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Power Distribution of Wind Diesel Generator in Isolated Network

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Abstract— Recent research and development of alternative energy sources have shown excellent potential to complement the contribution to conventional power generation systems. 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. This paper focuses on the combination of Wind Turbine and Diesel Generator systems for sustained power generation. As the wind turbine output power varies with the wind speed: a DG system can be integrated with the wind turbine to ensure that the system performs under all conditions. This paper presents Dynamic Modelling and Simulation of a Wind/DG Hybrid Power Generation System with power flow controllers.

Index Terms: point of common coupling (PCC), squirrel-cage induction generator (SCIG), Wind-Diesel system, Isolated network, Variable-Speed wind Turbines, DC Exciter, Discrete Frequency regulator.

1. INTRODUCTION

Wind energy is gaining increasing importance throughout the world. This fast development of wind energy technology and of the market has large implications for a number of people and institutions: for instance, for scientists who research and teach future wind power and electrical engineers at universities; for professionals at electric utilities who really need to understand the complexity of the positive and negative effects that wind energy can have on the power system; for wind turbine manufacturers; and for developers of wind energy projects, who also need that understanding in order to be able to develop feasible, modern and cost-effective wind energy projects. See Table 1 for an overview of important historical wind turbines.

TABLE 1
Over View of Important Wind Turbine

Turbine and country	Diameter (m)	Swept Area (m^2)	Power (kW)	Specific Power (kW/m^2)	Number of blades	Tower height (m)	Date in service
Poul LaCour, Denmark	23	408	18	0.04	4	—	1891
Smith-Putnam, USA	53	2231	1250	0.56	2	34	1941
F. L. Smidth, Denmark	17	237	50	0.21	3	24	1941
F. L. Smidth, Denmark	24	456	70	0.15	3	24	1942
Gedser, Denmark	24	452	200	0.44	3	25	1957
Hütter, Germany	34	908	100	0.11	2	22	1958

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2. CONCEPTS OF WIND POWER GENERATION

The main components of a wind turbine system, including the turbine rotor, gearbox, generator, transformer, and possible power electronics, are illustrated in Fig. 2.1. The wind turbines to be connected at remote sites with high average wind speed. Such sites are often situated far from a strong grid [1]. 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.

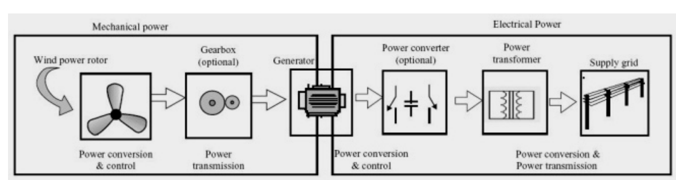

Fig 2.1 General Wind Power Generation

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

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breakers and electricity meters. The generator is coupled to the grid through a transformer and/or a power electronic converter, because the characteristics of the generator output do not match the characteristics of the grid with respect to frequency and voltage [2]. The connection of wind turbines to the grid is possible at low voltage, medium voltage, high voltage, and even at the extra high voltage system since the transmittable power of an electricity system usually increases with increasing the voltage level. While most of the turbines are now a days connected to the medium voltage system, large offshore wind farms are connected to the high and extra high voltage level. The amount of power produced by a turbine can be expressed as $P = 0.5\rho ACP\ V^3$ [3]. A high rated wind speed will give a large peak-power output for a particular swept area, and may give a greater overall energy production [4].

At the point of common coupling (PCC) between the single wind turbines or the wind farm and the grid, there is a circuit breaker for the disconnection of the whole wind farm or of the wind turbines. Also the electricity meters are installed usually with their own voltage and current transformers. The electrical protective system of a wind turbine system needs to protect the wind turbine and as well as secure the safe operation of the network under all circumstances.

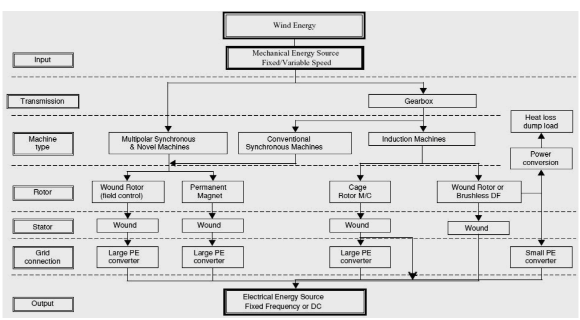

Fig 2.2 Roadmap for wind energy conversion

The possible technical solutions of the electrical system are many and Fig. 2.2 shows a technological roadmap starting with wind energy/power and converting the mechanical power into electrical power. Torque peaks in the gearbox and shafts are reduced, the wind turbine can operate with maximum aerodynamic efficiency and power fluctuations can be absorbed as inertial energy in the blades [5]. It involves solutions with and without gearbox as well as solutions with or without power electronic conversion.

3. GENERATOR SYSTEMS FOR WIND TURBINES

Both induction and synchronous generators can be used for wind turbine systems. Induction generators can be used in a fixed-speed system or a variable-speed system, while synchronous generators are normally used in power electronic interfaced variable-speed systems. Mainly, three types of induction generators are used in wind power conversion systems: cage rotor, wound rotor with slip control by changing rotor resistance, and doubly fed induction generators. The wound rotor generator with rotor-resistance-slip control is normally directly connected to an ac system, but the slip control provides the ability of changing the operation speed in a certain range. The doubly fed induction generators provide a wide range of speed variation depending on the size of power electronic converter systems. In this paper we discuss the systems without power electronics except the thyristor soft starter, and the variable-speed wind turbine systems, including those with partially rated power electronics and the full-scale power electronic interfaced wind turbine systems.

3.1 Fixed-Speed wind Turbines

In fixed-speed wind turbines, the generator is directly connected to the mains supply grid. The frequency of the grid determines the rotational speed of the generator and thus of the rotor. The generator speed depends on the number of pole pairs and the frequency of the grid. The Danish Concept, of directly connecting a wind turbine to the grid, is widely used for power ratings up to 2.3 MW. The scheme consists of a squirrel-cage induction generator (SCIG), connected via a transformer to the grid. The wind turbine systems using cage rotor induction generators almost operate at a fixed speed (variation of 1–2%). The power can be limited aerodynamically by stall control, active stall control, or by pitch control.

3.2 Variable-Speed wind Turbines.

In variable-speed systems the generator is normally connected to the grid by a power electronic system. All variable speed generators need converters to control the voltage and frequency of power supplied to the grid [6]. Only the rotor of the generator is connected through a power electronic system. This means the nominal power of the converter system can be less than the nominal power of the wind turbine. By controlling the active power of the converter, it is possible to vary the rotational speed of

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the generator and thus of the rotor of the wind turbines. The active power flow is represented by the wind turbine power curve which is the relation between the activepower produced and the wind speed [7]. For a variable speed wind turbine with a doubly fed induction machine, it is possible to control the load torque at the generator directly, so that the speed of the turbine rotor can be varied within certain limits [8].

4. MODEL DESCRIPTION

A model of the, Wind-Diesel system is presented in this Modeling and Simulation in this paper. The optimal wind penetration (installed wind capacity/peak electrical demand) for this system depends on the site delivery cost of fuel and available wind resource. The wind-diesel system presented in this demo uses a 300 kVA synchronous machine, a wind turbine driving a 275 kVA induction generator, a 75 kW customer load and a variable secondary load (0 to 446.25 kW). Simulation model shown in fig. 4.1.

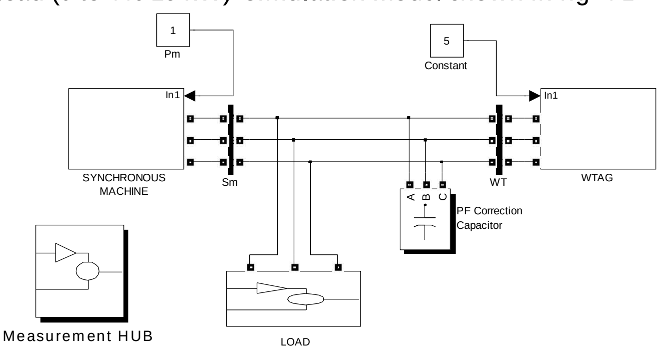

Fig 4.1 Simulation model

4.1 Diesel Generator

The mechanical power input to the synchronous machine which acts as a synchronous generator when the WTAG works below cut in speed is fed from a constant block of value 1 PU as shown in fig 4.2. There is also need of proper excitation system fig 4.3 shows a predefined model of simulink for excitation system. The Excitation System block is a Simulink system implementing a DC exciter.The basic elements that form the Excitation System block are the voltage regulator and the exciter.The output of the block is the field voltage Vf in pu, to be applied to the Vf input of a synchronous machine block.

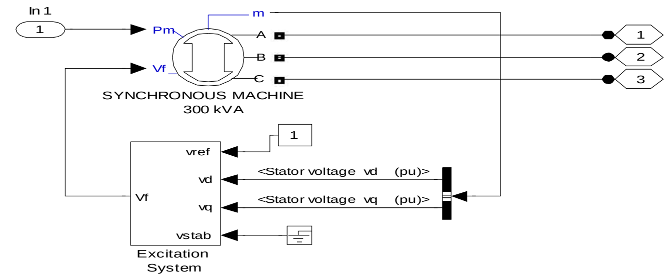

Fig 4.2 Simulink model for Diesel Generator

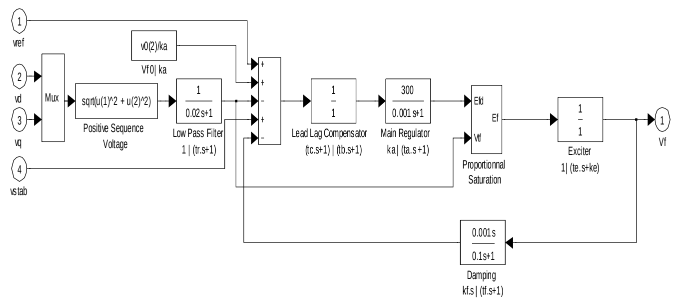

Fig 4.3 Excitation System

4.2 Wind Turbine Asynchronous Generator

The Wind Turbine Asynchronous Generator model is much of complicated part of whole simulation model. It consists of Asynchronous Generator & Wind Turbine. Wind Turbine Asynchronous Generator shown in fig. 4.4.The Wind Turbine block uses a 2-D lookup table to compute the turbine torque output (Tm) as a function of wind speed (w_Wind) and turbine speed (w_Turb). The lookup table graph between wind speed and turbine speed gives mechanical power. The mechanical torque is obtained by dividing mechanical power with wind speed. This mechanical torque is the input for asynchronous generator.

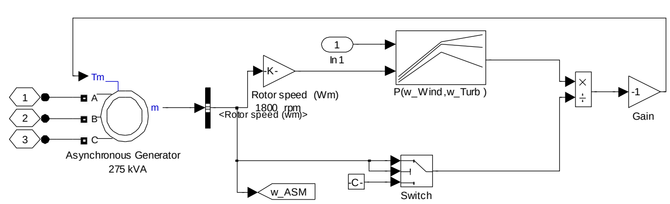

Fig 4.4 Wind Turbine Asynchronous Generator

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4.3 Load Centre

Load center consist of three major part, Main load (50 kw), Secondary Load (0 -446.25 kw) & Auxiliary Load (25 Kw) . All loads which are constant running are assumed to be in Main Load (Base Load) & Auxiliary load

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is a fluctuating load with 25 kW i.e. its that type of load which is not necessary to be in connected condition all the load for all time. While Secondary load is variable load which consumes extra generated power from wind turbine asynchronous generator and synchronous machine & dumps the fluctuated frequency.

In this load center, we used two circuit breakers for connecting and disconnecting auxiliary load and secondary load. When we want to control the frequency we close the circuit breaker of secondary load and vice versa. Fig. 4.5 shows Simulink model of Load Centre.

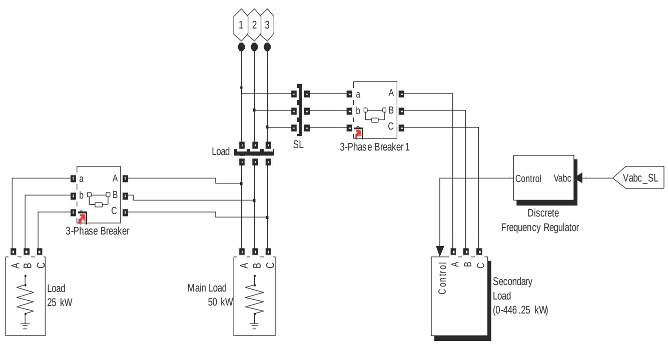

Fig 4.5 Details of Load Centre

4.4 Measuring Systems

Every Simulation requires results and results can pull out from measurement system. Hence explanation and details of it are shown in fig 4.6. At low wind speeds both the induction generator and the diesel-driven synchronous generator are required to feed the load. When the wind power exceeds the load demand, it is possible to shut down the diesel generator. A secondary load bank is used to regulate the system frequency by absorbing the wind power exceeding consumer demand.

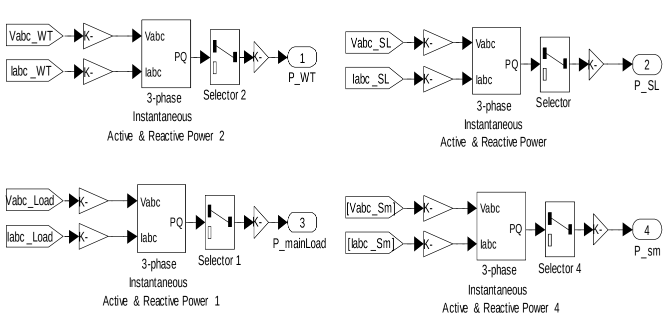

Fig 4.6 Measurement system

5 Results

The wind speed (0- 9 m/s) is such that the wind turbine produces enough power to supply the load. The synchronous machine operates with its mechanical power input (Pm) set at zero. The dynamic performance of the frequency regulation system when an additional 25 kW customer load is switched on. As the asynchronous machine operates in generator mode, its speed is slightly above the synchronous speed. Two different test cases are done for understanding the effect of all parameters on the isolated system. The case wise results are shown in this report as follows.

CASE-1 The mechanical power input (Pm) of synchronous machine is zero pu with the frequency control.

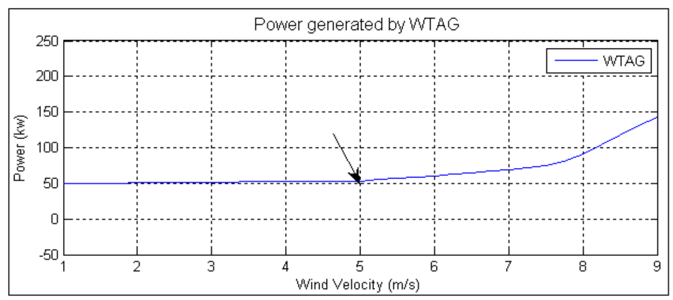

Fig 5.1 Graph between wind velocity and power of Wind Turbine Asynchronous Generator of case 1

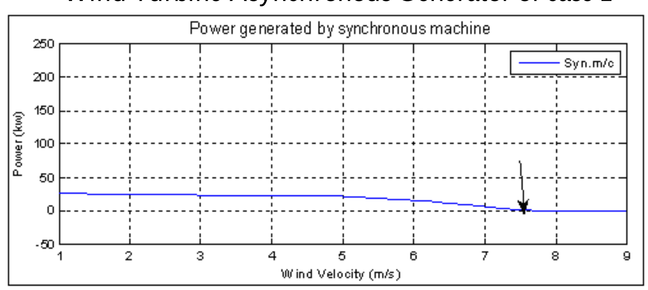

Fig 5.2 Graph between wind velocity and Power of Synchronous machine of case-1

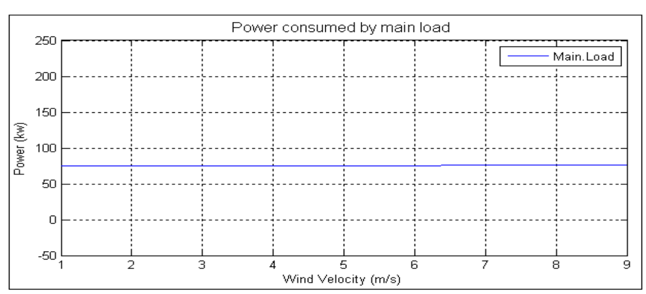

Fig 5.3 Graph between wind velocity and Power of Main Load of case-1

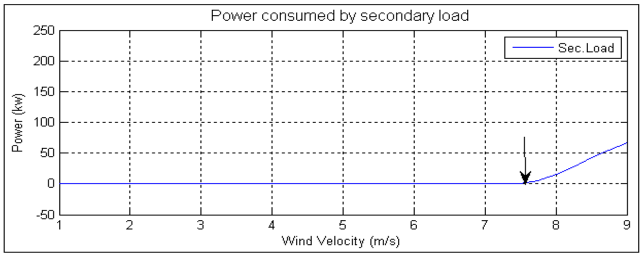

Fig 5.4 Graph between wind velocity and Power of Secondary Load of case-1

CASE-2 The mechanical power input (Pm) of synchronous machine is zero pu without the frequency control.

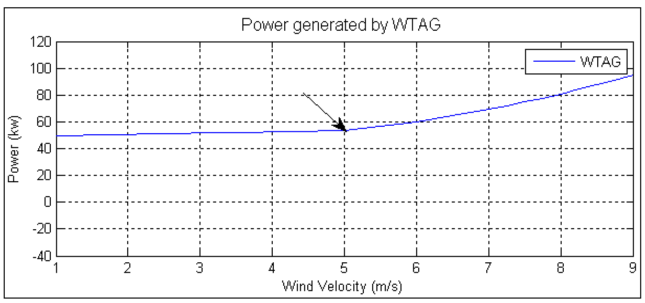

Fig 5.5 Graph between wind velocity and power of Wind Turbine Asynchronous Generator of case -2

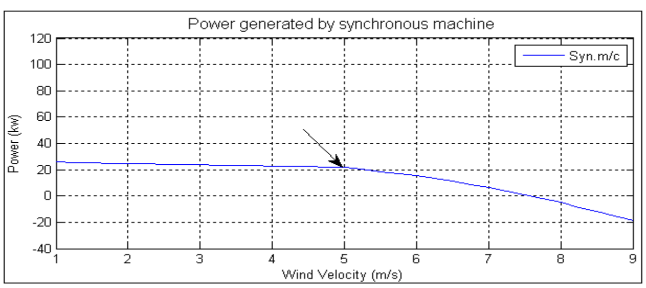

Fig 5.6 Graph between wind velocity and power of Synchronous machine of case -2

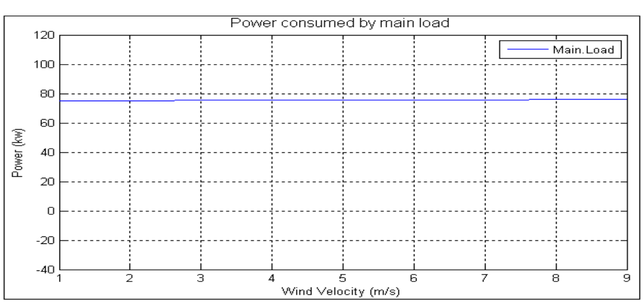

Fig 5.7 Graph between wind velocity and power of Main Load of case -2

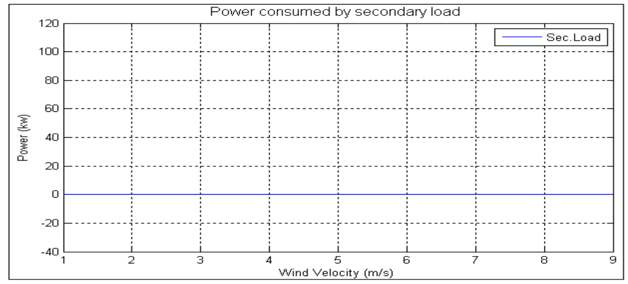

Fig 5.8 Graph between wind velocity and power of Secondary Load of case -2

6. Conclusions

As a part of paper, two major case studies are handled in this paper. All case studies are done with the intent to understand the behavior of whole system in different conditions. Results and conclusion drawn from simulations leads us towards need of studying and designing more efficient controllers in generation side as well as load center side. Though load center controller is simulated in this paper, it is required to investigate more robust controller.

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