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Cascaded Boost Inverter Based Converter for Wind Turbine Driven Ig System

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ABSTRACT: *In the wind energy conversion system (WECS) based on the Induction Generator, the topology that a wind generator is connected to a voltage source inverter through a diode rectifier and a boost chopper is widely adopted for its low cost and high reliability. However, with the increasing power level of the WECS, the power switch device of a boost chopper in the topology has to endure high instantaneous voltage and current stress, thus reducing the system reliability. Although the traditional multiple boost converter reduces the transmission power level of single circuit units in terms of structure, it is still limited by narrow speed regulation range. Thus, a novel switchable-cascaded-mode boost converter is proposed in this paper. At last, the effectiveness of the new converter is verified with an experimental prototype. The experimental results demonstrate that speed range is extended by using the new topology as generator-side converter in the induction generator wind generation system.*

Keywords: induction generator (IG); speed range; switchable-cascaded-mode boost converter (SCMBC); wind energy conversion system (WECS).

1. INTRODUCTION

Wind power contributes a significant proportion of consumers' increasing electrical power demands. Wind power generation has grown at alarming rate in the past years and will continue to do so as power electronic technology continues to advance. A number of power converter techniques have been developed for integrating with the electrical grid. The use of power electronic converters allows for variable speed operation of the wind turbine.

Power electronic converters play a vital role in obtaining high efficiency and good performance of the WECS. Initially, WECS were of the fixed speed type with squirrel cage induction generators. In the fixed speed type, the speed of the wind turbine is constant irrespective of the wind speed and is determined by the frequency of the grid. The fixed speed WECS are designed to achieve the maximum output only at one speed. Today, variable speed wind energy systems are popular with the Induction generator (IG)and the doubly-fed induction generator (DFIG). Variable speed wind turbines have many advantages like increased energy capture, operation at the maximum power point, higher efficiency, and improved power quality

2. WIND ENERGY CONVERSION SYSTEM

Fig. 1 shows the block diagram of the WECS with a IG, a diode bridge rectifier, a boost converter, MLI, and a three-phase load. The IG converts the wind energy into electrical energy, which is fed to the diode bridge rectifier. The rectified DC output is given to the boost converter, which operates in closed loop to obtain the output voltage at the desired value. The output of the boost converter is fed to the three-phase five-level CHB inverter, which feeds a three-phase load.

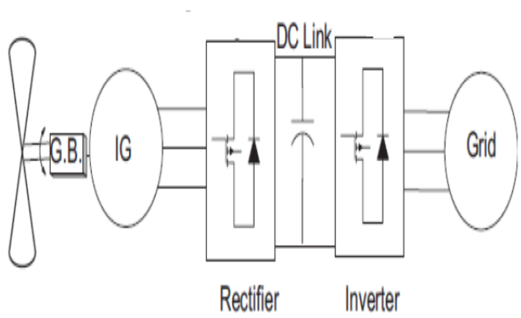

Figure-1 wind energy conversion system

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2.1 Wind turbine:

The amount of power captured from a wind turbine is specific to each turbine and is governed by

$$Pt=12\rho ACPvw3 \quad (1)$$

Where Pt is the turbine power, ρ is the air density, A is the swept turbine area, CP is the coefficient of performance and υw is the wind speed.

Aerodynamic torque of the wind turbine is given by

$$\tau_W = \frac{P_W}{\omega} \quad (2)$$

2.2 Induction generators:

The induction Generator converts the mechanical energy of the turbine into electrical energy. The use of induction generators (IG) is advantageous since they are relatively inexpensive, robust and require low maintenance. Induction generator need bi-directional power flow in the generator-side converter since it requires external reactive power support from the grid.

2.4 Diode Bridge Rectifier:

The diode rectifier converts the three-phase AC voltage of the PMSG into DC voltage. Eqn. (3) gives the average output voltage of the rectifier

$$V_{oavg} = \frac{3\sqrt{3}V_{mph}}{\pi} \quad (3)$$

V_{mph} is the peak value of the phase voltage of IG

2.3. DC-DC boost converter:

Incorporating an extra DC/DC converter gives the following advantages:

1. Control of generator-side DC-voltage through variation of the switching ratio

2. Maintains appropriate inverter-side DC-voltage, 3. Allows for selective harmonic elimination (SHE) switching, giving reduced losses,

4. Inverter no longer needs to control DC-voltage, and has more flexible control.

3. BOOST CONVERTER

The boost converter converts the rectified DC voltage into DC voltage of the desired magnitude. The boost converter operates in the continuous conduction mode. Fig. 2 shows the circuit of the boost converter. There are two modes of operation for the boost converter. In mode 1, the switch is ON, the diode is in the OFF condition and the inductor stores energy. During this period, the capacitor supplies the output current. In mode 2, the switch is in the OFF condition, the capacitor stores energy and the energy stored in the inductor gets dissipated. Eqn. (4) gives the average output voltage of the converter (V_{DCB}). Eqns. (5) and (6) give the design equations for the boost converter.

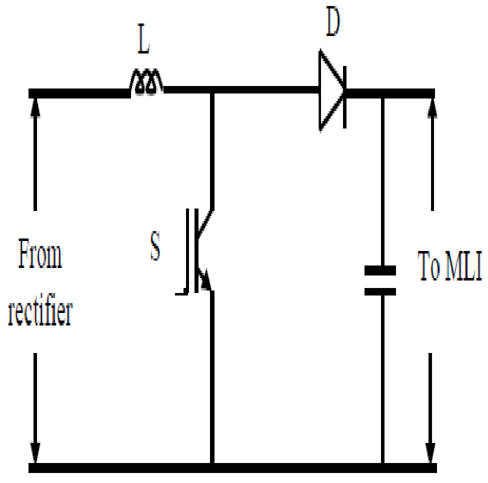

Figure-2 circuit of Boost converter in CCM

$$V_{DCB} = \frac{V_{oavg}}{(1-k)} \quad (4)$$

$$L = \frac{kV_{oavg}}{f_s \Delta I} \quad (5)$$

$$C = \frac{kI}{f_s \Delta V_c} \quad (6)$$

ΔI is the peak to peak ripple current of the inductor, ΔV_c is the peak to peak ripple voltage of the capacitor, k is the duty ratio of the switch S and f_s is the switching frequency.

4. CIRCUIT CONFIGURATION

Fig.3 shows a proposed system consisting of a phase shifting transformer, diode-rectifier, DC-DC boost converter connected to inverter containing grid side The power-factor also improved by using the combined system.

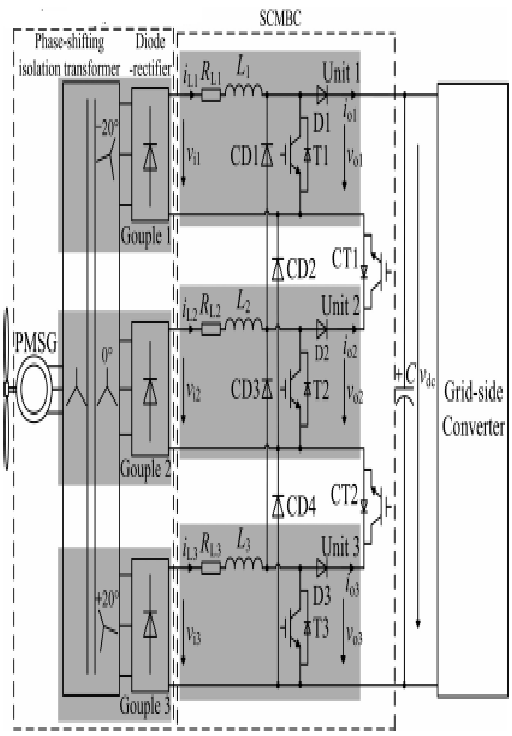

Figure 3: IG-WECS system with multi channel boost converter

Multi-pulse rectifier is applied to the IG-based WECS, which not only improves the stator current and reduces torque ripple, but also redistributes the whole transmission power of the system and reduces the power level of each boost chopper unit through the secondary windings of the transformer Wind Turbine model block in MATLAB implements a variable pitch wind turbine model. The performance coefficient Cp of the turbine is the mechanical output power of the turbine divided by wind power and a function of wind speed, rotational speed, and pitch angle (beta). Cp reaches its maximum value at zero beta. Select the wind-turbine power characteristics display to plot the turbine characteristics at the specified pitch angle.

The first input is the generator speed in per unit of the generator base speed. For a synchronous or asynchronous generator, the base speed is the synchronous speed. For a induction generator, the base speed is defined as the speed producing nominal voltage at no load. The second input is the blade pitch angle (beta) in degrees. The third input is the wind speed in m/s. The output is the torque applied to the generator shaft in per unit of the generator ratings. The turbine inertia must be added to the generator inertia.

5. SIMULATION RESULTS

The model FOR IG-WECS based boost converter has been successfully modeled and tested using MATLAB/SIMULINK toolbox.

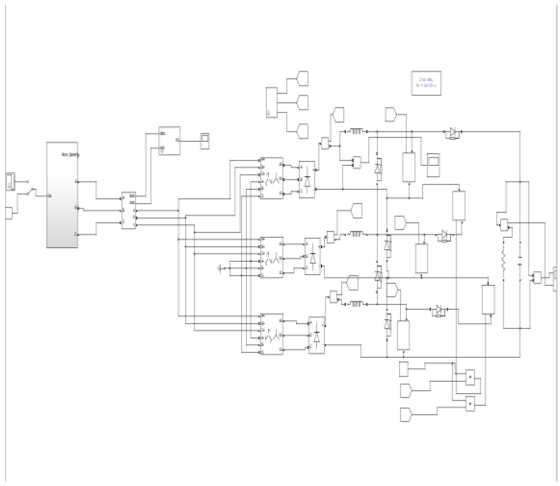

Figure 4: Simulation model of proposed work

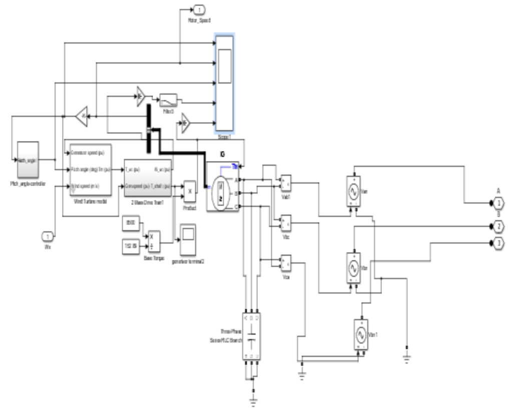

Figure 5: Simulation model of Wind energy generation system

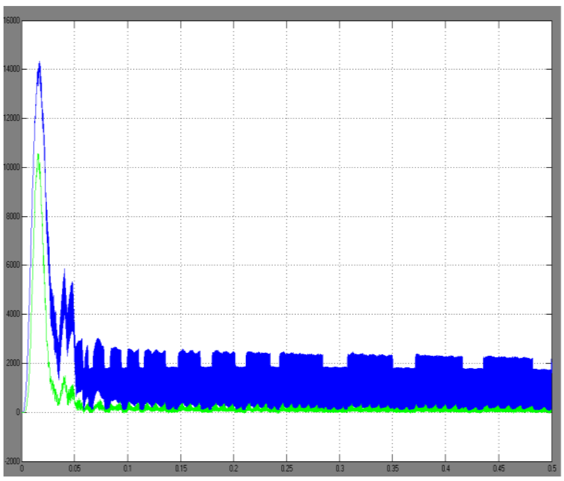

Figure 6: waveforms of instantaneous power containing P& Q component

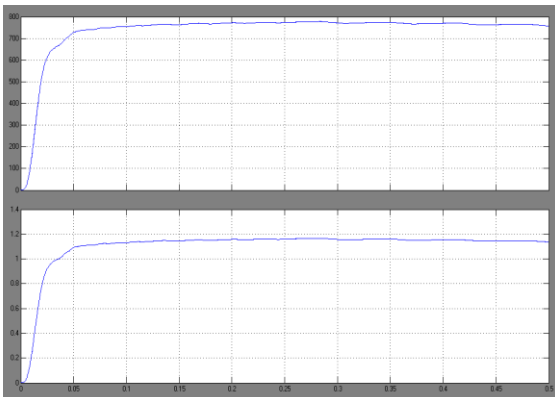

Figure 7: waveform of voltage and current across load

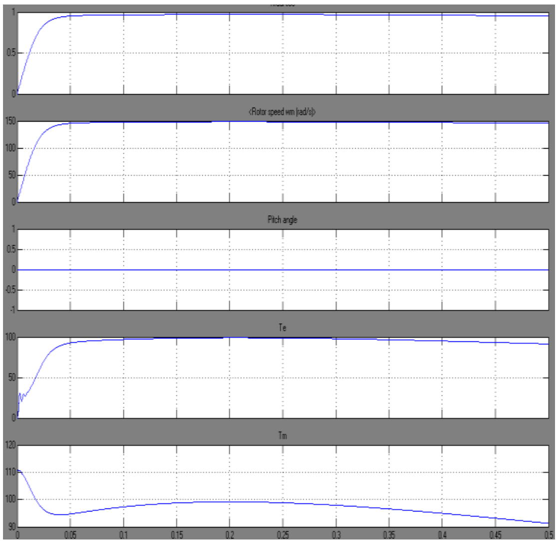

Figure 8: waveforms of wind speed (wm/sec),torque(Tm),speed of rotor, pitch angle

7. CONCLUSION

In the wind energy conversion system (WECS) based on the induction generator, the topology that a wind generator is connected to a boost inverter through a diode rectifier and a boost chopper is widely adopted for its low cost and high reliability The wind energy system is modeled with the IG in MATLAB/ Simulink. A boost converter is designed to step up or step down the voltage for decreasing or increasing wind speeds**.**

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