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Design and Development of Fuzzy Based Inverter Controller for Solar/Battery Hybrid Power System

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***Abstract* – In this paper fuzzy PWM based inverter controller is developed for solar-battery hybrid system. Here fuzzy logic controller is developed for the optimum selection of switching angles for harmonic mitigation in proposed cascaded multi level inverter. These inverters are highly recommended for high power application in the past few years. In order to reduce the harmonic distortion and to improve the RMS value in the inverter output voltage the proposed method is recommended. Here the fuzzy PWM control circuit is used for cascaded multi level inverters which generate the triggering control pulses for switches using sinusoidal pulse width modulation (SPWM). Input variables of FLC are error in voltage and output variable as amplitude of reference sine wave. Rule base generated for FLC control the amplitude of PWM Sine wave with respect to error voltage. Here super capacitors are used for charging and discharging applications instead of battery. The inverter output voltage generated in this proposed method reveals fuzzy PWM controller provides output with minimum distortion and better RMS output. The proposed method is simulated using MATLAB / SIMULINK.**

Keywords – Fuzzy PWM, hybrid system, SPWM, cascaded Multi level inverter, Switching angle.

I. INTRODUCTION

Power electronics inverters was becoming popular for various industrial drive applications. From the technical point of view, the use of electronic power converter introduces new and challenging issues like topological complexity, additional power losses and electromagnetic interference(EMI's),thus they are reducing the overall quality of service, efficiency and stability of the system. To overcome the disadvantages, the researchers are proposed the new control topologies or modifying the existing ones, and to improve the energy available at the inverter terminals .Among them, sinusoidal pulse width modulation(SPWM) cascaded multilevel alternative to current inverter topologies.

The cascaded power devices, thus overcoming their voltage limits and reducing harmonics. There are three main MLC topologies: neutral point clamped, cascaded H-bridge and flying capacitors(FCs).Typically, it is necessary to connect four to twelve inverters in serial connection to reach the required output voltage. A main problem in design of MLI is the complexity of their control. For the past fifteen years, fuzzy logic(FL) was successfully adopted. It is used in inverter control and modulation techniques were mainly in the field DC/AC converters. The cascaded power devices, thus overcoming their voltage limits and reducing harmonics. This paper proposes fuzzy based cascaded multi level inverters for low harmonic distortion, reduces power losses, cost effective one, clear waveform and also for voltage stability. The proposed method is simulated using MATLAB/SIMULINK.

II. LITERATURE SURVEY

Zhijun Qian has proposed an integrated four-port DC-DC Converter for Renewable Energy Applications. It is done by simply adding two switches and two diodes to the traditional half-bridge topology .These ports are used to maintain the power balance of the system. This system is used to achieve independent control over three port topology. The main concept is significant savings in component count and losses for renewable energy power-harvesting system.

Sathish Kumar Kollimalla has proposed the design and analysis of novel control strategy for battery and supercapacitor Storage System. In the proposed system, batteries are used to control the slow changing power surges and supercapacitors are used to balance the fast changing power surges. The main feature ,it has less computational burden and it also uses simple control strategy.

Leon M. Tolbert has proposed the Charge balance control schemes for cascade multilevel converter in hybrid electric vehicles.It has applications for high-power hybrid electrical vehicles.It is naturally fix for automotive hybrid electrical vehicles because it has several level of DC voltage sources like batteries, supercapacitors /ultracapacitors or fuelcells.

Sufang Wen has proposed the energy management and coordinated control strategy of PV/HESS AC microgrid during islanded operation. This AC microgrid includes the hybrid energy storage system (HESS) including the

battery and the supercapacitor (SC). This proposed system is used to achieve effective power sharing in HESS, the battery steady state power and SC supports transient power fluctuations. The AC bus voltage maintains constant voltage.

Jiatu Hong has proposed energy management and control strategy of photovoltaic/battery hybrid Distributed Power Generation Systems With an Integrated Three-Port Power Converter. The proposed method includes energy management and control strategy for PV/hybrid power system. It has better power density and the reliability of the system is improved. It also has better charging/discharging time.

III. EXISTING SYSTEM

Photovoltaic(PV)/battery hybrid power units have attracted researchers attention during recent years. An integrated three-port power converter as the interface for the PV/battery hybrid distributed power generation system is proposed. Compared with the conventional system topology containing an independent DC-DC unidirectional conversion stage and a bidirectional conversion stage, the proposed system has advantages in terms of higher power density and reliability. The phase shift angle of the full bridge and the switch duty cycle are adopted as two control variables to obtain the required DC bus voltage and realize the power balance among three ports. Different operating scenarios of the system under various power conditions are discussed in detail and a comprehensive energy management and control strategy is proposed accordingly. The priority controller can enable one of the control loops in different scenarios to optimize the whole system performance, taking both the MPPT benefits and the battery charging/discharging management requirements into consideration. Here the charging and discharging time is high, to overcome this super capacitors is used and the inverter controller is used.

1. Block Diagram

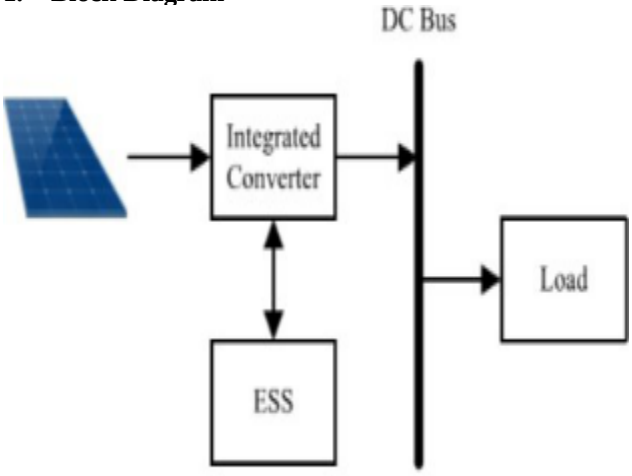

Fig.1.The block diagram of existing system.

The block diagram of the existing system shown in Fig 1 consists of the following components:

- 1.Solar panel
- 2.Integrated converter
- 3.Energy storage system/Battery
- 4.DC grid
- 5.Load

1. **Solar panel:** It is used to collect the solar energy from the solar or photovoltaic cells, which can be used to generate electricity through photovoltaic cell. These cells are arranged in a grid-like pattern on the surface.

2. **Integrated Converter:** The integrated converter consists of buck-boost converter and phase shift full bridge converter for solar hybrid power system.

3. **Energy storage system/Battery:**The Energy storage system/battery is used to store energy. The types of batteries are: lithium ion batteries, sodium nickel batteries and lead acid batteries etc.

4. **DC GRID:**A DC grid maintains a DC bus,which feeds DC loads connected to it. Normally, DC loads are used for low-power rating electronic devices such as laptops, mobile phones, DVD players, battery-powered vacuum cleaner. In DC grid, the loads is connected directly. For AC loads ,the DC energy is converted into AC by using DC-AC converters.

5. **Load:**An electrical loadis an electricalcomponent or portion of a circuit that consumes electricpower. This is opposed to a power source, such as a battery or generator, which produces power.

- In electricpower circuits examples ofloadsare appliances and lights.
- Demerits of existing system:
- The charging and discharging of the battery.
- The power loss in the converter.
- Efficiency is low.

IV. PROPOSED BLOCK DIAGRAM

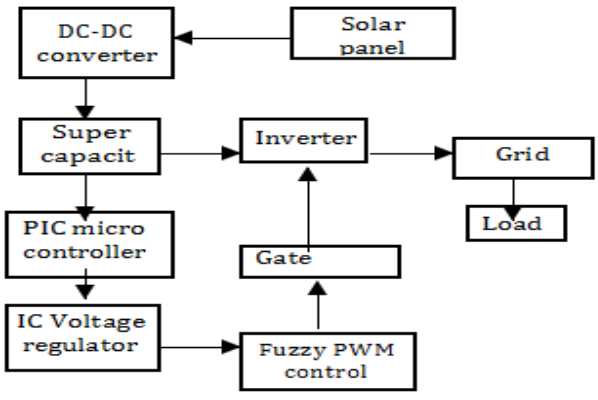

Fig.2.The block diagram of proposed system.

The proposed system shown in Fig 2 consists of the following components:

- Solar panel
- DC-DC converter 3.Super capacitor 4.Inverter
- PIC microcontroller
- IC voltage regulator(IC 7805)
- Fuzzy based PWM
- Load

The function of each block in the proposed block diagram is given below:

1. Solar panel

It is used to collect the solar energy from the solar or photovoltaic cells ,which can be used to generate electricity through photovoltaic cell. These cells are arranged in a grid-like pattern on the surface.

2. DC-DC Converter:

The DC-DC converter(boost converter) is the power electronic converter with an output voltage greater than the source voltage. It is used to step-up the maximum voltage from the solar
panel.

3. Super Capacitor

It is used to store the electrical energy from the Solar panels. It is mainly used to improve the energy density. By replacing batteries, it reduces current stress in the batteries in order to decrease its size, improve its life time, decrease discharge of battery and mainly reducing the operating and maintenance cost of the system.

4. Inverter

It is the power electronic device which is used to convert the direct current(DC) into alternating current(AC). Inverters are static, using electronic power switches to synthesize an AC waveform from the DC input.

5. PIC microcontroller

The name PIC initially refers to “Peripheral Interface Controller”. It is popular due to their low cost, wide availability, large user base, extensive collection of application notes and serial connectivity. It is mainly used to generate gate
pulses.

6. IC Voltage Regulator(IC 7805)

IC 7805 is a three terminal device. It is also a linear voltage regulator IC with a fixed output voltage of 5V which is used in many applications 7.

FUZZY PWM CONTROL The fuzzy based Pulse Width Modulation (PWM) is a type of digital signal. Pulse width modulation is used in a variety of applications including complex control circuits. The signal can only be high(5 Volt) or low (ground) at any time. The main purpose is used to harmonic distortion in inverters.

7. Fuzzy based PWM

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8. Load

An electrical loadis an electricalcomponent or portion of a circuit that consumes electricpower. This is opposed to a power source, such as a battery or generator, which produces power. In electricpower circuits examples ofloadsare appliances and lights.

9. Working Principle

The energy from sunlight is collected by the solar panel which is used to generate electricity by photovoltaic cells and it is given to DC-DC converter(Boost converter).It will boost the maximum energy from the solar panel.

The converted DC energy is stored in the super capacitors. It will reduce the discharging time of the battery, it will reduce the current stress and improves its life time. From the super capacitors the voltage is regulated to 5V by using IC voltage regulator. The regulated voltage is given to the PIC microcontroller. It will generate gate pulse for fuzzy based PWM. The fuzzy based PWM controls the inverter from harmonic distortion and power losses. Then DC energy is converted into AC energy by cascaded multilevel inverter. Finally the AC energy is given to the loads.

10. Rule Base Table for Fuzzybased Inverter Controller

In the design of a fuzzy based inverter controller, the formulation of its rule set plays a important role for better system performance. The rule base table contains 49 rules, where (LP, MP, SP,ZE, LN, MN, and SN) are linguistic codes (LP-large positive
;MP-medium positive; SP-small positive; ZE-zero; LN-large negative; MN-medium negative; SN-small negative).

Table-1:shows the fuzzy rule table for the proposed system

Fuzzy control rule table.

Δe	e						
	NL	NM	NS	EZ	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	EZ
NM	NL	NL	NL	NM	NS	EZ	PS
NS	NL	NL	NM	NS	EZ	PS	PM
EZ	NL	NM	NS	EZ	PS	PM	PL
PS	NM	NS	EZ	PS	PM	PL	PL
PM	NS	EZ	PS	PM	PL	PL	PL
PL	NL	NM	NS	EZ	PS	PM	PL

V. SOFTWARE DESCRIPTION

1. Matlab

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

- Math and computation
- Algorithm development
- Modelling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface building.

VI. MATLAB SIMULATION DIAGRAM

1. Design of Fuzzy Based Inverter Controller

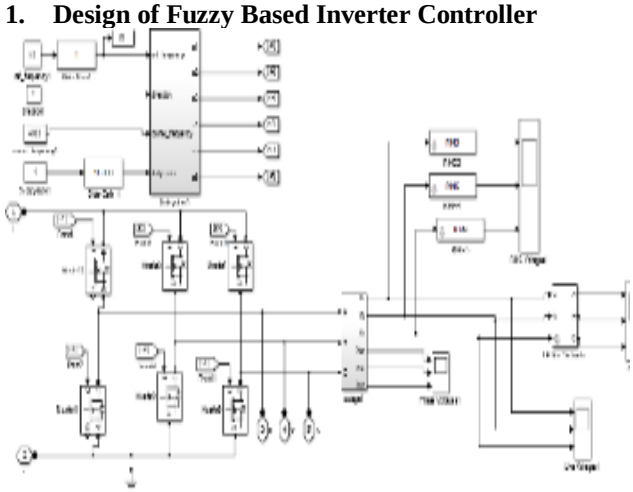

Fig .3.Output of fuzzy based inverter controller.

Fig.3.shows the overall simulation diagram for fuzzy based inverter controller of solar/battery hybrid power system.

2. Solar/Battery Block

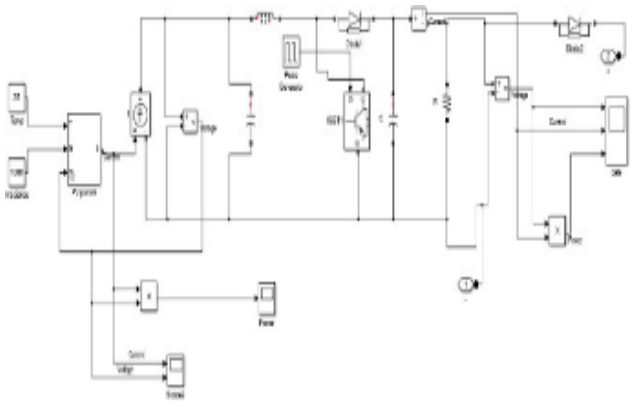

Fig.4.Simulation diagram of Solar/Battery Hybrid System.

3. DC-DC Converter Block

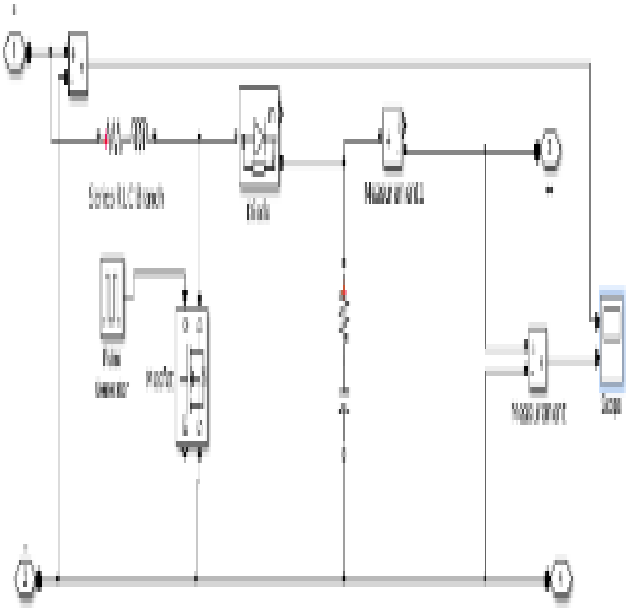

Fig .5. Simulation diagram of DC-DC converter.

Fig.5 shows simulation diagram of DC-DC converter is obtained.

4. Cascaded ML Inverter Controller Block

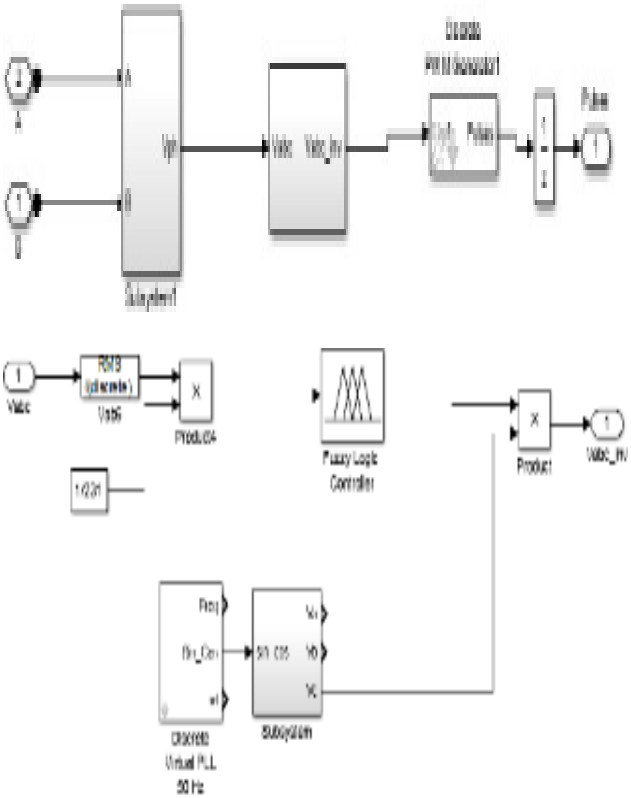

Fig. 6. Simulation of fuzzyinverter controller.

Fig. 6 shows simulation diagram of fuzzy based inverter controller for solar/battery hybrid power system

VII. RESULT AND DISCUSSION

1. Solar/Battery Output:

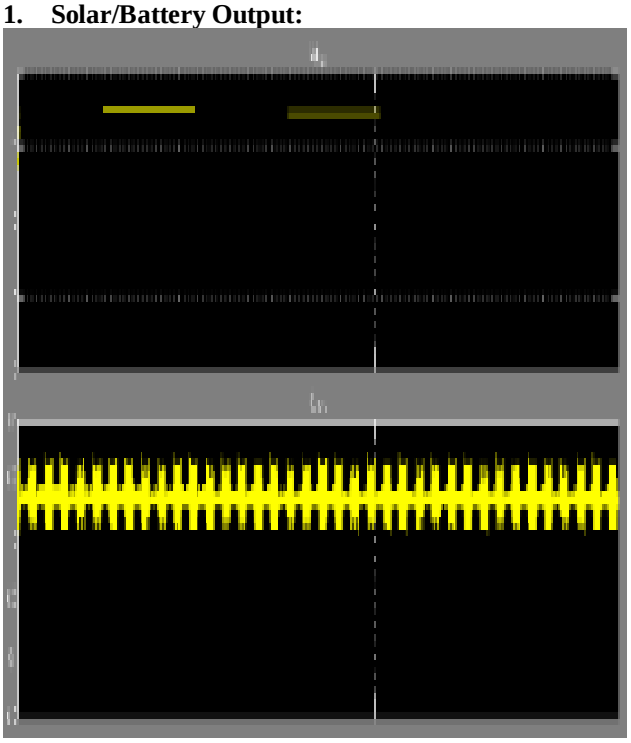

Fig .7. Voltage and Current output from solar panel.

Fig.7 shows that the voltage and current waveform obtained from the solar panel.

2. DC-DC Converter Output

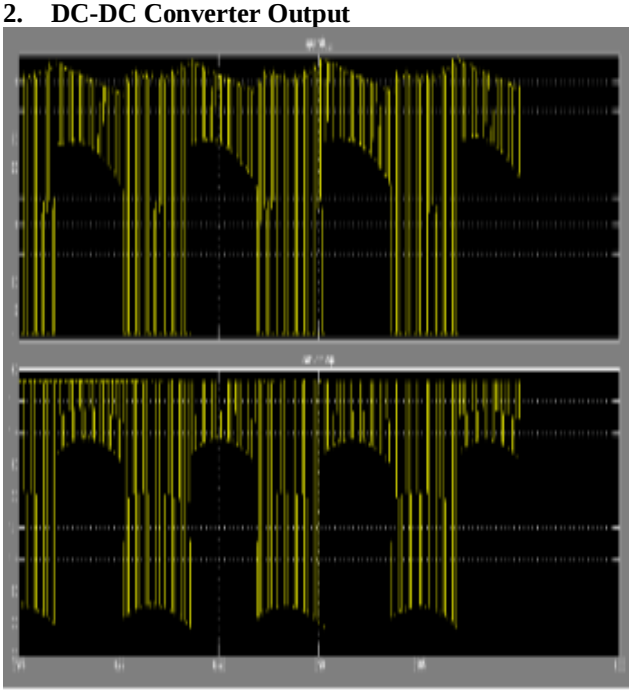

Fig. 8. Voltage and current output of DC-DC converter.

Fig.8. shows that the voltage and current waveform obtained from the DC-DC converter.

3. Cascaded Multi level Inverter Output

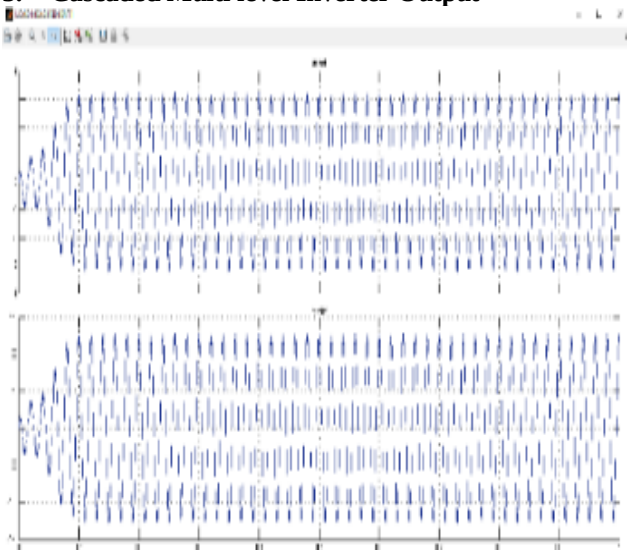

Fig. 9. Simulation output of Fuzzy cascaded MLI .

VIII. CONCLUSION

The fuzzy based inverter controller for solar/battery hybrid power system is proposed to limit the power devices voltage stress and power losses. The results obtained shows the usage of inverter in high voltage and also in high power applications such as PV generation system with grid connected. The proposed three-level inverter solves EMI, harmonics and high frequency switching problems. The simulation results shows that the THD for the output voltage of the proposed system is quite low as compared with the conventional two-level inverter. The FLC proves to be efficient than the conventional two level controller for nonlinear systems. The simulation results are provided by using MATLAB/ Simulink.

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