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A Review on Design Considerations for a Bidirectional Dc/Dc Converter

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***Abstract*- Recently the use of renewable energy resources has been increased to save the environment and remaining fossil fuel and the requirement of storing the energy is also increased. In many applications like electric vehicles the need of interfacing of energy storage with load and source is increased for a reliable and efficient system. Bidirectional dc to dc converter is the main device used to interface the Battery and super capacitor as a storage device to increase the system reliability A conventional buck-boost converter can management the power flow in one direction only but power can flow in both the direction in bidirectional converter. Bidirectional dc-dc converters are the device for the purpose of step-up or step-down the voltage level with the capability of flow power in either forward directions or in backward direction. Bidirectional dc-dc converters work as regulator of power flow of the DC bus voltage in both the direction. In the power generation by wind mills and solar power systems, output fluctuates because of the changing environment condition. the basic knowledge and classification of bidirectional dc to dc converters on the basis of galvanic isolation, the comparison between their voltage conversion ratio and output current ripple along with various topologies researched in recent years are presented in this paper. Finally, zero current and zero voltage soft switching schemes and phase shifted controlling techniques are also highlighted.**

***Keywords*- DC/DC Converter, Bidirectional DC/DC Converter, renewable energy, battery, super capacitor.**

I. INTRODUCTION

Recently the use of renewable energy resources has been increased to save the environment and remaining fossil fuel and the requirement of storing the energy is also increased. In many applications like electric vehicles the need of interfacing of energy storage with load and source is increased for a reliable and efficient system. Bidirectional dc to dc converter is the main device used to interface the Battery and super capacitor as a storage device to increase the system reliability.Moreover, as shown in Fig in electric vehicle bidirectional dc-dc converters used for capturing the kinetic energy of motor and charging the battery during regenerative breaking by reverse flow of energy.[1]

Similarly, the output of the hybrid system .the consisting of wind energy, solar energy etc. are environment dependent so fluctuation of output power and sudden change in load demand makes this hybrid system unreliable so, the solution for this issue is use of storage system like battery, super capacitor etc. with the help of bidirectional dc to dc converter for power conditioning and smooth flow of power to the load [7] [10]. In industrial application also, bidirectional dc-dc converters are used in many applications because devices are switch on and off at high frequency so DAB (Dual active bride)-IBDC (isolated bidirectional dc to dc converter) provide both galvanic isolation, storage of surplus energy and efficient flow of power without wasting the energy [2].

For proper understanding of hybrid energy system and electric vehicle, it is necessary to have knowledge the working principle of dc to dc converter. Therefore, this paper discusses the basic concept of bidirectional dc to dc converter, their classification based on galvanic isolation and various topologies such as interleaved converter and DAB converter. Also, the comparison between soft Switching and hard switching schemes is given. Finally, different control strategies such as SPS (single-phase shift), DPS (double phase shift), and EPS (extended phase shift) and TPS (triple phase shift) employed in IBDC for bidirectional power flow are highlighted.

A conventional buck-boost converter can management the power flow in one direction only but power can flow in both the direction in bidirectional converter. Bidirectional dc-dc converters are the device for the purpose of step-up or step-down the voltage level with the capability of flow power in either forward directions or in backward direction. Bidirectional dc-dc converters work as regulator of power flow of the DC bus voltage in both the direction. In the power generation by wind mills and solar power systems, output fluctuates because of the changing environment condition. These energy systems are not reliable to feed the power as a standalone system because

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of the large fluctuations in output and hence these energy system systems are always connected with energy storage devices such as batteries and super capacitors .These energy storage devices store the surplus energy during low load demand and provide backup in case of system failure and when the output of energy system changes due to weather conditions. Thus, bidirectional dc-dc converters are needed to allow power flow in both forward and backward the directions [12]–[18]. A conventional dc-dc converter can be converted into a bidirectional converter using bidirectional switch by using diode in anti-parallel with MOSFET or IGBT allowing current flow in both the direction using controlled switching operation.

II. BIDIRECTIONAL DC-DC CONVERTERS

Most of the existing BDCs are characterized by a current fed or voltage fed on one side. Based on the placement of an auxiliary energy storage, BDCs can be categorized into buck and boost type. In the buck type, energy storage is placed on the high voltage side and in the boost type on the low voltage side. To realize the double power flow in BDCs, the switch cell should carry the current in both directions. It is usually implemented with a unidirectional semiconductor power switch such as power MOSFET or IGBT in parallel with a diode (or body diode) because the double sided current flow power switch is not available. Depending on the application, different dc-dc converters are used to modulate the input voltage.

Generally, there are two basic types of BDCs, which are non-isolated and isolated .In the transformerless non-isolated power conversion systems, the boost type and the buck type dc-dc converters are commonly chosen. The high frequency transformer based system is a reasonable solution to obtain isolation between the source and the load side. Isolation is mandatory when the very high step-up or step-down ratio is required. But to improve the efficiency, size, weight and cost, the non-isolated type is much more attractive. Thus, in the high power or spacecraft power system applications where weight and size are the main concern, the transformerless type is more preferable.

1. Bidirectional DC/DC Converter Topologies:
Bidirectional operation can be implemented in a converter with a synchronous rectifier (SR) for both isolated and non-isolated topologies. This paper only focuses on non-isolated topologies to simplify the discussion. The conclusions can also be extended to an isolated topology by adding an isolation transformer. Typical non-isolated bidirectional converters are buck, boost, and four-switch buck-boost .It is obvious that a buck converter can run as a boost converter in the reverse direction. And a boost converter can run as a buck converter in the reverse direction. Since the four-switch buck-boost converter runs in either two-switch buck mode or two-switch boost mode, it can also easily work in reverse direction similarly to a single buck or boost converter.

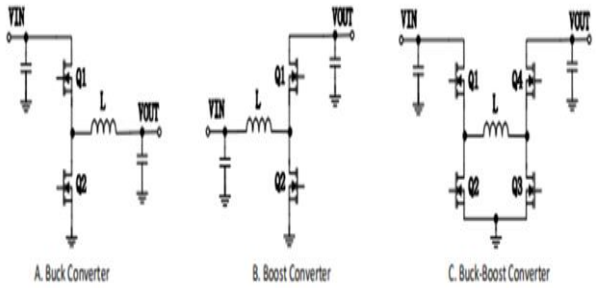

Fig 1. Bidirectional DC/DC converter topologies.

III. LITERATURE SURVEY

The general concept of a DC-DC converter to convert a fixed-voltage DC power supply into a variable-voltage DC power supply. The DC-DC converter output voltage may be higher or lower than the input voltage. DC-DC converters are widely used in traction engines for electric cars, trolley buses, offshore cranes and forklifts. They provide smooth acceleration control, high efficiency and fast dynamic response. The DC converter can be used for regenerative braking of DC motors to return energy back to the power supply. This function can save energy for frequently stopped transport systems and it is also used for DC regulation.

There are many types of DC-DC converters, including buck (buck converter, boost) converter and buck-boost (boost-buck) converter (Muhammad H. Rashid, 2004). From a control perspective, this is an interesting topic. Because of its inherent non-linearity, common control methods (such as voltage control and current injection control) require a full understanding of the system and precise adjustments to achieve performance.

Xu Jia et.al. (2018) When the electric car stops charging the battery, the car's driver in the car will not work. The transport system that supplies the vehicle's weapons system can be viewed. For some devices, it may have the ability to pay fast and V2G (drive to grid). This paper proposes a charge-coupled Z-source system with LCL filtering. The consolidation method based on the integrated sound system is used to reduce the current to the resonant frequency of the current output. The mathematical model of the proposed system is implemented, and the control mode on the DC and AC sides is proposed. Finally, the Z-source test domain is created during grid connection operation. Experience has proven the superiority of the system.

Chandra Sekhar Nalamati et.al. (2018) The growing popularity of renewable energy and electricity (EV) has transformed the structure of the global energy industry. In

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the charge-coupled charge system for renewable energy, bidirectional AC / DC converters are used for more reliable power generation operations. This paper presents a bidirectional AC / DC converter that combines an AC-DC bidirectional converter (GBC) and a bidirectional De-Battery (BBC) battery charger. The GBC printer can facilitate bidirectional flow between the AC and DC networks, while the BBC converter can provide bidirectional power between the energy storage / EV and DC grid systems. In order to transmit power in the trunk, powerful power management technology is required. Hysteresis based power management technology is used to inject electrical energy into the container. AC-DC conversion offers asymmetric PWM strategies with minimal conversion. PSCAD tools are used in simulation to validate the proposed control algorithm.

Fatama-Tuz-Zahura et.al. (2018) The draft proposal and the current control system for mains inverter are proposed. The Controller can also be used with an energy storage system (ESS). The volume management system described in this article is based on a standard PI regulator that provides a low DC connection voltage and low response speed. The current monitoring strategies used here can improve the old shortcuts and eliminate long-term errors. Simulation is performed with MATLAB Simulink. By comparing the simulation results to the literature results, the performance of the system is optimized. The system can be used to improve the short-term response of bidirectional operators.

Meng Runquan et al. (2019) when generating a DC microgram with an AC Microgrid, the bidirectional AC / DC converter (BIC) voltage associated with the AC and DC subnets must have a microgrant AC voltage with amplitude, frequency and phase the same magnitude. Therefore, the frequency, phase and amplitude of AC voltage needed for network services are known quickly and accurately. Therefore, a communication method is proposed. First, the principle of bidirectional AC / DC converter is introduced, and the problem of water loss during power relations is addressed. In the meantime, determine the BIC transmission status, and appropriate control strategies for AC / DC Microgrid connectivity. Finally, the proposed control algorithm is validated by the MATLAB / Simulink simulation.

Cui Yulu et.al. (2019) The two-phase two-way power supply circuit consists of two modules: inverter and rectifier. The mathematical model of the converter depends on two models. Based on this, the influence of delayed system control will be further explored. The results of the analysis are given, and the proposed control method is developed along with the Bode plot compensation. On the other hand, this control approach can eliminate the influence of delayed system optimization and improve system stability. On the other hand, the system's redesign and gradient boundaries can be improved to make it more attractive. Finally, a 5kw experimental prototype was installed to verify the error of the theoretical analyzes. The results show that in the inverter and rectifier mode, the maximum efficiency of the converter is less than 98%.

IV. SINGLE PHASE BIDIRECTIONAL CONVERTER

The objective of this paper is the study of a single phase Bidirectional converter developed with the aim of feeding energy back to the grid i.e. V2G operation of EV. The bidirectional converter is implemented using the subunits as mentioned in Fig.1.The choice of each sub modules depends on the purpose for which the converter is designed. V2G implementation with different types of circuits is reported in the literature. A full-bridge IGBT based Bidirectional AC/DC converter coupled to a nonisolated buck-boost BDC through a dc-bus capacitor is studied in [5].

Here the working of the charger for G2V, V2G, V2H modes and their control algorithms using PI Controllers are explained. In [3] also the circuit structure and the controller structure remains the same but the PI controller action is implemented in association with the Energy management system or the smart meter signals. Here the system design has been evolved ensuring a continuous communication with the grid and battery parameters and thus the flexibility and reliability of the V2G feedback is considerably improved.

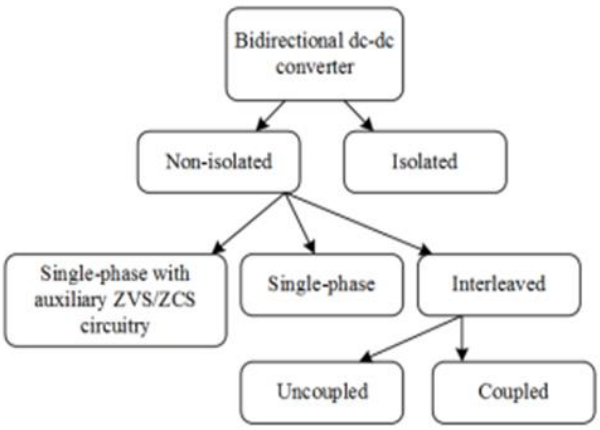

Fig 2. Simplified classification of the bidirectional dc-dc power converters.

In [7] has proposed a hysteresis current controller for the PWM control and grid synchronization of the AC/DC converter. In [2] the reactive compensation capability of such a bidirectional circuit is researched in detail used in India. The V2G mode is designed with the intention of feeding power back into the 230V, 50Hz grid at the rate of 10A.The design and implementation of the passive parameters and its control circuitry is explained. The

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converter that is developed could charge the batteries of electric vehicles or discharge the battery to Grid depending on the condition of power supply availability and the state of charge present in battery.

V. TYPES OF BIDIRECTIONAL CONVERTER

There are two types of Bi-directional dc/dc converter on the basis of galvanic isolation provided between input and output [9].

1. Non-Isolated Bidirectional Dc to Dc Converter (NIBDC):
NIBDC is a converter which does not use high frequency transformer to provide any electrical isolation between source and load. Hence these converters are not used in high power applications due to safety reasons but in low power application theses converter are more efficient because these are easy to control and light weight due to absence of transformer [2].

2. Bidirectional Buck-boost Converter:
This topology is basic circuit of bidirectional dc-dc converter .It is the anti-parallel combination of buck-boost converters. During the step-up operation Q1 is conduct according to the duty cycle whereas Q2 will not conduct in this mode. In step-down mode Q2 will conduct according to the duty cycle and Q1 will not conduct in this mode. A small dead time provided between both the operations so that cross conduction can be avoided .Given topology is a non-isolated half-bridge BDC topology and it is designed by the combination of boost converter connected antiparallel with buck converter. This topology is simple and has greater efficiency.

3. Cascaded Bidirectional Buck-boost Converter:
Cascading buck converter with boost converter. With this topology all four quadrant is possible hence this topology works as buck mode and boost mode in both the direction. 4-quardant operation of this topology makes this topology most flexible but it has some limitations also: more number of switches which leads to more switching losses, complex control algorithm and more turn-on losses because of reverse recovery of diodes.

4. Bidirectional CUK Converter:
Bidirectional CUK converter is obtained from unidirectional CUK converter by using MOSFET. The output of this converter has low ripple as compared to above described topologies hence this converter can be a better option for interfacing super-capacitor-battery in circuits .The ripple output current can be reduced by coupling of inductor L1and L2. In the forward power flow, Q1 works as controlled switch and Q2 remain off and body diode of switch Q2 works as main diode. Similarly, in backward power flow Q2 works as controlled switch and Q1 remain off and body diode of switch Q1 works as main diode.

5. Bidirectional SEPIC-ZETA:
Dc to Dc Converter SEPIC-ZETA dc to dc converter is modification of CUK converter so its output is not opposite polarity like CUK converter .In forward power flow mode this converter works as SEPIC converter and in negative power flow mode, this converter works as ZETA.

SEPIC-ZETA converter works in both buck and boost mode .In forward power flow, switch Q1 turn on and Q2 remain off and it works as buck converter and in backward power flow mode it works as boost converter with Q2 turn off. Coupling of inductor L1 and L2 can reduce the voltage output ripple and voltages rating stress on switches.

6. Switched Capacitor Bidirectional:
The switched capacitor bidirectional dc-dc converter which is used when ICs (integrated Circuits) are to use in dc-dc converter circuits [3]. Since no magnetic devices are present in non- isolated dc-dc converter, integrating of ICs are quite simpler. But theses converters suffer from high ripple current in output due to large number of passive component that leads to electromagnetic interference (EMI). These problems can be resolved by control scheme such as current control and voltage control techniques but this will increase the complexity and cost of the circuit.

7. Interleaved Non-isolated Bidirectional:
Dc to Dc Converter Interleaved converter is the parallel combination of two or more than two converters with relative phase shift 3600 /n. Interleaved converters have some the advantages: current splitting (I/n), cancellation of ripples in output current, higher efficiency of system, high-power density and, higher thermal capacity. Due to the current splits in parallel paths, conduction losses decrease with less number of switches. With the interleaving method in dc-dc converter, the ripple of the input current and the output voltages decreases without increasing the switching losses which leads to higher system efficiency [3].

8. Two-phase Interleaved Non-Isolated Bidirectional:
Dc-Dc converter 2-ø interleaved converter contains two output stages which is 180 degrees out of phase. Conduction losses (i2 r) are reduced by dividing the current into two paths which are connected parallel. More over overall efficiency increases as compared to 1-ø converter. Due to 2-phase combines at the capacitor which is connected at output, effective ripple frequency becomes doubled which reduces ripple in output voltage. Also, power pulses coming from the input capacitor are stumbled and reduces ripple in current. Basic circuit of 2-phase interleaved dc-dc converters is discussed. Interleaved half bridge converter is the mostly used topology [9] Theses converter facilitates higher voltage

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conversion with smaller size of converter. The switching losses also decrease .Hence these converters can be employed to interface ultra-capacitor/battery hybrid energy system for automotive applications like hybrid electric vehicle. Interleaved converter is designed as follows [8]

9. Isolated Bidirectional dc to dc Converter:
NIBDC are not capable to provide the safety standards of galvanic isolation. Hence in many applications, IBDC is used in place of NIBDC. In IBDC, high frequency transformer is used to provide galvanic isolation. Galvanic isolation is necessary in many applications for safety of source in overload condition, for noise reduction, for voltage matching between conditions. This converter works in two stages [9]. In first stage dc is converted to ac and second stage ac is converted into dc and both the stages are connected through high frequency transformer.

10. Dual Active Full Bridge (DAFB):
Isolated Bidirectional dc to dc Converter Full bridge isolated bidirectional dc-dc converters are more suitable choice in hybrid energy system because of the high-power density and high efficiency. The power capacity with the switches so the above discussed DAFB-IBDC has higher power capacity than another topology. Its efficiency is 95%.

Hence in high power application like hybrid energy system, this converter is most suitable for Control Technique for Isolated Bidirectional dc to dc converter for power flow in isolated bidirectional dc-dc converter, phase shift technique is used such as single-phase shift technique (SPS), extended phase shift (EPS) technique, double technique (DPS) and triple phase shift (TPS) technique. Single phase shift is widely used method in DAFB-IBDC. SPS technique has advantages: small inertia, high dynamics and ease of soft switching but power flow suffers from the leakage inductance of transformer.

VI. CONCLUSION

From the above discussion it can be concluded that the isolated bidirectional dc-dc converters are large in size and heavier in weight due to presence transformer so theses converters seem to unfit for electric vehicles and non-isolated interleaved bidirectional dc-dc converter are more suitable in electric vehicles. But in high power palpation where galvanic isolation is necessary, IBDC are more suitable for hybrid energy system.

Soft switching scheme should be used in place of hard switching because it reduces the switching the losses. In IBDC controlling scheme is used according to complexity of the circuit and application. Bidirectional dc to dc converter is used as a key device for interfacing the storage devices between source and load in renewable energy system for continuous flow of power because the output of the renewable energy system fluctuates due to change in weather conditions. Thus, bidirectional dc to dc converters are getting more and more attention in academic research and in industrial applications. Bidirectional dc to dc converters work in both buck and boost mode and can manage the flow of power in both the direction between two dc sources and load by using specific switching scheme and phase shifted control strategy and hence generated excess energy can be stored in batteries/super capacitors.

Therefore, the basic knowledge and classification of bidirectional dc to dc converters on the basis of galvanic isolation, the comparison between their voltage conversion ratio and output current ripple along with various topologies researched in recent years are presented in this paper.

Finally, zero current and zero voltage soft switching schemes and phase shifted controlling techniques are also highlighted.

REFERENCES

[1] XuJiaGuomingChuai ; HaonanNiu ; Qianfan Zhang Grid Connected Power Generation Control Method for Z-Source Integrated Bidirectional Charging System 2018 International Power Electronics Conference (IPEC-Niigata 2018 -ECCE Asia) Year: 2018
[2] PandlaChinnaDastagiriGoud ; Chandra SekharNalamati ; Rajesh Gupta Grid Connected Renewable Energy Based EV Charger with Bidirectional AC/DC Converter 2018 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON) Year: 2018
[3] Fatama-Tuz-Zahura ; Md. Ziaur Rahman Khan Advanced Control Scheme for Bidirectional Grid-Connected Inverter 2018 10th International Conference on Electrical and Computer Engineering (ICECE) Year: 2018
[4] Jiao Jiao ; RunquanMeng ; Zheng Guan ; ChunguangRen ; Lei Wang ; Baifu Zhang Grid-connected Control Strategy for Bidirectional AC-DC Interlinking Converter in AC-DC Hybrid Microgrid 2019 IEEE 10th International Symposium on Power Electronics for Distributed Generation Systems (PEDG) Year: 2019
[5] Yulu Cui ; Yifeng Wang ; Xiaoyong Ma A Delay Compensation Control Method Based on Interleaved Dual BUCK Full Bridge Grid-connected Bidirectional Converter 2019 22nd International Conference on Electrical Machines and Systems (ICEMS) Year: 2019
[6] H. G. Langer and H. -Ch. Skudelny (1989), “DC to DC converters with bi-directional power flow and

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controllable voltage ratio," in Proc. IEE EPE Conf., pp. 1245–1250.

[7] Capel (1986), "A bidirectional high power cell using large signal feedback control with maximum current control for space applications," in Proc. IEEE Power Electron. Spec. Conf., pp. 684–695.

[8] K. Venkatesan (1989), "Current mode controlled bidirectional fly back converter," in Proc. IEEE Power Electron. Spec. Conf, pp. 835–842

[9] Ray (1992), "Bidirectional dc–dc power conversion using quasiresonant topology," in Proc. IEEE Power Electron. Spec. Conf., pp. 617–624.

[10] Inoue, S. &Akagi, H. (2007). A Bidirectional DC-DC converter for an Energy storage system With Galvanic Isolation. IEEE Transactions on Power Electronics, Vol. 22, No. 6, (2007), pp. 2299-2306, ISSN 0885-8993.

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