Grenze International Journal of Engineering and Technology, Special Issue

A Resonant DC–DC Converter for Induction Motor Drive Application

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***Abstract*—In the hybrid micro grid, processes of multiple dc-ac dc or ac-dc-ac conversions are reduced in an individual ac or dc grid. The hybrid grid consists of both ac and dc networks connected together by multi directional converters. In this micro grid network, it is especially difficult to support the critical load without incessant power supply. The generated power can be extracted under varying wind speed, solar irradiation level and can be stored in batteries at low power demands. In this project, a hybrid AC-DC micro grid with solar energy, energy storage, and a pulse load is proposed. This micro grid can be viewed as a PEV parking garage power system or a ship's power system that utilizes sustainable energy and is influenced by a pulse load. The battery banks inject or absorb energy on the DC bus to regulate the DC side voltage. The frequency and voltage of the AC side are regulated by a bidirectional AC-DC inverter. The power flow control of these devices serves to increase the system's stability and robustness. The system is simulated in MATLAB/SIMULINK.**

I. INTRODUCTION

The increasing energy demand, increasing costs and exhaustible nature of fossil fuels, and global environment pollution have generated huge interest in renewable energy resources. Other than hydroelectric power, wind and solar are the most useful energy sources to satisfy our power requirements [1]. Wind energy is capable of producing huge amounts of power, but its availability cannot be predicted. Solar power is available during the whole day but the solar irradiance levels change because of the changes in the sun’s intensity and shadows caused by many reasons. Generally solar and wind powers are complementary in nature. Therefore, the hybrid photovoltaic and wind energy system has higher dependability to give steady power than each of them operating individually does. Other benefit of the hybrid system is that the amount of the battery storage can be decreased as hybrid system is more reliable compared to their independent operation. The key principle that drives the boost converter is the tendency of an inductor to resist changes in current [2]. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost power stage is shown in Fig. 1 When the switch is closed, current flows through the inductor, which stores energy from the current in a magnetic field. During this time, the switch acts like a short circuit in parallel with the diode and the load, so no current flows to the right hand side of the circuit. The construction and performance of fixed-speed wind turbines very much depends on the characteristics of mechanical sub-

Grenze ID: 01.GIJET.4.3.42

circuits, e.g., pitch control time constants, main breaker maximum switching rate, etc. The response time of some of these mechanical circuits may be in the range of tens of milliseconds [3]. As a result, each time a gust of wind hits the turbine, a fast and strong variation of electrical output power can be observed. These load variations not only require a stiff power grid to enable stable operation, but also require a sturdy mechanical design to absorb high mechanical stresses. This strategy leads to expensive mechanical construction, especially at high-rated power.In this paper, an improved full-bridge three-level (IFBTL) dc/dc converter is presented for an offshore wind turbine based on permanent magnet synchronous generators (PMSGs) in a dc grid (Fig. 2). The IFBTL dc/dc converter is applied to boost the dc voltage from a diode rectifier to a high voltage for the dc grid integration [4].

II. CONTROL OF IMPROVED FULL-BRIDGE THREE-LEVEL DC/DC CONVERTER FOR WIND TURBINES IN A DC GRID

The basic full-bridge three-level (FBTL) converter, with the advantage of the reduced voltage stress of the switches, reduced filter size, and improved dynamic response, is becoming highly suitable for medium-voltage and high-power conversion [5]. Although, both the basic FBTL and SMs-based FBTL configurations can create five-level output voltage to minimize voltage steps and reduce dv/dt in comparison with the basic HBTL configuration, particularly in the medium-voltage and high-power applications the basic FBTL converter has a simpler circuit structure and less number of switch devices than the SMs-based FBTL configuration. This leads to a small footprint and high reliability for the basic FBTL converter [6].

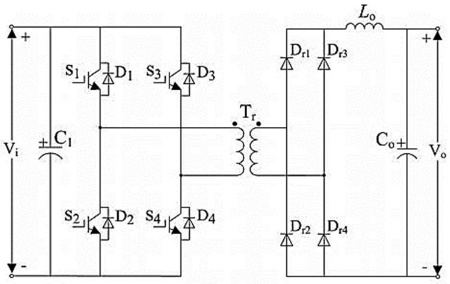

Fig. 1 Basic FB two-level converter

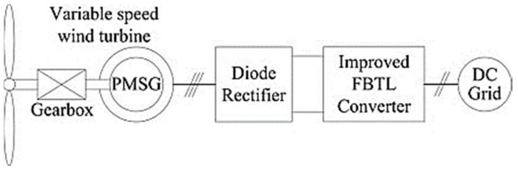

Fig. 2 Block diagram of the wind turbine connected to a dc grid

A. Offshore Wind Farm with Dc Grid Connection

The offshore wind farm with dc grid connection studied Fig. 3, which is composed with the wind turbines, collection and transmission systems, and converter stations. Four aggregated wind turbines with 100 MW each represent the studied wind-farm, respectively, as shown in Fig. 3. The direct-drive permanent-magnet synchronous generators (PMSG), which has some preferred features for large offshore wind farms, are used [7]. It is assumed that each aggregated model has twenty 5-MW wind turbines lumped together. The ac output of the generator is converted into the low dc voltage with a VSC. A full-bridge isolated boost (FBIB) converter is used as a dc/dc converter to step up the low dc voltage to a medium- voltage level, which effectively reduces the cable losses at the collection system [8].

III. CONTROL AND DESIGN OF DC GRIDS FOR OFFSHORE WIND FARMS

The collected power of all wind turbines is transferred via a dc-cable to a single inverter, which needs to feed the power into the ac grid via a transformer. In an ideal case, the instantaneous power from the dc grid is equal to the active power at the ac side [9]. Considering delay and detection times together with power fluctuations within the wind farm, this cannot be achieved for transient operations. Consequently, the dc-link capacitor of the inverter must be sufficient to compensate the unequal power at the ac and the dc side. Since we do not have a regular back-to-back operation and high-voltage capacitors are very expensive, this is an important aspect for the speed of the control system, all magnitudes are dc components, which are much easier to control (Fig. 4) [10].

IV. CONVERTER STRUCTURE AND OPERATION PRINCIPLE

The resonant step-up converter is shown in Fig. 5.The converter is composed of an FB switchnetwork, which comprises Q1 through Q4, an LC parallel resonant tank, a voltage doubler rectifier, and two input

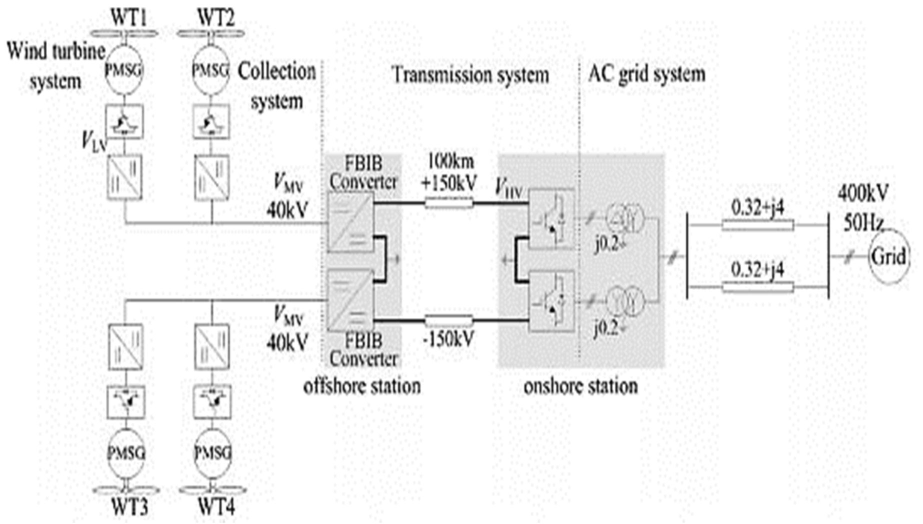

Fig. 3 Block diagram of the offshore wind farm with dc grid connection

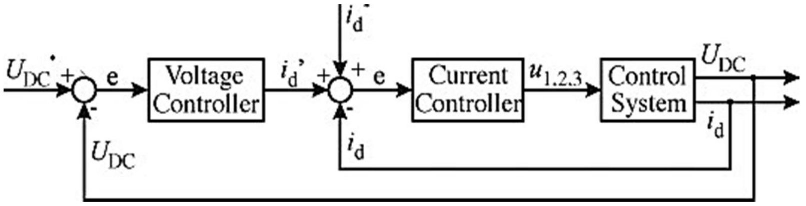

Fig. 4 Control structure

blocking diodes, Db1 and Db2. The steady-state operating waveforms are shown below and detailed operation modes of the converter [11]. For the 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, the following assumptions are made [12]:

1) All switches, diodes, inductor, and capacitor are ideal components.
2) Output filter capacitors C1 and C2 are equal and large enough so that the output voltage Vo is considered constant in a switching period Ts.

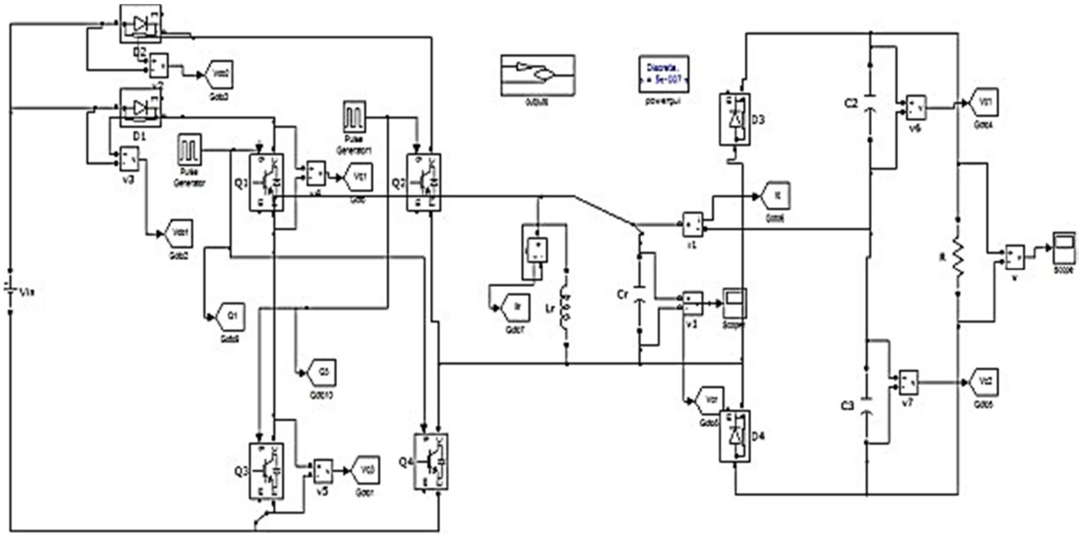

Fig. 5 Matlab / Simulation circuit of the resonant step-up converter

Mode 1 [t0, t1]

During this mode, Q1 and Q4 are turned on resulting in the positive input voltage Vin across the LC parallel resonant tank, i.e., vLr = vCr = Vin. The converter operates similar to a conventional boost converter and the resonant inductor Lr acts as the boost inductor with the current through it increasing linearly from I0. The load is powered by C1 and C2 [10]. At t1, the resonant inductor current iLr reaches I1.

$$I_1 = I_0 + \frac{V_{\text{in}} T_1}{L_r} \qquad \frac{1}{2} L_r I_1^2 + \frac{1}{2} C_r V_{\text{in}}^2 = \frac{1}{2} L_r I_2^2 + \frac{1}{2} C_r \left(\frac{V_o}{2} \right)^2$$

Steady-state simulation results under different load conditions when Vin = 4 kV, 5 MW are depicted in Fig. 6.

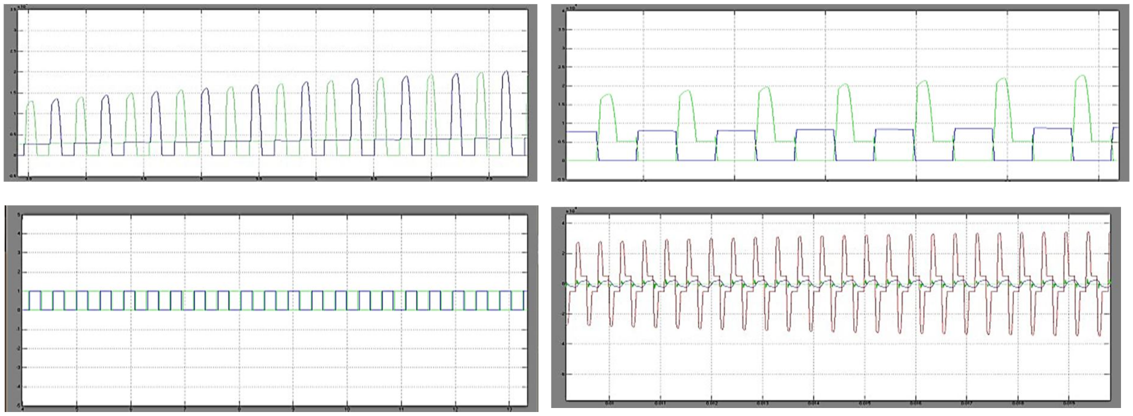

Fig. 6 Steady-state simulation results under different load conditions when Vin = 4 kV, 5 MW

Matlab/simulation circuit of the resonant step-up converter with PV and Induction Motor is depicted in Fig. 7 and its corresponding results related to stator current speed and electromagnetic torque are shown in Fig. 8.

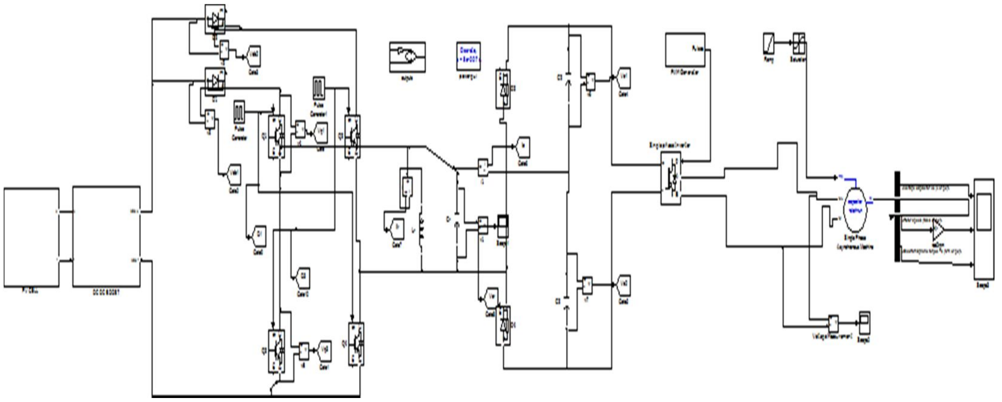

Fig. 7 Matlab/simulation circuit of the resonant step-up converter with PV and Induction Motor

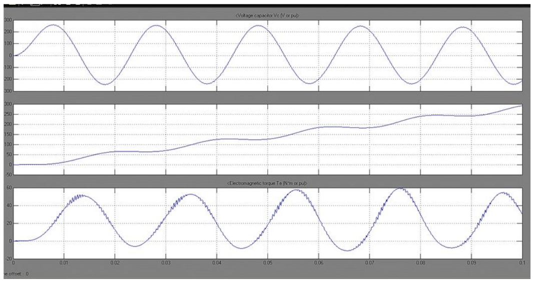

Fig. 8 Simulation wave form of step-up converter induction motor stator current speed and electromagnetic torque

V. CONCLUSIONS

A novel resonant dc–dc converter is in this project, 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. In this project, the converter was designed to drive a three-phase induction motor directly from PV solar energy and was conceived to be a commercially viable high efficiency, and high robustness.

REFERENCES

[1] CIGRE B4-52 Working Group, HVDC Grid Feasibility Study. Melbourne, Vic., Australia: Int. Council Large Electr. Syst. 2011.

[2] F. Deng and Z. Chen, “Design of protective inductors for HVDC transmission line within DC grid offshore wind farms,” IEEE Trans. Power Del., vol. 28, no. 1, pp. 75–83, Jan. 2013.

[3] W. Chen, A. Huang, S. Lukic, J. Svensson, J. Li, and Z. Wang, “A comparison of medium voltage high power DC/DC converters with high step-up conversion ratio for offshore wind energy systems,” in Proc. IEEE Energy

[4] F. Deng and Z. Chen, “Control of improved full-bridge three-level DC/DC converter for wind turbines in a DC grid,” IEEE Trans. Power Electron., vol. 28, no. 1, pp. 314–324, Jan. 2013.

[5] S. Fan, W. Ma, T. C. Lim, and B. W. Williams, “Design and control of a wind energy conversion system based on a resonant dc/dc converter,” IET Renew. Power Gener., vol. 7, no. 3, pp. 265–274, 2013.

[6] S. P. Engel, N. Soltau, H. Stagge, and R. W. De Doncker, “Dynamic and balanced control of three-phase high-power dual-active bridge DC–DC converters in DC-grid applications,” IEEE Trans. Power Electron.,vol. 28, no. 4, pp. 1880–1889, Apr. 2013.

[7] A. S. Abdel-Khalik, A. M. Massoud, A. A. Elserougi, and S. Ahmed, “Optimum power transmission-based droop control design for multi-terminal HVDC of offshore wind farms,” IEEE Trans. Power Syst., vol. 28, no. 3, pp. 3401–3409, Aug. 2013.

[8] F. Deng and Z. Chen, “Operation and control of a DC-grid offshore wind farm under DC transmission system faults,” IEEE Trans. Power Del., vol. 28, no. 1, pp. 1356–1363, Jul. 2013.

[9] C. Meyer, “Key components for future offshore DC grids,” Ph.D. dissertation, RWTH Aachen Univ., Aachen, Germany, pp. 9–12, 2007.

[10] C. Meyer, M. Hoing, A. Peterson, and R. W. De Doncker, “Control and ¨ design of DC grids for offshore wind farms,” IEEE Trans. Ind. Appl., vol. 43, no. 6, pp. 1475–1482, Nov./Dec. 2007.

[11] C. Meyer and R. W. De Doncker, “Design of a three-phase series resonant converter for offshore DC grids,” in Proc. IEEE Ind. Appl. Soc. Conf., 2007, pp. 216–223.

[12] L. Max, “Design and control of a DC collection grid for a wind farm,” Ph.D. dissertation, Chalmers Univ. Technol., Goteborg, Sweden, pp. 15– ¨30, 2009.