

Design of Non-Polluting Microgrid using Photovoltaic and Fuel cell

Vinay Kumar Chaurasia¹, Neha Verma², Md. Sharique Nawaz³

¹M.Tech Student, Dept. Of Electrical & Electronics Engineering, AISECT University, Bhopal, M.P.

²Asst. Prof., Dept. Of Electrical & Electronics Engineering, AISECT University, Bhopal, M.P.

³M.Tech Student, Dept. Of Electrical & Electronics Engineering, AISECT University, Bhopal, M.P.

Abstract - In this thesis, Hybrid PV/Fuel system has been demonstrated by using MATLAB/SIMULINK 2012. In Photovoltaic system, sunlight is converted into electrical energy and in fuel cell chemical energy is converted into electrical energy. Both the system is interconnected with distribution network and grid. Both system uses non-polluting energy and infinite source of fuel and both system are synchronize with grid using inverter. Both system produce DC as output which is converted into AC by voltage source inverter and then it integrated to Grid. Simulation results in thesis shows that both systems are compliment to each other.

Key Words: Buck Boosts, CSI(Current source inverter), LC Filter, PV Cell, VSI (Voltage source inverter).

I. INTRODUCTION

A micro grid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A micro grid can connect and disconnect from the grid to enable it to operate in both grid-connected and island mode. Requiring that the micro grid can operate in parallel with the electric utility grid leaves out a large number of systems on DoD installations that include multiple integrated generation sources and loads, but are not able to parallel with the grid.

While aligning for poles or for underground cabling, care should be exercised to determine the location of all underground services such as water. The domestic electric grid can be subdivided into three main components; the power generation plants that produce electricity, the transmission infrastructure that moves the electricity across long distances to load centres, and the local distribution system that provides power to end users.

II. CONFIGURATION

(a) PV CELL

Photovoltaic cell converts directly sunlight to electricity by photovoltaic effect, with no pollutant emission. It can generate direct electricity without any environmental impact

and contamination when exposed to solar radiation. They are made up of PN junction. When sunlight hits the cell, photons are absorbed by semiconductor atoms, freeing electrons of negative layer.

These modules are interconnected to form PV panel. The voltages are added with same current if modules are connected in series. when they are connected in parallel, their current are added while the voltage is same.

The three major families of PV cells are-

1-Monocrystalline technology:

This technology is based on microelectronic manufacturing technology and its efficiency is in general between 10% and 15%.

2- Polycrystalline technology:

This technology is also based on microelectronic manufacturing technology and its efficiency is in between 9% and 12%.

3- Thin film technology:

For thin film cells, the efficiency is 10% for a-Si, 12% for CuInSe₂ and 9% for CdTe.

So The Monocrystalline cell has highest efficiency. Thus, the model of Monocrystalline PV cell made possible the prediction of PV cell behaviour under different varying parameters such as solar radiations, ambient temperature, series resistor, shunt resistor, diode saturation current etc.

(b) PV Array

An array of 6 PV modules has been constructed to get benefit from these developed models. PV array means presence of whole group of modules (can be in series or in parallel) in a system. These modules are interconnected in series and all of them are connected to external control block. The PV array model was simulated similar to model of PV module and obtained results are shown in figures similarly. The modules in PV array are first connected in series to produce desired current and then individual string are connected in parallel to produce more current.

(c) MAXIMUM POWER POINT TRACKING

Maximum power point is the method which helps in increasing the efficiency of solar cell. Generally solar cell has low efficiency. To increase its efficiency, maximum power point tracking method has to be taken to enhance its functions. This technique is generally used to obtain maximum power from a varying source. As we know that the I-V curve in photovoltaic system is non linear, so this is difficult to be used to power a certain load. So, this done by utilizing a boost converter whose duty cycle is varied by using a mppt algorithm. A solar panel is used to power this boost converter.

(d) FUEL CELL

THE FUEL CELL is a device that converts chemical energy into electricity from a fuel by direct combustion. This device uses hydrogen as a fuel to produce electrons, protons, heat and water. It consists of two electrodes, on positive called anode and one negative called cathode. They are separated by an electrolyte that allows the moving of positively charged hydrogen ions between two sides of fuel cell. Hydrogen fuel is supplied to anode of fuel cell and oxygen is supplied to the cathode of fuel cell. In chemical reaction, hydrogen is split into an electron and a proton. The proton passes through the electrolyte while the electrons are drawn from anode to the cathode through an external circuit, producing direct current electricity. Both are reunited at the cathode. The electron, proton, and oxygen combine to form by product of water.

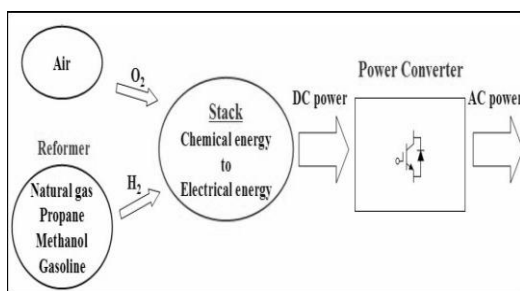


Fig 2.1 Fuel cell architecture

TYPES OF FUEL CELL (according to electrolyte used)

- PROTON EXCHANGE MEMBRANE FUEL CELL
- PHOSPHORIC ACID FUEL CELL
- DIRECT METHANOL FUEL CELL
- ALKALINE FUEL CELLS
- MOLTEN CARBONATE FUEL CELL
- SOLID OXIDE FUEL CELLS

(e) BUCK BOOSTS

The buck boost converter DC to DC type of converter which has an output voltage magnitude that is either greater than or less than the input voltage magnitude. The applications of DC-DC converters like provide power supplies for DC motor drives, telecommunication equipment, personal computers; aircraft etc. this circuit shows the configuration of voltage which converted unregulated DC to regulated DC. This DC converter can work in linear region in fuel cell stack, beyond this region this converter cannot be operated as it may cause damage to electrolyte membrane of fuel cell. To reduce the ripples, the value of inductor and capacitor should be taken appropriately. Before the switch off, the small inductance allows the coil current to boost to higher levels while the large inductance increases the start up time.

(e) INVERTER WITH CONTROL

It is a device that converts DC power into AC power at desired output voltage and frequency. In this thesis DC power input is obtained from fuel cell and photovoltaic array. Inverters can be broadly classified into two types:- one is voltage source inverter other is current source inverter.

- Current source inverter
- Voltage source inverter

(f) LC Filter

Whenever inverter is connected to the grid there is harmonics develops, to eliminate these harmonics in the system LC filter circuit is used.

III. MODELLING OF PV CELL AND FUEL CELL

(a) PV cell modelling

The PV cell equivalent circuit consist a current source, a diode, a series resistance and a shunt resistance.

$$I = I_{ph} - I_D \left[\exp \frac{q [v + R_s I]}{NKT} - 1 \right] - \frac{[V + R_s I]}{R_{sh}} \dots\dots\dots 3.1$$

- I_{ph} = Photocurrent
- I_D = Reverse saturation of the diode
- q = Electron charge
- V = Voltage across the diode
- K = Boltzmann's constant
- T = Junction temperature
- N = Ideality factor of the diode
- R_s = Series resistor of cell
- R_{sh} = Shunt resistor of cell

This is the Relation of PV Cell with I_{ph} I_s , R_s , and R_{sh} with two environmental parameters as the temperature and the solar radiation.

For given radiation, temperature the I-V and P-V curves are generated as shown in figure.

Effect of solar radiation variation-

According to equation.

$$I_{ph} = [I_{sc} + K_i (T - 298)] \frac{\beta}{1000} \dots\dots\dots 3.2$$

Where $K_i = 0.0017$ A/degree Celsius is the cell's short circuit current temperature coefficient and β is the solar radiation (W/m^2).

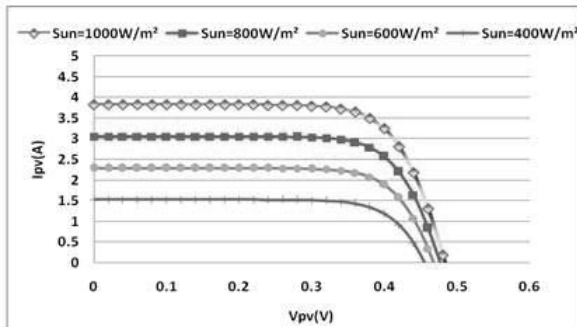


Fig 3.1 I-V curves for different solar radiations

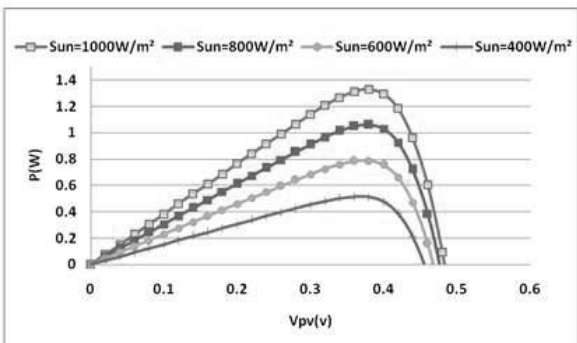


Fig3.2 P-V curves for different solar radiations

Effect of varying cell temperature:

The following expression suggest that the diode reverse saturation varies as cubic function of temperature:

$$I_d(T) = I_d \left[\frac{T}{T_{nom}} \right] \exp \left\{ \left[\frac{T}{T_{nom}} - 1 \right] \frac{E_g}{NV_t} \right\} \dots\dots\dots 3.3$$

I_d = diode reverse saturation current

T_{nom} = nominal temperature

E_g = band gap energy of the semiconductor

V_t = thermal voltage.

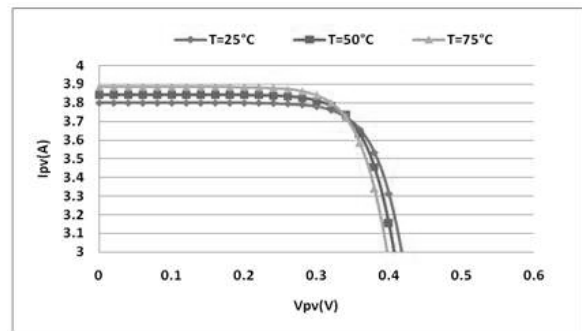


Fig3.3 I-V curves for different cell temperature

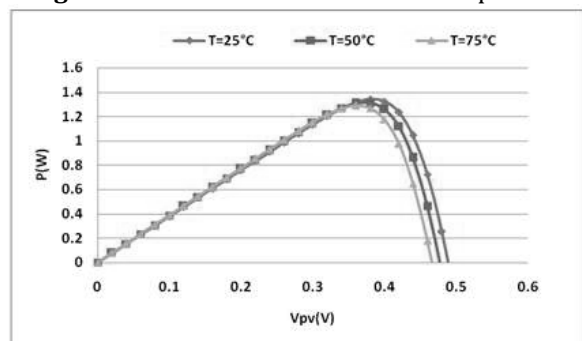


Fig3.4 P-V curves for different cell temperature

(a) Modelling of fuel cell-

1-Fuel cell with connected with grid and load

As we know that the fuel cell is that electrochemical cell which converts a source fuel into an electric current. In the presence of an electrolyte, it generates electricity through the reactions between a fuel and an oxidant inside a cell. In this process, reactants flow out into the cell and the reaction product flows out of the cell while the electrolyte remains within it in this reaction. If the necessary reactant and oxidant flows are maintained, the fuel cells can operate continuously. They resembles batteries in any ways but are different in that they consume reactant from an external source. By contrast battery can store chemical energy but like battery fuel cell cannot store energy hence fuel cell represented by open system and batteries represent thermodynamically closed system. Many combinations of fuels and oxidants are possible. Fuels include hydrogen, hydrocarbons and alcohol. oxidants include chlorine, oxygen and chlorine dioxide. A hydrogen fuel cell uses hydrogen as fuel and oxygen as its oxidant. A fuel cell consists of anode, cathode and an electrolyte which are sandwiched together. There is two chemical reactions occur inside the cell which results that the fuel is consumed, water or carbon dioxide is created, which produces the electric current that can be used by many electrical devices.

In this thesis, solid oxide fuel cell is used as fuel cell. The voltage of fuel cell, is define as the sum of three terms: the thermodynamic potential, the activation over voltage and ohmic over voltage. The voltage equation is.....

$$E = V - \text{Losses} \dots\dots\dots 3.4$$

IV.SIMULINK IMPLIMENTATION

In this chapter hybrid Fuel/PV is demonstrated using 100 KW PV Array and 50 KW Fuel Cell connected with utility grid and three loads L1, L2 and L3. The load supply is maintained by both utility grid and the micro grid (PV and Fuel cell). Firstly load took power from micro grid and if the power exceeded the capacity of micro grid then extra power is maintained by the utility grid. If the load is less than the capacity of micro grid the used power is supply towards utility grid side. The combine MATLAB SIMULINK model of fuel cell, pv cell and utility grid are shown in fig.-4.1

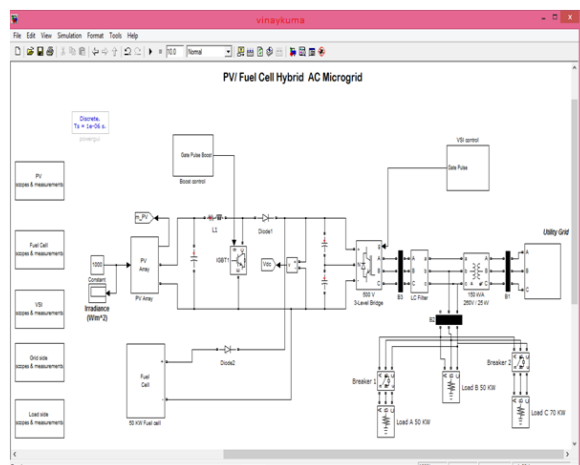


Fig 4.1 Hybrid fuel/ PV cell micro grid connected with utility grid.

4.1 Simulink model of PV ARRAY-

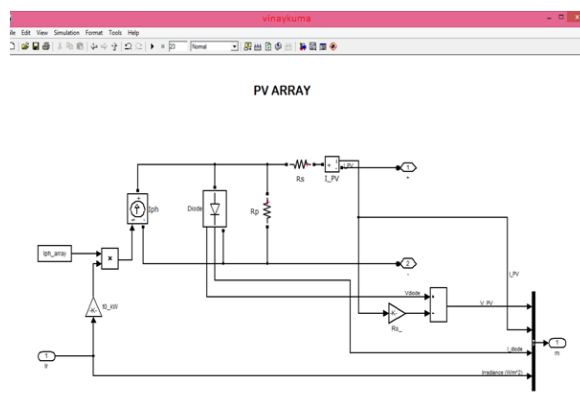


Fig4.2 Simulink model of PV array

4.2 Fuel cell simulink model-

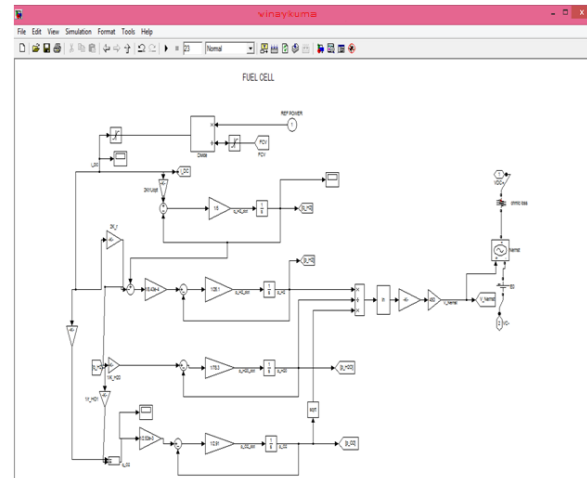


Fig4.3 Simulink model of Fuel Cell

4.3 Voltage source Inverter or converter-

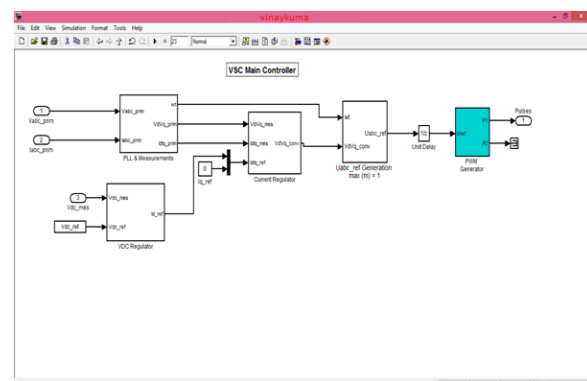


Fig4.4 Simulink model of PWM voltage source controller

4.4 Maximum Power Point Tracking (MPPT)

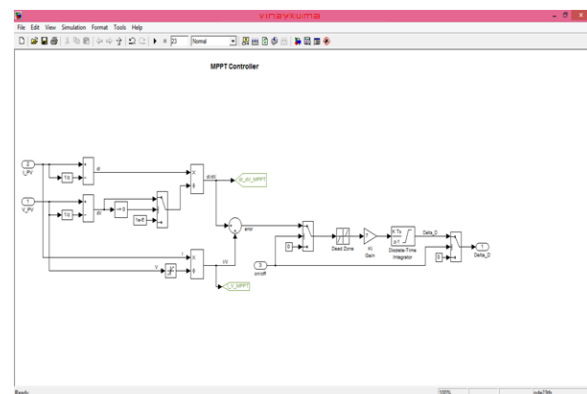


Fig 4.5 Simulink model of MPPT Controller

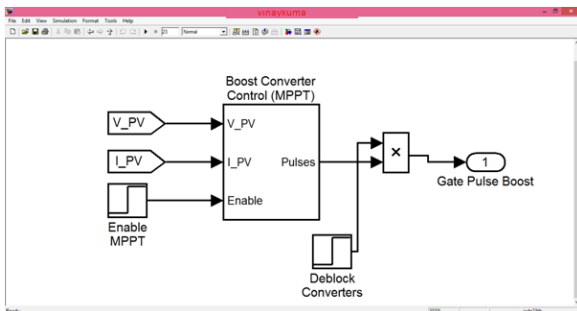


Fig4.6 Simulink model of Gate pulse boost controller

4.5-LC Filter-

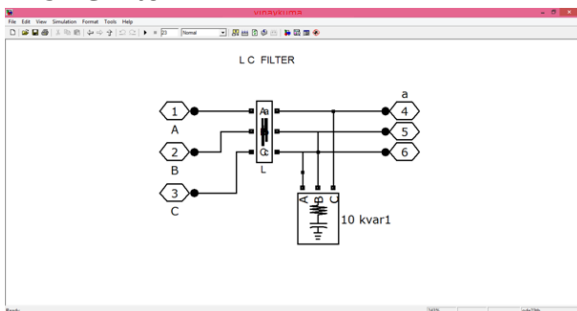


Fig 4.7 Simulink model of LC Filter

Output Response of PV Array incase of load greater then generation on PV and Fuel cell.

- **PV voltage, Current, diode current.** In Graph 3.3 voltage of Pv cell “ V_PV” , current of PV array “ I_PV” and diode current of PV cell are shown.



Fig 4.8 PV voltage, current, diode current of Array

- **Output response of boost converter connected to PV array-**

Output response of boost converter i.e power output, duty cycle of boost converter, voltage at output of boost converter and current of boost converter are shown in graph 3.4. This graph shows that output power of boost

converter is constant about 100 Kw at 1000 w/m² irradiance and voltage is about 260 to 272 V.

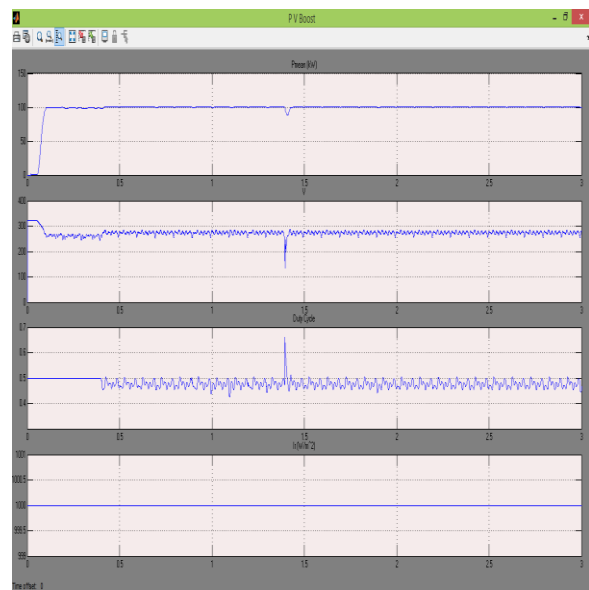


Fig4.9 Output response of boost converter connected to PV array.

■ Output response of Fuel

Output responses of fuel cell are shown in graph 3.4. In this graph the output power of the solid oxide fuel is constant 50 Kw and 420 V. Boost converter connected to fuel cell increase voltage from 420 v to 500 v.

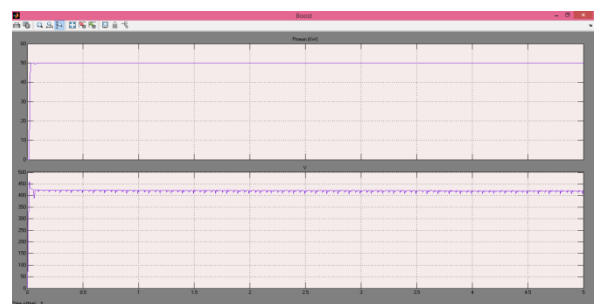


Fig4.10 Output response of solid oxide fuel cell

- **Input at Voltage source inverter**

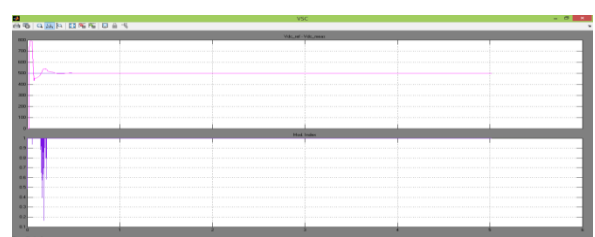


Fig4.11 Input at Voltage source inverter

- **Output response at Bus on Load side**

Output response on load bus is shown in graph 4.12 and 4.13. Graph 4.12 shows power on load side which is 50 KW load. Graph 4.13 shows voltage and current on load side which is 260V and 200 A.

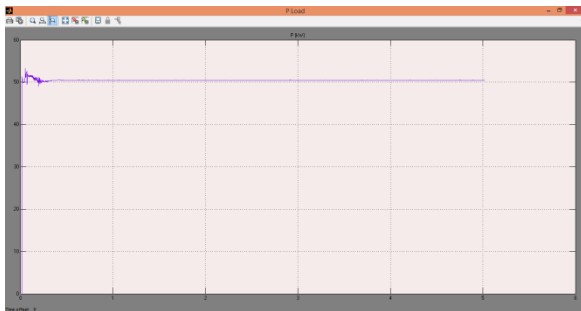


Fig4.12 Power on load side

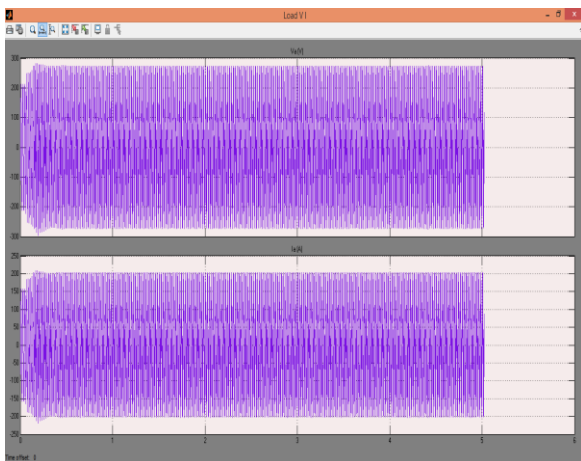


Fig 4.13 Voltage and Current on load side

- **Output on Bus at grid side-**

Graph 4.3 and 4.4 show the power, voltage and current on grid side. These graphs show that 98 KW from fuel cell and pv cell is supplied towards grid and 50 KW towards load. Voltage at grid side is 25 Kv and current is shown in graph 4.3.

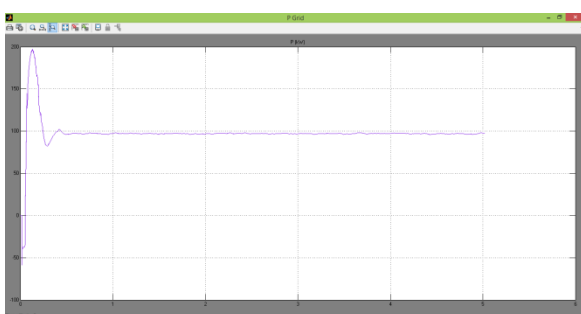


Fig4.14 Power at Grid side

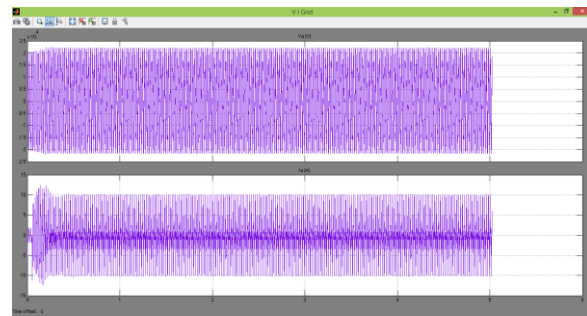


Fig4.15 Voltage and current on grid side

V. RESULT

The generalised simulink model of PV/Fuel hybrid micro grid connected with Grid and distribution network has been successfully demonstrated in this dissertation with the help of MATLAB SIMILINK R2012a. In this dissertation 50 KW of fuel cell and 100 KW of PV are connected with 25 KV grid and 50 KW load. As load only need 50 KW from micro grid and rest of 100 KW is to supply towards grid. By this arrangement load received supply from micro grid so that burden on grid are decrease and extra power produced by hybrid micro grid can sell to grid. In this arrangement pollution free energy as well as infinite source of energy are use to produce electricity.

VI. CONCLUSION

The concept of micro grids, which are (semi-) autonomous entities that co-ordinate DERs and loads in a decentralized manner, has been put forth to tackle the problem of large scale control for renewable integration. To meet carbon reduction goals and minimize electricity generation costs, it is imperative that the micro grids incorporate as large a fraction of the renewable energy generated as possible. Intelligent scheduling of generation sources and loads is essential to the operation of a micro grid, to allow the integration of volatile DERs such as wind while ensuring stability and reliability. In this thesis hybrid PV and Fuel cell is successfully demonstrated with the help of MATLAB SIMULINK. This shows that electricity produced by renewable resource can be used with utility grid which future decrease the burden on utility grid and consumer can also earn by selling the excess electricity produced by micro grid to grid.

ACKNOWLEDGEMENT

I express my regards and sense of gratitude to my Guide and faculty members for giving inspiration, expert guidance, moral support and encouragement throughout this work. Their wide experience, sharp and incisive intellect, dynamism, timely help, and painstaking efforts has unerringly steered the work on smooth and steady course.

I deeply acknowledge the support and advice provided by my Guide, faculty members and classmates.

REFERENCES

- [1] M.T.Iqbal; "Simulation of a small wind fuel cell hybrid energy system", 11 June 2002, pg 511-522.
- [2] Francisco M.Gonzalez-longatt, "Model of photovoltaic module in Matlab", 2 CIBELEC 2005, pg 1-5
- [3] Chiara Boccaletti, Gerardo duni, Gianluca fabbri, Ezio santini, "Simulation models of fuel cell systems", 11 July 2006, pg 1-6.
- [4] Dorin Petreus, Cristian farcas, Ionut ciocan, "Modelling and simulation of photovoltaic cells", ACTA Technica Napocensis Electronics and telecommunications, volume 49, no. 1,2008, pg 42-47.
- [5] Jawad faiz and Ghazanfar Shahgholian, "Modelling and simulation of a three- phase inverter with rectifier-type nonlinear load",Amenian journal of physics, vol. 2, 2009, issue 4, pg. 307-316.
- [6] Mahesh Gowdan M, Yadu Kiran, Dr. S.S Parthasathy, "Modelling of buck DC-DC converter using simulink" , ISSN: 2319-8753, vol. 3, issue 7, july 2014, pg.14965-14975.
- [7] B.Haritha, P.Dhanamajaya, "A Grid connected fuel cell based on boost inverter system" ,international journal of innovative research in electrical, electronic, instrumentation and control engineering, vol. 2, issue 8, august 2014, pg. 1829-1834.
- [8] Michael Green, "Design calculations for buck-boost converters" ,SLVA535A, September 2012, pg.1-12.
- [9] Eduardo Alegria, Tim Brown, Erin Minear, Robert H. Lasseter," CERTS Microgrid Demonstration with Large-Scale Energy Storage and Renewable Generation, "Energy Storage Applications for Smart Grid". Special Section of IEEE Transactions on Smart Grid,2013 IEEE.
- [10] Toby Considine, William Cox, Edward G. Cazalet," Understanding Microgrids as the Essential Architecture of Smart Energy, *Grid-Interop Forum 2012*.
- [11] Astha Pandya, Prof. R.R .Kapadi j, Prof. S.N Shivani ," Smart Control of Parameter of Microgrid Having Renewable Sources Using ZIEGLER-NICHOLSMETHOD, ISSN - 2250-1991.
- [12] Amit Sachan," Microgrid: Low Power Network Topology and Control,World Academy of Science,Engineering and Technology International Journal of Electrical, Robotics, Electronics and Communications Engineering Vol:7 No:12, 2013.
- [13] Pertti Järventausta, Sami Repo, Antti Rautiainen, Jarmo Partanen," Smart grid power system control in distributed generation environment, Tampere University of Technology, P.O.Box 692, 33101 Tampere, Lappeenranta University of Technology, P.O.Box 20, 53851 Lappeenranta .
- [14] Yang HAN, Lin XU," A survey of the Smart Grid Technologies background motivation and practical applications, Przegląd Elektrotechniczny (Electrical Review), Issn 0033-2097, R. 87 Nr 6/2011.
- [15] Abhas Kumar Singh, Sanjeev Kumar Gagra," TECHNOLOGY ISSUES IN MICROGRID SYSTEM, International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163,Volume 1, Issue 7 (August 2014).
- [16] M.r vivek, S.vijaya raj,C.thirugomathi," Economic Analysis of a Micro Grid Power Generation, International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 2, Issue 2, March 2013
- [17] Yan Zhang, Baolong Li, Tao Zhang,Bo Guo1," An Intelligent Control Strategy of Battery Energy Storage System for Microgrid Energy Management under Forecast Uncertainties, Int. J. Electrochem. SCI, 9 (2014) 4190 – 4204.
- [18] Rukun Mao, Yan Xu, Huijuan Li, and Husheng Li," Wireless communicationforControllingMicrogrids: Co-simulation and PerformanceEvaluation, Department of Electrical Engineering and Computer Science, The University of Tennessee, Knoxville, TN 37996,2Oak Ridge National Laboratory, Oak Ridge, TN 37831,3Oak Ridge Associated Universities
- [19] Christian Dufour, Jean Bélanger," On the Use of Real-Time Simulation Technology inSmart Grid Research and Development, ECCE-2013 IEEE Energy Conversion Congress and Expo, Denver, Colorado, USA, Sept. 15-19, 2013.

Mr. Vinay Kumar Chaurasia , M.Tech (Power System) student, Department of Electrical & Electronics Engineering, AISECT University, Bhopal (M.P) INDIA, +91-8130865594, vinaychaurasia288@gmail.com

Miss. Neha Verma, Assistant Professor, Department of Electrical & Electronics Engineering, AISECT University, Bhopal (M.P) INDIA.

Md. Sharique Nawaj, M.Tech (Power System)
student, Department of Electrical & Electronics
Engineering, AISECT University, Bhopal (M.P) INDIA.