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## Grid Connected Wind-Hydro Hybrid System with Battery Energy Storage for Critical Load

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**ABSTRACT:** In the grid connected network, it is especially difficult to support the critical load without uninterrupted power supply. The proposed Wind-Hydro hybrid system with battery energy storage is used to maintain the voltage profile and support the real and reactive power in the grid. The proposed system employing one squirrel cage induction generator driven by variable speed wind turbine and another squirrel cage induction generator driven by constant power hydro turbine feeding to the grid. The main objective of this project is to maintain constant voltage with various types of load and under varying wind speed conditions. The system provides rapid response to support critical loads. The scheme can also be operated as stand-alone system in case of grid failure. The system is simulated in MATLAB/SIMULINK and results are presented for various types of linear, nonlinear, and dynamic loads and under varying wind speed conditions.

### I.INTRODUCTION

The renewable energy sources are one of the biggest concerns of our times. High prices of oil and global warming make the fossil fuels less and less attractive solutions. Wind power is a very important renewable energy source. It is free and not polluter unlike the traditional fossil energy sources. It obtains clean energy from the kinetic energy of the wind by means of the wind turbine. The wind turbine transforms the kinetic wind energy into mechanical energy through the drive train and then into electrical energy by means of the generator. Although the principles of wind turbines are simple, there are still big challenges regarding the efficiency, control and costs of production and maintenance. Wind power is growing and most of the wind turbine manufactures are developing new larger wind turbines.

Wind power, as an alternative to fossil fuels is plentiful renewable widely distributed clean and produces no greenhouse gas emissions during operation. The wind energy stands out to be one of the most promising new sources of electrical power in the near term. Many countries promote the wind power technology by national programs and market incentives. The International Energy Agency (IEA), with funding from 14 countries supports joint research projects and information exchange on wind power development.

In India today has the largest growth rate of the wind capacity and is one of the largest producers of wind energy in the world. India currently ranks fifth amongst the wind energy producing countries of the world after Germany, Spain, USA and Denmark. The wind turbine generator system safely and efficiently converts wind energy to electrical energy. A large wind farm may consist of several hundred individual wind turbines which are connected to the electric power transmission network.

As per the current projections, the country will require an additional 150,000 MW of installed power generation capacity by 2012, which would entail an annual addition of about 10,000 – 15,000 MW every year. Wind is one of the largest resources in country with a potential of about 45,000 MW at 50m about the ground level. Five nations namely Germany, USA, Denmark, Spain and India account for 80% of the world's installed wind energy capacity.

**II.COMPONENTS USED TO GENERATE WIND POWER AND HYDRO POWER**

**2.1.1 Squirrel cage induction generator (SCIG)**

Squirrel Cage Induction Generator (SCIG) stator winding is connected directly to the grid and the rotor is driven by the wind turbine. The power captured by the wind turbine is converted into electrical power by the induction generator and is transmitted to the grid by the stator winding. In the case of SCIG due to the slip, the rotor speed varies with the amount of power generated and the rotor speed variations being small approximately 1 to 2 percent. The SCIG always consumes reactive power and therefore the reactive power consumption is nearly always partly or fully compensated by capacitors in order to achieve power factor close to unity. SCIG has inherent advantages such as cost effectiveness, robustness and there is no need for separate field excitation. In this project there are two generators are used. one squirrel-cage induction generator (SCIG) driven by a variable-speed wind turbine and another SCIG driven by a constant-power hydro turbine

**2.1.2 Components of variable speed wind energy conversion system**

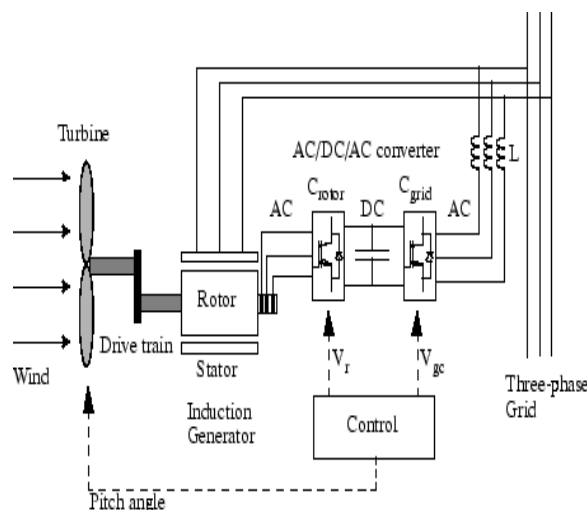


Figure 2.1 Schematic diagram of variable speed induction generator

The basic components of wind energy conversion systems are shown in Figure 2.1. Wind turbine converts wind energy into mechanical energy. A mechanical interface consists of drive train which is connected between wind turbine and generator. The electrical power output of the generator is connected to the grid.

**2.1.3 Wind power integration challenges**

Injection of the wind power into an electric grid affects the power quality and the influence of the wind turbine in the grid system concerning the power quality measurements are the active power, reactive power, variation of voltage, flicker, harmonics, and electrical behavior of switching operation. The major issues of wind power integration are related to: changed approaches in operation of the power system, connection requirements for wind power plants to maintain a stable and reliable supply, extension and modification of the grid infrastructure, and influence of wind power on system adequacy and the security of supply.

**2.2 WIND TURBINE**

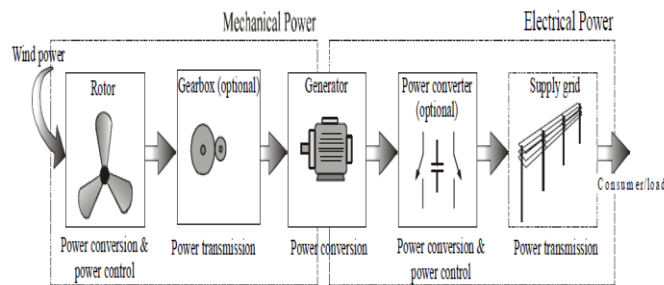
A Wind turbine is a rotating machine which converts the kinetic energy of wind into mechanical energy. If the mechanical energy is converted to electricity, then the machine is called a wind generator, wind turbine, Wind Power Unit (WPU), Wind Energy Converter (WEC) or aero generator.

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Figure



## 2.2 Converting wind power to electrical power in a wind turbine

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.

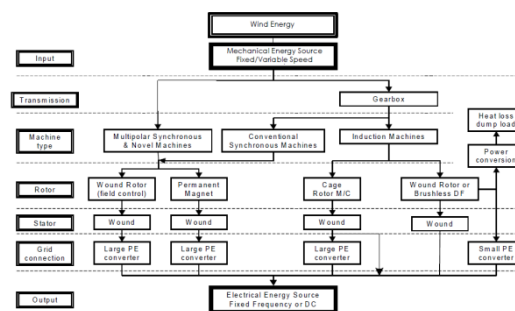


Figure 2.3 Road-map for wind energy conversion

As the blade tip-speed typically should be lower than half the speed of sound the rotational speed will decrease as the radius of the blade increases. The most weight efficient way to convert the low-speed, high-torque power to electrical power is using a gear-box and a standard fixed speed generator as illustrated in Figure 3.1. The gear-box is optional as multi-pole generator systems are possible solutions. Between the grid and the generator a power converter can be inserted.

The possible technical solutions are many and Figure 3.2 shows a technological roadmap starting with wind energy/power and converting the mechanical power into electrical power. It involves solutions with and without gearbox as well as solutions with or without power electronic conversion. The electrical output can either be AC or DC.

## III. WIND POWER AND HYDRO POWER GENERATION SYSTEM

### 3.1.1 Introduction

Wind energy has today emerged as the most promising renewable energy technology for generating grid connected power amongst various renewable energy sources. The Ministry's wind power programmed covers survey and assessment of wind resource, facilitation and implementation of demonstration and private sector projects through various fiscal and promotional policies. A total capacity of 13,184 MW has been established up to January, 2011 in the country. India is now the fifth largest wind power producer in the world, after USA, Germany, China and Spain.

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## IV. GRID CONNECTION REQUIREMENTS

### 4.1.1 Grid connection

When a considerable part of the electrical power is coming from the wind turbines, the network operators will have many technical and economical problems to manage the system. Therefore it is clear that one of the important aspects of research must be concentrated on the grid interaction of the wind turbines. One of the main concerns of the network operators is the power quality which depends on what kind of sources are connected to the grid. The wind energy has to be grid compatible, because in any power system the operator has to control the frequency and the voltage. These are the most important grid connection requirements.

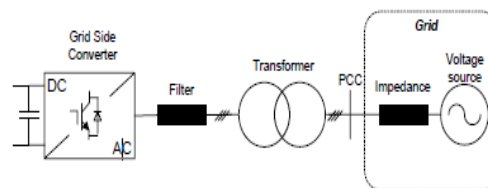


Figure 4.1 The scheme of the plant.

The output currents of the grid side converter contain the ripple caused by the switching. Therefore, it has to pass through a filter in order to have a lower current THD. It will be represented by an inductance and a small resistance which takes into account the losses of the inductance. At this point the voltage level has to be increased in order to be connected to the transmission line. Therefore a transformer is used and it is connected to the PCC. After the filter a transformer brings the voltage to a proper value for the connection to the transmission line.

### 4.1.2 Wind farm requirements

If wind farms would be installed solely to maximize energy output, they would have major limitations in terms of:

1. Power control and frequency range.
2. Power factor and voltage control
3. Transient fault behaviour, voltage operating range.

These are the three main issues that new grid codes must address for wind farm connection. The most worrying problem that wind farms must face is a voltage dip in the grid. The effects of transient faults may propagate over very large geographical areas and the disconnection of wind farms under fault conditions could pose a serious threat to network security and security of supply because a great amount of wind power could be disconnected simultaneously.

### 4.1.3 Reactive power control

Voltage and current are typically measured 128 times per alternating current cycle, (i.e. 50 x 128 times per second or 60 x 128 times per second, depending on the electrical grid frequency). On this basis, a so called DSP processor calculates the stability of the grid frequency and the active and reactive power of the turbine. (The reactive power component is basically a question of whether the voltage and the current are in phase or not). The term "power quality" refers to the voltage stability, frequency stability, and the absence of various forms of electrical noise (e.g. flicker or harmonic distortion) on the electrical grid. More broadly speaking, power companies (and their customers) prefer an alternating current with a nice sinusoidal shape.

## V. WIND-HYDRO HYBRID SYSTEM WITH BATTERY ENERGY STORAGE SYSTEM (BESS)

For the test system of wind-hydro hybrid system, there are three modes of operation. In the first mode, the required active power of the load is less than the power generated by the SCIGh. Moreover, the power generated by the SCIGw is transferred to the BESS. In the second mode, the required active power of the load is more than the power generated by the SCIGh but less than the total power generated by SCIGw and SCIGh. Thus, portion of the power generated by SCIGw is supplied to the load through the load-side converter and remaining power is stored in BESS. In the third mode, the required active power of the load is more than the total power generated by SCIGw and SCIGh. Thus, the deficit power is supplied by the BESS, and the power generated by SCIGw and the deficit met by BESS are supplied to the load.

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## 5.1 Simulation Models and Results

The test system comprises of A 150 KW wind energy conversion system system exports power to a 150 kV grid through a 30 km, 25 kV feeder. Wind turbines using a Squirrel Cage Induction generator (SCIG) consist of a cage rotor induction generator and an AC/DC/AC IGBT-based PWM converter. The stator winding is connected directly to the 50 Hz grid while the rotor is fed at variable frequency through the AC/DC/AC converter. The SCIG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed while minimizing mechanical stresses on the turbine during gusts of wind. Here the wind speed is maintained constant at 11 m/s.

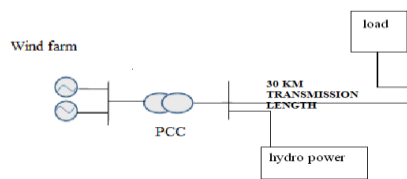


Figure 5.1 Single line diagram of the conventional system

The SCIG technology allows extracting maximum energy from the wind for low wind speed by optimizing the turbine speed. The optimum turbine speed producing maximum mechanical energy for a given wind speed is proportional to the wind speed. For wind speeds lower than 10 m/s the rotor is running at sub synchronous speed and at high wind speed it is running at hyper synchronous speed.

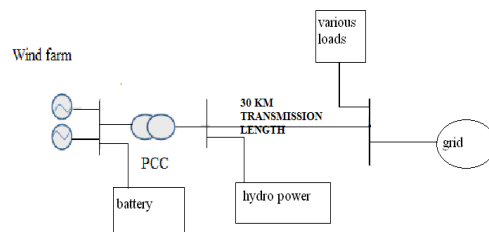


Figure 5.2 Single line diagram of the proposed system

## 5.2.2 Wind power and hydro power generation system

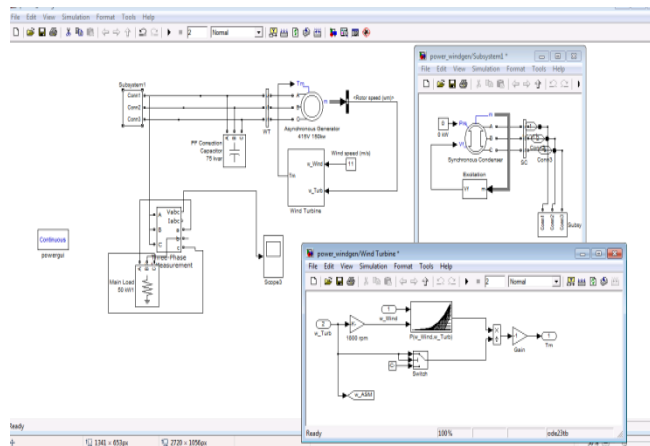


Figure 5.3 wind power generation system.

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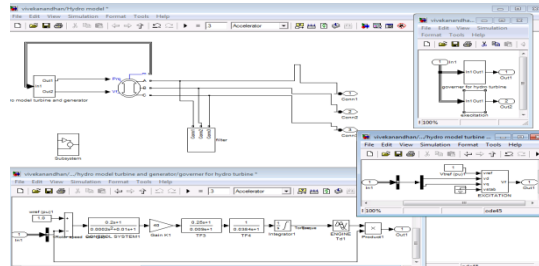


Figure 5.4 small hydro power generation system.

Thus the above figure 5.4 shows the constant hydro power generation system with turbine and governor model blocks. Installed capacity of 35KW, three phase, 415V squirrel cage induction generator(SCIG) is used. SCIG driven by a constant-power hydro turbine feeding to the grid.

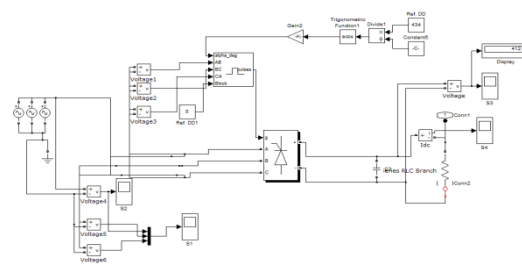


Figure 5.5 AC to DC PWM converter.

Thus the above figure 5.5 shows the AC to DC PWM converter which converts 415V AC voltage into 412V DC. At the time of grid connection requires synchronization of source voltage and grid voltage, so the system needs 415V dc is achieved with the help of battery energy storage system(BESS).

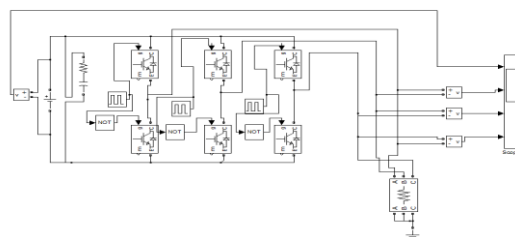


Fig.5.6 DC to AC inverter.

Thus the above figure 5.6 shows the AC to DC inverter. The converted 415V DC voltage is again inverted into 415V AC with the help of above DC to AC inverter. Then the corresponding voltage is feeding to the grid. The basic requirement for connecting to grid is synchronization of voltage, frequency and phase sequence. To achieve this requirement we need voltage of 415V and frequency of 50HZ. If any mismatch in voltage means that mismatch voltage improved by battery energy storage system(BESS)

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## 5.2.3 Grid connected system

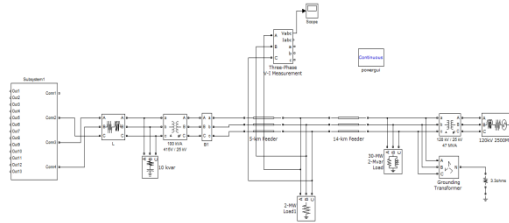


Fig.5.7.Test system of grid connected wind energy conversion system except hydro.

Thus the above figure 5.7 shows the grid connected wind energy conversion system. The generated power can be varied under varying wind speed conditions. The extracted power from wind can be stored in battery with help of PWM converter.

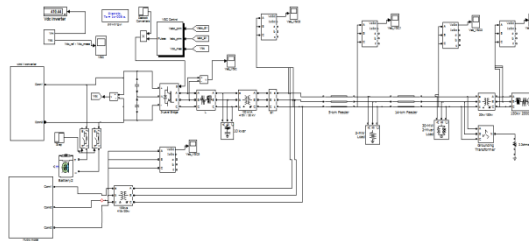


Figure 5.8 Test system of grid connected wind-hydro hybrid system with battery energy storage system.

Thus the above figure 5.8 shows the grid connected wind-hydro hybrid system with battery energy storage. The proposed system studied for various types of loads like linear, non linear, static and dynamic loads. Hydro generator driven by constant power hydro turbine.

## 5.3 SIMULATION RESULTS

For the above test system, the output waveforms for wind generator model, PWM converter, converter with battery, DC to AC inverter, the output waveforms for small hydro generator model, output voltage of 150KV and 30KV load, test system with various types of linear, non linear, static and dynamic loads are presented below:

### 5.3.1 Generator and conversion output voltage

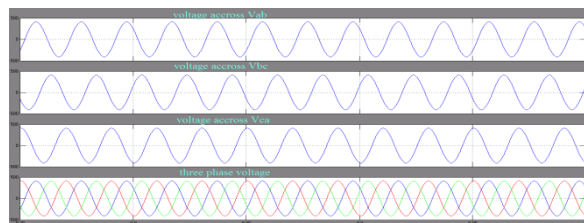


Figure 5.9 Wind generator output 3-phase,415V.

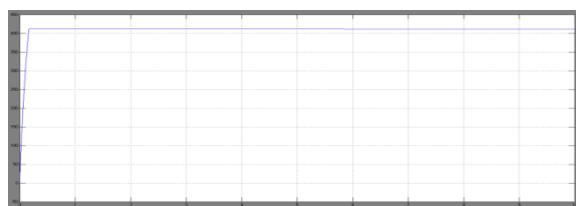


Figure 5.10 Converter output Voltage of 412V.



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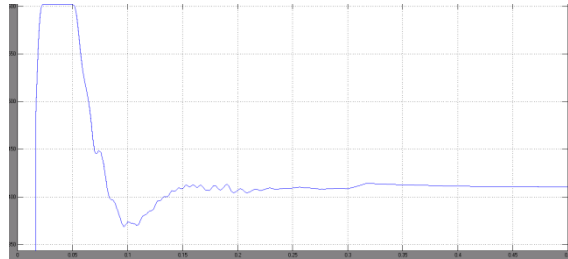


Figure 5.11 Converter output with battery energy storage 415V.

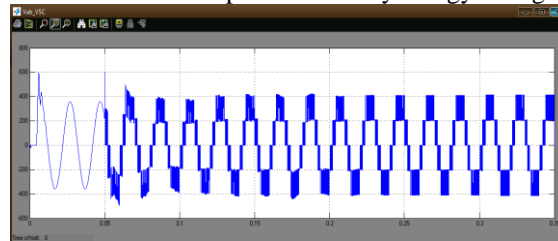


Figure 5.12 Inverter output 415V.

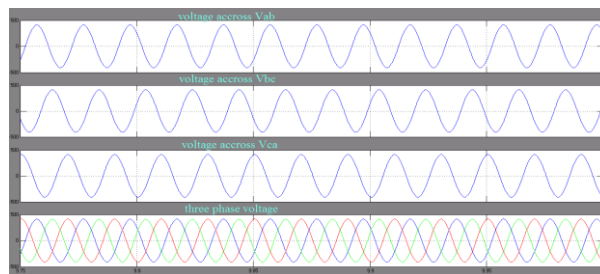


Figure 5.13 Hydro generator output 3-phase, 415V.

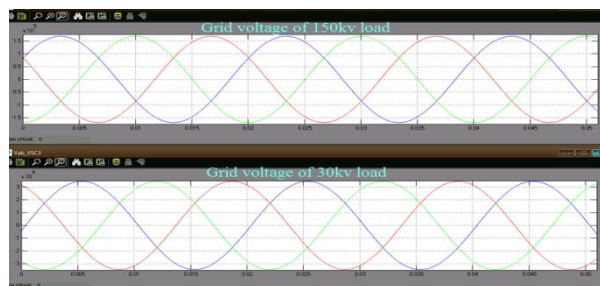


Figure 5.14 output voltage of 150KV and 30KV load.

## 5.3.2 System output with various load

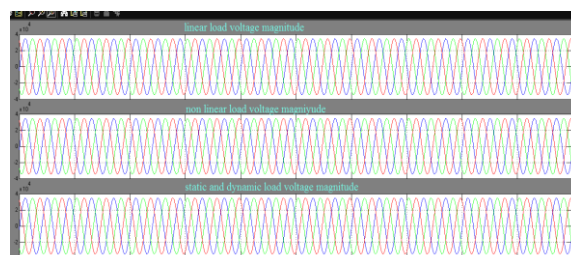


Figure 5.15 Voltage magnitude of linear, non linear, static and dynamic loads.



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## VI. CONCLUSION AND FUTURE ENHANCEMENT

Among the renewable energy sources, small hydro and wind energy have the ability to complement each other. The proposed system connected to the grid and where the wind potential and hydro potential exist. One cage generator driven by wind turbine and another cage generator driven by hydro turbine along with BESS, has been modeled and simulated in MATLAB using Simulink and Sim Power System tool boxes. The design procedure for selection of various components has been demonstrated for the proposed hybrid system. The performance of the proposed hybrid system has been demonstrated under different electrical (consumer load variation) and mechanical (with wind-speed variation) dynamic conditions. It has been demonstrated that the proposed hybrid system performs satisfactorily under different dynamic conditions while maintaining constant voltage. The battery energy storage provides rapid response and enhances the performance under the fluctuation of wind turbine output and improves the voltage stability of the system.

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