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In this modern world the energy is the integral part of our daily life. In India the electricity is generated mostly by burning of fossil fuels like coal and diesel. As we know that these fossil fuels are in limited quantity and also produce pollution. So we must think to generate energy from renewable energy sources. There are many renewable energy based generation systems available these days. Among them solar photovoltaic technology is most preferable technology to generate electricity in Indian scenario. In has strong potential to generate electricity from solar PV technology. We receive solar radiation in a range of 4 to 7 kWh/m^2/day. Such amount of solar radiation is good enough to fulfill the entire amount of demand using solar PV technology. This thesis focuses the light on technical issues of small solar PV systems.

Various MPPT methods are available for extracting power from SPV systems. The Perturb & Observation (P&O) method is a widely employed MPPT technique. This algorithm is simple but under steady state condition, high oscillations are found around MPP. The performance of the P&O MPPT technique is dependent on the trade-off between tracking of speed and oscillations around MPP. Under some special conditions like the partial shading on PV modules, this technique often fails to track the maximum power point (MPP) due to multiple peaks in the P-V curve, and MPPT algorithm is not able to recognize the global peak among local peaks.On the other hand, another popular MPPT, i.e. incremental conductance (IC) technique has a quality not to lose the tracking direction, but it suffers from oscillation and speed problems as that of P&O technique.

Some artificial intelligence (fuzzy-logic and neural network) based control approaches are also available in the literature to tackle the oscillating problem around MPP. The fuzzy-logic based system consists of fuzzification, defuzzification, inference mechanism and storage subsystems. Neural network based systems also require a large amount of data to train the system.
Judicious detection of MPP under PSC is also a point of concern because if a false partial shading condition is detected (but it does not exist), the algorithm may be unnecessary busy in finding peak (GP) which reduces the efficiency of MPPT algorithm. To improve the system performance and to track MPP under PSC there are several advance soft computing based MPPT techniques are found in the literature. Some soft computing based techniques use artificial intelligence (EA, Fuzzy logic, ANN, etc.) to track MPP. Requirement of large training data affects the performance of these MPPT techniques, which reduces the tracking speed.

Operation of stand-alone PV systems is very much dependent on battery storage to satisfactorily fulfill power demands. Generally, in these systems, the batteries are charged in peak sun time and the stored energy is used when required. The solar radiation varies all over the day and this irregular radiation pattern affects the PV power generation. A battery suffers from rapidly changing charging/discharging patterns due to intermittent radiation conditions appearing in a day. This condition affects the battery performance, decreases the life span and adds to the battery replacement cost.
Hybrid energy storage system (HESS) is a solution to minimize the stress of unnecessary charging/discharging on batteries. It is reported that combination of battery and supercapacitor as a HESS enhances the stand-alone PV system's performance and minimize the battery maintenance cost. A battery-supercapacitor duo has been widely considered in most HESS developments as they complement limitations of each other and have relatively low costs. The implementation of HESS would also reduce the dynamic stress on battery during fast transient or sudden climate change condition.

To optimize the stand-alone PV system performance and to exploit the advantages of HESS, a control strategy is essential. This control strategy manages the power flow of the battery and supercapacitor according to input irradiance and load demand conditions. For HESS control, two control strategies are commonly found in the literature. First is the Rule Based Control (RBC) which is simple and easy to implement. But it lacks the ability to adopt real time weather conditions, since it has a pre-defined set of rules and threshold values for operations. Second is the Filtration Based Control (FBC). It decomposes the dynamic power demand into high and low frequency components using a filter. Different strategies based on particle swarm optimization (PSO) or Combined Heat & Power (CHP) control have been developed for HESS, but these techniques are very complex and not suitable for small-scale stand-alone PV systems.

The small or residential low cost PV systems do not have high performance processors to implement all the above-said MPPT techniques. High performing processing units increase the PV system cost, but small or residential PV systems are bounded to be affordable for middle-class consumers. So there is a need for a new simple and fast MPPT technique which can easily implement in small or residential PV systems, compensate steady state oscillations around MPP and stabilize the output PV voltage during RRC condition efficiently. Also, in small isolated PV systems the voltage stability is more important than power loss reduction during PSC as criteria for the control system.

The variable nature of solar radiation and fluctuations in load makes the stand-alone PV system operation challenging. Hence, the stand-alone PV systems strictly require an energy storage system backup to provide power in a reliable way. Lead-acid battery has a high storing capacity but it has low power density with low charge-discharge rate and subsequently a slow response. On the other hand, a supercapacitor has a high power density and can discharge with a high current for a very short duration. Also, it has a fast charging and discharging feature along with a long life cycle and maintenance-free operation when compared to batteries. Due to its fast discharging property, it has an ability to maintain power quality during fast transients. Therefore, there is a need for a simple and efficient control strategy which can optimally control the power flow of battery and supercapacitor in a HESS used in domestic stand-alone PV applications.

This thesis proposes a simple modified P&O (MP&O) MPPT algorithm for small or residential solar PV systems to eliminate such above said drawbacks. The proposed MPPT controls the step size (dD) of the boost converter duty cycle (D) according to the system input conditions and have the ability to compensate the transient as well as steady-state oscillations around MPP and stabilize the output voltage under RRC and variable load conditions. The proposed MP&O MPPT algorithm has capability to accurate detection of PSC which stabilizes the system output voltage without compromising with power efficiency. To validate the proposed algorithm, a 1kW photovoltaic system model is simulated using MATLAB/Simulink, and the performance of the system is also investigated under RRC. The performance of the proposed algorithm is also investigated using dSPACE controller, solar PV emulator and a SiC Mosfet switch under PSC.

A domestic stand-alone PV system with Hybrid Energy Storage System (HESS) that is a combination of battery and supercapacitor is developed. A new Fuzzy Logic Control Strategy (FHCS) is implemented to control the power flow of the battery and supercapacitor. To investigate the proposed system's performance, simulation studies are performed with real data collected in Sultanpur, India (Latitude [N] 26.29 and Longitude [E] 82.08). The developed system is validated to provide an effective alternative which would enhance the battery life span and reduce the system maintenance cost. Considering the prohibitive upfront costs for rural systems, such an improvement helps electrify more underserved communities.

An economic analysis of solar PV stand-alone systems for rural areas in India is also done here. Based on load profiles, a stand-alone system has been designed and simulated for rural areas of Jodhpur location. These systems are designed to provide solar electricity for small rural household using different load profiles. In this work, four types of load profiles are under consideration for the actual performance assessment of the system. Battery bank and PV modules size estimated for all load profiles under same environmental conditions. An optimized load profile is proposed and a standalone PV system designed to investigate its performance. The cost analysis shows that the optimized load profile type system is the most economical design for a standalone PV system.