltage sensitivity matrix is utilized to propose a coordinated individual characteristic curves between reactive power and active power for each PV system along a radial feeder by using only local measurements. Since the grid configuration is addressed in the voltage sensitivity matrix, the proposed method basically introduces a characteristic based on the grid configuration for each PV system. The voltage sensitivity matrix has been used in [3] to compare impacts of active power curtailing and reactive power support through

PV systems on the voltage profile in low voltage grids. The voltage sensitivity matrix in [4] is used to define coordinated droop factors in the active power curtailment of PV systems. The sensitivity matrix contents and control theories are employed in [5] to demonstrate the voltage control interaction among PV systems. The voltage sensitivity matrix is used in [6] to eliminate the voltage variation at a target node due to the operation of a wind turbine in a microgrid via reactive power support. In the proposed APD method, the voltage sensitivity matrix is employed to systematically design two main parameters of the GGC Q(P) characteristic for each individual PV system in a radial grid, namely the active power threshold and the slope factor. The proposed APD method considers all the variants for designing the slope factor and the power threshold. The results demonstrate that the proposed method can regulate the voltage to the steady-state voltage limit, while the voltage regulation in the GGC method is not addressed. Because the proposed method explicitly includes the steady-state voltage limits. By doing so, the proposed APD method can decrease the total consumed reactive power by PV systems as well as active power loss caused by reactive power in comparison with the GGC.

In active power dependent methods do not directly measure the voltage as an input. This can, therefore, be noted as a shortcoming of these methods on the grounds that demand variations might simultaneously be in a harmony with the generation for the long range of time periods. PV systems may consequently consume reactive power while there is no voltage violation. Concerning high penetration of PV systems, as mentioned earlier unnecessary reactive power consumption by PV systems is undesirable. Therefore, using the droop-based voltage (DBV) regulation can prevent unnecessary reactive power usage.

Coordination of droop parameters among several PV systems is a challenge on the grounds that PV systems at the beginning of the feeder participate less in the voltage regulation compared to those at the end. The voltage sensitivity matrix is used to propose a coordinated voltage droop parameters for individual PV systems along a radial grid.

The graphical DBV regulation is shown in Fig. 2 . In the DBV regulation, reactive power supports the voltage profile once the voltage is outside a dead-band, which is defined either by standards or distribution system operators. Since voltage rise is more of a concern in this approach, only the right hand side of the graph shown in Fig. 2 is taken into consideration. Once the voltage profile hits the dead-band limit, PV systems must contribute reactive power to support the voltage in accordance with occurred voltage deviations.

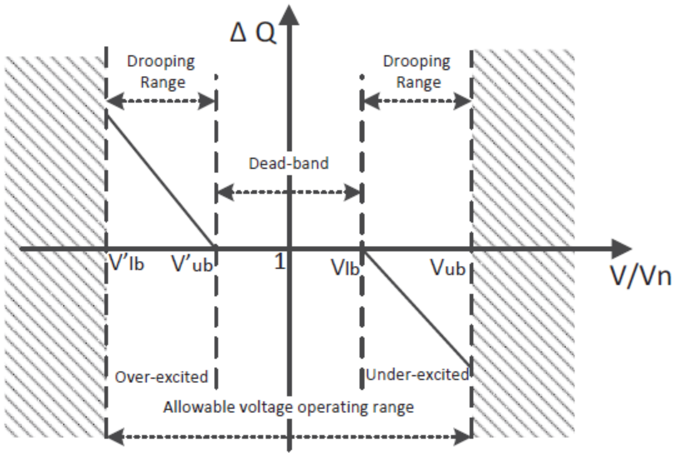

Fig.2 : Graphical schematic of droop-based voltage control.

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