

Speed Control of a Dual Input Converter fed DC Motor with High Voltage Gain and Internal Battery Charging for Hybrid Electric Vehicles

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ABSTRACT: Renewable energy resources like solar, wind etc are widely used due to its advantages of non pollution and omnipresent. Thus it has become an alternative source to fossil energy which is now used in the Hybrid electric vehicle technology to reduce the pollution due to hydrocarbon emission. Since the solar energy is unstable and discontinuous in nature a multi input converter circuit is used to integrate the energy sources like battery etc. A dual input converter with solar power as primary source and battery as an auxiliary source is proposed here. The high voltage gain and the internal battery charging is attained by using the coupled inductors. According to measure of solar irradiation there are three states of operations, the standalone power supply state (when solar power is enough to drive motor) , the charge state (when solar power is more than enough to drive motor) and the unify power supply state (when the solar power is not sufficient to drive the motor).The speed of the motor is controlled by using the fuzzy logic controller to run the motor at a 1500 rpm. The hardware prototype is implemented to check its feasibility.

KEYWORDS: Dual input converter, Hybrid Electric Vehicles, Fuzzy Logic Controller, Renewable resources

I. INTRODUCTION

One of the most critical issues for the environment today is pollution generated by hydrocarbon combustion which is one of the main sources of power for transportation. Hybrid Electric Vehicles (HEV's) and Electric Vehicles (EV) are an alternative to conventional fuel powered cars and are efficient, more reliable, significantly less complex, cost effective, and environment friendly. However, HEV's have some disadvantages which are the primary obstacle to their widespread distribution. One of the major issues is that the battery should be charged overnight from the electric power grid where energy can be generated from renewable sources. Another major disadvantage of HEV's is short driving range with electric motors due to low efficient electric power supply system. Power electronic converters and new semiconductor devices are key components to meet the targets of extended mileage range and reduced pollution. The growing concern about the protection of natural environment, global warming and depletion of non renewable energy resources has paved the way for the use of renewable energy resources. Solar energy is the most prominent renewable resource which is present abundantly in the nature. The Maximum Power Point Tracking (MPPT) is a technique used with solar systems to maximize power output. The purpose of MPPT system is to sample the output of the PV cells and apply the proper resistance to obtain maximum power for any given environmental conditions. Single input boost converters will be giving a voltage gain of 2 to 3 which is not sufficient for HEV's application. Different green energy sources such as solar-PV, wind, fuel cell, battery, ultra capacitor etc., are highly utilized as a primary energy sources in the modern HEV's to improve the performance and efficiency. The conventional approach of connecting multiple energy sources is placing them either in series or parallel with each other. Sources that are placed

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in series have to conduct the same current which is not always desirable. Also, as different sources have different voltage levels, they cannot be directly connected in parallel. Hence, multi power converters are required to connect multiple sources in a single system in order to supply the load demand. If we are using separate converters for each source the cost, complexity and size gets increased. A multi input converter will integrate different energy sources thus can reduce the size, cost, weight and complexity.

In recent years, multi input converters with high voltage gain have been receiving more attentions. All the dual input converters designed for HEV's so far, use a boost, buck-boost converter, transformers, coupled inductors etc. to achieve the high voltage gain. Also internal battery charging is done by using two switches thereby bidirectional mode of operation is conducted for charging and discharging. A new topology, with a high gain in voltage and internal battery charging by using a coupled inductor, is introduced here which can eliminate the use of these extra switches and high voltage gain also can be attained.

II. RELATED WORK

Seyedrasoul Saneifard et al. ^[1] described the development of a fuzzy logic controller to maintain constant speed in a shunt connected DC motor operating under various shaft loading conditions. Using a commercially available fuzzy logic development kit, fuzzy sets and fuzzy "If-Then" rules are developed for this application, and minimization is performed on a speed error signal.

B. G. Dobbs and P. L. Chapman ^[2] discussed about the topology of multi input DC-DC converter derived from a buck boost converter. The energy is stored in a single inductor and discharges to capacitor which is connected across the load. It will operate in different modes of operations such as buck, boost, buck-boost. The circuit is simple with less number of components and cost effective. The limitations include less voltage gain, switching losses etc.

Zhao Q. and Lee F.C. ^[3] discussed about a family of high efficiency, high step-up clamp mode converters without extreme duty ratios. Circuit is similar to the active clamped flyback converter with an additional diode and capacitor. The coupled winding and output rectifier together act as a switch similar to a magnetic switch serving the same function as the active-clamp switch. Topologies with one active switch have significantly reduced cost and circuit complexity, thus the reliability of the converter could be dramatically increased.

Hirofumi Matsuo et. al. ^[4] developed a new multiple input DC DC converter for realizing the zero emission electric power generation system. The buck boost type DC DC converter, in which multiple input windings having magnetic coupling through the energy storage reactor L and using the magnetic coupling of the isolation transformer T, to obtain the forward type multiple input DC DC converter. They developed a circuit configuration for the dual input buck boost converter with solar array and the commercial ac line as input power resources dividing into four states of operation with three major modes. The static and dynamic characteristics are clarified theoretically, and the results are confirmed by experiment.

Wai R. J. and Duan R. Y. ^[5] discussed about the design of a high-efficiency, high step-up converter with coupled-inductor to regulate a stable constant DC voltage. To achieve this goal, the manipulation of a coupled inductor with a lower voltage rated switch and a passive regenerative snubber circuit is adopted to promote the voltage gain. The designed converter circuit has the following features of high voltage gain, the stray energy can be recycled by a passive regenerative snubber. The diode short-circuits and reverse-recovery problems are solved because of all the diodes possessing voltage clamping properties.

Chan, C.C. ^[6] discussed about the state of the art of Electric Vehicles (EVs), HEVs and Fuel Cell Vehicles (FCVs), with a focus on HEVs. Significance, key issues, history, engineering philosophy and the architectures of EVs, HEVs and FCVs are studied. It also provides an overview of the current status of HEVs and FCVs. Also discusses the key technologies, including electric motor technology, power converter technology, control and power management technology, and energy storage device.

Wai R.J. et al. ^[7] developed a multi input single stage bidirectional converter with a three winding coupled inductor and two switches to accomplish multi input mechanism. Depending on the switching conditions the circuit is operated in discharge, charge and alone states. The winding voltage in the high voltage side of the coupled inductor is manipulated further to increase the voltage gain. This is useful for low power applications. All switches and diode have favourable voltage clamping effects so that the voltage spikes caused by the leakage inductor energy can be alleviated effectively, and reverse recovery currents within diode is reduced. There is also a low voltage type charge circuit with

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no increase in additional circuit elements. This helps to avoid power losses caused from multi stage conversions in traditional power systems. This also utilizes the synchronous rectification technique to further decrease conduction losses.

Wai R.J. et al.^[8] discussed about a high step-up bidirectional isolated converter with two input power sources, and this converter directly utilizes the current-source type applying to both input power sources. An active clamping circuit is employed for avoiding the switch voltage spikes caused by the leakage inductor. The salient features are high step-up ratio, electric isolation between the clean energy and output voltage, multiple input power sources, bidirectional power flow control of batteries, and the excellent property of low-voltage side with high current and high-voltage side with low current for selecting suitable power devices could be obtained. According to the power dispatch, this converter could be operated at three different states, including a stand-alone state, a united power supply state, and a charge and discharge state. The limitations are the use of transformer and seven switches (due to ac to DC conversion) increases the cost, size and complexity.

Qian Z. et al.^[9] discussed about a integrated four-port DC/DC converter having bidirectional capability with solar, wind and battery as three input port and one isolated output. Its components include four main switches, two diodes, one transformer, and one inductor. Zero-voltage switching (ZVS) can be achieved for all main switches to allow higher efficiency at higher switching frequency, which will lead to more compact design of this multiport converter. A decoupling network is introduced to allow the separate controller design for each power port. The limitations are cost and size gets increased due to use of transformers and also the use of four switches increases the control complexity. The circuit is also complex.

C. C. Chan et. al.^[10] provided a timely review of the state of the art of BEVs, HEVs, and FCVs, with a focus on architectures and energy-management models. Three issues are important in the development of these vehicles: 1) system architecture; 2) energy management; and 3) commercial concerns. There are three types of system architectures used in hybrid vehicles, i.e., series, parallel, and series-parallel. Graphical formalisms, e.g., EMR, are interesting tools, allowing a global overview of the system while taking into account the main physical properties. Commercialization roadmaps generally include strategic plans, sufficient funding, innovative core technology, an understanding of the market demand, as well as the required infrastructure and services.

Muhammad Firdaus Zainal Abidin et al.^[11] performed a comparative study between PI, fuzzy and hybrid PI-Fuzzy controller for speed control of Brushless DC (BLDC) motor. A fuzzy controller offers better speed response for start-up while PI controller has good compliance over variation of load torque but has slow settling response. Hybrid controller has an advantage of integrating a superiority of these two controllers for better control performances.

Kumar L. and Jain S.^[12] discussed about the non-isolated two input sources DC-DC converter with the possibility of bidirectional power flow and is capable of operating in buck, boost and buck boost modes. In addition, all the input sources are connected to the load through a single inductor. Unidirectional and bidirectional modes of operations are possible by using four switches in the circuit. The limitations are cost and size gets increased due to the use of four switches which also increases the control complexity.

Yuanmao Y. and Cheng K.W.E.^[13] discussed about the level shifting switched voltage-copier circuitry which converts the two voltage levels to other eight voltage levels. This multilevel switched-capacitor converter is composed of five kinds of switched-capacitor conversion circuits. It includes summation circuit, subtraction circuit, double circuit, half circuit, and inverting circuit. Each of the circuits used only two switches, two diodes and two capacitors thus, the size of the circuits is very small and simple enough to handle. The major drawbacks of this circuitry are the limitation of duty cycles restrains the amount of output power, and the problem of reverse recovery currents within diodes is existed.

Wai R. J.^[14] developed a high efficiency converter with two input power sources for a distributed power generation mechanism. The converter can boost the varied voltages of different power sources in the sense of hybrid power supply to a stable output dc voltage for the load demand. An auxiliary circuit is employed for achieving turn on zero voltage switching (ZVS) of all switches. According to various situations, the operational states of the proposed converter can be divided into two states including a single power supply and a dual power supply. In the dual power supply state, the input circuits connected in series together with the designed pulse width modulation can greatly reduce the conduction loss of the switches. In addition, the effectiveness of the designed circuit topology and the ZVS properties are verified by experimental results, and the goal of high-efficiency conversion can be obtained.

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Jay Patel and Gaurag Sharma^[15] presented the modeling, simulation and implementation of the solar photovoltaic cell using MATLAB/SIMULINK. The I-V, P-V and I-V characteristics are obtained for single solar cell module, solar PV module with variable temperature and fixed radiation, solar PV module with fixed temperature variable radiation with M-file and mathematical model. With increase in the solar radiation, higher would be the solar input to the solar cell and hence power magnitude would increase for the same voltage value also the open circuit voltage of the PV panel increases.

Wai R. J. and Lian Sheng Hong^[16] discussed about a dual input converter with internal charge circuit and high voltage gain. High voltage gain is attained through coupled inductor and this proposed coupled inductor based converter could be operated at the standalone power-supply state, the charge state and the united power supply state. The auxiliary power source battery is charged through coupled inductor from the main source thus provides redundant source of energy. Voltage clamping and soft switching techniques are employed to reduce the switching stress.

Sivaprasad A et.al.^[17] developed a non - isolated dual input DC DC converter for the integration of nonlinear VI characteristic DC sources for the vehicle propulsion system. The multi input DC DC buck boost converter having different operating modes i.e., boost, buck, and buck boost is proposed here. The main limitation of this is the less voltage gain and if battery is using as a secondary then it should be charged separately. The energy from both sources is required to drive the motor.

III. PROPOSED DUAL INPUT CONVERTER FOR HEV's

A high efficiency dual input coupled inductor based converter with an internal charge circuit and high voltage gains convert two low voltage input power sources to a high voltage DC. The coupled inductor based converter uses only two semiconductor switches for converting the two different low voltage input sources to a high voltage DC. The battery is internally charge through coupled inductor from the main source. Thus energy is saved efficiently and effectively. The system configuration of a high efficiency dual input converter is depicted in Fig. 1. According to measure of solar irradiation there are three states of operations, the standalone power supply state (when solar power is enough to drive motor), the charge state (when solar power is more than enough to drive motor) and the unified power supply state (when the solar power is not sufficient to drive the motor). The speed of the motor is controlled by using the fuzzy logic controller to run the motor at a 1500 rpm.

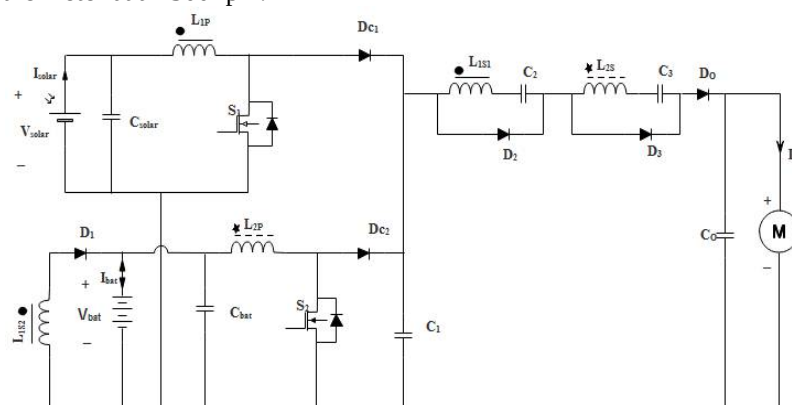


Fig.1.Circuit diagram of dual input converter

The circuit explanations are as follows. $V_{solar}(I_{solar})$ and $V_{bat}(I_{bat})$ denote the voltage (currents) of the main source (solar panel) and the auxiliary source (battery), respectively. I_o represents the output current. C_{solar} , C_{bat} and C_o are the filter capacitors; C_1 represents the clamping capacitor; C_2 and C_3 are the middle voltage capacitors. L_{1P} , L_{1S1} and L_{1S2} represents the individual inductors in the primary, secondary and tertiary sides of the coupled inductor (Tr_1), respectively; L_{2P} and L_{2S} represent individual inductors in the primary and secondary sides of the coupled inductor (Tr_2), respectively. S_1 and S_2 are the main and the auxiliary switches in this converter circuit. D_{c1} and D_{c2} are the clamping diodes, D_1 is the charge diode, D_2 and D_3 are the middle voltage diodes, D_o is the output diode. The output load is represented as DC Motor. According to measure of solar irradiation there are three states of operations, the standalone

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power supply state (when solar power is enough to drive motor) , the charge state (when solar power is more than enough to drive motor) and the unified power supply state (when the solar power is not sufficient to drive the motor).

Standalone Power Supply State

In the proposed system main source represents the solar panel and the auxiliary/secondary dc sources is a battery which is utilized here as a backup source. When the solar power or the irradiation is enough to drive the motor only the solar energy is utilized making battery as idle source. The different modes of operation of the standalone power supply state are depicted in Fig 2 (a) Mode 1 of the Standalone Power Supply State. (b). Mode 2 of the Standalone Power Supply State. (c). Mode 3 of the Standalone Power Supply State. (d). Mode 4 of the Standalone Power Supply State. (e). Mode 5 of the Standalone Power Supply State.

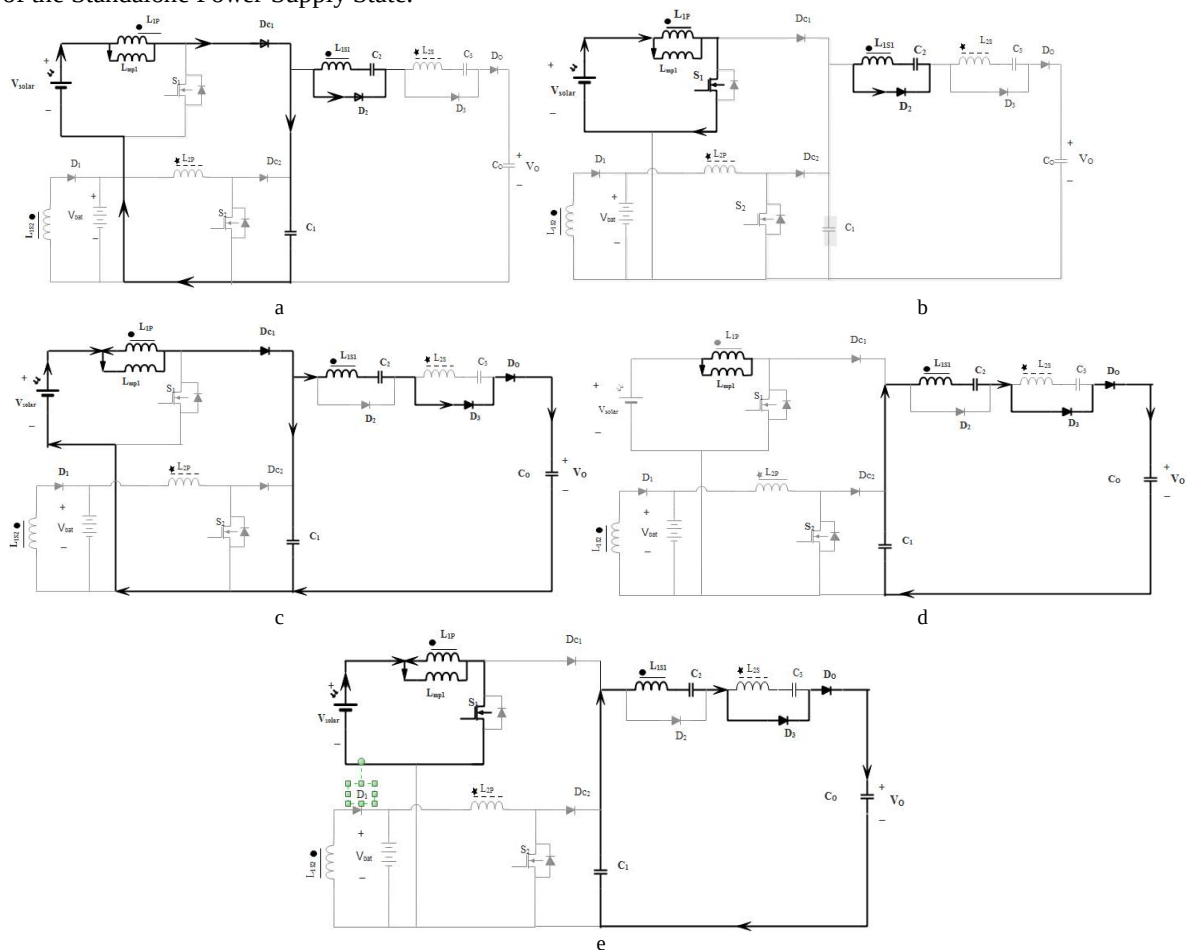


Fig. 2. Modes of operation of the standalone power supply state (a).Mode 1 (b). Mode 2 (c).Mode 3 (d).Mode 4 (e).Mode 5

Mode 1: The main switch S_1 was turned on and the diodes D_3 and D_0 are turned off. The primary DC input source (PV panel) delivers energy to the primary of the coupled inductor (T_{R1}). The diode D_2 gets turned on when the secondary of the coupled inductor (T_{R1}) gets charged at positive polarity. The secondary current charges the capacitor C_2 .

Mode 2: The switch S_2 is turned off. The diode D_2 is turned on and charges the capacitor C_2 . Since the voltage across the switch S_1 is greater than the voltage across the capacitor C_1 , the diode D_{c1} gets forward biased and conducts to charge the capacitor C_1 . Thus the energy gets transferred from the inductor to the clamping capacitor. The diode D_2 gets reverse biased or turned off when the inductor energy is completely released to charge the capacitor C_2 .

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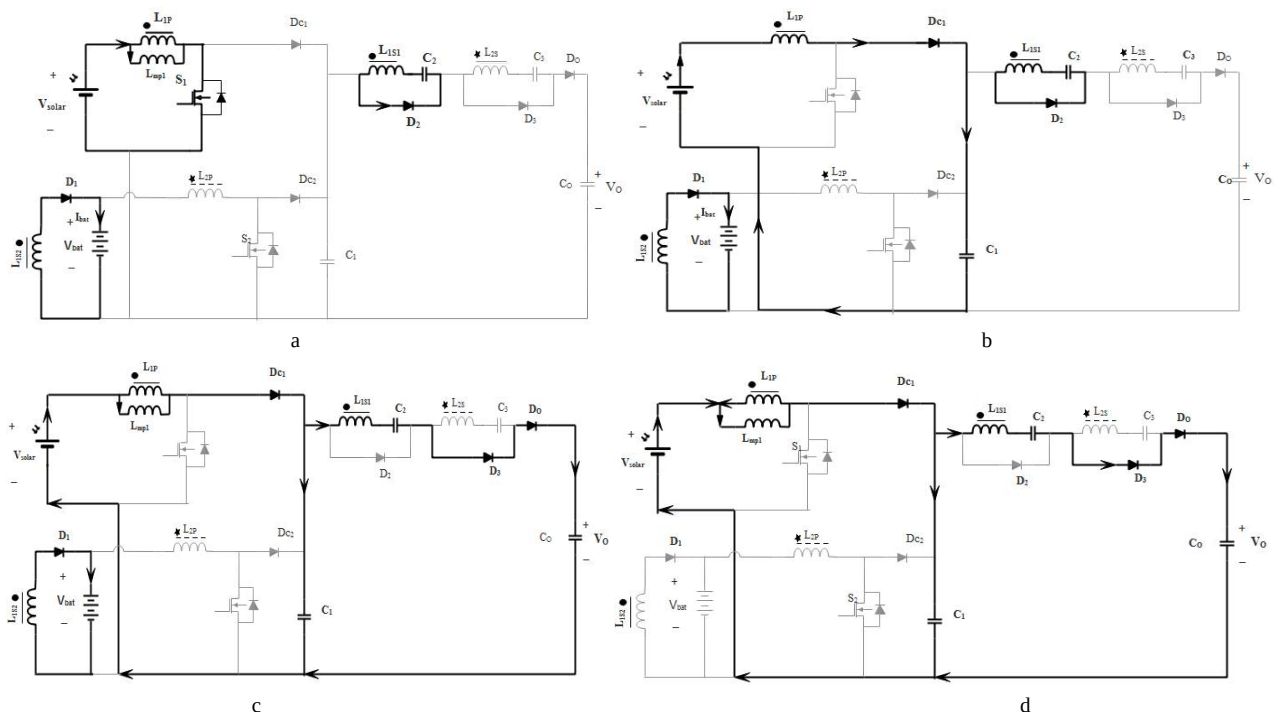
Mode 3: The switch S_1 is turned off and the secondary current of coupled inductor (T_{R1}) flows through diodes D_3 and D_0 to charge the output side capacitor C_0 . The diode D_{C1} still conducts to transfer the energy from the coupled inductor (T_{R1}) to the capacitor C_1 .

Mode 4: The switch S_1 is turned off. Now the diode D_{C1} turns off or gets reverse biased since the primary current is fully released to charge the capacitor C_1 and the voltage across capacitor C_1 is greater than voltage across the switch. The capacitor C_1 and C_2 is connected in series to release the energy through the diode D_3 and D_0 to charge the output capacitor C_0 .

Mode 5: In this mode the switch S_1 is turned on again and the capacitor C_1 and C_2 is connected in series to release the energy through the diodes D_3 and D_0 to charge the output capacitor C_0 . the diode D_{C1} is a low voltage schottky diode so that it will cutoff without a reverse recovery current.

Charge State

In the proposed system main source represents the solar panel and the auxiliary/secondary dc sources is a battery which is utilized here as a backup source. When the solar power or the irradiation is more than enough to drive the motor that extra available energy is efficiently utilized here to charge the battery. Thus energy can be saved efficiently and effectively with the use of a coupled inductor (T_{R1}) and a diode D_1 . The charge state is similar to the standalone power supply state and the only difference is that the tertiary current from the coupled inductor T_{R1} is utilized to charge the battery (V_{bat}). The different modes of operation of the charge state are depicted in Fig 3. (a). Mode 1 of operation of the charge state. (b). Mode 2 of operation of the charge state. (c). Mode 3 of operation of the charge state. (d). Mode 4 of operation of the charge state. (e). Mode 5 of operation of the charge state. (e). Mode 6 of operation of the charge state.



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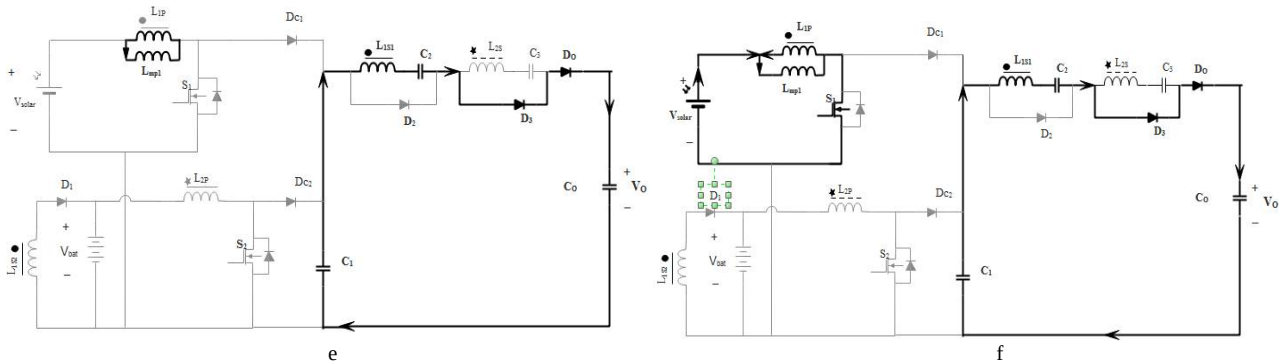


Fig. 3. Modes of operation of the charge state (a). Mode 1 (b). Mode 2 (c). Mode 3 (d). Mode 4 (e). Mode 5 (f). Mode 6

Mode 1: The main switch S_1 was turned on and the diodes D_3 and D_0 are turned off. The primary DC input source (PV panel) delivers energy to the primary of the coupled inductor (T_{R1}). The diode D_2 gets turned on when the secondary of the coupled inductor (T_{R1}) gets charged at positive polarity. The secondary current charges the capacitor C_2 . The tertiary winding inductor current flows through diode D_1 to charge the battery.

Mode 2: The switch S_2 is turned off. The diode D_2 is turned on and charges the capacitor C_2 . Since the voltage across the switch S_1 is greater than the voltage across the capacitor C_1 , the diode D_{C1} gets forward biased and conducts to charge the capacitor C_1 . Thus the energy gets transferred from the inductor to the clamping capacitor. The diode D_2 gets reverse biased or turned off when the inductor energy is completely released to charge the capacitor C_2 . The tertiary winding inductor current flows through diode D_1 to charge the battery.

Mode 3: The switch S_1 is turned off and the secondary current of coupled inductor (T_{R1}) flows through diodes D_3 and D_0 to charge the output side capacitor C_0 . The diode D_{C1} still conducts to transfer the energy from the coupled inductor (T_{R1}) to the capacitor C_1 . The tertiary winding inductor current flows through diode D_1 to charge the battery.

Mode 4: The switch S_1 is turned off and the secondary current of coupled inductor (T_{R1}) flows through diodes D_3 and D_0 to charge the output side capacitor C_0 . The diode D_{C1} still conducts to transfer the energy from the coupled inductor (T_{R1}) to the capacitor C_1 .

Mode 5: The switch S_1 is turned off. Now the diode D_{C1} turns off or gets reverse biased since the primary current is fully released to charge the capacitor C_1 and the voltage across capacitor C_1 is greater than voltage across the switch. The capacitor C_1 and C_2 is connected in series to release the energy through the diode D_3 and D_0 to charge the output capacitor C_0 .

Mode 6: In this mode the switch S_1 is turned on again and the capacitor C_1 and C_2 is connected in series to release the energy through the diodes D_3 and D_0 to charge the output capacitor C_0 . the diode D_{C1} is a low voltage schottky diode so that it will cutoff without a reverse recovery current.

Unify Power Supply State

In the proposed system the auxiliary/secondary DC sources is a battery which is utilized here as a backup source. When the solar power or the irradiation is not sufficient to drive the motor that energy is drawn from the battery with the use of a coupled inductor (T_{R2}) and a auxiliary switch S_2 . The different modes of operation of the unify power supply state is depicted in Fig 4 below. (a). Mode 1 of operation of the unify power supply state. (b). Mode 2 of operation of the unify power supply state. (c). Mode 3 of operation of the unify power supply state. (d). Mode 4 of operation of the unify power supply state. (e). Mode 5 of operation of the unify power supply state. (f). Mode 6 of operation of the unify power supply state. (g). Mode 7 of operation of the unify power supply state. (h). Mode 8 of operation of the unify power supply state.

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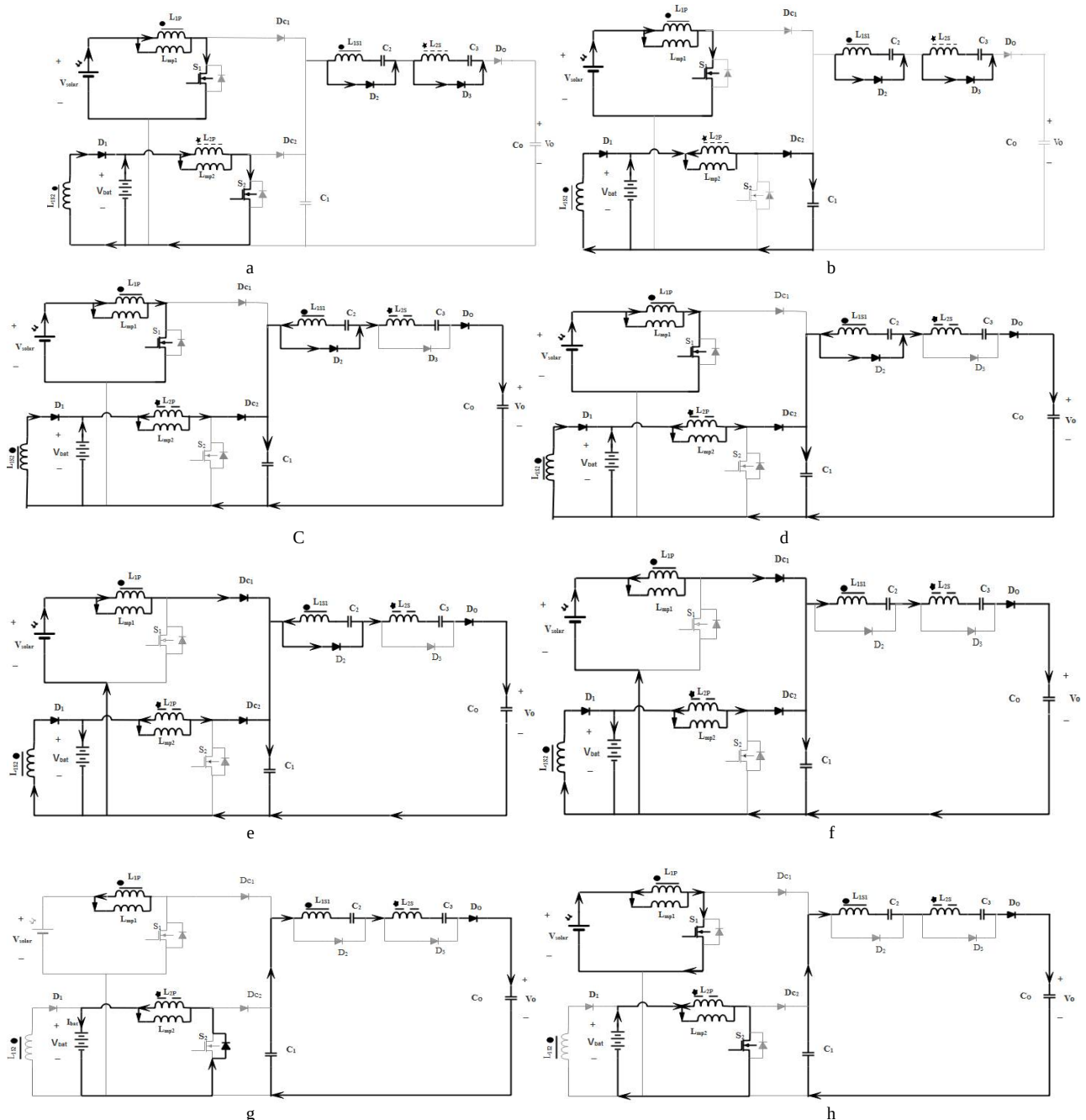


Fig. 4. Modes of operation of the unify power supply state. (a). Mode 1 (b). Mode 2 (c). Mode 3 (d). Mode 4 (e). Mode 5 (f). Mode 6 (g). Mode 7 (h). Mode 8

Mode 1: In this mode both the switches S_1 and S_2 are turned on. The primary source of solar panel and secondary source of battery delivers energy to the primary of the respective coupled inductors (T_{R1} and T_{R2}). The diode D_0 is turned off. The diodes D_1 , D_2 , and D_3 get forward biased since the secondary of the coupled inductors (T_{R1} and T_{R2}) charges at positive polarity. The capacitor C_2 and C_3 get charged by the respective secondary current of coupled inductor (T_{R1} and T_{R2}).

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Mode 2: The switch S_1 is turned on while the switch S_2 is turned off. Since the voltage across the switch S_2 is greater than the voltage across the capacitor the diode D_{C2} gets forward biased. Thus the energy is transferred from the primary of the coupled inductor (T_{R2}) to the capacitor C_1 . The diode D_3 gets reversed biased when the energy gets completely released to charge the capacitor C_3 from the coupled inductor (T_{R2}).

Mode 3: The switch S_1 is turned on while the switch S_2 is turned off. The voltage across the capacitor C_3 charges the output capacitor C_O through the diode D_O . The diode D_{C2} gets reverse biased when the energy is completely released. The tertiary current of the coupled inductor (T_{R1}) flows through diode D_1 to charge the battery source (V_{bat}). This mode ends when the energy from the coupled inductor gets fully transferred to the clamping capacitor that is C_1 .

Mode 4: The switch S_1 is turned on while the switch S_2 is turned off. The capacitors C_1 and C_3 are connected in series to deliver the energy for the charging of the output capacitor C_O through the diodes D_3 and D_O . The tertiary current of the coupled inductor (T_{R1}) flows through diode D_1 to charge the battery source (V_{bat}).

Mode 5: The switch S_1 is turned on while the switch S_2 is turned off. The diode D_{C1} conducts to transfer the from the primary of the coupled inductor (T_{R1}) to the clamping capacitor C_1 . The energy from the secondary of the coupled inductor (T_{R1}) charges the capacitor C_2 through diode D_2 . The tertiary current of the coupled inductor (T_{R1}) flows through diode D_1 to charge the battery source (V_{bat}). This mode ends when the energy from the coupled inductor (T_{R1}) is fully transferred to charge the capacitor C_2 and the diode D_2 gets reverse biased.

Mode 6: Both the switches (S_1 and S_2) are turned off. The secondary current of the coupled inductor T_{R1} flows through diode D_O to the output side. This mode ends when the diode D_{C1} and D_1 gets reverse biased that is when the inductor energy gets completely transferred.

Mode 7: Both the switches (S_1 and S_2) are turned off. The capacitors C_2 and C_3 are connected in series to transfer the energy to the output side.

Mode 8: In this mode both the switches S_1 and S_2 are triggered and the capacitors C_2 and C_3 are still connected in series to transfer the energy to the output side through diode D_O and the same cycle is repeated.

IV. SIMULATION RESULTS

The simulation of the highly efficient dual input converter is carried out in the MATLAB/Simulink. The primary input voltage source V_{Solar} is 12V solar panel with a MPPT (P&O algorithm) technique employed to track the maximum power and V_{Bat} as Battery source of 24V. The load connected is a separately excited DC Motor of 5HP, 240V, 1750 rpm. Thus has attained a voltage gain of 20 with an efficiency of 95%. The various parameters used in the simulation are given in Table 1.

Table 1. Simulation parameters used

Parameters	Specifications
Input Voltage of Source 1(V_{Solar})	12V
Input Voltage of Source 2(V_{BT})	24V
Load (DC Motor)	5 HP, 240 V, 1750 rpm
Switching Frequency	10 kHz
Coupled Inductor(Turns Ratio)	$Tr_1=2:14:4$, $Tr_2=3:9$
Switches	S_1 (MOSFET) 100V
	S_2 (MOSFET) 100V
Capacitor	$C_1=845\mu F$, $C_2=17\mu F$, $C_3=28\mu F$, $C_0=100\mu F$
Diode	$D_2=220V$, $D_3=220V$, $D_{C1}=100V$, $D_{C2}=100V$

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The closed loop control of the converter was done using Fuzzy Logic Controller to control the speed of the motor to run at a constant speed of 1500 rpm. Fuzzy logic control (FLC) is a control algorithm based on a linguistic control strategy which tries to account the human's knowledge about how to control a system without requiring a mathematical model. Mamdani type of fuzzy logic is used for speed controller. Inputs for fuzzy logic controller are the speed (S) and change of speed (ΔS). Change of speed (ΔS) is calculated with comparison between reference speed and the actual speed. The most important things in fuzzy logic control system designs are the process design of membership functions for input, outputs and the process design of fuzzy if-then rule knowledge based. The Figure 2 shows the simulation diagram of the proposed converter and its corresponding waveforms are shown in Figures 5,6 and 7. Switching pulses for the switch S_1 is obtained by comparing the MPPT voltage with a carrier signal to produce the pwm signals. For the switch S_2 the output from the fuzzy controller is given.

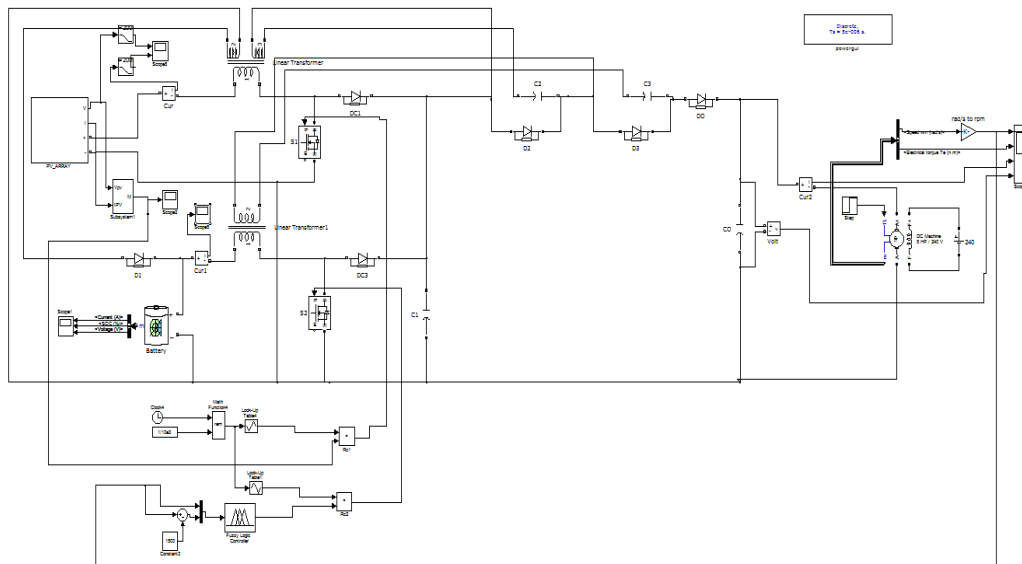


Fig. 5. Simulation diagram of the dual input converter.

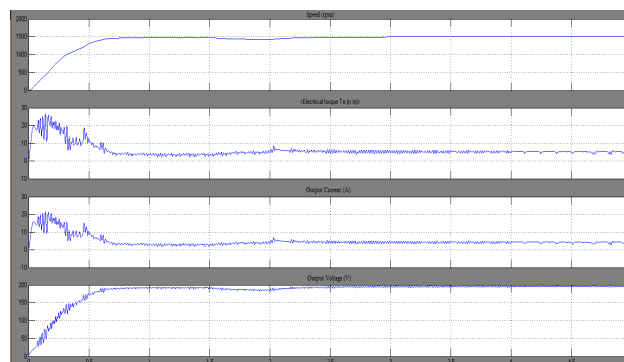


Fig. 6. Waveform obtained from simulation of dual input converter connected to the 5HP DC Motor.

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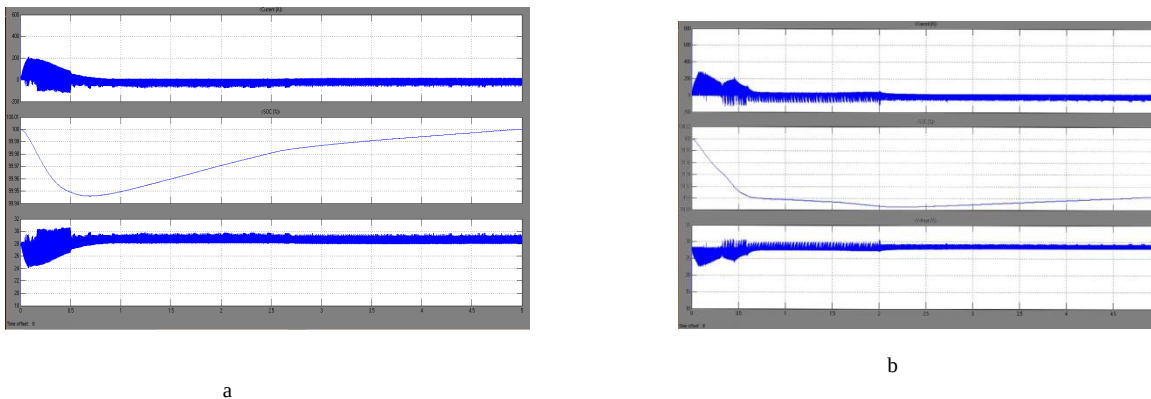


Fig. 7. Battery status (a). Standalone power supply state (b). Charge/discharge state

From the simulation waveforms obtained it is observed that the DC Motor of 5HP is running at a speed of 1500 rpm even when the load torque gets increased from 0.4 Nm to 2 Nm at a step time of 2.5 sec. At standalone power supply state the value of irradiation given is 10 and for unified power supply state irradiation is given as a step input of value 0.5 to 10 at the step time of 2. The battery power is utilized only during starting; where starting current is high for a motor and when the primary voltage source is not sufficient to run the motor.

V. HARDWARE IMPLEMENTATION

The hardware unit consisting of solar panel and battery as two input sources, universal DC motor as load, a dual input converter circuit, two MOSFET driver circuit, a PIC microcontroller for controlling the system. The actual speed of the motor is sensed by the proximity sensor and the analog input is converted to digital using a ADC and fed to the microcontroller. The reference speed is set using a potentiometer and fed to the microcontroller. In the PIC the fuzzy logic is implemented in C program and by using a compiler MicroC Pro it is converted to hex codes. These hex codes are directly burned in to the chip in to the flash memory. According to the fuzzy set rules, the required output is generated. These switching pulses are of 5 volt which is not sufficient to power the MOSFET switch. Using a MOSFET driver circuit the required switching pulses with 12 volt is generated. These pulses are given to the MOSFET. The LCD will display the input voltage and speed of the motor. The Fig. 8 represents the hardware prototype implemented.

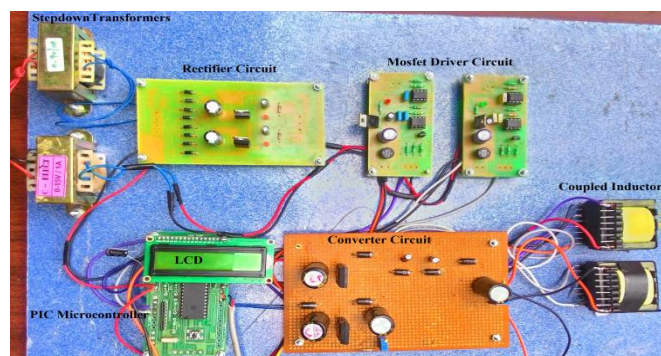


Fig. 8. The hardware prototype

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Hardware Output

The output of the hardware implementation is shown in the Fig. 9 below. In order to operate the hardware prototype in the three states of operation i.e., standalone power supply state, charge state and the unify power supply state the panel voltage is adjusted. In the standalone power supply state the solar panel voltage is set at 12V and the motor gets power only from it. The CRO is connected across the gate terminals of two switches to show that switch across panel is only triggered right now and is shown in Fig.9.a. In the charge state the solar voltage is set above 12 volt and the extra power is utilized to charge the motor. This can be indicated by connecting a ammeter parallel to the battery. The CRO connected across the gate terminals of two switches to show that switch across panel is only triggered right now is shown in Fig.9.b. In the unify power supply state where solar power is not sufficient to drive motor the panel voltage is set below 12V and we can find that from the Fig.9.c. both the switches are triggered and supply from panel and battery is utilized to drive the motor now all for a constant motor speed. The output voltage attained is 65V and is shown in the Fig 9.d. in order to run the motor at a speed of 1500 rpm for a universal DC motor of 9000 rpm, 50 watts, 220/230 V.

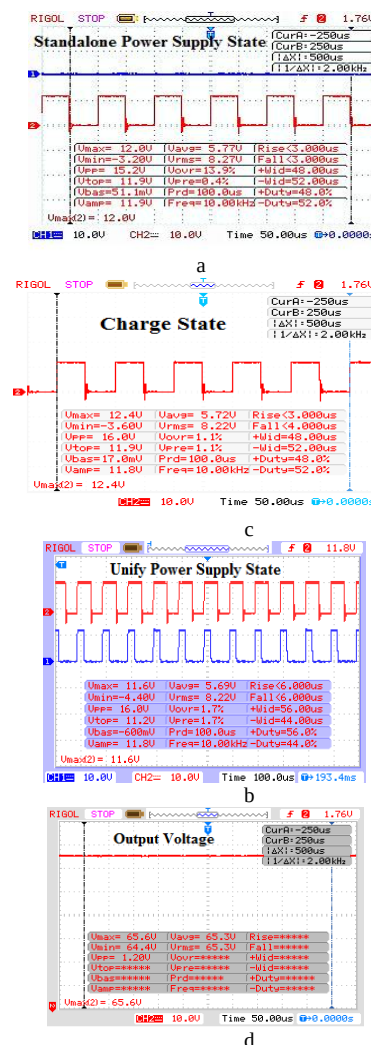


Fig. 5.10. Hardware Output. (a). Duty Cycle of Both Switches at Standalone Power Supply State. (b). Duty Cycle of Both Switches at Charge State. (c). Duty Cycle of Both Switches at Unify Power Supply State. (d). Output Voltage.

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VI. CONCLUSION

A high efficiency dual input converter with high voltage gain and internal charge function was designed to drive a DC motor. The speed control is done using an artificial intelligence fuzzy logic controller to control the speed of the dc motor to run at a constant speed of 1500 rpm. Two coupled inductors are used for each input sources. The turns ratio is designed such that with solar panel of 12V and battery of 24V, a 5HP DC motor is driven. The voltage gain attained is 20. The switching stresses are reduced considerably with voltage clamping and soft switching techniques. The efficiency of the proposed system increases to 95%. The hardware prototype is implemented to check the feasibility. Thus a hybrid electric vehicles powered by dual input converter is designed such that with each source can drive the motor alone and also by sharing, if the energy from each source is insufficient.

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