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Bidirectional Based DC-DC Converters for Photovoltaic Generation Energy Storage System

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***Abstract*- In this paper a novel solar cell stand-alone photovoltaic power system is proposed, which is mainly composed of a uni directional DC/DC converter and a bi-directional DC/DC converter. Compared to the traditional stand-alone photovoltaic power system, this system exhibits the advantages of better protection and more efficient control on charge/discharge of the battery. Furthermore, it can make better use of solar energy and realize energy management of the system. The key point of energy management for the system is to control the bi-directional converter efficiently, where bi-directional voltage and current must be controlled. The overall structure of the MPPT system consists of a DC-DC converter (an electronic device that converts DC energy from one voltage level to another) and a controller. During changes in weather conditions, MPPT uses a tracking algorithm to find and maintain operation at the point of maximum power. Many different algorithms for MPPT have been proposed and discussed in the literature, but most of these methods have disadvantages in terms of efficiency, precision, and flexibility. Due to the non-linear behavior of the current voltage characteristics of the PV module and the non-linearity of the DC-DC converter due to switching, conventional controllers cannot provide an optimal response, especially when dealing with a wide range of shifting line parameters and transients. The purpose of this work is to design and implement a maximum power point tracker using fuzzy logic control algorithms. Simulink designed and simulated an MPPT system consisting of photovoltaic modules, DC-DC converters, batteries, and fuzzy logic controllers. Perform the characterization of the buck, boost and buck-boost converter to find the most suitable topology for the PV system used. The integrated model of the PV module with the identified converter and battery was simulated in MATLAB to gain the necessary experience to formulate and adjust the fuzzy logic controller. The simulation results show that fuzzy logic**

***Keywords*- Photovoltaic; Solar Cell; Bi-directional Converter; Energy Management.**

I. INTRODUCTION

With the rapid depletion of the conventional fossil fuels, energy crisis and environmental pollution become more serious. In recent years much effort has been made to find renewable clean energies in The countries all over the world, and solar energy is found to be such an ideal and durable one. Since the 1970s solar energy photovoltaic power has received great attention and experienced impressive progress. The solar energy photovoltaic power will play an important role in alleviating the energy crisis,

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reducing the environmental pollution and improving the greenhouse effect.

There are two operation modes for solar energy photovoltaic generation: a stand-alone photovoltaic power system consists of a photovoltaic array, a battery and a load, while a grid-connected photovoltaic power system consists of a photovoltaic array and a special technology inverter. The stand-alone photovoltaic system will dominate for long the application of solar energy photovoltaic power according to the present state and trend of development, though the photovoltaic grid-connected system. In remote or isolated regions where power grid can not extend to, stand-alone photovoltaic schemes, shown in Figure1, have found a fairly wide application to meet the need for low but essential electric power.

According to the control manners, stand-alone photovoltaic power systems may be classified into two categories: one is the on-off directly control system, and the other is the control system with DC-DC converter, both are shown in respectively. These systems have simple structures and control-units, and have the advantages of storing the residual energy from the solar cell.

However, their drawbacks are also apparent: first, the battery is connected to the DC bus, whose voltage fluctuates with the battery voltage; second, no control is applied on the battery charge and discharge, which may result in large overcharge current and shorten the duration of the battery; third, for the on-off directly control system. The solar cell, the battery and the DC load are equipollently in parallel connection when both charge switch K1 and discharge switch K2 are conducted simultaneously.

In this case, the number of solar cells in solar array is highly dependent on the number of battery cells in battery series. For example, a solar array of 17V functions well with a charge battery of 12V. When the solar irradiation decreases to such a level that the output voltage of the solar array is lower than the battery voltage, the solar array gives no output power and the solar energy is lost.

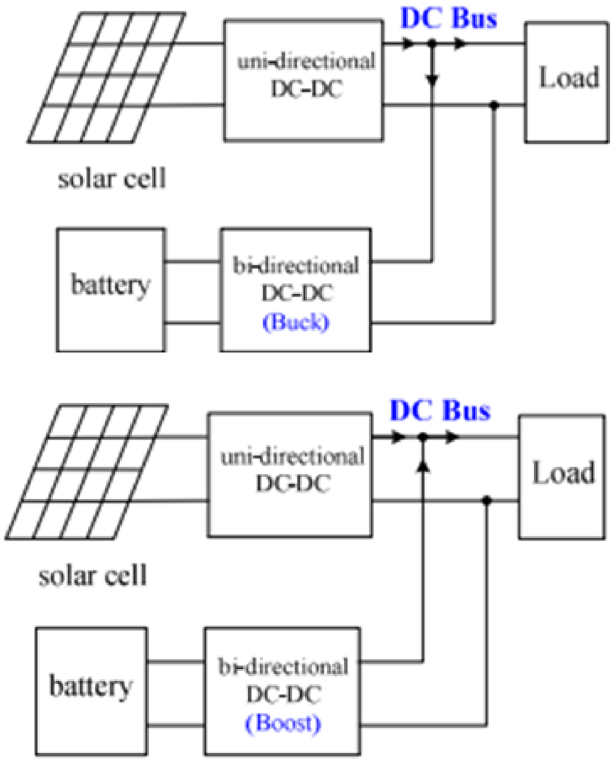

Fig 1. system framework of the photovoltaic power generation system.

The energy management framework of stand-alone photovoltaic power generation systems can provide a stable power supply for small-scale air-conditioners using a bidirectional buck-boost converter with battery charging and discharging characteristics. In the framework of general bidirectional buck-boost converters, the diode component of the boost converter is substituted with a power semiconductor switch.

Consequently, a synchronous rectification framework and bidirectional energy flow characteristics are provided for the converter. The switch conduction losses can be reduced by applying a synchronous rectification framework [9-15] to increase the energy conversion efficiency provided for comparing to that of general boost converters.

To appropriately employ the power output of the photovoltaic power generation system, we combined the bidirectional buck-boost converter developed in this study with a lithium-iron rechargeable battery. Furthermore, we proposed a small-scale air-conditioner energy management strategy based on a hybrid power supply provided by a photovoltaic power generation system and lithium-iron rechargeable battery to increase the photovoltaic power generation system's stable supply of power.

II. TOPOLOGY AND CONTROL STRATEGY

The topology of PV system studied herein is shown in Fig. 5: Its one end is a solar panel, which is connected in parallel to the bidirectional DC-DC converter (connected in series with the lead-acid battery) via unidirectional DC/DC boost transformer and supplies power to the grid or load through full bridge inverter. The advantages of using a two-stage structure are the achievement of boost and inversion, buck and rectification decoupling control; simple, easy-to-implement control algorithm; and functional comprehensiveness.

Since the addition of isolation transformer will bring the volume and weight problems, a non-isolated topology is adopted for the first-stage bidirectional DC/DC converter. Such a progress in topology cuts the cost of PV system; reduces the stage of transmission energy; enhances the efficiency of power generation; and boosts the DC output from the PV module to a certain voltage through the unidirectional DC/DC boost converter.

This way, the stability of output voltage can be ensured by exploiting the role of smoothing energy storage capacitor at the DC side, which also plays a role in lowering the current and boosting the voltage, thereby reducing the energy loss of inverter part and improving the grid generation efficiency. As for the second-stage bidirectional DC/AC part, a full bridge converter is used, which can achieve both the rectification and inversion functions.

III. LITERATURE SURVEY

The general concept of a DC-DC converter to convert a fixed-voltage DC power supply into a variable-voltage DC power supply The DC-DC converter output voltage may be higher or lower than the input voltage. DC-DC converters are widely used in traction engines for electric cars, trolley buses, offshore cranes and forklifts. They provide smooth acceleration control, high efficiency and fast dynamic response. The DC converter can be used for regenerative braking of DC motors to return energy back to the power supply. This function can save energy for frequently stopped transport systems and it is also used for DC regulation.

There are many types of DC-DC converters, including buck (buck converter, boost) converter and buck-boost (boost-buck) converter.

(Muhammad H. Rashid, 2004). From a control perspective, this is an interesting topic. Because of its inherent non-linearity, common control methods (such as voltage control and current injection control) require a full understanding of the system and precise adjustments to achieve performance.

Xu Jia et.al. (2018) when the electric car stops charging the battery, the car's driver in the car will not work. The transport system that supplies the vehicle's weapons system can be viewed. For some devices, it may have the ability to pay fast and V2G (drive to grid). This paper proposes a charge-coupled Z-source system with LCL filtering. The consolidation method based on the integrated sound system is used to reduce the current to the resonant frequency of the current output. The mathematical model of the proposed system is implemented, and the control mode on the DC and AC sides is proposed. Finally, the Z-source test domain is created during grid connection operation. Experience has proven the superiority of the system.

Chandra Sekhar Nalamati et.al. (2018) The growing popularity of renewable energy and electricity (EV) has transformed the structure of the global energy industry. In the charge-coupled charge system for renewable energy, bidirectional AC / DC converters are used for more reliable power generation operations. This paper presents a bidirectional AC / DC converter that combines an AC-DC bidirectional converter (GBC) and a bidirectional De-Battery (BBC) battery charger. The GBC printer can facilitate bidirectional flow between the AC and DC networks, while the BBC converter can provide bidirectional power between the energy storage / EV and DC grid systems.

In order to transmit power in the trunk, powerful power management technology is required. Hysteresis based power management technology is used to inject electrical energy into the container. AC-DC conversion offers asymmetric PWM strategies with minimal conversion. PSCAD tools are used in

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simulation to validate the proposed control algorithm.

IV. PROPOSED SYSTEM

The simulation was developed in the MATLAB simulation program. To verify the effectiveness of the simulation model, an experimental device was developed. He developed a buck-boost circuit using MOSFET as the switching element. The fuzzy logic controller that generates the PWM signal duty cycle is programmed. Simulation and experimental results show that the output voltage of the buck-boost converter can be controlled according to the value of the duty cycle.

The proposed network-connected bi-directional simple power conversion converter system with low input battery voltage for the proposed converter, only one power processing stage is needed to perform bidirectional power flow control and meet common interface standards. The current input and output of the folded network represents the power flow and the transmitted power level. It also includes power quality on the grid side.

Therefore, controlling the input and output of the folded grid current can lead to the feasibility of the proposed converter for individual power conversion.

This project designs and proposes a fuzzy controller for the Buck-boost DC-DC converter. To control the output voltage of the buck-boost converter, the controller is designed to change the converter duty cycle. The mathematical model of the buck-boost converter and the fuzzy controller is derived, and the simulation model is designed. This framework combines a maximum power point tracking controller and a bidirectional buck-boost converter equipped with a charge and discharge control function.

The battery charge and discharge controller employ a bidirectional buck-boost converter that simultaneously exhibits the energy conversion characteristics of buck and boost converters. Thus, the energy conversion efficiency is significantly increased.

Furthermore, this converter in the system framework provides not only battery energy storage functions, but also facilitates auxiliary power supply at the load terminal. By implementing the system characteristics are mentioned previously, the power supply can be managed and controlled. The maximum power point tracking controller is focused on tracking and controlling the output power of the photovoltaic module array. Therefore, the system's DC link voltage (VH) varies according to solar irradiation and tracking processes.

If VH is directly connected to the load terminal system, the system will become compromised. Therefore, we proposed a control strategy that allowed VH to be controlled at a V setting through the charge and discharge control function of a bidirectional buck-boost DC-DC converter. The control method involves adopting the error between of the DC link voltage VH and its command value to further obtain the battery charge/discharge current command value through the DC link voltage controller.

Subsequently, the hysteresis current controller senses the charge and discharge current (IL) of the battery to follow its command value to achieve DC link voltage (VH) regulatory functions. Additionally, to prevent excessive IL, the system restricts the maximum charging current.

Therefore, when the charging current exceeds the default value, the system discontinues the maximum power tracking procedure to protect the battery from damage.

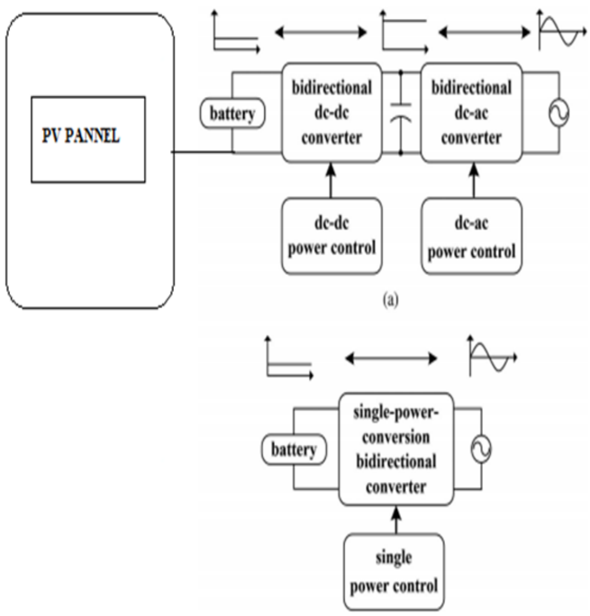

Fig 2. Proposed Block Diagram.

Due to the small signal model, the dc-dc boost converter is a non-linear duty cycle function, and its control method has been applied to boost converter control. Fuzzy controllers do not require precise mathematical models. Instead, they are designed according to the general knowledge of the factory. The diffuse controller is designed to adapt to changing operating points. The Fuzzy Logic Controller is designed to use the Mamdani Fuzzy Inference System to control the boost DC-DC converter output.

The main switches Sp and Ss in the proposed converter operate at a frequency significantly higher than the mains frequency therefore, the gate voltage vg can be considered constant during the switching period Ts, and it is assumed that the folded gate voltage vo is the same as the absolute value of the gate voltage vg.

The proposed converter only has the following two sub-ranges: the on state of the main switch Sp and the off state of the secondary main switch Ss, or the off state of the main switch Sp and the on state of the secondary main switch Ss. Two modes of operation. Suppose that the duty cycle of the primary circuit breaker Sp defines the duty cycle of the primary circuit breaker D.

The fuzzy logic controller has been applied to the system by developing a fuzzy logic control algorithm. The design and calculation of the inductor components have been completed to ensure that the converter operates in continuous driving mode.

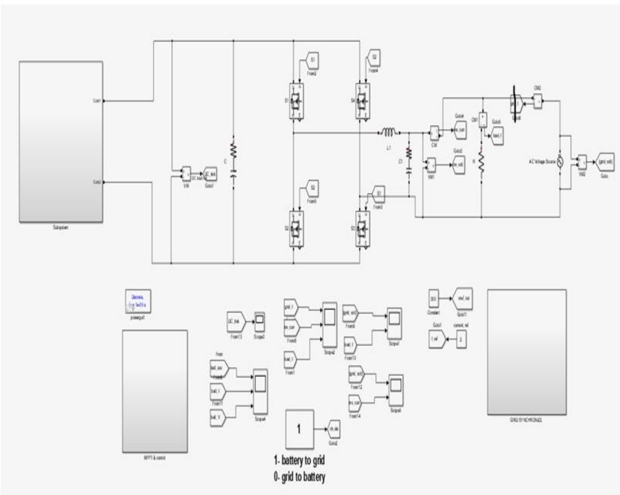

Fig 3. Proposed Simulink Model.

V. FUZZY CONTROLLER STRUCTURE

The structure of the fuzzy logic controller is based on fuzzy sets, where variables are members of one or more sets with a specific degree of membership. The advantage of using fuzzy logic is that it allows us to simulate human inference processes in computers, quantify inaccurate information, and make decisions based on fuzzy information, such as connecting resistive loads to photovoltaic modules through booster DC / DC converters The block diagram of the MPPT-based fuzzy logic control is shown in Figure 3.

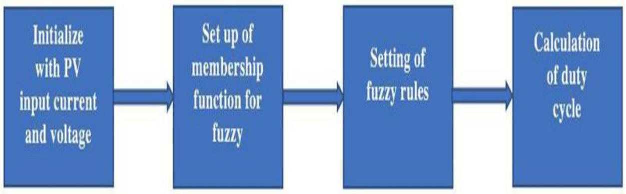

Fig 4. Block diagram of the fuzzy logic algorithm.

1. Membership functions of the proposed fuzzy system:

The definition of fuzzy sets for each input and output variable is shown in Figure 4. Three fuzzy subsets; select the input and output variables of the fuzzy controller as small, medium, and high. As shown in Figure 4-4, the membership function uses a trapezoidal shape. The input membership range is the PV voltage and the PV current.

The characteristics of the proposed photovoltaic module (Voc @ 22 V, Isc = 15 Arespectively. Similarly, the duty cycle that the fuzzy controller output represents is between 0 and 1 to provide more flexibility to change the buck-boost converter.

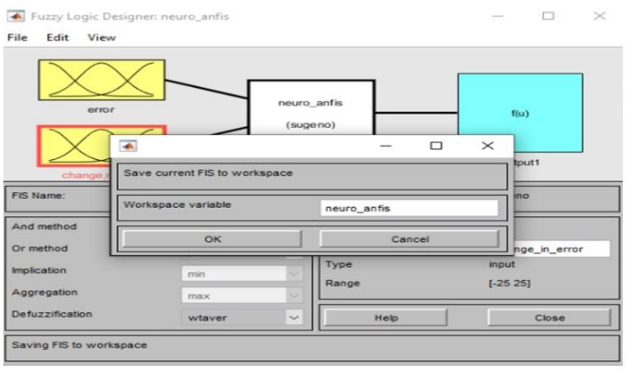

Fig 5. Membership functions fuzzy system of save current to workspace.

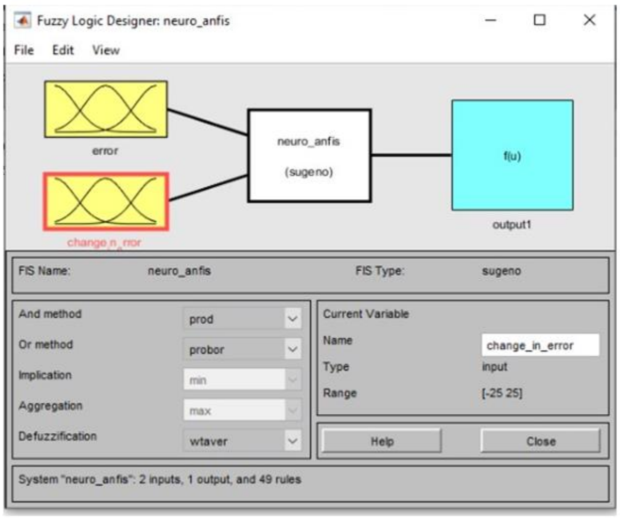

Fig 6. The Membership Function plots of change error.

Figure5 illustrates the surface of the fuzzy controller ruler, which is a graphical representation of the ruler base. Figure6 shows the rule viewer, which indicates the operation of the fuzzy controller during input changes.

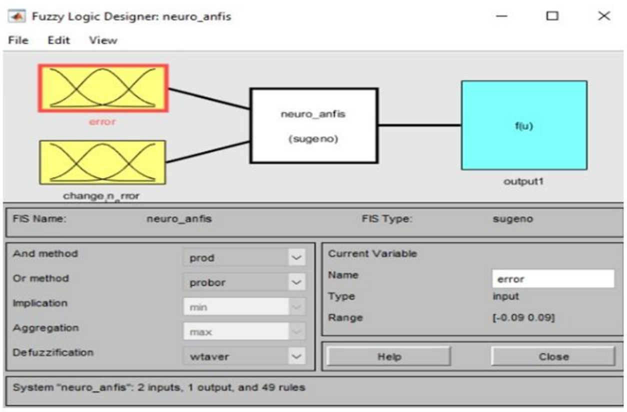

Fig 7. The Membership Function plots of error.

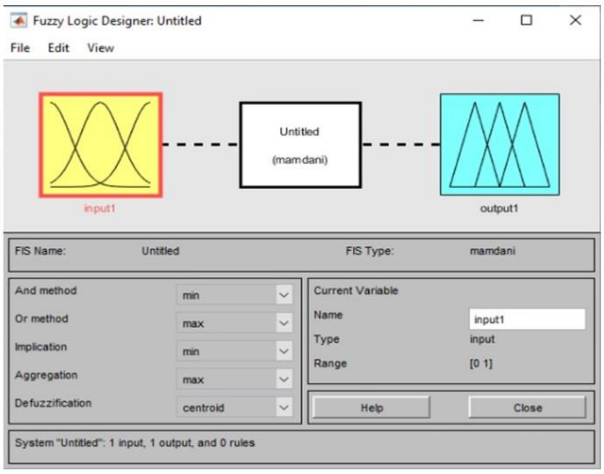

Fig 8. The Membership Function plots of duty ratio.

2. Fuzzification:

Each input / output variable is required in a fuzzy logic controller, and these variables define a control surface that can be represented in a language-level fuzzy set symbol. Each input and output variable of the linguistic value divides its emission range into adjacent intervals to form a membership function. The value of the member indicates the degree to which the variable belongs to a specific level. The process of converting variable input / output processes at the language level is called fuzzification.

3. Inference:

A set of rules is used to control the behavior of the control surface related to the input and output variables of the system. A typical rule is: if x is A THEN y is B. Under the premise of each rule with real degree, reading a set of input variables will activate a rule and help form a control to approximate it. Then, when all the rules are activated, the generated control interface will appear. It is expressed as a fuzzy set representing the restricted output. This process is called inference. [9]

4. Single Power Conversion:

For the proposed converter, only one power processing stage is needed to perform bidirectional power flow control and meet common interface standards. The current input and output of the folded network represents the power flow and the transmitted power level. It also includes power quality on the grid side Therefore, controlling the input and output of the folded grid current leads to the feasibility of a single energy conversion in the proposed converter.

5. Control:

The converter proposed by a single AC-DC power conversion converter with a high power factor is obtained by integrating a full-bridge diode rectifier and a series resonant active clamp DC-DC converter. The proposed converter achieves a high power factor without a power factor correction circuit by using a novel control algorithm for power factor correction and output control, thus providing a unique power conversion. Compared to the two-stage AC-DC converter, the traditional single-stage AC-DC converter has higher voltage voltage or lower power factor.

Similarly, PFC circuits used in single-stage AC-DC converters require DC link electrolytic capacitors and inductors. DC bus electrolytic capacitors and inductors increase the size and cost of the converter. To resolve these problems, the DC link electrolytic capacitors must be removed from the circuit. A high power factor based single power conversion AC-DC converter, which is obtained by integrating a full bridge Mosfet diode rectifier and a series resonant active clamp DC-DC converter to obtain a high power factor without power correction circuit.

The proposed converter provides a unique power conversion by using a new control algorithm for power factor correction and output control. Similarly, the active clamping circuit clamps the breaker overvoltage and recovers the energy stored in the leakage inductance of the transformer.

Additionally, it provides a zero voltage conduction switch for the switch. Also, the series resonant circuit of the output voltage duplicator eliminates the problem of reverse recovery of the output diode. The proposed converter can provide a maximum power factor of 0.995N and a maximum efficiency of 95.1% at full load. Analyze and verify the operating principle of the converter. Experimental results were obtained from a 400 W AC-DC converter at a constant switching frequency of 50 kHz to show the performance of the proposed converter.[8]10]

6. Solar Power:

Standard Solar, Inc. recently completed one of the first grid-interactive battery pack solar microgrid systems in the country. The first challenge is to make this project a reality after months of dedication, innovative engineering design and coordination with key partners, public services and government departments.

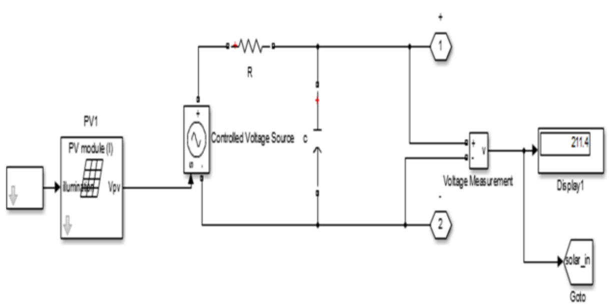

Fig 9. Solar Panel.

The first half of this article will set the stage explaining how to set up the microgrid, its features, and its uniqueness. Then, I will discuss the time required to design and install a solar microgrid system, the lessons learned from this groundbreaking project, and what technical considerations should be considered when implementing this new technology.

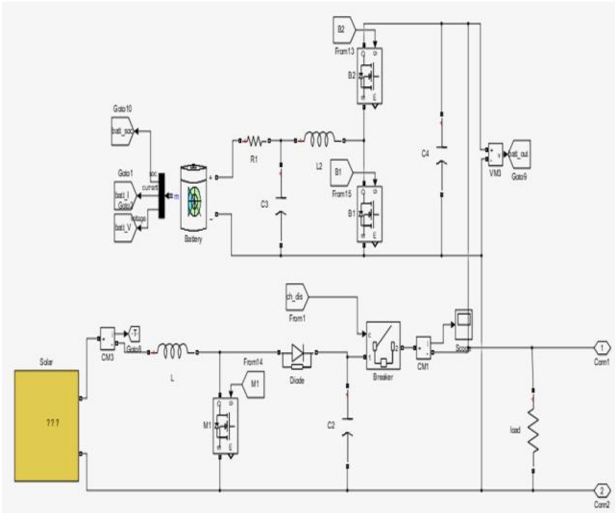

Fig 10. Solar Panel.

The solar microgrid system is designed to operate in two modes: network interaction and island mode. In the grid interaction mode, the battery system works in parallel with the photovoltaic system. Photovoltaic systems generally function as a grid-connected photovoltaic solar system. During peak daylight hours, the battery system is less active, but when the PV system does not use most of the inverter's capacity (for example, at night), it can actively participate in the frequency response fast response. The control system is designed to always prioritize the use of the inverter capacity for the generation of photovoltaic solar energy, and then use the rest for frequency regulation.

In the case of total sunlight, photovoltaic systems generally require approximately 700 W of capacity, while the remaining 75 W of reverse capacity can be used in the frequency regulation market. When the power grid is interrupted, the microgrid system will detect the loss of the power grid and send a signal to the isolation breaker to trip and switch to island mode. The system will automatically adjust from the grid connected current source to the island voltage source in a few cycles.

As long as there is enough sunlight to generate and enough charging capacity or battery to absorb, the PV system will continue to generate electricity. The

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energy storage system acts as a buffer between the PV and the load, so users will not notice power fluctuations due to unstable sky conditions. The duration of the power supply is difficult to predict because it depends on the amount of available sunlight, the demand for the selected backup charge and the state of charge of the battery system when it is isolated from the grid.

7. Maximum Power Point Tracking:

The power of photovoltaic (PV) modules is highly dependent on the operating voltage of the connected load, the battery temperature, and the level of solar radiation. By connecting 70 variable load resistors R between the module terminals, the operating point can be determined from the intersection of the load characteristics I-V and the I-V curve of the module. The area of the current source is area I, and the area of the voltage source is area II. The internal impedance of the module in zone-I is high, whereas in zone II the opposite occurs.

The inflection point of the power curve is the point of maximum power Pmp. The increase in short-circuit current is due to the increase in temperature under constant solar radiation, resulting in a decrease in internal impedance. This is due to the decrease in open circuit voltage. When the load impedance and the internal impedance of the source are equal, according to the theory of maximum power transmission, the transmission of power to the load will be maximized.

The load characteristics can be determined by the slope of the straight line with I / V = I / R. When the module only uses a value close to Isc as a constant current source in the AB region, R is very small. In contrast, when the module is used as a constant voltage source, the value in the CD area is close to Voc, so R is large. By searching for the best Ropt equivalent output resistance and adjusting the load and weather conditions, you can track the point of maximum power. In this way, by using the controller to change the drive's duty cycle, the DC-DC converter can be used to perform load line adjustment.

Optimal Identification of Inverter Topology for Maximum Power Point Tracking In this section, different inverter topologies will be analyzed to identify the performance and applicability of maximum power point tracking of the required system.

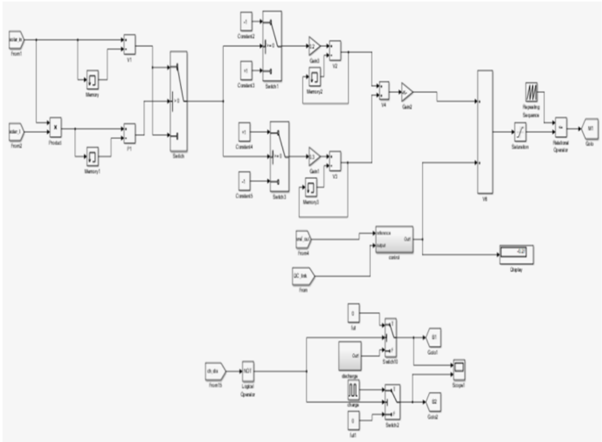

Fig 11. Grid Synchronization.

Grid synchronization is an important part in the control of grid-connected electronic power converters. The basic phase angle at the common coupling point must be tracked online to control the energy transfer.

Digital implementation allows the implementation of high performance algorithms that are very robust in the presence of power quality phenomena. However, various distortions will lead to a reduction in effective bandwidth.

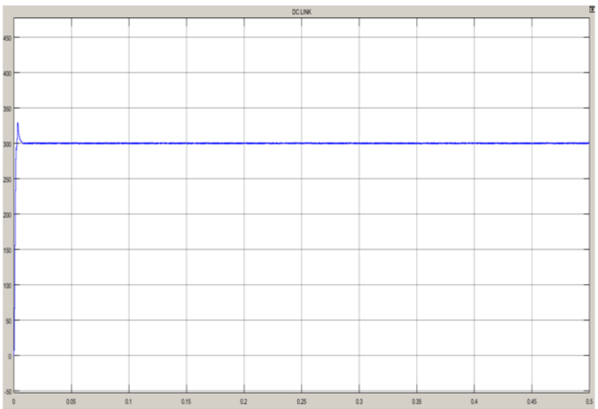

Fig 12. Dc Link.

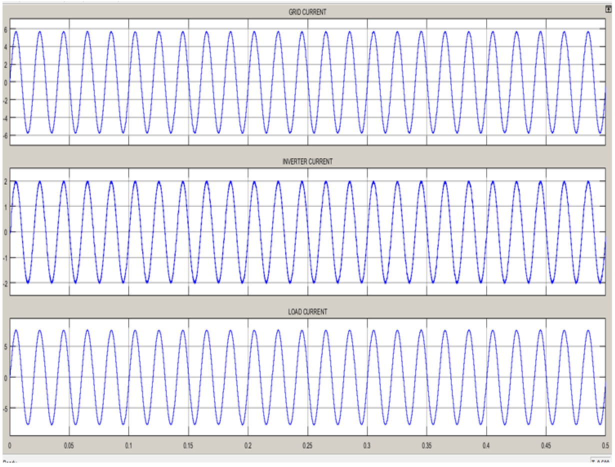

Fig 13. Grid, Inverter and Load Current.

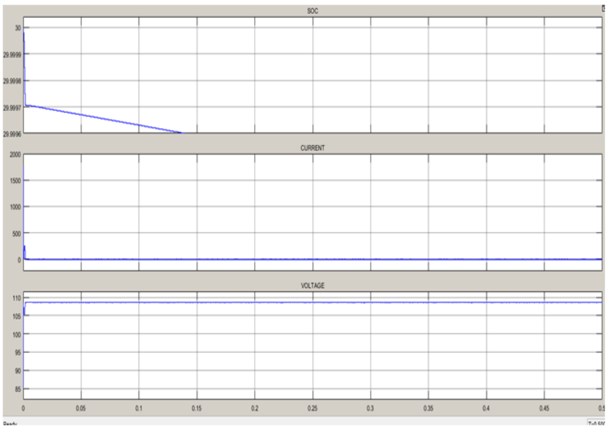

Fig 14. Battery Soc, Voltage and Current.

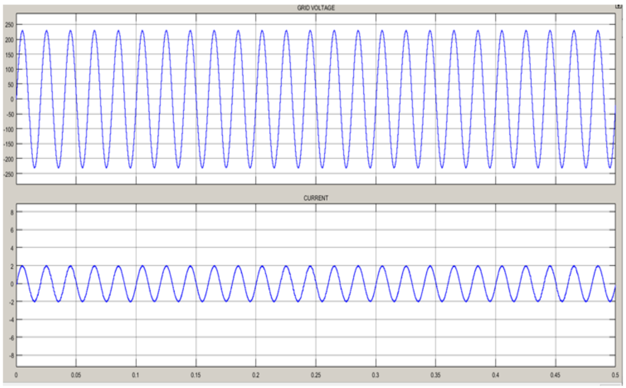

Fig 15. Grid Voltages and Current.

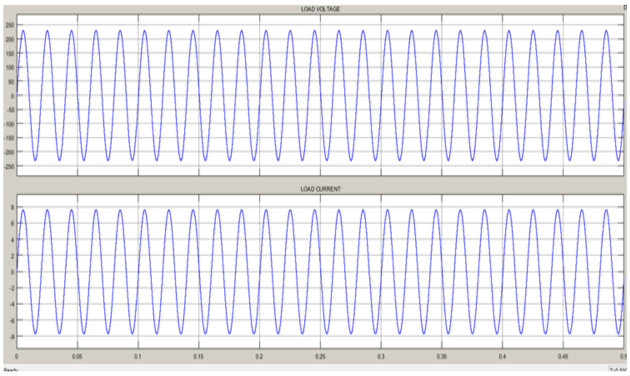

Fig 16. Load Voltage and Current.

VI. CONCLUSION

A fuzzy controller to track the maximum power point of the photovoltaic power source, and simulates it in Simulink / MATLAB. The controller is based on the basic modules of the fuzzy system, namely fuzzification, reasoning and de-fuzzification. These blocks read ambiguous inputs and program the device process, and convert the programs into output actions respectively.

In this controller, the trapezoidal shape of the input and output membership functions is proposed, and the Mamdani fuzzy inference method and centroid method are also selected as the de-fuzzification.The entire system includes photovoltaic, booster converter, diffuse controller and modeling and simulation of the load under different irradiance changes.

The results show that the proposed fuzzy controller performs well and is effectively applied to real-time systems.

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