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Engineering

REGENERATIVE ENERGY STORAGE AND G2V CHARGING FOR BLDC MOTOR DRIVEN ELECTRIC VEHICLE

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ABSTRACT A new bridgeless single-phase ac–dc converter with a natural power factor correction (PFC) is discussed for grid to vehicle charging, a dc-dc bidirectional converter for regeneration and energy storage to battery. Compared with existing single-phase bridgeless topologies, the proposed topology has the merits of less component counts. The absence of an input diode bridge and the presence of only one diode in the current path during each stage of the switching cycle result in higher power density and less conduction losses; hence, improved thermal management compared to existing PFC rectifiers is obtained. The proposed topology is designed to work in resonant mode to achieve an automatic PFC close to unity in a simple and effective manner. The resonant mode operation gives additional advantages such as zero-current turn-on in the active power switches, zero-current turn-off in the output diode and reduces the complexity of the control circuitry. Principle of operation and the feasibility of the discussed converter are provided. The overall systems consist of an ac-dc converter, a battery, a bidirectional converter and a BLDC motor with control.

KEYWORDS : Power factor correction, soft switching, ac-dc converter, bidirectional dc-dc converter, BLDC motor, battery.

I.INTRODUCTION

There is an increasing interest in deployment of electric vehicles (EVs) to reduce greenhouse emissions and fuel usage. The growing environmental awareness, innovation, and the government support are together paving the way for EVs. However, the wide adoption of these vehicles is limited. One of the reasons for this is the limited availability of electric vehicle battery chargers. Moreover, EV charging technologies that are fast, efficient, and low cost with a small form factor are needed. In addition to that, these technologies should have features to minimize harmonics and operate at high power factor. Their impact on the grid should be minimal as they would contribute to a significant share of the grid load in future. Another desirable feature is the ability to provide ancillary services to support smart grids [1].

A new bridgeless single-phase ac–dc converter with a natural power factor correction is discussed. Compared with existing single-phase bridgeless topologies, the discussed topology has the merits of less component counts. The absence of an input diode bridge and the presence of only one diode in the current path during each stage of the switching cycle result in higher power density and less conduction losses; hence, improved thermal management compared to existing PFC rectifiers is obtained.

The discussed topology is designed to work in resonant mode to achieve an automatic PFC close to unity in a simple and effective manner. The resonant mode operation gives additional advantages such as zero-current turn-on in the active power switches, zero-current turn-off in the output diode and reduces the complexity of the control circuitry. The focus of this project is to analyze the present EV charger technologies and introduce a topology that has the potential to bridge the gap between the infrastructure and the demand for EVs. The system consist of a BLDC motor drive for regeneration with fuzzy logic controller and a bidirectional dc-dc converter .The proposed system with block diagram and circuit is given in figure1.1. The following section discusses the different types of EV charger. The following section discusses the different types of EV charger.

a.Types of EV Chargers

EV chargers are classified into two types based on their energy transfer methods. Both the methods have different power electronics interfaces and their own advantages and limitations related to efficiency, usage, and the infrastructure [3] [4] [5].

- Conductive Chargers
- Inductive Chargers

a.Standards of EV charger

This section deals with the Charge Method Electrical Ratings according to SAE EV Charging Power Levels. The chargers are classified by power they can provide to the battery pack. The classification is separately shown for AC and DC Charging systems [7] [8].

- AC Charging System
- DC Charging System

II.PROPOSED BLOCK DIAGRAM

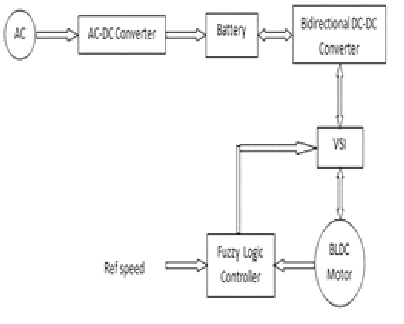

Fig.1. Block diagram of proposed system

The proposed system consists of an ac-dc converter to convert the ac supply to dc and is fed to the battery. The battery is connected to a bidirectional dc-dc converter. The converter converts dc voltage to the required value for the smooth working of motor. The speed of the motor is controlled using fuzzy logic controller where forward operation and regeneration mode is controlled. The ac-dc converter here used is a pseudo resonant boost converter and bidirectional converter is buck boost converter. The detailed explanations and block diagram is given in figure 1.

a.A Resonant Pseudo boost PFC Rectifier For EV Charging

Power supplies with active power factor correction techniques are becoming necessary for many types of electronic equipment especially in the telecommunication and computer industries to meet harmonic regulations and standards, such as the EN61000-3-2. Also, higher power density and lower system cost are always very desirable features, especially for low-power supplies. In addition, new energy saving initiatives (e.g., 80 PLUS) are forcing the designers to search for new topologies to further reduce losses while keeping low input-current harmonics and PFC capability. Most of the PFC rectifiers utilize a boost/buck–boost topology converter at their front end due to its high power factor capability [1]–[4]. However, a conventional PFC scheme has lower efficiency due to significant losses in the diode bridge. During each switching cycle interval, the current flows through three power semiconductor devices. The forward voltage-drop across the bridge diodes degrades the converter efficiency, especially at low-line input voltage.

A bridgeless PFC circuit allows the current to flow through a minimum number of switching devices compared to the conventional PFC circuit. Accordingly, the converter's conduction losses can be significantly reduced, and higher efficiency and lower cost can be obtained. However, most of the previous proposed bridgeless PFC converters have at least one of the following drawbacks: 1) high components count, 2) components are not fully utilized over whole ac-line cycle, 3) complex control, 4) dc output voltage is always higher than the peak input voltage, 5) lack of galvanic isolation, and 6) due to the floating ground, some topologies require additional diodes and/or capacitors to minimize EMI. In order to overcome most of these problems, an interesting reduced component count topology has been introduced.

b.AC-DC Converter Operation

The proposed converter is designed to operate in discontinuous-conduction mode (DCM) during the switch turn-on interval and in resonant mode during the switch turn- off intervals. As a result, the switch current stress is similar to the conventional DCM PFC converter, while the switch voltage stress is higher. Moreover, the two power switches Q_1 and Q_2 can be driven by the same control signal, which significantly simplifies the control circuitry. However, an isolated gate drive is required for the power switch Q_1. Referring to figure 2, the switching conduction sequences are as follows: 1) during positive ac-line cycle, Q_1, D_{Q2}, D_2, D_1, X (all switches are off); and 2) during negative ac-line cycle, Q_2, D_{Q1}, D_1, D_2, X. To simplify the analysis, it is assumed that the converter of figure is operating under steady-state condition. In addition, the following assumptions are made: input voltage is pure sinusoidal, ideal lossless components, the switching frequency (f_S) is much higher than the ac line frequency (f_L), and the output capacitor C_o is large enough such that the output voltage can be considered constant over the whole line period. Based on these assumptions, the circuit operations in one switching period Ts in a positive ac-line cycle can be divided into four distinct topological stages.

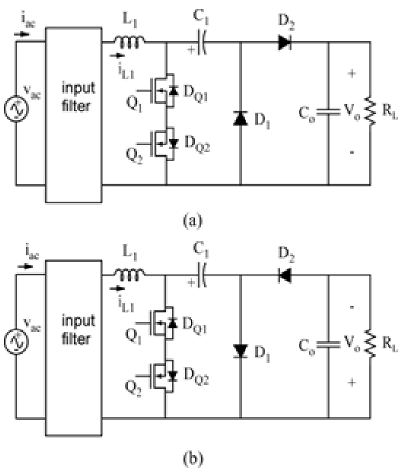

Fig.2. bridgeless ac–dc PFC converter with: (a) Positive output polarity. (b) Negative output polarity.

c.BLDC Motor with Bidirectional DC-DC Converter

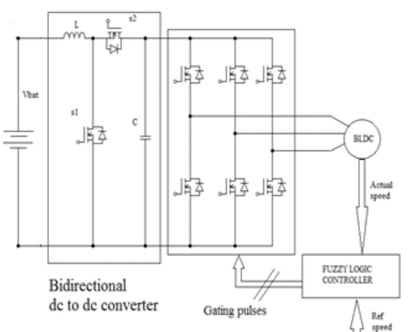

Fig. 3. BLDC motor with control circuit.

The bidirectional dc-dc converter is also known as buck boost converter, which has more applications such as controlled battery charging. The circuit diagram of the system is given in figure 3. The dc-dc converters are being increasingly used to achieve power transfer between two dc power sources in either direction. The dc-dc converter can be categorized in to buck; boost and buck boost types which are of low cost, compact in size, without transformer and easy to control due to common ground. There are number of variations of this basic Buck-Boost circuit, some designs work at lower frequencies or at high voltages which may use bipolar transistors instead of MOSFET. In this project a bidirectional dc/dc converter will be developed to control power flow between the battery and BLDC motor, hence the desired control variables are both output current and voltage. The proposed bidirectional buck-boost converters are applicable in energy storage based on battery applications. Brushless DC (BLDC) motors are becoming more popular in industrial and traction applications. This motor has less inertia, therefore it is easier to start and stop the motor. BLDC motors are potentially clean, fast, less noisy, more efficient and more reliable. The Brushless DC motor is driven by rectangular or trapezoidal voltage strokes which is coupled with the given rotor position. The voltages stroke must be properly aligned in the phases, so that the angle between the stator flux and the rotor flux is kept closer to 90^0 in order to get the maximum torque. The actual rotor position of BLDC motor can be detected without sensors but it often incorporates internal or external position sensors to sense the position. When the acceleration command is issued, the electric machine is operated in the motor mode.

Output torque of the motor is controlled by a voltage source inverter (VSI) by adjusting the direction and amplitude of the phase current. If the input phase voltage is in phase with back EMF, motoring torque is developed and when the input current is out of phase with back EMF, braking torque is developed. The regenerative braking refers to charge a battery using back EMF voltage of the motor. In this project fuzzy logic controller is used for controlling the speed of brushless DC motor using bidirectional converter. BLDC motor has a wide range of speed hence speed control is very important issue for it. The efficient speed control mechanism for the motor is done using meaningful fuzzy sets and rules.

III.FUZZY LOGIC CONTROL

Fuzzy logic controller is a rule-based controller. The fuzzy logic control is designed using the fuzzy inference systems (FIS) with the defined input and output membership functions. The fuzzy sets and rules are designed and accordingly the motor can be controlled. The inputs for fuzzy logic controller are the speed error (e) and change in speed error (e). Speed error is calculated with comparison between reference speed and the actual speed. The simulation diagram of fuzzy logic controller is shown in figure 4. Fuzzy rule has 7*7 decision table with two input variables and one output variable. The look up table with the input and output rules defined with seven linguistic variables such as Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM), and Positive Big (PB) respectively are given in table.1

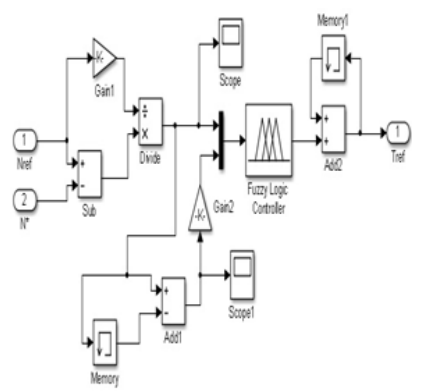

Fig. 4. Simulation diagram of Fuzzy Logic Controller

TABLE. I FUZZY RULE BASE

e/Δe	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

IV.SIMULATION AND RESULTS

The simulation of fuzzy logic controller based speed control and regeneration of brushless dc motor using bidirectional converter and ac-dc converter is performed using MATLAB/Simulink model. The developed MATLAB model shown in figure. The fuzzy logic controller is used to control speed control circuit. The simulation results provide the necessary wave forms for the analysis of speed control of BLDC motor drive.

The simulation result of proposed BLDC motor and regenerative energy storage system with Fuzzy Logic Controller is shown in figure 5

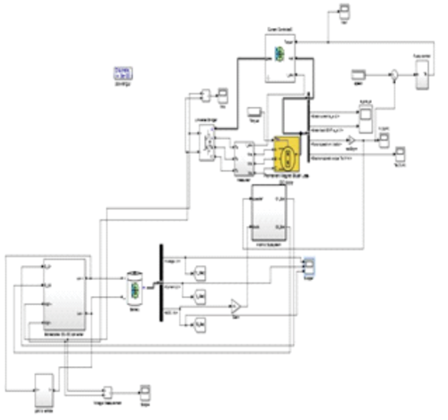

Fig. 5. Simulation diagram of proposed BLDC motor and regenerative energy storage system with Fuzzy Logic Controller.

The output voltage wave form of ac-dc converter for grid to vehicle charging which is given as the input of battery for driving BLDC motor and for regeneration is shown in figure 6.

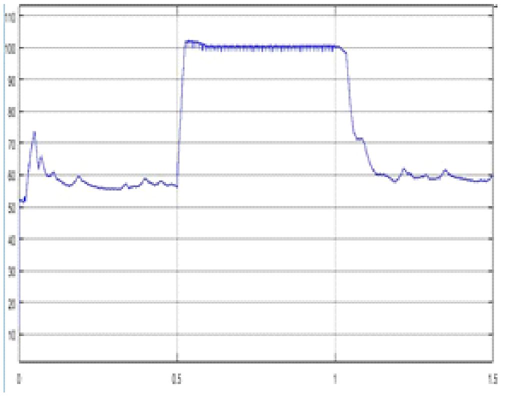

Fig.6. Output voltage wave form of ac-dc converter for grid to vehicle charging.

The input voltage and current wave form of ac-dc converter is in phase for grid to vehicle charging is shown in figure 7.

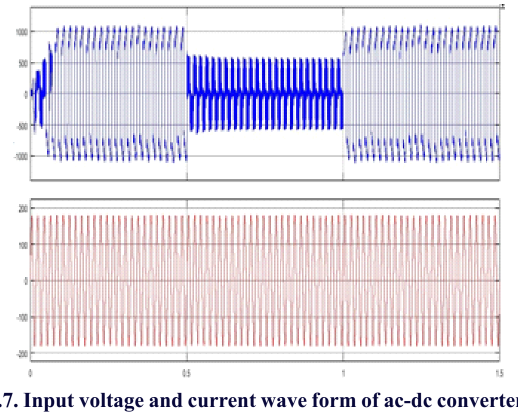

Fig.7. Input voltage and current wave form of ac-dc converter for grid to vehicle charging.

The operating characteristics of battery during normal mode and when regenerative mode happens is shown in figure 8.

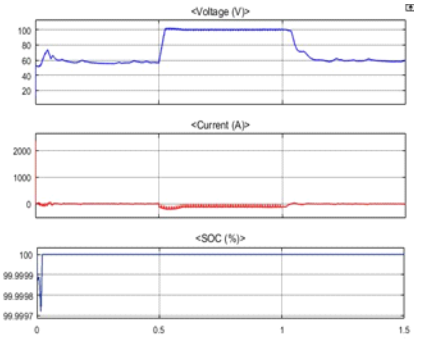

Fig.8.Battery characteristics during charging and discharging mode of operation.

The stator current and back emf of BLDC motor driven electrical vehicle during regenerative mode and discharging mode of operation is shown n figure 9.

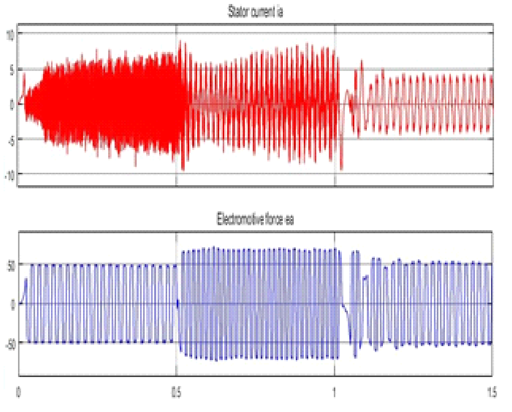

Fig.9.Stator current and back emf of BLDC motor during regeneration and discharging mode.

V.CONCLUSIONS

In this paper, an ac-dc converter along with a fuzzy logic control scheme for the speed control of Brushless motor is proposed. The ac-dc converter is used to charge the battery direct from the grid .There is a bidirectional dc-dc converter to control the power flow. In braking modes of operation, excess kinetic energy is stored in a battery. The excess energy is effectively stored in the battery based on the mode of operation of the bidirectional converter. Simulation studies were conducted and evaluated the performance of both proportional integral controller and fuzzy logic controller based speed control method. The advantages of this proposed method are excellent speed control, smooth transition between the quadrants and efficient conservation of energy.

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