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A BIDIRECTIONAL RESONANT CONVERTER WITH FUZZY BASED MPPT FOR ENERGY STORAGE SYSTEM APPLICATIONS

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ABSTRACT:

This paper presents a bidirectional resonant converter with fuzzy based maximum power point tracking for energy storage system applications. Resonant converters are commonly selected for applications which demand for a high power density and a high energy efficiency. Resonant inverters are electrical inverters based on resonant current oscillation. It is also known as dc-dc converter or dc-ac pwm inverter. Its main function is to reduce switching loss of the devices MOSFET or IGBT.Boost converter is used for increasing the output voltage and is also known as step-up chopper. Here, the maximum power can be tracked from the solar panel for improving the efficiency and performance of the system. The power point tracker operates by taking the dc input current and changing it to ac and running through a transformer and then rectifying back to dc which is followed by the output regulator. For further improving the efficiency, an intelligent control technique called fuzzy logic control is associated to an MPPT in order to improve the energy conversion efficiency. Once, the maximum peak level is reached, the output power is compared with the new level of output power which is obtained from fuzzy logic and this energy will be stored in the battery and available it for future use which will be used in applications like battery operated vehicles and water pumps.

Key Terms: Maximum Power Point Tracking (MPPT), Fuzzy logic, Dc-Dc converter, Boost converter, energy storage system (ESS), resonant converter.

I. INTRODUCTION

In recent years, renewable energy sources are the most significant source of energy. Among all the renewable energy sources, photovoltaic generation becomes increasingly important since it offers many advantages such as no fuel cost, not polluting and requires little maintenance. The output power of the photovoltaic varies according to the sunlight conditions such as solar irradiation, shading and temperatue.Among the intelligent based techniques fuzzy logic controller has its own merits so that the MPPT algorithm can be easily formed. The shape of the membership function of the fuzzy logic controllers can be adjusted so that the gap between the operating point and maximum power point can be optimized. The proposed intelligent fuzzy logic technique comprises of expert knowledge which extracts maximum power from a PV module under varying solar irradiation, temperature and load condition. The fuzzy logic controller is used to change the duty cycle of the dc-dc converter

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which is the control parameter. In fuzzy logic controller, the modifications are done in rule base and membership functions according to the changes in solar radiation and temperature. The output of the fuzzy logic controller is the change in duty cycle of the dc-dc boost converter. The advantage of using this fuzzy logic control to be robust and hence simple design is required.

MAXIMUM POWER POINT TRACKING

Maximum power point tracker is an electronic dc-dc converter that optimizes the match between the solar array and the battery bank or utility grid. They convert a higher voltage dc output from solar panels down to the lower voltage needed to charge batteries. The MPPT maximizes the energy that can be transferred from the array to an electrical system. Its main function is to adjust the panel output voltage to a value at which the panel supplies the maximum energy to the load.

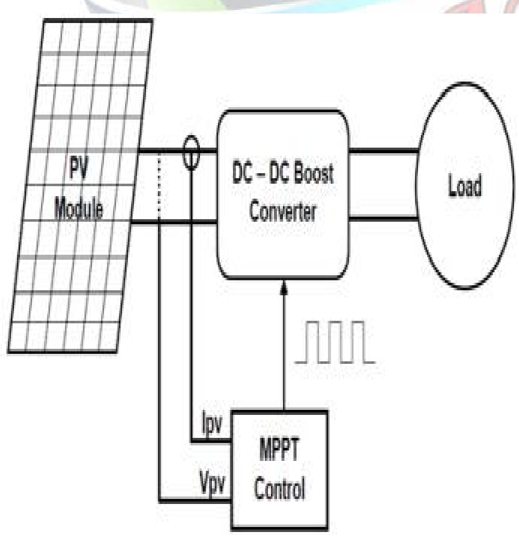

Fig 1.1 Typical diagram of MPPT in a PV system

The power point tracker is a high frequency dc-dc converter and it takes dc input from the solar panel, changing it to high frequency ac, and convert it back to a different dc voltage and current to exactly match the panels to the batteries.DC supply is taken from the solar panel and it is fed to the boost converter and again it is fed the load.MPPT control is fed to the dc-dc converter for increasing the power at the peak level and after a certain time it reduces and the energy is stored in the battery. During day time, the energy is much more used in vehicular applications and household appliances.

MODELLING OF A PV ARRAY

PV system converts sunlight to electric current. It can produce electric current any time the sun shining but more amount of power is produced when the sunlight is more intense and strikes the PV module directly. When solar thermal system use heat from the sun to heat water or air, PV does not use the sun's heat to make electricity.PV allows you to produce electricity without noise or air pollution from a clean renewable energy resource. A PV system never runs out of fuel and it will not increase oil imports. The typical equivalent circuit of a solar cell is shown in figure 1.2

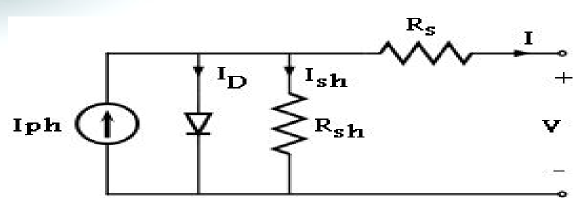

Fig 1.2 Equivalent circuit of a solar cell

The equivalent circuit of a solar cell consists of current source, diode, series resistance and shunt resistance. Solar

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cells are connected in series and each module consists of 36 solar cells and several modules to be connected in parallel respectively. Only limited power can be produced from a single solar cell.

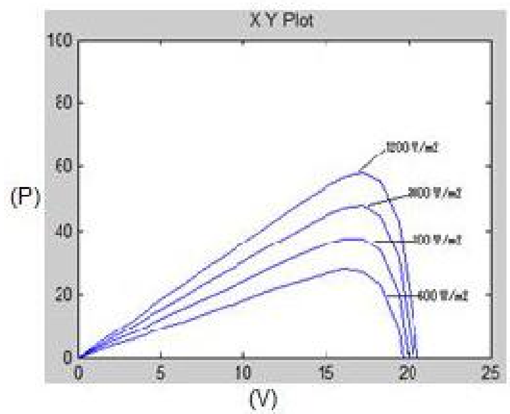

Fig 1.3 PV curves with variation in solar radiation

The above graph showsthe voltage in X-axis and power in Y-axis. Hence, it shows that the PV curves are changing with solar radiation.

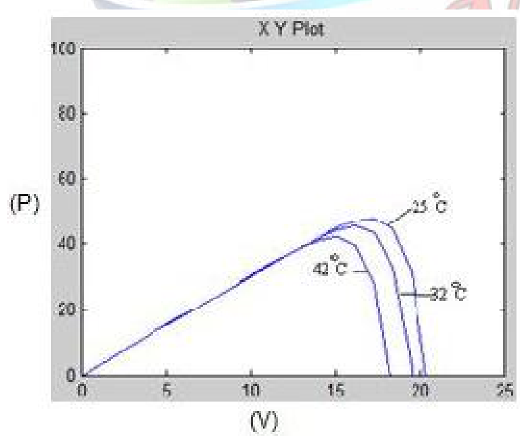

Fig 1.4 PV curves with variation in temperature

The above figure shows that the PV curves are changing with temperature. Here, the voltage is represented in X-axis and the power is represented in Y-axis.

DC-DC CONVERTER

A boost converter is a step-up dc-dc power converter because its output voltage is greater than its input voltage. The boost converter circuit is designed using MOSFET switch. In order to reduce the output voltage ripple, filters are added to the output side of the converter. In a boost converter output voltage is always higher than a input voltage. The circuit diagram of boost converter is shown in figure 1.5. When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores the energy. When the switch is opened, current will be reduced as the impedance is higher. Therefore, change or reduction in current will be opposed by the inductor. As a result two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

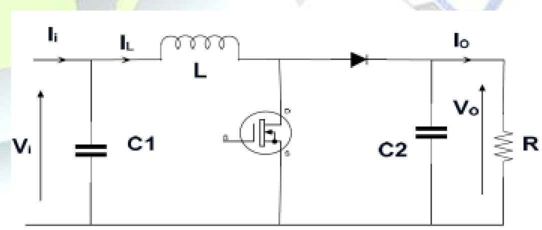

Fig 1.5 Circuit diagram of boost converter

It is a class of switched mode power supply. The converter operation can be subdivided into two modes. When the transistor is switched on, the current in boost inductor increases linearly and the diode comes to off state. This completes

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the mode 1 operation. When the transistor is switched off, the energy stored in the inductor is released through diode to the load. This completes the mode 2 operation. The power flow is controlled by varying on/off time of the MOSFET.The relationship between the input and output voltages are given by,

$$\frac{V_o}{V_i} = \frac{1}{(1 - D)}$$

Where, V_i is the input voltage and V_0 is the output voltage and D is the duty cycle which can be expressed by,

$$D = \frac{T_{on}}{T}$$

Where T_{on} is the time when MOSFET is switched on and T is cycle period time.The transistor operates as a switch.It is turned on and off depending upon the pulse-width modulated control signal.PWM operates at constant frequency,that is,T is constant and T_{on} is varying and hence the duty cycle varies from 0 to 1. A DC-DC converter converts fixed-voltage DC source into a variable DC source directly and is simply known as a DC converter.

II. PROPOSED SYSTEM WITH FUZZY BASED MPPT CONTROLLER

A fuzzy logic control scheme is proposed for maximum solar power tracking of the PV array with an inverter for supplying isolated loads. The advantages of the fuzzy logic control to be robust and simple to design since they do not require the knowledge of exact model. On the otherhand, the designer requires the complete knowledge of PV system operation. The fuzzy control algorithm is capable of improving the tracking performance for both linear and non-linear loads. Fuzzy technique gives better and more reliable control. Fuzzy logic controller have the advantages of working with imprecise inputs and does not need to have accurate mathematical model and it can handle the non-linearity. The two fuzzy logic control input variables are error E and change of error CE.The behaviour of fuzzy logic control depends upon the shape of the membership functions of the rule base.

FUZZY LOGIC CONTROLLER

Fuzzy logic controller uses the fuzzy logics for the purpose of making decisions and to control the output of the controller. The main components in fuzzy logic based MPPT controller are fuzzification, rule-base, inference engine and defuzzification.The basic block diagram of fuzzy logic controller areshown in figure 2.1

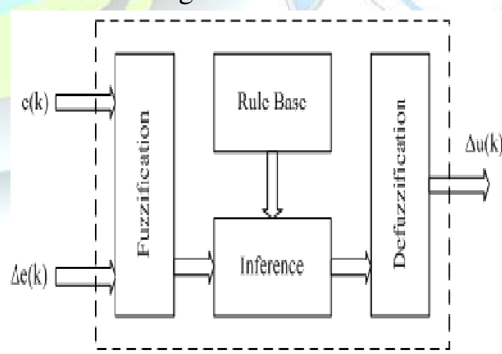

Fig 2.1 Basic block of fuzzy logic controller

There are two inputs for the fuzzy logic controller-error e(k) and change of errorΔe(k).Fuzzification is the process of converting the crisp inputs into fuzzy

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inputs. These variables can be expressed in terms of five linguistic variables such as zero, positive big, positive small, negative big and negative small. Fuzzy rule-base is a collection of if-then rules which contains all the information for the controlled parameters. It is set according to the system control operation. The fuzzy rule algorithm includes 25 fuzzy control rules shown in the table 1.

E \ CE	NB	NS	ZE	PS	PB
NB	ZE	ZE	PB	PB	PB
NS	ZE	ZE	PS	PS	PS
ZE	PS	ZE	ZE	ZE	NS
PS	NS	NS	NS	ZE	ZE
PB	NB	NB	NB	ZE	ZE

Table 1: Fuzzy logic Rule-base

Fuzzy inference engine formulates a logical decision based on fuzzy rule setting and transforms the fuzzy rule into fuzzy linguistic output. The fuzzy inference is carried out by mamdani'smethod.Defuzzification block converts the fuzzy output into crisp output and also uses the centre of gravity to simulate the output of the fuzzy logic control which is the change in duty cycle.

III. RESULTS AND DISCUSSION

By implementing fuzzy based MPPT algorithm in this bidirectional resonant converter, the output voltage can be controlled. When the voltage increases, current also increases and hence the output power produced by the PV module also increases, thereby improving the efficiency of the system. Hill climbing or fuzzy logic control is one type of MPPT which is used here for obtaining the maximum power output.

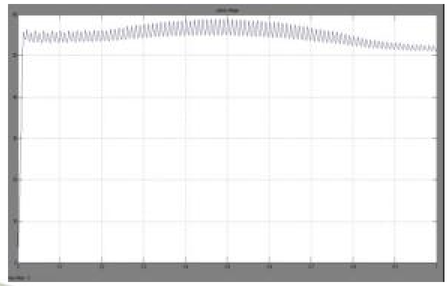

Fig 3.1 Dc output voltage waveformVs time

Figure 3.1 shows the output voltage waveform with respect to time.Here, the output voltage is represented in Y-axis and time in X-axis. It is seen that the voltage has been increased from the input source voltage to the maximum power point and after reaching the maximum point the voltage decreases significantly. Fuzzy logic control algorithm is applied here for further improving the efficiency of the system.

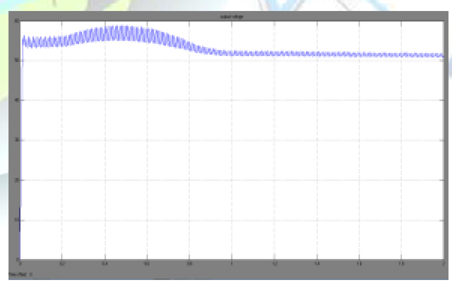

Fig 3.2 Dc output current waveformVs time

Figure 3.2 shows the output current waveform with respect to time.Here, the output current is denoted in Y-axis and time in X-axis. When the voltage decreases, current increases significantly by programming the fuzzy

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logic based MPPT controller. The efficiency of the system increases significantly and yields better performance.

IV. CONCLUSION

This paper presents a novel bidirectional resonant converter with a new technique called fuzzy based MPPT is designed which is very useful for energy storage system applications. The proposed fuzzy logic based MPPT was investigated and the design of PV panel and boost converter were also presented in detail. By using this fuzzy based MPPT,a peak level of output power is obtained. This proposed technique improves the efficiency and also providing good steady state and dynamic performances of the system. Transformer based circuit topologies are commonly employed in conventional bidirectional converters and soft switching techniques, including zero voltage switching and zero current switching are frequently applied to mitigate switching losses. Inthis, proposed scheme the storage time will be more because of using batteries and hence power losses are reduced. It is useful in applications like battery operated vehicles, flight control system and water pumps for improving the efficiency and performance.

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