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Wind Energy Conservation with Grid Levelling for Transient Loads

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Abstract

The paper discusses the maximum power point tracking in a grid connected PMSG based WECS. To the variable-speed wind turbine, if the rotor speed can always be adjusted to make the turbine operate under optimum tip speed ratio then it means that the turbine realizes the MPPT operation. For this purpose the P and O tracking algorithm is adopted. In addition to fully recognize the wind energy it is necessary to integrate it to the grid and hence grid parameters are regulated as well. The proposed system is developed in Matlab environment.

Keywords: Grid integration; MPPT control; PMSG; Wind energy systems

Introduction

Among different sorts of renewable vitality, wind vitality is dealt with as the most difficult one because of its free accessibility, arrangements encouraging, and the development of turbine systems. Renewable vitality particularly wind vitality conversion systems have attracted an expanding enthusiasm for the past years since they could be considered as affirmed choices for sustaining the consistent developing vitality needs [1,2]. The development of renewable energy in India is colossal and wind energy demonstrates to be the best answer for the problem of exhausting fossil powers, importing of coal, nursery gas emission, and ecological contamination and so on. In this way, wind vitality transformation innovation has turn into the examination centre of scientists everywhere throughout the world. Renewable Energy in India is colossal and Wind Energy demonstrates to be the best answer for the problem of exhausting fossil powers, importing of coal, nursery gas emission, and ecological contamination and so on. In this way, wind vitality transformation innovation has turn into the examination centre of scientists everywhere throughout the world [3].

In advanced wind vitality change framework two turbine structures are favoured: DFIG and PMSG Albeit, both of these structures highlight enhanced proficiency, diminished streamlined loads, and simplicity of dynamic and receptive force regulation, recent is significantly more dependable than the previous, considering the likelihood of wiping out of gearbox. In this way, an immediate commutes PMSG based WECS is considered in this paper. To collect more vitality from the variety winds, MPPT control ought to be incorporated in the power control framework. The diverse strategies for MPPT framework are characterized in [4-6]. However till date, there is no decisive proof is accessible as to which MPPT framework is prone to give a more effective and less costly in written works.

Wind Energy Conversion System Technology

A WECS is a structure that transforms the kinetic energy of the incoming air stream into electrical energy. Modern Wind Energy Conversion System (WECS) is shown in Figure 1 and the energy conversion chain is organised into four subsystems:

Aerodynamic subsystem

Consisting mainly of the turbine rotor, which is composed of blades and turbine hub, which is the support for blades.

Drive train

This is generally composed of low-speed shaft–coupled with the turbine, hub, speed multiplier and high-speed shaft–driving the electrical generator.

Electromagnetic subsystem

It mainly consists of the electric generator.

Electric Subsystem

Electrical subsystem includes the elements for grid connection and local grid. The circuit diagram of the proposed system as in Figure 1 includes variable speed wind turbine, permanent magnet synchronous generator, power electronic components which includes rectifier, inverter, boost converter and the control system which is a PI controller [7-9]. The description of the circuit diagram parameters are described in the following sections (Figure 2).

The tip speed ratio of a wind turbine is a variable expressing the ratio between the peripheral blade speed and the wind speed. It is denoted by λ and computed as below:

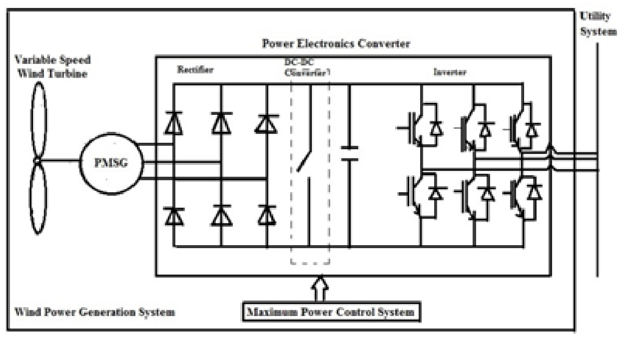

Figure 1: Circuit diagram of the proposed system.

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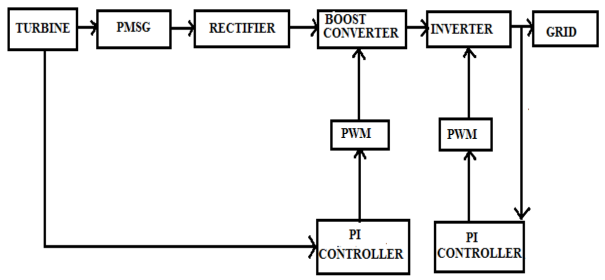

Figure 2: Block diagram of the proposed grid-connected WECS.

$$\lambda = \frac{R\omega}{v} \quad (1)$$

Where R is the blade length, ω is the rotor speed, v is the wind speed and the power extracted by a wind turbine whose blade length is R is expressed as:

$$P_T = \frac{1}{2}\rho\pi R^2 C_p(\lambda)v^3 \quad (2)$$

Therefore,

$$C_p = 4a(1-a)^2 \quad (3)$$

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The maximum value of Cp occurs for a=1/3 and hence Cpmax=0.59 known as the Betz limit and represents the maximum power extraction efficiency of a wind turbine [10].

Working

(a) When wind speed is below cut-in speed the machine does not produce power. If the rotor has a sufficient staring torque, it may start rotating below this wind speed. However, no power is extracted and the rotor rotates freely. In many modern designs the aerodynamic torque produced at the standstill condition is quite low and the rotor has to be started (by working the generator in the motor mode) at the cut-in wind speed.

(b) At normal wind speeds, maximum power is extracted from wind. The maximum power point is achieved at a specific (constant) value of the TSR. Therefore, to track the maximum power limit point, the rotational speed has to be changed continuously in proportion to the wind speed [11,12].

(c) At high winds, the rotor speed is limited to maximum value depending on the design limit of the mechanical components. In this region, the Cp is lower than the maximum and the power output is not proportional to the cube of the wind speed.

(d) At even higher wind speeds, the power output is kept constant at the maximum value allowed by the electrical components.

(e) At a certain cut-out or furling wind speed, the power generation is shut down and the rotation stopped in order to protect the system components.

The output power evolves according to Equation (2), proportionally with the wind speed cubed, until it reaches the wind turbine rated power. This output power from turbine is fed into the PMSG. PMSG is favoured more and more in developing new designs because of its higher efficiency, high power density, availability of high-energy permanent magnet material at reasonable price, and the possibility of providing smaller turbine diameter in direct drive applications [13].

Then power conversion for wind energy systems occurs in two stages. The first stage is rectification, where the alternating current (AC) is transformed into direct current (DC). The boost converter steps up the input DC voltage. The second stage is inversion where the direct current is transformed back into alternating current. PI controller is adopted in this system as this will optimize the conversion coefficient to maintain maximum power output. The inputs to the controller are the wind speed and voltage, current that are to be fed into the grid. The PI controller regulates the inputs and feeds the error signal to PWM. The PWM scheme is most commonly used because of the possibility of voltage regulation, but it will also cancel out multiples of the third harmonic to help improve output power quality. The inverter receives the switching signals from the PWM which in turn regulates the incoming DC link voltage and current and feeds it into the grid. The wind speed tracking is also shown.

The basic device in the wind energy conversion system is the wind turbine which transfers the kinetic energy into a mechanical energy. The wind turbine is connected to the electrical generator through a coupling device gear train or a direct drive system. The output of the generator is given to the electrical grid by employing a proper controller to avoid the disturbances and to protect the system or network. The detailed description of various blocks are already discussed in the above sections [14-16].

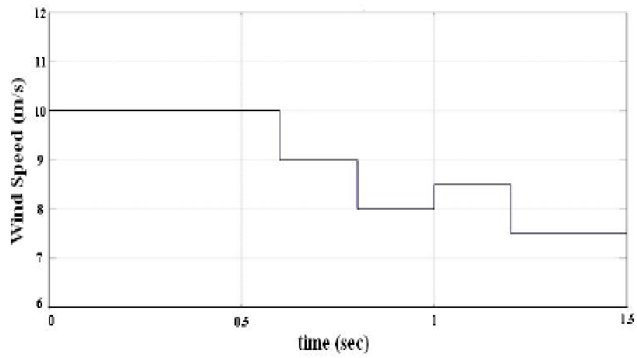

Figure 3: Tracking of wind speeds with varying time.

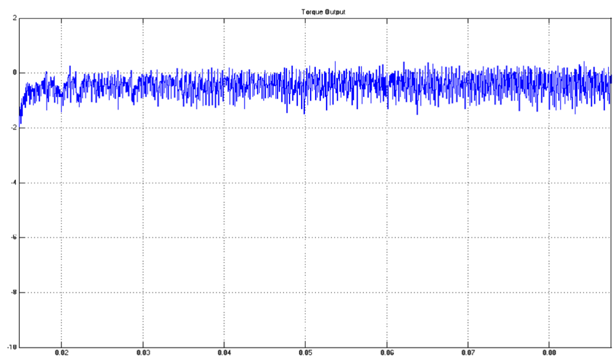

Figure 4: Generated torque.

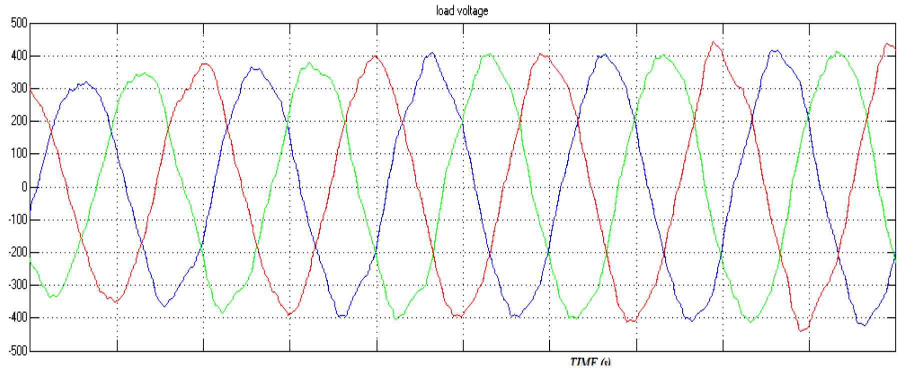

Figure 5: Input voltage to grid.

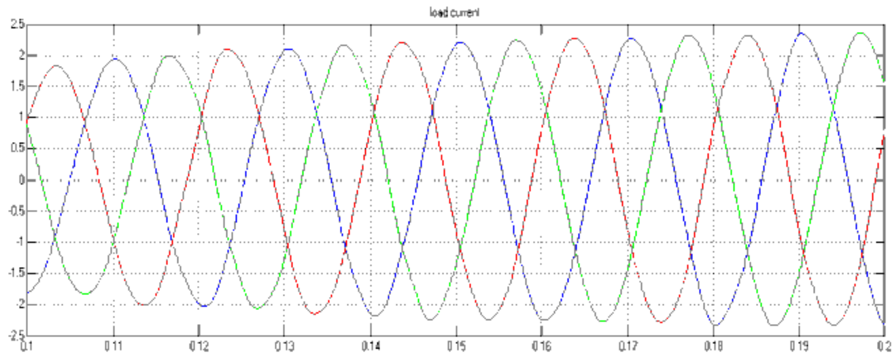

Figure 6: Input current to grid.

Simulation Results

This chapter presents the results of the proposed wind energy conservation system with grid levelling for transient loads. Simulation results are shown below in the following sections.

The intended contribution of this paper is to find out a relation between the MPPT speed and the transient loads (torque ripples). Hence a graph showing the waveform of the tracking of wind speed with time is shown in Figure 3 generated torques is shown in Figure 4.

The WTS controller outputs a torque command which contains the turbine dynamic information to the inverter, which is working in torque control mode. Because the PMSG is driven by this inverter, it will generate a torque that is equal to that of a real wind turbine. The validity of the wind turbine emulator has already been verified in the previous work. As mentioned earlier the output from the wind energy system is integrated with the grid in order to fully utilise its potential (Figure 5).

The voltage fed into the grid from the inverter. The current waveforms that are free from ripples which are obtained as outputs from the inverter are also given to the grid are shown in Figure 6.

The first plot is the output voltage, as can be seen, without the harmonic filters; the output is essentially a square wave due to the switching nature of the inverter. The second plot is of the output current, it is not in phase with the output voltage. Both the unclean output voltage and current lead to an unstable output active power (P) and a large, also unstable, reactive power (Q) output.

Conclusion

The main focus of this paper is on proposing a systematic study on the MPPT system to get a good compromise between the MPPT speed and the transient load. Furthermore, to confirm that the WECS can operate at the designed system bandwidth, P and O control method is proposed. The MPPT controller helps in tracking wind speeds varying with time. In addition, the system includes a PI controller to control the turbine speed and the grid voltage on the generator side and the grid side respectively. The controller further inputs pulses to the PWM inverter, the output of which are fed to grid.

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