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ABSTRACT

Over the last two decades there has been a tremendous spurt for exploiting renewable sources of energy due to the growing economic and environmental concerns. Among the various renewable resources, photovoltaic (PV) has emerged as one of the most promising source of future power and has become the most attractive solution in the form of clean & green energy. India has already achieved a milestone of 20 GW PV installations and now it has been planned to achieve 100 GW PV power by the end of year 2022. Still the PV power has only 5.5% share in the country's total installed capacity at present and hence there is the need to strive for advancements in PV system technology.

In general, there are two means of harnessing PV power. One of the alternatives is to use it as the stand-alone systems, providing power to the distant areas where the power lines are unavailable or not economical from installation point of view. Another possibility is feeding the PV power directly into the AC grid. Although there are many similarities among these two technologies, but there is significant difference in terms of their control functions. For the grid connected PV systems, power conditioning module plays the vital role while interfacing the PV panels to the utility grid. For feeding power to the utility, power electronic converters are required to condition the variable DC output of PV panels ensuring proper AC conversion, for which appropriate control strategies have to be designed. This research work focuses on some of the major challenges for large scale penetration of PV systems and proposes the control algorithms in order to enhance the performance of integrated PV systems.

From the functional perspective, broadly two control strategies are essentially required for PV interfacing, one for the maximum power point tracking (MPPT) and other for the power conditioning module (inverter). As the PV panel characteristics are non-linear in nature and vary greatly with the operating conditions, hence it becomes very much important to ensure that PV panels operate at optimum point for which effective tracking algorithm has to be incorporated. Therefore, in order to optimize the PV system performance, first of all modeling of PV system starting from that of a PV cell is presented in this work. Various PV circuits (differing in the number of diodes) have been analyzed where the single-diode model has been found to be most suitable one, being simple and accurate enough and hence it has been applied here. The impact of parameters like temperature, insolation and partial shading on the PV characteristics are analyzed. Here it is observed that solar insolation has greater effect on short circuit current, whereas temperature has greater effect on open circuit voltage.

Once having analyzed the variation in PV power output in accordance with the change in operating conditions, this work focuses on MPPT where the advantages and disadvantages of the commonly applied techniques have been discussed in details. A common drawback is found that in the rapidly varying environmental conditions, these fail to track effectively as the operating point drifts away from MPP. Therefore, this work proposes a model-based (MB) MPPT algorithm, which overcomes this limitation and ensures effective tracking in dynamic conditions. The proposed MB algorithm estimates the parameters precisely that allows fast jump of the array voltage under rapidly varying conditions and hence permits dynamic response in convergence.

Then the focus is shifted to second essential control aspect for PV system penetration. The power conditioning module plays a very crucial role for PV interfacing, as it has to ensure grid reliability and stability all the while maintaining the power quality. This research work proposes novel control schemes for both these challenges. First, the problem of grid stability is addressed and then the issue of power quality has been tackled. With the continuously growing PV penetration, one of the biggest challenges that are being faced is the deterioration in grid stability during voltage and frequency perturbations which demands new strategies to be designed. As the PV systems are inherently non-inertial in nature, they do not provide any regulation for grid frequency or voltage and thus even a small perturbation in these may result in a disaster leading to total blackout. Therefore, a novel control algorithm based on synchroconverter concept has been proposed, which offers the advantage of inertia and damping and thus enables the inverter to regulate grid voltage and frequency, compensating for fluctuations under load variations. Inverter performance is tested for different modes of operation where it is seen to respond well to the disturbances on the grid side, offering control of active and reactive power injection.

Finally, impacts of large scale PV penetration on system power quality (PQ) have been analyzed, where limitations of the commonly applied passive filters have also been discussed. This work incorporates an active power filter (APF) scheme for compensation of the PQ deteriorations. A novel control technique for PQ enhancement has been proposed where a Kalman filter is applied for estimation of the reference current. Also, adaptive hysteresis controller is employed for generation of gate pulses, maintaining almost constant switching frequency, thereby, avoiding the acoustic noises and other losses. The proposed APF scheme effectively eliminates the harmonic distortions and improves the power factor as shown by the simulated results.