ABSTRACT

The primary objective of this research work is to design and develop efficient MPPT techniques to optimize power in Standalone Photovoltaic System (SPVS). Photovoltaic power generation is gaining prominence as it is an important renewable energy resource and the output power induced in the PV panel depends on the solar irradiation and temperature of the Photovoltaic (PV) panel. Therefore, tracking of Maximum Power Point (MPP) becomes indispensable to deliver maximum possible power leading to an improvement in the efficiency of the panel. MPPT enabled PV systems are largely in demand at remote areas where there is difficulty in connecting to the grid. In this research, the performance of standalone photovoltaic system is investigated under constant and varying environmental conditions by deploying various control strategies using Revised Variable Step Size Incremental Conductance (RVSS INC), Takagi Sugeno (TS) Fuzzy, Adaptive Particle Swarm Optimization (APSO) and Linear Quadratic Regulator (LQR) methods. A Standalone Photovoltaic system (SPVS) utilizing boost converter and MPPT control is designed and simulated in MATLAB/Simulink environment in order to analyze the feasibility and the performance of all the proposed methods.

The conventional INC method is slightly complex when compared to Hill Climbing and Perturb and Observe methods but became easier to implement because of the advent of microcontrollers and Digital Signal Processors. It uses a fixed iteration step size determined by the accuracy at steady state and response speed of MPPT. There must be an adjustment between dynamics and steady state oscillations that has to be addressed by corresponding design. Also, when the solar irradiation level changes suddenly from low to high, the conventional method fails to observe the change and implements inaccurate first step change. To solve these issues, Variable Step

Size (VSS) INC method is developed. The step size for variable step size INC method is determined based on the inherent characteristics of the PV panel. If the operating point is far away from Peak Power Point (PPP), the step size is increased to improve the fast tracking ability and if the operating point is close to PPP, the step size is largely decreased such that the oscillations gets reduced contributing to better efficiency. But, there is no possibility in VSS INC method to find the suitable scaling factor in rapidly changing environmental conditions. To overcome the problem, an effort is made to develop a revised VSS INC method which determines variable step size according to the existing solar irradiation level. As the irradiation level is directly related to the PV current in this work, PV panel current is used to estimate the irradiation level based on which step size is determined. The effectiveness of the proposed RVSS method in tracking PPP is evaluated through simulation.

The Fuzzy Logic Controller (FLC) allows in finding its parameters without an accurate mathematical model and also performs significantly well when applied to nonlinear systems. Because of these reasons, FLC based MPPT algorithm attracts research interests. The TS-Fuzzy model proposed by Takagi and Sugeno replaces the fuzzy consequent of Mamdani rule with the function of input variables and constitutes fuzzy if-then rules that represent local input output relationship of a nonlinear system. The local dynamics of each rule can be expressed by a linear system model which obviously is the reason for choosing TS-Fuzzy logic method. It can be applied for complex and high dimensional problems and the rules can be generated systematically from a given input output data set. The effectiveness of TS-Fuzzy MPPT controlled SPVS is assessed by comparing with existing FLC method that uses Mamdani rule set. Both the methods are simulated in MATLAB/Simulink. The appropriate rules are fed to the rule editor and the performances exhibited while tracking MPP are examined for fixed and varying solar irradiation levels.

When TS-Fuzzy method is used, though oscillations are reduced, steady state error is relatively large compared to actual value of MPP. Therefore, an improvement in the dynamic performance and MPP tracking accuracy of SPVS is addressed by the use of Evolutionary Algorithm (EA) techniques. Because of the ability of EA techniques to handle nonlinear objective functions, it is envisaged to be effective in dealing with MPPT problem. Among the available EA techniques, PSO is highly potential due to its flexible and well balanced mechanism to enhance global and local exploration abilities. As PSO remain unaffected by the size and nonlinearity of the real world optimization problems, adopting PSO as a tool to locate MPP despite changing environmental conditions is possible. The conventional PSO method has two dynamic properties that degrade its searching capability. The first problem is the premature convergence and the next is the inability of PSO to maintain balance between global search and local search. These limitations impose constraints on the wider application of PSO to real world problems. Therefore, adaptive PSO whose inertia weight is adapted based on the success rate of particles is proposed to ensure faster tracking and higher efficiency. An Adaptive Inertia Weight Factor (AIWF) is introduced in the velocity update equation of conventional PSO to change the inertia weight according to the nearness of particle towards optimal solution, thereby improving the speed of convergence and precision in tracking MPP. The efficacy of the APSO in providing improved tracking speed is tested through simulation and the performance of the proposed APSO technique is compared with that of the conventional PSO.

In addition, the design and implementation of Linear Quadratic Regulator (LQR) based maximum power point tracking method for standalone photovoltaic system that possesses the advantages of faster tracking ability, transfer of maximum deliverable power and its implementation with reduced complexity is reported in the work. LQR is an optimal state feedback controller that aims to minimise the quadratic cost function to provide an optimal response. The quadratic cost function relates both the state and input vectors. A dedicated computer program is developed in MATLAB/Simulink environment and simulations are carried out extensively in a view to evaluate the performance of LQR based MPPT under constant and changing weather conditions. The simulation findings suggest that LQR based tracking is far superior to all other proposed methods interms of tracking speed and efficiency. The LQR method that resulted in improved tracking of MPP is implemented in real time using dSPACE controller, in order to confirm its functionality. The tracking speed and efficiency for all the proposed methods are reported in detail and this would suggest the electrical engineers to select the right method for MPPT applications.

The dynamic analysis of the PV systems become essential as the equilibrium points of the system changes with change in irradiation. The behaviour of PV systems can be described by set of nonlinear equations, representing bypass and blocking diodes models and is characterized by a sparse Jacobian matrix. Small signal stability is defined as the ability of the system to maintain synchronism when it is subjected to small disturbances. Such an analysis is to examine the stability of the system under various solar irradiation levels. The stability of double diode model based system is analysed with Krasovskii’s method based on second method of Lyapunov and Eigen value approach. Two equilibrium points are obtained using analytical method and the stability is assessed.