

# **Review on A Step-Up Resonant Converter for HVDC Grid Connected Renewable Energy Sources**

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**ABSTRACT:** With the rapid development of large-scale renewable energy sources and HVDC grid, it is a promising option to connect the renewable energy sources to the HVDC grid with a pure dc system, in which high-power high-voltage step-up dc-dc converters are the key equipment to transmit the electrical energy. This paper proposes a resonant converter which is suitable for grid-connected renewable energy sources. The converter can achieve high voltage gain using an LC parallel resonant tank. It is characterized by zero-voltage-switching (ZVS) turn-on and nearly ZVS turn-off of main switches as well as zero-current-switching turn-off of rectifier diodes; moreover, the equivalent voltage stress of the semiconductor devices is lower than other resonant step-up converters.

**KEYWORDS:** Renewable energy, resonant converter, soft switching, voltage step-up, voltage stress.

## **I. INTRODUCTION**

The improvement of renewable energy sources is crucial to relieve the pressures of exhaustion of the fossil fuel and environmental pollution. At present, most of the renewable energy sources are utilized with the form of ac power. The generation equipments of the renewable energy sources and energy storage devices usually contain dc conversion stages and the produced electrical energy is delivered to the power grid through dc/ac stages, resulting in additional energy loss. Moreover, the common problem of the renewable energy sources, such as wind and solar, is the large variations of output power, and the connection of large scale of the renewable sources to the power grid is a huge challenge for the traditional electrical equipment, grid structure, and operation. DC grid, as one of the solutions to the aforementioned issues, is an emerging and promising approach which has drawn much attention recently. At present, the voltages over the dc stages in the generation equipments of the renewable energy sources are relatively low, in the range of several hundred volts to several thousand volts; hence, high-power high-voltage step-up dc-dc converters are required to deliver the produced electrical energy to the HVDC grid. Furthermore, as the connectors between the renewable energy sources and HVDC grid, the step-up dc-dc converters not only transmit electrical energy, but also isolate or buff kinds of fault conditions; they are one of the key equipments in the dc grid. Recently, the high-power high-voltage step-up dc-dc converters have been studied extensively.

## **II. LITERATURE SURVEY**

### **1. High power solidstate step-up resonant Marx modulator with continuous output current for offshore wind energy systems**

A.Parastar, A. Gandomkar, M. Jin, and J. Seok in *Proc. IEEE Energy Convers. Congr.* in Proc. IEEE Energy Convers. Congr. Expo., 2013, pp. 1709–1716.

This paper presents a new solid-state step-up resonant Marx modulator (SRM) with a continuous output current for offshore wind energy applications. The developed topology is based on the Marx generator concept, where magnetic

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switches are replaced by solid-state switching devices. The proposed converter is characterized by resonant switching transitions to achieve minimal switching losses and maximum system efficiency. Therefore, a higher switching frequency is conceivable to attain a higher power density.

## 2. Analysis and design of a parallel-connected single active bridge DC-DC converter for high-power wind farm applications.

K. Park and Z. Chen in *Proc. Eur. Conf. Power Electron.* in Proc. Eur. Conf. Power Electron. Appl., 2013, pp. 1–10.

This paper presents a parallel-connected Single Active Bridge dc-dc converter for high-power applications. Paralleling lower-power converters can lower the current rating of each modular converter and interleaving the outputs can significantly reduce the magnitudes of input and output current ripples without increasing switching losses or device stresses. Analysis of both the input and output current characteristics and design aspects of the transformer, the filter inductor, and the input and output filter capacitors will be presented. Considering the high maintenance cost and fault tolerant requirements, this modular converter concept is expected to be highly beneficial especially for the offshore wind farm application.

## 3. Step up DC DC converter for megawatt size application.

D. Jovicic, *IET Power Electron.*, vol. 2, no. 6, pp. 675–685, 2009.

This study describes a novel DC-DC converter concept which is capable of achieving very high step-up gains with megawatt level power transfers. The converter is based on two four-switch bridges around a LC circuit and does not utilise iron core transformers. The converter topology is simple and utilises thyristors as switches, with potentially soft switching operation. The high-voltage circuit does not suffer from excessive switch stresses or reverse recovery problems. The analytical modelling indicates that loading, and not the voltage gain, determines the converter size and the control input magnitude. For a given converter, the gain and either loading or operating frequency can be arbitrary selected. The converter shows good controllability with a linear characteristic if the operating frequency is used as the control input. The detailed digital simulation on PSCAD platform confirms conclusions from theoretical analysis on a 5 MW test system, which connects 4 kV source to 80 kV high voltage DC grid. The simulation studies of losses, with realistic internal resistances, indicate that efficiencies of around 95% could be expected.

## 4. Comparative Evaluation of a New Family of Transformerless Modular DC–DC Converters for High-Power Applications.

A. A. Hagar and P. W. Lehn, *IEEE Trans. Power Del.*, vol. 29, no. 1, pp. 444–452, Feb. 2014.

This paper investigates a new family of converters for high-power transfer between dc buses with different voltage levels. The proposed converters achieve high-voltage dc-dc conversion without an intermediate ac conversion stage. Three converter circuits are investigated, all based on the use of a common switching cell module. The first is a step-down converter, the second is a step-up converter, and the third is an inverting step-up/downconverter. For each converter, the structure is presented, its operation principle is explained, and the design equations are derived. A comparative analysis between the converters is carried out to highlight the merits and limitations of each topology.

## 5. High-Frequency Operation of a DC/AC/DC System for HVDC Applications.

T. Luth, M. Merlin, T. Green, F. Hassan, and C. Barker, *IEEE Trans Power Electron.*, vol. 29, no. 8, pp. 4107–4115, Aug. 2014.

Voltage ratings for HVdc point-to-point connections are not standardized and tend to depend on the latest available cable technology. DC/DC conversion at HV is required for interconnection of such HVdc schemes as well as to interface dc wind farms. Modular multilevel voltage source converters (VSCs), such as the modular multilevel converter (MMC) or the alternate arm converter (AAC), have been shown to incur significantly lower switching losses than previous two- or three-level VSCs. This paper presents a dc/ac/dc system using a transformer coupling two modular multilevel VSCs. In such a system, the capacitors occupy a large fraction of the volume of the cells but a significant reduction in volume can be achieved by raising the ac frequency. Using high frequency can also bring benefits to other passive components such as the transformer but also results in higher switching losses due to the higher number of waveform steps per second. This leads to a tradeoff between volume and losses which has been

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explored in this study and verified by simulation results with a transistor level model of 30-MW case study. The outcome of the study shows that a frequency of 350 Hz provides a significant improvement in volume but also a penalty in losses compared to 50 Hz.

## 6. A novel three-phase three-level ZVS PWM dc-dc converter.

Elio Agostin Jr. Ivo Barbi.978-1-4244-4783-1/10/\$25.00 ©2010 IEEE

This paper presents a novel three-phase dc-dc converter based on the three-phase neutral point clamped (NPC) commutation cell. A static analysis is made for a particular mode of operation, allowing the development of a design procedure for the power stage. The small-signal analysis based on the phasor transformation is also proposed, providing fundamental knowledge for a satisfactory compensation in closed-loop operation. From the theoretical analysis carried out, a design procedure is elaborated, providing the values of all power stage components.

## 7. A Prototype of Modular Multilevel Converters.

Y. Zhou, D. Jiang, P. Hu, J. Guo, Y. Liang, and Z. Lin, *IEEE Trans. Power Electron.*, vol. 29, no.7, pp. 3267–3278, Jul. 2014.

This paper introduces a modular multilevel converter (MMC) based prototype for investigating the control of large-scale MMCs. The prototype contains 264 submodules (SMs) totally, which are designed in such a way that they can be rearranged between the half-bridge model and full-bridge model conveniently. Therefore, the characteristics of various typologies based on voltage-sourced converters can be studied. Meanwhile, a novel control system for large-scale MMCs is proposed, which is characterized for modular design and excellent expansibility. The designed control system is composed of one central control unit and several arm control units, while each arm control unit is composed of several valve-group control units. Besides, a new voltage-balancing method composed of internal voltage balance and external voltage balance is proposed to balance the SM voltages. Finally, experiments on a three-phase dc/ac MMC are carried out to verify the prototype and the control system, as well as the new voltage-balancing method. The results show that the proposed control system is feasible and the new voltage-balancing method is valid.

## 8. Design and Control of Wind Energy Conversion System Based On Resonant DC/DC Converter.

S. Fan, T. Lim, H. Zhang, S. Finney, B. Williams

introduced the series parallel resonant converter is to interface with wind energy source. Design procedures and analysis of the series and parallel resonant converter for the WECS has been presented using the FMA. It is verified that the DC/DC resonant converter can be designed at the rated power, while it can provide enough DC gain as the wind speed decreases without increasing the transformer ratio compared to other converters. The whole WECS performance was investigated. It was proven by the simulation and experimental results that the DC/DC resonant converter can make wind turbine operate at maximum power point.

## 9. High Step-Up Converter With Three-Winding Coupled Inductor for Fuel Cell Energy Source Applications

Kuo-Ching Tseng, Jang-Ting Lin, and Chi-Chih Huang, *IEEE TRANSACTIONS ON POWER ELECTRONICS*, VOL.30,NO.2, FEBRUARY2015

analyzed a high step-up dc-dc converter for fuel cell hydroid electric vehicle applications is clearly and successfully verified. By using technologies of three-winding coupled inductor, switched capacitor, and voltage doubler circuit, the high step-up conversion can be efficiently obtained. The leakage energy is recycled and large voltage spike is alleviated; thus, the voltage stress is limited and the efficiency is improved. The full-load efficiency is up to 91.32% and the maximum efficiency is up to 96.81%. The voltage stress on the main switch is clamped as 120 V at  $D_{max}$ . The low-voltage-rated switch with low RDS-ON can be selected for the reduction of conduction losses. Thus, the proposed converter is suitable for high-power applications as fuel cell systems in hydroid electric vehicles.

### III. MOTIVATION

The Environmental friendly renewable energy technologies such as wind and solar energy systems are among the fleet of new generating technologies driving the demand for distributed generation of electricity. Power Electronics has

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initiated the next technological revolution and enables the connection of distributed generation (DG) systems to the grid. Thus the increasing power demand will be met by Distributed Generation (DG) system which are based on renewable energy sources such as solar power, wind power etc. These systems need to be controlled properly in order to ensure direct current injection into grid.

## IV. OBSERVATION FROM LITERATURE SURVEY

- ❖ The voltages over the dc stages in the generation equipment's of the renewable energy sources are low, High-power high-voltage step-up dc-dc converters are required to deliver the produced electrical energy to the HVDC grid.
- ❖ The converter between the renewable energy sources and HVDC lines, the step-up dc-dc converters not only transmit electrical energy, but also isolate of fault conditions.
- ❖ For the application where galvanic isolation is not mandatory, the use of a transformer would only increase the cost, volume, and losses, especially for high-power high-voltage applications. Several non-isolated topologies for high-power high-voltage applications have recently been proposed and studied in the literature.

## V. OBJECTIVES

After the literature survey the benefits has been noted for step up resonant converter for HVDC grid connected renewable energy sources In the proposed converters, all the power switches are operated at fixed 50% duty cycle, and the output voltage regulation is achieved by adopting phase shift control between the primary and secondary-side switches. ZVS performance has been achieved for both the primary-and secondary-side switches in a wide voltage and load range. Furthermore, the reverse recovery problems associated with the rectifier diodes are alleviated. Further improvements on performance of efficiency, power density, and electromagnetic noise.

## VI. PROPOSED WORK AND METHODOLOGY

The proposed resonant step-up converter is shown in Figure. The converter is composed of an FB switch network, which comprises Q1 through Q4 , an LC parallel resonant tank, a voltage doubler rectifier, and two input blocking diodes, Db1 and Db2 . The steady state operating waveforms are shown in Fig. 2 For the proposed converter, Q2 and Q3 are tuned on and off simultaneously; Q1 and Q4 are tuned on and off simultaneously. In order to simplify the analysis of the converter.

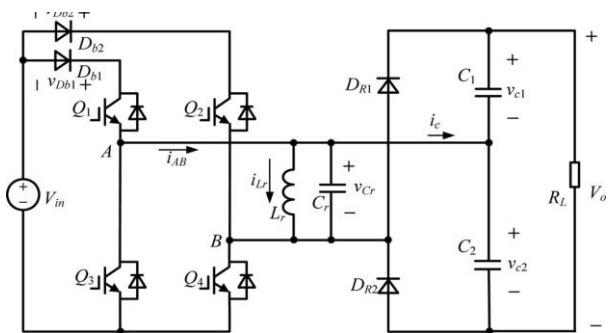


Fig.1. Topology of the proposed resonant step-up converter.

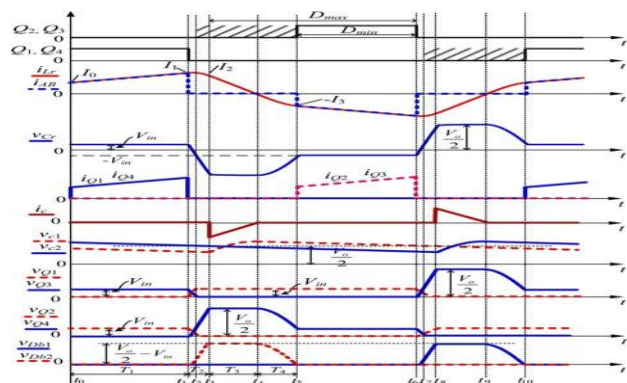


Fig.2. operating waveforms

The soft-switching technology is critical to improve the conversion efficiency, especially for high-voltage applications. Recently, several soft-switching topologies for high power high-voltage applications have been proposed. the converter topologies based on resonant switched capacitor (RSC) are proposed with reduced switching loss and modular structure.

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The shortage of the RSC-based converter is the poor voltage regulation and the requirement of a large number of capacitors. Jovcic et al. proposed a novel type of resonant step-up converter with potentially soft-switching operation, which utilizes thyristors as switches and does not suffer from excessive switch stresses and reverse recovery problems; moreover, a large voltage gain is easily obtained. Similarly, a new family of resonant transformerless modular dc/dc converters is proposed and the main feature of the proposed converters is that the unequal voltage stress on semiconductors of thyristor valve is avoided with the use of active switching network, which is composed of an ac capacitor and four identical active switches. Thyristors have large voltage and current ratings; however, the use of thyristor limits the switching frequency of the converter, resulting in bulky passive components and slow dynamic response. Moreover, the resonant inductors of the converters are unidirectional magnetized, leading to lower utilization of the magnetic core, which means that a great volume of core is required.

## VII. CONCLUSION

This paper proposed resonant dc–dc converter which can achieve very high step-up voltage gain and it is suitable for high-power high-voltage applications. A resonant converter which is suitable for grid-connected renewable energy sources. The converter utilizes the resonant inductor to deliver power by charging from the input and discharging at the output. The resonant capacitor is employed to achieve zero-voltage turn-on and turn-off for the active switches and ZCS for the rectifier diodes. The analysis demonstrates that the converter can operate at any gain value ( $> 2$ ) with proper control; however, the parameters of the resonant tank determine the maximum switching frequency, the range of switching frequency, and current ratings of active switches and diodes.

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