A Medium Voltage Bidirectional Dual Active Bridge Resonant DC-DC Converter

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***Abstract*-the DC-DC converter which is capable of transferring the power in both the directions is proposed. The existing system has the DC-DC converter based on immittance network is proposed which is acting as filter and to achieve unity power factor. This immittance network is helpful to attain the resonant condition. It is making the system complex and the efficiency of the system is decreased. To overcome this proposed system has the resonant and dual active bridge converter. It produces the resonant condition by the system configuration. It works in normal as well as over current operation. In the normal operation, the converter carries out the resonant condition by the soft switching techniques such as ZVS and ZCS, attained by frequency control. In the over current operation, the diode conducts the electric current in only one direction and prevents exceeding the reference value and across the capacitor. This is used to protect the circuit from over current. It is functioning partly as resonant converter and partly as dual active bridge converter with the constant switching frequency. Thus over current protection is afforded by the diode clamping and the power flow analysis is done by the boost and buck modes using the simulation software PLEXIM.**

***Keywords*- immittance network (IMN), dual active bridge (DAB), zero voltage (ZVS) and current switching (ZCS), resonant converter, isolated bidirectional converter (IBDC)**

I.INTRODUCTION

The bidirectional DC-DC converter is very reliable, power flow in both directions, high power density making the converter to be widely used. The BDC can be either full bridge or half bridge according to the requirements and design considerations. In the dual active bridge converter (DAB) polarity of current and voltages are different which may cause circulating power. The power flow is from high voltage side to low voltage side and vice versa i.e., in buck mode and boost mode. The resonant condition is achieved in the system by soft switching techniques rather than hard switching.

The soft switching techniques are attained when the current through the inductor is less than the resonant inductor current. During ZVS condition for both buck mode and boost mode, the switches are adjusted by pulse frequency modulation [2]. The immittance networks used in paper [1] have the filter ability, to attain resonant condition and to get unity power factor as it increase the efficiency of the system [1]. But it is making the system complex and there is a back flow of power during the bidirectional power flow it results in current stress. So the proposed system is designed by eliminating the immittance network, the DC-DC converter is designed to operate partly LLC resonant converter and partly dual active bridge converter. The power flow is bidirectional and having the ability to operate at high frequencies. The reduction of switches in this system to reduce the switching losses. The system is operating in normal as well as over current operation. The over current protection techniques are to have larger switching frequency, variable frequency with the PWM control, diode clamping method [5].

II.EXISTING SYSTEM

The existing system can include two full bridges, dual active bridge converter, two network which an immittance network is acting as a filter. It is connected in series with transformer which is used to limit the duty cycle and provide galvanic isolation between the dc bus.

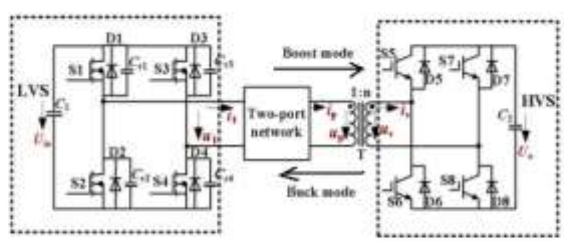

Fig.1. Existing system based on immittance network

A.T-Lcl Network With Bidirectional DC-DC Converter

T-LCL network is an immittance network. It is connected with dual active bridge and BDC. The operation goes on with the two modes, i.e., buck mode [LVS-HVS] and boost mode [HVS-LVS]. Due to the design specifications, the HVS switches are designed with IGBT and LVS switches are designed with MOSFET.

B.The Underlying Feature of IMN

It is derived from the combination of impedance and admittance.

$$Z_1 = \frac{V_1}{I_1} = Z_n^2 \frac{I_2}{V_2} \qquad (1)$$

The above equation implies the impedance in the input terminal is proportional to the admittance at the output terminal. It is also meant that admittance at the output port is converted to the impedance at the input port. This conversion characteristic is called as the immittance conversion characteristics.

III.PROPOSED SYSTEM

The isolated bidirectional DC-DC converter binding the resonant and dual active bridge converter. Generally, LLC resonant converter allows ZVS of the main switches and lowers the switching losses and boosts the efficiency. The resonant network is made up of capacitance and inductance. The primary inductance of the transformer is designed to be larger so that it does not affect the resonant network.

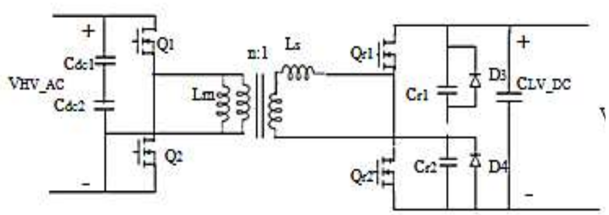

Fig.2 Proposed bidirectional dual active bridge resonant DC-DC converter

The converter is operated through frequency modulation. The resonant network having the impedance which is proportional to the switching frequency when load changes. The dual active bridge (DAB) is applicable for the isolated DC-DC conversion. It is having the advantages of ZVS, bidirectional power flow, soft switching techniques, symmetric structure, control can be simple. But the circulating current may decrease the efficiency of DAB. It is eliminated by phase shift control with pulse width modulation. It is designed for normal and over current operation.

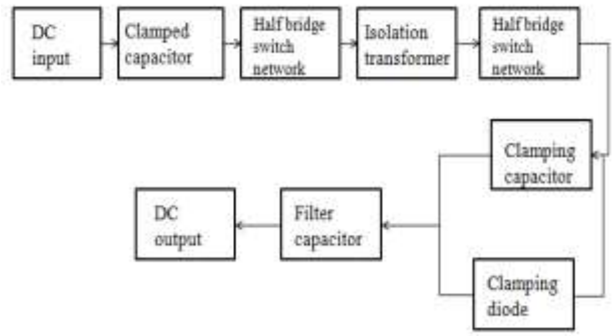

Fig.3. Block diagram of the proposed system

According to the power flow it is working in boost as well as buck mode. The difference of impedance in inductor and capacitor is fallen to zero. This is called as resonant frequency. At this frequency LLC resonant converter is operating in normal condition. This is also called as resonant mode. The diode is getting clamped across the capacitor in order to prevent the current from reaching the value greater than the reference value. So that the over current protection is simple in this circuit.

A. Converter Operation

The high voltage V_{HVdc} is given in the input terminal. Q_1,Q_2,Q_{r1},Q_{r2} are the switches. Due to the design considerations, here MOSFET is used. The capacitance C_{dc1},C_{dc2} connected in the input terminal. It is having quite large capacitance. The full bridge or half bridge circuit is used in the circuit for the bidirectional power flow. L_m, L_s are the magnetizing and leakage inductance of the transformer. Diode is placed across the capacitor in the low voltage side. This diode is used for clamping purpose during the over current operation. During normal operation these diodes do not conduct. The both capacitor in the low voltage side is having equal capacitance.

B.Boost and Buck Mode

In the boost mode of operation, the switches in the high voltage side are conducting where as in the buck mode of operation, the switches in the low voltage side is conducting.

In boost mode, the input side the control switches is conducting, in the output side the diode is conducting. At t_0 the resonant capacitance C_{r1}, C_{r2} is paralleled with the switches. So the inductance L_s begin to resonate. Then the voltage across the switches rises. At t_1, diode is forward biased. At t_2, the switches Q_2 is turned on. Here the modes of converter retained constant because the current through the inductor i_s is positive and flows through diodes in the LVS side. At t_3, the current and attains natural commutation. The switches Q_1 is zero voltage and zero current turn on. The switch Q_2 is having zero voltage and zero current turn off. At t_4, the pulses of t_4 are turned off but the modes of converter are undisturbed.

In the buck mode, the operation is similar to that of the boost mode but polarity of the elements gets changed.

The power flow taking place in BDC can be calculated as follows,

$$P = \frac{2\sqrt{2}V_{hv}V_{lv}}{n\pi Z_0}\cos\frac{\alpha}{2} \qquad (3)$$

If the power gets increased, the α is getting decreased. If α = 0, the power flow will be maximum.

$$P_{max} = \frac{2\sqrt{2}V_{hv}V_{lv}}{n\pi Z_0} \qquad (4)$$

Where Z_0 is the resonant impedance. It can be formulated by,

$$Z_0 = \frac{2\sqrt{2}V_{hv}V_{lv}}{n\pi P_{max}} \qquad (5)$$

C.Simulation Results

The proposed system is simulated by buck mode and boost mode using the software PLEXIM. To facilitate understanding merits, a bidirectional isolated DC-DC converter is proposed. It executes both step up and step down conversion with the switching frequency of 40KHz.

1)Step Down Operation

For the buck operation, the input voltage is 200 volt. The voltage is steped down using the transformer present. This transformer mainly limits the duty ratio and for the isolation purpose. The output voltage is about 40 volt. The power flow will be in both the directions. So that the buck mode and boost mode takes place.

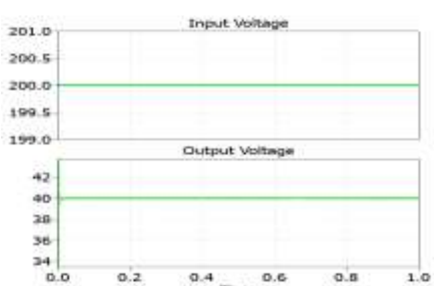

Fig.4. Input and output voltage

2)Step Up Operation:

For the boost operation,

Input voltage = 40 V.

Output voltage = 187 V.

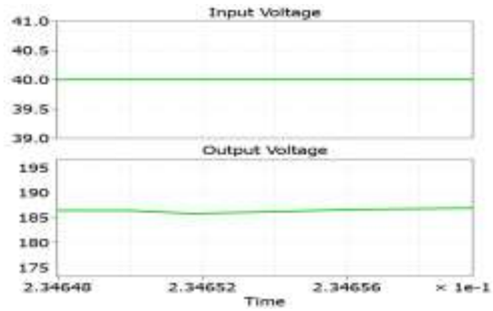

Fig.5. Input and output voltage

D.Hardware Implementation

The diode bridge rectifier that provides bridge rectification in the control circuit. A PIC 877A microcontroller is used to generate the PWM to switch the gates of the MOSFET IRF840N. The control circuit consist of the voltage regulated IC 7805 that restricts the output voltage to 5V. The crystal oscillator having the frequency of 20 MHz determines the speed of the microcontroller. An opto coupler MCT2E is used for isolation between power circuit and control circuit. The MOSFET driver is connected at the output of the opto coupler that drives the PWM signal. The power circuit which consist of H-bridge translates the input voltage to suitable level which is step up or step up operation

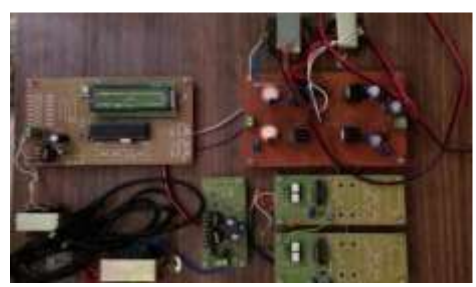

Fig.6.HARDWARE PROTOTYPE

E.Hardware Results

STEP UP MODE		STEP DOWN MODE	
INPUT VOLTAGE (V)	OUTPUT VOLTAGE (V)	INPUT VOLTAGE (V)	OUTPUT VOLTAGE (V)
15	30	36	9
17	34	32	8
19	38	24	6

F.Conclusion:

The bidirectional dual active bridge and resonant DC-DC converter which is operating in boost mode and buck mode is proposed. In the existing system, IMN makes the system complex. This system has the full bridge configuration. But in the proposed system, it is half bridge configuration so there is a reduction of switches and switching losses are reduced. The over current protection is taking place because the diode prevents the current from exceeding the reference value. This is taking place cycle by cycle. In the normal operation, the converter is purely resonant mode. So the operation is similar to that of the resonant converter. But in the over current operation, the converter is partly resonant and partly DAB mode. Thus no external component such as IMN is needed to achieve the resonant condition. The design of bidirectional converter with DAB is implemented. The power flow in boost mode and buck mode is simulated using the PLEXIM software and the same is implemented using PIC 877A.

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