A FUZZY LOGIC CONTROLLED PHOTOVOLTAIC SYSTEM FOR ENERGY MANAGEMENT

[1]S.Swathi Priyanka,[2]J.Hema Latha,

[1]PG Scholar,[2]Sr.Associate professor

[1,2]Department of Electrical and electronics engineering,

[1,2]Prasad. V. Potluri Siddhartha Institute of Technology, Vijayawada, India.

Abstract: For integrating renewable energy resources such as a PV or battery to a Micro grid there requires an efficient energy management system (EMS) due to the intermittent nature of renewable sources. Since the operation performance of such sources are not same for different hours of a day as well as different seasons of the year, an energy management is required to a sustainable energy supply users. An energy storage system such as battery storage system is always used along with PV as an auxiliary energy source. The fuzzy rule is need to be designed by considering the availability of PV power, the state of the battery charge and the total load power consumption. The fuzzy logic controller will take the decision and corresponding switching signals will be produced. An EMS using a Fuzzy decision making (FDM) process is proposed in this paper in order to manage the supply power from PV or battery to load. In this project the fuzzy logic controller has three inputs and three outputs. "Mamdanis" fuzzy inference system will be used. Based on Mamdanis fuzzy inference the switching signals will be produced. The proposed FDM can be implemented in MATLAB/SIMULINK to validate the performance of the overall system.

IndexTerms- **Photo-voltaic (PV), fuzzy logic controller (FLC), Fuzzy Decision Making (FDM), Energy management system (EMS)**

I. INTRODUCTION

Developing non-conventional energy sources like wind, solar, biomass, tidal etc are major challenges for twenty first century. Solar photovoltaic energy is one of the significant sources which can afford us the desired power for battery bank and grid tied systems. Inquisitiveness for developing maximum power from a PV cell leads us to design different algorithms. Researchers developed a number of algorithms for PV module which not only give better efficiency, but also a faster response to a changing environmental condition. Despite many attractive advantages the non-linear characteristics form a major role of PV systems. Operating this PV system in a non-linear varying atmospheric condition several maximum power point tracking (MPPT) techniques have been proposed.

Comparing number of different MPPT techniques tell us to use which one is best for a PV system. To extract maximum power from the PV module a DC-DC converter is designed to go as per the duty cycle defined by the MPPT techniques. The DC-DC converter is interfaced between the PV array and load to extract the maximum power [6].Earlier some conventional MPPT techniques like perturb and observe P&O) method, incremental conductance method (ICM) and modified perturb and observe (MP&O) achieves moderate performance with acceptable implementation.

But nowadays these are not sufficient to implement in a practical life. Several efficient MPPT techniques like artificial neural network (ANN), fuzzy logic controller, adaptive network-based fuzzy inference system (ANFIS) are developed. These modern advance MPPT techniques vary from several aspects like controller configuration, required measurement signal, training algorithm and robustness. It can be changed into electrical energy by using energy converters.

Fuzzy logic controller (FLC) is one of the most widely used applications of fuzzy set theory. It can be used instead of digital control systems using fuzzy sets. In the fuzzy controller, computation is made by using word rather than numbers [7]. Membership functions which are the main tools for the fuzzy operations are used to describe the Fuzzy sets. The implementation of linguistic fuzzy rules by human operators is desired for a complex and nonlinear systems without the requirements of mathematical models parameter estimation. The FLC has faster transient responses and is more robust than several control method [1, 3]

II. . BLOCK DIAGRAM

This paper presents a controller for energy management using a fuzzy logic for PV-Battery based micro grid by monitoring the variation in PV power, battery status and load condition.

The role of Fuzzy logic controller is to monitor the status of PV output, SOC of the battery and the load demand. The controller also provides switching signals to charge the battery from solar power. The power flow management is done by fuzzy logic controller to increase the reliability of the system. The model of micro grid with PV and Battery is shown in Fig. The proposed system has been done for analyzing the control strategy for micro grid with fuzzy logic controller.

An energy storage system is necessary in a micro grid in order to maintain the power and energy balance between generation and demand. Hence switching of the source from renewables to storage and vice versa is very important.

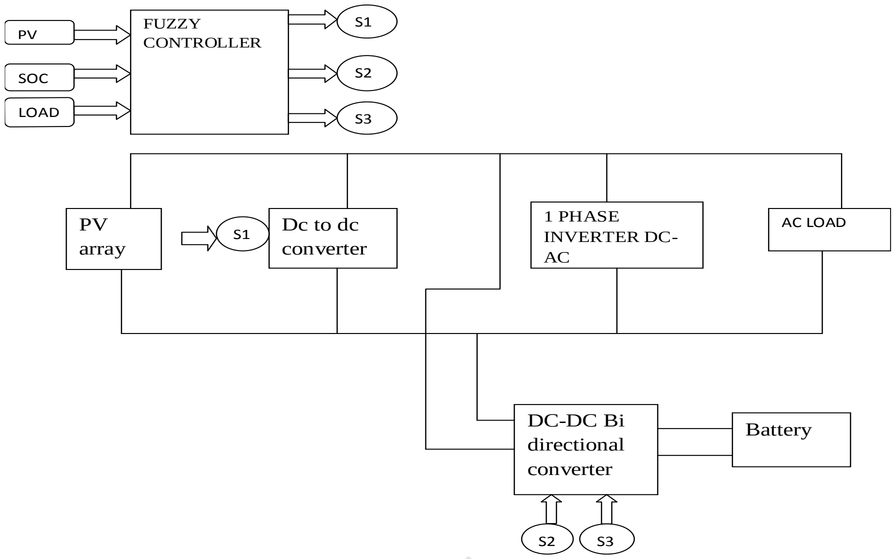

FIG1: BLOCK DIAGRAM OF A PROPOSED SYSTEM

III.FUZZY LOGIC CONTROLLER FOR POWER FLOW MANAGEMENT

Fuzzy logic is widely used intelligent control mechanism. The merits of fuzzy logic are it can work with multiple and vague inputs. The fuzzy logic controllers can also handle non-linearities. In the proposed system fuzzy logic controller manages the switching of different sources in the system based on the availability of different sources. Here the power flow management is done by checking the availability of PV, load condition, SOC of battery. The proposed fuzzy logic controller has three input membership function and three output membership function. The output of PV varies with the weather conditions. During sunny days the output of PV is high that is PV voltage greater than 50V and during rainy seasons the output will be low that is PV voltage less than 50V. SOC of the battery is high means battery SOC greater than 60%. SOC of the battery is low means battery SOC less than 40%. The load may be constant even if the weather conditions changes. Hence the controller have to check the conditions of PV and generate the switching signals to change the source i.e, either PV or battery to meet the demand. The alternative source used here is the battery. The battery output depends on the state of charge of battery. The battery can meet the load demand, if the SOC level of the battery is sufficient to give the required output. When the load demand varies the converter output should be changed accordingly.

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3.1 Mamadanis Fuzzy Inference Method

The Fuzzy Logic Comprises Of three Main Parts:

A. Fuzzification,
B. Rule Base or Expert Knowledge
C. De-fuzzication

A. Fuzzification

The input variables are output of PV, Load, Battery and SOC. The membership functions for each variable are assigned. The membership functions of PV power are divided into range of membership functions based on its power at any instance of time. Battery SOC is alienated into range of membership functions based on it's a Charge availability. Load is divided into range of membership functions based on the load demand at anytime.

B. Rule base

Fuzzy inference is the process of generating the mapping from an input to an output using Fuzzy logic. Here we are using Mamdanis fuzzy inference method.

Rule 1:

If PV is high and SOC is high and load is high then PV control is high and buck control low and boost control low.

Rule 2:

If PV is high and SOC is low and load is low then PV control is high and buck control is high and boost control is low.

Rule 3:

If PV is low and SOC is high and load is low then PV control is low and buck control is low and boost control is high.

C. De-Fuzzification

De-Fuzzification is the process of combining the successful fuzzy output sets formed by the inference mechanism. The function is to produce the most definite low-level controller action. Numerous methods exist to perform de-fuzzification, in this paper centroid method is used for de-fuzzification

3.2 Fuzzy Controller

In the recent years, the fuzzy logic control has increased its interest in MPP tracking applications. These Fuzzy logic controllers are advantageous of working on the systems with nonlinearities [9], which does not need an accurate dynamic model and can work easily with imprecise inputs. Fuzzy logic control is mainly based on three stages [10].The first stage is fuzzification stage, which converts input variables into linguistic variables. This is based on a membership function as shown in Figure. Here, we have seven fuzzy levels, which are NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE (zero), PS (Positive Small), PM (Positive Medium) and PB (Positive Big). In general, the output of fuzzy logic controller is nothing but the change in duty ratio (D) of power converter which can be calculated and converted to the linguistic variables. In de -fuzzifcation, the controller produces an analog output which can be converted to digital signal and this controls the power converter of the MPPT system. The membership functions and controller surface associated with the fuzzy controller.

IV.SYSTEM DESCRIPTION

The system consists of a standalone micro-grid with load, inverter, PV panel, dc-dc converter, bidirectional converter, battery module and a fuzzy logic controller. The power produced by PV panel supplies the micro grid load and battery. The fuzzy logic controller senses the changes in PV power generation, battery charge, Load Demands. If the PV power is very high it can charge the battery and feed the load. Likewise the battery power can be used for supplying to the load. The boost converter boosts PV output to the DC link voltage, the Bi-directional converters is used for the charging and discharging of the battery. When the battery is in charging mode the bi-directional converter will be stepping down the dc link voltage to the battery voltage and when the battery is in discharge mode the bi-directional converter will be boosting the battery voltage to the required DC link voltage level. The single phase inverter converts the dc voltage at the dc-link to AC voltage. The load used is RLC load.

4.1 Solar photovoltaic array

In this paper the PV array module is chosen as Kyocera solar kc200GT, with one parallel string and one series string, the number of cells connected is 54 cells per module, maximum power is 200W.

4.2 Battery

Lithium-Ion battery is chosen for this paper. These batteries are known for their high energy and power density, long battery life and recyclability. The typical battery model with internal resistance is chosen. In this model the battery is equivalent to a voltage source and an internal resistor

4.3 Buck Boost Bi -Directional Converter

In this bi-directional converter it has two stages one is for charge state and other is one discharge state to charge and discharge the battery, the switching operation is based on the fuzzy logic controller.

V.RESULTS AND DISCUSSION

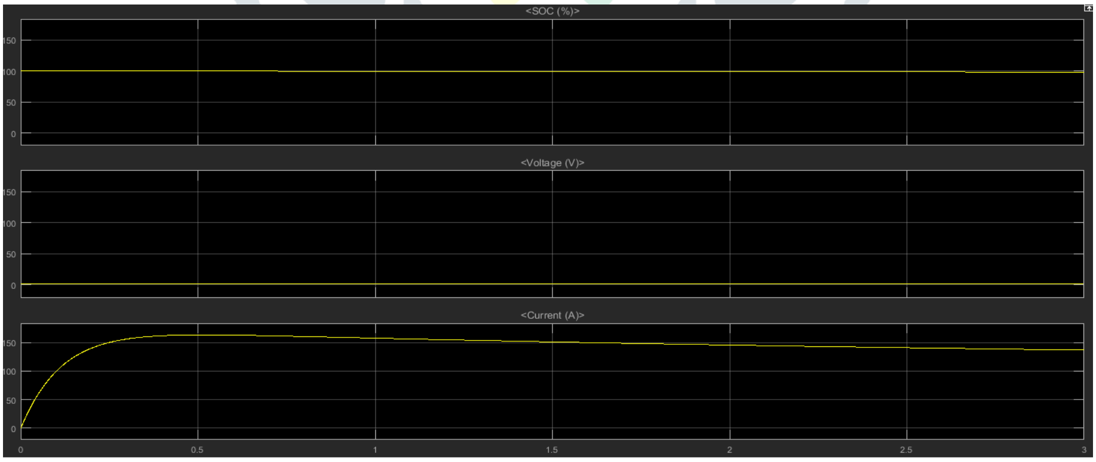

Fig1: Battery Voltage, Current and SOC wave forms

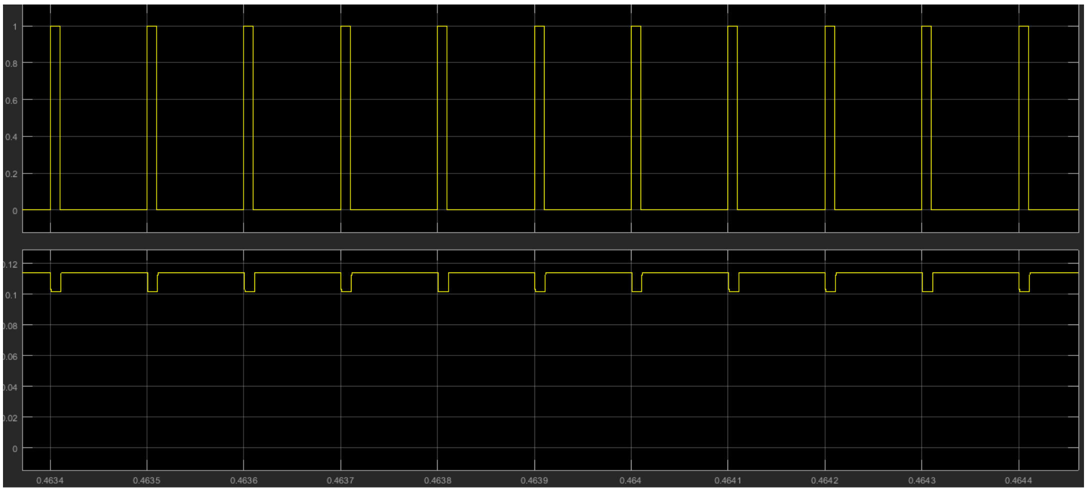

Fig 2 Gating Signals of Bidirectional Converter

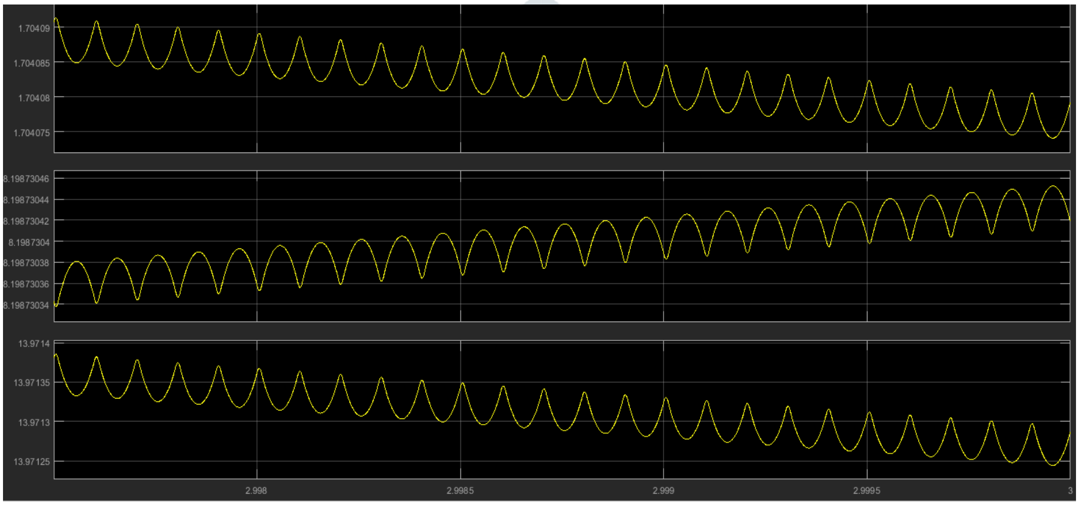

Fig3: PV Voltage, Current and Power Waveforms

V. Conclusion

The importance of energy storage system for power balance in a micro grid has been tested and a power management strategy using fuzzy logic controller is implemented. The conditions of PV, Battery, and load have been varied in order to test the working of controller. It has been observed that the switching signals are generated according to the controller input and output functions. The work proposes a Power Management system under a set of cons trains using a rule based fuzzy logic-controller. The Rule based Controller developed can detect the non-stop variations in PV power generation, Load Demands and Battery SOC so as to take proper and fast decisions.

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