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A Step-up Resonant Converter for 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. The operation principle of the converter and its resonant parameter selection is presented in this paper. The operation principle of the proposed converter has been successfully verified by simulation and experimental results.

1. INTRODUCTION

1.1 General

The development 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 equipment 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 been drawn much attention recently. Solar energy is a primary and renewable source of energy. As the cost of photovoltaic (PV) panels is seen to reduce continuously, PV-based power generation is gaining in popularity for both grid-connected and stand-alone systems. Solar panels harness the sun's energy in the form of light and convert the energy into electricity. Although the average consumer might associate solar panels with residential rooftop assemblies, solar panels are available for a wide range of applications, including powering individual gadgets, electronic devices and vehicle batteries. The smallest unit of a solar panel is the solar cell, also called a photovoltaic, or PV cell; it's the individual PV cell that turns sunlight into electricity. Individual cells arranged in a group are called a "module" or panel; a collection of two or more panels is called an array.

2. LITERATURE SURVEY

2.1 Amir Parastar, Ali Gandomkar, MingGuoJin and Jul-Ki Seok,"High Power SolidState Step-up Resonant Marx Modulator with Continuous Output Current for Offshore Wind Energy Systems" 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 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.

2.2 Amir Parastar and Jul-Ki Seok, "High power step-up modular resonant DC/DC converter for offshore wind energy systems" this paper presents several multilevel modular DC/DC conversion systems based on the capacitor-clamped module concept for high power offshore wind energy applications. The interest in offshore wind farms has been increased significantly because of the stronger and more stable winds at sea, which will lead to a higher power production. DC/DC power conversion solutions are becoming more popular for fulfilling the growing challenges in the offshore wind power industry. Two types of the capacitor-clamped modules, the double-switch module and switchless module, are discussed.

2.3 S.Balakumar and B.Baskaran, "Design and modeling of wind fed resonant DCDC converter through synchronous generator using MATLAB/Simulink" this paper presents the design, modeling and simulation of variable speed wind turbine through the LCL type DC-DC resonant converter for grid connected wind energy system using MATLAB/Simulink. Owing to enhancing the power demand and environmental issues, power generation from renewable energy is getting more consideration. The designed converter has main merits like reduced switching loss using soft switching methods, reduced transformer size, and filter size.

2.4 Caitríona E. Sheridan, Michael M.C. Merlin and Timothy C. Green, "Study of a Resonant DC/DC Converter in Alternate Discontinuous Mode" this paper looks at DC to DC conversion for high power applications.

After having briefly reviewed the domain, a resonant bidirectional DC/DC converter already suggested in the literature is closely studied using a novel mode of operation, dubbed Alternate Discontinuous Mode. This operating mode alternates the two halves of the converter in such a way that the two DC grids are never connected. This alternative operating principle ensures the converters fault blocking capabilities and, by operating in discontinuous conduction mode, the switching losses are minimized..

2.5EloiAgostiniJr and Ivo Barbi, "A novel three-phase three-level ZVS PWM dc-dc converter" 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.

3. PROPSED SYSTEM

3.1 Overview

A novel resonant step-up DC-DC converter is proposed, which not only can realize soft switching for main switches and diodes and large voltage-gain, but also has relatively lower equivalent voltage stress of the semiconductor devices and bidirectional magnetized resonant inductor. The operation principle of the converter and the design of the resonant parameters are presented. A 100V (±20%)/1000V, 1kW prototype is built in the lab to verify the effectiveness of the converter.

3.2 Proposed Converter Structure

The proposed resonant step-up converter is shown in Fig 3.1. The converter is composed of a full-bridge switch network, which is made up by through, a LC

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parallel resonant tank, a voltage doubler rectifier and two input blocking diodes, and . The steady-state operating waveforms are shown in Fig 3. 2 and detailed operation modes of the proposed converter are shown in Fig. 3.3-3.11.

1) All switches, diodes, inductor and capacitor are ideal components;
2) Output filter capacitors and are equal and large enough so that the output voltage is considered constant in a switching period.

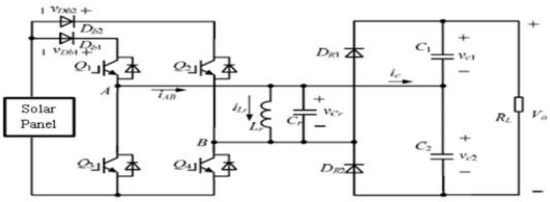


Figure 3.1: Topology of resonant step up converter

3.3 Solar Panel

Solar panel refers to a panel designed to absorb the sun's rays as a source of energy for generating electricity or heating. A photovoltaic (in short PV) module is a packaged, connected assembly of typically 6×10 solar cells. Solar Photovoltaic panels constitute the solar array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions, and typically ranges from 100 to 365 watts.

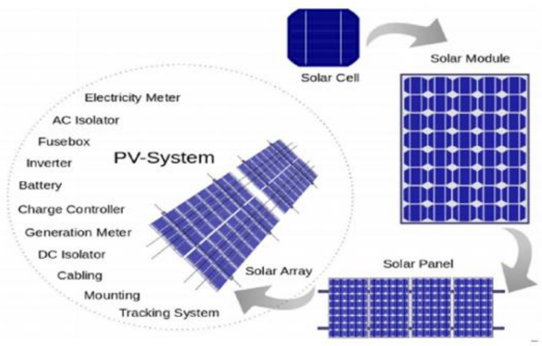


Figure 3.3 : From a solar cell to a PV system

A photovoltaic system typically includes a panel or an array of solar modules, a solar inverter, and sometimes a battery and/or solar tracker and interconnection wiring.

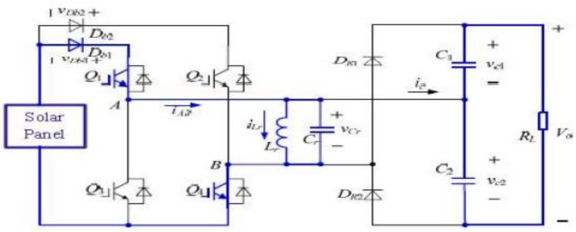
The price of solar power, together with batteries for storage, has continued to fall so that in many countries it is cheaper than ordinary fossil fuel electricity from the grid. Solar modules use light energy (photons) from the sun to generate electricity through the photovoltaic effect.

3.4 Converter Operation Principle

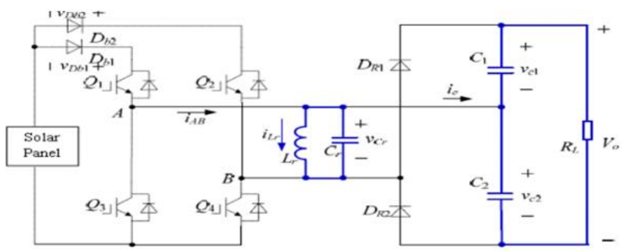
A. Mode 1 [t0 ,t][See Fig. 3(a)] During this mode, Q 1 1 and Q 4 are turned on resulting in the positive input voltage V across the LC parallel resonant tank, i.e., v Lr = vCr = V in in .
The converter operates similar to

$$I_1 = I_0 + \frac{V_{\text{in}} T_1}{L_r} \qquad (1)$$

$$E_{\text{in}} = \frac{1}{2} L_r \left(I_1^2 - I_0^2\right). \qquad (2)$$



B. Mode 2 [t1 ,t 3][See Fig. 3(b)] At t 1 , Q 1 and Q 4 are turned off and after that L resonates with I 1 r , v Cr decreases from V in , and I Lr r increases from in resonant form. Taking into account the parasitic output



In order to realize zero-voltage-switching (ZVS) for and , an additional capacitor, whose magnitude is about 10 times with respect to , is connected in parallel with.

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Hence, the voltage across is considered unchanged during the charging/discharging process and is equivalent to be shorted. Due to be much larger than the parasitic capacitances, the voltages across and increase slowly. As a result, and are turned off at almost zero voltage in this mode

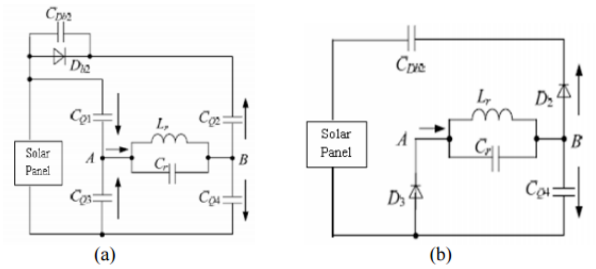
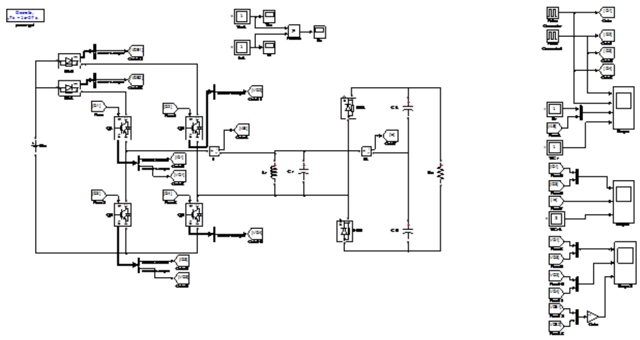
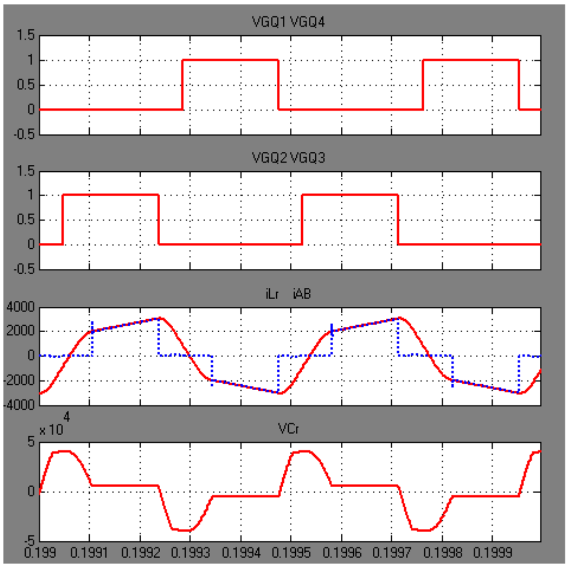


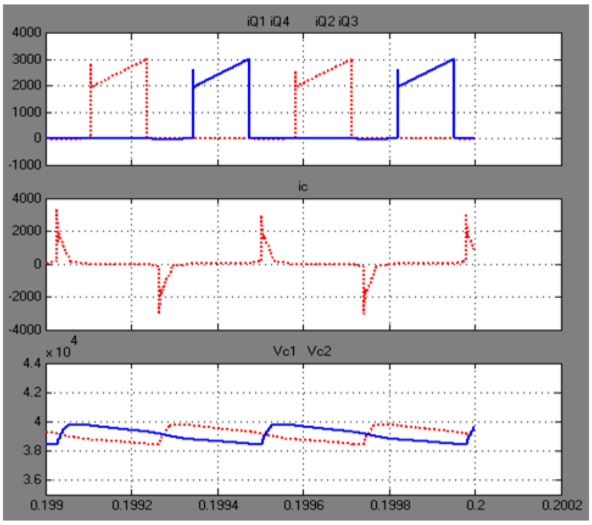
Figure 3.6: Further equivalent circuits of Mode 2 (a) [t1,t2] (b) [t2,t3]

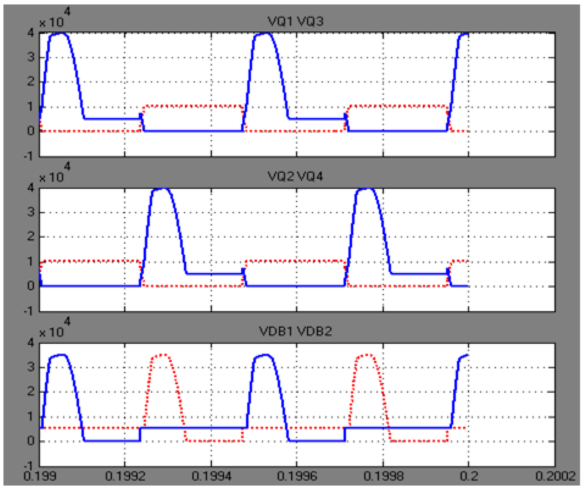
4. SIMULINK RESULTS AND OUTPUTS

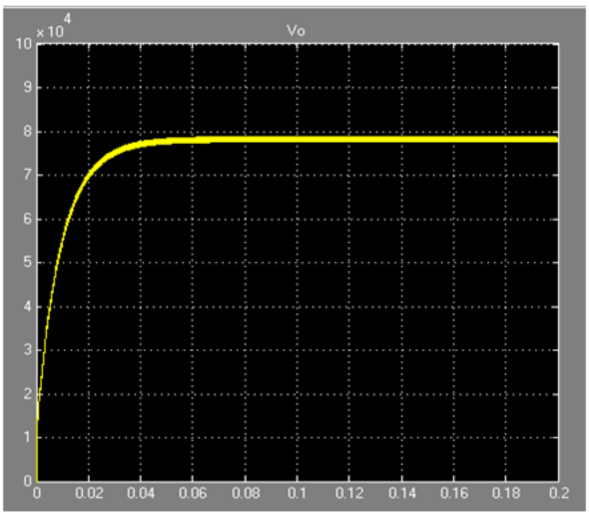


Simulation snapshot









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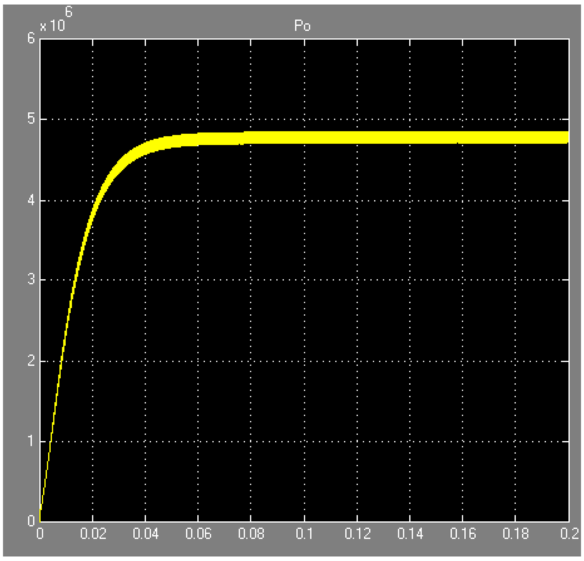

CONCLUSION:

A novel resonant dc–dc converter is proposed in this paper, which can achieve very high step-up voltage gain and it is suitable for high-power high-voltage applications. 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. The converter is controlled by the variable switching frequency.

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