WIND ENERGY CONSERVATION WITH GRID LEVELING 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 realises the MPPT operation. For this purpose the P & O tracking algorithm is adopted. In addition to fully recognise the wind energy it is necessary to integrate it to the grid and hence grid parameters are regulated as well using PI controller. The proposed system is developed in Matlab environment.

Keywords*:* Wind Energy Systems, HAWT, PMSG, MPPT, PI Controller, Voltage, Current regulation, Grid Integration.

INTRODUCTION: The potential of renewable energy sources is enormous as they can in principle meet many times the world's energy demand. The depletion of fossil fuels and concomitant global climate change has compelled nations to seek new non-polluting ways to produce energy. Among various kinds of renewable energy, wind energy is treated as the most challenging one because of its free availability, policies fostering, and the maturity of turbine techniques. Renewable energy especially wind energy conversion systems have drawn an increasing in interest in the past years since they could be considered as confirmed alternatives for sustaining the continuous growing energy needs. The growth of Renewable Energy in India is enormous and Wind Energy proves to be the most effective solution to the problem of depleting fossil fuels, importing of coal, greenhouse gas emission, environmental pollution etc. Thus, wind energy conversion technology has become the research focus of researchers all over the world.

In modern wind energy conversion system two turbine structures are preferred: DFIG and PMSG. Although both of these structures feature improved efficiency, reduced aerodynamic loads, and ease of active and reactive power regulation, latter is much more reliable than the former, considering the possibility of cancellation of gearbox. Therefore, a direct-drive-PMSG based WECS is considered in this paper. To harvest more energy from the variation winds, MPPT control should be included in the power control system. The different methods of MPPT system are defined in [9]. However till date, there is no conclusive evidence is available as to which MPPT system is likely to provide a more efficient and less expensive in literatures.

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

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,** generally composed of: low-speed shaft – coupled with the turbine, hub, speed multiplier and high-speed shaft – driving the electrical generator;
- **Electro Magnetic subsystem,** consisting mainly of the electric generator.
- **Electric subsystem,** including the elements for grid connection and local grid.

The circuit diagram of the proposed system as in figure 3.1 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. The de description of the circuit diagram parameters are described in the following sections.

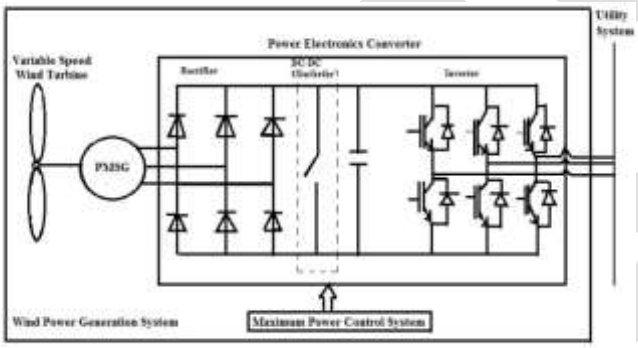

Figure 1: Circuit Diagram of the proposed system

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,

$$\text{TSR}= \frac{\text{(Blade length*rotor speed)}}{\text{wind speed}} \qquad (1)$$

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

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

Therefore, $C_p = 4a(1-a)^2$ (3)

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.

Working:

(a) When wind speed is below cut-in speed the machine does not produce power. If the rotor has a sufficient torque to start, 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.

(c) At high winds, the rotor speed is limited to maximum value depending on the design limit of the mechanical components that are the turbine blades and hub. In this region, the power co-efficient 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 wind speed or otherwise known as furling wind speed, the rotation of turbine blades are stalled and hence no power generation is done 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.

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.

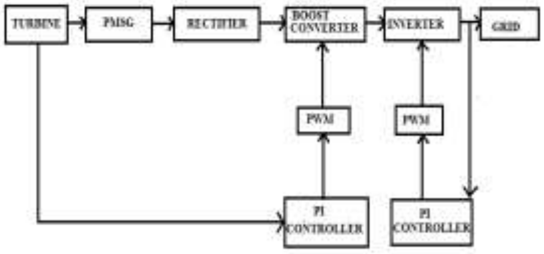

Figure 2: Block Diagram of the Proposed Grid-Connected WECS

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

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.

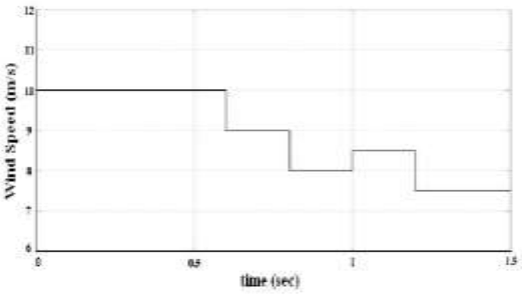

Figure 3: Tracking of wind speeds with varying time

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

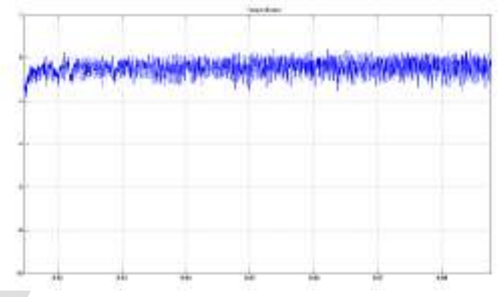

Figure 4: Generated Torque

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.

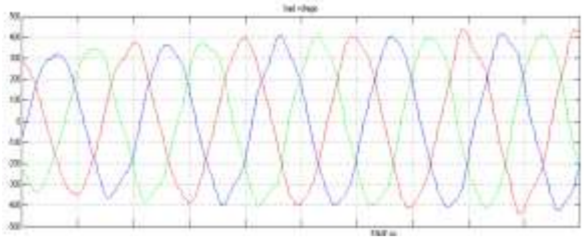

Figure 5: Input Voltage to Grid

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.

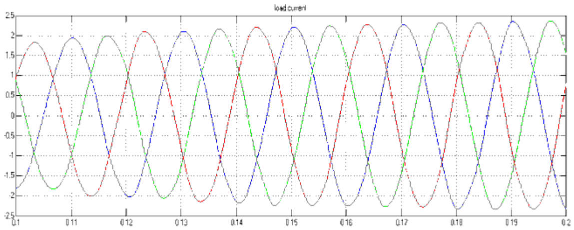

Figure 6 : Input current to grid

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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