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PMSM for Wind Power Generation Using a Boost Regulator and PID Controller with Proposed MPPT Algorithm

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ABSTRACT: A wind power system with Permanent Magnet Synchronous Machine (PMSM). The total system consists of a wind turbine, a permanent magnet synchronous machine and a three phase diode rectifier, a boost converter, a three phase diode rectifier, a transformer-less step down circuit, and cascade multilevel inverter with PID controller. The three phase AC output from the Permanent Magnet Synchronous Machine is sent to the three phase diode rectifier for conversion to DC and a boost regulator is used to step-up (i.e)increases this DC voltage to the desired level. This step-upped DC voltage is then converted into AC output by the cascade multilevel inverter. The switching technique of the proposed inverter is done by using PID controller for grid synchronization conditions. As the suggested method is minimizes its size and entirely transformer-less, it reduces Total Harmonic Distortion (THD) to less than 0.1%. The TLCL Immittance Converter not only reduces the harmonics of the inverter output and it provides a nearly constant output current thereby stabilizing the system. Then, main MPPT control methods are used which, MPPT controllers used for extracting maximum possible power in WECS are possible. The system modelling and the simulation results were obtained using the MATLAB - simulink software.

KEYWORDS: PID controller, Wind Turbine, Permanent Magnet Synchronous Machine, Boost Converter, Step- down Circuit, T-LCL Immittance Converter, cascade multi level Inverter, PID controller.

I. INTRODUCTION

Energy is the essential part for the national development and it has become a major contribution for improving the quality of life and enhancing the economic growth. With the sources for energy such as coal and the use of fossil fuel is slowly killing our planet. Also, the cost of fossil fuel is also increasing day by day and its sources are gradually becoming exhausted, so that the world and its people must look to a new and renewable source of energy to sustain our way of life.

As a result, the cost of the utilization amount of the renewable energy systems is on the decreasing trend making them ideal for use in power generation systems. One way is to harness the energy of the wind. Wind energy is a source of energy that is free, pollution less, renewable and unlimited. Thus, the use of wind turbine in the form of a renewable energy has become as one of the most alternative resource of power generation due to some compensations of it such as cost-effective and eco-friendly. Therefore, a considerable amount of research studies has been devoted to using wind turbines in electricity generation. Where conventional ways of supplying electricity fail, and people to fully make use of the wind energy. The most common controls to improve overall system efficiency of wind turbine are power absorption by minimizing the number of losses and hence, more power extraction.
In conventional wind energy systems, transformers are generally used to step-down grid voltages. But transformers are bulky and cost equipment and also contribute to the Total Harmonic Distortion (THD) of the inverter output. Hence, in this paper a transformer-less wind generation and there are Several techniques reported in literature to reach an optimum performance and process efficiency by using a conventional control system such as proportional-integral derivate (PID) controller topology has been proposed.

The proposed model wind power system block diagram is shown in Fig1. The design includes 1) a 3–phase PMSM which has 3-phase windings on the stator and a permanent magnet on the rotor. 2)a three-phase diode rectifier to

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give AC output from the PMSM to DC output; 3) a boost converter to step up this DC output to the required level. 4) an cascade multilevel inverter for converting the DC output of the boost converter into AC output; 5)a T-LCLconverterto suppressthe harmonicsof the inverteroutputandproducea puresinusoidal waveand6)cascade multilevel inverter is controlled PID controller.

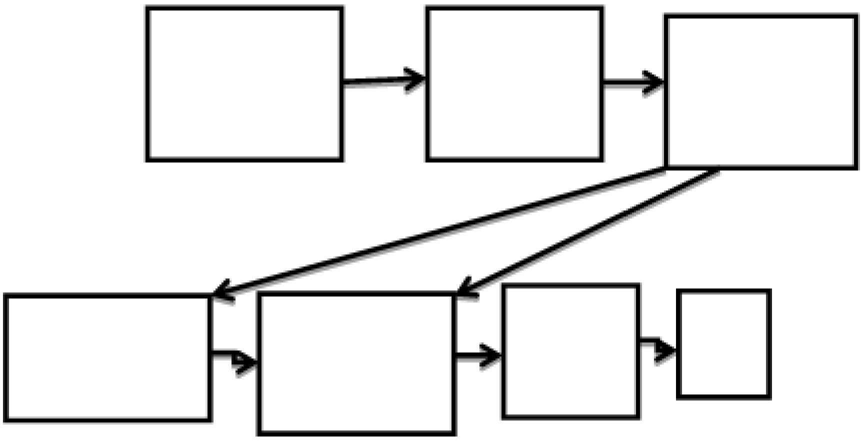

Fig.1 Blockdiagramof WindPower GenerationSystem

II.WIND TURBINE

When movingair exerts forceon the propellerlikebladesaroundarotorofthewindturbines,electricityisgenerated. Permanent magnet synchronous machine is used in wind turbine to produce power. The rotor is connected to a lowspeed shaft which in turn is connected via gear box to a high speed shaft. The gear box is responsible for increasing the rotational speed from10-60rpm to 1200-1800 rpm. The high speed shaft is connected to a generator which is then used for generating electricity. The output of PMSM will be 3- phase supply.

III. PROPOSED DESIGN

The design and the performance of the proposed wind power generation system were performed using the MATLAB SIMULINK simulation software. The input was taken by means of the built-in wind turbine block of the software. In Simulink the PMSM was then connected to the is controlled by controlling by in the wind turbine a generator speed, pitch angle, wind speed and torque is fixed and the 3- phase supply output is taken from the PMSG. The various sections of the whole system are discussed in details below.

3.1 PERMANENT MAGNET SYNCHRONOUS MACHINE

The generator used for the design was a 3-phase permanent magnet synchronous machine. A 3-phase permanent magnet synchronous machine has 3-phase winding on the stator and permanent magnet on the rotor as shown in Figure 2.and c are the stator winding terminal and the shaft node is used for establishing connection with the high speed mechanical shaft. The back emf of the machine is sinusoidal.

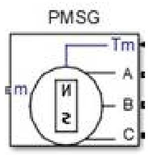

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Fig.2Permanent Magnet Synchronous Machine

3.2 THREE-PHASE DIODE BRIDGE RECTIFIER

Here the variable frequency sinusoidal voltage produced by the generator cannot be used for establishing connection with the grid. First, there is a need to be rectified into DC and then Converted into AC voltages of desired frequency and Amplitude. The rectification is done by a Three -phase diode bridge rectifier as shown in Fig-3. The output of the rectifier is then converted into 3-phase AC voltage into 230V DC supply.

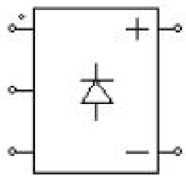

Fig.3Three phase Diode Bridge Rectifier

3.3 STEP-UP BOOST CONVERTER

The output of the rectifier is then converted into 230V DC by means of a boost converter as shown in Figure 4. The boost converter's output should be 230V since it is the input of the inverter, the output of which should be the same as the grid voltage 230V for single phase. The output voltage of the boost converter is given by:

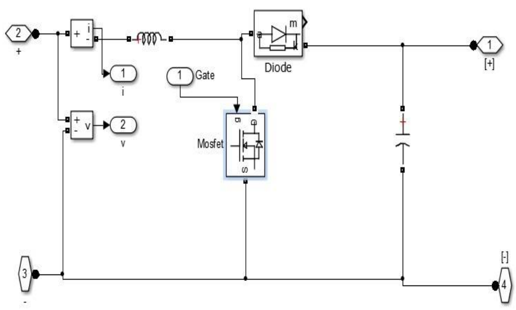

Fig.4Boost Converter for stepping up voltage to requiredLevel.

These converters effectively combined both boost converters as one and other different converter combinations are developed to carry out high step-up voltage gain by using the coupled-inductor technique. Due to voltage gain has restricted by the voltage stress on the active switch, once the leakage inductor energy of the coupled-inductor can be recycled that reduced the voltage stress on active switch, this leads to the coupled inductor and the voltage-multiplier or voltage-lift techniques are successfully accomplished the goal of higher voltage gain. This paper presents a cascaded high step-up dc–dc converter to increase the output voltage of the micro source to a proper voltage level for the dc interface through dc–ac inverter to the main electricity grid. With three phase rectifier capacitor rating of 1mF. In this MOSFET is used as switch with capacitor rating of 50mF and boost inductor of 100mH.

3.5 CASCADE MULTI LEVEL INVERTER

Thesingle-phase7-level invertertopologyis used in the system. Theinverteradoptsafull-bridgeconfiguration withanauxiliarycircuit. A boost converter isconnected tothe inverter.

Because the proposed inverter is used in agrid-connected wind power system,utilitygridis usedinsteadofload. The Simulink model for cascade 7-level multi level inverter is shown in figure 5. Theinjectedcurrentmustbesinusoidal

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withlowharmonicdistortion. Inordertogeneratesinusoidal current, the cascade multi level inverter is controlled by PID controller. The sample of grid voltage is taken and it is compared with boost converter output. To produce a sinusoidal current as on grid by connecting with cascade inverter. With capacitor rating with capacitor C1 of 3mF, capacitor C2 of 2mF, capacitor C3 of 2mF, and capacitor C4 of 2mF.

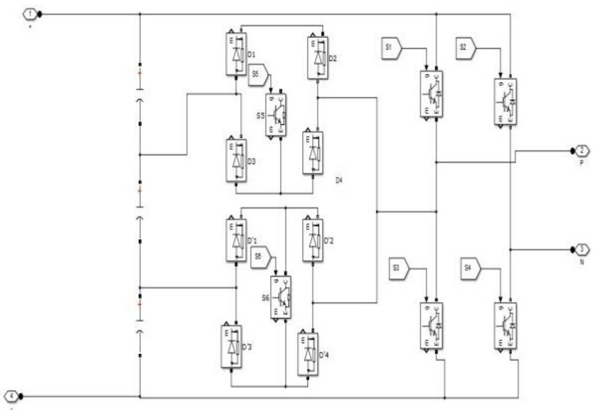

Fig.5 Control Circuit of the cascade multi-level Inverter

3.6 INVERTER SWITCHING CIRCUIT

PID controller is used control cascade inverter. In the proportional control there is a drawback that it mostly results in a static or steady state error. The control algorithms used in practice are, therefore, usually more complex than the proportional controller. It has been found empirically that a so called PID controller is a useful structure. Thus the PID controller has three terms. The proportional term P corresponds to proportional control. The integral term I give a control action that is proportional to the time integral of the error.

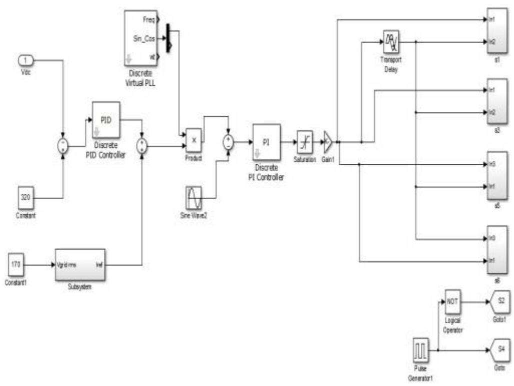

Fig.6 Control Circuit of the PID controller

This ensures that the value of steady state error becomes zero. The derivative term D is proportional to the time derivative of the control error. This term generally allows prediction of the future error. There are many variations of the basic PID algorithm that will improve its performance and operability. With PID controller gain Kp of 10, gain Kd of 5 and gain with Ki of 0.1. The output cascade inverter is connected to LC filter with inductor rating of Lf1 of 1mH and Lf2 of 1mH and capacitor rating of Cf is 1mF.

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3.6 FILTER CIRCUIT

To cancel the harmonics from the inverter output, a filter circuit is employed. In conventional inverters, LC filter is used but this model employs a T-LCL Immitance Converter. The filter circuit consists of two inductors L1 and L2 and a capacitor C in the shape of a T as shown in Fig-7.

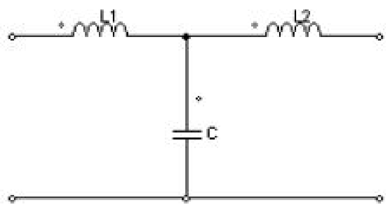

Fig.7 T-LCL Filter

The output cascade inverter is connected to LC filter with inductor rating of Lf1 of 1mH and Lf2 of 1mH and capacitor rating of Cf is 1mF.

IV. SIMULATION RESULTS

The MATLAB simulation results are provided in this section.

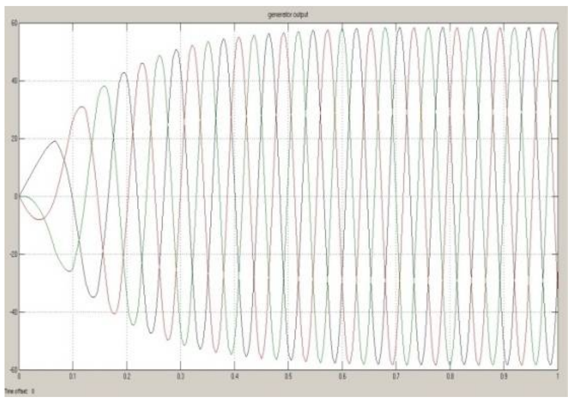

Fig.8output waveform of PMSM

In the wind turbine a generator speed, pitch angle, wind speed and torque is fixed and the 3- phase supply output is taken from the PMSG. The pitch angle is controlled by pitch angle controller. Generator speed is fixed as 1.5pu and wind speed fixed as 50m/s. the torque is controlled with generator. The output of PMSG is shown in figure 8. Hence the need for the rectifier improves for converting it into DC voltage and then the conversion of DC to 50Hz (grid frequency) AC voltage.

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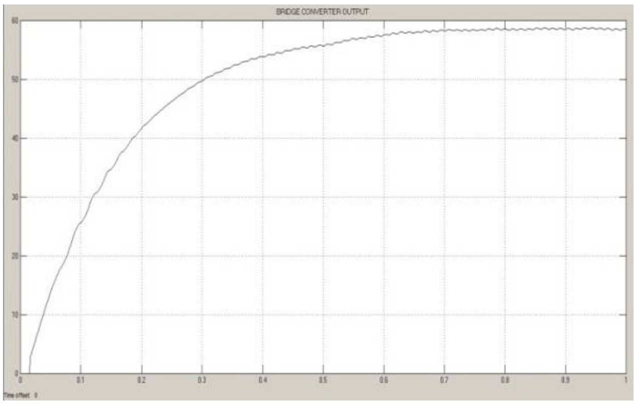

Fig.9 output waveform of rectifier output

Figure-9: shows the bridge converter output. Where the PMSM output three phase output voltage is converted in single phase voltage.

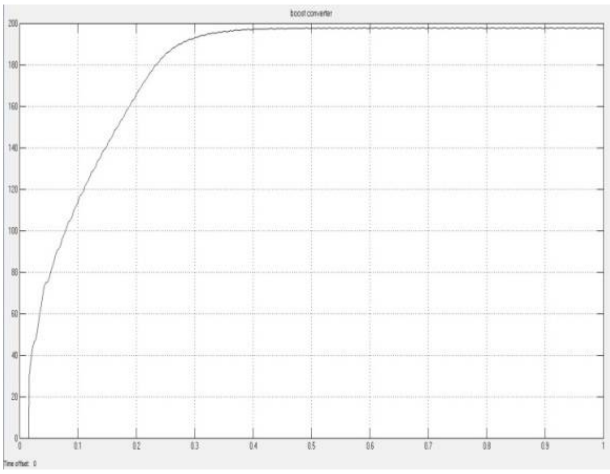

Fig.10 output waveform of boost converter

The output of 3-phase supply bridge rectifier is and it is sent to boost regulator it is as 1-phase supply. In this MOSFET is used as switch with capacitor rating of 50mF and boost inductor of 100mH.
The output waveform for boost converter is also shown in figure 10.
Figure-9: shows the bridge converter output. Where the PMSM output three phase output voltage is converted in single phase voltage.

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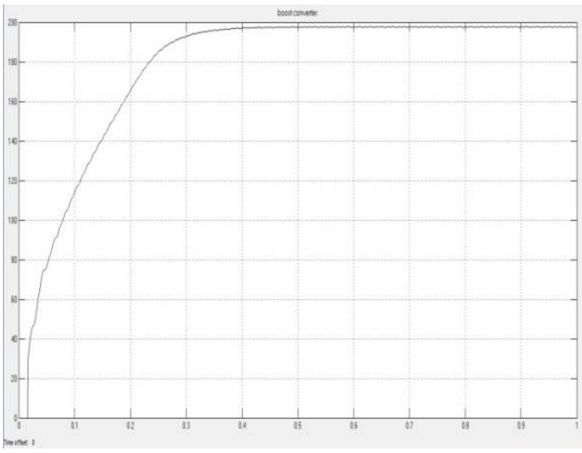

Fig.10 output waveform of boost converter

The output of 3-phase supply bridge rectifier is and it is sent to boost regulator it is as 1-phase supply. In this MOSFET is used as switch with capacitor rating of 50mF and boost inductor of 100mH.
The output waveform for boost converter is also shown in figure 10.
From the output for boost converter is sent to cascade multi-level inverter. Where the dc output voltage is converter into ac voltage to a required voltage level by using PID controller. In the PID controller is taken as reference signal from the grid voltage. Thus the output of cascade multi-level inverter as grid voltage.
The output of cascade multi-level inverter is shown in figure-11.

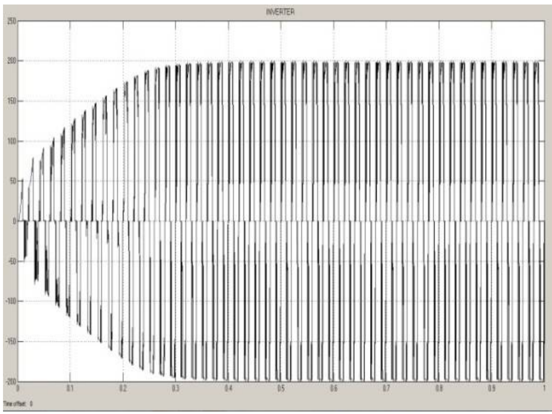

Fig.11 output waveform of cascade inverter

The waveform is non-sinusoidal and contains lots of harmonics. To eliminate these harmonics, a low pass T-LCL filter is employed at the output of the inverter which produces a pure, sinusoidal voltage.

After filtering, we obtained a pure sinusoidal voltage of frequency 50Hz and of rms value 220V as shown in Fig-12.

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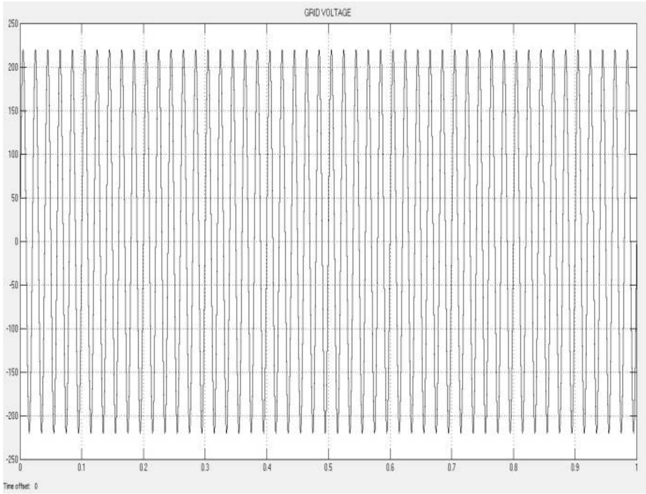

Fig.12 output waveform of grid voltage

V.CONCLUSION

The design of a wind power generation system using a permanent magnet synchronous machine along with a boost regulator and a transformer-less Step down circuit has been presented. The MALAB simulation results show that a 220V, 50Hz output voltage can be obtained using the particular set-up. The total harmonic distortion (THD) was found to be 0.01% which is much lower than the IEEE 519 standard. Thus the proposed wind power generation system can be used for sending power to the grid.

In future, the simulation results would be expanded and variable wind speeds would be taken into account. And we can increase the number of level of cascade multilevel inverter with three phase grid voltage. And it can be controlled by some soft computing tools.

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