PERFORMANCE ANALYSIS OF ADVANCED MPPT BASED SOLAR ENERGY SYSTEM

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Abstract – This project focuses on the performance analysis of an advanced Maximum Power point Tracking (MPPT) based solar energy system, utilizing MATLAB-SIMULINK simulation. The MPPT algorithm is crucial in optimizing the power output of solar panels by continuously adjusting the operating point to track the maximum power available from the photovoltaic array under varying environmental conditions. The system incorporates sophisticated control techniques to ensure efficient power conversion and grid integration. By employing advanced MPPT algorithms, the system demonstrates superior performance in extracting maximum power from the solar panels, thereby enhancing overall energy yield. Simulation results validate the effectiveness of the proposed MPPT strategy in achieving high efficiency and reliable operation of the solar energy system under diverse operating conditions.

Keywords – Solar Energy, MPPT, MATLAB, Simulink.

I. INTRODUCTION

The conventional sources like fossil fuels are used to supply the energy demand in the world, which is the most basic cause of generating the carbon contents in the environment. These carbon contents are responsible for the unwanted change in the climate or for Global Warming.

Solar energy is the most efficient renewable energy source if it is efficiently harnessed by the modern technology [1]. In solar PV system, the sun light is directly converted into the electrical energy. The energy that can be produced by a solar cell basically depends on the intrinsic properties of the cells and the amount of solar radiation which falls on the panel [2]. The typical size of the solar array as well as AC inverter required for solar PV applications depends on the type of loads connected. The energy from the panel can also be stored by using batterys to rage for later use.

Basic disadvantage of solar PV system is its lower efficiency as panels are hugely dependent on highly unpredictable at mospheric parameters,i.e.,the solar radiation and temperature. So, it is bit difficult to extract the maximum power from the panel resulting into reduced efficiency of system. To increase the system efficiency and to extract maximum power from the panels, different MPPT (Maximum Power Point Tracking) techniques are used [3][4].

The power obtained from the PV panel is of fluctuating dc in nature. To convert this value into constant dc value, dc-dc converter (either step up or step down) is used. Other than the boost converter (Step up converter); buck converter (Step down converter), buck-boost converter, SEPIC converter and Cuk converter configurations can also be used. The duty cycle of the dc-dc converter is regulated to vary the load impedance as seen by the source, to match point of the maximum value of power of the source in order to transfer the maximum power of the panel to the load [4]. Thus, using MPPT techniques the PV array is made to operate on MPP (Maximum Power Point). There are many MPPT techniques used like: Perturb and Observe (P&O) method, Incremental Conductance (IC) method, Fuzzy Logic Method, Constant Voltage method, etc. [5]. The simplest technique amongst them is P&O method which is used mostly, as it provides fast tracking of MPP and it have easy algorithm to implement [6][7][8].

The panel voltage and current obtained are dc quantity, which should be converted into ac quantity by means of inverters to feed the ac loads or for grid connection. The solar PV systems are of two types: Grid-connected system and Standalone-system. In the grid connected system, the solar PV system will supply the power to the connected grid along with the loads connected to it. The grid connected solar PV inverters used can have different configurations like: Central inverters, String inverters and Multi-String inverters. The central inverter configuration is the simplest one having main drawback that when different solar irradiation falls on the module then the strings of the panel will operate at different MPPs. The string inverters have advantage of operating at common MPP even for different irradiance value. The selection of inverter configuration is based on the cost, power requirement and the area of project. In the Standalone system, the solar PV system will feed the loads which are directly connected to it. Both of the systems are capable of feeding ac and dc both types of the load. The standalone systems are mostly preferred for house hold applications.

a) Solar PV System Description

The solar PV system consists of mainly two power electronic components: boost converter and inverter. The block diagram of close loop solar PV system having inter-connected power electronic components is showing Fig.1, where boost converter will convert the fluctuating dc obtained from PV panel into constant dc value and the inverter will convert this constant dc value into ac value which his compatible for the connected ac loads.

The system parameters like dc link voltage and inverter output voltage will change, as the output parameters (loads) as well as input parameters (solar radiation and temperature) are changed which is not required and accepted.

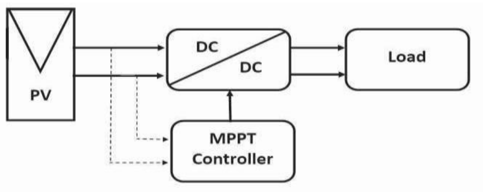

Fig. 1: Block diagram of solar PV system

II. SOLAR PHOTOVOLTAIC TECHNOLOGY

Photovoltaic offer consumers the ability to generate electricity in a clean, quiet and reliable way. Photovoltaic systems are comprised of photovoltaic cells, devices that convert light energy directly into electricity. Because the source of light is usually the sun, they are often called solar cells. The word photovoltaic comes from "photo" meaning light and "voltaic" which refers to producing electricity. Therefore, the photovoltaic process is" producing electricity directly from sunlight. Photovoltaic are often referred to as PV[1].

This chapter discusses the fundamentals of PV cells and modeling of a PV cell using an equivalent electrical circuit. The models are implemented using MATLAB and Psim (Power simulation) software to study PV characteristics and simulate are al PV module.

a) Photovoltaic Cell

Solar cells are made from semi conduct or materials (pn junction, usually silicon), which are specially treated to from an electric field, positive on one side (backside) and negative on the other (towards the sun). When solar energy (photons) hits the solar cell, electrons are knocked loose from the atoms in the semiconductor material, creating electron-hole pairs. If electrical conductors are then attached to the positive and negative sides, 8 forming an electrical circuit, the electrons are captured in the form of electric current Iph (photo current).

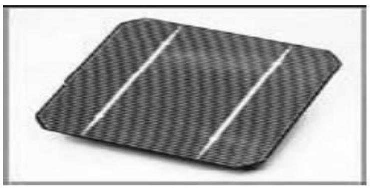

Fig. 2: Photovoltaic cell

b) Modeling of Photovoltaic Module by Matlab Simulink and Psim

The use of equivalent electric circuits makes it possible to model characteristics of a PV cell. The method used here is implemented in MATLAB and PSIM programs for simulations. The same modeling technique is also applicable for modeling a PV module.

c) Ideal cell

Solar cells consist of a p-n junction fabricated in thin wafer or layer of semi conductors, whose electrical characteristics differ very little from a diode represented by the equation of Shockley. Thus the simplest equivalent circuit of a solar cell is a current source in parallel with a diode as shown in Fig.3. The output of the current source is directly proportional to thelight falling on the cell (photocurrent IPV, cell) .

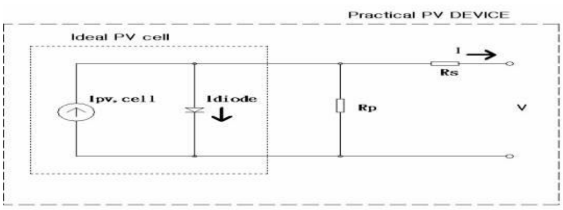

Fig.3: Equivalent model of a photovoltaic cell.

III. POWER ELECTRONICS IN A PV SYSTEM

The voltage produced by the photovoltaic cells will vary according to the sunlight intensity (irradiance), but the system output requires a constant voltage value to be able to process and control the electric energy in the system (i.e. the voltages, currents, frequency) there is a need for a power electronic interface. A typical setup of a power electronic system is shown in figure 4. The power flows from the input to the output through a processor stage, which is controlled through a negative feedback signal from either the input or the output (or both).

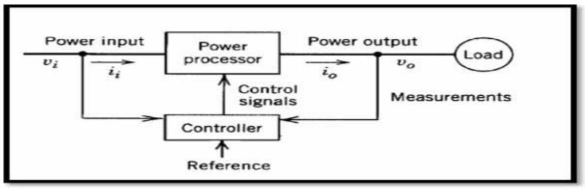

Fig. 4: Block diagram of a power electronic system

The power input can be a DC as well as an AC signal. The output depends on the requirement from the load. In a PV system the power input will always be a DC signal given by the functionality of the PV cell (which is varying with the amount of energy absorbed from the sun).

The power processor can be described as a power conversion stage. It typically consists of one or more converters, often with an energy storage element included. A PV system intended for grid connection usually has a power processor as shown in figure 5. In the system considered in this master thesis Converter 1 corresponds to a DC-DC converter, while Converter 2 is a DC-AC converter. This way the output is connected directly to an AC load or to the grid.

The controller can be implemented to control both the converters separately to ensure a stable interface between each of the stages, i.e. between the input and converter1 and converter 2 and the output.

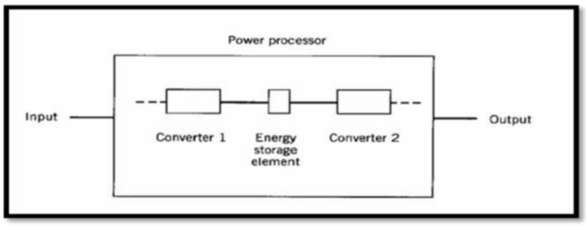

Fig. 5: Block diagram of a power processor.

a) DC-DC switch mode converters

The purpose of DC-DC Switch Mode Converters in general DC power supplies is to convert unregulated DC input to regulated or controlled DC output at a desired voltage level. In such systems the input is often fluctuating due to rectification and the output is requiring a constant output. In a PV system, on the other hand, the DC-DC converter is actually controlling the input by considering the unregulated output. By help of MPP Tracking the converter adjusts its operation according to the output value to find the optimal operating voltage of the PV module.

b) MPPT Algorithms Used

Solar energy has emerged as a promising renewable energy source, with photovoltaic (PV) systems being widely adopted for power generation. However, the efficiency of solar panels can be significantly affected by varying environmental conditions such as sun light intensity, temperature, and shading. Maximum Power Point Tracking (MPPT) technology addresses this challenge by dynamically adjusting the operating point of the PV system to maximize power output.

Traditional offline MPPT methods involve periodic scanning of the power-voltage (P-V) curve of the solar panel to identify the MPP. One of the commonly used techniques is the Perturb and Observe (P&O) method, which incrementally adjusts the operating voltage and observes the resulting change in power output. Another method is the Incremental Conductance (IncCond) algorithm, which calculates the derivative of the power-voltage curve to track the MPP.

While offline MPPT techniques are relatively simple and easy to implement, they may suffer from oscillations and slow tracking under rapidly changing environmental conditions.

Perturb And Observe algorithm (P&O):

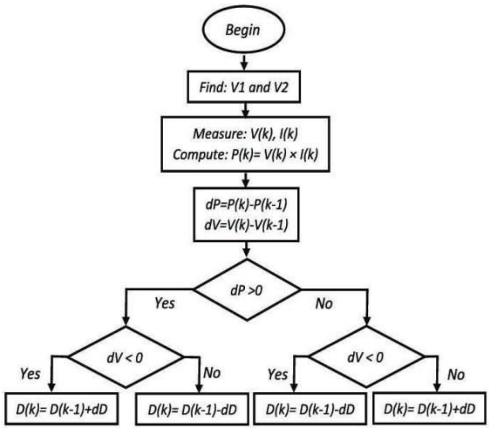

Fig. 6: Perturb and Observe Algorithm Flow Chart.

Perturb And Observe Algorithm Script Developed Form Flow Chart

```
function D  = PandO( V, I)

Dinit = 0.41;
Dmax = 0.9;
Dmin = 0.4;
deltaD = 0.01;

persistent Vold Pold Dold;

dataType = 'double';

if isempty(Vold)
    Vold=0;
    Pold=0;
    Dold=Dinit;
end
P= V*I;
dV= V - Vold;
dP= P - Pold;

if dP ~= 0
    if dP < 0
        if dV < 0
            D = Dold - deltaD;
        else
            D = Dold + deltaD;
        end
    else
        if dV < 0
            D = Dold + deltaD;
        else
            D = Dold - deltaD;
        end
    end
else D=Dold;
end

if D >= Dmax | D<= Dmin
    D=Dold;
end

Dold=D;
Vold=V;
Pold=P;
```

IV. RESULTS

The simulation is performed in order to analyze the behavior of the solar PV system having changes at its input and output side. The entire simulation is Conducted within the MATLAB Simulink environment, the simulation results are presented herein. Specifically, the system's response is examined under input and output conditions, focusing on the voltage output across the boost converter. This simulation serves as a critical component in assessing the performance of an advancedMPPT-based solar energy system for our project. In this project we simulated:

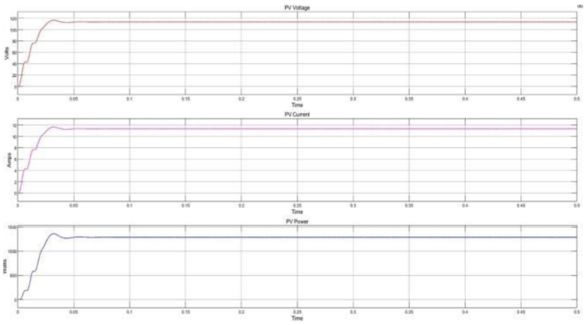

Fig. 7: Output wave forms of offline MPPT technique (OCV).

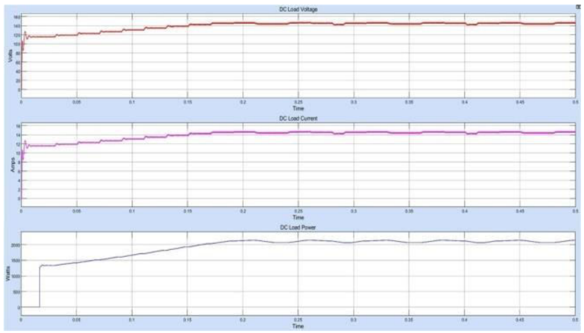

Fig. 8: Output wave forms of online MPPT technique (Perturb and Observe).

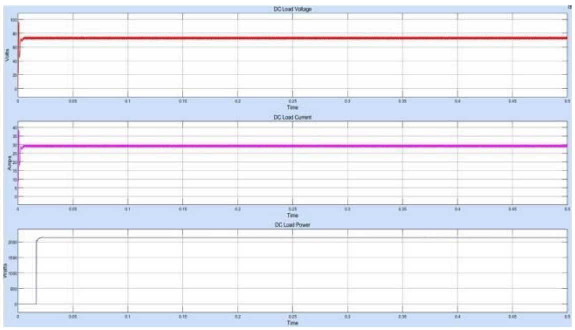

Fig. 9: Output wave forms of online MPPT technique (Incremental Conductance)

The simulation results and theoretical analysis underscore the importance of employing advanced MPPT techniques in solar energy systems to enhance energy harvesting efficiency. From the comparison of the OCV, P&O, and INC methods, several conclusions can be drawn.

Efficiency: The Incremental Conductance (INC) method demonstrates superior efficiency compared to the Open Circuit Voltage (OCV) and Perturb and Observe (P&O) methods. By dynamically adjusting the duty cycle based on both voltage and current characteristics, the INC method more accurately tracks the maximum power point (MPP) under varying environmental conditions, leading to higher overall system efficiency.

Tracking Speed: The Perturb and Observe (P&O) method exhibits faster tracking speed in response to rapid changes in irradiance or temperature. However, its reliance on trial-and- error perturbations may lead to oscillations around the MPP, affecting system stability.

Stability: The Incremental Conductance (INC) method offers better stability compared to the Perturb and Observe (P&O) method. By continuously adjusting the operating point based on the slope of the power-voltage curve, the INC method mitigates oscillations and maintains steady operation at the MPP.

Robustness: The Open Circuit Voltage (OCV) method provides a simple and robust solution for MPPT, requiring minimal computational resources. However, its performance may be limited under non-ideal conditions such as partial shading or dynamic changes in load.

V. CONCLUSION

The three advanced techniques PSO, Perturb- and observe (P&O) and Incremental Conductance (I_C) are utilized to simulate and model the PV system based MPPT. The best operation and performance of the MPPT controller for the three algorithms are studied and analyzed at different irradiance at constant temperature. By fine adjustment of the controlling parameters of PSO algorithm, it proved best results than the other two algorithms. PSO led to obtaining slightly higher tracked power (nearly 1 kw more than the other two algorithms) for the different irradiance.

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