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Grid Connected Photovoltaic System Based on Modified SEPIC Converter Using Fuzzy-Maximum Power Point Tracking

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Abstract

This paper describes a grid connected photovoltaic system with Fuzzy Maximum Power Point Tracking (Fuzzy-MPPT) based on Modified Single Ended Primary Inductor Converter (Mod-SEPIC). The Mod-SEPIC with the fuzzy logic based MPPT helps in turn to provide a variable voltage into a constant voltage for a Photovoltaic (PV) system. This converter is highly preferred to obtain a high voltage gain. The constant dc output voltage obtained from Mod-SEPIC converter is given to three phase Hex bridge inverter which helps to invert the incoming DC into AC. The proposed system is designed and monitored with an embedded controller mainly a PIC controller which generates a control signal and activates the relay/driver unit. The voltage and frequency conditions are explained in order to achieve grid synchronization. The main objective of this paper deals with the PV system to supply required renewable power to the AC load and the excess power produced from the PV array during high radiation period can be fed into the grid. Thereby, it reduces the cost of the system. The whole system is developed and tested using MATLAB/Simulink software under various climatic and load conditions.

Keywords - Photovoltaic System, Modified SEPIC Converter, Fuzzy MPPT Control.

1. Introduction

The characteristic voltage and power of a photovoltaic (PV) array is non linear and time varying because of the changes caused by the atmospheric conditions so that the maximum power point tracking (MPPT) algorithm is adopted to maximize the output power. In recent years the grid connected PV system has become more popular because they do not need battery backups to ensure MPPT. The typical two configurations of a grid-connected PV system are single or two stages. In two stages, the first is that it uses the conversion of the power into high AC voltage the second is to boost the solar array voltage and track the maximum power. The presence of Mod-SEPIC converter allows to maintain the fixed DC link voltage enough high to make the inverter to operate. Although there is much information in the literature, development of dynamic models of grid-connected PV system which includes PV array a control system using PI, a distribution network and a load, a PWM technique. The typical configuration of three-phase grid-connected photovoltaic system consists of solar array, a three-phase Hex bridge inverter, and a grid voltage. The three-phase Hex bridge inverter with filter inductor converts a DC input voltage into an AC voltage by using a corresponding switch signals to make the output current in phase with the utility voltage and obtain a unity power factor. Many algorithms have been developed for the MPPT of a PV array. The fuzzy logics are applied for the maximum power point tracking controller in which the MPPT techniques are more popular because of the simplicity of its control structure. The sliding-mode controller is famous for signal stability and easy implementation [14]-[18]. Different authors used one cycle control for MPPT [19] whereas, the authors used conventional PI regulator along with the MPPT scheme [20]. Among different intelligent controllers, the fuzzy logic is the simplest way to integrate with the system and provides greater response than conventional controllers. .

2. Proposed System

The change of voltage is fed to the Mod SEPIC converter is the main function of this paper.The purpose of this converter keeps the voltage without any changes with the help of fuzzy MPPT is shown in Fig. 1.

The voltage level can be increased or decreased depending on the maximum power. The three phase Hex bridge inverter helps to invert the incoming signal from the converter. This paper seeks to use Mod SEPIC converter with a fuzzy based MPPT to extract the maximum power under various load and climatic conditions.

The Embedded controller changes the voltage level by changing the duty cycle of the pulse width-modulated (PWM) signal which helps in tracking of reference signal. The output signal is compared with the sinusoidal reference signal to produce zero error signal.

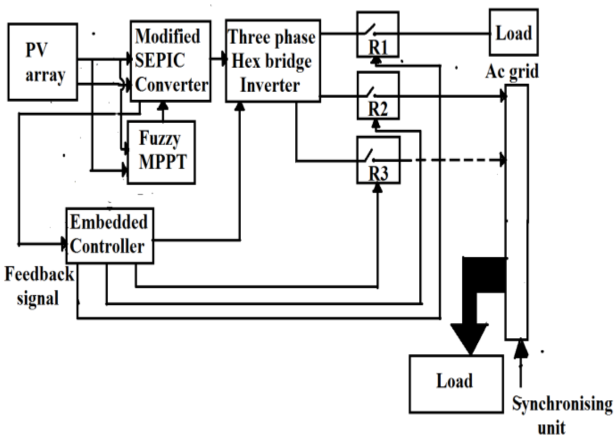

Fig. 1 Block diagram for the proposed system.

The Mod SEPIC'S output is compared with another reference signal to achieve the maximum power. As the inverter is used in the PV system more accurate output sine wave is employed using FLC under varying atmospheric conditions which exploits the maximum power effectively and improved total harmonic distortion (THD). When R1 is activated solar power supplies to load. When R2 is activated solar power supplies to grid. When R3 is activated fetches supply from the grid and then supplies to load.

3. Modified SEPIC Converter with MPPT

The Mod SEPIC converter can use a single switch and is shown in Fig. 2. As with dc-dc converters the Mod SEPIC exchanges the energy between the capacitor and the inductor to convert voltage into another. The amount of energy exchange is controlled by using a transistor which is a MOSFET. MOSFET's offer low voltage drop and higher input impedance than FET's. However for PV application the dc-dc converter can be used to supply the inverter and also to charge the batteries in stand alone systems using bidirectional switch.

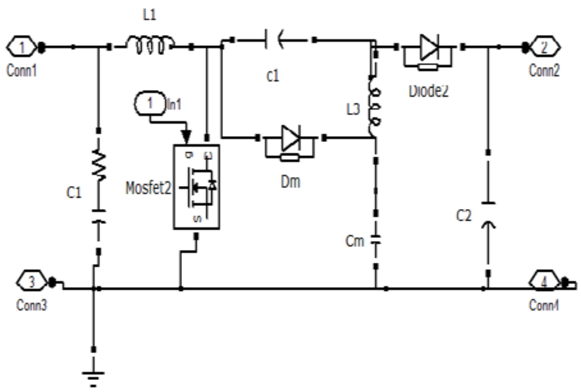

Fig. 2 Modified SEPIC converter

The fuzzy controller is applied to the Mod-SEPIC converter to minimic the new signal from the MPPT. The new duty cycle $\delta_{(k)}$ is adjusted by adding or subtracting the previous duty cycle $\delta_{(k-1)}$. Eq.(1) represents the relation between the present and previous duty cycle i.e.,

$$\delta_{(k)} = \delta_{(k-1)} \pm \Delta\delta \quad (1)$$

where, $\Delta\delta$ is the change in duty ratio resulting from the change of reference signal.

4. Fuzzy Logic Controller (FLC)

The FLC which makes use of the fuzzy logics to control the output of the Embedded controller. The main components in MPPT controller based on fuzzy systems are the fuzzification , inference ,rule-base , and the defuzzification unit.The error e(k) and change in error $\Delta e(k)$ these are the two inputs to the controller. The Fuzzification block converts the inputs of crisp into inputs of fuzzy The rules are formed in rule base and are applied in the inference block. The defuzzification converts the fuzzy into the crisp output. The fuzzy inference is carried out using Mamdani's method and the defuzzification uses the centre of gravity. The design of fuzzy controller was done using Mamdani's method for both converter and three phase Hex bridge inverter. The fuzzy unit consists of membership fuctions is shown in Fig. 3.

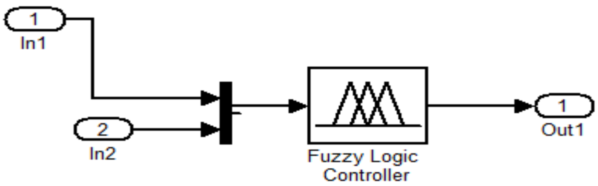

Fig. 3 Fuzzy Logic Controller

5. Embedded Controller Operation

The solar power (P_S) is subtracted with the load power (PL) to achieve the three conditions. The conditions are listed below in Fig. 4.

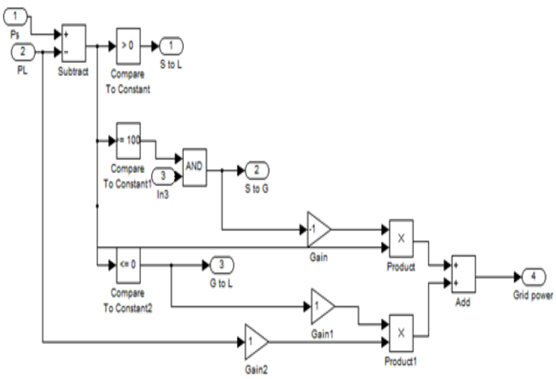

Fig. 4. Embedded Controller Model

- The first condition shows that, when P_S-P_L is greater than 0 (P_S-P_L > 0) the power from the solar array feeds the power to the load.
- The second condition shows that, when P_S-P_L equal to 100 (P_S-P_L=100) the solar array feeds the power to the grid.
- The third condition shows that, if P_S-P_L is less than or equal to 100 (P_S-P_L $\leq$0) the power should be fetched from the grid and it supplies to load.

6. Simulation Results & Discussion

Simulation is applied on MATLAB/SimuLink to verify the practical implementation of the simulation of the proposed Mod SEPIC for the three phase Hex bridge inverter. The waveform of three phase Hex bridge inverter is shown in Fig. 5.The graph consists of voltage 450V, current 8A and the load power 1000W is represented in waveforms.

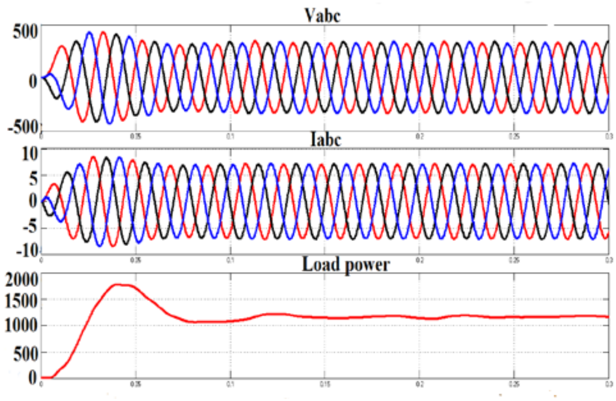

Fig. 5 Output waveform of three phase Hex Bridge Inverter

Case 1: Solar Power Generation for 890W/m² Radiation

The graph which consists of Irradiance, solar power, load power, and grid power. The radiation is set to 890W/m² the generated power is 1795.6 at this case the load power is about 1000W is shown in Fig. 6. The above statement is justified by Eq. (1)

$$\left.\begin{array}{l} P_{Generation} = 1795.6W \\ P_{Load=} 1000W \\ P_{solar} > P_{Load} \end{array}\right\} \quad (2)$$

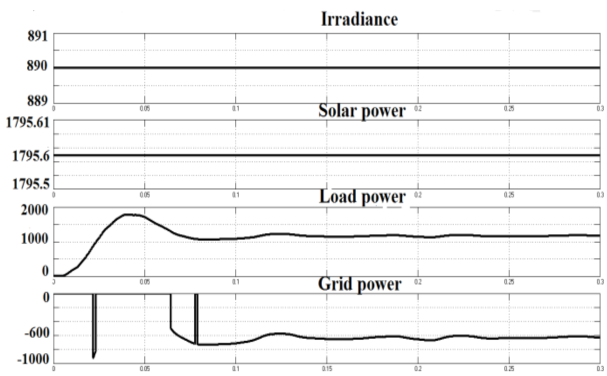

Fig. 6. Power Generation of Case 1

As a result solar to load (R1) and solar to grid (R3) switches are activated and is shown in Fig. 6.1 and the corresponding equation verifies the above statement represented in Eq. (3).

$$P_{Generation} = R_1 + R_3 \text{ ON} \quad (3)$$

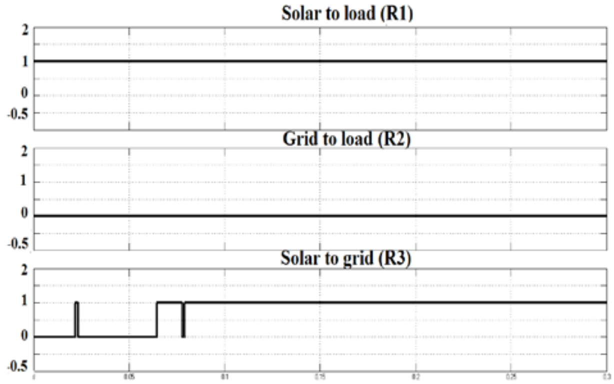

Fig. 6.1 Switching Function of Case 1

Case 2 : Solar Power Generation for 690 W/m² Radiation

The radiation is set to 690W/m² the generated power is 1406.4W. At this case the load power is about 1000W is shown in Fig. 7 .The Eq. (4) which clearly explains the above statement.

$$(4) \quad \left.\begin{array}{l} P_{Generation} = 1406.4W \\ P_{Load=} 1000W \\ P_{solar} > P_{Load} \end{array}\right\}$$

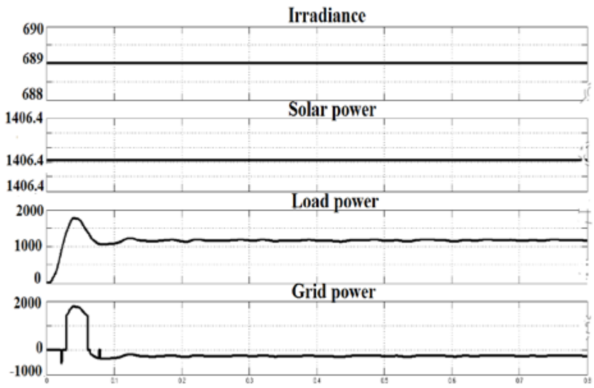

Fig. 7 Power Generation of Case 2

As a result solar to load (R1) hence there is no excessive power generated by the PV array therefore it is capable to supply only to the load and not to the grid and is shown in Fig. 7.1 and the corresponding equation verifies the above statement represented in Eq (5).

$$P_{Generation} = R_1 \text{ ON} \quad (5)$$

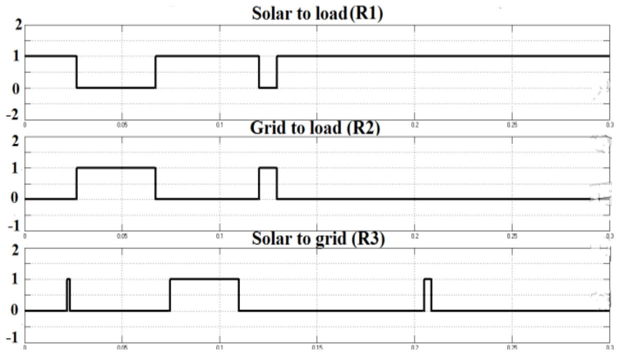

Fig. 7.1 Switching Function of Case 2

Case 3: Solar Power Generation For 185 W/m² Radiation

The radiation is set to 185W/m² and the power generation of 2000W from the PV array reduces to 350W. The corresponding load power is 1000 W. In this case, $P_{solar} < P_{Load}$ and as a result second relay (R2) should be activated. The generated power is feed to grid to load. The corresponding power generation is shown in Fig. 8. The Eq. (6) explains the above statement is shown below.

$$\left.\begin{array}{c} P_{Generation}=350W \\ P_{Load=}1000W \\ P_{solar} < P_{Load} \end{array}\right\} \quad (6)$$

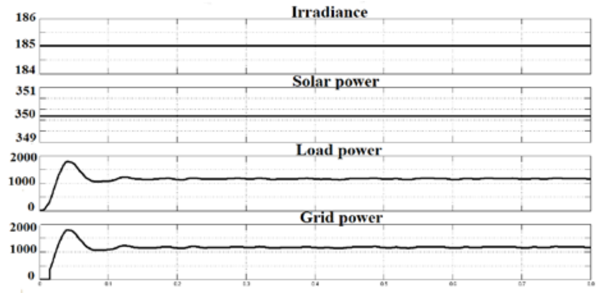

Fig. 8. Power Generation Case 3

The switching function of Case3 is shown in Fig. 8.1 and the corresponding equation verifies the above statement represented in Eq. (7).

$$P_{Generation}=R_2 \text{ ON} \quad (7)$$

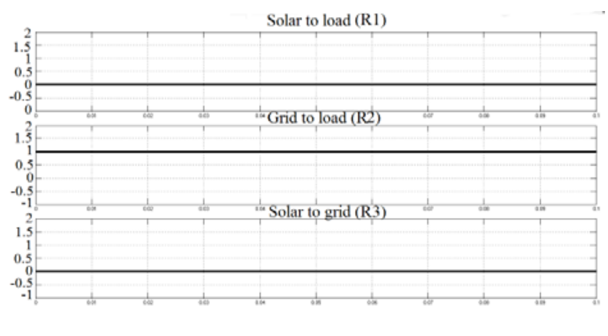

Fig. 8.1 Switching Function of Case 3

7. Conclusion

The grid connected photovoltaic system Fuzzy Maximum Power Point Tracking (Fuzzy.MPPT) based on Modified Single Ended Primary Inductor Converter (Mod.SEPIC) using Fuzzy Maximum Power Point Tracking (Fuzzy.MPPT) has been presented in this paper. The performance can be achieved with the help of fuzzy based MPPT to track the maximum power thereby increases the reliability and performance of the system.The voltage and frequency conditions were explained helps in turn to achieve grid synchronization. The purpose of three phase Hex bridge inverter was explained and the system was monitored using Embedded controller. The simulation was performed by using MATLAB/Simulink software. The whole system has been analyzed and tested and the results were tabulated for various radiations under different climatic and load conditions.

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