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LC SERIES RESONANT CIRCUIT BASED SOFT-SWITCHING BIDIRECTIONAL DC-DC CONVERTER FED PMDC DRIVE

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Abstract: A soft-switching bidirectional dc/dc converter fed PMDC motor with a LC series resonant circuit is proposed. The proposed converter has been obtained by adding LC series resonant tank in the conventional bidirectional dc/dc converter. The conventional type DC/DC converter incorporating the old switching techniques would raises the switching losses and voltage stresses on the devices. The above drawback is rectified with the help of soft switching techniques. The proposed topology performs soft switching at both buck and boost operations. Through the theoretical boost and buck mode analysis, Zero Voltage Switching (ZVS) operation is explained. A zero voltage switching operation of the power switches reduces the switching loss during the switching transition and improves the overall efficiency and the PMDC motor used for low voltage, continuous operation.

Keywords: Battery charger, Bidirectional DC/DC converter, Resonant converter, Soft-switching, PMDC motor.

I.INTRODUCTION

The bidirectional dc-dc converter has been widely studied for various industrial applications such as renewable energy system, hybrid electric vehicles. The buck-boost converter topology allow power flow in either direction, i.e., toward battery or away from battery. To reduce the corresponding switching losses and the size of passive components, soft switching techniques are required. Many industrial type of equipment driving a load need prime mover. There are various types of prime movers such as hydraulic, steam, and other type of engines but most commonly used prime mover is an electric motor. The main advantage is characteristics like speed-torque, speed-current etc. The dc motor running at different constant speed driving different load requires different constant input voltage.

In some conventional bidirectional buck-boost converter topologies applied with soft-switching technique [2],[3],[5] not only the resonant components but also additional power switching devices are required. Additional switching losses and conduction losses can be caused by the additional power switching instead of the switching loss reduction for the main switches.

In order to overcome these problems, a bidirectional buck-boost converter fed PMDC motor with soft switching technique of Zero Voltage Switching (ZVS) technique is proposed. In the new proposed topology only the resonant components are required without any additional switching devices. In order to increase the efficiency and power conversion density, a soft switching technique is required [4] in bidirectional DC/DC converter. In proposed system, PMDC motor and PI controller is used. The controller provides a balance of complexity and capability that makes them by far the most widely used algorithm in process control application. A zero voltage switching operation of the power switches reduces the switching loss during the switching transition and improves the overall efficiency. [1]

The ZVS condition can be achieved when the current of resonant inductor is larger than that of main inductor. The current of resonant inductor can be increased by series resonance between resonant inductor and capacitor during the switch-off time interval. The snubber capacitor can be fully discharged by the difference between currents of resonant inductor and of main inductor. After the discharge of snubber capacitor, the excessive current flow conducts the antiparallel diode of the main switch. Consequently, the ZVS condition of main switch can be satisfied due to the excessive current flow. The turn-off signal of main switch has to be supplied during this time interval for ZVS. [6]-[10]

POWER SUPPLY UNIT:

The dc supply Voltage is given to buck/boost converter with soft switching cell. The PMDC motor load is connected to the buck/boost converter. The speed of the motor is controlled by the PI controller.

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BLOCK DIAGRAM

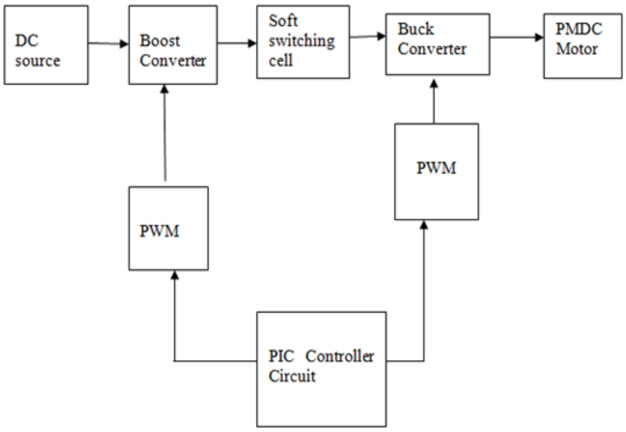

Figure-1: Block Diagram

BOOST CONVERTER:

A **boost converter** (**step-up converter**) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

SOFT SWITCHING CELL:

The soft switching of the proposed converter is achieved by LC resonance. The soft switching cell consists of snubber capacitor Cs, a resonant inductor Lr, and a resonant capacitor Cr is added. The ZVS condition can be achieved when the current of resonant inductor is larger than that of main inductor.

BUCK CONVERTER:

A **buck converter** is a step-down DC to DC converter. Its design is similar to the step-up boost converter, and like the boost converter it is a switched-mode power supply that uses two switches (a transistor and a diode), an inductor and a capacitor. The simplest way to reduce a DC voltage is to use a voltage divider circuit, but voltage dividers waste energy, since they operate by bleeding off excess power as heat; also, output voltage isn't regulated (varies with input voltage).

Pulse-width modulation (PWM)

PWM or **pulse-duration modulation (PDM)**, is a commonly used technique for controlling power to inertial **(PWM)**electrical devices, made practical by modern electronic power switches. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

II. SOFT-SWITCHING BIDIRECTIONAL DC/DC CONVERTER FED PMDC MOTOR

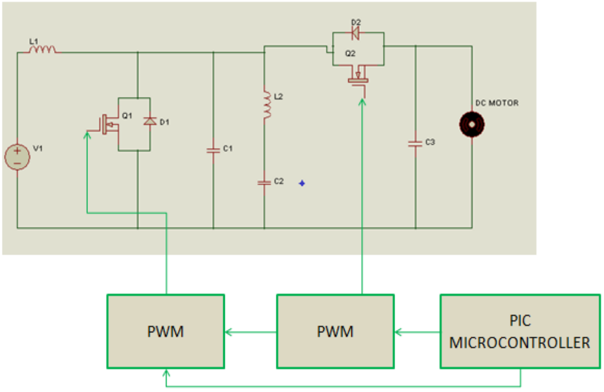

Fig 2:Proposed soft switching bidirectional dc/dc converter

Fig. 1 shows a schematic of the proposed bidirectional dc/dc converter of new soft-switching cell. The soft switching of the proposed converter is achieved by *LC* resonance. The proposed converter is based on the conventional bidirectional buck–boost converter. The soft-switching cell that consists of a snubber capacitor *Cs* , a resonant inductor *Lr* , and a resonant capacitor

Cr is added. In the boost mode, the snubber capacitor *Cs* induces the switch Sboost to turn OFF under ZVS condition by changing the current path flowing to switch. The ZVS condition is achieved by series resonance between resonant inductor and resonant capacitor

OPERATION MODE: To simplify the analysis of the proposed converter, some conditions are assumed as follows:

1) the circuit operates under steady state;

2) all of the switches are considered as ideal devices;

3) the parasitic capacitances of switches are equal;

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4) all of energy storage components are free of loss in this section, an operating mode analysis of the proposed converter is performed according to the different current paths of each elements and the voltage of the switch. The operation mode of

proposed topology is divided into seven modes.

III. ANALYSIS OF PROPOSED CONVERTER

A. Design of Resonant Inductor

The current variation of resonant inductor current to satisfy the resonant condition has to be greater than main inductor current ripple as represented by,

$$I_{L\_\min} \leq I_{Lr\_\text{peak}} \qquad (1)$$

The minimum value of main inductor current can be represented by

$$I_{L\_\min} = \frac{V_{\text{out}}}{V_{\text{in}}} \times I_O - \frac{T_{\text{on}}}{2 \cdot L} \cdot V_{\text{in}}$$

the maximum value of resonant inductor current can be represented by,

$$I_{Lr\_\text{peak}} = \frac{1}{2} \cdot \frac{V_{\text{in}}}{L_r} \cdot T_{\text{on}} \qquad (3)$$

B. Design of Resonant Capacitor

To achieve the ZVS operation, the resonant frequency should be lower than a half of switching frequency. In this paper, the resonant frequency is selected as 40% of the switching frequency. It can be represented by,

$$\frac{2.5}{2\pi\sqrt{L_r \cdot C_r}} \leq f_{\text{sw}} \qquad (4)$$

C. Design of Snubber Capacitor

The snubber capacitor voltage is recharged to the output voltage during turn-off interval, and it is discharged to zero voltage by the difference between resonant inductor current and the main inductor.

IV. SIMULATION RESULT

MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering and science. In industry, MATLAB is the tool of choice for high productivity research, development, and analysis. MATLAB features a family of add-on application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neutral networks, fuzzy logic, wavelets, simulation, and many others.

Sim Power Systems libraries contain models of typical power equipment such as transformers, lines, machines, and power electronics. These models are proven ones coming from textbooks, and their validity is based on the experience of the Power Systems Testing and Simulation Laboratory of Hydro-Québec, a large North American utility located in Canada, and also on the experience of École de Technologie Supérieure and Université Level. The capabilities of SimPowerSystems software for modeling a typical electrical system are illustrated in demonstration files. And for users who want to refresh their knowledge of power system theory, there are also self-learning case studies.The Sim Power Systems main library, powerlib, organizes its blocks into libraries according to their behavior. To open this library, type powerlib in the MATLAB Command Window. The power lib library window displays the block library icons and names. Double-click a library icon to open the library and access the blocks. The main powerlib library window also contains the Powergui block that opens a graphical user interface for the steady-state analysis of electrical circuits.The simulation circuit diagram is shown in figure 3&4

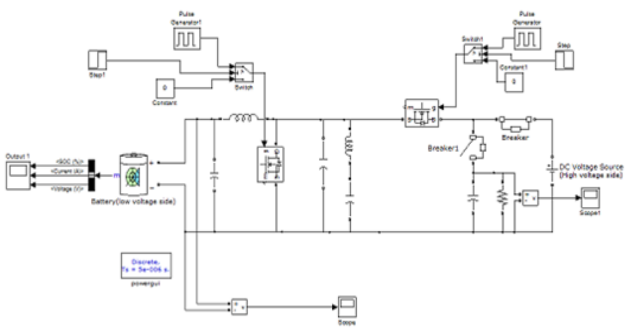

Fig 3: Simulation circuit of soft-switching bidirectional dc/dc converter with a LC series resonant circuit

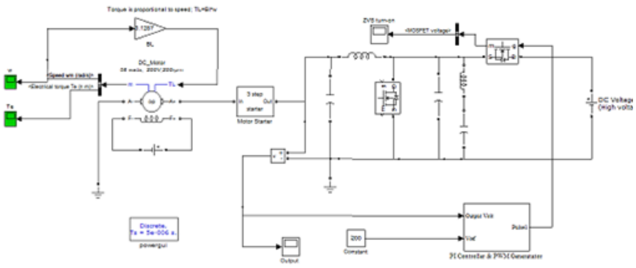

Fig 4. Simulation circuit of soft-switching bidirectional dc/dc converter fed PMDC motor with a LC series resonant circuit (Buck mode)

And the carrier output waveform is,

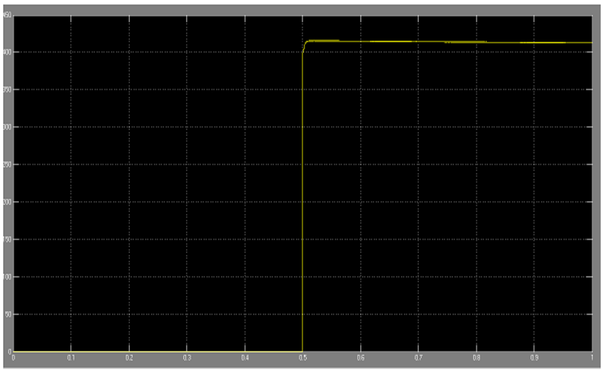

Fig 5: Output voltage waveform of bidirectional dc/dc converter

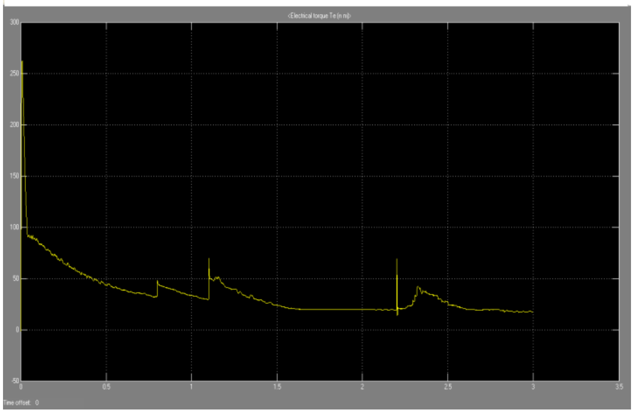

Fig 6: output waveform of proposed converter with Buck mode

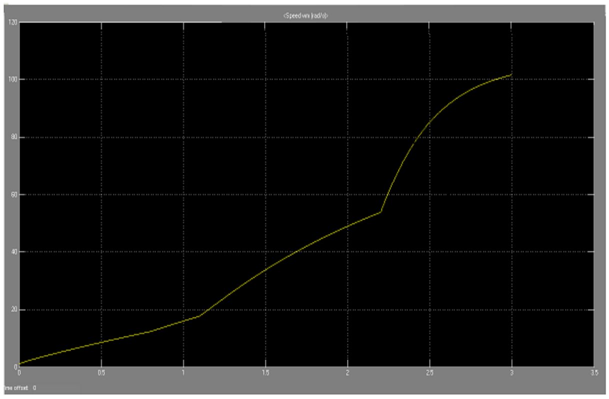

Fig 7: Output waveform of proposed converter with Boost mode

V.CONCLUSION

In this paper, a soft-switching bidirectional buck boost converter fed PMDC motor with an *LC* series resonant circuit for the battery charge and discharge system of dc distribution power system is proposed. The proposed topology is analyzed using the circuit analysis method of operating mode. The designed proposed topology is simulated using PSIM simulation software program. The various waveforms obtained for changes in load. The simulation results show ZVS turn ON. Based on the analysis, the proposed converter has been obtained for soft switching at all over load of bidirectional. The switches are turned ON and OFF under zero-voltage condition by adding the *LC* series resonant circuit to the conventional bidirectio the design of *LC* resonant component is also considered. The proposed topology is verified through simulation result. The proposed topology can be applied to the renewable energy system using battery with high efficiency.

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BIOGRAPHY

Dr.Govindaraj Thangavel born in Tiruppur , India , in 1964. He received the B.E. degree from Coimbatore Institute of Technology, M.E. degree from PSG College of Technology and Ph.D. from Jadavpur University, Kolkatta, India in 1987, 1993 and 2010 respectively. His Biography is included in Who's Who in Science and Engineering 2011-2012 (11th Edition). Scientific Award of Excellence 2011 from American Biographical Institute (ABI). Outstanding Scientist of The 21st century by International Biographical centre of Cambridge, England 2011.

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