Efficiency Enhancement of Permanent Magnet Synchronous Generator Wind Turbine Through Maximum Power Point Tracking using SIMULINK/MATLAB

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Abstract - *The Renewable energy sources (RESs) more utilized because of its abundant availability everywhere. The Wind Energy is gaining interest because of technology enhancement and significant power cost reduction. In order to enhance the efficiency of a wind energy conversion system (WECS), the maximum power point tracking (MPPT) algorithm is usually employed. This paper presents to extract the maximum available power under a sudden wind speed change condition, which is applied in a permanent magnet synchronous generator (PMSG)-based WECS and in order to eliminate the dependence on the characteristic curve of wind turbine, a conventional perturbation and observation (P&O) method has been proposed. This method perturbs a control variable in a certain step size, and then observes the changes of output power until the MPP can be obtained. Since the P&O method does not require the wind speed sensor as well as the prior information on wind turbine, it is known to be a reliable and flexible method. Beside theoretical analyses, the simulation results are provided to prove the effectiveness of the proposed MPPT algorithm.*

Key Words: **Maximum Power Point Tracking (MPPT), Permanent Magnet Synchronous Generator (PMSG), Torque Observer, Wind Energy Conversion System (WECS), Hill Climb Search (HCS) , Perturbation and Observation (P&O).**

1.INTRODUCTION

In recent years, renewable energy resources are attracting great attention due to the scarcity of fossil energy and the requirement of restricting carbon dioxide emission in worldwide. Among renewable energy resources, wind energy is considered as one of the most potential and promising resources. In a wind energy conversion system (WECS), the kinetic energy of wind is transformed into the mechanical energy via a wind turbine, and then, this energy is converted into the electrical energy by using a generator.

Even abundance of wind power ,the output power is unstable in wind turbine due to the variation of wind speed. To overcome this challenge, the maximum power point tracking (MPPT) algorithm is mainly employed to enhance the efficiency of WECS. By this algorithm to maintain the output power of wind turbine at the maximum power point (MPP) irrespective of the wind speed variation.

Until now, various MPPT algorithms have been proposed for the purpose of tracking the MPP in a WECS. To achieve the maximum power of wind turbine at a given wind speed, according to characteristic curve the torque of a permanent magnet synchronous generator (PMSG) is controlled. The main drawback is the difficulty in determining the optimal power-speed curve of wind turbine which significantly varies by each wind turbine. Moreover, the optimal curve would be varied as the operating environment is changed.

A perturbation and observation (P&O) method has been proposed due to independent of wind turbine design and information. This method perturbs a control variable in a certain step size, and then observes the changes of output power until the MPP can be obtained. Since the P&O method does not require the wind speed sensor as well as the prior information on wind turbine, it is known to be a reliable and flexible method. However, the main limitation of this algorithm is its poor MPP tracking performance under the rapid variation of wind speed.

This paper proposes an MPPT algorithm for a WECS only to eliminate the need of wind speed sensor and wind turbine parameters. The proposed algorithm uses the instantaneous power of wind turbine and the rotor speed of generator as inputs to produce an optimal rotor speed as the output, which enables to obtain the MPP of wind turbine at a given wind speed. The output power of wind turbine can be generally obtained by measuring the mechanical torque and angular speed of shaft.

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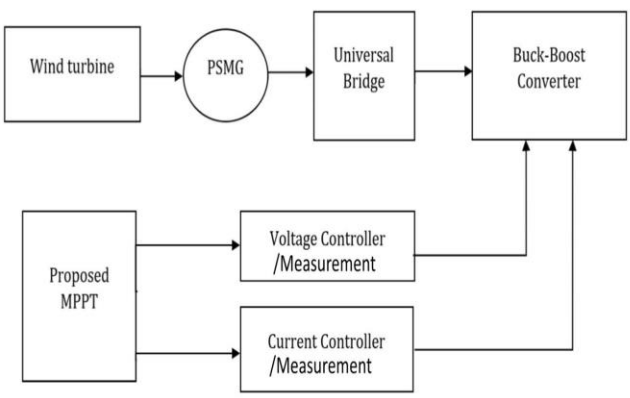
1.1 Wind turbine

A wind turbine turns wind energy into electricity using the aerodynamic force from the rotor blades, which work like an airplane wing or helicopter rotor blade. When wind flows across the blade, the air pressure on one side of the blade decreases. The difference in air pressure across the two sides of the blade creates both lift and drag. The force of the lift is stronger than the drag and this causes the rotor to spin. The rotor connects to the generator, either directly (if it's a direct drive turbine) or through a shaft and a series of gears (a gearbox) that speed up the rotation and allow for a physically smaller generator. This translation of aerodynamic force to rotation of a generator creates electricity.

Fig-1: Block Diagram of Wind Energy Conversion System using MPPT Algorithm.



The mechanical power generated by a wind turbine can be expressed as

$$P_m = \frac{1}{2}\rho\pi R^2 C_p(\lambda,\beta)V^3$$

where P_m is the mechanical power of the wind turbine, ρ is the air density, R is the radius of the blades, C_p is the power coefficient, β is the blade pitch angle, and V is the wind speed. The tip speed ratio λ is defined by the relation between the wind speed and the rotor speed of turbine ω_m as

$$\lambda = \frac{\omega_m R}{V}.$$

The power coefficient is described by a nonlinear function of both the tip speed ratio and the blade pitch angle as

$$C_p(\lambda,\beta) = 0.5176\left(116\frac{}{\lambda_i} - 0.4\beta - 5\right) e^{\lambda_i}$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{1+\beta^3}.$$

1.2 Permanent Magnet Synchronous Generator

A permanent magnet synchronous generator (PMSG) is a type of electrical generator that uses permanent magnets instead of traditional field windings in the rotor. PMSGs are used in wind energy conversion because they have several advantages over traditional electric generators, including with high efficiency because there are no losses associated with rotor excitation and low Maintenance due to the absence of slip rings and brushes ensures low maintenance and high reliability. So Flexible active and reactive power control and Power Higher power factor. This PMSG has no gearbox system.

The dynamic equation of a generator is given as

$$T_m{}^{gen} = J\frac{d\omega}{dt} + B\omega + T_e{}^{gen}$$

where $T_m{}^{gen}$ is the mechanical torque of generator, $Tegen$ is the electromagnetic torque of generator, ω is the generator rotor speed, J is the inertia, and B is the viscous friction coefficient. Assuming that there is no gearbox, the mechanical torque of wind turbine T_m will be directly transmitted to generator. Hence, it can be rewritten as

$$T_m = J\frac{d\omega}{dt} + B\omega + T_e{}^{gen}$$

Generally, the information on T_m would be obtained by using a torque sensor. However, this approach is not desirable because it significantly increases the total cost of a WECS. A disturbance observer is introduced as an alternative solution to estimate the mechanical torque of wind turbine.

1.3 MPPT Algorithm

The Hill Climb Search (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.

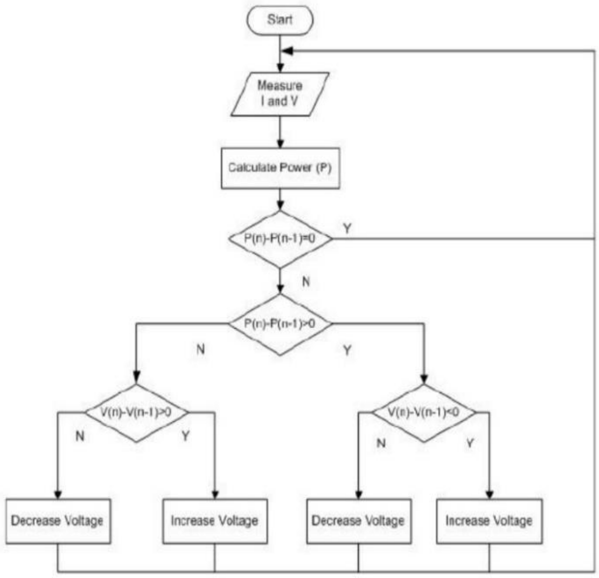


Fig-2: Proposed MPPT Algorithm

2. SIMULATION RESULTS

To validate the effectiveness of the proposed MPPT algorithm, the simulations have been carried out using the SIMULINK software. The simulation configuration of the proposed algorithm which consists of a wind turbine model, a PMSG, and a Buck-Boost converter is constructed as depicted in Fig.3. The PSMG Model, wind turbine model, and the proposed MPPT algorithm are implemented by using the MATLAB blocks.

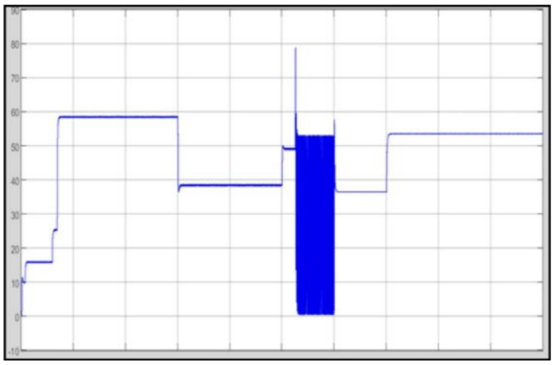


Fig-3: Waveform of Electromagnetic Torque T_e (N*m)

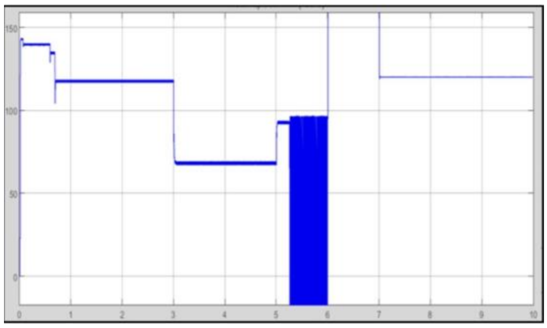


Fig -4: Waveform of Rotor speed Wm (rad /s)

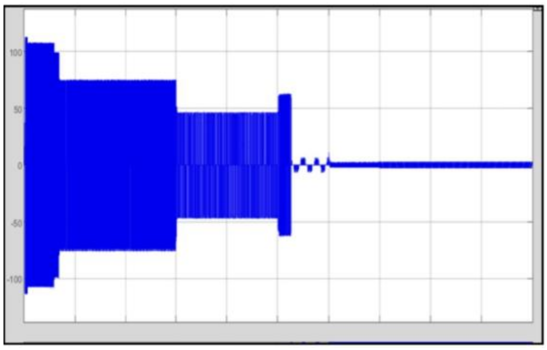


Fig-5: Waveform of AC Line voltage

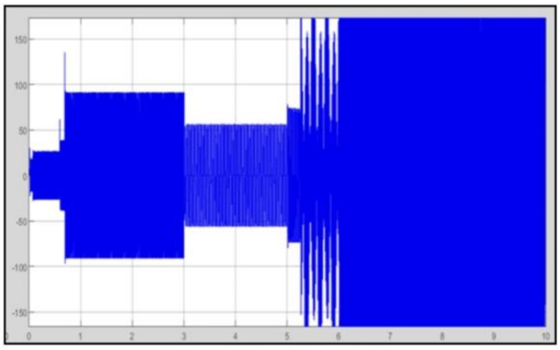


Fig-6: Waveform of AC Line Current

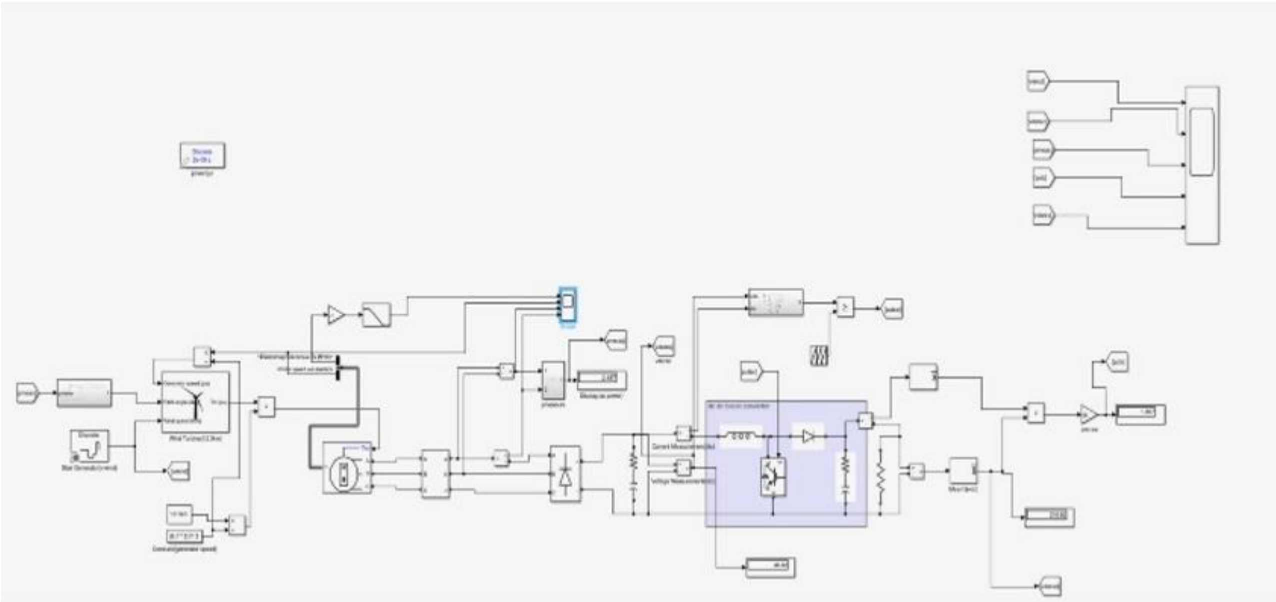


Fig -7: Simulation Configuration of the Proposed MPPT Algorithm

3. CONCLUSIONS

Enhancing the efficiency of a PMSG wind turbine through Maximum Power Point Tracking (MPPT) holds significant promise for improving renewable energy generation. By continuously optimizing the turbine's operating point to extract maximum power from varying wind conditions, MPPT enables higher energy yields and better overall performance. This technology not only maximizes energy output but also enhances the economic viability and sustainability of wind power systems. As we continue to advance MPPT algorithms and integrate them seamlessly into wind turbine control systems, we can expect even greater efficiency gains and broader adoption of wind energy as a clean and reliable power source.

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