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A Dual stage MPPT based SEPIC Converter for Battery Charging Unit

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Abstract: Solar energy is widely used in this day and age as it is sustainable. The Extraction of the Maximum Power Point (MPP) is made by arranging the solar module to draw out from its non-linear behavior of the I-V curve. In this paper Perturb and Observe (P&O) and Fractional Short Circuit Current (FSCC) are brought together as a hybrid technique and is used in a SEPIC converter. This DC-DC converter is beneficial as it gives non-inverted output. Rapid tracking near MPP is achieved by using FSCC and then P&O allows to track the exact MPP. Analysis and implementation of this novel method is done by using MATLAB/SIMULINK software.

Key words: Photovoltaic system · Modeling and Simulation · SEPIC · P&O · FSCC · Hybrid MPPT

INTRODUCTION

Natural resources such as sunlight, wind, rain, tides and geothermal heat are renewable energy. These resources are inexhaustible unlike fossil fuels, which are decreasing with its use and also lead to harmful effects due to pollution. As there is growth in the development of Technology, it is better to use renewable energy as they are clean and in abundance. The demand for electricity is increasing and the changes in the environment lead to global warming thus leading to the need of a new source of energy. Solar power is the most commonly used resources as it is cheaper and sustainable. The best way to harness energy from the sun is by using the photovoltaic panel which acts as a conductor by absorbing the sun's rays, heating up and creating electricity. Solar energy has promising results for finding solutions to problems.

Maximum Power Point Tracking (MPPT) converts a high DC voltage output from the solar panel down to low voltage that is required to charge batteries is shown in Fig. 1. It is a DC-DC electronic converter optimizing the match for the panel and battery bank. MPPT is categorized into online and offline method. Each has its own response speed, complexity, the amount of investments the quantity and type of sensors required. The efficiency of these techniques can be improved by combining the online and offline techniques to form a hybrid MPPT. By doing so, the drawbacks of these techniques individually can be overcome by the other. For an essential PV system MPPT is essential as the module has non-linear behavior. Due to change in isolation and temperature, the MPP varies. There are various MPPT techniques available as follows

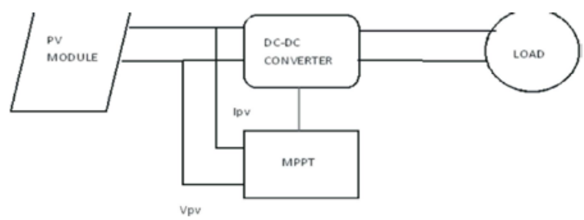

Fig. 1: Block diagram of Typical MPPT

- Fractional Open Circuit Current (FOCV)
- Fractional Short Circuit Current (FSCC)
- Perturb and Observe (P&O)
- Incremental Conductance (InC)

In this paper a novel hybrid MPPT is presented where merging of Fractional Short Circuit Current (FSSC) along with Perturb and Observe (P&O) is used in sepic converter. In the proposed algorithm under the constant irradiance it oscillates near MPP but comparatively less

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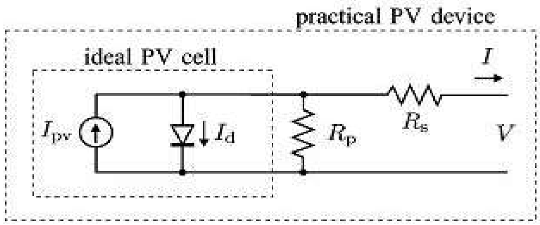

Fig. 2: Equivalent model of PV module

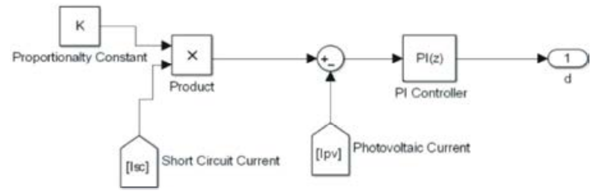

Fig. 3: Simulink circuit for duty cycle using FSCC

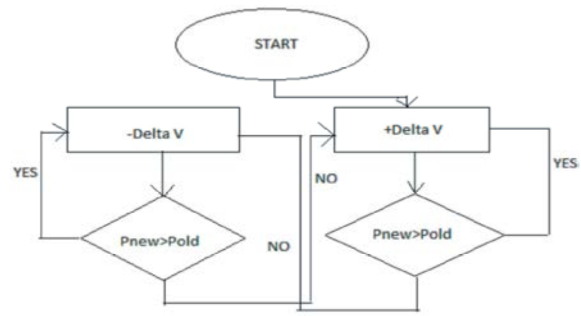

Fig. 4: Basic P&O algorithm

than the conventional method. However for change in irradiance FSCC takes action by rapidly tracking near MPP leading P&O to track down the exact point. This is simulated in MATLAB and when compared with conventional it has more efficiency. With the proposed method increase in efficiency with non-inverted output is obtained.

Solar Pv Modelling: Several cells form the photovoltaic system. Approximately 1 or 2 W of energy is generated from a PV cell which is basically a semiconductor diode exposing its p-n junction to the light. PV cells are connected together they are capable of producing high power output. Since a single PV cell is not applicable for any applications, it is necessary that it is connected in series or parallel to get feasible power to use in the majority of applications as shown in Fig. 2. As sunlight falls on the photovoltaic system, the solar cells convert the photons of the sunlight to electricity using the photoelectric phenomena commonly found in semiconductor materials of certain types such as silicon and selenium. The output current and voltage of PV module has nonlinear and exponential relation between them indicating the PV module characteristics. Peak watt rating gives the key performance of the solar module. The spectral distribution of the solar radiation estimates the efficiency of the PV module.
The current in PV cell [11] is given as in equation (1)

$$I = I_{pv} - I_0 \exp\left(\left(\frac{V+IR_s}{nV_t}\right) - 1\right) - \frac{V+IR_s}{R_p} \qquad (1)$$

where,
I_{pv} is the PV current of module
I_0 is the current saturation of module
V_t is thermal voltage of module.
R_s is series resistance
R_p is parallel resistance

Here Rp and Rs are the leakage current to the ground and current flow due to internal losses of the module.

Fractional Short Circuit Current Mppt: Fractional Short Circuit Current method tracks the MPP in a simple way is shown in Fig.3. This method is similar to Fractional Open Circuit Voltage which does not accurately track down the MPP. This technique purely depends on the PV array. Analog and Digital method can be implemented in this technique. Under difference irradiance and temperature conditions the current I_{SC} depends linearly on the maximum power point current as in equation (2).

$$I_{mpp} = kI_{sc} \qquad (2)$$

According to the PV module datasheet the proportionality constant K can be calculated. The constant K ranges from 0.75 to 0.95. Implementation is cheap as it requires only one current sensor.

Perturb and Observe Mppt: Perturb and observe is widely used for its simplicity and reasonable accuracy. Fig.4 shows the basic flowchart of the algorithm. The main aim of this algorithm is to get increasing output from the PV system by pushing it towards that direction. The duty cycle of the power converter is perturbed along with a perturbation in the voltage of the PV array. According to this algorithm it is seen that the power increases with increase in the voltage on the left side of the MPP, while the power decreases with decrease in voltage on the right side of MPP. Subsequently the increasing power must be proceeded with the same perturbation until the MPP is obtained else the contrary.

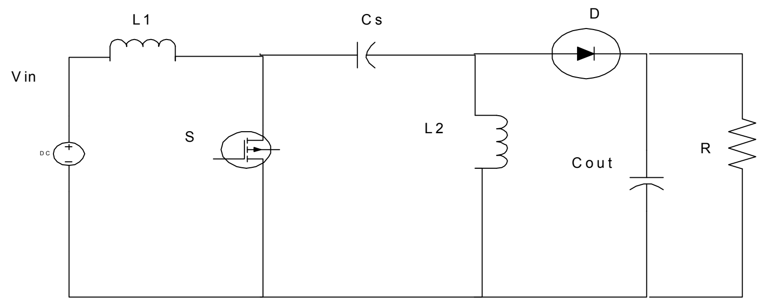

Fig. 5: SEPIC converter circuit diagram

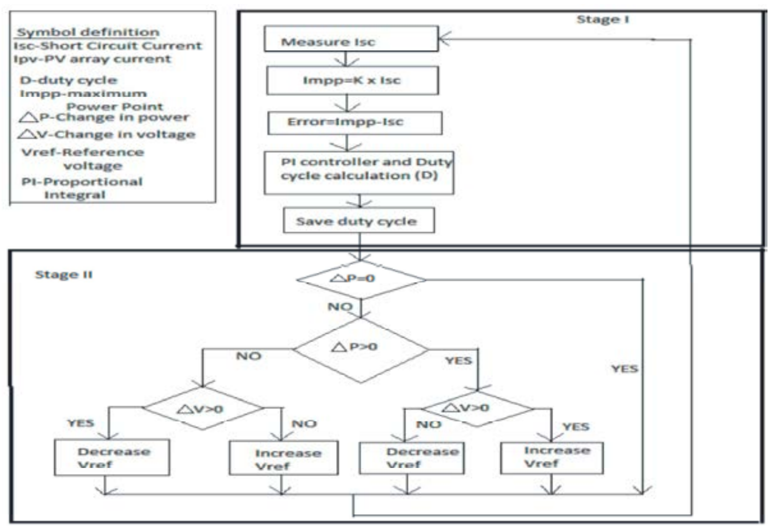

Fig. 6: Proposed MPPT algorithm

Sepic Converter Analysis: Fig 5 shows the circuit diagram of SEPIC converter. A Single Ended Primary Inductor Converter (SEPIC) is capable of producing output voltage that is greater than, less than or even equal to that of the operating input voltage. This converter has an advantage of operating as both buck and boost converter with less active component and low noise due to clamped switched waveforms. It also has non-inverted output, less ripple and building of heat is prevented which make it reliable for a wide range of applications. In order to efficiently maximize the output power of the PV panel to supply load or battery, a power converter is used along with MPPT algorithm. The input power to the converter is the output power of the PV panel. The input resistance characteristic of this converter is found to be directly or inversely proportional to the switching frequency. Hence the nominal duty cycle of the switch in the power converter is adjusted to make the input resistance of the power converter equal to the panel's equivalent output resistance. Maximum power transfer is ensured by this operation. A small signal sinusoidal perturbation is adapted into the switching frequency after the measurement of short circuit current. The average terminal voltage of the panel is compared with ac component leading to locate the MPPT.

Proposed Mppt Algorithm: The proposed hybrid technique is a combination of Fractional Short Circuit Current (FSCC) and Perturb and Observe (P&O) algorithm which is designed to give better efficiency than the conventional hybrid using boost converter. The proposed sepic converter is used as the output voltage obtained is non-inverted. Also it is advantageous as the voltage acquired at the output can be controlled such that it is greater than, less than or even equal to the input voltage. The main goal is to track the MPP faster so it makes it possible for extracting maximum power from the module. In order to overcome the drawbacks of these algorithms individually, it is combined to form hybrid. Fig. 6 shows the flowchart for proposed MPPT algorithm.

Stage I: In stage I of the proposed system the main goal is the estimation of I_{SC} to determine the MPP. The PV panel is isolated in this loop for measuring the I_{SC}.

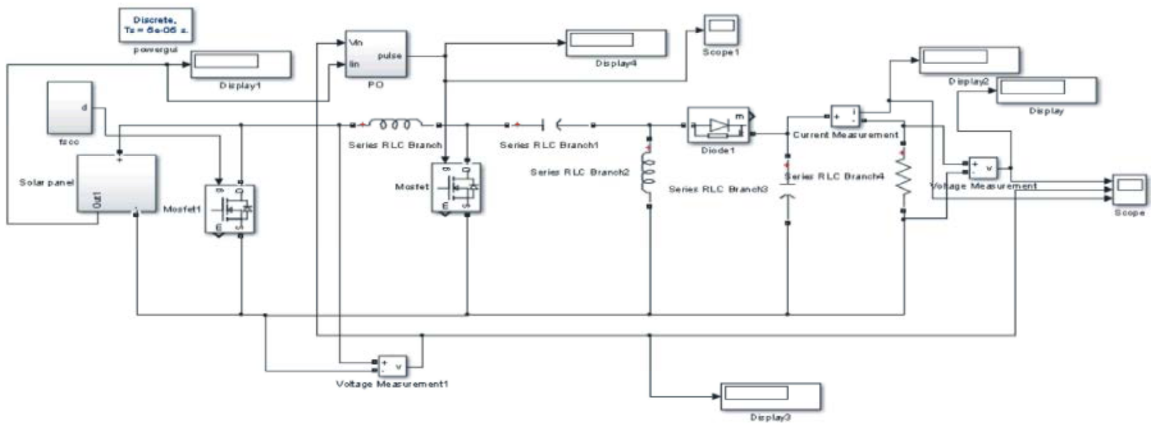

Fig. 7: Simulation Circuit of the Proposed system

This value is stored in memory. After determining the value, I_{mpp} is calculated using equation (1). The output current of the PV panel I_{pv} is also measured and compared to evaluate the error difference between I_{mpp} and I_{pv}. The difference is then fed to the compensator for the calculation of duty cycle. If the error is made equal to zero by the compensator, the system moves to the next loop which is P&O. Before reaching the next loop it stores the duty cycle and the power. Later loop measures I_{SC} whenever required.

Stage II: After the completion of FSCC loop, the obtained duty cycle (D) is stored by the P&O loop when the algorithm reached the compensator block in stage I. In stage II P&O methods observes the change in the Power by perturbing the PV array after the initial D is obtained. Initially the system is brought to steady state. Then new power is compared with old power. If the new value is more than the old value then there is no change it precedes further with positive perturbation step. If the new value is less than old value then the following Perturbation must be negative step size. If there are any modifications again I_{SC} must be estimated in order to improve the duty cycle of PI controller.

Simulation Setup: The outcome of the proposed system can be understood effectively through Matlab/Simulink as shown in Fig. 7.

- Inductor L_1 =78mH
- Capacitor C_1 =0.016μF
- Inductor L_2 =74.28mH
- Capacitor C_2 =0.008μF
- Switching frequency =25Khz
- Sampling time =10msec

The simulation circuit of the proposed system is as shown in Fig. 7. The efficiency of the proposed system is better in comparison to the conventional system.

RESULTS

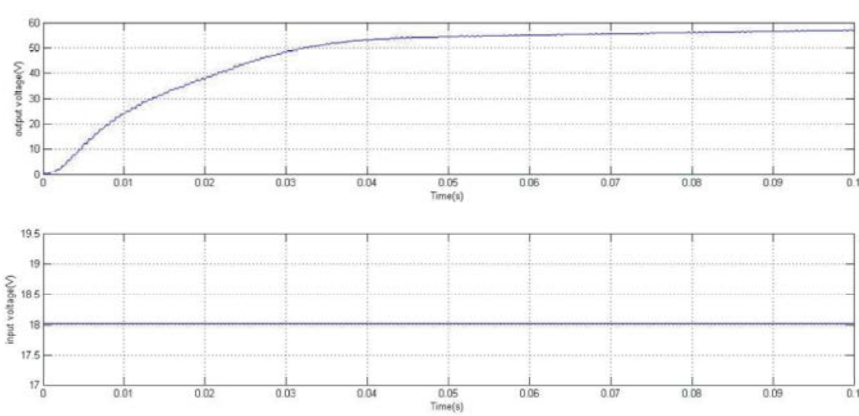

Fig. 8(a): Voltage response of conventional system

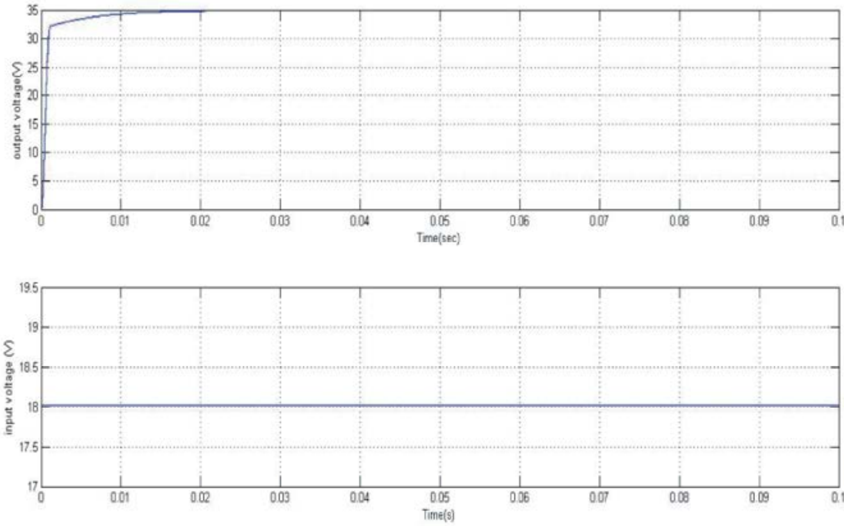

Fig. 8(b): Voltage response of Proposed system

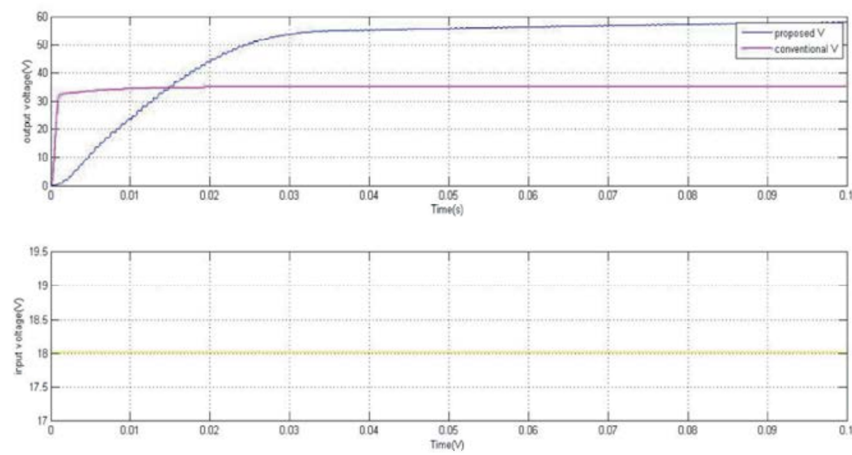

Fig. 9: Comparison of conventional and proposed system

Table I: Performance analysis of Proposed and Conventional system

Parameters	Conventional system	Proposed system
Input voltage	18V	18V
Output voltage	34.68 V	56.94 V
Power	35.27 W	38.85 W
Efficiency	92%	97%

CONCLUSION

A novel hybrid MPPT algorithm has been developed to improve the efficiency and performance of conventional FSCC and P&O method. The algorithm focuses to improve the speed for transient tracking and the stability of steady state is increased. The importance of this proposed hybrid algorithm is detecting the changes in solar irradiance and the temperature of the cell to reach near the MPP. The perturbation change leads to the speed of convergence faster with less oscillation losses around MPP. During swift changes in solar radiation the proposed system can forbear from tracking deviation. It is close to ideal MPP. Hybrid algorithms are being progressed to encounter the demand of power even during partial shading conditions. Advancement in this field deals with improving the existing algorithms by either simplifying or merging with other algorithms to achieve more efficiency cost effectively.

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