

Power Management of Wind and Solar Dg

Gundip Singh

Department of Electrical Engineering, Manav Bharti university Solan (H.P.)

Abstract: Distributed Generation (DG) involves utilization of small and modular generator units dispersed throughout the distribution side or consumer side. Hybrid DG has evolved as a major technology where renewable generations are integrated together to satisfy the energy needs of the consumer. In this paper a model for integrating renewable generating units using MATLAB Simulink is described. The developed model is tested on the load system. The switching between the two generating units is operated according to the load demand.

Keywords: Distributed Generation, MATLAB Simulink and Power Management Switching.

I. INTRODUCTION

DG systems are small-scale generator connected directly to the distribution network. DG is widely used to promote the wind, solar and some renewable energy deployment and utilization. It is considered an important technology to enhance the energy efficiency, supply energy to remote areas far from load centres and achieve energy saving and emission reduction.

Wind and solar power generation are two of the most promising renewable power generation technologies. Different alternative energy source can complement each other to some extent. Multisource hybrid alternative energy systems have great potential to provide higher quality and more reliable power to customers than a system based on a single resource.

Conventional electric grid was conceived as a centralized unidirectional system of electric power transmission, distribution and demand. The increase in energy consumption, the increase in cost and worsening global environment has created interest in renewable energy resources. For a large and dispersed rural country, decentralized power generation system is solution. In the current economic scenario, India is focussed on reducing its energy deficit by expanding its grid penetration, which is far less when compared to other developing and developed nations. Daily and seasonal effects and limited predictability result in intermittent generation of renewable resources. Hence integrated generation will provide more reliable power to the consumers [1].

In this paper, simulation of two renewable generating units is integrated with each other. The developed model is tested on the load system. The switching between the two generating units operates according to the total load on the system. When load consumption is less than solar generating capacity then the other generating unit is used to supply to the battery system for storage. When load increases above the capacity of the generating unit supplying the previous load then automatic switching takes place which connects the second unit to the load system. This automatic switching helps reducing human

intervention and also prevents overloading of the first generating unit due to overloads. The output power at the load and the switching status of the generating units are monitored at a central monitoring station through zigbee communication system.

Moreover use of renewable resources for generation also provides several advantages such as reduction in greenhouse gas emissions, reliable supply of power etc., Hence this system is effective solution for growing energy demand [2].

II. DISTRIBUTED GENERATION

“Distributed generation refers to use of onsite. i.e., local or non-centralized power sources to augment and / or replace the traditional centralized utility grid”. Distributed generation include solar, wind, geothermal and certain types of fuel cells. It is an approach that employs small-scale technologies to produce electricity close to the end users of power. These distributed generations can provide lower-cost electricity, higher power reliability and security with fewer environmental consequences than traditional power generations [3]. The total percentage of electrical energy produced by utilising different sources of energy is given in fig 1

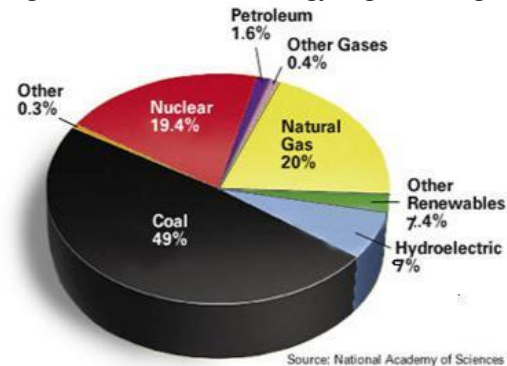


Fig 1: Power Production in India by Different Sources

2.1 Need for Distributed Generation

The current model for electricity generation and distribution in the India is dominated by centralized power plants. The power at these plants is typically combustion (coal, oil, and natural) or nuclear generated. This system of centralized power plants has many disadvantages like transmission distance issues, greenhouse gas emission, the production of nuclear waste, inefficiencies and power loss over the lengthy transmission lines, environmental distribution where the power lines are constructed, and security related issues. Many of these issues can be mediated through distributed energies. By locating, the source near or at the end-user location the transmission line issues are rendered obsolete.

Mass distributed generation of renewable energy, such as wind and solar generation is one of the smart grid technologies and characteristics that leads to many benefits to environment such as significant reduction of CO₂ and other harmful gaseous emissions, and to utility like reduction in the peak demand, optimisation of assets use that leads to reduced stresses on all high voltage equipment's and customers who have Photovoltaic's (PV) units like balancing electricity bill. The comparison between central generation and distributed generation is shown in fig 2

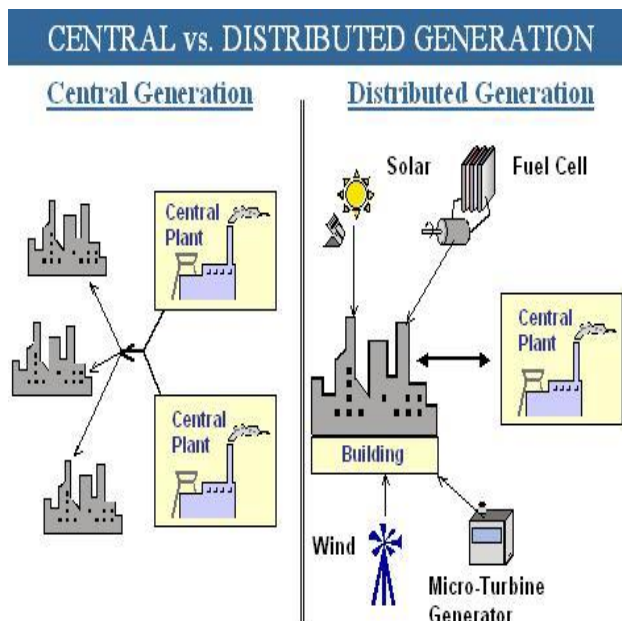


Fig 2: Central Generation vs. Distributed Generation

With the enactment of Indian Electricity Act 2003 and due to the major changes in the Power Sector and the fast move towards liberalization of the energy markets, utilities are inclined to install small capacity generating units to distribution systems. The estimated growth of distributed generation in world market by 2015 is depicted in fig 3

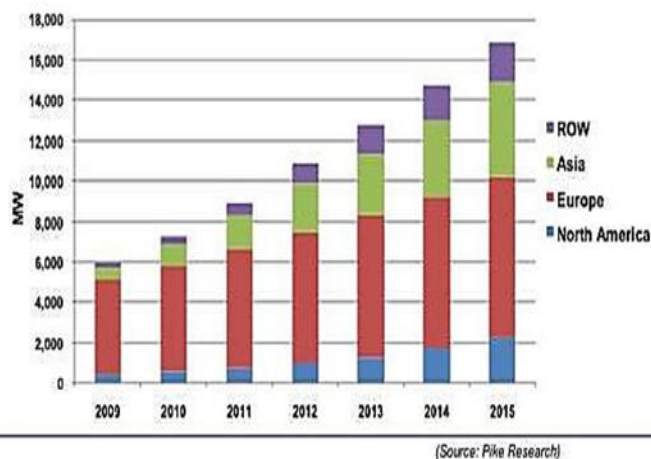


Fig 3: Annual Renewable Distributed Energy Generation Capacity Additions, World Markets: 2009-2015

In India wind and solar energy sources are available everywhere throughout the year at free of cost whereas tidal and wave energy are available in coastal area and geothermal energy at specific location. Due to natural intermittent properties of wind energy and the tidal and geothermal energies, the storage or other generating sources are integrated with each other to cater this challenge of supplying continuous supply. Such interconnection of two or different generating sources are known as Hybrid Systems/ Hybrid distributed generation [4].

The main objectives of these systems are to extract maximum power at low costs with good power quality, low pollution and reliable supply. There are many combinations of different alternative energy sources and storage devices to build a hybrid system.

Among available hybrid energy systems, the wind energy and photo voltaic system integration is the most effective combination.

Differential heating of the earth's surface by the sun causes the movement of large air masses on the surface of the earth, i.e., the wind. Wind energy conversion systems convert the kinetic energy of the wind into electricity or other forms of energy. Wind power generation has experienced a tremendous growth in the past decade, and has been recognized as an environmentally friendly and economically competitive means of electric power generation.

PV is more mature technology with a total global installation of around 40 GW as per the end of 2010, a more than 69% increase compared to 2009, when 97% of total solar power was generated from PV. The efficiency of PV ranges from 6 to 16% at 25°C (the standard temperature) Regarding the operating temperature, PV technology, it is affected by a number of factors, particularly the high temperature. Simulink provides a graphical user

interface (GUI) for building models. The interactive graphical environment simplifies the modelling process, eliminating the need to formulate differential and difference equations in a language or program. Models are hierarchical and it is possible to build models using both top-down and bottom-up approaches. The system can be viewed at a high level, then double-click blocks to see increasing levels of model details. This approach provides insight into how a model is organized and how it parts interact [5].

Modelling of proposed simulink model is as shown in fig 4. It comprises of four main blocks.

They are:

- Solar power generating system
- Wind power generating system
- Electrical load with effective switching system
- Zigbee Communication System

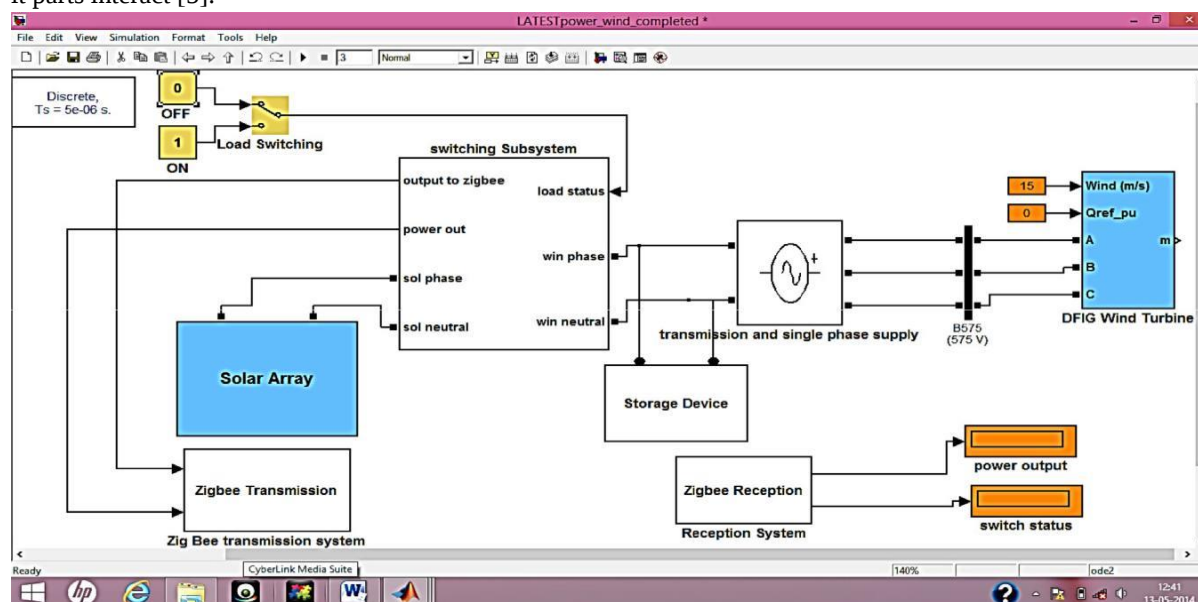


Fig 4: Proposed Simulink Model

3.1 Solar Power Generating System

The solar energy is directly converted into electricity using solar modules. The DC output of this solar array or module is then converted into 3 phase AC with the help of an inverter. Further AC voltage is stepped up for transmission purpose and stepped down near consumer ends. A single phase supply is taken to the load system. Hence the Solar Generating System consists of following two units [6]:

1. Solar array or PV array
2. Inverter

3.1.1 PV array

Photo Voltaic array represents the fundamental power conversion unit of a PV generator system. A Photovoltaic array (or solar array) is a nothing but linked collection of solar cells. Solar energy incident on the solar cell is measured in terms of Irradiance. Solar irradiation can be defined as the amount of energy transmitted from the sun to earth's outer atmosphere. This measurement is normally done in square units per units of time. This solar irradiance is taken to be constant 1000 W/m² at 25°C. Each solar cell has three ports:

1. Incident Irradiance
2. Positive electrical voltage

3. Negative electrical voltage

The output voltage of a typical solar cell is very much less about 0.6volt and 200mA. Hence to obtain higher values of current and voltage these cells are connected in parallel and series as per requirement. In this model a subsystem of 6 cells are connected in series.

Then three such subsystems of 6 cells is further connected to form 18 cell system and 18 cell system further connected to 36 cells. This is continued until the voltage across the array is 32 volt.

The next task is to interconnect the subsystem such that the total output current rises to 4.57A. The whole system consists of totally 72 cells which produce a DC output voltage of 32 volts and 4.57 A.

The PV array formed with 72 cells is formed as a subsystem with three terminals. One is the input to the subsystem i.e., irradiance which is 1000W/m² at 25°C. The total electricity produced is measure across the other two terminals which are positive and negative output terminals. The Simulated model of solar array with other measuring blocks is shown in fig 5. It contains solar array, input to solar array i.e., Irradiance , current measurement block, voltage measurement block and the power measurement .The graph of the DC output voltage, current and power at the PV array is shown in fig 6.

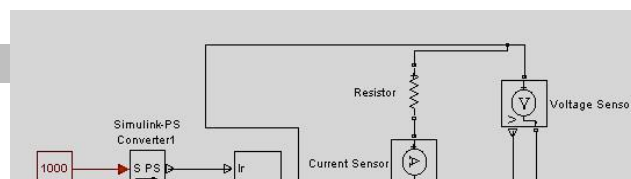


Fig 5: Simulink Model of Solar Array Unit with measuring Blocks

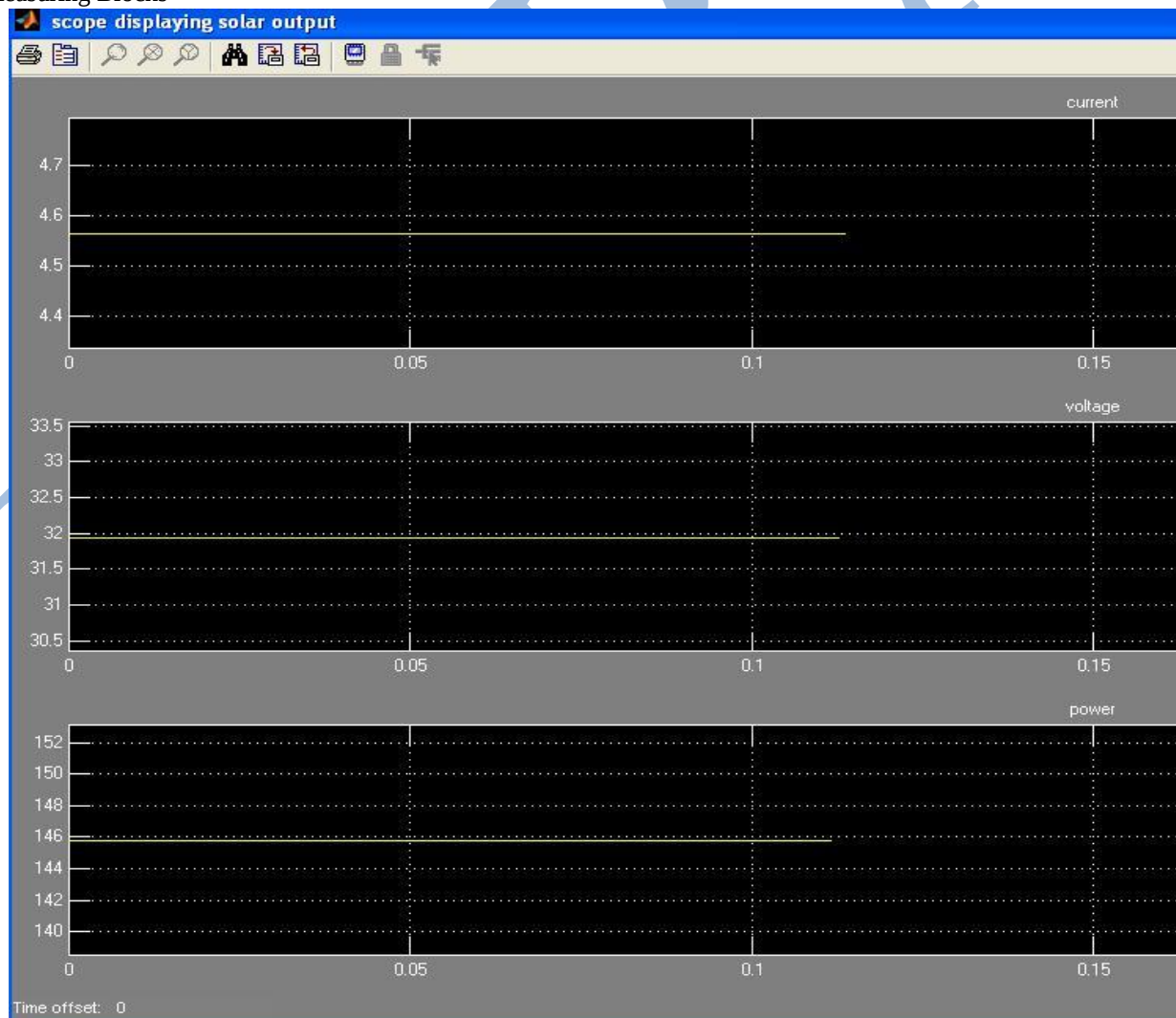


Fig 6: DC Output Current, Voltage and Power Graph at PV Array Output

3.1.2 Inverter

The DC output obtained from PV array is fed to a 3 phase DC to AC converter universal bridge which gives converted 3 phase AC output. The inverter used in this system is a PWM inverter. In a conventional inverter the output voltage changes according to the changes in the load. To nullify effect caused by the changing load, the PWM inverter correct the output voltage according to the value of the load connected at the output. This is accomplished by changing the width of the switching frequency generated by the oscillator section [7].

The AC voltage at the output depends on the width of the switching pulse. The process is achieved by feed backing a part of the inverter output to the PWM controller section based on this feedback voltage the PWM controller will make necessary corrections in the pulse width of the switching pulse generated at oscillator section. This change in the pulse width of the switching pulse will

cancel the changes in the output voltage and the inverter output will stay constant irrespective of the load variations. This inverter converts the DC output of the PV array to constant AC voltage of 440volts. The output of the inverter is not a pure sinusoidal wave, hence LC filters are provided at the output of the inverter to provide sinusoidal output. The Simulink model of PV array connected to inverter and the LC filter with the final 3 phase AC output voltage is shown in fig 7.

The inverter output is connected to a step up transformer where 440V is stepped up to 33KV. This high voltage of 33KV is transmitted along a 30KM line. It is then stepped down at the consumer end to 230V. Since Solar generating system is anytime connected to the load system, the output waveforms of voltage and current at the secondary terminal of the step down transformer is shown in fig 8.

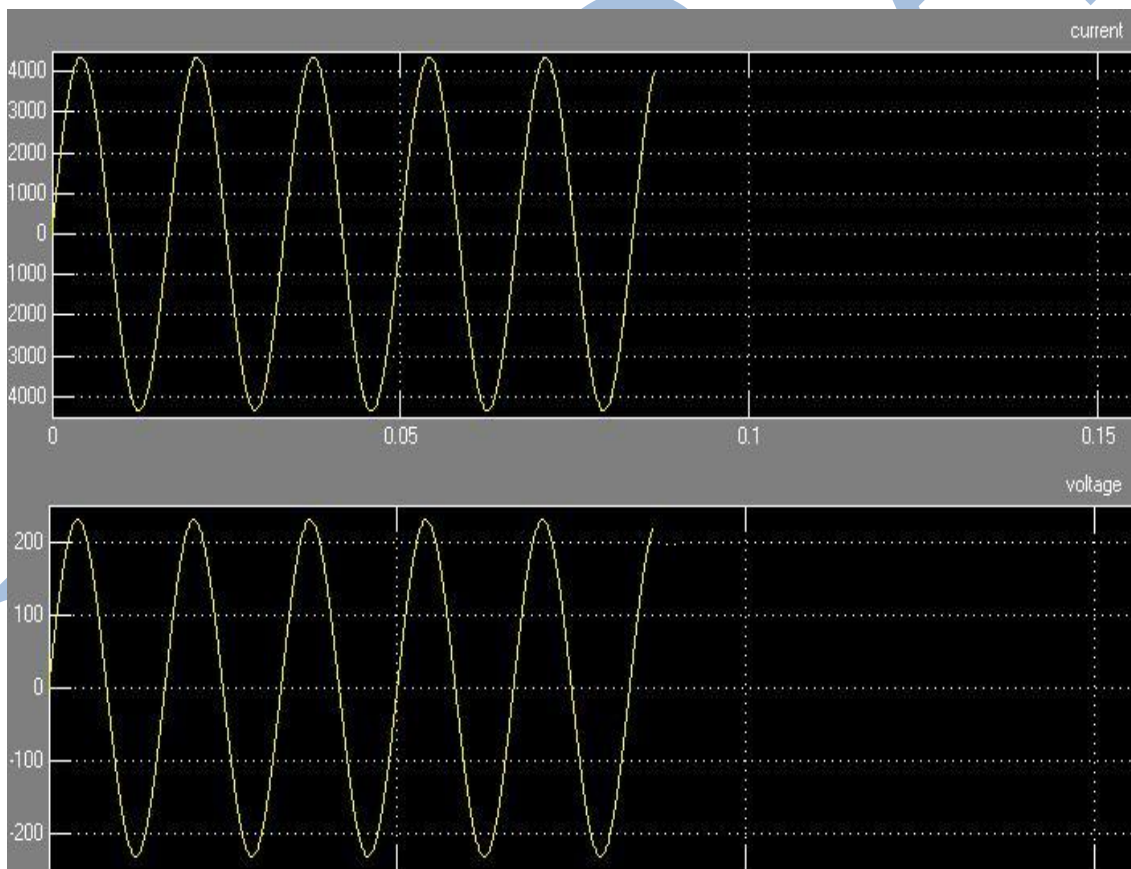


Fig 8: Secondary Output Voltage and Current of Step-down Transformer

3.2 Wind Generating System

A Wind energy conversion system consists of a wind turbine and a 3 phase generator and Interconnection apparatus which are used to achieve power control, soft start and interconnection functions and control systems. The system under discussion uses a Doubly Fed Induction Generator (DFIG) .Wind turbines using a doubly-fed induction generator (DFIG) consist of a wound rotor induction generator and an AC/DC/AC IGBT-based PWM converter modelled by voltage sources. The stator winding is connected directly to the 60 Hz grid while the rotor is fed at variable speed through the AC/DC/AC converter. The DFIG 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. The simulink model of Wind turbine doubly fed induction generator as in fig 9 consists of following ports:

- A,B,C – Output 3-phase voltage ports of the generator
- Wind (m/s) - This input is not visible when the External mechanical torque parameter is checked. Simulink input of the wind speed is in m/s. Generally wind speed is given as 8m/s.
- Trip - A Simulink logical signal (0 or 1) is applied to this input. When this input is high the WTDFIG is disconnected and its control system is disabled. Hence a '0' signal is applied to this port

This WTDFIG generates a voltage of 440V. This is transmitted to the consumer side through 3 phase transmission system

3.2.1 Wind Transmission System

The Wind generating system is not always connected to the load system. It is connected to a other grid system along with load system under consideration with a switching system between the two systems. When the load in the system increases above the capacity of the solar generating unit which is directly connected to the load system, then an automatic switching process takes place and the wind generating unit is connected to the load system and detached from the supplementary grid system. This can be easily understood by the waveforms of voltage and current at the step down transformer secondary where the current will be 0 when the wind generating unit is not supplying the load system

The output of Doubly Fed Induction Generator is connected to a step up transformer which steps up 440 to 33KV. This high voltage is transmitted along a 30 KM (π) line. This voltage is then stepped down at the consumer side using a step down transformer which steps down 33KV to 230V. The simulink model of wind energy transmission system is shown in fig 10.

The fig11 and fig 12 gives the waveform of voltage and current delivered by wind generating unit to the consumer end, when connected to load system and when not connected to the load system respectively.

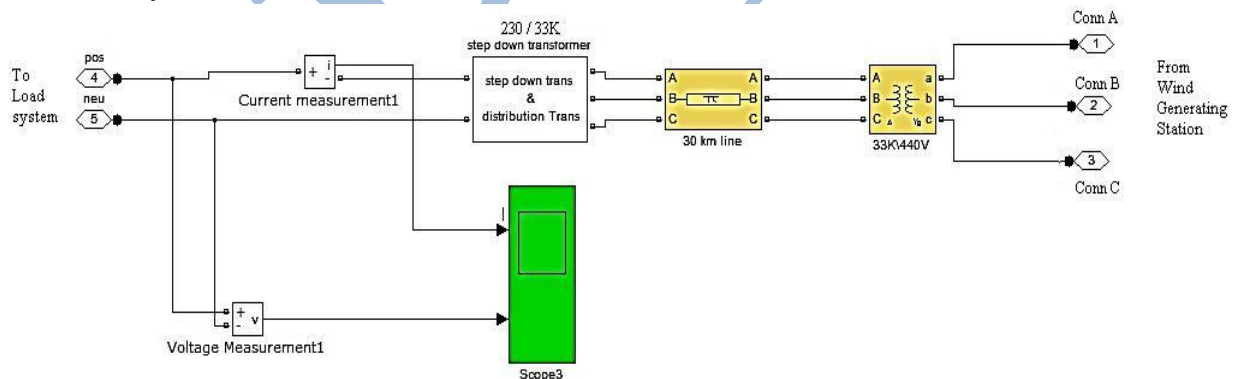


Fig 9: Simulink Model of Wind Turbine Generating 440 V

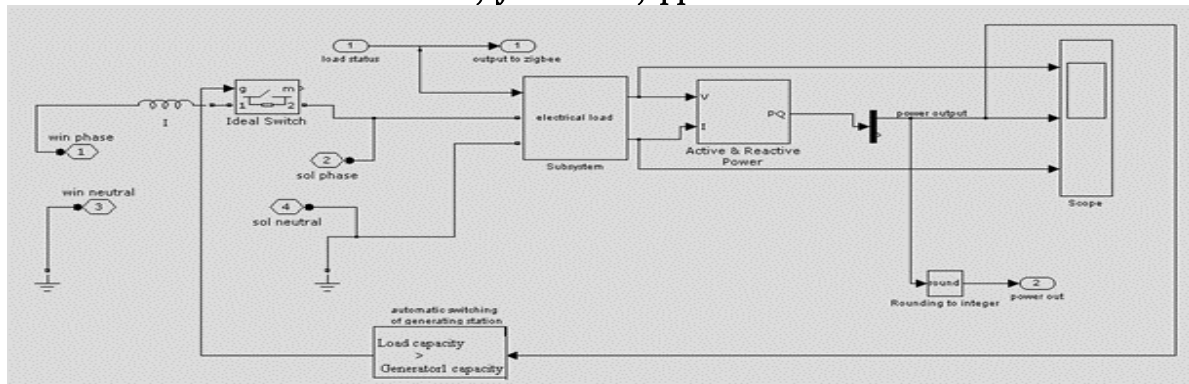


Fig 10: 3 Phase Transmission of Voltage from Wind Turbine to Load System

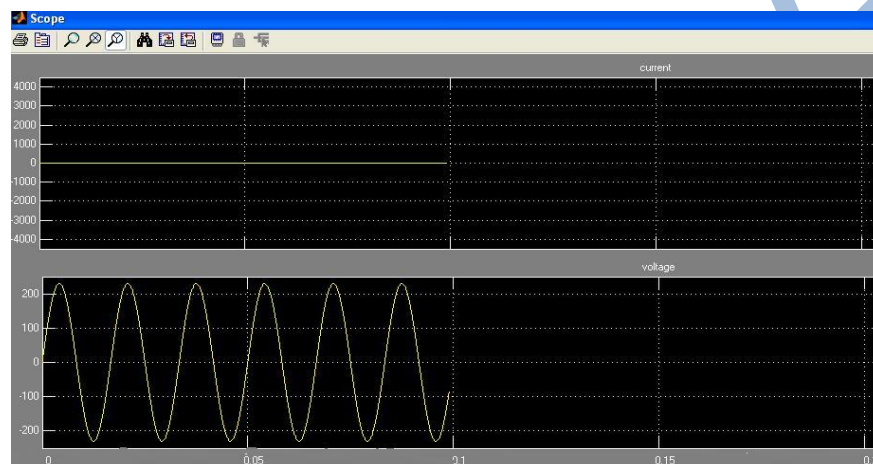


Fig 11: Voltage and Current Waveforms when Wind Generating Unit is not connected to the Load

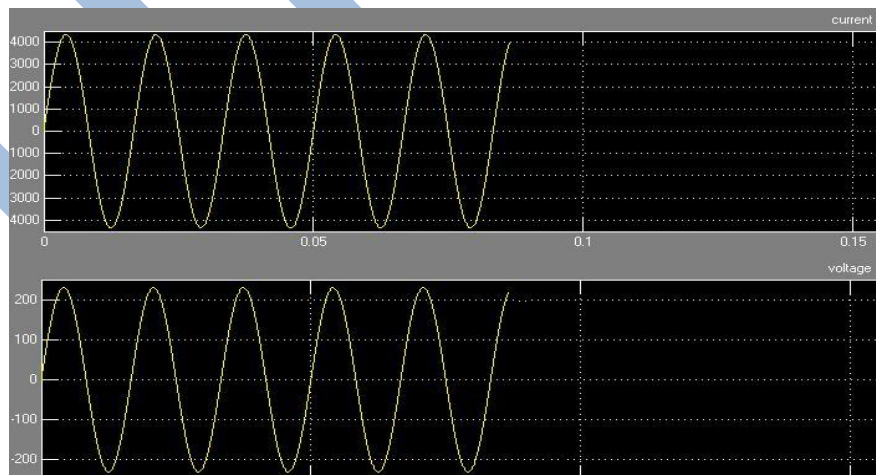


Fig 12: Voltage and Current Waveforms when Wind Generating Unit is Connected To the Load

3.3 Electrical load system with effective switching system

The Electrical load system implemented in current model consists of Series RLC loads. In Simulink a Series RLC

load block implements a linear load as series combination of R L C elements. At the specified frequency, the load exhibits constant impedance. The active power and the reactive power absorbed by the load are proportional to square of the applied voltage.

Fig 14: Simulink Model of Zigbee Receiver

III. RESULT

Case 1: Load switching at '0' position

The current model consists of two RLC loads connected in parallel. Load demand up to 0.8MW is catered by solar generating unit. In this model solar generation system is permanently connected to the load system and wind generation system is switched between the load and storage system.

Under this case load consumes 0.8MW power and voltage across the load is 230V and the current is measured to be 4347 A. The power consumption at the load end and switch status is transmitted to the zigbee receiver placed in control centre. Switch status '0' indicates that wind generating unit is supplying to storage system

The output power, voltage and current waveforms of the load at '0' position is shown in fig 15.

Case 2: Load switching at '1' position

When both the loads are turned on the total power required increases to 1.6MW. The solar generating unit connected to the load system is unable to meet the present load. Hence another generating unit has to be connected to the load system. The switching between generating units are done.

The total current drawn will be equal to 8694 A and the voltage across the load will remain 230V and total power consumed will be 1.6 MW. The output power, current and voltage waveforms of the load at '1' position is shown in fig 16.

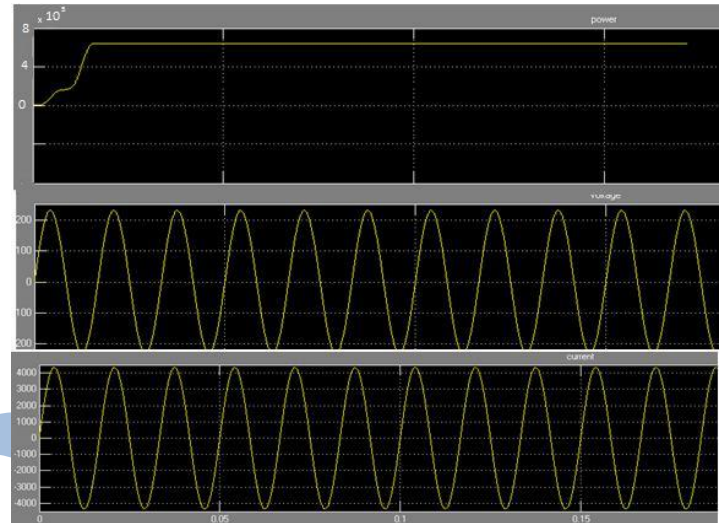


Fig 15: Output Power, Voltage and Current waveforms of Load System at '0' Position

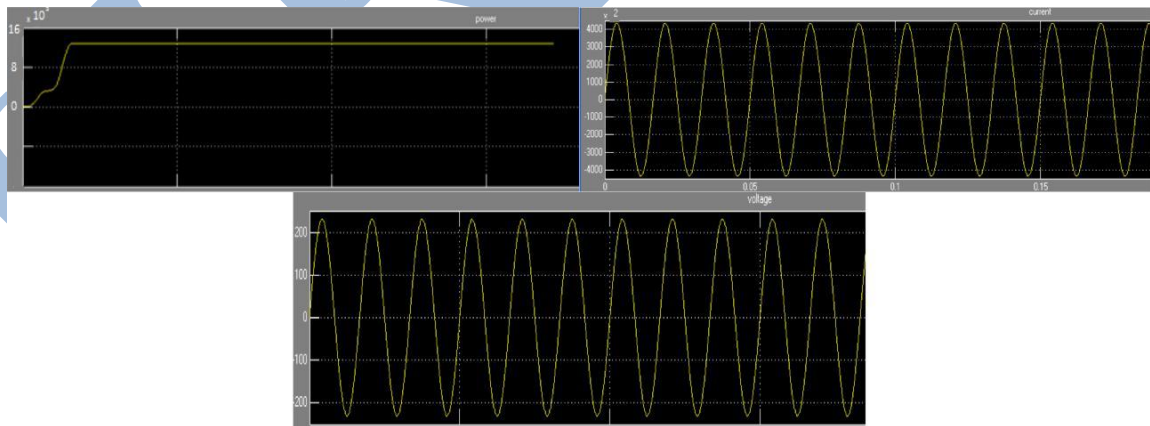


Fig 16: Output Power, Current and Voltage Waveform of Load System at '1' Position

IV. CONCLUSION

Conventional Grid faces several disadvantages such as greenhouse gas emission, inefficiency, power loss over lengthy transmission line. Distributed generation eliminates many of the above mentioned issues. Effective hybrid distributed generation management prevents power failure due to overloading.

Solar and wind generation are smartly managed to satisfy the load fluctuation. Solar generating unit is designed to supply a maximum of 1MW load and hence it successfully supplies a load of 0.8 MW. Similarly wind system is also designed for 1MW capacity. Solar and wind hybrid configuration is capable of supplying total of 2 MW. When load increases from 0.8MW to 1.6 MW effective switching of wind system takes thereby satisfying the objective of the proposed system. Zigbee network is used to transmit/receive system parameters

such as load demand and switching status. The entire system is simulated using matlab/simulink.

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