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Wind Energy Conversion System with Duty Ratio Control

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ABSTRACT: This project presents the simulation of Variable speed Wind Energy Conversion (WECs) using Permanent Magnet Synchronous Generator (PMSG). PMSGs are used by these technologies due to special characteristics of PMSGs such as low weight and volume, high performance, and the elimination of the gearbox. In this project a new variable-speed WECS with a PMSG is proposed. The permanent magnet synchronous generator is controlled to obtain maximum power from the incident wind with maximum efficiency under different load conditions. The literature extensively investigates modeling effective wind turbine systems to optimize and effectively utilize the turbine power output through the maximum power point tracking (MPPT) technique. MPPT is the key to improve the conversion efficiency of wind energy. Here, WECs with duty ratio control refer to wind turbines equipped with a control mechanism that can regulate the duty cycle of the system. The duty cycle refers to the percentage of time the wind turbine is in operation compared to the total time. In a wind energy conservation system, the duty ratio control system regulates the amount of power generated by the wind turbine. The control mechanism can adjust the angle of the blades or the rotor speed to maintain a constant power output while the wind speed varies. This system optimizes the energy generation process by utilizing the wind at its optimal speed, which increases the efficiency of the wind turbine. By controlling the duty ratio, the wind turbine can be operated in a consistent and stable manner, without exceeding the operating limits of the system. Overall, wind energy conservation systems with duty ratio control are a more efficient way of utilizing wind power and can greatly increase the output of wind energy system.

KEYWORDS: Wind Turbine, Wind Speed Forecasting, Permanent Magnet Synchronous Generator, Wind Energy Conservation System, MPPT (Hill Climb Algorithm), Matlab/Simulink .

I. INTRODUCTION

Due to increased awareness regarding climate change another environmental issues, the expectations for generating power from renewable sources of energy have increased. Various studies have been conducted to suggest cost-effective and efficient systems for generating electricity. Wind used as widely distributed huge reserves of green energy, has dramatic increased in grid connected power these years. Thus, to improve the efficiency of wind power system becomes an essential part, both to reduce the costs of wind power generation systems, and to increase the proportion of renewable energy in the national power grid. High efficiency, good robustness and low costs have become the research focus of wind energy harnessing. Currently, The literature extensively investigates modeling effective wind turbine systems to optimize and effectively utilize the turbine power output through the maximum power point tracking (MPPT) technique. MPPT is the key to improve the conversion efficiency of wind energy. By the adoption of variable speed wind turbine (VSWT), adjusting the rotation speed of wind turbine rapidly according to the variable wind speed can achieve for high efficiency to harness wind source. These technique adopted by MPPT controller.

Wind energy conservation systems with duty ratio control refer to wind turbines equipped with a control mechanism that can regulate the duty cycle of the system. The duty cycle refers to the percentage of time the wind turbine is in operation compared to the total time. The permanent magnet synchronous generator is controlled to obtain maximum power from the incident wind with maximum efficiency under different load conditions . Characteristics of inverter are used for maximum power tracking control and delivering power to the grid, simultaneously.

Extracting maximum power from wind and feeding the grid with high-quality electricity are two main objectives for WECSs. To realize these objectives, the ac-dc-ac converter is one of the best topology for WECSs. The inverters have been reported recently as a competitive alternative to existing inverter topologies with many inherent advantages such as voltage boost. This inverter facilitates voltage boost capability with the turning ON of both switches

in the same inverter phase leg. In this proposed topology, boost converter is omitted without any change in the objectives of the WECs. Reliability of the system is greatly improved, because the short circuit across any phase leg of inverter is allowed. Also, in this configuration, inverter output power distortion is reduced. The control mechanism can adjust the angle of the blades or the rotor speed to maintain a constant power output while the wind speed varies. This system optimizes the energy generation process by utilizing the wind at its optimal speed, which increases the efficiency of the wind turbine. By controlling the duty ratio, the wind turbine can be operated in a consistent and stable manner, without exceeding the operating limits of the system. Overall, wind energy conservation systems with duty ratio control are a more efficient way of utilizing wind power and can greatly increase the output of wind energy systems.

II. RELATED WORK

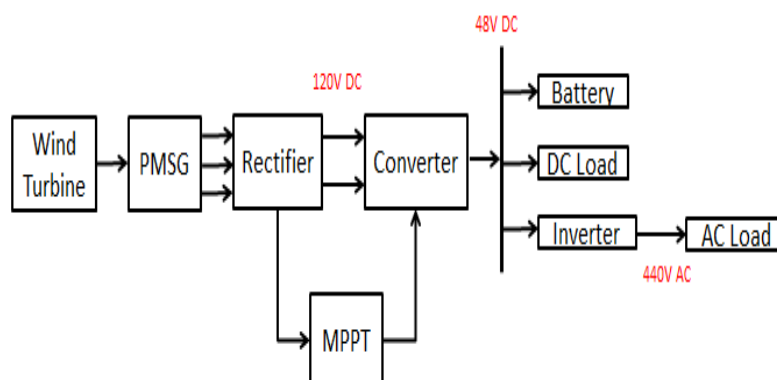
Some of the gaps identified based on the forecasting carried out are as given below:

We are unable to extract the full potential of the renewable energy systems. Some amount of energy gets wasted due to inefficient operation. Change of wind speed requires a very short response time; lag of wind speed measurement in turbines and eliminate the discontinuity of wind speed sequence. System proposed to give only DC outputs under variable speed conditions i.e., 6m/s to 12m/s whereas most applications need AC. Controller to capture the maximum power with reduced oscillation on the drive train.

The objectives of the proposed model based on the gaps identified are as given below:

- Implementation of a Low cost and small WECS system which works nearer to cut in speed.
- Implementation of sensor less Duty Ratio Based MPPT for Low Wind Speed Conditions.
- Implementation of Full Power Electronic converter for working with low wind speeds when WECS works much below rated speed.

When the wind blows to the wind turbine, the turbine's Mechanical energy is given as input to the PMSG. It converts mechanical energy into electrical energy by producing AC voltage. The AC voltage is rectified to produce constant 120V DC voltage. The MPPT senses the current and voltage and produces duty cycle of certain pulse width as input to the converter. The DC-DC converter reduces the voltage to 48V DC and it is given to a DC grid, which is connected to a battery to store energy, DC loads such as LED's, electrical vehicle charging etc. and an inverter is connected to DC grid, which converts DC to 3 phase, 440V AC Supply, which can be connected to AC loads.



Wind Turbine: The wind turbine converts the kinetic energy of the wind into mechanical energy through the rotation of its blades.

Generator: The mechanical energy from the turbine's rotation is transmitted to an electrical generator, which converts it into electrical energy.

Power Converter: The electrical energy generated is typically in the form of alternating current (AC), but for grid integration and efficient power transmission, it needs to be converted into direct current (DC) using a power converter.

Duty Ratio Control: The duty ratio control is applied to the power converter to regulate the amount of power that is sent to the grid. It adjusts the on and off time of the power converter's switching devices (like transistors) to control the flow of power.

Maximum Power Point Tracking (MPPT): In addition to duty ratio control, a good wind energy conservation system often employs MPPT techniques. MPPT is a method used to continuously track and find the maximum power point of the wind turbine, where the energy extraction is most efficient, given the varying wind conditions.

Rectifier: It converts Alternating Current to Direct Current.

Inverter: It converts Direct Current to Alternating Current.

By adjusting the duty ratio, the system can extract maximum power from the wind, even under varying wind conditions, thus increasing overall energy capture and turbine efficiency. The duty ratio control helps in maintaining a stable grid by regulating the power output from the wind turbines, preventing sudden fluctuations that could affect the power grid. Overall, the combination of wind energy conservation with duty ratio control and MPPT algorithms results in a more efficient and stable wind energy system, contributing to renewable energy integration and sustainability

III. METHODOLOGY

3.1 Wind Energy Conversion System

The wind energy conversion system is a high nonlinear and complex coupled system. The system comprises of the wind turbine, transmission device, induction machine and converters. The basic components and general scheme of a wind energy system are shown in Figure, which contain the following main parts:

1. Wind turbine, which is a installation capturing wind energy by blades and transferring the wind kinetic power to mechanical torque;
2. Induction machine, which can convert the power from the mechanical side into the electrical side.
3. Gearbox and shaft, which is a transmission device to adapt the rotation speed for the generator;
4. Power converters, it is composed of the grid side inverter and the machine side rectifier, connected by a DC- bus.

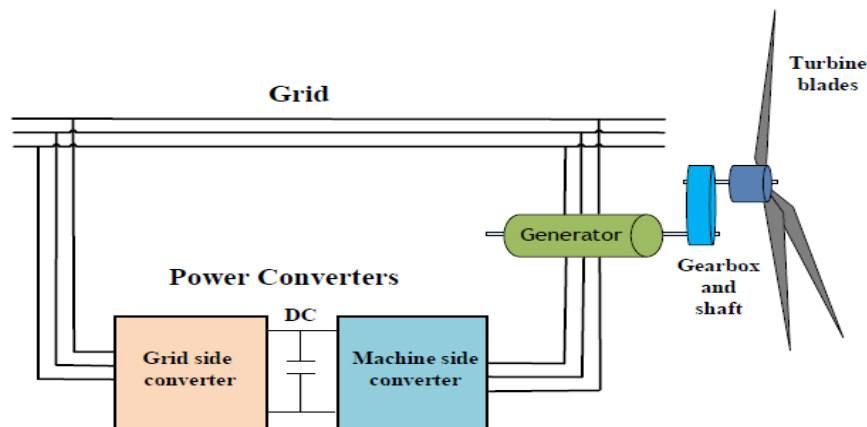


Figure 1. Block diagram of the wind turbine.

3.2 Wind Turbine Model

The wind turbine extracts power by the wind blades in the turbine nacelle, then converts it into mechanical power.

3.3 Wind Speed Forecasting

As an anticipatory control strategy, predict wind velocity is more conducive to smooth the output power of wind turbines, since the power generation process is a complex nonlinear process, which will be affected by the wind speed and torque of the power generator. Besides, wind speed forecasting can estimate daily output of wind turbines in advance, and improve the planning ability of wind farms for electric power transmission and distribution. In addition, the maximum power point tracking can be achieved precisely by wind forecasting even without anemometers. Considering that there is a significant time-lag in the wind speed measurement of wind turbines for the anemometers' inertia is great, suitable prediction model should be chosen from the model base according to certain principles.



3.4 Controller Design

In order to achieve the MPPT control, the state feedback controller is designed by measuring the stator current and flux linkage compared with the desired current and flux reference. Considering the time lag in the turbine’s wind speed measurement, we adopt the turbine mechanical speed from blade shafts to predict the one-step wind speed. The rotor flux is estimated with current flux model.

3.5 MPPT Control Objective

The MPPT algorithm should be applied to extract the maximum power from the wind turbine when the rotor speed is below the rated speed. Moreover, a rotor power control mechanism should be activated when the rotor speed exceeds the speed of rated power. On account that different wind speed corresponds to unique optimal turbine speed, and the maximum power point is expected so that the power can be extracted as much as possible. The reference of generator speed is calculated by the optimal tip-speed ratio which is Currently, the wind speed used in the control system is usually measured with an anemometer. While in practical, the wind speed is changeable parameters.

3.6 Permanent Magnet Synchronous Generator

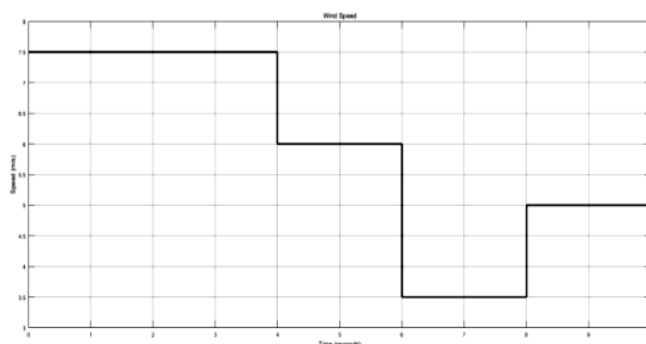
The permanent magnet synchronous generator (PMSG) creates an excitation field using permanent magnets rather than coils. Moreover, PMSG has fewer moving parts than electrically excited generators or PMSG requires less attention..The synchronous generators (SGs) require controllers to efficiently maximize the amount of wind energy from wind to meet grid integration requirements. Thus, before sending electricity to the grid, PMSG is connected to a frequency converter that comprises a converter for the machine (rotor-side converter) and one for the grid (grid-side converter). The rotor-side converter regulates the operation of the PMSG. This converter can either be a diode-based rectifier or a pulse-width modulated voltage source converter.

3.7 Hill Climb Search Method

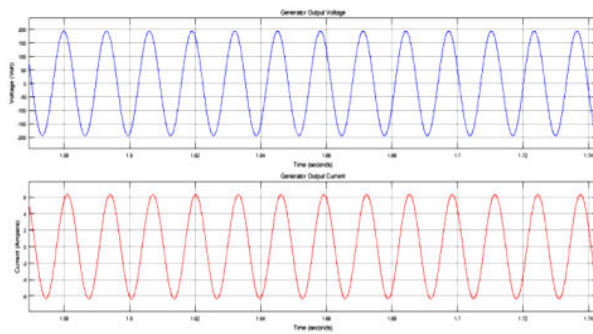
The HCS is also called perturbation and observation (P&O) since it observes the perturbation in power and according to that it provides the corrections in the particular parameter like duty cycle of the DC–DC converter to control the dc voltage or to regulate current in order to adjust the rotor speed and track the MPP. This method is based on perturbing control variable in arbitrary small steps, and the next perturbation is decided on observing the changes in power curve due to preceding perturbation. P&O approach is a widely used MPPT algorithm because of its simplicity and absence of mechanical speed sensor or anemometer for implementation.

IV. EXPERIMENTAL RESULTS

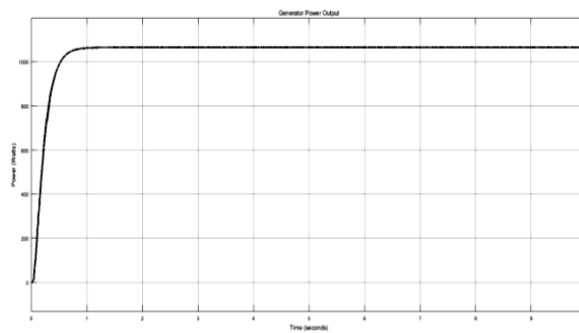
In The Experimental Results Section Of ”Wind Energy Conversion System With Duty Ratio Control,” The Findings And Performance Of The Proposed Approach Would Be Present.



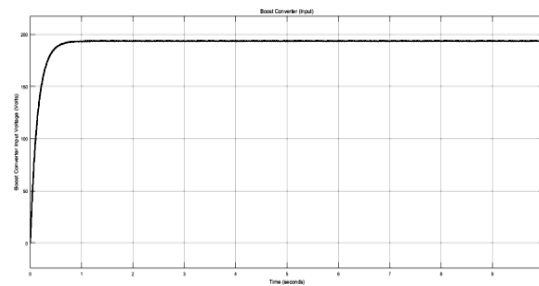
INPUT: WIND SPEED AT TURBINE:



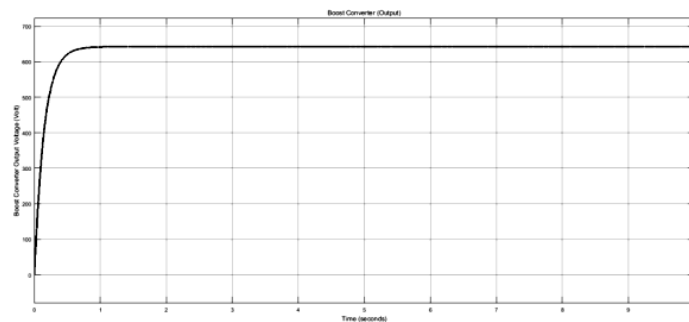
GENERATOR OUTPUT VOLTAGE AND CURRENT



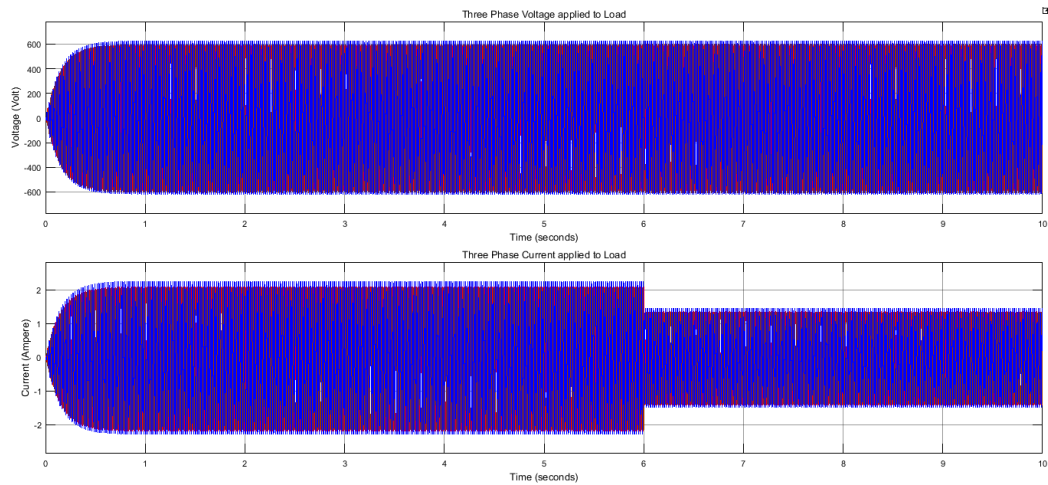
GENERATOR OUTPUT POWER



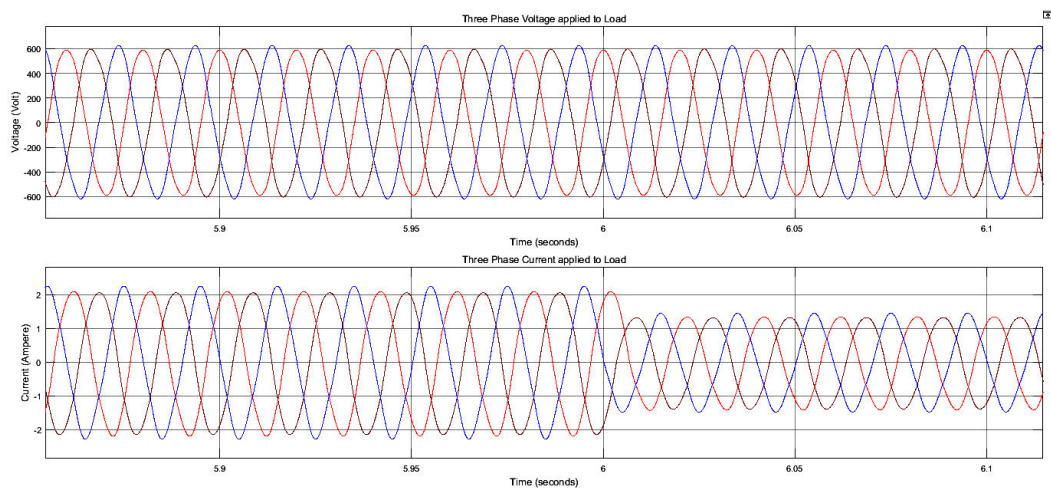
DC BOOST CONVERTER VOLTAGE INPUT



DC BOOST CONVERTER VOLTAGE OUTPUT



THREE PHASE INVERTER VOLTAGE AND CURRENT



THREE PHASE INVERTER VOLTAGE AND CURRENT (EXPLODED VIEW FROM 5.8 TO 6.1 SECOND)

V. CONCLUSION

In this study, Permanent Magnet Synchronous Generator based Wind Energy Conversion System with Z-source inverter is proposed. Z-source inverter is used for maximum power tracking control and delivering power to the grid, simultaneously. Compared to conventional WECS with boost converter, the number of switching semiconductors is reduced by one and reliability of system is improved, because there is no requirement for dead time in a Z-source inverter. For active power control, two control methods: capacitor voltage control and dc-link voltage control is proposed and compared. It is shown that with dc-link voltage control method is more power fluctuations compared to capacitor voltage control. Finally, with same value of passive components, inductor current ripple is the same for both systems.

This paper investigates a complete modeling of a maximum power point tracking (MPPT) wind energy system with prediction model proposed to tackle the lag of wind speed measurement in turbines and eliminate the discontinuity of wind speed sequence. The state feedback control technique is adapted and combined with speed forecasting model to tracking the maximum power in induction generator, in which the turbine torque has been compensated based on the control law. Here the PI controller is also applied to enhance the controlling performance and robustness. Simulation results show that the flux linkage and turbine rotational speed tracking the reference value almost without oscillation and back to stable state, which indicates its highly acceptable tracking performance, considering the quick reaction and following-up time. Thus, the maximal power point in Wind Energy Conservation System can be obtained with the tracking characteristics allow for the industrial variable-speed-tracking application. It can be seen that the proposed

technique is a great method and can be adopted in the industrial applications.

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