

Modeling and Control of the Distributed Energy Resources in Microgrid

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Abstract-Renewable energy obtained from the environment is an alternative option for providing clean energy to homes and industries. But the power obtained from the renewable energy is not sufficient to meet the demand of consumers individually. This has to be integrated to the grid so that there is an exchange of power during demand. To implement the integration of the DC microgrid plays a significant role. DC Microgrid is an efficient way to combine renewable energy to the grid. At the domestic level, DC microgrids can be efficiently integrated with the distribution and generation of power. Hence they act as effective component in the power system.

In this project, we are proposing a DC Microgrid with power Electronics control .The renewable energy sources are Solar and Fuel cells, with storage system is to be integrated to form a DC Microgrid and integrated to the utility grid through Power electronic interface with controller.

Keywords: DC Microgrid, Solar Power Generation, Fuel Cells

I. INTRODUCTION

Nowadays because of the air pollution caused by the excessive use of fossil fuels for the power generation, renewable energy sources are gaining importance in the field of power generation. Renewable energy resources are eco friendly and available in abundance unlike the non renewable energy resources which are on the verge of extinction. Fuel Cells, battery and photovoltaic systems are the examples of the renewable energy resources which produce DC power. Using the above mentioned resources DC microgrid can be made that can operate in islanded mode and in the grid connected mode.

In this paper, the modeling of the DC microgrid with photovoltaic system and fuel cells is proposed. A conventional boost converter and a three phase bridge inverter is used to create a DC and an AC bus. The simulation results are analyzed by using MATLAB Simulink.

A. Photovoltaic System.

This system operates on the principle of photovoltaic effect. This effect states that when semiconductor is exposed to a light energy, electric current is generated. A solar cell when exposed to sunlight converts the solar energy into electrical energy because of the creation of some electron hole pairs. The equivalent circuit diagram of a photovoltaic cell is as shown in Fig. 1

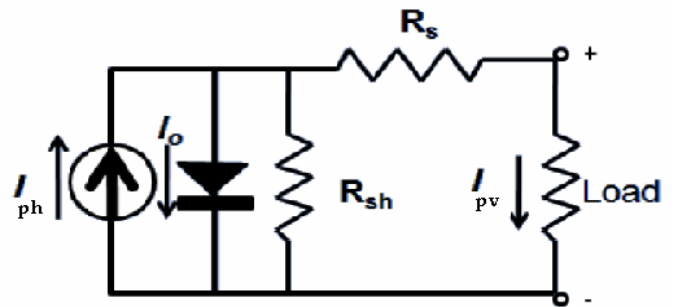


Fig. 1. Equivalent Circuit of Photovoltaic cell

R_{sh} is the shunt resistance of the photovoltaic cell.

R_s is the series resistance of the photovoltaic cell.

I_{ph} is the current source.

The following are the main equations for the modeling of the Photovoltaic System:

The module photo current

$$I_{ph} = [I_{scr} + K_i(T - 298)] * \lambda / 1000$$

Module reverse saturation current

$$I_{rs} = I_{scr} / [\exp(qV_{oc} / N_s kAT) - 1]$$

Module Saturation Current

$$I_o = I_{rs} \left[\frac{T^3}{T_r^3} \right] \exp \left[\frac{q * E_{go}}{Bk} \left\{ \frac{1}{T_r} - \frac{1}{T} \right\} \right]$$

The output current of Photovoltaic module

$$I_{PV} = N_p * I_{ph} - N_p * I_o \left[\exp \left\{ \frac{q * (V_{PV} + I_{PV} R_s)}{N_s A k T} \right\} - 1 \right]$$

B. Fuel Cells

In the coming future fuel cells will find great applications not only in the field of energy production but also on the other areas like motor vehicles. A fuel cell converts chemical energy into electrical energy. The construction of a fuel cell is very simple. It consists of an electrolyte solution and two electrodes (anode and cathode) dipped into the electrolyte. The anode is supplied with gaseous fuels while the cathode is supplied with oxidant. As a result of electrochemical reactions electricity is produced giving heat and water as by-products.

Fuel Cells have many advantages than the conventional resources used for power generation. The efficiency of the Fuel cells is 35 to 40% more than the gas or thermal power stations. The efficiency can be further increased to 90% if the waste heat of the fuels is reused. The noise levels during the operation are very low. The energy production is clean as pollution level emissions are low.

II. SYSTEM MODEL

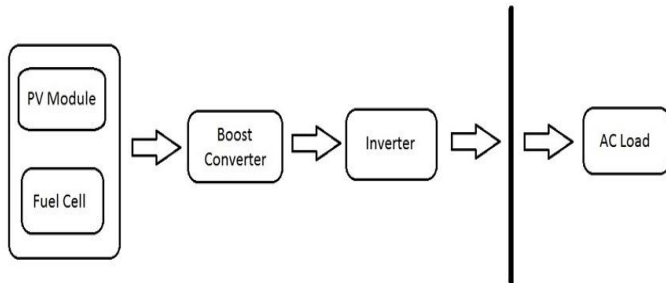


Fig. 2. Block Diagram of DC Grid

The network under consideration is a DC Microgrid of the rating 700Volts as shown in “Fig.2”. The system comprises of 6 photovoltaic modules of the rating 60Watts 21Volts connected in series and 4 fuel cells of the rating 1.26KiloWatts 24 Volts with voltage at 0Amperes and 1Amperes equal to 42 Volts and 35 Volts connected in series. The output of each renewable energy source is fed two conventional boost converters with frequency of 50 Kilohertz. The inductance and capacitance values for the two converters are 120 microhenry and 4.6 millifarad and 4.256 millifarad with duty cycle of 82.4% for photovoltaic module and 76% for fuel cell. The output of the two boost converters is fed to a 3 phase bridge inverter and thus forming an AC Grid with a peak voltage of 450 Volts.

A. Photovoltaic module in MATLAB

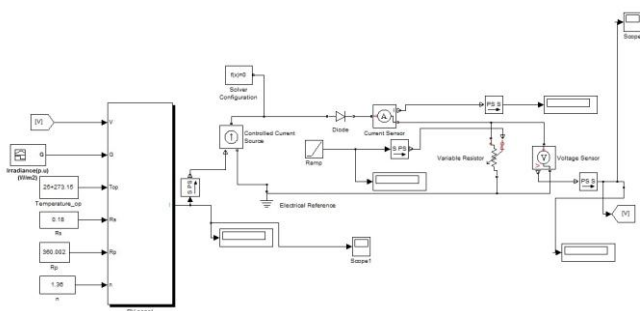


Fig. 3. Photovoltaic Module

Fig 3 shows the MATLAB model of the Photovoltaic module. The Photovoltaic Module used for simulation is of the rating 60 Watts 21 Volts. The module has 36 cells connected in series and 1 cell connected as parallel. The irradiance value of 1 is taken during simulation. The operating temperature taken is 25° C. The series resistance is 0.18 ohms.

B. Fuel Cell Stack in MATLAB

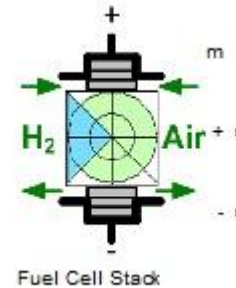


Fig. 4. Fuel Cell stack

Fig 4 shows the fuel cell stack used for simulation in MATLAB. The Fuel Cell Module used for simulation is Proton Exchange Membrane Fuel Cell (PEMFC). The fuel cell used is of the rating 1.26Kilo Watts 24Volts. The output voltage of the fuel cell at 0 Amperes and 1 Amperes is 42 Volts and 35 Volts respectively. The nominal operating point for the fuel cell is 52 Volts and 24.23Amperes and the maximum operating point is 100 Volts and 20 Amperes.

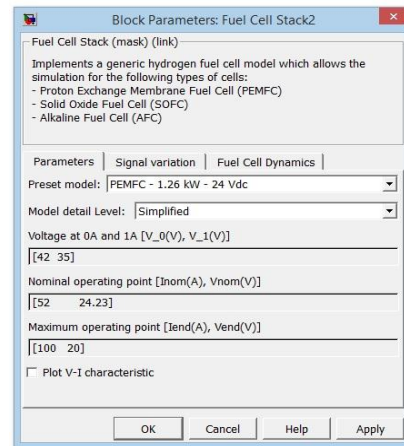


Fig. 5. Fuel Cell Ratings

C. Boost Converter Module in MATLAB

The two boost converters are fed from the dc voltages generated by the photovoltaic modules and the fuel cells. The gate pulse to the MOSFET is provided using pulse generator. The operating frequency for the switch is 50 Kilohertz and the duty cycle is 82.4% and 76% respectively. The output of the boost converter is then fed to form a DC bus of 700 Volts.

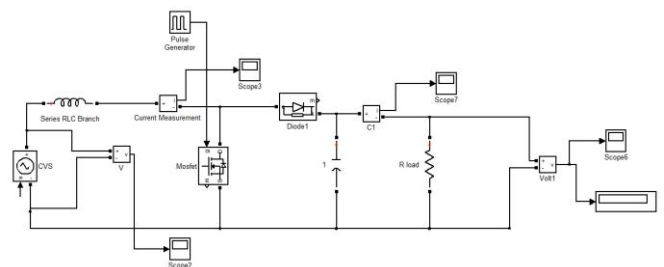


Fig. 6. Boost Converter Model

D. Three Phase Bridge Connected Inverter in MATLAB

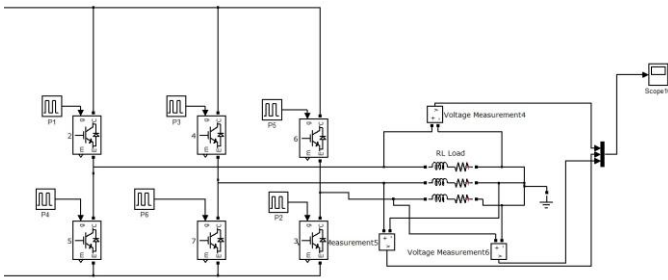


Fig. 7. Three Phase Inverter Model

The inverter used for the simulation is a three phase bridge connected inverter. The inverter works in 180° conduction mode. The input to the inverter is from the DC bus and the inverter output forms the AC bus.

III. SIMULATION AND RESULTS

A. The output of the photovoltaic and fuel cell modules before giving it to the boost converter is as follows:

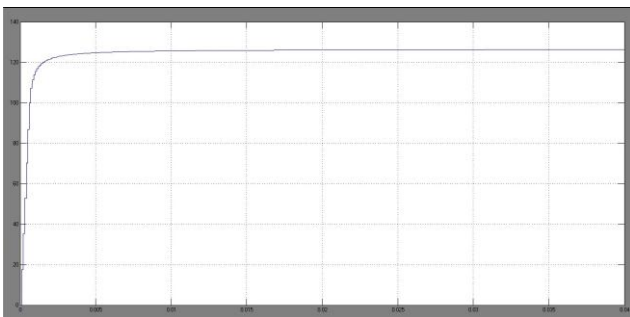


Fig. 8. Output of the photovoltaic modules

- The Fig 8 shows the output of six photovoltaic modules connected in series. The output voltage is 126 volts.

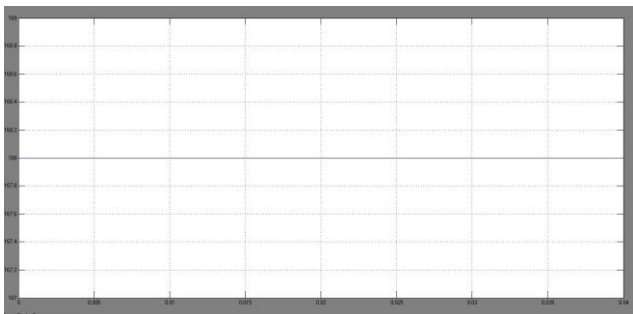


Fig. 9. Output of the Fuel cell module.

- The Fig 9 shows the output of four fuel cells. The output is 168 volts

B. The output of the photovoltaic modules and fuel cell modules after giving it to boost converter is as follows:

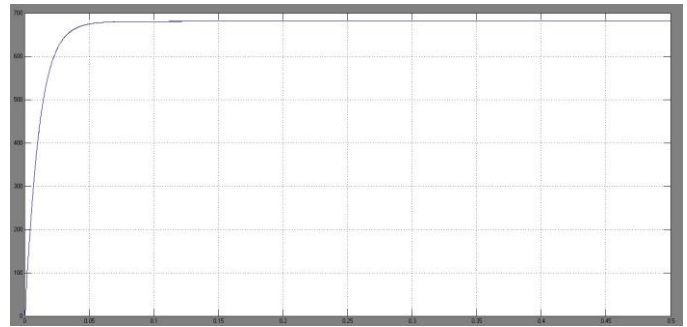


Fig. 10. Output of photovoltaic cells after boost.

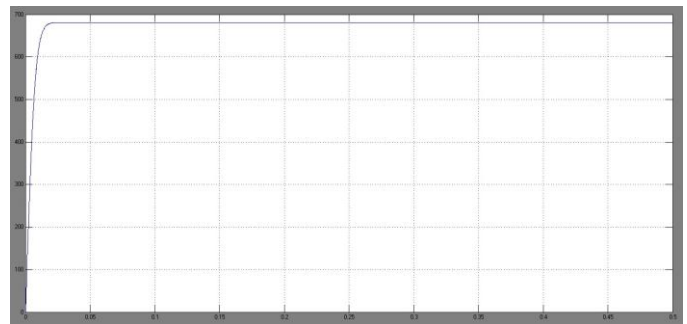


Fig. 11. Output of fuel cells after boost.

- Fig 10 shows the output of the six photovoltaic modules after boost. The output voltage is 680 volts.
- Fig 11 shows the output of the fuel cells after boost. The output is 680 volts.

C. The output of the three phase inverter is as shown:

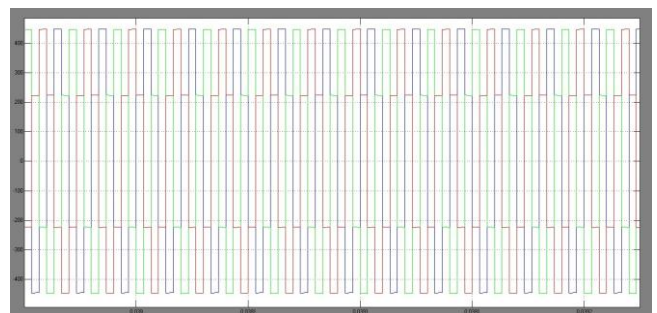


Fig. 12. Output of the three phase inverter

- The Fig 12 shows the output of the three phase inverter. The output voltage is 450 Volts.

CONCLUSION

This paper gives the simulated result of the microgrid with two renewable resources integrated together. The power from the resources is used to form a DC bus of the rating of 700 Volts. This bus further feeds a three phase inverter to form an AC bus of the voltage rating of 450 Volts.

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