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ABSTRACT

Smart Grid may be defined as the "digital upgradation of existing power infrastructure to incorporate dynamic gateways for existing as well as new and renewable energy sources and consumers". Switching at different stages are required in smart grid, during integration of the renewable energy sources, for connecting the controllers, switching the FACTS devices, for connecting the smart meters and measurement techniques etc. Therefore, a lossless switching method has been developed using Zero Voltage Switching – Pulse Width Modulation (ZVS-PWM) active clamp/reset technique. The results are validated by comparing it with the theoretical analysis and ideal wave shapes. After the development of lossless switching technique, model of Solar Photovoltaic (SPV) plant has been developed and simulated in MATLAB. The model of Wind Turbine Doubly Fed Induction Generator (WTDFIG) has been considered and six WTDFIG are arranged to model a wind farm. The simulation results have been obtained for their standalone operation as well as for a hybrid model based on SPV and WTDFIG. It has been found that the two systems are working in synchronism and are able to fed power to standalone loads or to the grid. Later, modelling and simulation of FACTS controllers (Static Synchronous Series Compensator and Unified Power Flow Controller) and Power Oscillation Damper (POD) have also been carried out. The above discussed FACTS controllers are applied in a model of six bus power system and run for four conditions (i) without FACTS controllers, (ii) with SSSC alone, (iii) with UPFC alone and (iv) with SSSC and POD, in order to observe the congestion on transmission lines. It is observed that when the transmission system is equipped with FACTS controllers, the power handling capabilities of the transmission lines increases. The simulation results indicates that the SSSC with POD controllers give results better than UPFC as far as congestion management and loadability enhancement is concerned that too keeping the nominal voltages of each bus well within stable limits. A hybrid SPV-WTDFIG model has also been developed to study the integration problems. Now, IEEE 14 bus system has been selected in order to develop a larger model of smart grid. The smart grid model based on IEEE 14 bus system is made to operate under the same conditions as simulated for the 6 bus system. Similar simulation results have been obtained for same operating conditions for smart grid model based on IEEE 14 bus system as

well as 6 bus system. The results again confirm that SSSC with POD controllers give better results for loadability enhancement and congestion management compared to UPFC. Therefore, SSSC with POD controllers are more useful for the decongestion of different transmission component like transformers and transmission lines, that too, keeping the nominal voltages of each bus well within stable limits. It has been shown that, by the use of FACTS controller, the availability of active power on the transmission lines can be redistributed and hence the loadability can be improved.

The models of SPV and WTDFIG plants are integrated and synchronized to the considered power system model. Further, the six bus power system model is operated under the same operating conditions stated above for the measurement, estimation and analysis of Total Harmonic Distortion (THD). It is observed that the considered power system model introduced harmonics into the system when operated with FACTS controllers. The THD is analysed on three buses; B1 and B4 which are PV bus and B3 which is a PQ bus. It is observed that the THD is as high 132.60% when operated with SSSC; 122.46% when operated with UPFC, 169.63% when operated with SSSC and POD. When the model is run without any FACTS controller, the system operation is almost devoid of harmonics. It is to be noted that the SSSC with POD which gives better result for the decongestion and loadability enhancement of transmission lines, introduced more harmonics in the system. It is, then, obvious that filtering becomes a necessity whenever the power system is operated with FACTS controllers. The three phase harmonic filters are studied and designed. A filter is designed and simulated by combining different three phase filters which is working well for the systems upto 600 MVAR. This filter is introduced in the considered 6-bus power system model. The model is further operated for all the conditions i.e. with UPFC, with SSSC alone and with SSSC and POD. It is observed that when the considered system is operated with the designed filter having SSSC alone, the THD is reduced from 132.60% to 52.39%. The filter caused a reduction in the THD from 122.46% to 57.27% when operated with UPFC. When operated with SSSC and POD, the filter reduced the THD from 169.63% to 45.30%. It can now be unequivocally concluded that the designed filter gives satisfactory results as it improves the power quality to a greater extent by reducing the THD.

To augment the applicability and feasibility of all the analysis, further, IEEE 14 Bus system is considered. The models of WTDFIG and SPV generator are integrated to develop the model of smart grid. This smart grid model is operated for observing the power flow, line flow, bidirectional power flow, voltage profiles and many other parameters. The FACTS controllers are added in order to observe the changes in the performance characteristics. The results of all the FACTS controllers are in close association with previous results. The results are obtained initially for STATCOM. It was observed that STATCOM caused a reduction in losses and improvement in power flow with a very low margin but was suitable for maintaining and managing the voltage profiles within a transmission system. The results with other FACTS controllers are in close association with the results obtained previously with the 6-bus system.