PPS control based Bidirectional DC-DC converter using fuzzy logic in EV application

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***Abstract*— this project presents a compact but fully functional design by combining and integrating basic converters to form a simplified converter structure by utilizing high gain soft-switching bidirectional dc-dc converter HSBDC technique for an electrical vehicle (EV), keeping minimum number of switches. HSBDC with PPS operation is analyzed. High efficiency is achieved by designing a passive component based on the analysis. The control variables, phase shift angle and duty cycle are proposed using PWM plus phase shift (PPS) method. The resultant converter is fully reconfigurable that all possible power flow combinations among the sources and load are achieved through different switching patterns.**

Keywords—HSBDC,PWM plus phase shift(PPS)

I. Introduction

Energy storage system widely used in several applications such as uninterrupted power supplies (UPS), electrical storage system, micro-grids and hybrid electric vehicles (HEV). The bidirectional DC-DC converter is connected between power generation and power utilization and also storage devices like supercapacitors and batteries are used to boost up the efficiency.

The non-isolated buck-boost bidirectional DC-DC converter, is the simplest bidirectional converter which is used for low voltage applications because of replacing passive diode in buck converter or a boost converter with an active switch. The converter has many advantages which include low cost, simple control and low voltage MOSFETs performance is good.

There are several bidirectional DC-DC converters like conventional buck-boost BDC, coupled-inductor-based BDC, conventional PWM controlled buck-boost BDC and dual-active-bridge (DAB) BDC. These converters are not suitable for high step-up/down applications. The drawback behind the conventional buck-boost BDC is hard switching, voltage conversion ratio is limited, duty cycle of switches is extreme and reverse recovery problem is severe in the body diode of active switch. The disadvantage of coupled-inductor-based BDC is that the ratio of voltage conversion is not improved. The soft-switching of the main switch cannot be achieved using conventional PWM controlled buck-boost BDC. The voltage/power regulation is difficult while maintaining high efficiency with DAB BDC. Suppose, if the voltages on the two sides of this converter are not matched, its leads to high circulating current, turn off power loses are high, losing of soft switching which decreases the efficiency of conversion.

The bidirectional DC-DC convert is associated between storage battery those voltage is similar to lower range of 12v to 24v at the same time the other side is connected to high voltage electric vehicle of 24v.The battery management system has the main advantage of correcting the imbalance of cell by their properties which may conclude in inefficient utilization of energy storage devices. Therefore, non-isolated bidirectional DC-DC converter which has high step-up/down gain is required when the voltage of storage devices is low.
The PWM control method was invented for high step-up/down applications like electric vehicles. This PWM gives rise to asymmetrical operation in the modes of forward and backward. There are some of the issues on PWM control are according to voltage and load variation the delay times must continuously varying to achieve soft-switching which leads to complexity of switching pattern generation. Here, another method called PPS control method has the improvisation of

symmetrical switching between the modes of forward and backward. There are two parameters of control variables that are used, phase-shift and duty cycle. The most advantageous thing in this proposed system is that the delay time are not needed in meantime. So, by means of load and voltage variation, the efficient step-up/down gain is not affected.

II. HSBDC COVERTER FOR EV APPLICATION

A. Battery management system

Keeping in mind the end goal to unravel the key innovation of electric vehicle(EV), a battery management framework(BMS) is proposed here to settle the basic issues. The framework incorporates a few regular modules: information obtaining unit, communication unit and battery state estimation display. Two extra management units are produced here, one is thermal management and high voltage management which enhances the security condition of the battery.

The BMS have been effectively utilized as a part of the electrical vehicle (EV), the test outcomes demonstrate the validity and reliability of the framework.

In this system BMS serves as both storage and power generating devices. The difference between power consumption and power generation is compensated.

B. DC-DC converter

The proposed converter comprises of a general buck/support converter as the primary circuit and a helper circuit which incorporates capacitor Ca, inductor La and two high voltage side (HVS) switches S3 and S4. The objective of control in this paper is expected to manage the HVS voltage VH while permitting bidirectional power stream as indicated by the bearing of inductor current IL_f.

C. PPS control

Current stress and conduction losses are reduced by combining PWM and phase shift control, ZVS ranges are expanded. Rms currents and current stress of the converter can be reduced by PPS control when compared with PS control. ZVS at higher load variations can be achieved by the converter.

D. Fuzzy logic

Additional output is given by the fuzzy logic circuit which enhances the system to support multiple tenders. Overall performance of the converter can be increased, under closed loop operation when compared to conventional converters. Simulation and analysis of closed loop operation are carried out using Mat lab Simulink software.

III. OPERATING PRINCIPLE

A. Block diagram

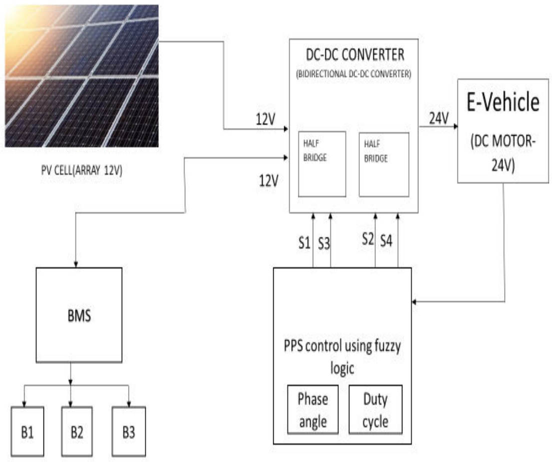

Fig-1. Blockdiagram of PPS control based Bidirectional DC-DC converter using fuzzy logic in EV application

A 12V dc supply from photovoltaic cell is given to high gain soft switching bidirectional dc-dc converter where two half bridge converters are connected together by a passive component. Incase of failure of supply from PV cell a battery management system serves as input source. In addition to input it acts as a storage device. Phase angle and duty cycle are controlled by PPS technique using fuzzy logic. HSBDC performs both buck/boost operation. A 24V dc with high step up/down gain is given to electric vehicle. Meanwhile closed loop operation is performed through fuzzy logic where voltage and speed are the two parameters.

B. Circuit operation.

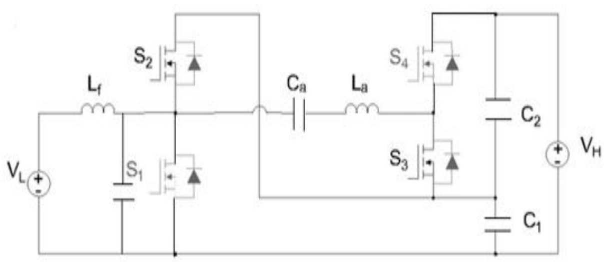

Fig 2. Circuit diagram-*High gain soft-switching bidirectional dc-dc converter (HSBDC)*

As on the principle of HSBDC with PPS control the capacitor-passive component is added to attain higher efficiency. Auxiliary capacitor Ca connects two half bridge cells in a way that C1 and C2 are held in series to achieve high step gain. Low voltage side(LVS) switches S1, S2 at high voltage side(HVS) switches S3, S4 are functioned by asymmetrical switching through duty cycles D and 1-D respectively.

The seven modes of conversion are possible. They are

- PV to DC converter
- PV to battery
- PV to converter and battery
- PV and converter to battery
- PV and battery to converter
- Converter to battery
- Battery to converter

According to the voltage difference the converter automatically select the mode where bidirectional flow is possible. The amount and direction of delivered power are controlled by gate drive signals S3 and S1 where ϕ is the phase difference between them. Power is carried from LVS to HVS since gate drive signal for S1 leads that for S3 ($\phi > 0$) in the forward mode. so that power is carried from the LVS to the HVS. On the contrary, power is carried from HVS to LVS since S1 lags that for S3 ($\phi < 0$) in the backward mode. Forward and backward modes operation of the HSBDC with PPS control are performed using eight modes under different duty cycles from(t_0-t_8)

IV. EXPERIMENTAL RESULTS

TABLE I COMPARISION OF HSBDC WITH PPS CONTROL AND THE CONVENTIONAL HALF BRIDGE CONVERTER

	HSBDC with PPS control	**Conventional half bridge converter**
Switching frequency	50kHz	50kHz
Switching characteristic	ZVS turns-on	Hard switching
Voltage gain	1.5/(1-D)	1/(1-D)
Duty cycle range	0.3-0.5	0.7-0.8
Switches	S1 : 225V / 40Arms S2 : 225V / 18Arms S3 : 225V / 13Arms S4 : 225V / 14Arms	S1 : 450V / 32.7Arms S2 : 450V / 15.8Arms
Capacitor	C1,2 : 30μF / 225V / 10A Ca : 30μF / 225V / 20A	CH : 12μF / 450V / 12.1A
Inductor	Lf : 37.5μH / 36A La : 12μH / 20A	Lf : 57.4μH / 36A
Total energy volume	28.3mJ	37mJ

A prototype was built and tested to verify the validity of the HSBDC with PPS control. The design specification and passive components values for experiment are the same as that used. Also, experimental variance between the PPS and PWM switching methods is provided. The switches were implemented using V-class MOSFETs. The filter and auxiliary inductors were implemented. The auxiliary capacitor Ca and the HVS capacitors C1 and C2 were implemented using the film capacitor. The LVS capacitor CL was implemented using the film capacitor. It can be seen that all the switches were turned ON under ZVS in both forward and backward modes. It is seen that power flow change of the HSBDC is performed seamlessly in both directions. In order to demonstrate the advantages of the proposed PPS method over the PWM method presented in [1] experimental evaluation between PPS and PWM method is given. In the forward mode operation, as we can perceive both PWM and PPS methods achieve soft-switching under full load power and voltage gain range, thereby showing like measured efficiencies. In the backward mode the proposed PPS method correspondingly shows high efficiency as it ensures in the forward mode, achieving soft-switching by whole load.

V. CONCLUSION

In this paper a non-isolated soft switching BDC has been proposed for high voltage gain and high power applications. The proposed converter can achieve ZVS turn on of all switches and ZCS turn of some switches in both boost and buck operations. An optimized switching sequence is presented along with an intermediate switching pattern to carry out seamless mode change. A 5kW prototype of the proposed converter has been built and tested to verify the validity of the proposed operation. A nominal duty cycle of 0.64 was used to achieve voltage gain of 5.5 in the both buck and boost modes of operations.

In this paper, novel high efficiency high step-up/step-down bidirectional DC-DC converter is proposed by integrating a dual-active half-bridge (HSBDC) into the conventional buck-boost BDC. The voltage stresses of switches have been reduced and the voltage conversion ratio has been increased by connecting the outputs of the buck-boost BDC and the HS BDC in series. Voltage matching control for the HSBDC is achieved by regulating the switches duty cycles of the buck-boost BDC. As a result, the voltages on the two sides of the HSBDC are always matched to reduce the conduction losses and improve the soft-switching performance of the HSBDC. Power flow regulation is achieved by adopting phase shift control to the HSBDC. Furthermore, ZVS soft switching is realized for all of the switches to lower the switching losses. Finally, the effectiveness of the proposed BDC topology and control is verified using a 1kW, 40-60V to 400V prototype. Experimental results indicate that the proposed solution is a good candidate for high efficiency energy storage system applications with steep voltage gain and wide battery voltage range.

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