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SIMULATION OF INTEGRATION OF WIND AND SOLAR BASED POWER GENERATING SYSTEMS IN MICROGRID FOR RURAL APPLICATION

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ABSTRACT: Renewable energy sources have become a popular alternative, electrical energy source where power generation in conventional ways is not practical. This paper proposes an integrated energy system consisting of wind and solar photovoltaic with the battery energy storage system. The integration of these sources is very useful for remote rural applications, where the extension of conventional power grid is economically and/or technically not practicable. The integration of renewable energy sources and energy-storage systems has been one of the new trends in power-electronic technology. The Battery energy storage system (BESS) is designed to supply continuous power and provide the deficit power when the combined wind and photovoltaic sources cannot meet the net load demand. It works as an uninterruptible power source that is able to feed a certain minimum amount of power into the load under all conditions. Operational controls are designed to support the integration of wind and solar power within micro grids. An aggregated model of renewable wind and solar power generation forecast is proposed to support the quantification of the operational reserve for day-ahead and real-time scheduling. Then, a droop control for power electronic converters connected to battery storage is developed and tested. This is shown to maintain the equilibrium of the micro grid's real-time supply and demand. The controls are implemented for the special case of a dc micro grid that is vertically integrated within a high-rise host building of an urban area. Previously untapped wind and solar power are harvested on the roof and sides of a tower, thereby supporting delivery to electric vehicles on the ground.

I. INTRODUCTION

With increasing load demand and global warming, many are looking at environment-friendly type of energy solutions to preserve the earth for the future Generations. Other than hydro power, many such energy sources like wind and photovoltaic energy holds the most potential to meet our energy demands. While some others like fuel cells are in their advanced developmental stage. The world's fastest growing energy resources, a clean and effective modern technology that provides a hope for a future based on sustainable, pollution free technology. Today's photovoltaic and wind turbines are state-of-the-art of modern technology modular and very quick to install. These generation systems have been attracted greatly all over the world. The integration of renewable energy sources and energy-storage systems has been one of the new trends in power-electronic technology. The increasing number of renewable energy sources requires in this paper, the study presents a methodology for the optimal sizing of autonomous PV/wind systems with storage batteries. The methodology adopted, taken as the favoured approach, is to suggest, among a set of system components, the optimal number and type of units in terms of technical and economical concepts. First, the mathematical model of hybrid PV/wind system, including PV modules, wind generators and battery storage, is developed and the simulation results and conclusion are presented. In this paper Wind and Solar are complementary, so hybrid Wind/PV power system is an ideal solution to provide reliable and stable power supply at remote places. Due to the uncertainty in climatic conditions, isolated PV energy system or wind energy system cannot provide a continuous and reliable power supply. In this perspective, to ensure continuous power, installation of the battery bank is necessary. Hybrid Wind/PV system is more consistent and economical when compared to two sources considered separately. This further reduces the overall cost and battery storage requirements. With the development of power electronics there is significant growth in solar-wind application with optimization in the size of the system. Usually sunny days are silent and wind speed is rapid at night and at cloudy days, thus hybrid Wind-solar can eliminate the intermittency of single energy source. Another alternative is to provide battery supply to get constant power with maximum power tracking from both PV and wind energy system. The utilization of solar and wind power has become increasingly significant, attractive and cost-effective. In recent years, hybrid wind/PV system (HWPS) has become viable alternatives to meet environmental protection requirement and electricity demands.

II. MODELLING AND RESULTS OF SOLAR-PV SYSTEM

A 30 KW panel is considered as consisting of 24,080 solar cells arranged in 344X70 combinations. The solar array consists of number of panels connected in series-parallel configuration and a panel consists of number of cells. The power characteristics of the solar cell are formulated using its equivalent circuit. The equivalent circuit of the cell is presented as a current source in parallel with diode and a parallel resistance with a series resistance.

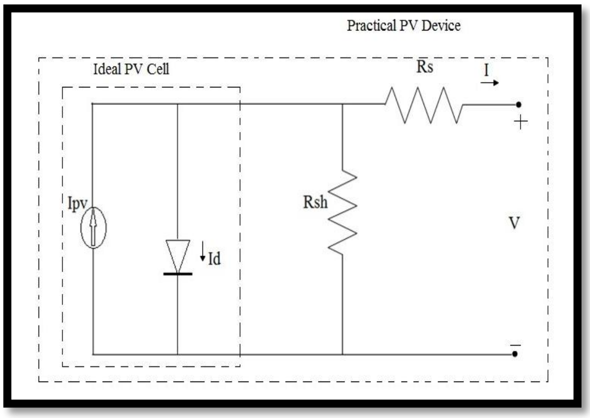

Fig-1: Equivalent circuit of a practical PV device [6]

The output current can be measured by subtracting the diode currents and current through resistance from the light generated current. From this circuit, the output current of the cell is expressed as,

$$I = Ipv - Id - I_{Rsh} \quad (1)$$

$$I = Ipv - I_0\left[\exp\left(\frac{V+IRs}{a}\right) - 1\right] - \left(\frac{V+IRs}{Rp}\right) \quad (2)$$

Where, $a = \frac{NS.A.K.Tc}{q} = Ns.A.V_T$

$$\frac{Isc + Kv * dT}{\exp\left(\frac{Voc+Kv*dT}{a*V}\right) - 1}$$

Where, ns are numbers of cells connected in series. The output current of the solar panel is I. The light generated current is Ipv. Saturation currents through diodes are I_0. The voltage at output of panel is V Series resistance of cell is Rs which represents the internal resistance of cell and it is considered as 0.55 Ω. The Boltzmann's constant is K (1.38 X 10^{-23} J/K). Ambient temperature (in Kelvin) is T and charge constant is q (1.607 X 10^{-19}C).

A 30 KW solar-PV array is realized considering 24,080 cells (344×70 dimensions) using (1)-(2). A Matlab model for the same is developed.

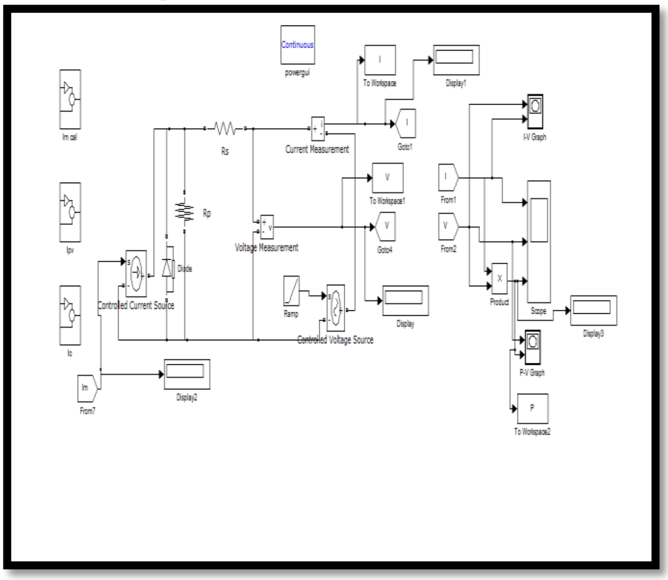

Fig-2: Simulink model of a PV device

Table 1: Parameters of the PV module at 25^0C, 1000 W/m^2 [6]

Imp	2.88 A
Vmp	17 V
Pmp	49 W
Isc	3.11 A
Voc	21.8 V
Rs	0.55 Ω
Kv	-72.5×10^{-3} V/K
Ki	1.3×10^{-3} A/K
Ns	36

RESULTS:-

After the simulation, we obtained the following results,

Simulation Results of solar panel

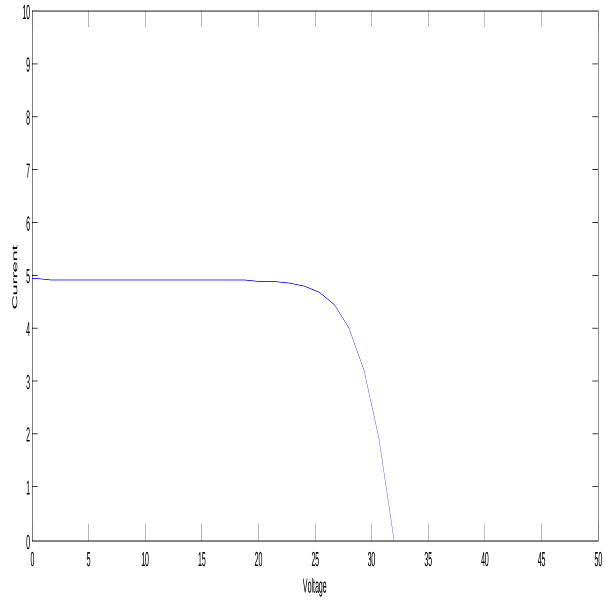

Fig 3-I-V Characteristic

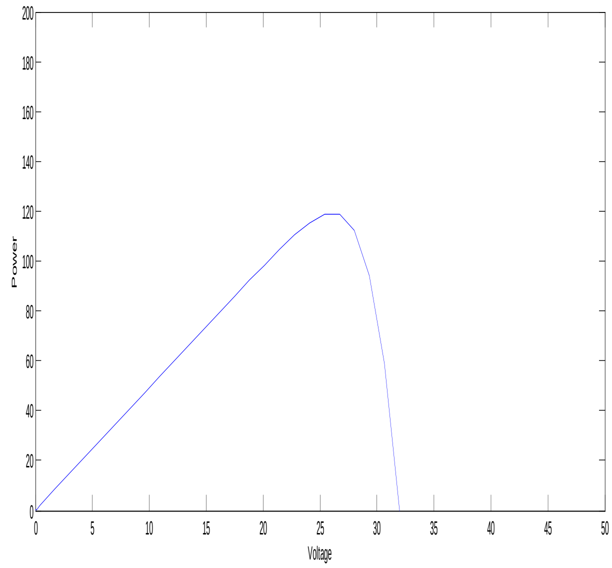

Fig 4-P-V Characteristic

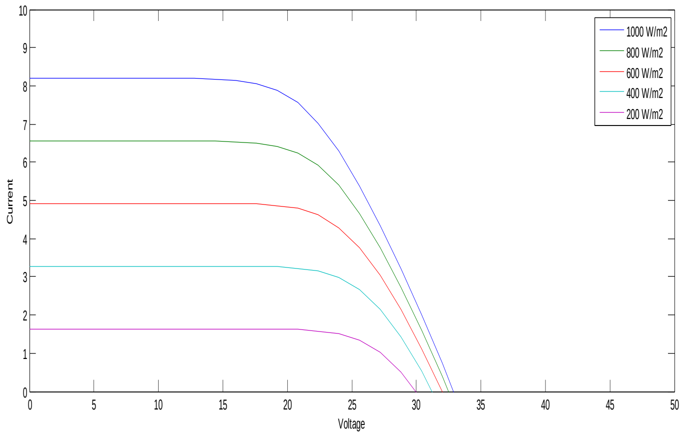

Fig 5-Diiferent Radiation I-V Characteristic

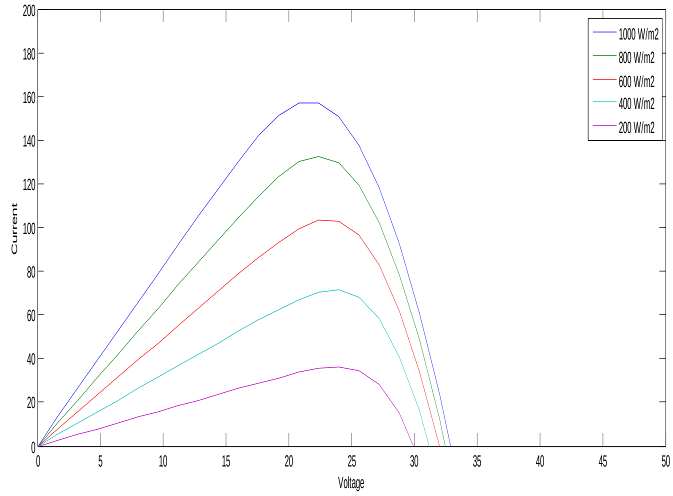

Fig 6-Diiferent Radiation P-V Characteristic

III. MODELLING THE WIND SYSTEM

Modelling of the wind energy converter is made considering the following assumption:-

- frictionless
- stationary wind flow
- constant, shear-free wind flow
- rotation-free flow
- incompressible flow (ρ=1.22 kg/m3)
- free wind flow around the wind energy converter

On the above condition the maximum physically achievable wind energy conversion can be derived by a theoretical model that is independent from the technical construction of a wind energy converter. Energy of the flow air mass has certain energy. This energy is obtained from the air movement on the earth surface determined by difference of speed and pressure. The wind turbines use this energy as the main energy for obtaining electric power. The kinetic energy W taken from air mass flow m at speed v1 in front of wind turbine pales and in the backside of pales at speed v2 is illustrated by following equation:-

$$W = \frac{1}{2} m (v_1^2 - v_2^2) \quad \text{........... (3)}$$

The Matlab modelling of PMSG type wind power plant is shown in the fig.2 below. The Excitation system and Wind turbine section is provided with synchronous generator. The simulation results shows the output voltage of wind turbine and also shows the different parameters output like stator voltage, excitation voltage and other mechanical parameters also. The Matlab model of wind power plant includes the subsystem of wind turbine and PMSG generator at input side and the models of DFT and Hysteresis controller for wind power generation controlling are also shown in the below section figures of different blocks subsystems.

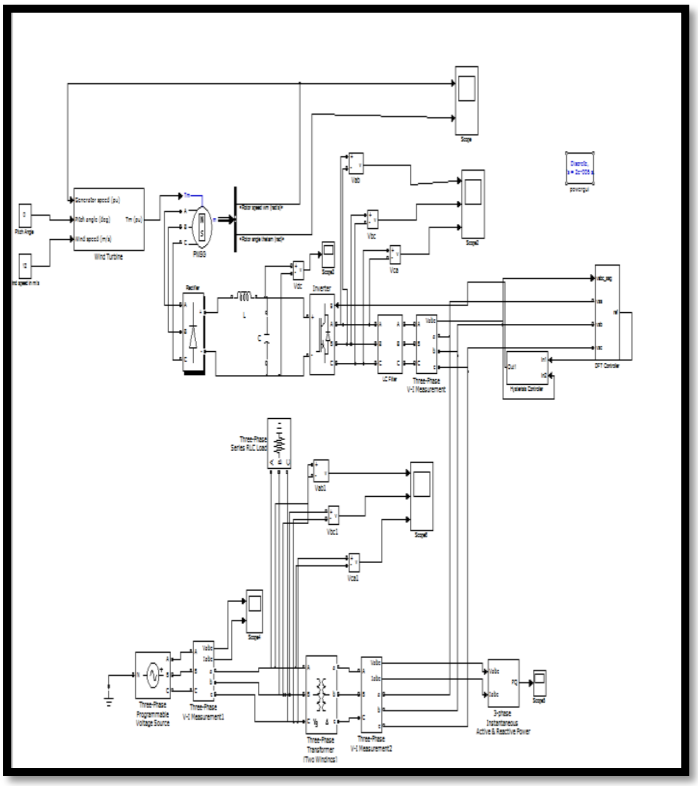

Fig.7- Wind Power Plant Matlab Simulink model

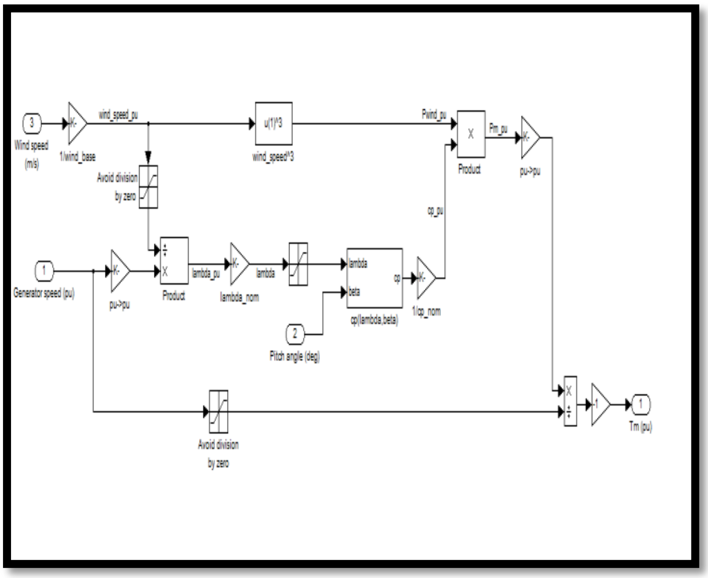

Fig.8- Subsystem of wind turbine

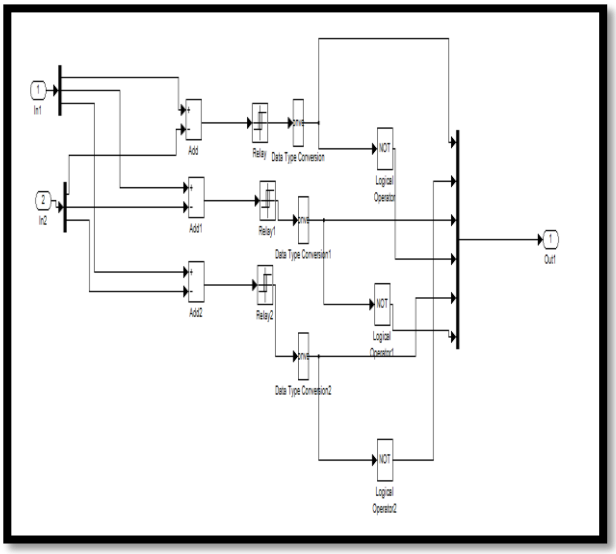

Fig.9- Hysteresis controller subsystem

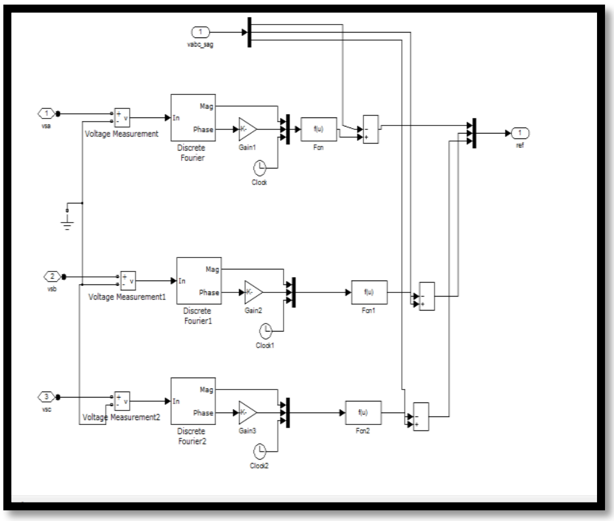

Fig.10- DFT controller subsystem

For harmonics mitigation in the proposed system we have providing the LC filter also in the system. So the Matlab subsystem of LC filter is shown in the fig.6 below:-

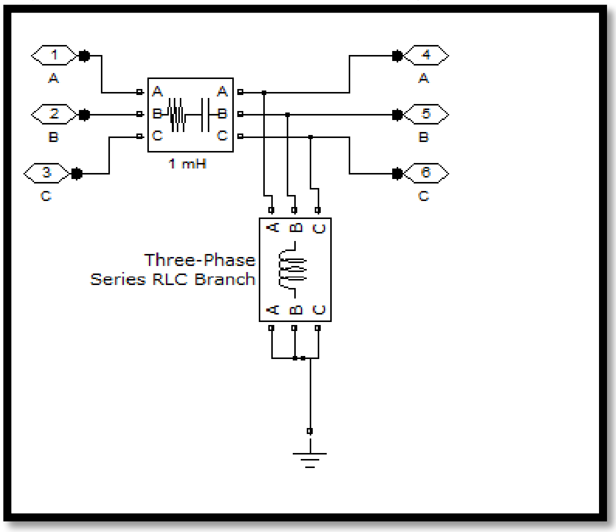

Fig.11- LC-Filter subsystem

Now the simulation results of output voltage, current, active and reactive power and other characteristics of wind speed and angle is shown in the fig below:-

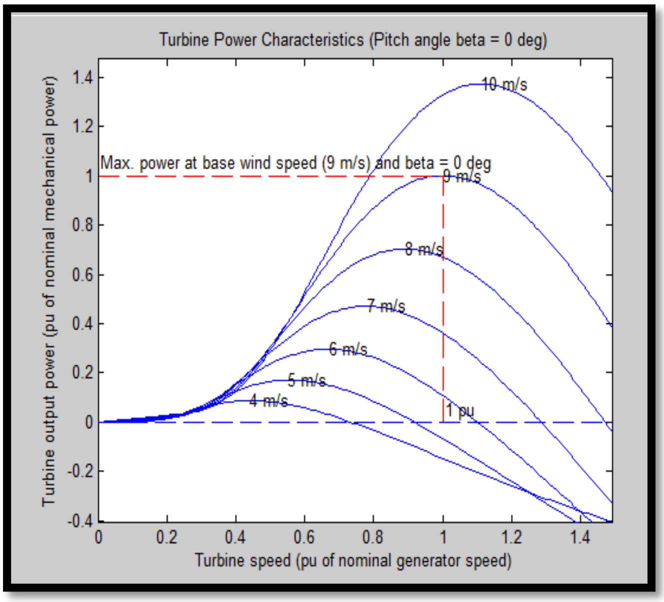

Fig.12- Turbine speed and mechanical output power relation

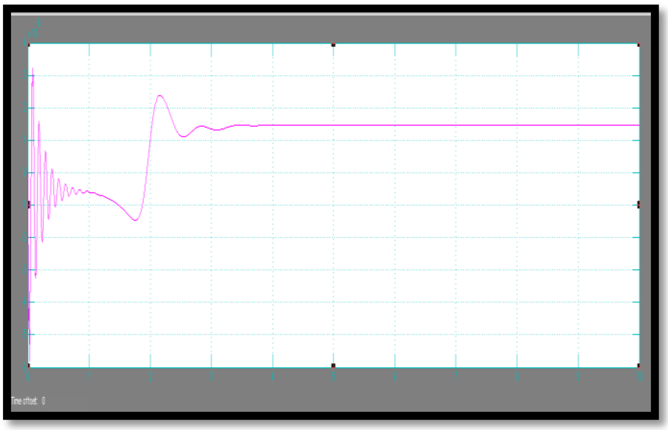

Fig.13- Constant output active power

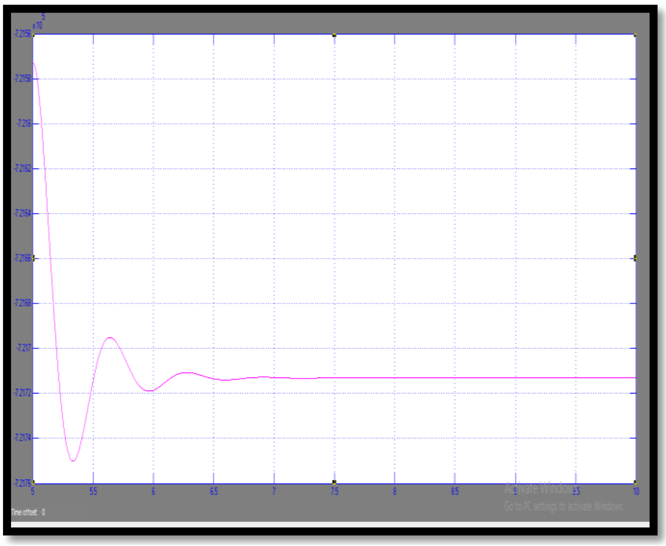

Fig.14- Reactive power

IV. INTEGRATION OF SOLAR PV AND WIND WITH MICROGRID

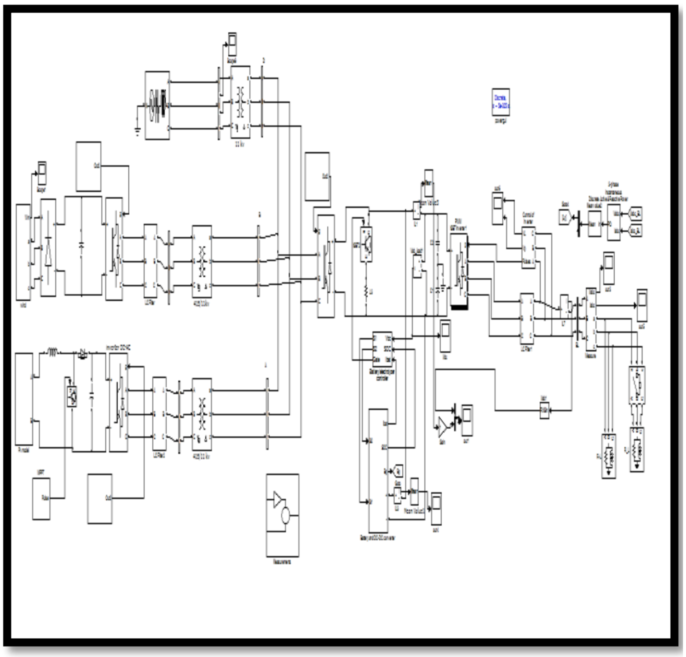

Fig.15– main system of hybrid

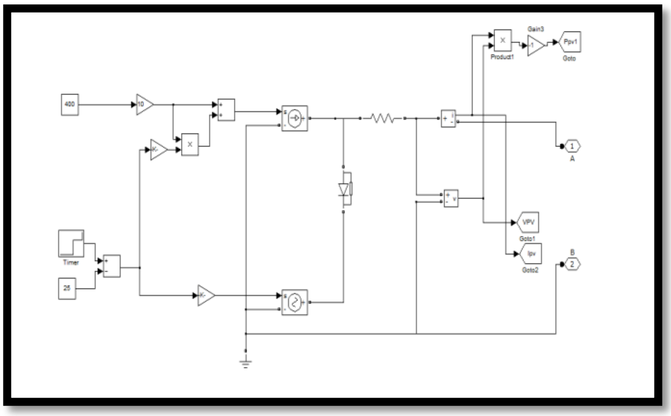

Fig.16- subsystem of solar PV

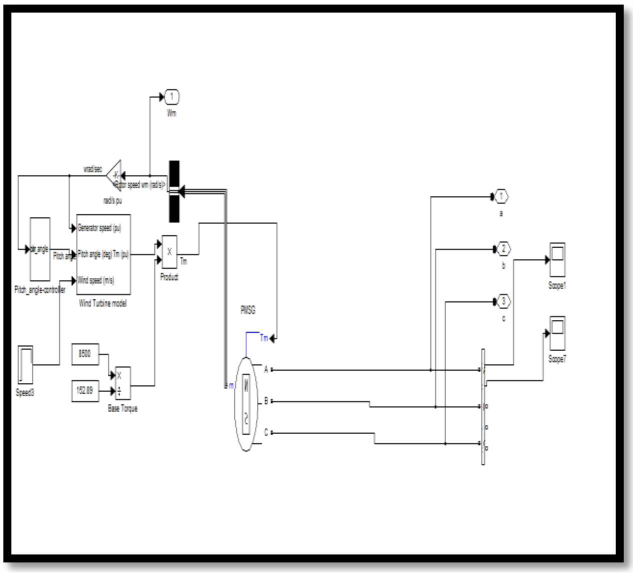

Fig.17- subsystem of wind

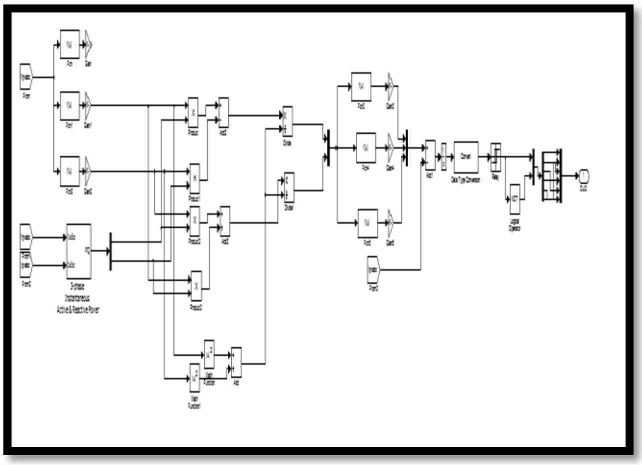

Fig.18– triggering pulses for IGBT

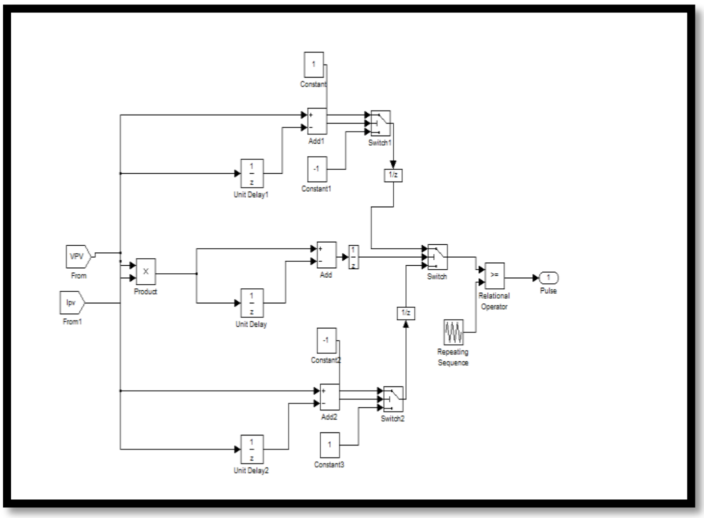

Fig.19- MPPT Controller

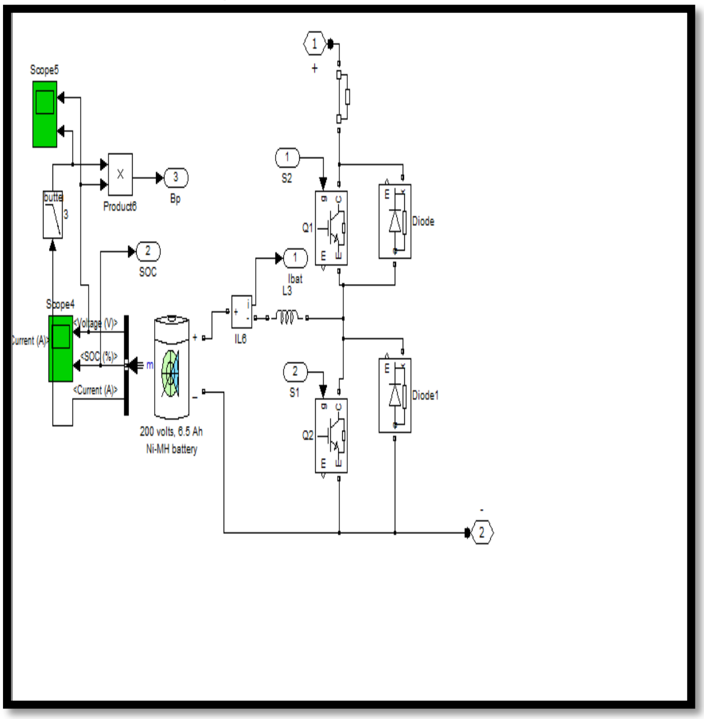

Fig.20- Subsystem of Battery

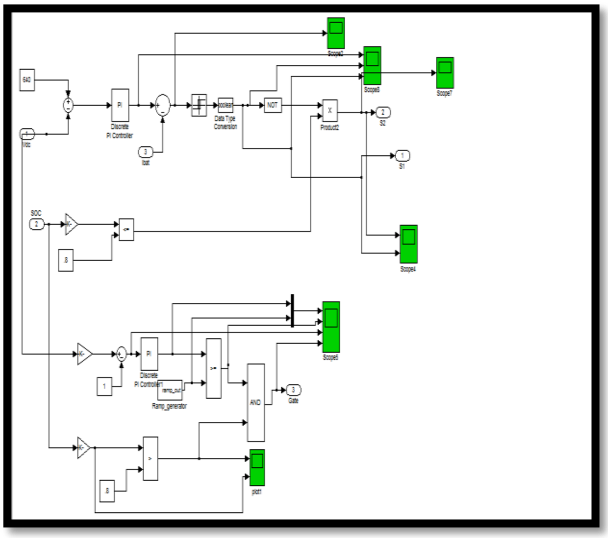

Fig.21 – Battery and charge controller

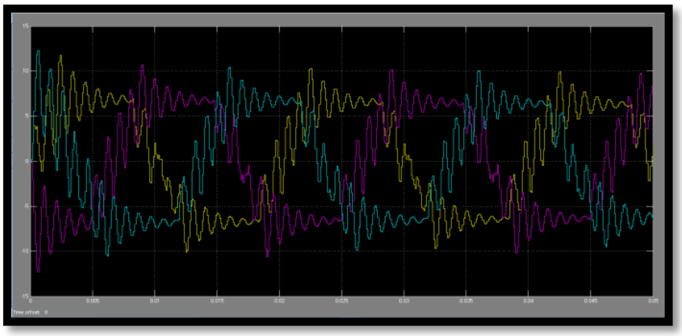

Fig.22 –output voltage

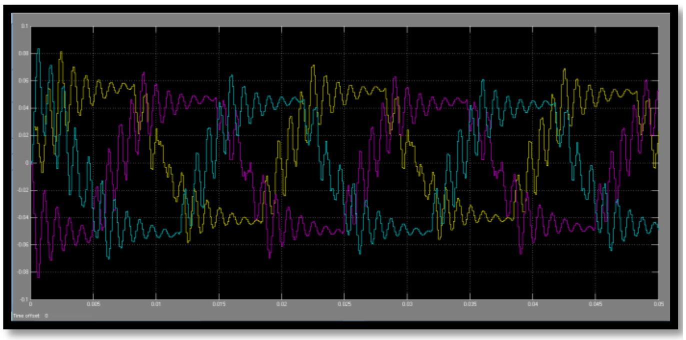

Fig.23 – output current

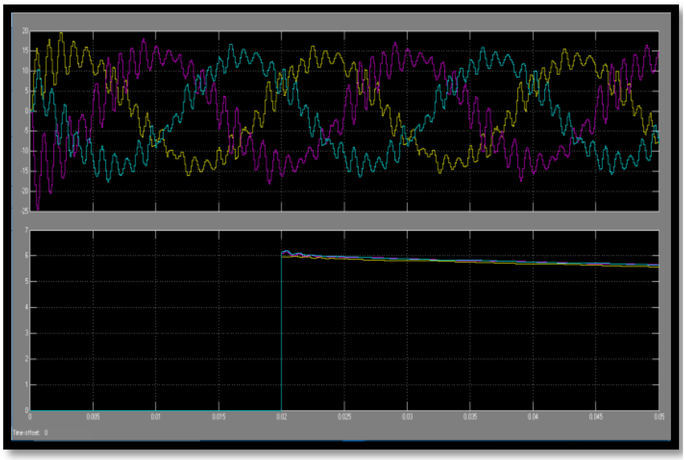

Fig.24- output of voltage and d.c current of battery

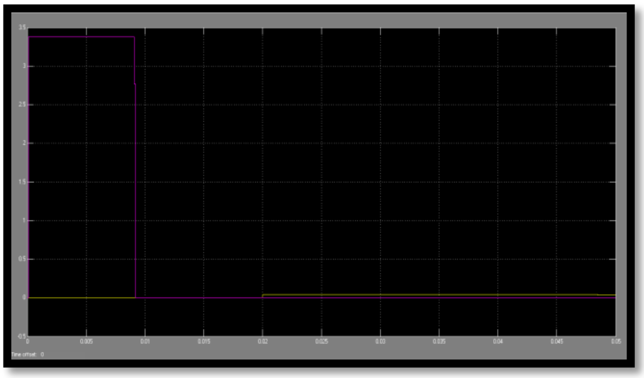

Fig.25 – Battery output d.c parameters

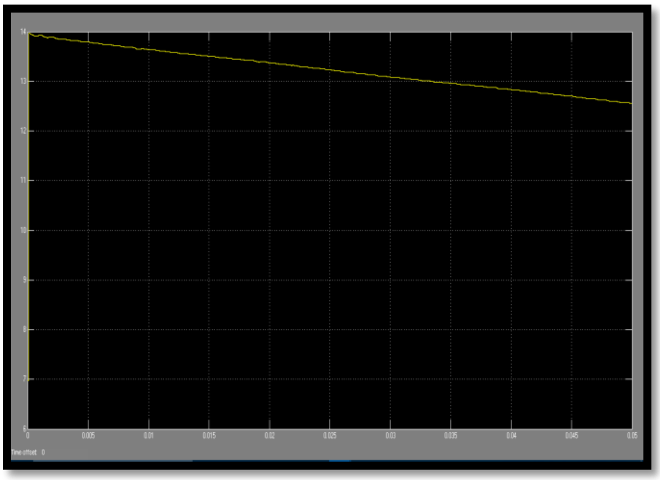

Fig.26- Output D.C voltage

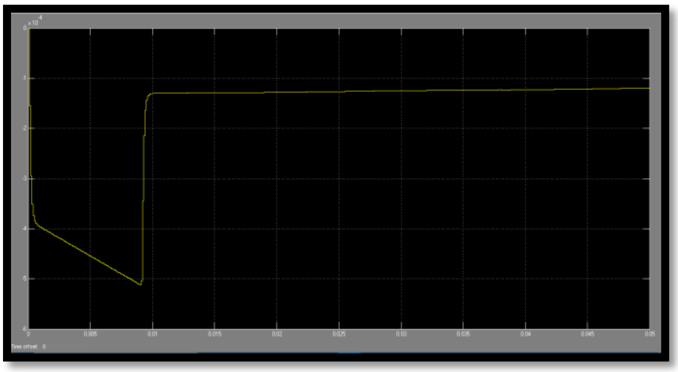

Fig.27- Charging Rate

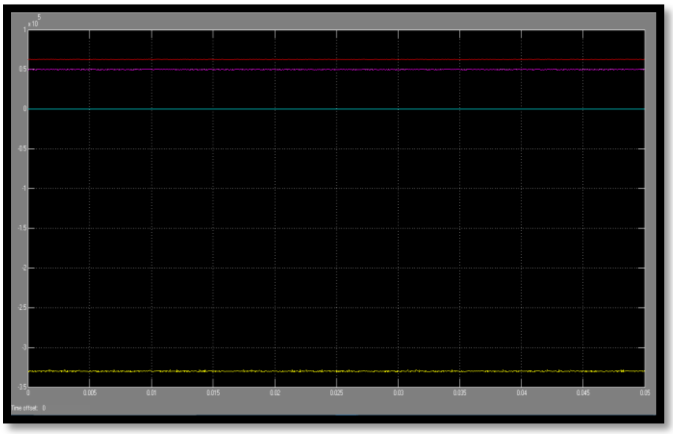

Fig.28- Output power of Hybrid system

V. CONCLUSION

Accelerated installation of variable renewable generation coupled with the introduction of the smart grid, have created an increased interest in micro grids. This paper has demonstrated the voltage regulation in a micro grid system comprising hybrid solar PV/wind turbine in the autonomous operation mode. Solar PV and wind turbine size and locations in the micro grid were preselected. Simulation studies were carried out on a micro grid system to test the impact of various individual and variable renewable energy (solar/wind) combination. The hybrid solar PV/wind generation provided more effective voltage regulation to the micro grid system as compared with each of the solar PV/wind turbine acting alone. Furthermore, when the voltage variation fell beyond the capabilities of the hybrid system, the combination of demand response (DR), a feature of the smart micro grid, with the hybrid PV/wind system were apt to bring the voltage back within statutory limits. Voltage drop across the distribution feeders reduce in the case of load curtailment due to DR, causing an increase in the voltage at the far end of the MG's feeder system.

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