International journal of imaging science and engineering

ISSN: 1934--9955 www.ijise.net

Vol-13 Issue-01 Feb 2018

An Analysis of a Wind Power Plant with Synchronous Excitation

ABSTRACT:

Wind power is becoming more competitive as a result of the rising demand for renewable energy-generated electricity on global markets. There are two main categories of wind generators, induction and synchronous, according to the literature [1]–[8]. High efficiency, dependability, and controlled output power are only a few of the reasons why the excitation synchronous generator—powered by hydraulic, steam turbine, or diesel engines—has become so popular in large-scale utility power generation. With the exception of doubly fed induction generators, these characteristics are attained by wind power generators utilizing variable speed constant frequency technology in grid connection applications.

KEYWORDS: dependability and regulated output power. For use in grid-connected applications, a wind generator
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Introduction:

Unfortunately, due to wind power dynamics instabilities and unexpected generator synchronous speed influencing properties, most excitation synchronous wind generators cannot be directly linked to the grid. In order to meet the criteria for connecting to the grid, the direct-drive permanent magnet synchronous wind generator (PMSWG) makes use of power converter and variable-speed technologies; this has the benefit of being
This research introduces a new kind of converterless wind power generator that uses a servo control system, signal sensors, a permanent magnet (PM) synchronous servo motor, and an excitation synchronous generator as its control framework. The power from the wind turbine and the servo motor are combined and sent to the excitation synchronous generator via a coaxial arrangement. To keep the generator speed constant, the servo motor supplies compensating energy when the wind speed changes. The extra power from the servo motor is likewise converted to electricity and sent to the load. Thus, the power of the engine is not squandered. The suggested robust integrated servo motor control system mitigates wind disturbances' effects on the excitation synchro-nous generator's output voltage phase shift via the use of an accurately designed phase tracking function. The suggested maximum power tracking technique regulates the excitation field current in response to the size of the servo motor power and the generator power, allowing the excitation synchronous generator to completely absorb the wind power and provide energy to the loads. In light of the physical theorems, a mathematical model for the proposed system is established to evaluate how the control function performs in the designed framework.

1. Power Flow and Speed

For simplicity, assume that all energy transmission elements behave ideally, allowing us to ignore the mechanical power losses of the wind turbine, the servo motor, and the excitation synchronous generator. Fig. 1 shows the power flows of the proposed system, where T , T , and T denote the torques and , , and are the wind turbine, servo motor, and excitation synchronous generator speeds, respectively. The total excitation synchronous generator input power is the product of T and . The power flow equation can thus be defined as

ω ω ω

$$T_g \cdot \omega_g = T_w \cdot \omega_w + T_m \cdot \omega_m.$$

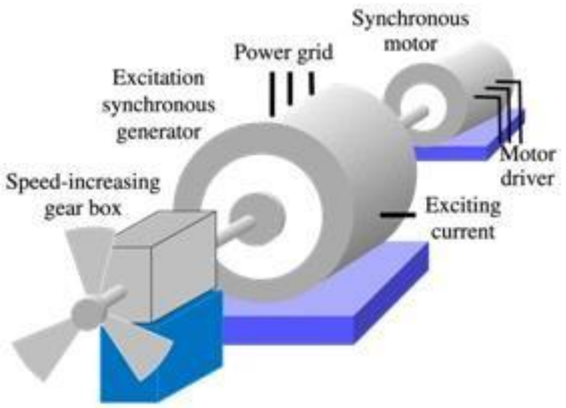


Figure 1: Proposed coaxial construction configuration

Fig. 1 shows the corresponding coaxial configuration. The wind generator rotor shaft input-end receives rotatingtorques from the speed increasing gear box. The tail-end of the generator rotor shaft is coupled with a servo motor. The input energy of the excitation synchronous generator is the sum of the wind power and servo motor powers. The speed and rotating direction for the wind turbine output, servomotor, and excitation synchronous generator is the same,i.e., the system speeds satisfy W_w=W_m=W_g This arrangement can reduce the power trans-mission losses.

2. Proposed System Configuration

Fig. 4 schematically depicts the servo motor and maximum power tracking control (MPTC) loops which are designed to stabilize the speed, frequency, and output power of the excitation synchronous generator under wind disturbances. The wind turbine provides mechanical torque to rotate the generator shaft via the speed-increasing gear box. As the generator shaft speeds reach the rated speed, the generator magnetic field is excited. The MPTC then controls the output voltage reaching grid voltage. Moreover, the generator output waveform is designed in phase with the grid using the servo motor control track grid sine waveform. Owing to the difficulty in precisely estimating the wind speed, the proposed MPTC scheme measures the motor output power as the reference signals to determine the generator output power. The excitation synchronous generator output frequency, voltage-phase, and output powerare fed back into the control scheme. The phase/frequency synchronization strat-egy in Fig. 4 compares the grid voltage-phase and frequency with the generator's feedback signals, and produces the position command with pulse- type signals to the servo motor driver. The MPTC also adjusts the excitation field current I_f based on the wind power and motor power inputs, where θ denotes the servo motor rotor mechanical rotor angular displacement de-tectedby an encoder. Due to the coaxial configuration, detecting the relative position of the rotor allows us to determine the generator voltage phase during the wind power generator system

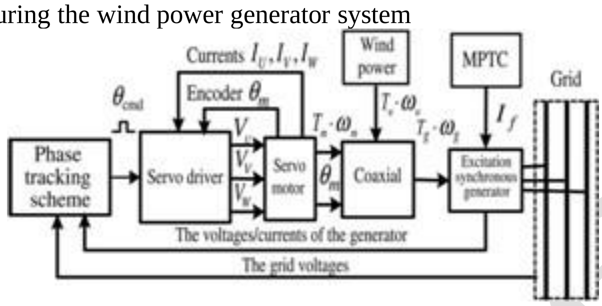
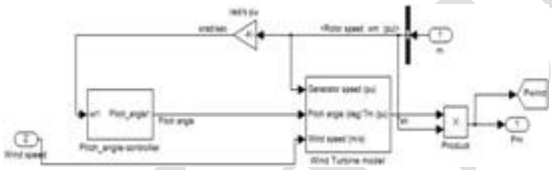


Figure 2: Proposed system configuration



3. Servo Motor Controller Design

The transient and dynamic responses of the servo motorcontroller must satisfy robustness requirements to reduce theinfluence of wind fluctuations to the generator. Thus, the robust integral structure control (RISC) method is chosen to ensure the voltage phase and the frequency in phase with thegrid. Among general electrical motors, the three-phase PM synchronous motor has the advantages of high-efficiencyand low-maintenance requirements, the reason controllable power for the servo control structure was chosen in theresearch [17]–[20]. This study de-signs an analysis model based on the electrical circuit, motor torque, and mechanical theorems. Fig. 5 shows the block dia-gram of the three- phase PM synchronous motor, and Table I lists the

International journal of imaging science and engineering

ISSN: 1934--9955 www.ijise.net

Vol-13 Issue-01 Feb 2018

parameters of the PM synchronous motor. According to (1), wind power, generator power, and servo motor power can be transformed into three torque functions and incorporated in the three-phase PM synchronous motor model.

The electromagnetic torque T of the servo motor can be expressed as [17]

$$T_m = \frac{P}{2}\lambda_m \cdot \left[I_U \cdot \sin\theta_r + I_V \cdot \sin\left(\theta_r - \frac{2}{3}\pi\right) + I_W \cdot \sin\left(\theta_r - \frac{4}{3}\pi\right)\right] \quad (2)$$

where P denotes the number of motor poles, and I_U, I_V, and I_W are the applied stator currents. The mechanical torque can be expressed as

$$T_m + (T_w - T_g) = Js\left(\frac{2}{P}\right)\frac{d\omega_r}{dt} + B\left(\frac{2}{P}\right)\omega_r$$

$$\theta_r = \int \omega_r\, dt$$

$$\theta_m = \frac{2}{P}\theta_r. \quad (3)$$

4. Modeling of System

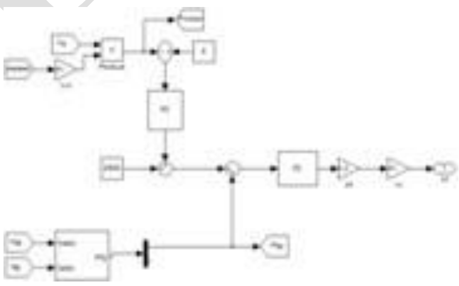


Figure 3: MPPT modeling using MATLAB/SIMULINK

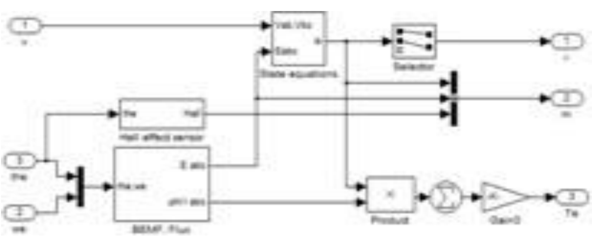
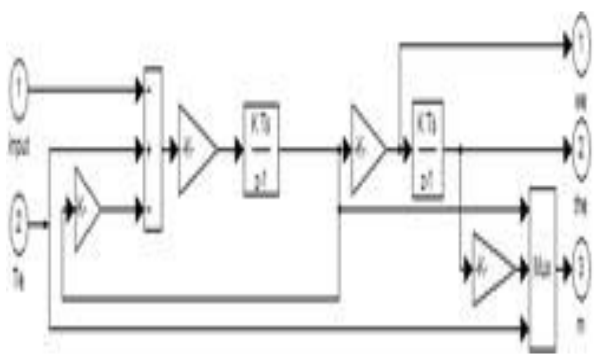


Figure 4: Wind turbine modeling in SIMULINK



ISSN: 1934--9955 www.ijise.net

Vol-13 Issue-01 Feb 2018

Figure 5: modeling of servo motor

5. Simulation Results

The functioning of the generator design is verified via the use of MATLAB/Simulink and MATLAB/Simpower software, in a wind power generator framework simulation model. This model includes an excitation synchronous generator and its accompanying sub-systems. The wind power input, maximal power tracking control, excitation synchronous generator, servo motor phase tracking control, and grid connection are the sub-systems that make up the overall system. The excitation synchronous generator has to run at 1800 rpm with 4-pole windings in order to output the three-phase voltage signals at 60 Hz.The voltage phase tracking performance of the system at generator output 2 kW is investigated. Fig. 10(a) shows the phase voltage and current waveforms of the excitation synchro-nous generator. Fig. 10(b) shows the grid and generator voltage phase tracking waveforms. The simulation voltage and current waveforms in Fig. confirm that the proposed system has high-quality power and sufficient control stability during grid connection. The generator output phase voltage is in phase with the grid in Fig. Owing to the excitation synchronous generator rotation speed control and excitation control, the output power, voltage,and frequency are constant. The wind power generator system can thus connect directly to the grid

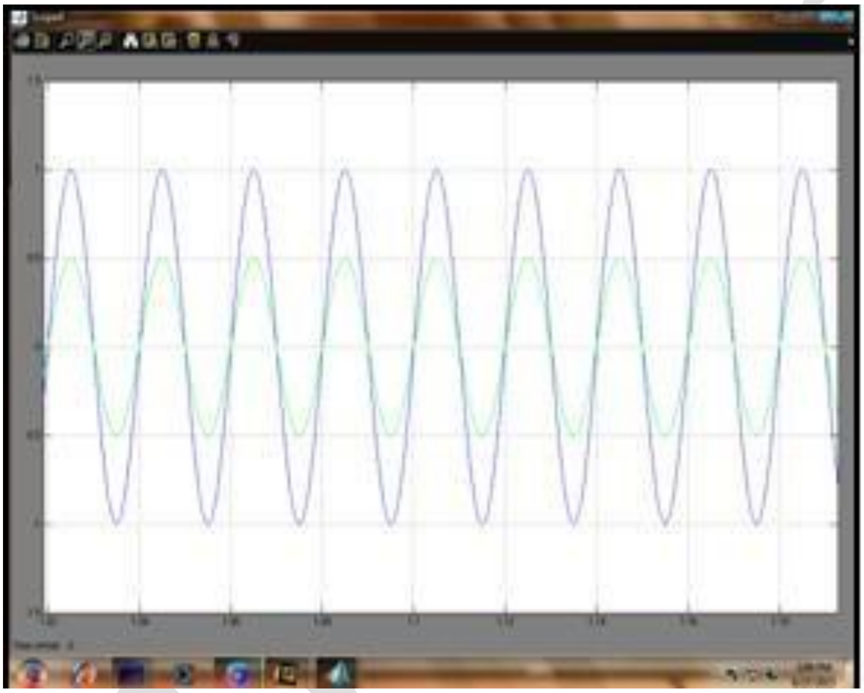
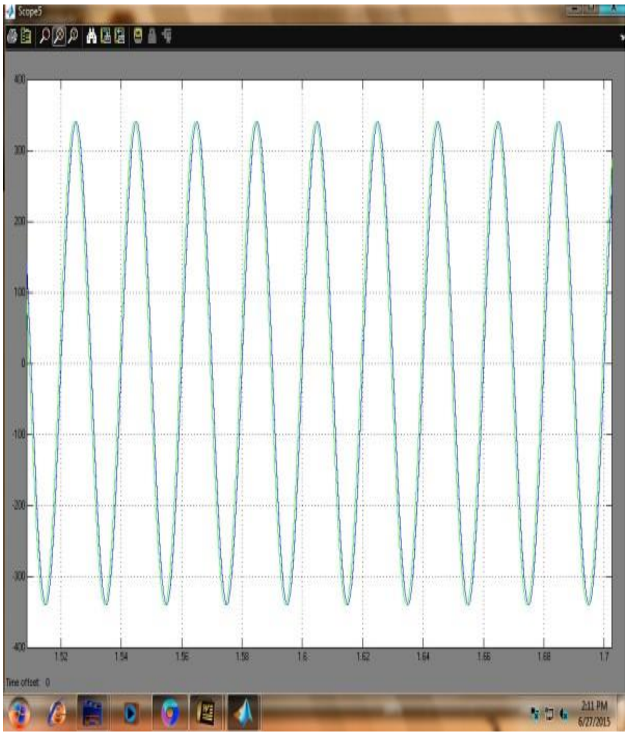


Figure : Vsg And Isg Of Phase A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