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# Design, Modelling and Cost Analysis of Hybrid Power System

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**ABSTRACT**: In this Paper we have designed and modeled a renewable power system for rural electrification and in addition to this we also did the cost analysis. Firstly, we modeled a Fuel cell, PV cell, Inverter and filter. We constructed the hybrid system and supplied power to the grid and to the loads connected. This modeling and design was done in MATLAB. In this thesis we also included the cost analysis of the micro grid in the software known as HOMER. In HOMER we designed three different models, first was when we used only diesel generator to supply the load. In the second model, we modeled renewable energy resources (PV cell, Fuel cell) and in the third model we used diesel generator as well as renewable energy resources together. Thus, we did the cost analysis comparatively.

**KEYWORDS:** Renewable power system, hybrid system, fuel cell and PV Cell.

## I. INTRODUCTION

Energy plays a vital role in our daily activities. The degree of development and civilization of a country is measured by the amount of utilization of energy by human beings. The more noticeable benefits of electric power include; improved health care, improved education, better transportation system, improved communication system, a higher standard of living, and economic stability. The fossil fuel supply viz. coal, petroleum and natural gas will thus be depleted in a few hundred years. The energy consumption increasing day by day, supply is depleting resulting in inflation and energy shortage. Hence alternative or renewable sources of energy have to be developed to meet future energy requirement. The distributed generation includes micro turbines, fuel cells, photovoltaic system, wind energy system, diesel engines, and gas turbines. Renewable energy has an abundant potential to contribute to growth of national sustainable energy setups in many countries in the world. An increase in percentage of renewable energy to total national power generation is beneficial in both economic and political point of view; reducing the nation dependency on fossil fuels decreases the undesirable effects to the nation’s economy. Due to its competitive cost of energy compared to fossil fuel, wind energy and solar energy are proving to be the fastest growing, cost effective and reliable renewable energy source of electricity in the remote areas around the world. Global environment concerns, growing demand of energy and progress in RE technologies are opening more opportunities in using renewable energy resources. A number of studies have shown that renewable energy based power system offer attractive and more practical approach to meet electrical power needs in rural communities around the globe. Solar energy is a good choice for electric power generation .The solar energy is directly converted in to electrical energy by PV cell. The process of generation of electricity from PV systems is totally pollution free but the PV modules manufacturing and system setup will impose some environment cost.

## II. SIMULATION AND MODELLING

In this chapter there is detailed description of all the parts of the model. Here we used solar cell, fuel cell, inverter, filter, transformer and load. A hybrid power system is designed and power generated is supplied to the utility grid.

### a) DESIGN AND MODELLING OF PHOTOVOLTAIC SYSTEM

Photovoltaic devices (solar cells) are solid state devices that can absorb sunlight and then convert it into electricity. Solar cells are made up of semiconductor material (usually the material used is silicon). When sunlight falls on solar cell, electrons are knocked from the n layer of semiconductor material. These free electrons moves towards the positive layer. If electric field is applied then these electrons constitutes electric current from positive layer to negative layer. This electricity is used to power a load. The photovoltaic system can generate dc current. The basic building block of

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PV arrays is the solar cell. The output characteristic of PV module depends on the cell temperature, solar irradiation, and output voltage of the module. The generated voltage of this PV cell is around 0.5 to 0.8 volts. This voltage cannot be used as it is small. Thus many solar cell are connected in series and parallel to form a PV module.

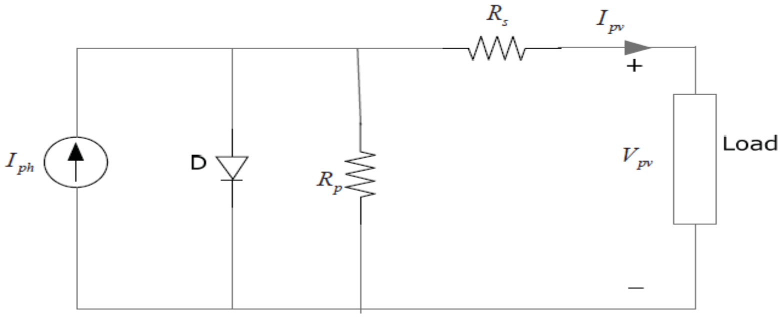


Fig 1 Equivalent circuit of PV Cell

This equivalent circuit of a general PV cell consists of a photocurrent, a diode, a parallel resistor which expresses a leakage current, and a series resistor which describes an internal resistance to the current flow. The current source Iph represents the cell photo current; D is used to represent the p-n junction, Rsh and Rs are used to represent the intrinsic series and shunt resistance of the cell.

**b) FUEL CELL**

An FC is a static electrochemical device that convertsthe chemical energy of a reaction directly into electricalenergy. It can be categorized as afirst-rate electricitysource because of its ability to produce constant power atfull load. FC operation is nearly similar to a battery system.However, an FC continuously provides DC electrical powerinto a system as long as hydrogen gases are supplied, afeature which a battery is not able to perform. An FCgeneration system needs oxygen and hydrogen to performchemical reaction and produce electricity in DC form. Theoxygen required for an FC comes from the air, which is pumped into a cathode. The hydrogen can be supplieddirectly or indirectly; it is produced by a reformer fromavailable fuels, such as methane, natural gas, gasoline, andalcohol. Primary products from this chemical reaction are electrical energy, water, and heat.
The overall reaction happening inside an FC stack can be described as follows:

$$2H_2\text{gas}+O_2\text{gas}=2H_2O + \text{power} + \text{heat}$$

There are two electrodes one is anode and the other is cathode. Both are separated by electrolyte that is a solid membrane. The Fig.3.13 shows the PEM fuel cell. Hydrogen fuel flows from one side to the anode, Air ($O_2$) also flows from another side to the cathode. Hydrogen dissociates into protons and electrons. Electrons are collected by the external circuit constituting the current and protons flow through the membrane to the cathode. Oxygen combines with the electrons that were produced in the external circuit and the protons flowing through the membrane and produce water.

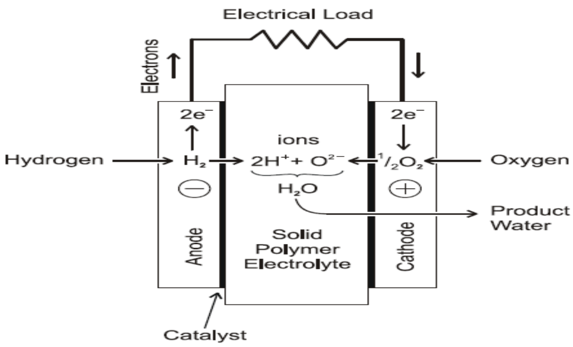


Fig.2 Fuel Cell

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The fuel cell static characteristic is presented in the polarization curve. At zero current point, the voltage value represents the fuel cell open circuit voltage.

**c) Design of DC/DC Boost Converter**

Because of the existence of the switches, the boost converter works in two modes. When switch is closed, the inductor stores energy and the capacitor releases energy. When switch open, the inductor releases energy and the capacitor stores energy.

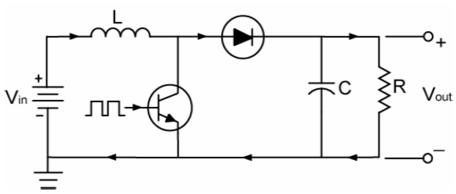


Fig 4 DC-DC Boost Converter

The first law involves the energy balance, which requires that the input energy equals the output energy:

$P_{in} = P_{out}$ $\quad$ $I_{in} V_{in} = I_{out} V_{out}$

The second law is the charge balance, which means the input charge equal to output charge. Because of the switch, the input current can only provide charge to output side when switch is open, and the time is (1-d)T in one T-period.

$$Q_{in} = Q_{out} \qquad I_{in}(1-d)T = I_{out}T$$

Using the two equations we can derive the basic relationship between the input voltage and output voltage.

$$V_{out} = \frac{Vin}{(1-d)}$$

Where d is the duty cycle, which is a positive number less than 1. From the relationship we can see clearly that output voltage is greater than input voltage.

**d) UTILITY GRID**

The power that is generated in the hybrid system is supplied to the grid where load is connected. This part of the model consists of load, transformer, transmission line and three phase AC source. A three phase AC source powers the grid. The output from the LC filter is given to the utility grid where loads are connected to the lines. Two transformers are used to step up and step down the voltage at the two ends of the grid. The two transformers are connected by transmission line whose length is taken 25km. Two three phase loads purely resistive of 2kW are connected at the two ends of two transformer.

## III. SIMULATION AND MODELLING

**a) COST OF DIESEL GENERATOR**

The parameter of cost detail of diesel engine is shown in fig 5.

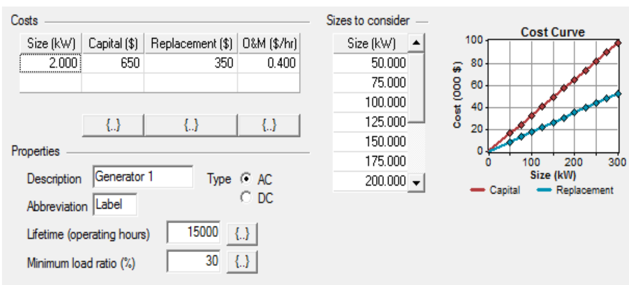


Fig. 5 Cost of Diesel Generator

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**b) EMISSIONS IN DIESEL GENERATOR**

The parameter of emission of the diesel engine is shown in fig 6.

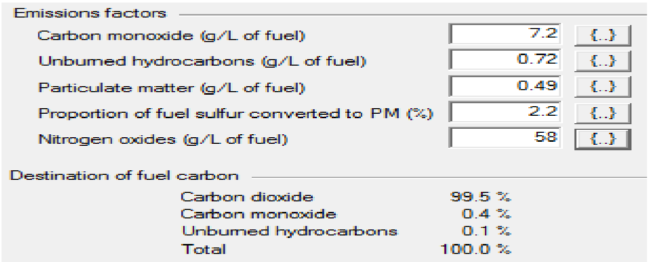


Fig.6 Emission in Diesel Generator

**c) PV CELL COST DETAILS**

The cost detail of PV cell is shown in figure 7.

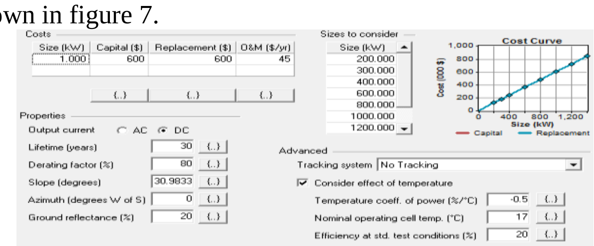


Fig.7 Cost of PV Cell

**d) TEMPERATURE DETAILS**

The parameter of Temperature details shown in figure 8.

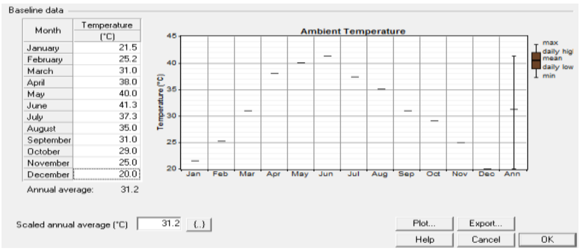


Fig.8 Temperature Detail

**e) BATTERY COST DETAILS**

The battery detail cost is shown in fig 9.

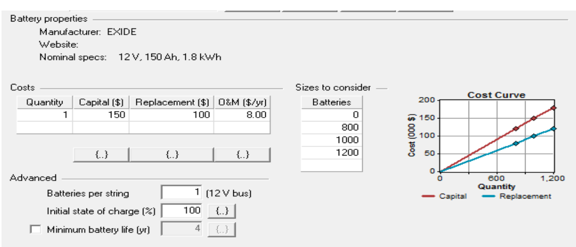


Fig.9 Cost of Battery

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### f) FUEL CELL COST DETAILS

The fuel cell cost detail is shown in figure 10.

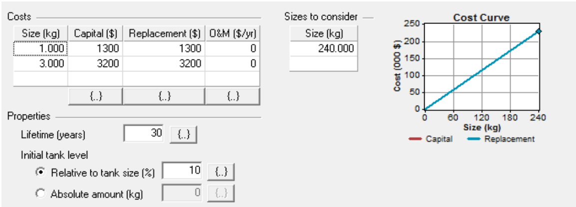


Fig.10 Cost of Fuel Cell

### g) POWER SYSTEM MODEL WHEN ONLY DIESEL GENERATOR CONNECTED

The model of power system when diesel engine is connected is shown in figure 11.

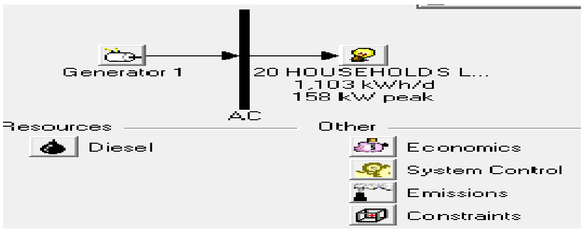


Fig.11 Diesel connected power System

### h) POWER SYSTEM MODEL WHEN RENEWABLE ENERGY RESOURCES USED

The model of power system when renewable energy resources is connected is shown in figure 12.

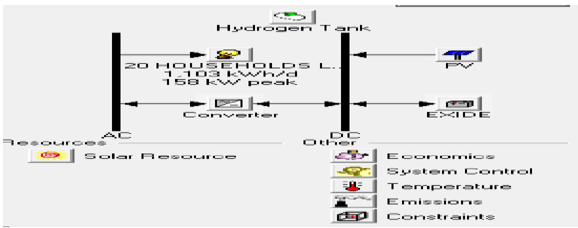


Fig.12 Power System of Renewable Energy

### i) POWER SYSTEM MODEL WHEN RENEWABLE ENERGY RESOURCES AND DIESEL GENERATOR USED

The model of power system when renewable energy resources and diesel engine is connected is shown in figure 13.

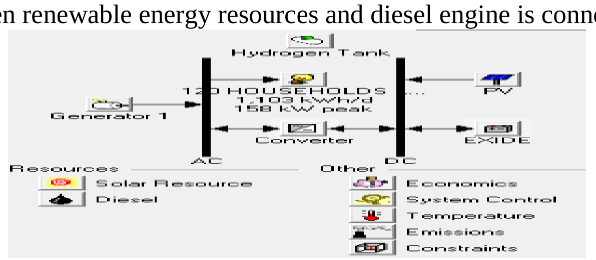


Fig.13 Power System of Renewable Energy and Diesel Generator

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## IV. MATALB OUTPUT RESULTS

**a) PV cell output results**
The result of PV Panel is shown in figure 14.

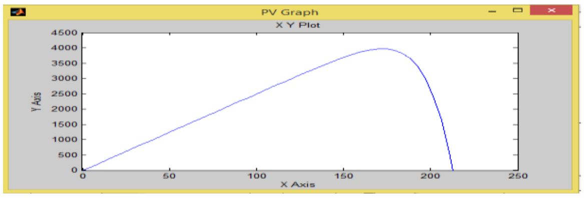


Fig 14 Photovoltaic cell PV characteristics

**b) FUEL CELL OUTPUT RESULTS**
The result of Fuel cell is shown in figure 15.

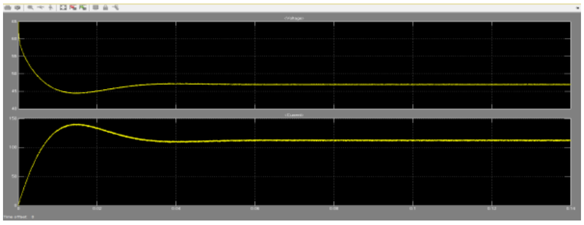

Fig 15 Fuel cell output current and voltage graph

**c) DC-DC CONVERTER OUTPUT RESULTS**
The result of DC-DC converter is shown in figure 16.

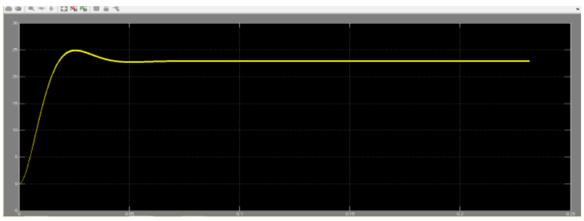

Fig 16 Output current of dc-dc converter

**d) UTILITY GRID OUTPUT**
Voltage input to the utility is 200volts (Phase voltage, maximum value). The value of line to line voltage can be calculated as $200*\sqrt{3} = 346.41$volts.

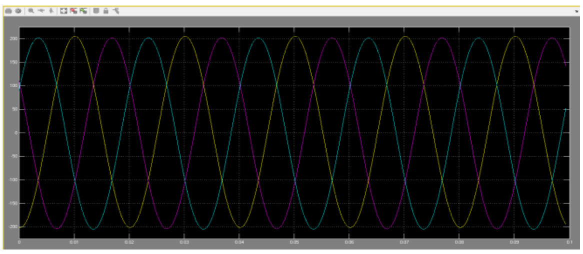

Fig 18 Three phase input voltage waveform to the grid

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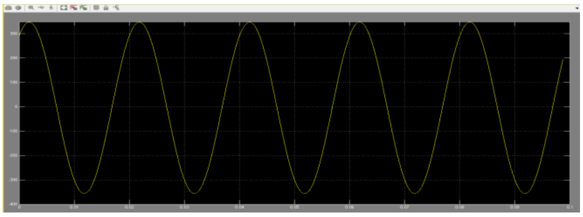

Fig 19 Line to Line input voltage waveform to the grid

Two three phase load of 2kW are supplied by the hybrid system at the two ends of the grid. A transmission line of 25km is used to transmit the power from one end to the other end and supply the loads. At the two sides of the transmission line two three phase transformers are connected to step up and step down the voltage level. A three phase source is also connected at the other side.

## V. CONCLUSION

It is observed that demand increases day by day and pollution is also increasing by a very fast rate. We require a power system which having a very less pollution content should also fulfil the energy demand. By using any renewable energy resources in standalone condition does not give the optimized solution, Also, it becomes very costly. Grid connected solar power plant gives the good optimal results and it is very cost effective. The total renewable energy potential in India is 1, 52000 MW, if we use more and more renewable energy than it is cost effective and also environment friendly.

## VI. ACKNOWLEDGEMENT

I feel much honoured in presenting this theses in such an authentic form of sheer and strength and continual efforts of inspiring excellence from various coordinating factor of cooperation. I'm grateful to my guide Mr. Akhilesh Dobhal whose expertise, understanding, generous guidance and support made it possible for me to work on this topic which was of great interest to me. My sincere thanks to Mr. Akhilesh Dobhal Head of Department Of Electrical Engineering, Mr. Prashant Thapliyal Asst. Prof. Department of Electrical engineering, GRD IMT, Dehradun.

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