

Abstract

Gradual increasing installation of solar photovoltaic inverters (SPVIs) at the low voltage (LV) network causes over-voltage issues at the SPVI-connected point-of-common-couplings (PCCs) during high irradiance period. The over-voltage issue at the point-of-common-couplings (PCCs) occur due to the inherent radial nature of the distribution network, and it further degrades the Voltage regulation (VR) of the Distribution Transformer (DT). To mitigate the over-voltage in the network, IEEE 1547 recommends the constant QV-droop and PV-droop characteristics in the SPVIs. Due to the high R/X ratio of the lines, active power curtailment (APC) occurs at the SPVIs due to the PV droop. Further, unplanned and dramatically increasing trends in the single-phase converter (SPC) deployment significantly impacts on phase voltage unbalance factor (PVUF) and voltage regulation (VR) of the LV-ADS. High PVUF at the buses may lead to the tripping of SPVIs and poor voltage regulation at the DT.

This thesis focuses on developing novel control strategies for SPVIs and SPCs. A new control philosophy has been formulated in the thesis to minimize the APC issue among the SPVIs. Further, in this thesis, a novel algorithm is formulated to mitigate the over-voltage issue in SPC and SPVI-dominated LV-ADS. To address the above-mentioned issues, an irradiance driven adaptive PQV (IAPQV) droop mechanism is formulated to resolve using the distributed control approach. The IAPQV proposes irradiance driven QV-Droop and PV-Droop to improve voltage regulation in the ADS. In the latter part of the thesis, a time-coordinated leader-follower feedback-based algorithm (CLFFA) is formulated to operate the SPVIs and SPCs. CLFFA is orchestrated in a time-graded approach to reduce the PVUF and improve the VR in the LV-ADS. Both the formulations, IAPQV and CLFFA use a smart and novel cluster selection algorithm (CSA). The basic aim of CSA formulation is to optimally choose a portion of the network that requires attention a priori in terms of PVUF or VR.

Since the IAPQV and CLFFA control methodology makes use of the communication links between SPVIs and SPCs, the resiliency of the links becomes extremely important from both the perspective of utility and prosumer. Hence, to operate these power infrastructures in an efficient and reliable manner, cooperative/distributed control is incorporated as a control solution. The communication medium is an inherent infrastructure to exhibit cooperative control in microgrids. The measurement states are communicated using the medium. Thereby, the states communicated come under the realm of the attacker. Voltages of the converters in grid-connected/islanded microgrids is one such state that may be vulnerable to cyber attack. Hence, the last part of the thesis details an event-driven resilient control strategy to detect and mitigate such attacks.