Abstract

The focus of the thesis is to improve the stability of an inverter system when it is tied to the utility grid. It has been observed that integration of power electronic inverters to the grid gives rise to inter harmonic frequency components in the voltage and current waveform at the point of integration. Such sustained oscillation differs in magnitude and frequency when the point of integration in the grid changes. The work analyses the cause and proposes mitigation measures from the viewpoint of the grid operator as well as the inverter manufacturer.

Investigation into the cause of such oscillations has been performed with the help of impedance-based stability analysis. It is observed that at the frequency corresponding to the point of intersection of the wideband grid impedance and the wideband inverter impedance, an oscillation is observed. A weak grid condition with high grid impedance is the cause of such a scenario. Therefore, mitigation measure involves re-engineering the wideband impedances. While re-engineering the grid impedance at the point of integration is not feasible, the thesis proposes indices that may help grid operators to perform future integrations, considering contingencies that may make the grid weak and consequently result in oscillation. This forms a planning approach towards alleviation of the instability problem.

The sensitivity indices illustrate the contribution of line outages to the weakness/strength of every bus in the system. The proposed indices rank buses on their susceptibility to becoming weak due to changes in the network topology. To show the effect of line outages on the system voltage profile and further validate the proposed ranking indices, a power hardware in loop (PHIL) experiment has been conducted where a physical 5kW grid tied inverter is connected to a particular bus in the IEEE 30 bus system. The results show that the indices successfully map the lines and buses according to their potential to weaken/strengthen the power system. With

the help of the developed indices, the system operator can choose buses whose strength will not change significantly due to contingencies. However, a techno-economic and geographical constraint can force an operator to integrate a grid tied inverter at a highly critical bus, as shown by the sensitivity indices. In such a scenario, an operational approach to mitigation of the instability is proposed.

The operational approach involved re-engineering the wideband inverter impedance. It is observed that the inverter impedance is a function of the control system and the passive elements like filters. Therefore, initially, the contribution of the control parameter gains in changing the wideband impedance profile has been explored. The knowledge may help in location-specific off-line parameter tuning of the inverter by the inverter manufacturer before project commissioning.

Post commissioning of the inverter, due to grid strength variability, an unstable scenario can arise. Therefore, an adaptive augmentation to the existing control system which will perform dynamic gain tuning of the existing control system has been proposed. The control augmentation design is performed using a sensitivity index formulation. Such a grid cognizant control system requires an accurate estimate of the grid Thevenin's impedance. Therefore, grid impedance estimation at fundamental as well as wideband frequencies has been proposed.

Thus, to summarise, the thesis give planning as well as an operational solution for removal of oscillatory instability arising at the point of integration. The planning measure can be used by grid operators to perform new integration planning while the operational solution can be used by inverter manufacturers to counteract the problem arising due to the dynamics of the grid.