Control of Voltage and Frequency of a Wind Electrical System using Frequency Regulator

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Abstract-- **As a result of increasing demand of electricity, one way of generating power from renewable energy is from wind turbines .The places across the world where velocity of wind is conducive for power generation; the wind turbines influence the behaviour of power system. In order to meet sustained load demands during varying natural conditions, different energy sources and converters need to be integrated with each other for extended usage of alternative energy. In this paper, we focused on control of both voltage and frequency when an additional load is switched on using frequency regulator.**

Keywords: Discrete Frequency Regulator, Grid network, Squirrel cage induction generator (SCIG), Variable speed wind turbine.

I. INTRODUCTION

Wind energy is one of the most important and promising sources of renewable energy all over the world, mainly because it is considered to be nonpolluting and economically viable. At the same time, there has been a rapid development of related wind turbine technology [1]. The desire to reduce dependence on fossil fuels and mitigate anthropogenic climate change is resulting in numerous policy incentives for renewable energy. Since wind generation is arguably the most affordable of the new renewable energy options, wind generation capacity quadrupled between 2004 and 2008 [2]. With this rapid increase in wind generation comes the need to better understand the impact that the variability and intermittency of wind generation have on the reliability of the power grid. As a result, numerous large-scale wind integration studies produced by government, industry, and academic organizations have worked to estimate the reliability impacts of large-scale wind power and the feasibility of various levels of wind power production [3]-[4]. However, estimating the impact of large amounts of new wind energy production in systems that currently have only a small number of existing wind plants requires an estimate of the time-varying output from power plants that do not yet exist. Such estimates typically require large amounts of predicted wind speed data for hypothetical wind farm locations, which are then transformed to produce estimates of wind power output. This paper presents the control of the voltage and frequency of a wind using frequency regulator.

II. MATERIALS AND METHODS

A. Wind Power Generation

The power (P_0) contained in wind is given by the kinetic energy of the flowing air mass per unit time.

$$P_0 = \frac{1}{2} \times (air\ mass\ per\ unit\ time) \times (wind\ velocity)^2$$

$$\text{Hence,}\quad P_0 = \frac{1}{2}(\rho A)V_\infty^3$$

Where P_0 is the power contained in wind (in watts), ρ is the air density (≈ 1.225 kg/m3 at 150c and normal pressure) A is the rotor area in and is the wind velocity (in m/sec) without rotor interference, i.e., ideally at infinite distance from the rotor.

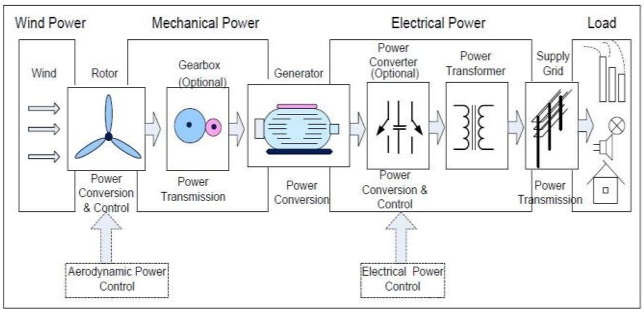

Figure1: Representation of the complete wind energy conversion systems (WECS), which converts the energy present in the moving air (wind) to electric energy

The main components of a wind turbine system include the turbine rotor, gearbox, generator, transformer, and possible power electronics (Figure 1). The wind passing through the blades of the wind turbine generates a force that turns the turbine shaft. The rotational shaft turns the rotor of an electric generator, which converts mechanical power into electric power. The major components of a typical wind energy conversion system include the wind turbine, generator, interconnection apparatus and control systems .The power developed by the wind turbine mainly depends on the wind speed, swept area of the turbine blade, density of the air, rotational speed of the turbine and the type of connected electric machine. The turbine rotor converts the fluctuating wind energy into mechanical energy, which is converted into electrical power through the generator, and then transferred into the grid through a transformer and transmission lines. Wind turbines capture the power from the wind by means of aerodynamically designed blades and convert it to rotating mechanical power. The number of blades is normally three and the rotational speed decreases as the radius of the blade increases. For MW range wind turbines the rotational speed will be 10–15 rpm. The weight efficient way to convert the low-speed, high-torque power to electrical power is to use a gearbox and a generator with standard speed. The gearbox adapts the low speed of the turbine rotor to the high speed of the generator. The gearbox may be not necessary for multi-pole generator systems. The generator converts the mechanical power into electrical energy, which is fed into a grid through possibly a power electronic converter, and a transformer with circuit breakers and electricity meters. The generator is coupled to the grid through a transformer and/or a power electronic converter.

B. *Frequency Regulator*

To ensure a functional and reliable grid, the Independent System Operators (ISOs) that operate the various regional grids must maintain their electric frequency very close to 60 hertz (Hz), or cycles per second (50 Hz in Europe and elsewhere). When the supply of electricity exactly matches the demand (or "load"), grid frequency is held at a stable level. Grid operators, therefore, seek to continuously balance electricity supply with load to maintain the proper frequency. They do this by directing about one percent of total generation capacity to increase or decrease its power output in response to frequency deviations. Squirrel cage motors are asynchronous induction machines whose speed depends upon applied frequency, pole pair number, and load torque. . The trend in system frequency is a measure of mismatch between demand and generation, and so is a necessary parameter for load control in interconnected systems. Frequency of the system will vary as load and generation change. Increasing the mechanical input power to a synchronous generator will not greatly affect the system frequency but will produce more electric power from that unit. During a severe overload caused by tripping or failure of generators or transmission lines the power system frequency will decline, due to an imbalance of load versus generation.

C. *Circuit Description*

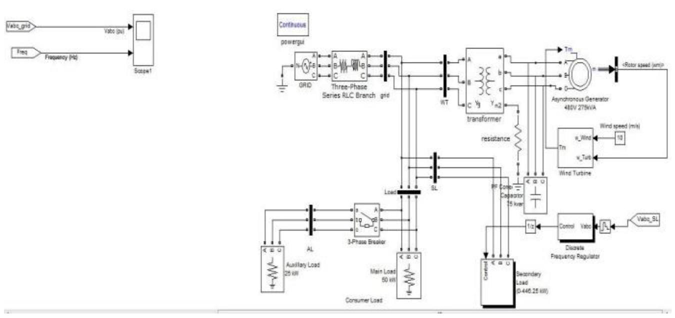

Figure 2: Model of wind electrical system

Subsystem

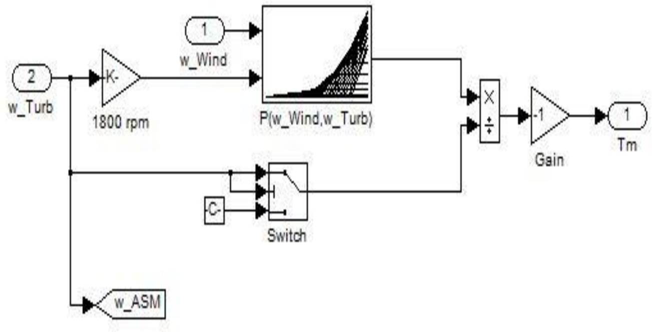

Figure 3: Subsystem of wind turbine

Asynchronous generator rating 480 V,275 KVA is connected to a wind turbine .The wind turbine block uses a 2-D look up table to compute the turbine torque (T_m)as a function of w_wind (wind speed) and W_turbine(turbine speed).The look up table graph between wind speed and turbine speed gives mechanical power .The T_m (mechanical torque) is obtained by dividing mechanical power wind speed .This mechanical torque is the input for asynchronous generator. A step up transformer is used to increase the voltage of the generator which is supplied to the grid .A secondary load bank is used to regulate a system frequency by absorbing the wind power exceeding consumer demand .Here three loads are used ,viz. main load ,secondary load and auxiliary load .The loads which are constant running are assumed to be in main load which is 50KW .The secondary load is variable load which consumes extra generated power from wind turbine asynchronous generator and dumps the fluctuated frequency .The nominal power of this load follows a binary progression so that the load can be varied from 0 to 446.25KWby steps of 1.75 KW .Auxiliary load is a fluctuating load of 25KW which is switched on at t=0.5 sec through a circuit breaker.

III. RESULTS AND DISCUSSION

The primary reason for accurate frequency control is to allow the flow of alternating current power from multiple generators through the network to be controlled. Frequency of the system will vary as load and generation change. A drop in frequency will generally reduce load. In part this is because motors will slow down, and so will consume less power, but there are other effects, perhaps including a general drop in average voltage, and so reducing resistive load. At t=0.5 s, the additional load of 25 kW is switched on. The frequency momentarily drops to 49.85 Hz and the frequency regulator reacts to reduce the power absorbed by the secondary load in order to bring the frequency back to 50 Hz. Voltage stays at 1 p.u and no flicker is observed.

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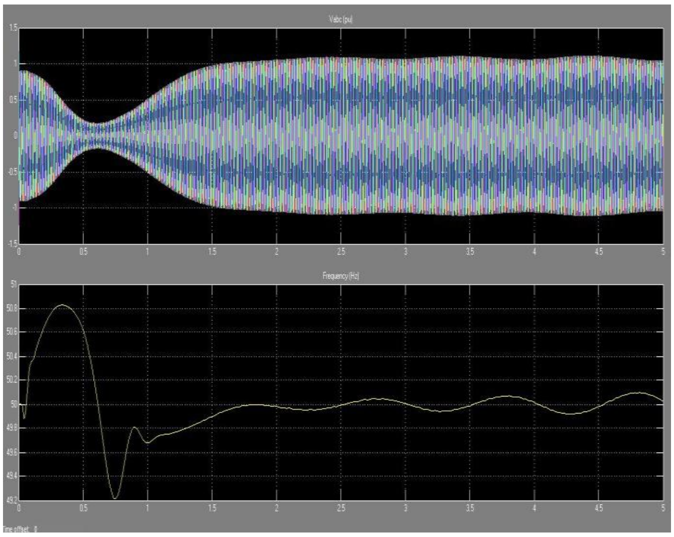

Figure 4: Voltage and frequency characteristics

At 0.5 sec when the auxiliary load is switched on the frequency drops. and as a result a discrete frequency regulator block is used to maintain a constant frequency at 50 Hz .The function of frequency controller uses a standard three phase locked loop(PLL) system to measure the system frequency. The measured frequency is compared to the reference frequency (50Hz)to obtain the frequency error. This error is integrated to obtain the phase error. In order to minimize voltage disturbances, switching is performed at zero crossing of voltage.

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