Development of Advanced MPPT Algorithms And Power Management Scheme For Standalone PV Systems

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Abstract- *In this paper Maximum Power Point Tracking (MPPT) algorithms based on the popular Perturb and Observe (P&O) method, is analyzed in which primarily aim is to stop the steady state oscillations and provide a steady power output. A Power Management Scheme (PMS) is also discussed for the Standalone Photovoltaic System (SPVS) with battery storage. In the P&O algorithm, the operating point oscillates around the Maximum Power Point (MPP) resulting in lower power output at every alternate perturbation, thus reducing the overall efficiency. A steady maximum power output can be achieved if the oscillations around the MPP are stopped when steady state is reached, This would also improve the efficiency. This paper deals with modelling of a stand-alone solar PV system with MPPT (Maximum Power Point Tracking) algorithm to enhance its efficiency for a dedicated load pattern. The Perturb & Observe (P&O) algorithm has been used to track the maximum power operating point of stand-alone Solar PV system.*

Keywords- MPPT,SPVS, Perturb and Observe (P&O) method,

I. INTRODUCTION

Prolonged extraction and use of conventional energy resources, namely coal, petroleum and natural gas have caused unpleasant effects on the environment, also leading to energy crisis. The present energy scenario has raised the necessity of renewable energy resources. Globally appreciated such energy sources include Solar, Wind, Biomass etc. It has been found that the amount of solar energy supplied to the earth in one day is sufficient to power the total energy demand of the earth for a year. Solar PV electricity can be harnessed for use in industries or for domestic purposes. But the main challenge in this path is its intermittency and storage of energy. Also the initial investment is very high and there is a significant loss of energy due to the poor efficiency of solar cells. Hence Maximum power point tracking is not a choice, but a necessity. Here in this work instead of mechanically tracking the maximum power we have applied electronic adjustment of PV output I- V operating point to achieve MPP at a particular solar irradiance level.

Standalone-PV systems are generally used for isolated loads or household purposes [12-15]. The increase in power demand in the utility side with less harmonics and fluctuation are the major issues .The conventional sources of energy have the probability to last for limited time but renewable sources of energy like solar energy is infinite and also eco-friendly. With the increased efficiency of power electronics devices we can use this solar energy to provide the power to the consumers. The only flaw of solar energy is that the set-up required is quite expensive. The output power of PV depends on many criteria's like insolation and temperature. With variation in these two parameters the output is also varied, which will thereby lead to fluctuation in the utility side, which is totally undesirable. So it is important to have a control which will make our SOLAR-PANEL's output totally independent of weather conditions. Currently there are many algorithms like incremental inductance, perturbation and observation, fuzzy logic etc. [2]-[7]. In this project we totally concentrate on the method of PERTURBATION and OBSERVATION. This algorithm controls the duty cycle of boost converter and it is given as gate pulse to the converter then. The battery used here is like an energy storage element. It not only maintains dc link voltage across the capacitor constant but also supplies to the load during bad weather conditions when PV is unable to generate the power required by the load. A standalone PV system has many practical applications. For household purposes it can be used for any type of loads -- linear or nonlinear. The simulation results and the hardware design shows that STANDLONE-PV system can be efficiently used for isolated loads.

Normally a solar panel is able to convert only 30-40% of the total incident solar irradiation into electrical energy. Maximum Power Point Tracking (MPPT) is used to improve the efficiency of a particular solar panel.

Maximum Power Point Tracking (MPPT) is an algorithm that is used to extract maximum power from PV under specific conditions. Maximum power of a PV panel depends on factors such as solar irradiation, ambient temperature and cell temperature[18],[20].

Normally a PV module produces maximum power voltage at cell temperature of 25°C. However depending on outside temperature it can fall or rise. MPPT checks the output of a particular PV panel and after comparing it with battery voltage decides the most efficient voltage i.e. maximum power point voltage. The purpose of a MPPT system is applying proper resistance after sampling output of PV cell in order to obtain maximum power. MPPT is most effective in cooler conditions and when the battery is deeply discharged.MPPT devices are integrated with power electronics creating an electric power

II. SYSTEM MODEL

The overall system for simulating the standalone PV system as proposed in many research literature [1-5] is represented by the schematic diagram given in Fig. 3.1.The boost converter is used as the power conditioning unit between the PV panel and load. The required PWM is generated based on the P&O algorithm to trigger the switch of the converter to track the maximum power point.

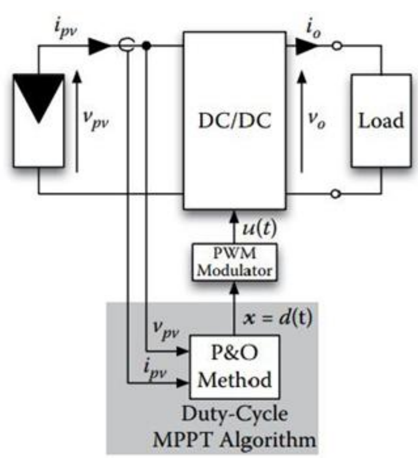

Fig. 1 Schematic of the overall system topology

A direct connection of the PV generator to the input port of a power processing system imposing a constant voltage level would be a simple but poor choice from the energy productivity point of view. For instance, a PV battery charger obtained by connecting merely the PV array terminals to the battery would force the PV generator to work at a constant voltage. If this voltage is higher than the PV array open-circuit voltage, then the PV system does not deliver any electric power. Otherwise, the closer the battery voltage to the actual higher the electrical power generated by the PV array. Unfortunately, due to the inherent time variability of VMPP caused by the changes in the operating conditions.The probability that the PV array delivers the maximum power at any time of the day is almost near zero.Thus it becomes evident that there should be an interfacing unit, interfacing the PV array load that utilizes the power generated by PV source. The interfacing unit should allow the system to operate at a condition where maximum available power is extracted while complying with the load voltage and current requirement interfacing unit must be a dynamic optimizer. This dynamic optimizer is known as maximum power point tracker.

The word “perturb” means to disturb slightly. In simple words, P&O algorithm tracks the MPP by adjusting the voltage by a small amount from the array of PV cells, and calculates the power. If the power increases then perturbation direction is unchanged and if the power decreases then the direction is reversed and it continues these steps until the power no longer increases i.e. the MPP has been found. The operating principle of this algorithm is very simple. In this method the panel voltage and current is sensed and power is calculated every time. This power is compared to the previous power and according to that the voltage is adjusted to give the maximum power irrespective of solar irradiance and temperature. In the details of the algorithm the output power of the solar panel is compared to the previous power every time. If the present power is greater than the previous power and it goes on increasing then the voltage also will be continuously increased by a fixed step to track the maximum power. The flowchart algorithm is given in Figure is less than the previous at a point then the voltage is decreased by the same step to stay on that point of maximum power.

Modeling of SPV SYSTEM WITH MPPT

The circuit shown in the Fig. 4.1 was simulated using Sim Power System toolbox in Simulink and the operation of the proposed algorithm is verified. The solar cell module as per the electrical model defined in Fig. 3.4 was built in Simulink to simulate the exact behavior of a PV array. Both the proposed MPPT control algorithm and Incremental Conductance Algorithm (IncCond) for comparison purpose were implemented using State flow toolbox.

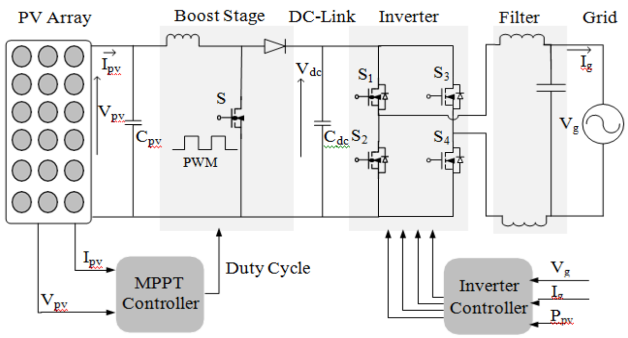

Fig 2: Circuit Diagram of the proposed system

A PWM Generator block, which can generate pulse width modulated (PWM) signals with a variable duty cycle was built by using Simscape toolbox. The PV voltage and current are sensed and used by the MPPT control algorithm to calculate the duty cycle for boost converter. The Simulink model is as shown in the Fig. 2.Multiple subsystems are used for the purpose of verification. The irradiation condition was changed using the irradiance block. The irradiance value of 1000 W/m2 defines a sun condition of 1 sun whereas irradiation value of 500 W/m2 is the value for 0.5 sun.

The proposed algorithm implemented in Stateflow generates duty cycle for the PWM Generator block. It produces the required switching signal for the MOSFET switch of the boost converter. The switching frequency of the boost converter is 100 KHz. The input PV capacitance of the boost converter is 178 µF which designed based on switching frequency ripple. The time-interval between the each iterative loop of the MPPT control algorithm defines the speed of the method and inverse of this parameter is termed as MPPT frequency. For the simulated system, the MPPT frequency is chosen as 49.5 KHz i.e., half of the switching frequency. The inverter was controlled by the sinusoidal pulse-width modulation (SPWM) scheme with a 10 KHz switching frequency.

Simulations were initially carried out for the full capacitance case. In order to validate the proposed method, the results were compared to IncCond method. The performance of any MPPT method is tested for a step change input of irradiance.Next the simulations was performed with a reduced capacitance system and the operation of proposed algorithm and IncCond method are analyzed. This method retains the concept of MPP locus method and thereby carries all the advantages of the other MPP Locus methods proposed in the literature..

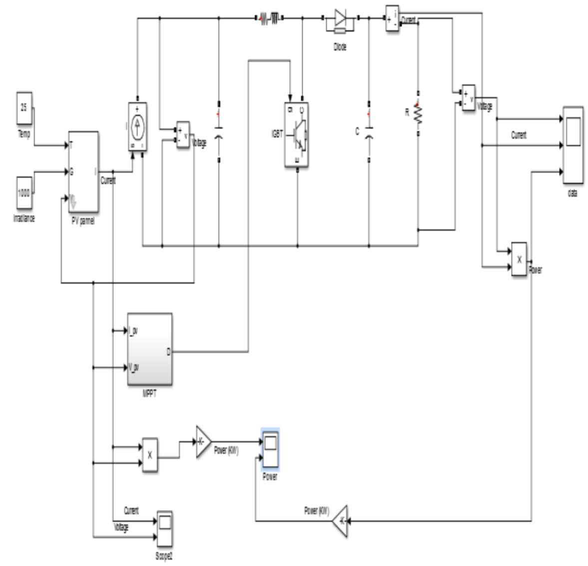

Fig 3**:** Details of PV panel using MPPT

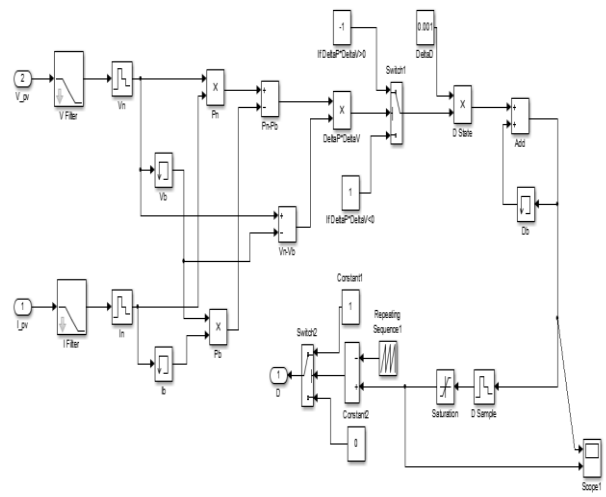

Fig 4.: Subsystem of MPPT

III. RESULT

The model is simulated in MATLAB and result is observed.

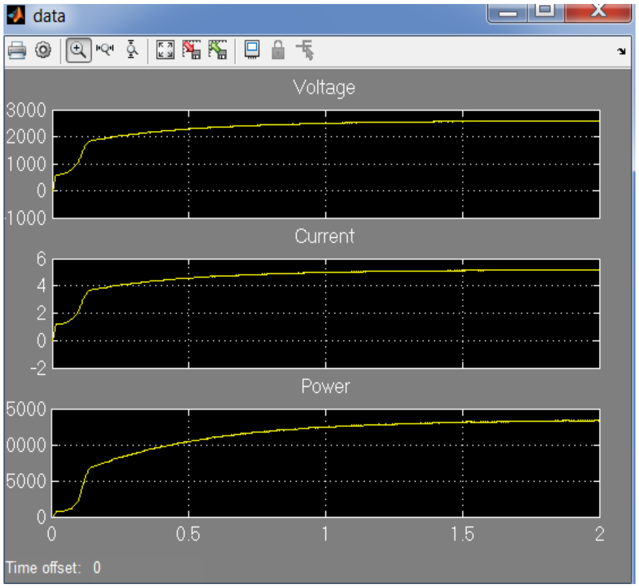

Fig. 5: MPP tracking with variation in environmental parameters (Temperature, Irradiance)

figure 5 shows the voltage-time,current-time and Power-time characteristics of PV Module. In figure 5, Y Axis shows the time and X Axis shows the voltage and in figure 6, Y Axis shows the time and X Axis shows the current. In figure 7 Y Axis shows the time and X Axis shows the power.

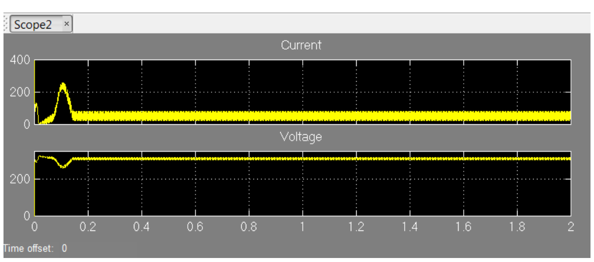

Fig. 6 Characteristics of scope2

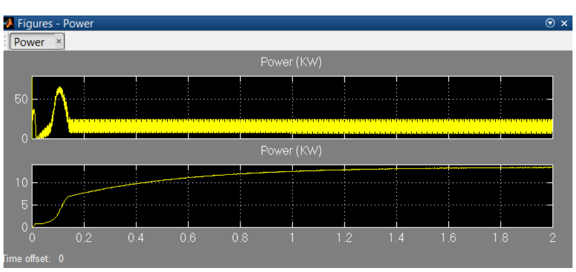

Fig. 7 Characteristics of power

IV. CONCLUSIONS

The P&O MPPT technique employed here has its own follies because it was observed that with relatively smaller step size the power loss in minimized in the steady state but the tracking process is sluggish, whereas an increased step size reduces the tracking time at the cost of the power loss in the steady state. Although it can strongly be argued that the MPPT using P&O loses its tracking ability when and if subjected to sudden change in irradiance and/or temperature levels. As a result, the entire system becomes unstable. The problems associated with the P&O can be overcome using schemes mentioned in the introduction of this paper. The problems related to the PCU can be overcome by using next generation DC-DC converters (e.g Super-Lift Luo converters).

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