Fuzzy-PI Control of Bidirectional DC-DC Converter for 250KW Distributed Solar-Solar Off-Grid System

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***Abstract*—Distributed generation (DG) is one of the main features of micro grid being achieved by different renewable energy sources (RES's). RES's are the vital part of Micro grids but due to their intermittent nature, their power output is not reliable and stable. RES such as solar panels connected to DC micro grid have to be connected alongside some ESS such as batteries, fuel cells etc to ensure reliable output. Bidirectional DC-DC converters have been used to provide required power output from DC micro grid to AC micro grid either from battery and solar panels. Control of Bidirectional DC-DC converter ensures reliable output from both battery and solar panels. This paper specifically discuss the design and control of Fuzzy-PI control for bidirectional DC-DC converter. Fuzzy-PI control using State of Charge (SOC) have been implemented in Matlab/Simulink for 250KW load. Results show that bidirectional DC-DC converter improves the reliability of DC power output as well as controlling the charge and discharge of battery.**

***Index Terms*—micro grid, AC micro grid, DC micro grid, bidirectional DC-DC converter, fuzzy, PI**

I. Introduction

As the world electricity demand increases, more and more renewable energy sources (RESs) i.e. solar panels (PV), wind turbines (WT), biomass etc. have been incorporated into power systems. These RESs are being incorporated as distributed generation (DGs) units in Micro grid as shown in Fig. 1 [1]. As shown in Fig. 1, RES such as PV as well as battery produce DC output so DC-AC converter is used to convert DC to AC voltage as our load consumes AC voltage only [2].

Solar panels (PV) as well as battery provide DC output while load operates on AC so DC-AC converters have been used [3].

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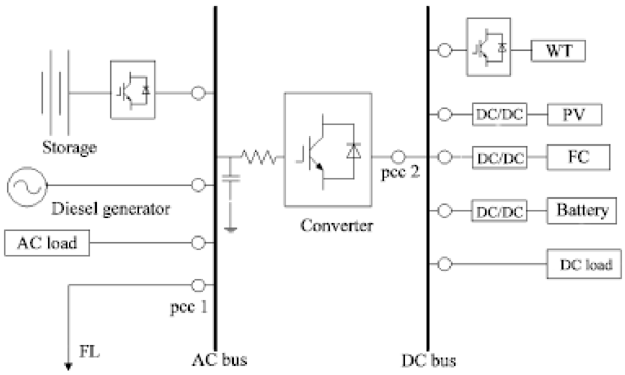

Figure 1. Micro grid architecture with RES.

II. Micro Grid Architecture

Utsan [4] focus on environmental issues and propose to reduce the distributed generation impact by using microgrids instead of conventional grid. The paper provides review of existing and current literature along with current projects around the world and possible fields for future research. The paper also highlights fields for further research which includes microgrid energy management systems, designing of new protection plans and type of system suitable for deploying microgrid. Whenever solar panels (PV) along with batteries have been used, DC and AC buses are being used in micro grid. [5] examines existing microgrid systems used around the world and systems presented in literature. The study reveals the type of energy storage and systems, load type and type of microgrid control deployed in different regions of the world. The requirements of system vary according to region for instance some regions are focused on reliability of power supply while some are more focussed on use of renewable and new power generation technologies. This examination provides various architectures for deploying microgrid systems. It shows that traditional systems are commonly used while emphasizing to research on new technologies. In this paper [6], autonomous integration of DER to microgrids

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is presented for higher efficiency and accuracy. This paper presents design of microgrid that employs MAR technology for plug and play functionality along with implementation of secondary control system for grid connected and islanded operations. The tests are carried out at Labein-Tecnalia's microgrid laboratory. The scenario of test includes grid connected with aim of power exchange with the main grid to maintain predefined values using secondary control system. Further research can be performed on validating control of microgrid in islanded mode. The result shows the reliability of secondary control system and economical operation of microgrid. [7] This research provides definite energy management methods related to microgrid system for business customers. The main purpose is to plan for future smart grids while taking into consideration current grid requirements. Further research on hypothetical business cases of smart grids can be carried out. The proposed system is implemented in two stages; Stage I manages the central energy of microgrid while stage II manages power on consumer side. The experimentation is carried out in two scenarios; Day mode and night mode. The results show that in the day mode as the energy of PV module increases the power balancing is done and battery power remains steady. While in night mode the batteries are discharged with high power to maintain the stability of power reference.

[8] This paper presents an optimal energy management system that caters different weather conditions and provides forecasting of one day ahead. The system includes power forecasting module, energy storage system, management module and optimization module. The paper provides a matrix real coded genetic algorithm for practical load management. This system also sells power to consumer at reduced prices. This system tested two types of data i.e. no day different which included all three sunny days and different day type in which two days were sunny and one day was rainy. Further research can be done by considering industrial and commercial factors of the region. The results show that according to weather forecast this system is able to forecast power generation on hourly basis and its optimal schedule can fulfil certain load demand. [9]In the paper "CERTS Microgrid Laboratory test bed", the researchers presented a system that can assimilate power sources to the microgrid without the requirement of complex transmission systems. This paper is based on the idea of placing distributed power sources on microgrid when required without modifying the control system. The purpose of this research is to make the microgrid able to reconnect to the power sources when fault occurs in the main grid and make the system able to maintain the standard power quality. The system is tested using three tests i.e. reduced system tests, power flow control, and difficult loads. The result shows stability in the autonomous peer-peer and plug and play functionality. Conventional micro grid architecture have been shown in Fig. 1. Batteries and PV provide DC output to DC bus of micro grid through DC-DC converter [10]. DC output from DC bus is being converted into AC output through DC-AC converter. In this paper microgrid architecture as shown in Fig. 2 have been used in which SOC from battery and Pdc from DC grid and Pref have been given as input to Fuzzy controller which decides the charging or discharging of the battery accordingly.

A. Bidirectional DC-DC Converter

As shown in Fig. 2, Bidirectional DC-DC converter is being used between battery and DC bus. Whenever DC bus have enough voltage/current then battery is being charged otherwise battery also provides required DC voltage/current [11].

Bidirectional DC-DC converter has been used as charge/discharge controller. Either it charges or discharges the battery. Bidirectional DC-DC converter have been shown in Fig. 3 [2].

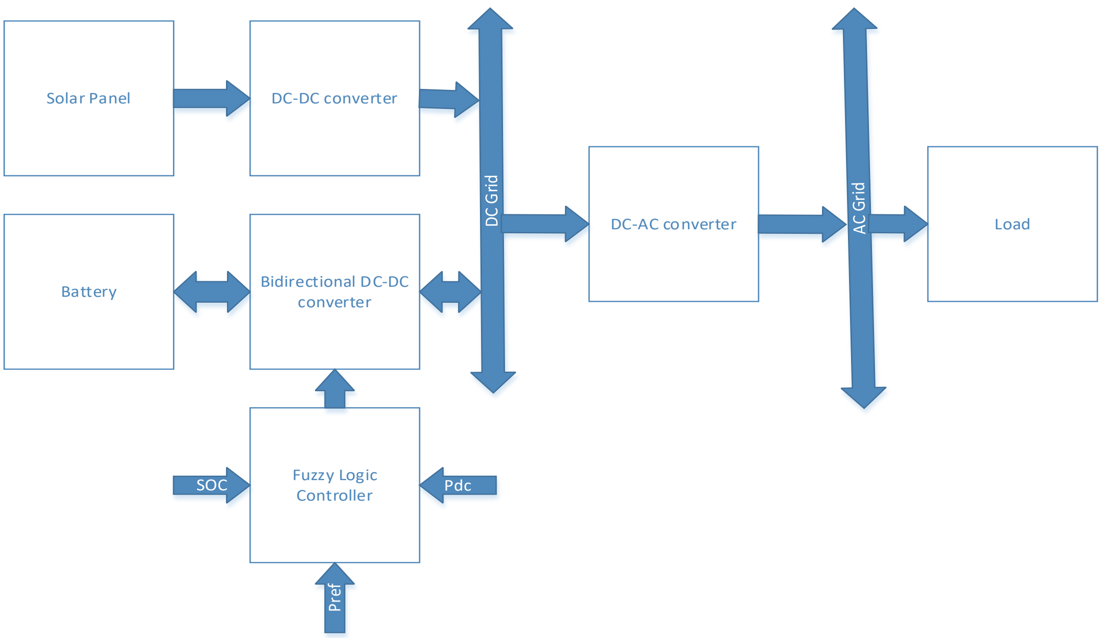

Figure 2. Proposed Microgrid architecture.

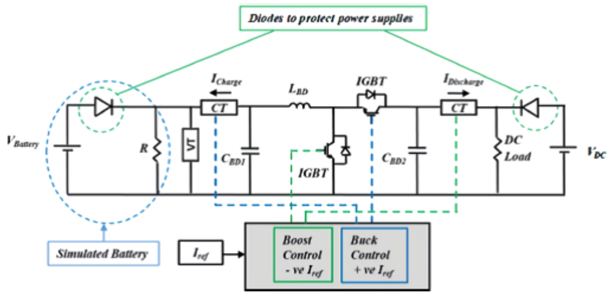

Figure 3. Topology of the Bidirectional DC-DC converter.

Bidirectional DC-DC converter topology is being selected to provide 500V DC voltage and 125A DC current [12]. The critical values of L and C have been calculated from below equations (1 to 6) to ensure stable 500V DC voltage output [2], [13].

$$L_C = \frac{D(1-D)R}{2f} \tag{1}$$

$$C_C = \frac{D}{2fR} \tag{2}$$

$$\Delta I_{HV\ Side} = \frac{V_{in}D}{fL} \tag{3}$$

$$\Delta V_{HV\ Side} = \frac{I_{out}D}{fC} \tag{4}$$

$$\Delta I_{LV\ Side} = \frac{(V_{in}-V_{out})V_{out}D}{fLV_{in}} \tag{5}$$

$$\Delta V_{LV\ Side} = \frac{V_{in}D(1-D)}{8LCf^2} \tag{6}$$

B. *Fuzzy Charging/Discharging Algorithm*

Fuzzy charging/discharging algorithm have been shown in Fig. 4. First of all the algorithm senses reference power (Pref) and DC bus power (Pdc). If Pref>Pdc then it means more power is needed by the load so algorithm will take battery SOC into consideration. If SOC> 0.5 then algorithm will discharge the battery by enabling PI control signal of Boost converter in bidirectional DC-DC converter. If SOC<0.5 then algorithm will charge the battery by enabling PI control signal of Buck converter in bidirectional DC-DC converter. Fuzzy rules for bidirectional DC-DC converter have been shown in Table I.

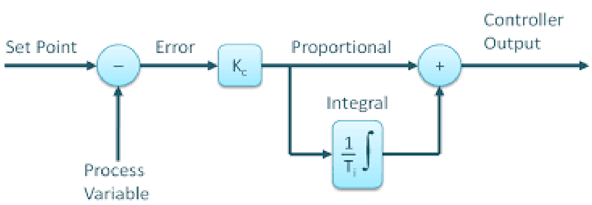

Figure 4. PI controller block diagram.

TABLE I. FUZZY RULES OF BIDIRECTIONAL DC-DC CONVERTER

S.no.	SOC	Current of PV	Buck/Boost
1	Low	Low	Buck
2	High	Low	Boost
3	Low	High	Boost
4	High	High	Boost

C. *PI Control*

PI control shown in Fig. 4 & Fig. 5 have been used to control the amount of charging/discharging current to/from batteries [14]. Reference current (Iref) is being provided to PI control and then Iref is being compared with DC current (Idc) and then based on that value PI control gives PWM signal to control switching speed of Boost or Buck converter.

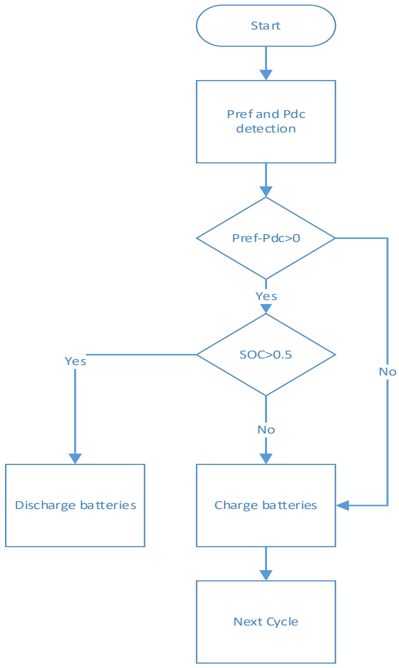

Figure 5. Battery charging/discharging algorithm.

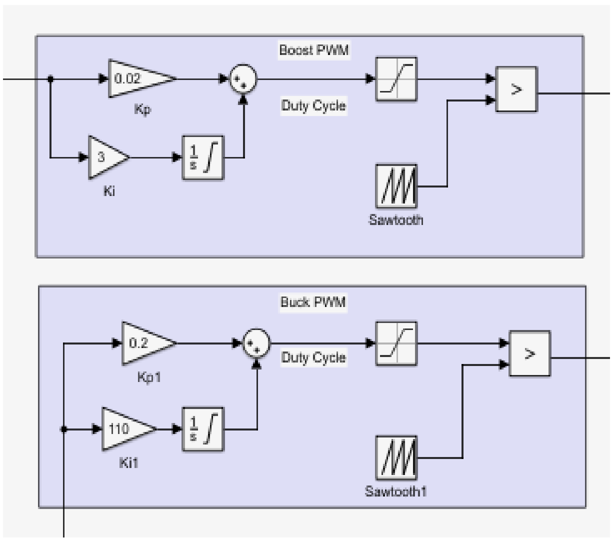

Figure 6. PI control for buck and boost switch of bidirectional DC-DC converter.

III. SIMULATION RESULTS

Solar is an intermittent source of energy due to which PV produces power fluctuation in a micro grid. So when simulating the performance of Fuzzy controller, one should consider all the scenarios of power fluctuation from PV. There may be times that PV will be producing more power than its rated power and sometimes PV will be producing less power than its rated power. So Fuzzy logic controller should smooth out the power fluctuation caused by variation in PV power output. Normally at the start of the day, PV does not produce rated power as sunshine is not at its peak value. As the mid-day arrives, sunshine is at its peak so PV will produce rated power. In afternoon, sunshine again decreases due to which PV will not produce rated power again. In the night time PV will not produce power at all. So all of these scenarios needs to be simulated where PV produces zero power, less than rated power or more than rated power. All of these scenarios have been shown in Fig. 7. As shown in Fig. 7, at the start irradiance of the PV was at 1000W/m^2 so PV was providing required current to the load. As soon as irradiance drop to 200W/m^2 in Fig. 7(a), current from solar panel drop to 50A in Fig. 7(c). At that moment, current from battery increases to 200A to provide the required total current of 250A in Fig. 7(e) and relatively SOC drops in Fig. 7(d).

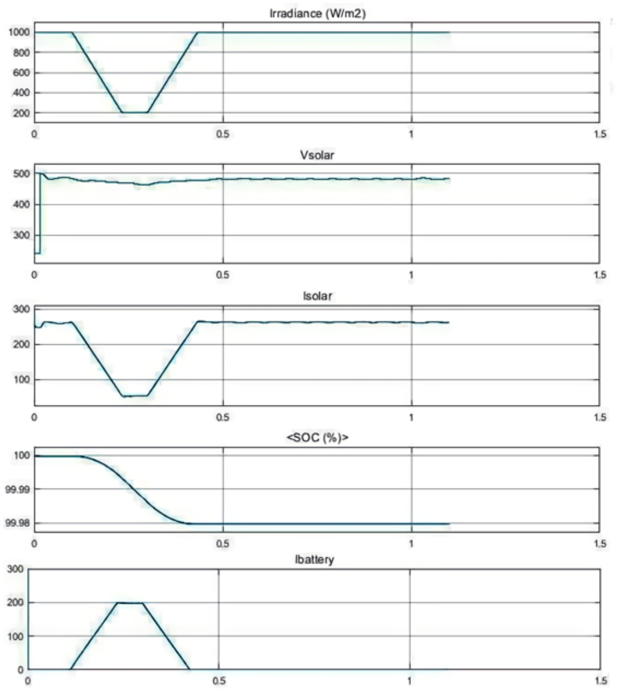

Figure 7. (a) Irradiance waveform (b) PV voltage waveform (c) PV current waveform (d) Battery SOC waveform (e) Battery current waveform.

IV. Conclusion

In this paper we have simulated the fuzzy PI control system for bidirectional DC-DC converter to stabilize DC output from DC bus to AC bus thus running the load in stable mode of operation. We use SOC, Pdc and Pref as input to fuzzy controller and fuzzy controller controls the switching of Bidirectional DC-DC controller.The simulation results shows that our proposed microgrid architecture when implemented with Fuzzy-PI control using State of Charge (SOC) in Matlab/Simulink for 250KW load have considerably improved the reliability of DC power output from bidirectional DC-DC converter as well as controlling the charge and discharge of battery.

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