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Modeling and Simulation of a Microgrid with Multiple Energy Resources.

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Abstract— this paper presents the modeling and simulation of a Microgrid with three power sources and along with a battery as a storage system. The renewable sources are solar photovoltaic, fuel cell and wind turbine. The objective of this paper is to describe useful model of integration of non renewable sources and how the Microgrid performs accordingly along with a comparison in between output of Microgrid and the output with power quality improved. The modeling of the full system including all the stages is performed using MATLAB and SIMULINK software package. The Microgrid, for general analysis is connected to a load and is analyzed. The Microgrid operated appropriately where the settling time is considered as 2e-6.

Keywords: Batteries, Fuel cells, Microgrid, Photovoltaic cells, inverter, wind power, three phase measurement, load and Simulink.

I. INTRODUCTION

A Microgrid is a model of a power system that integrates the renewable energy sources along with a storage, for optimal generation and distribution of power for a confined area. When a general scenario is considered, the transmission losses are of about 30% of the energy generated, hence representing the drawback of a largely interconnected power system. The general power system in effect, of course can fulfill a large power demand but when it comes to the case of generation or transmission or distribution failures, the solution becomes a much complicated one. But, when a Microgrid power system is taken into account, there are no transmission losses besides renewable energy and ecofriendly power.

This paper outlines the simulation model of a Microgrid where the input is solar for photovoltaic cell, H_2+Air for fuel cell and wind for windmill integrated together for an output of 3 phase AC power.

II. MICROGRID

As Microgrid is defined as an effective integration of renewable energy sources for optimal and ecofriendly power generation, the models of renewable sources are discussed. The power is integrated dynamically so as to maintain the output power constant. The harmonics are eliminated using the active filter. The circuit is as shown in figure 1.

A circuit breaker is used to trip automatically when wind provides the sufficient amount of power. It also helps in protecting the over current sensitive renewable energy sources. The load is considered as a 3 phase grounded one.

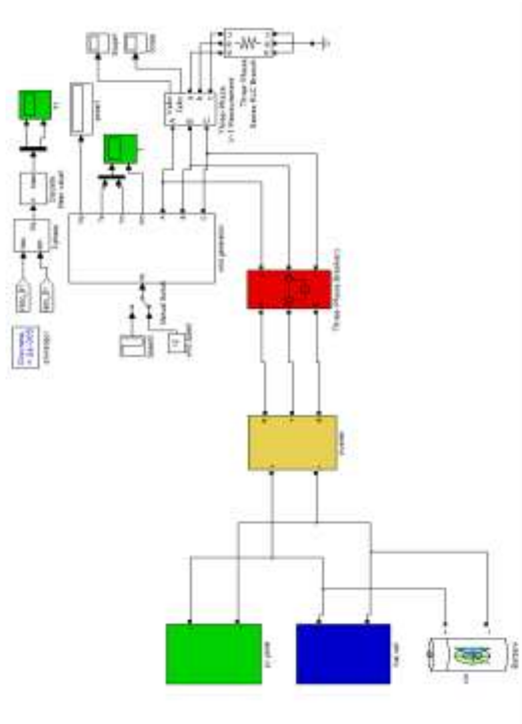

Fig1: Microgrid simulation

This model consists of renewable sources like photo voltaic cells, fuel cells and wind mill integrated together with an assumption that all sources are at their maximum potential.

III. MODELING OF ENERGY SOURCES

The important concept in modeling the sources are based on their maximum power deliverance, without considering intelligent controlled switching. The models are briefly described as followed below.

MODELING OF PV CELL

The main consideration in modeling the PV cell is the voltage equation with respect to the standard consideration of irradiance and efficiency.

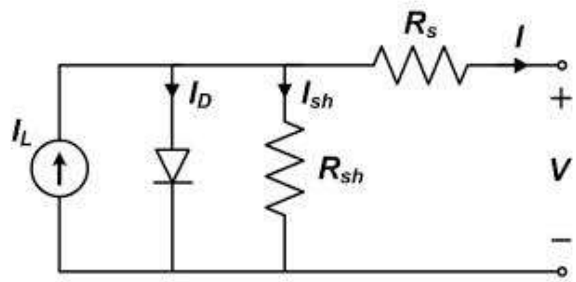

fig2: pv model

$$I=Iph-Is*(e^{\wedge}((V+I*Rs)/(N*Vt))-1)- Is2*(e^{\wedge}((V+I*Rs)/(N2*Vt))-1) - (V+I*Rs)/Rp$$

The above shown as in figure 2 is the standard cell equation and PV cells are integrated depending on the power requirement as shown below.

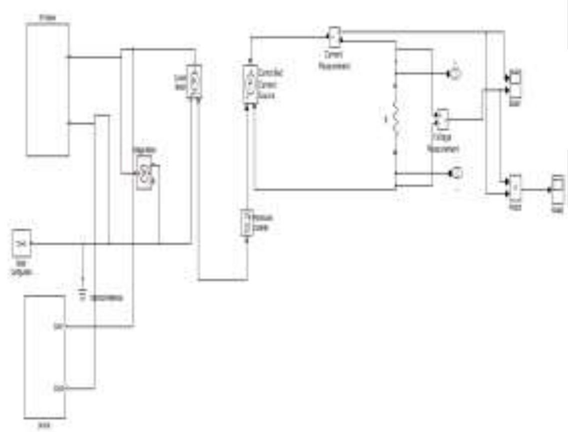

Fig 3: Pv panel

The model is desined using voltage and current sensors which are integrated with simulink converter to obtain the required solar power output as sown in the figure 3.

The output of the simlation is as in figure 4 and 5.

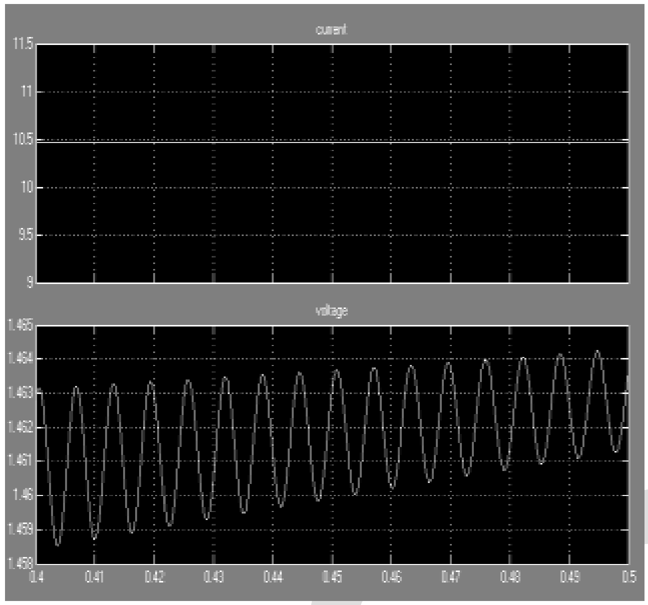

Fig4: voltage and current of pv panel model

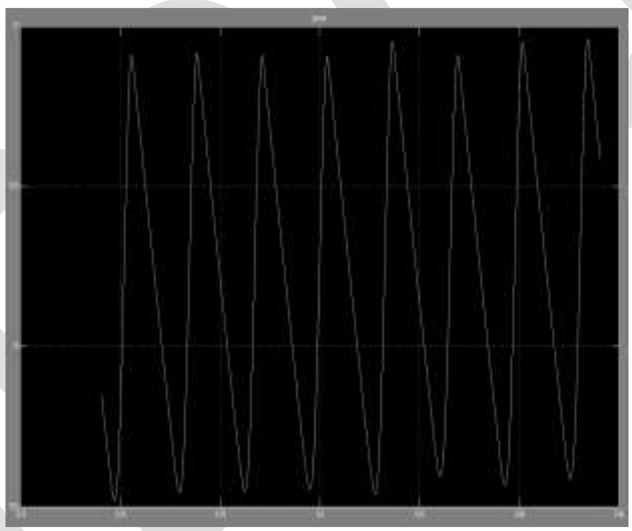

Fig5: power of pv panel

MODELING OF FUEL CELLS

Initially a fuel cell stack is considered which is provided with a flow rate selector which functions in the feedback of the desired output. The flow rate selector pumps in the requited amount of air accordingly where the input is given through flow rate regulator which regulates the amount of air to be pumped on a feedback.

As the output is not in the required range, a voltage booster or DC/DC converter of 100vdc is used for the required output which is as in figure 6.

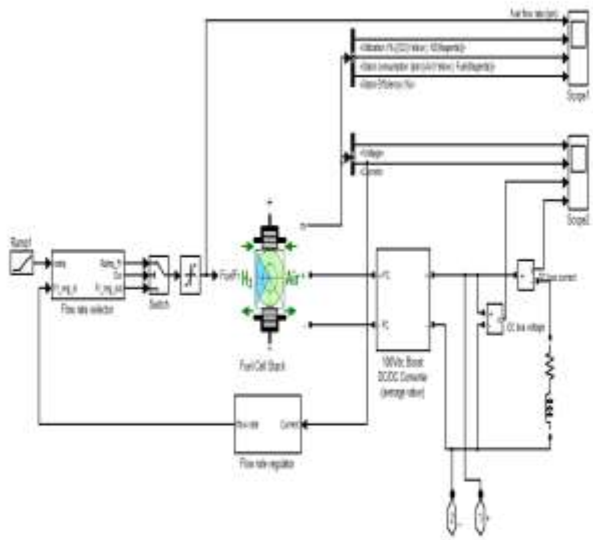

Fig6: model of fuel cell

The output of the fuel cell is as shown below.

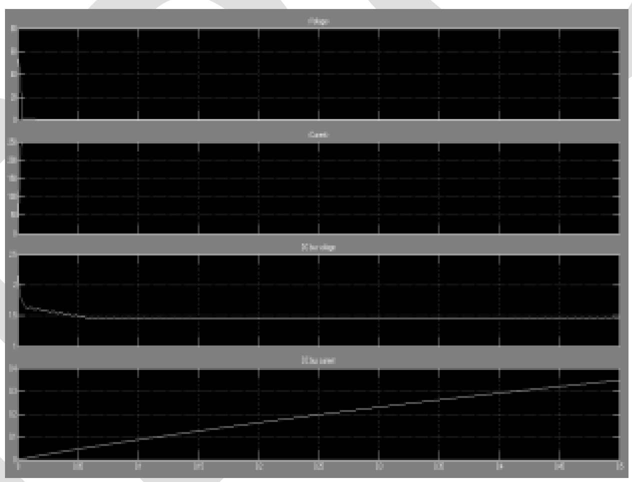

Fig7: output of fuel cell

MODELING OF WIND TURBINE.

The wind model in Simulink is designed using PMSG. The important components in the design are wind turbine model and pitch angle controller.

The main output is from PMSG where the three phase output's voltage and current are taken into RMS form. The harmonics can be reduced using an active filter and the wind turbine is the major and important source as compared to the other sources.

We need to have a steady output voltage and frequency which is taken care of controllers and gains as shown in the figure 9. The three phase output obtained from PMSG wind turbine is integrated with the three phase output of inverter. The load is considered as resistance, three phase grounded.

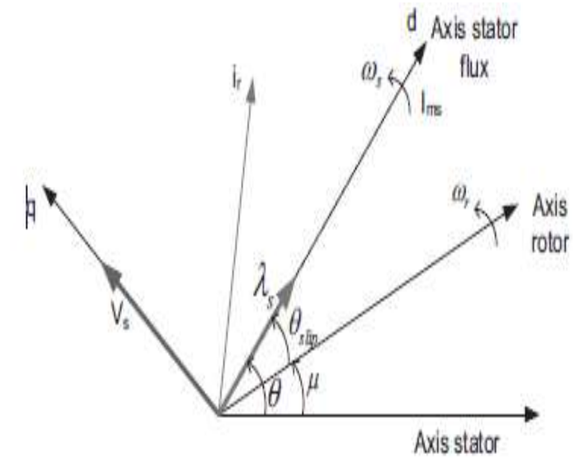

Fig8. Phasor diagram of stator and rotor axes.

The wind turbine is simulated as shown in the figure 9.

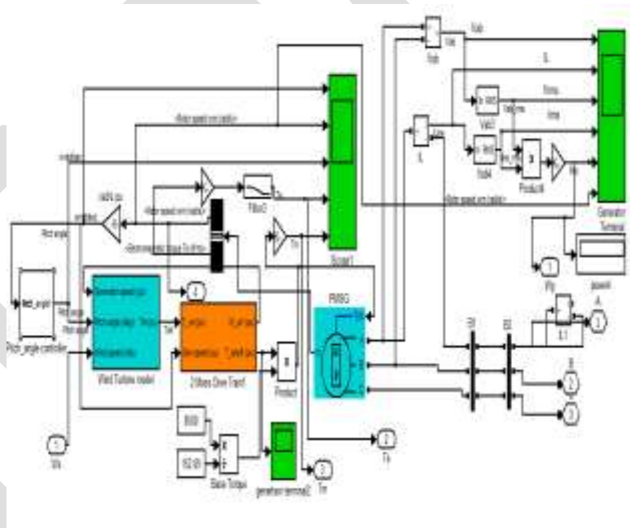

Fig9: simulation model of PMSG wind turbine.

The output of wind turbine is as shown in the figure 10.

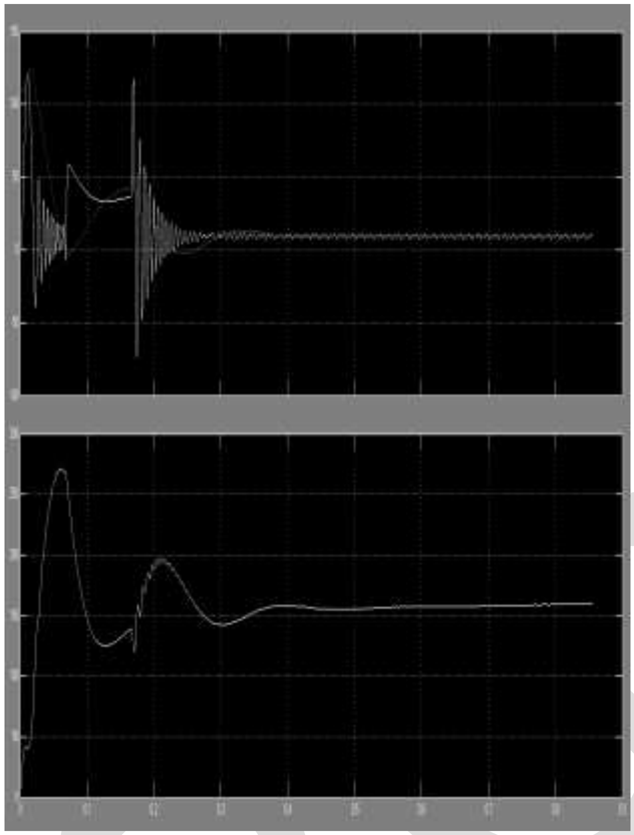

Fig10: output of PMSG wind model.

MODELING OF INVERTER

The main component of inverter is PWM IGBT, which receives a gate pulse from pi controller. The output of the three sources is integrated and is supplied to the inverter. An LC filter is used to reduce the harmonic content. For the desired voltage output, the output of inverter is fed back to gate pulses through a voltage regulator, which sets out the pulses accordingly.

The simulink model of an inverter is as shown in figure 11.

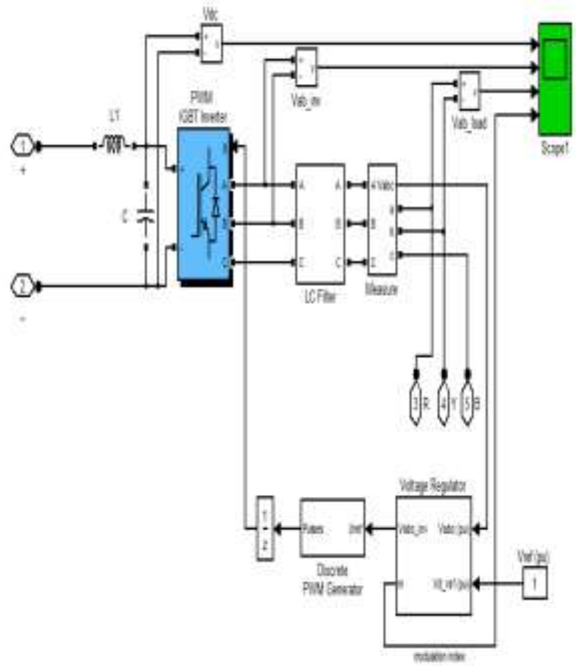

Fig 11: Inverter simulink model

The output of the inverter is as shown in the figure 12 which is three phase output.

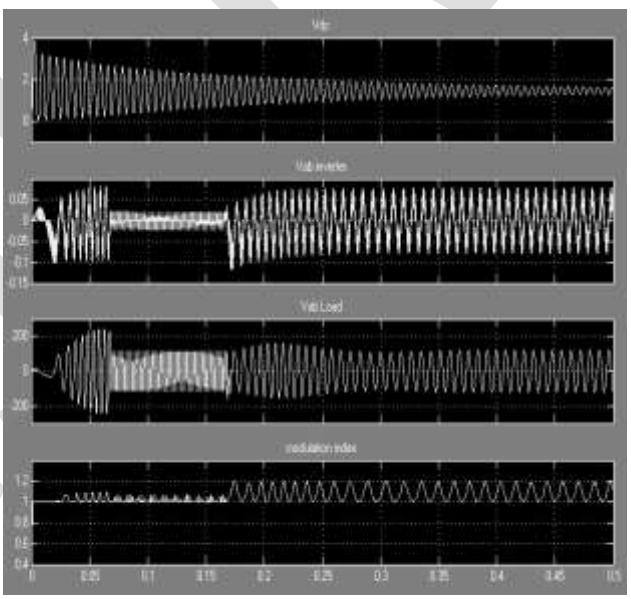

Fig12: output of inverter model

IV. FINAL SIMULATION RESULT

The output of the inverter is integrated with the output of the wind via a circuit breaker, which protects as well as trips when wind turnime provides the sufficint power. The output if the simulation result is as shown in the figure 13, 14, 15 and 16, a three phase sinosidal output.

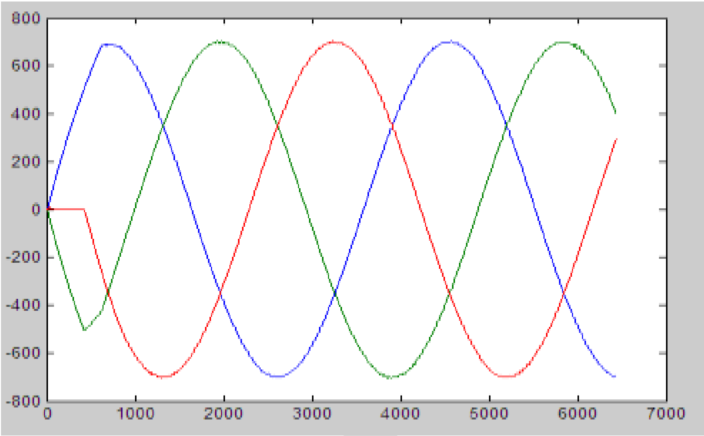

Fig13: final output voltage of microgrid model.

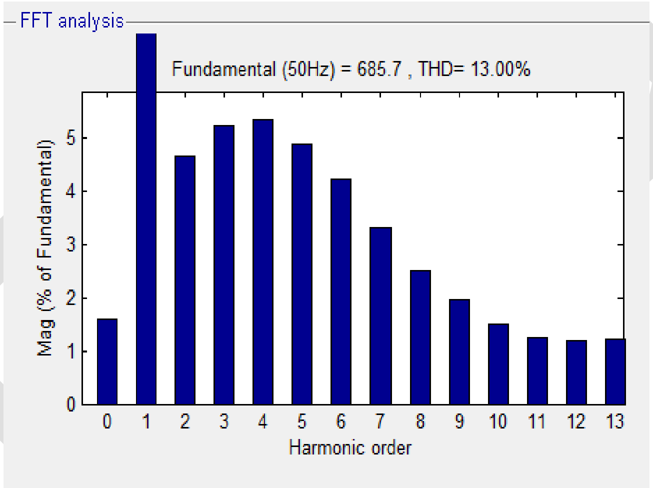

Fig14: Final FFT analysis of voltage.

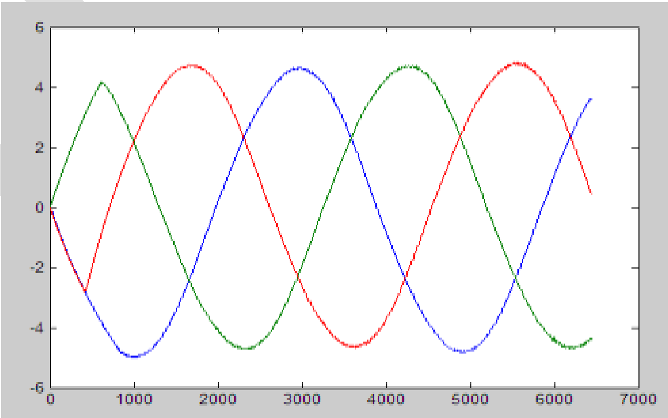

Fig15: Load current

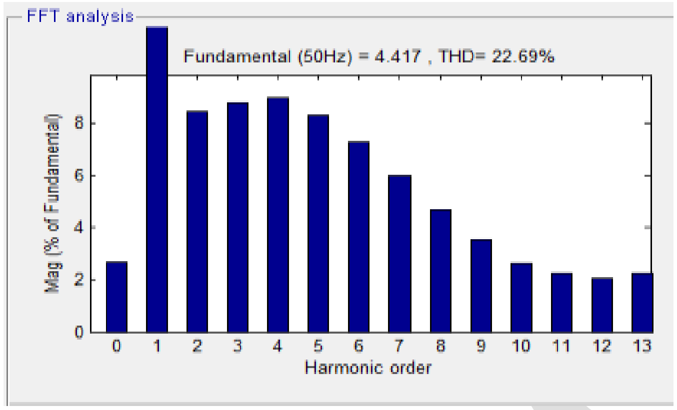

Fig16: FFT analysis of Load current

V. CONCLUSION

The paper has presented useful models of single and three phase micro sources and battery bank of a Microgrid. The simulation results are based as in matlab and simulink software environment. The energy resources parameters were obtained using the datasheet and operating curves as per the requirements that are to be used as part of the Microgrid. The final integrated output is connected to a resistive load so as to analyze the harmonic content. The load is considered as resistive but it can be connected to a grid. The inverter used for PV cells and fuel cells is efficient because of a feedback loop. This model helps to physically construct a Microgrid that can supply power for far off places where natural sources are of only available resources.

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