CONVERTER FOR UNIVERSAL MOTOR DRIVE SYSTEMS WITH FUZZY LOGIC CONTROLLER

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Abstract
A high gain multi-input dc-dc converter with a fuzzy logic controller is proposed in this paper. The converter can draw continuous current from two input sources. In this converter, diode and capacitor are cascaded together with four voltage multiplier stages. Thus it improves the gain of the converter. This converter which is controlled by a fuzzy logic controller is connected to the universal motor. The converter has several desirable features such as low ripple current and reduced voltage stress. The fuzzy logic controller has been implemented to the system by developing fuzzy logic control algorithm. The evaluation of the output has been carried out and compared by using MATLAB/ Simulink environment. Finally, prototype circuit is operated to verify its performance

Index Terms:Modified Boost Converter, Voltage Multiplier, Switched Capacitor, Multi Input Converter, Fuzzy Logic Controller.

I. INTRODUCTION

Nowadays due to reduced environmental contamination and energy shortage, renewable sources such as photovoltaic, fuel cell etc received great attention. These renewable sources are used as input voltage in various applications. DC-DC converters are used to boost the low voltage dc to a high level. So, various converters such as boost, buck, etc., are used to boost the low voltage levels, but it contains large duty ratios. This result in high current stress and the efficiency is reduced so finally lead to diode reverse recovery problem. So, to overcome these disadvantages, transformers or coupled inductors are used. But due to the complexity of the circuit and as the leakage inductance is large, voltage spikes occur.

Conventionally, PI, PD and PID controller are most popular controllers and widely used in most power electronic closed loop appliances. However recently many researchers successfully adopted Fuzzy Logic Controller (FLC) to become one of the intelligent controllers to their appliances.

After classical converters, the different converter has been introduced. Boosting in done in a single stage for increasing the efficiency. So low cost and compact size can be obtained [1]. Converters with Single Pole Triple Throw Switch are used to increase the efficiency and reducing the cost [2]. By using a dead time between two switching commands in the multi-input converter makes the dynamic system gets improved [3]. An active ripple reduction technique is proposed in the fuel cell by adding a current loop control into the existing voltage loop control system thus reducing the ripple current [4].

A clamp mode converter with high step up voltage is proposed which adds two pairs of additional capacitors and diodes to achieve high step-up voltage gain. It has low conduction losses. Clamping circuit clamps the voltage across the circuits [5]. Non-isolated dc-dc converter with a voltage multiplier is proposed thus providing high static gain and high [6].

An interleaved high step up converter with voltage lift capacitor technique and voltage multiplier module is proposed which extends the voltage gain and increases the voltage conversion ratio [7]. Then, a high step up converter with voltage multiplier module is proposed which contains a clamping circuit to obtain soft commutation, thus reducing the voltage stress and increases the flexibility [8]. Thus a conventional interleaved boost converter integrated with a voltage multiplier module. The voltage multiplier module is composed of switched capacitors and coupled inductors. To extend step up gain coupled inductors are used. Voltage conversion ratio is increased by using switched capacitors [9]. Thus an interleaved high step-up converter integrated with winding cross coupled inductors [WCCI] and voltage multiplier cells is proposed. Voltage stress can be reduced and voltage multiplier cells absorb the voltage spikes [10]. Because of these reasons, it is necessary to find new converters which have to overcome these various disadvantages.

A modified boost converter which is used as a high gain dc-dc converter with diode and capacitor cascaded together to boost up the voltage are presented in this paper [11]. The major advantages are high voltage gain, low voltage stress, and low current ripple.

The Fig.1 shows the block diagram of the proposed system. It consists of two input source i.e., battery and a PV panel. The output from the PV panel is given to the converter. The battery stores the charge from the PV panel using a boost converter during day time and utilizes the charge during night. The converter is controlled by a fuzzy logic controller. The converter output is given to the inverter for converting the dc into ac which is then connected to the universal motor.

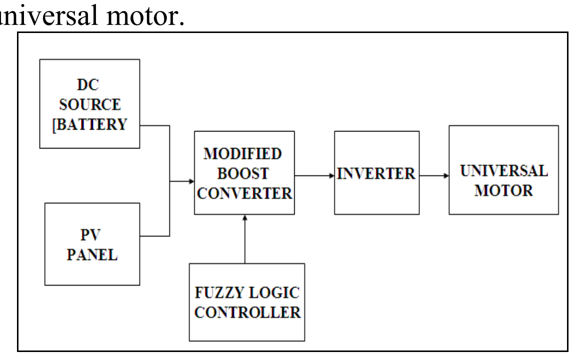

Fig.1 Block Diagram

II. MULTI INPUT CONVERTER

A. STRUCTURE

A modified boost converter (shown in fig 2) with diode and capacitor cascaded together with four voltage multiplier stages are proposed in this paper. It has four boost stages which are integrated together at the input. An overlap time is present for the normal converter. So in order to avoid the overlap time the converter operates in three modes of operation.

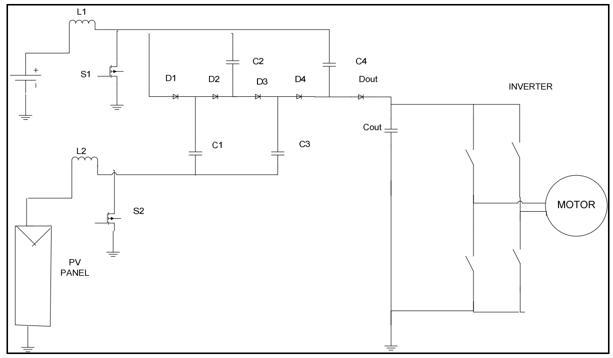

Fig.2 Circuit diagram of modified boost converter

B. OPERATION

Mode 1:

In this mode, as shown in Fig.3, S1 and S2 are ON at the same time. Vin1 and Vin2 input sources are used for charging the inductor. The diode is reverse biased and output capacitor is used for supplying to the load

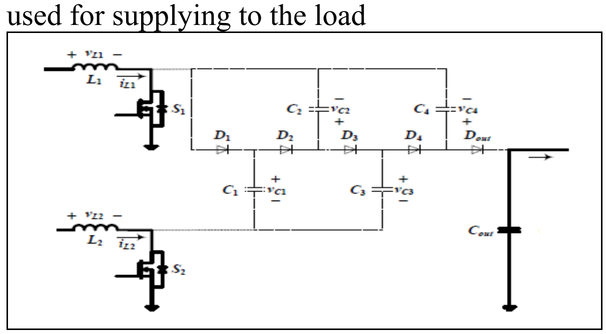

Fig.3 Mode 1 operation

Mode 2:

In this mode, shown in Fig.4, switch S2 is ON and switch S1 is OFF. As there are four stages forward biasing the output diode thus charging the output capacitor.

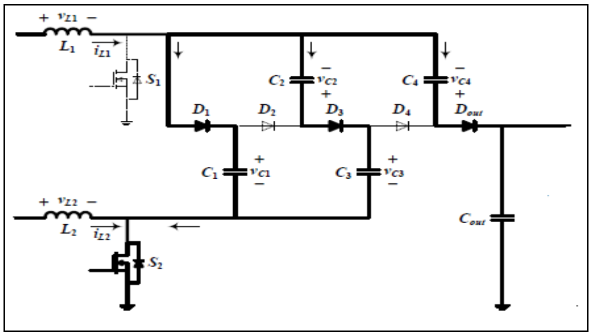

Fig.4 Mode 2 operation

Mode 3:

In this mode (shown in fig 5), S1 is ON and S2 is OFF. As there are four stages reverse biasing the output diode and output capacitor is used for supplying the load.

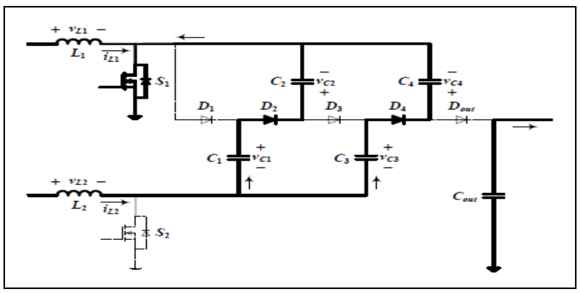

Fig.5 Mode 3 operation

III. FUZZY LOGIC CONTROLLER

In a fuzzy logic controller, controlling is done from a set of linguistic rules. A block diagram of fuzzy logic controller is shown in Fig 6.

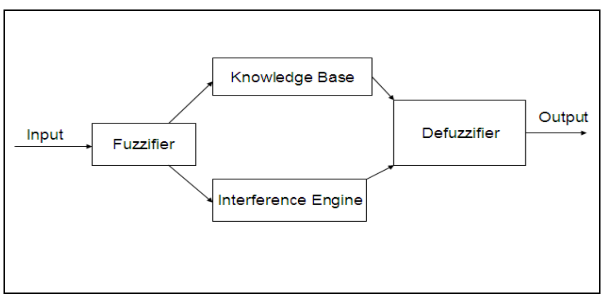

Fig.6 Fuzzy Logic Controller

It consists of four blocks in which fuzzifier is used to classify the input value into a certain linguistic values. The Knowledge base consists of certain control rule sets. Decision making is done in the interference engine. Defuzzifier converts the control action into crisp signals.

Fuzzification consists of input error and change in error. By subtracting the output voltage and the desired voltage the result obtained is an error. These values are multiplied by the gain and fed to a fuzzy logic controller. The result will change in duty cycle. The change in duty cycle and the previous duty cycle are added and given to the MOSFET.

Membership functions of input and output are decided in the first step of fuzzification. Membership functions to input and outputs are PB, PS, ZE, NS, NB. Where NB = Negative big, NS = Negative small, ZE = Zero equal, PS = Positive small, PB = Positive big. Following is rule Table.1 given which is used for change in duty cycle values

TABLE 1 FUZZY CONTROL RULES

Error / Change in Error	NB	NM	NS	ZE	PS	PM	PB
PB	ZE	PS	PM	PB	PB	PB	PB
PM	NS	ZE	PS	PM	PM	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
ZE	NB	NM	NS	ZE	PS	PM	PB
NS	NB	NM	NS	NS	ZE	PS	PM
NM	NB	NM	NM	NM	NS	ZE	PS
NB	NB	NB	NB	NB	NM	NS	ZE

IV. DESIGN CONSIDERATION

The charge is transferred progressively from input to the output by charging the VM stage capacitors. For a converter with four level voltage multiplier the voltage can be derived by,

$$Vc1 = \frac{Vin1}{(1-d1)} \quad (1)$$

$$Vc2 = \frac{Vin1}{(1-d1)} + \frac{Vin2}{(1-d2)} \quad (2)$$

$$Vc3 = \frac{2Vin1}{(1-d1)} + \frac{Vin2}{(1-d2)} \quad (3)$$

$$Vc4 = \frac{2Vin1}{(1-d1)} + \frac{2Vin2}{(1-d2)} \quad (4)$$

$$Vc1 = Vc3 - Vc2 = \frac{Vin1}{(1-d1)} \quad (5)$$

If N is odd,

$$Vout = VCN + \frac{Vin1}{(1-d1)}$$

$$= \frac{N+1}{2}\frac{Vin1}{(1-d1)} + \frac{N+1}{2}\frac{Vin2}{(1-d2)} \quad (6)$$

If N is even,

$$Vout = VCN + \frac{Vin1}{(1-d1)}$$

$$= \frac{N+2}{2}\frac{Vin1}{(1-d1)} + \frac{N}{2}\frac{Vin2}{(1-d2)} \quad (7)$$

The output voltage equation of the voltage multiplier capacitor stages depends upon the number of N stages. If d1 and d2 have the same value, the equation for the output voltage is

$$Vo = \frac{(N+1)Vin1}{(1-D)} \quad (8)$$

The inductor currents in both the boost stages depend on the number of VM stages.
The average inductor current in each boost is given by

$$L = \frac{[(1-d1)Vin1]}{[([N+2)]IoutFsw]} \quad (9)$$

The voltage multiplier stage capacitor is given by

$$C = \frac{\Delta Iout(1-d)}{Fsw\Delta Vc} \quad (10)$$

V. RESULTS AND DISCUSSION

In open loop, the voltage will not be constant for load variations on the motor so a closed loop technique is implemented. For controlling the converter, a fuzzy logic controller is used shown in Fig.8. It consists of input error and change in error. By subtracting the output voltage and the desired voltage the result obtained is an error. These values are multiplied by the gain and fed to a fuzzy logic controller. The result will change in duty cycle. The change in duty cycle and the previous duty cycle are added and given to the MOSFET.

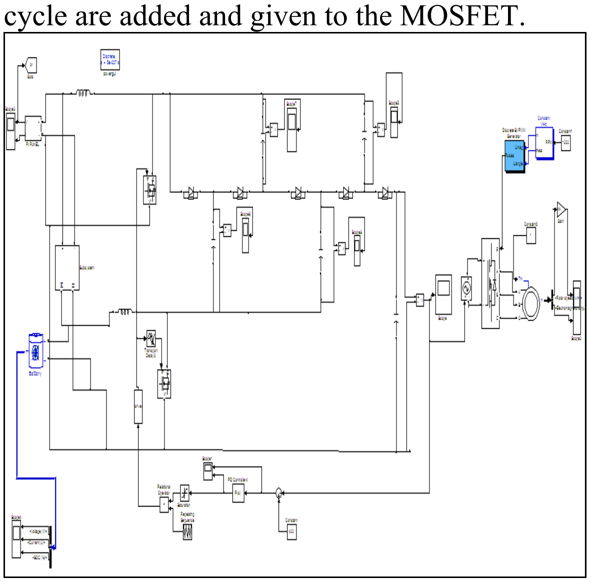

Fig.7 Simulation Model of Multi Input Dc-Dc Converter with High Gain for Solar Powered Systems

Table 1 Boost Converter Parameters

Parameters	Value
Input voltage	25V
Output voltage	30V
Duty ratio, D	0.2593
Inductor, L	1.7Mh
Capacitor, C	3300Mf
Switching frequency	5KHz
Output voltage ripple	0.0159V
Inductor current ripple	0.48V

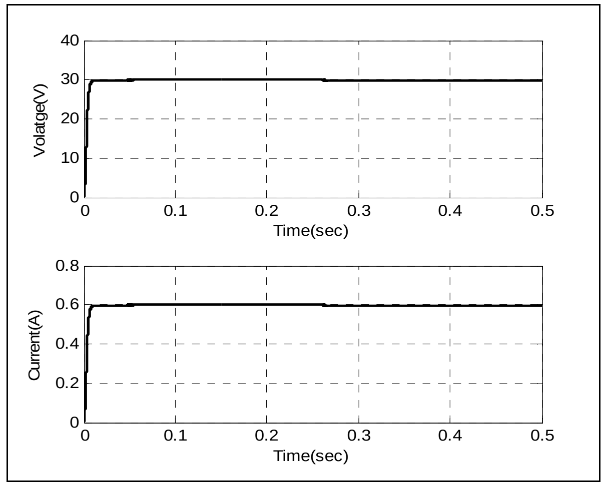

Fig.8 Simulation Result of Photovoltaic System

The photovoltaic system supplies the power to the converter. Battery accumulates the excess energy created by the PV system. For charging and discharging the battery, a boost converter is used. So, by giving an input voltage of 25V, 30V output voltage can be obtained with a switching frequency of 5 kHz.

Table 2 Modified Boost Converter Parameters

Parameters	**Value**
Input voltage	20V
Output voltage	400V
Duty ratio, D	0.75
Inductor, L1, L2	100µH
Capacitor, C1, C2, C3, C4	20µF
Switching frequency	100KHz

The output voltage of the converter is 400V by giving an input voltage of 20V.For the voltage multiplier stage capacitors, the ripple current will be higher therefore a capacitor of 20µF is selected. Thus the developed fuzzy logic controller is very efficient to suppress the fluctuations caused by the variations of the capacitor values and is able to maintain the constant voltage at the output.

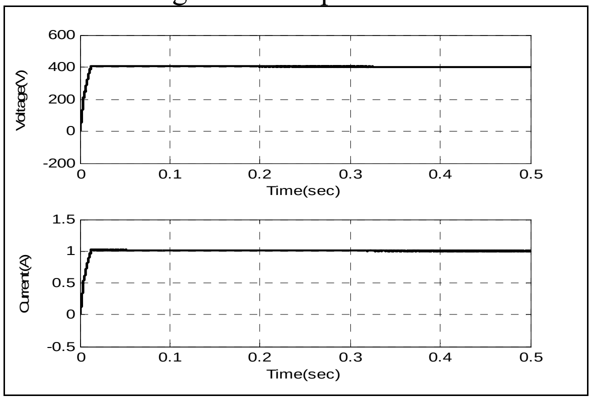

Fig.9 Simulation Result of Multi Input Dc-Dc Converter with High Gain for Solar Powered Systems

The speed and torque waveform of the motor is shown in Fig.10. The noise produced in the PWM inverter is also observed in the electromagnetic waveform Te. However, motor inertia prevents this noise from appearing in the motor's speed waveform

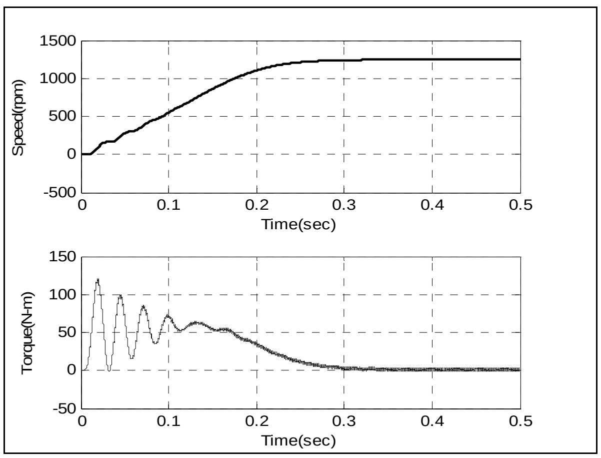

Fig.10 Speed and Torque Waveform

VI. DESIGN AND EXPERIMENT OF PROPOSED CONVERTER

A prototype of the multi input converter is tested. The design consideration of the converter is based on the components selections which are presented in the previous section.

The Fig.11 shows the pulse waveforms of the converter and the Fig .12(a) and (b) shows the pulse waveform of the two legs of the inverter

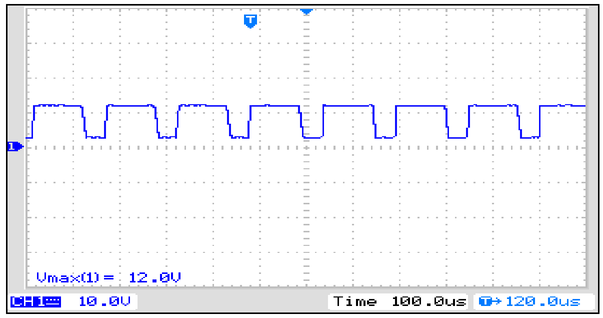

Fig.11 Pulse waveform of converter

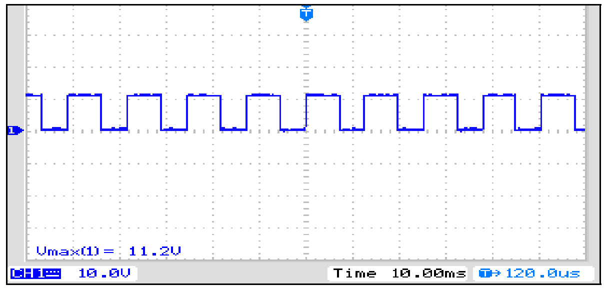

Fig.12 (a) Pulse waveform of inverter

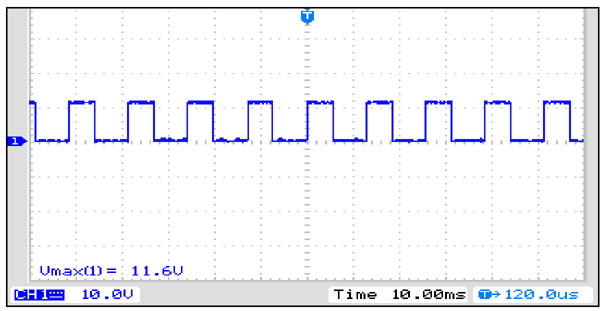

Fig. 12(b) Pulse waveform of inverter

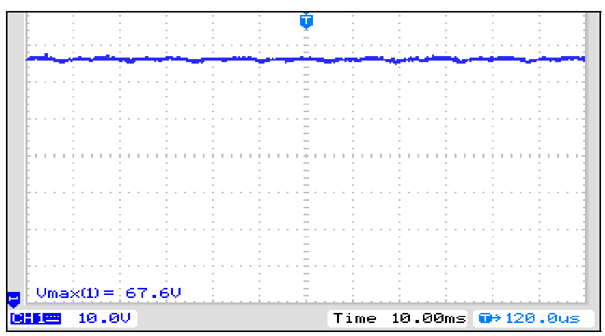

Fig. 13 Output voltage of converter

Fig.13 shows the output voltage of the converter. The output voltage is 67.6V which is obtained by giving an output voltage of 18V. The output voltage is obtained from MOSFET by giving pulse from the MOSFET driver.

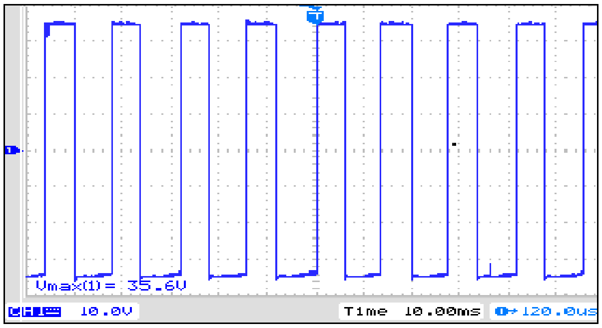

Fig.14 Inverter Phase voltage

The Fig.14 shows the phase voltage from the inverter which is connected to the load which is used to drive the motor. Fig.15 shows the prototype of the converter


Fig. 15 Prototype photograph of the converter

VII. CONCLUSION

In this paper, high gain multi input dc-dc converter with a fuzzy logic controller is proposed. The converter consists of four diode-capacitor voltage multiplier stages. As the number of voltage multiplier stages are increased, the voltage gain is also increased. The converter which is controlled by a fuzzy logic controller is simulated and it is validated through hardware implementation. A simple algorithm based on the prediction of a fuzzy logic controller, possibly using the fuzzy rules parameters is showing to be more convenient. Thus it is observed that the output voltage of the system using a fuzzy logic controller is boosted and thus improves the efficiency of the converter.

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