Smart Grid Integration:Renewable Based Micro Hybrid Power System

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Abstract-Electrical energy generation from renewable energy sources are increasing as increase in electricity consumption. Increasing energy cost, transmission loss, risk of radioactive radiation from nuclear power plant, carbon pollution leads global environmental changes are motivating a the conventional ways of generating electricity to RES. Globally, there is a desire to rely more on renewable energy resources for electricity generation. The electricity grid is presently evolving towards an intelligent grid the so-called smart grid. One of the major goals of the future smart grid is to move towards 100% electricity generation from renewable energy resources. This paper presents the overview of recent efforts that aim to integrate renewable energy resources into the smart grid. Renewable energy based micro hybrid power system consist photovoltaic and small wind turbine equipped with Cuk-DC-DC converter, three phase inverter and filter circuit. The impact of connecting Renewable energy sources to the Smart Grid with regard to improving Power Quality aspects and impact of integrating renewable energy sources on Power Quality indices in the smart grid was analyzed and the measures for avoiding the negative impact are included in the paper.

Keywords-Renewable Energy based Resources, Smart Grid, Converter, Battery, Power Quality

I. INTRODUCTION

Energy technologies are the focal point in a social and economic development of country in all scales. Energy is closely linked to quality of living, economic growth of community. Demand is dependent on non-renewable fossil fuels that have been and will continue to be a major cause of pollution and climate change. Because of these urgent finding is required of sustainable alternatives. Major challenge in realizing a sustainable future is to develop technology for integration and control of renewable energy sources in smart grid. Nowadays, there is a high demand for renewable energy and this demand is increasing due increase in energy consumption leads to rising energy cost and global environmental changes.

In the future Smart grid, one major goal is to move towards achieving a 100 percentage renewable grid i.e., to make the future grid an inverter dominated grid. First, RERs are typically intermittent in nature, e.g., available only during certain hours of the day or seasons of the year. Second, RERs are based on highly heterogeneous technologies that each has their unique characteristics, e.g., solar plants have very different characteristics compared to wind farms or tidal wave power plants. Third, compared to fossil fuel based energy resources renewable energy resources have typically less capacity. Finally, RERs are more spread out in terms of their geographic locations. These unique properties of inverter-connected RERs make the integration into the SG very challenging.

Photovoltaic (PV) energy system and wind energy is one of the popular energy sources among all renewable energy sources because it is clean, inexhaustible and versatile and it would play an important role in future smart grids. Both energy systems can be standalone or grid connected system. Grid connected PV systems have become very popular because they do not need battery back-ups since all of the energy generated from the Photovoltaic plant is delivered to grid for direct transmission, distribution, and consumption. Hence, they are more cost effective and require less maintenance than stand-alone systems.

The basic structure of grid connected photovoltaic system given in consists of a photovoltaic array, a DC-DC converter, which transform the power provided from the PV source, an inverter and the grid. Photovoltaic cell is the main component of the system. Photovoltaic (PV) cell is made up of silicon, gallium arsenide and cadmium telluride and so on which transforms sunlight to electricity. To increase the efficiency, a number of individual PV cells are interconnected together to form a module. Trends lead to technical and non-technical challenges. For maintaining a reliable and cost effective supply, new efforts have to be undertaken for the management of energy networks, integration of RES and DO in the distribution networks, for generation, load management and for limits of other technical and socio economic aspects of decentralized energy markets. In this paper Hybrid model of PV and wind are considered under study. Increase in PV and wind energy systems energy generation is concerns of some utilities because of the possible negative impacts of the power fluctuations generated by complex network leads to unstable operation of the electric network prior to fault condition, high power swings in the feeders and unacceptable voltage fluctuations at certain nodes in the complex network. Random fluctuations generated these systems does not allow to consider in scheduled electricity generation process.

II. LITERATURE SURVEY

A novel grid integration scheme for a hybrid electric power generation scheme using Photovoltaic power generation and induction generator based wind power generation. The proposed scheme adopts Fuzzy Logic Control (FLC) for the Maximum Power Point Tracking (MPPT) of the wind turbine driven induction generator and the incremental conductance based MPPT for the solar PV system. The power from the wind source and the photo voltaic source are brought to a common DC link and a DC to AC three phase inverter is used to upload power into the grid and a novel control scheme is adopted for sinusoidal current injection at the point of grid integration .[1]

The model includes a hybrid system consisting of wind and solar panels and it is connected to the smart grid through a 6-switched 3-level inverter. A 6-switched 3-level inverter is preferred in this study as an inverter due to its success in minimizing the harmonics. [2]

Integration of Solar PV array with main distribution grid has been proposed mainly for battery charging in this paper. Towards power quality improvement, a shunt connected hybrid filter consisting passive and shunt active filter has been proposed. The proposed configuration can be further expanded depending on the vessel class and space availability [3].Thyristorised converter with line commutated, two level and multilevel VSI including energy shunting converters overcome the fault through and reactive power compensator.

With the advent of DC grids DC-DC converters are required for interfacing different voltage levels and novel designs are required.[4] A renewable energy hybrid power system based on photovoltaic (PV) and wind, and equipped with Cuk DC-DC converter Different irradiance value and varying wind speed are the input parameters for the project simulation.[5]

Integration of RES to utility grid depends on the level of power generation. Large voltage level power generations are connected to transmission systems where as small voltage level distributed power generation is connected to distribution systems. The challenges in the integration of both types of systems directly. This paper presents the some issues and challenges encountered during grid integration of different renewable energy sources with some possible solutions.[6]

Analyses an approach of integrating a solar-battery system with an existing power grid. This paper also provides an energy efficient methodology to control and optimize the energy consumption and usage from the power grid. This leads to a smart grid platform which can help not only to increase the efficiency, security, reliability but also to reduce the impact on health problems and environmental effects.[7]

Multilevel Inverter is intended to feed a micro grid from renewable energy sources (RES) to overcome the problem of the polluted sinusoidal output in classical inverters and to reduce component count, particularly for generating a multilevel waveform. The proposed converter consists of „n" two-level (n + 1) phase inverters connected in parallel, where n is the number of RES.

An increase in RERs adds the voltage level gives the sinusoidal output wave form.

In this topology, to reduce the number of switching states i.e switching losses and total harmonics distortion (THD), pulse weight and height are pre calculated by using a pulse width and height modulation (PWHM).[8]

A pulse width modulated Current source converter controls the turbine and direct integrate with AC grid. Control strategy which based on a square relation between the voltage and the current is used. The main advantage of this proposal is its simplicity, efficiency and low cost.[9]

III. BLOCK DIAGRAM

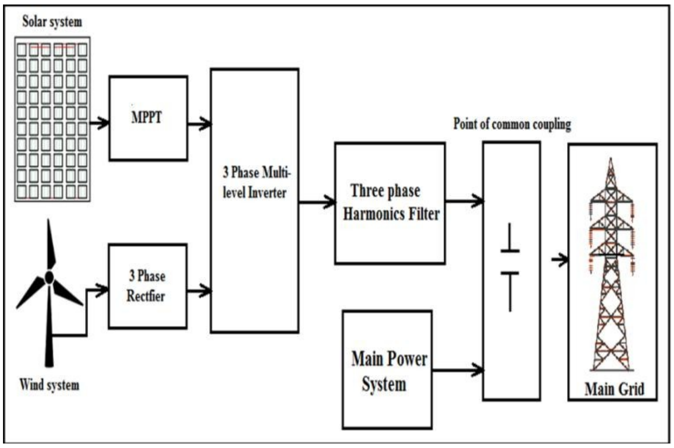

Fig.1 Block diagram proposed hybrid power system

Hybrid power system considered in this study consists solar and wind energy including a battery which stores energy. The functional block diagram of hybrid power system is shown in fig.1. Power generated by wind turbine is converted in DC by rectifier circuit and CUK convertor is used for the regulation of solar power generation which regularly refers the operation of sources and switches the corresponding converters and fed into change the battery or to the load through inverters. Inverter output is connected to the load and converter voltage is stepped up by a transformer. Wind turbine is used to convert the wind power into electric power. Wind turbine systems are available in range between from 50W to 3-4 MW.

In DC-DC CUK Converter the capacitor C connected alternatively to input and output and transfer energy of the converter commutation of the transistor and the diode. To convert the input voltage source (V_i) and the output voltage source (C_o) into current sources inductor L are used. Charging a capacitor with a current source prevents resistive current limiting and its associated energy loss.

As with other converters the Ćuk converter can either operate in continuous or discontinuous current mode. However, unlike these converters, it can also operate in discontinuous voltage mode .The power losses of the converter are minimized in order to maximize the converter. A genetic algorithm was implemented as the optimization technique, and the optimal duty cycle and switching frequency of the converter were found based on the reliability constraints. The capacitors, inductances, and other parameters of the converter were selected to satisfy the desired electrical constraints of the converter. Simulation and experimental results were presented to validate the feasibility of the proposed design methodology

Inductor L is in series and capacitor C is in shunt with load. Dc resistance is very small hence choke (L) allows the dc component to pass through easily. Very high capacitive reactance acts as open circuit and passes DC current through Dc output voltage is obtained. Inductive reactance X_L=2PfL is high for AC components therefore ripples are reduced.

Use of Choke filters current flows continuously therefore transformer is used more efficiently. Low ripples at output and independent of load current voltage, drop across inductor is smaller than load resistance R because load resistance small.

Fully electronic MPPT System that changes the operating point. Model delivers maximum available power and increase charging current.

A PWM INVERTER is a circuit which converts a DC power into an AC power at desired output voltage and frequency. The harmonics content of output voltage can be minimized or reduced significantly by switching technique of variable high speed power semiconductor devices.The DC power input to the inverter may be battery, fuel cell, solar cell or other DC source.

IV. SIMULATION WORK

The model is simulated using MATLAB Simulink Tool.

A. Hybrid power system model

The complete MATLAB simulation model of hybrid power system in which solar PV system and wind energy system generates DC power. This DC power get fed to MPPT maximum power point tracking system for reaching the maximum available DC power from solar and wind energy system. This maximum available power then fed to inverter which convert this dc power to ac power which fed to AC grid by proper synchronization. In parallel with this process one battery charging unit was connected for charging battery. That battery charging is utilized for dc applications. Table 1 shows the complete MATLAB model specifications and power system rating.

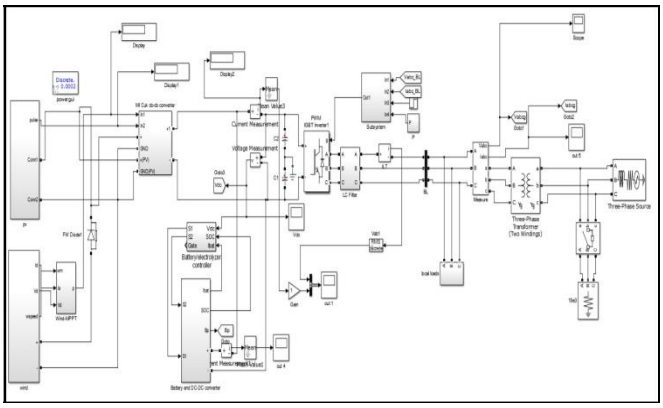

Fig.2 Complete MATLAB simulation model of proposed hybrid power system.

B. Solar PV Subsystem Model

A solar PV subsystem in which solar PV cell output dc terminal connected with maximum power point tracking (MPPT) algorithm block for calibrating or tracking maximum solar dc output voltage according to irradiation available at atmospheric condition.

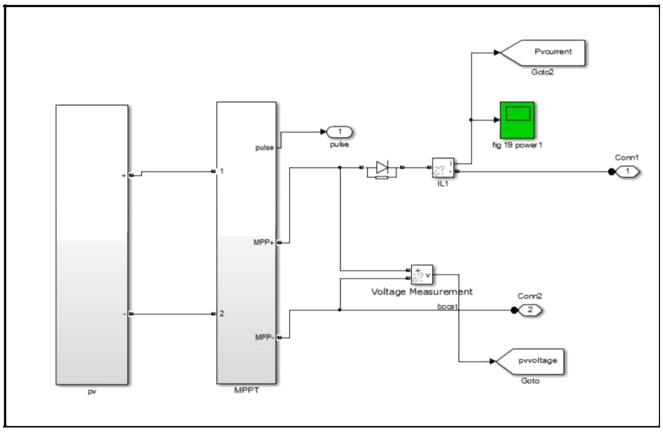

Fig.3 Solar PV subsystem MATLAB model coupled with MPPT algorithm Subsystem

The interconnection of 36 solar cell for achieving the desire ratings. After series and parallel connection diode connected to solar cell power output for avoiding the back power or reverse bias condition. That diode is called as revere blocking diode which avoids the reverse current of reverse polarity of solar cell during rainy or cloudy season due to shading effect.

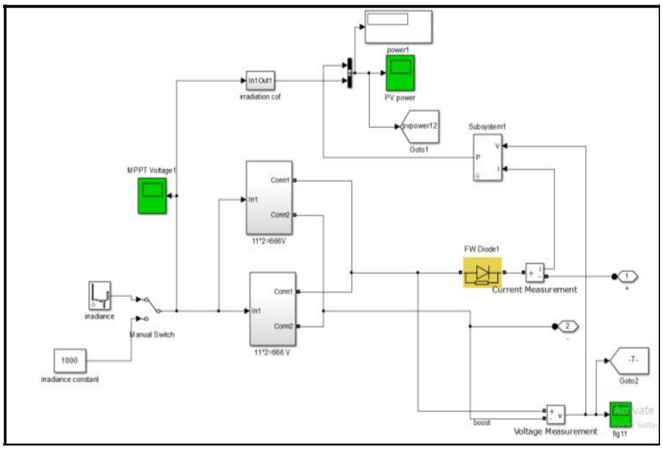

Fig.4 Solar PV cell interconnected subsystem MATLAB model

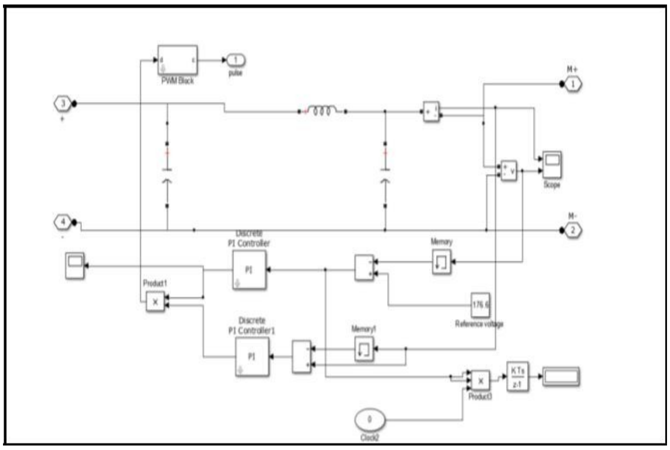

Fig.5 MPPT algorithm subsystem MATLAB model

C. Wind energy subsystem model

A wind energy turbine system in which wind turbine generates the AC three phase power then transfer to rectifier circuit for conversion of AC power to DC power. Because solar power system output becomes in DC form but wind energy generator power in AC form then for coupling both the solar and wind energy system we need to convert wind energy AC power into DC power with equal magnitude.

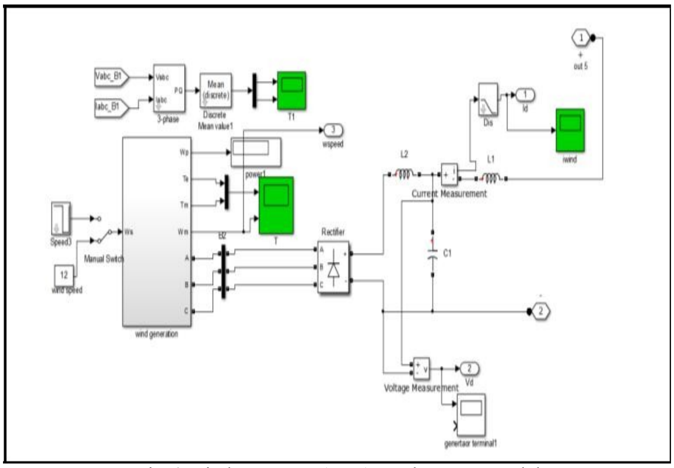

Fig.6 Wind energy MATLAB subsystem model

The controlling mechanism for wind energy system which control the wind turbine wind speed, mechanical torque, mechanical input, speed of turbine. Also wind turbine consist of three phase AC alternator which generates the AC power also control by controller circuit.

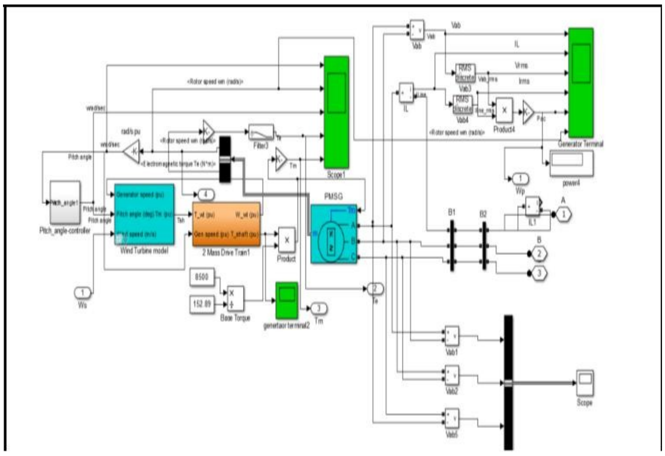

Fig.7 Wind energy controller subsystem, generator, and mechanical subsystem

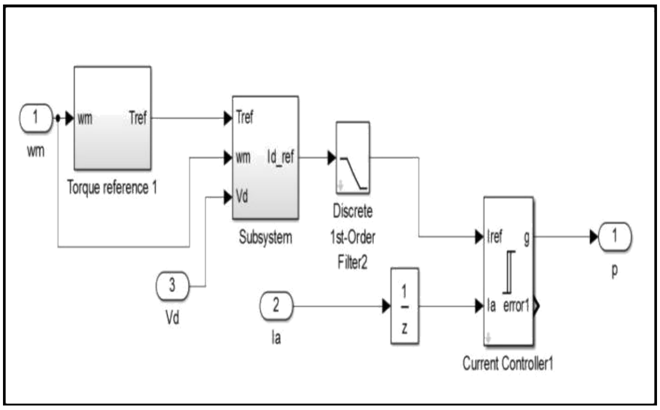

Fig.8 Wind energy MPPT subsystem MATLAB model

D. Cuk DC-DC convertor subsystem model

A DC-DC Cuk converter which converts variable DC input in constant DC output. That convertor coupled both solar power and wind energy system with same amount of DC power magnitude. This variable dc power received from solar and wind system then convert into constant DC power. This constant dc power then fed to inverter for generation of three phase power which coupled with main power system.

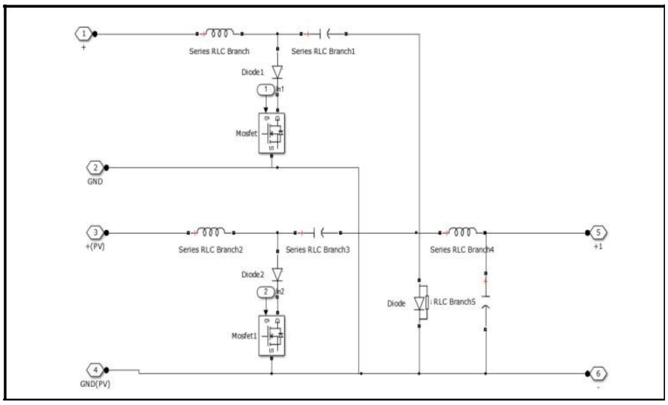

Fig.9 Cuk DC-DC convertor MATLAB subsystem model

E. Battery subsystem model

The battery subsystem MATLAB model, which is coupled with main power system using three phase inverter circuit. That battery system stored the energy during normal power system operation and utilize this stored power during abnormal atmospheric condition at which wind or solar PV system not available.

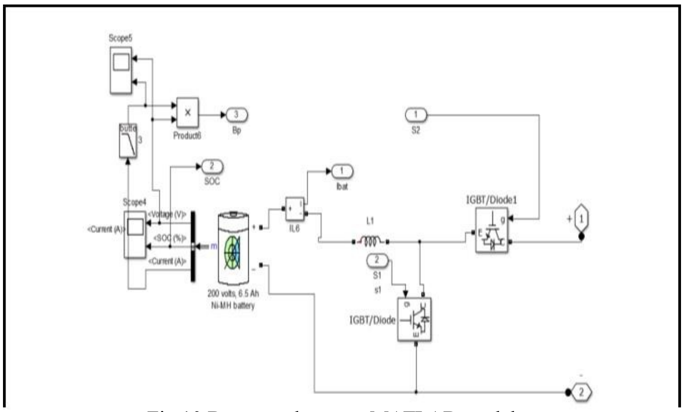

Fig.10 Battery subsystem MATLAB model

F. LC filter subsystem model

The three phase LC filter circuit forremoving harmonics and flickers from inverter output. Thatoutput voltage then coupled with main power system.

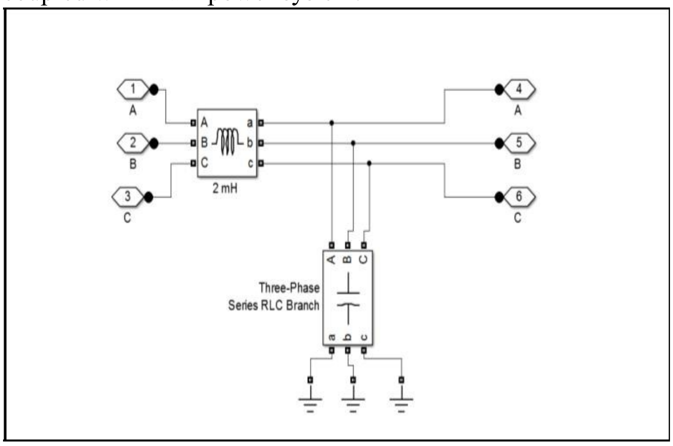

Fig.11 LC three phase filter bank

V. RESULTS AND DISCUSSION

A. Power system voltage and current

Fig.12 and Fig.13 Shows the power system three phase voltage and three phase current during normal power system working. This voltage and current waveform was free from harmonics and ripple contents due to the proper synchronization of wind/solar power system with main AC grid system.

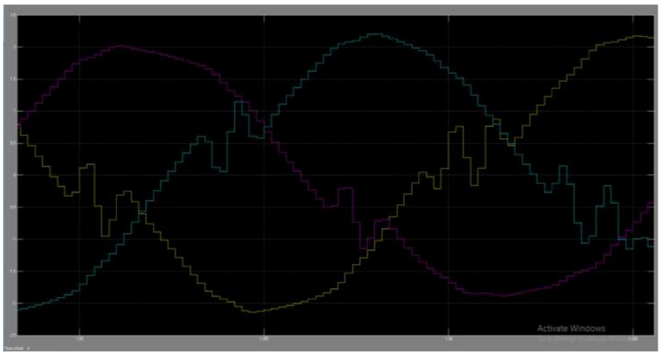

Fig.12 Power system three phase current with integration of wind and solar system without interruption

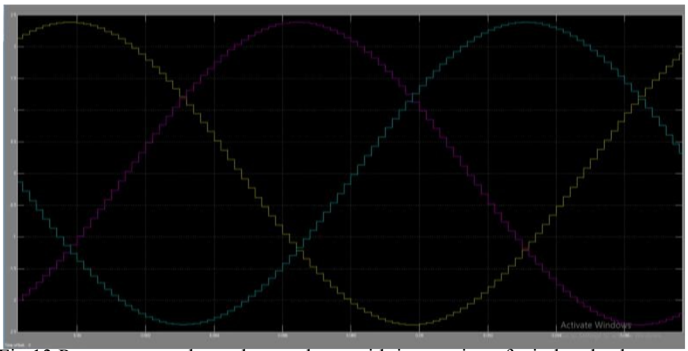

Fig.13 Power system three phase voltage with integration of wind and solar system without interruption

B. Solar PV system parameters

Fig.14 shows the solar PV output current waveform having the constant output current of 1 Ampere. During starting period of waveform, the output current of solar system was oscillated for 0.2 seconds.

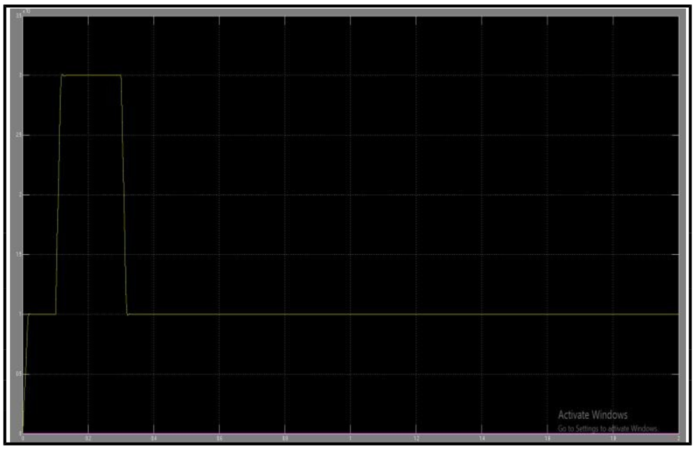

Fig.14 Solar PV system constant power output waveform

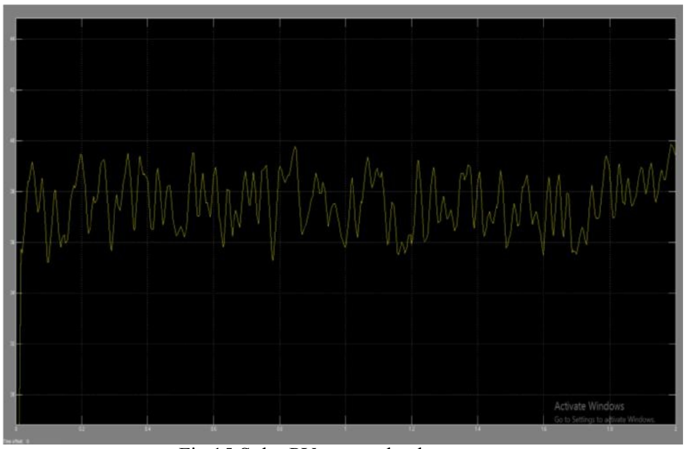

Fig.15 Solar PV system load current

C. Wind energy parameter

Fig.16 shows the output voltage of wind power system after rectifier output. The constant voltage of 50 Voltage generated continuously the power system operation process. Wind power system take short time of 0.2 second to achieve the standard rated voltage of 50 volt for power output generation.

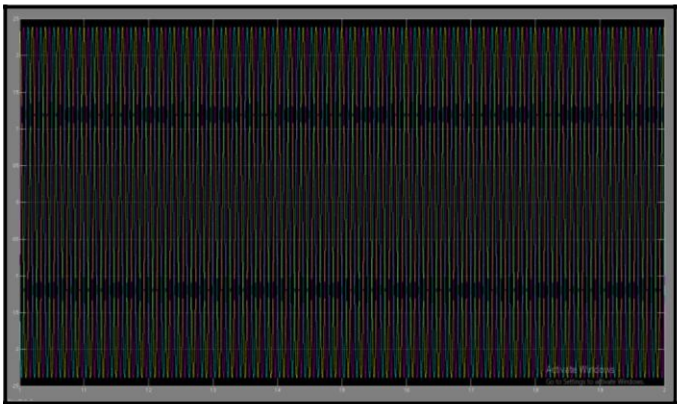

Fig.16 Wind energy three phase power output voltage

D. Battery parameters

Fig.17 the state of charging (SOC) is shown and the charging and discharging behaviour of battery system can be seen. The battery discharges from 60V to 35 V in 20 second time duration. It means that, if the loss charging of battery is 20 second then the loss potential of 25 Volts.

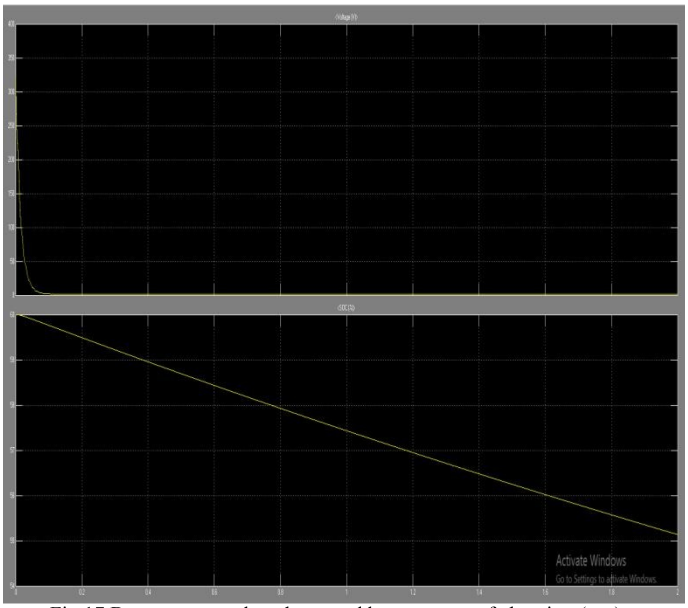

Fig.17 Battery output dc voltage and battery state of charging (soc)

V. CONCLUSION

A renewable energy hybrid power system is presented is based on photovoltaic (PV) and wind. The hybrid power system completely depends on the intermittent renewable energy sources generates a fluctuating output voltage that leads to damage to the machines that operate on a stable supply. The modeling of the hybrid system with Cuk converter, three phase inverter and LC filter are built using MATLAB Simulink. We have used different irradiance value and varying wind speed as the input parameters for the project simulation. The results show that hybrid system has greater reliability in terms of output voltage generation. In addition, Diode Clamped Multi-Level Inverter and LC filters that are installed in the hybrid system are able to reduce the fluctuation output voltage.

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