Grid-Connected Boost-Half-Bridge Photovoltaic Micro-inverter System Using MPPT with Fuzzy Controller

B.PRIYADHARSHINI [1], B.KARTHIK [2]

[1] M.E. Scholar, Department of EEE, Sona College of Technology, Salem- 636 005, Tamilnadu, India.

[2]Associate Professor, Department of EEE, Sona College of Technology, Salem- 636 005, Tamilnadu, India.

***Abstract*— This project presents a grid-connected boost half- bridge photovoltaic (PV) micro inverter system and its control implementations. A full-bridge pulse width-modulated inverter is cascaded and injects synchronized sinusoidal current to the grid. Solar Photovoltaic (PV) exploitation is a significant renewable energy source in our world. The energy converted directly from sunlight through PV panel is not stable due to different solar intensity. Maximum power point tracking (MPPT) is used extract maximum power from the solar panel, high-performance soft computing techniques like fuzzy logic controller can be used as a MPPT. In this paper, a fuzzy logic control (FLC) is proposed to monitor and control the MPPT for a photovoltaic (PV) system. The proposed technique uses a FLC for the enhancement of these Maximum Power Point (MPP) trackers are designed. The step-up transformer and rectifier are also used in this method. Dynamic stiffness is achieved when load or solar irradiance is changing rapidly. Variable step size is adopted such that fast tracking speed and high MPPT efficiency are both obtained. Simulation and experimental results are provided to verify the validity and performance of the circuit operations and MPPT algorithm.**

***Keywords*— PV panel, Inverter, Fuzzy, MPPT, Resonant converter, Voltage step up, Rectifier.**

I. INTRODUCTION

The electrical energy supplied by a photovoltaic power generation systems depends on the solar irradiation and temperature. The PV system can supply the maximum power to the load at a particular operating point which is generally called as maximum power point, at which the entire photo voltaic system can be operated with maximum efficiency and can be used to produces maximum power through it. Generally, MPPT is included to track the maximum power point in the PV system. The efficiency of MPPT depends on both the MPPT control algorithm and the MPPT hardware[1-4]. The MPPT control algorithm is usually applied in the DC-DC Buck boost converter, which is normally used as the MPPT circuit. Hence, MPPT methods are used to maximize the PV panel output power by tracking continuously the maximum power point. One of the most applied and studied MPPT method is the well-known P&O. In this project, a FLC for the enhancement of these MPP trackers are designed. In Perturb and observe method the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This method is called as perturb and observe method and this is the most common one, although this method can result in oscillations in the power output. It is referred to as a hill climbing method [3]. In incremental conductance method of PV, the controller measures the incremental changes in the current and voltage of the PV panel to figure out the effects of a voltage change [11]. This method requires more computation in the controller, but can track changing conditions more rapidly than the perturb and observe method (P&O) [2].

II. OPERATION PRINCILPE

A. *Working Principle*

The efficiency of the PV panel with MPPT depends on both the MPPT controlling algorithm and also the MPPT's circuit. The MPPT control algorithm is usually applied in the DC-DC converter, which is usually used as the MPPT circuit. Typical diagram of Fuzzy Logic based MPPT in a PV system is shown in Fig.1. PV system cannot be modeled as a constant DC current source because its output power is varied depending on the load current, temperature and irradiation. Generally, MPPT is adopted to track the maximum power point in the PV system.

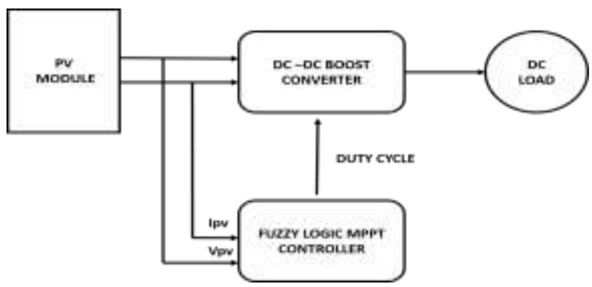

Fig.1. Working process of proposed system

The MPPT control algorithm is generally applied in the DC-DC converter section, which is used as the MPPT circuit normally. One of the most familiar algorithms of

MPPT is the P&O (Perturb and Observe) technique. Convergence problem and oscillation are occurred at some points during the tracking in that method. To improve the performance of the P&O algorithm, this paper presents the implementation of Fuzzy Logic Control (FLC) into the conventional MPPT control.

B. Existing problems and Discussions

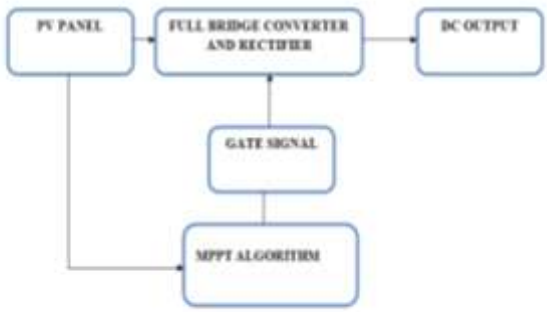

Fig.2. Block diagram of Existing system

The solar panel is used to obtain power through irradiance and temperature. Maximum power is obtained using MPPT technique. From that, the DC supply is converted into AC with the help of full-bridge micro-inverter. Then, the AC signal is given to the LC resonant converter which filters the harmonics and oscillations present in the supply. Then the AC signal is converted into DC signal using rectifier and then the signal is given to the grid section. The drawbacks of Existing system are:

- ❖ The tracking time is reduced in MPPT due to present of oscillation.
- ❖ The construction is bulky size and Increase to power loss.
- ❖ It requires two stage of AC to DC Converter.

C. Proposed system with fuzzy controller

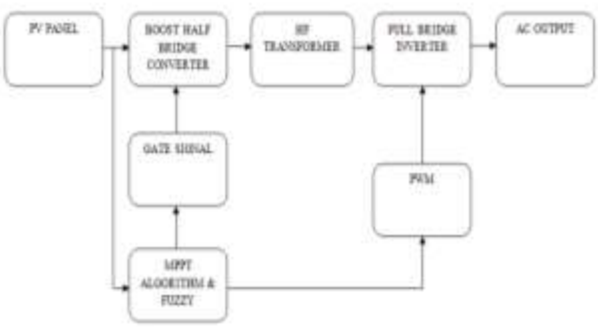

Fig.3. Block diagram of proposed system

The idea of micro inverter will become a future trend for the single-phase grid-connected solar photovoltaic (PV) power systems because of its removal of energy yield mismatches among the system PV modules. In general, a photovoltaic micro inverter system is often supplied by a low-voltage solar panel, which requires a high-voltage step-up ratio to produce desired output ac voltage. A dc to dc converter cascaded by an inverter is the most popular topology, in which a transformer (HF) is more likely implemented within the dc–dc conversion stage.

(1) Introduction of Fuzzy Controller

Control algorithms based on fuzzy logic approach have been implemented in most of the processes. The reason for the implementation of such control techniques is due to the following reasons:

- ❖ Improved robustness compared to the conventional control algorithms
- ❖ Control design is very simple for difficult systems and Implementation is easier.

Analyzing the system in this perspective, a set of linguistic control rules relating to the dual concepts of fuzzy implication and the compositional rule of the inference form the essential part of the fuzzy logic controller (FLC). A fuzzy logic controller (FLC) uses a set of control rules and inference mechanism to determine the control actions. In recent years, fuzzy logic control has become a powerful technique and is being used for various power system applications.

Fig.4. Fuzzy control of proposed system

(2) Benefits of Fuzzy Logic Controller

The Fuzzy Logic technique can be applied in the development of linear and non-linear systems for the embedded control. By using fuzzy logic controllers, the development costs are reduced and better performance and high quality product output is achieved.

(3)Fuzzy set operations

The three basic fuzzy set operations are

- ❖ Union
- ❖ Intersection
- ❖ Complement

The fuzzy equivalents of the logical OR, AND and NOT operations are used to build up a fuzzy logic rules in the fuzzy logic method. In conventional the set theory, AND is said to be the intersection of the sets and OR as the union. The fuzzy operators based on values between zero and one, are sometimes said to be true generalizations of the Boolean operators

(4) Schematic Diagram of a Fuzzy Logic Controller

The design feature of the fuzzy logic controller needs proper selection of control elements and parameters as a scaling factor for input and output signals, a set of fuzzy rule base, defuzzification / fuzzification methods and operations for fuzzy reasoning, which include an significance operation, a integrative operation and accumulation operations of ascendants and consequents.

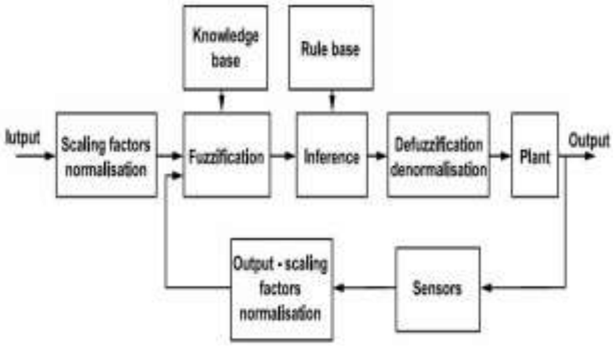

Figure.5. Block diagram of a fuzzy logic controller

(5) Membership Functions

Membership functions are used to characterize the fuzziness in a fuzzy set. Since all the information contained in a fuzzy set is described by its membership function only. The membership of a single object in the fuzzy set can be approximated. The membership to adapt various "degrees of membership" on the real and continuous interval is [-1, 1]. But there are infinite number of values in between the end points [-1, 1], which can represent various degrees of membership for an element. The various forms of membership functions are

- ❖ Triangular membership function
- ❖ Gaussian membership function
- ❖ Trapezoidal membership function
- ❖ S membership function
- ❖ L membership function

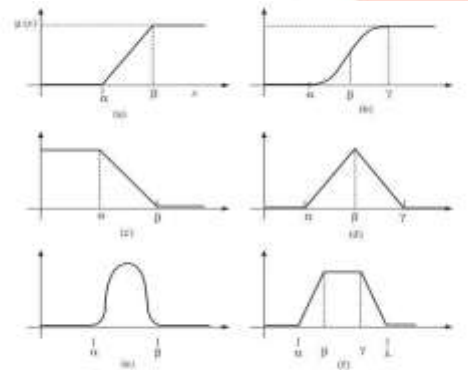

Fig.6. Types of membership functions (a) □ function (b) S function (c) L-function (d) Triangular function (e) Gaussian function (f) Trapezoidal function

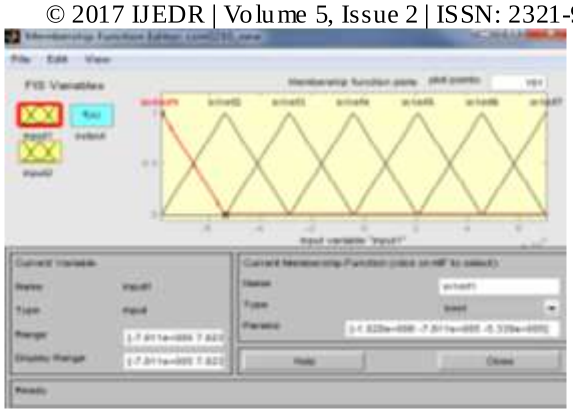

Fig.7. Membership function of proposed system

(6) Fuzzy Rule Base

The main aim of the fuzzy logic is to form a theoretical creation for reasoning about inexact propositions. This rule-based system is differentiated from the old expert systems in a manner that the rules consisting of a rule-based system derive from origins other than human experts. The IF-THEN rules can be made as compound rules by adding AND in between IF-THEN. There are mainly four approaches in the formation of fuzzy rules

- ❖ From the experience and control engineering knowledge of the experts
- ❖ From the behavior of the human operators working in the process
- ❖ Using a fuzzy model of a process and
- ❖ Obtaining a relationship through experience or simulation with a learning process.

Fig.8. Rule view of proposed system

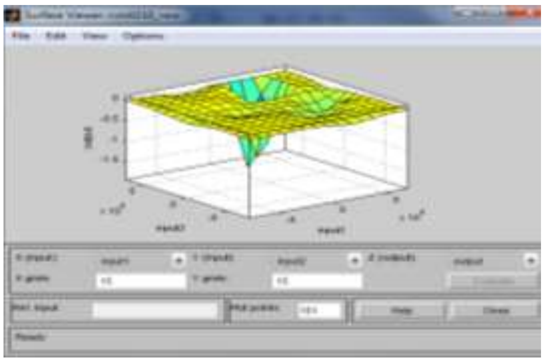

Fig.9. Surface view of proposed system

(7) Inference Engine

It works on the principle of fuzzy if-then rules and fuzzy reasoning technique. It has a fruitful outcome in many fields such as automatic control, data classification, decision analysis, expert systems robotics etc. It implements a non-linear mapping from its input space to output space. It is accomplished by a number of if-then rules. There are mainly two forms of inference systems available.

- Mamdani Fuzzy Inference System and
- Sugeno Fuzzy Inference System

The basic difference between the two methods is in obtaining the consequent of fuzzy rules. Mamdani FIS uses fuzzy sets for the rule consequents and Sugeno FIS uses linear functions of input variables.

III. Component Description

A. *PV Panel*

The electric power supplied to a photovoltaic power generation systems depends on the solar irradiation and temperature. The PV system can supply the maximum power to the load at a particular operating point is generally called as maximum power point (MPP), at which the entire PV system will operate with high efficiency and produces the maximum power output. Maximum Power Point Tracking (MPPT) method is integrated with the Photovoltaic (PV) systems in order to maximize the solar energy

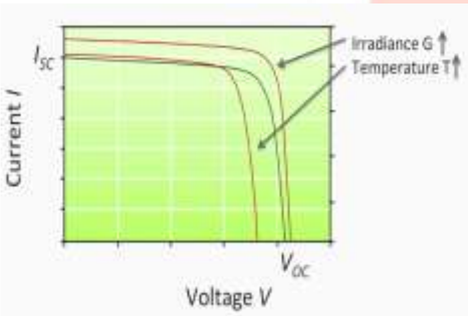

Fig.10. Generic I-V Curve of PV Module

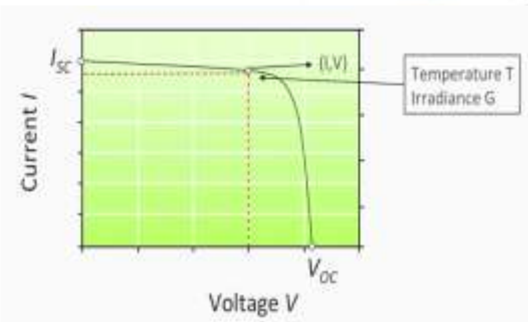

Fig.11. PV Module – Operating Point

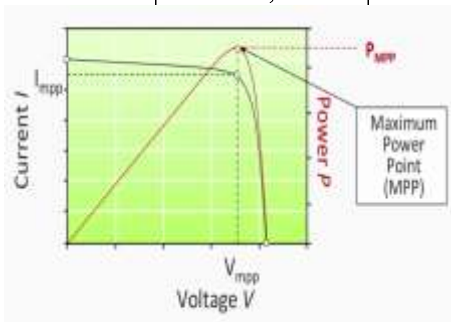

Fig.12. PV Module – Maximum power point

B. *Maximum Power Point Tracking*

MPPT algorithms are necessary in PV applications because the MPPT of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from solar array. Over the past decades many methods to find the MPPT have been developed and published. Among these techniques, the P&O and the In Cond algorithms are the most common. These techniques have the advantage of an easy implementation. Other techniques based on different principles are fuzzy logic control, neural network, fractional open circuit voltage or short circuit current, current sweep, etc.

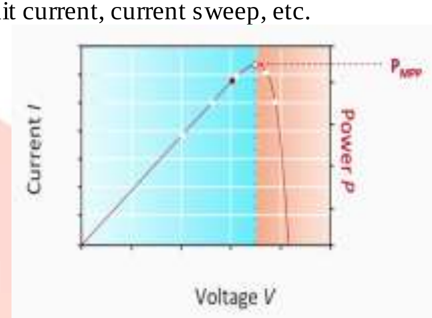

Fig.13. Perturb & Observe

The P&O algorithm is also called as “hill-climbing”. Hill-climbing involves a perturbation on the duty cycle of the power converter and P&O of perturbation in the operating voltage of the DC link between the PV array and the power converter.

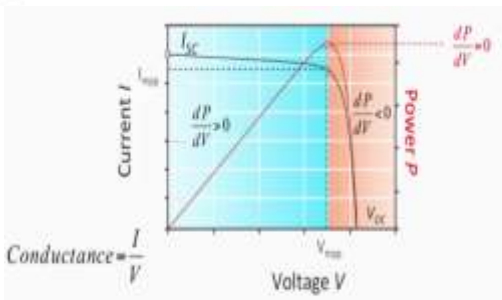

Fig.14. Incremental Conductance

C. *Half-Bridge Microinverter*

A **solar micro-inverter**, or simply called as a **micro-inverter**, is a device which is used in photo voltaic system to convert direct current (DC) generated by a single solar module to an alternating current (AC). The output from the several micro-inverters are combined and fed to the electrical grid. Micro-inverters have several advantages over conventional inverters. Each micro-inverter harvests optimum power by performing maximum power point tracking for its connected module. Micro-inverters are very small sized inverters and they are rated to handle the output from a single solar panel. Modern grid-tie panels are normally rated between 225 and 275W, but rarely produce this in practice, so micro-inverters are typically rated between 190 and 220 W. Micro-inverters will produce grid-matching power directly at the back side of the solar panel.

D. Step-up Transformer

The transformer is static electrical equipment which is used to transform electrical energy to the magnetic energy and again to the electrical energy. The value of operating frequency and the nominal power are approximately equal on the primary and secondary transformer sides as the transformer is very efficient equipment, while the voltage and current values are generally different. Essentially, that is the main work of the transformer, converting the high voltage (HV) and low current from the primary side to a low voltage (LV) and high current on the secondary side and vice versa. Also, it provides galvanic isolation in the electrical power system. The transformer can be able to transfer energy in both directions, from LV to HV side as well as inversely. That's the reason why it can work as voltage step up or step down device. Both of the transformer types have the same design and construction.

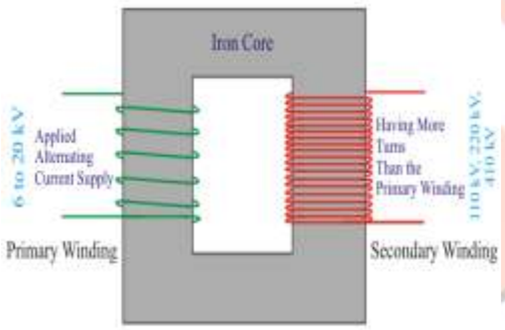

Fig.15. step-up transformer

E. Rectifier

A rectifier is a device that converts alternating current to direct current. The process of conversion is known as rectification. Physically, rectifiers can be seen in number of forms like, mercury-arc valves, vacuum tube diodes. Rectifiers have many uses, but are more often they are used as the components of DC power supplies and in high-voltage direct current power transmission systems.

F. RLC resonant circuit

In a circuit containing inductor and capacitor, the energy is stored in two different ways

1. When a current flows in a inductor, energy is stored in magnetic field.
2. When a capacitor is changed, energy is stored in static electric field.

The magnetic field of the inductor is built by the current, which is provided by the discharging capacitors. Similarly, the capacitor is charged by the current produced by the collapsing magnetic fields of the inductor and this process keeps continuing, causing electrical energy to oscillate between the magnetic fields. This forms a harmonic oscillator for current. In RLC circuit, the presence of resistor causes these oscillations to die out over period of time and it is called as the damping effect of resistor.

IV. SIMULATION AND EXPERIMENTAL RESULTS

MATLAB is a high-performance tool for technical computing. It integrates computation, visualization, and programming in a graphical user interface (GUI) based environment where the problems and their solutions are expressed in mathematical form. From the solar PV module, we generate an input voltage of about 370V. Solar irradiation is maintained at 370 and temperature is maintained 8.2. Then the boost half bridge micro inverter system converts the DC supply to AC supply.

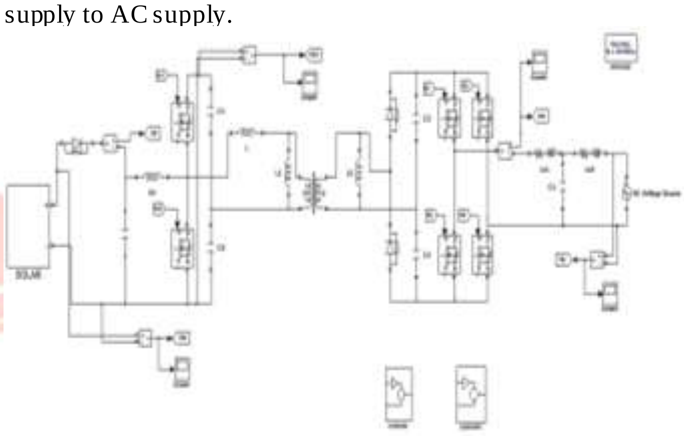

Fig.16. Simulation model of the entire system

Then the AC supply is given to the Step-up transformer which boosts the voltage from 370V to 900V. The Stepped-up voltage is given to the Rectifier which converts the AC supply to DC supply and again the full-bridge micro inverter is used to convert the DC supply to AC supply. The output voltage obtained is 200V. The simulation model and its output is given below.

Fig.17. Waveform of Input Voltage

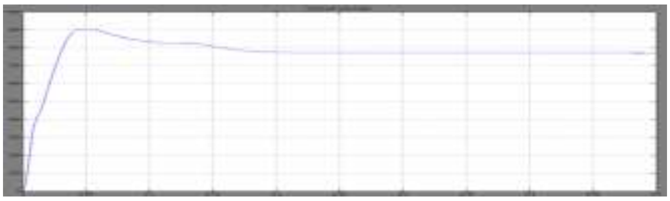

Fig.18. Waveform of Step-up Voltage

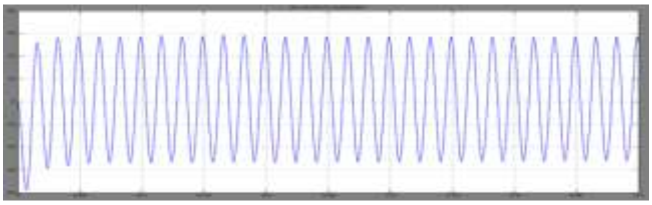

Fig.19. Output waveform of AC Current

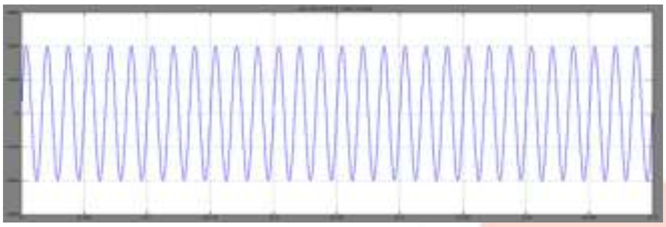

Fig.20. Output waveform of AC Voltage

V. CONCLUSION

This project presents an intelligent control strategy of MPPT for the PV system using the FLC. Simulation results show that the proposed MPPT can track the MPP faster when compared to the conventional P&O and incremental conductance method. Thus, the proposed MPPT system using fuzzy logic controller can improve the performance of the system more effectively than the conventional technique. For the future scope of work, we intend to implement the proposed technique in the real PV system.

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