Design of Fuel cell based Co-generation systems: An approach for battery less Solar PV system

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Abstract - *In Solar PV generation 40 % of the cost is to be invested in battery storage systems. The main drawback of battery storage system is they are not eco friendly and every 3 to 4 years they have to be replaced. The popularity of the renewable energy sources are favoring the Solar PV power generation but the financial viability of the project is not attractive because of the usage of the Batteries.*

In this project, a new methodology has been suggested to replace the batteries with Fuel cell based power generation. This model analyzes a standalone PV-hydrogen system. Excess solar power goes to the electrolyzer, which generates hydrogen for storage in the hydrogen tank. The fuel cell generates electricity using the stored hydrogen as fuel. The round-trip efficiency of the hydrogen storage system is not more than 50%. Because so much power is lost in the storage system, the energy production of the PV array exceed the electrical load. Although the average electric load is only 8.3 kW, the optimal PV array size is 100 kW. As a result, the cost of energy is very high, but in near future the cost of fuel cell and solar PV systems will drop further.

***Key Words*: Solar PV, Electrolizer, Battery bank. Fuel cell, Hydrogen Storage, CHP, CCHP.**

1. INTRODUCTION

Cogeneration is nothing but the Combined Heat and Power (CHP) which can be defined as the subsequent generation of two different forms of energy with a single primary energy source, mostly mechanical energy and thermal energy. Mechanical energy used to drive an alternator for producing electricity and rotating equipment such as motor, compressor, pump or fan for delivering other services. Thermal energy can be utilize may be for direct process applications or for indirectly production of steam, hot water, hot air for dryer or chilled water for process cooling.

2. CHP and CCHP Technology

Eco-generation defines the optimization of economic and ecological benefits in the power generation process. There are two major eco-generation initiatives and technologies that we will discuss in this article – cogeneration. CHP can volunteer a variety of economic benefits for large energy users. The high efficiency of CHP technology can result savings in energy when compared to conventional, separately purchased power and onsite thermal energy systems. To determine if CHP is likely to assist a compelling return on investment at a particular site, the costs of the CHP system (capital, fuel and maintenance) should be compared to the capital of purchased power and thermal energy (hot water, steam or chilled water) that would otherwise be necessary for the site. CHP can be installed in place of boilers or chillers in new construction project sites or when major heating, ventilation, and air conditioning (HVAC) equipment needs to be replaced or updated.

The conventional process of heating and cooling system causes a huge environmental pollution, which can be replaced by the technology of present era which is cogeneration and tri-generation. By this technology the wasted heat again can be utilized for the purpose of hot water system and by introducing paltrier cooling system. This will increase air quality by reducing emissions of air pollutants and greenhouse gases. The major regulated pollution includes particulates, SO2, nitrous oxide (NOx).

Cogeneration and tri-generation reflects distributed power generation at local or near the point of utilisation, so generation of electricity close to the end user helps in reduction of losses associated with transmission. Heat can extracted from the combustion process and can be stored as hot water and used for heating close to the source of generation. This process stabilizes the grid by reducing the need for expensive extensions to the grid and also minimizes the impact of prices in electricity and reduction of losses.

3. Fuel Cell System

Fuel cells are promising technology with the potential to serve power and thermal needs with very low emissions and with high efficiency. Fuel cells use an electrochemical or battery-like process to convert the chemical energy of hydrogen into water and electricity. Hydrogen and oxygen react to produce water in the presence of an electrolyte and, in doing so, generate and electrochemical potential that drives a current through an external circuit. In addition, the reaction produces waste heat. The hydrogen required for the cell is obtained from fossil fuels, usually methane, CH4. Because methane occurs naturally only in natural gas, fuel conversion is necessary if coal or biomass are the ultimate sources of the hydrogen.

The hydrogen can be extracted from processing natural gas, coal, methanol, and other hydrocarbon fuels.

3.1 Type of major fuel cells

There are four different types of fuel cells that are used for stationary combined heat and power (CHP) applications. Which are phosphoric acid (PAFC), molten carbonate (MCFC), solid oxide (SOFC) and proton exchange membrane (PEMFC). Two additional fuel cell types which are direct methanol (DMFC) and alkaline (AFC) utilized as primarily in transportation and non stationary fuel cell applications. The electrolyte and operating temperatures vary for each of the fuel cell types. The operating temperatures range from near ambient to 1800°F and electrical generating efficiencies range from 30 percent to around 50 percent on a range of Higher Heating Value (HHV) basis.

3.2. Fuel Cell Stacks

Convenient fuel cell systems require voltages higher than 0.55 to 0.80. When we combine several cells in electrical series with a fuel cell stack achieve the stack. Typically, there are several hundred cells in a single cell stack. With increasing in the active area of individual cells manages current flow. Typically, cell area can range from 100 cm2 to over 1 m2 depending on the type of fuel cell and application power requirements.

3.3. Power Conditioning Subsystem

Fuel cells always generate direct current of electricity, which requires habituation before serving a load. Depending on the cell area and number of cells, the direct current electricity is approximately 200 to 400 volts per stack. Stacks can operate in series to multiple individual stack voltages if the system is large.

4. HEAT RECOVERY FROM FUEL CELL

Heat can be recovered from fuel cell in the form of hot water or low-pressure steam (< 30 psig), but the quality of heat is vary, which depends on the type of fuel cell and its operating temperature. The one exception to this is, some manufactures of SOFC don't recover the heat for use in other applications rather uses the heat to boost the internal processes which helps to improve electrical generation efficiencies.

5. GREEN BUILDING TECHNOLOGY

Green building involves a building, which is designed, built, operated, maintained or reused with objectives to protect occupant's health, improves the employee productivity, use wisely natural resources and reduce the environmental impact. Green building which is also known as green construction or sustainable building expands and complements the building design concerns of economy, utility, durability, and comfort.

A Green Building where less water utilized, optimizes energy efficiency, conserves natural resources, generates less waste materials and provides healthier space for employee as compared to conventional buildings.

5.1. Objective:

The objective of the green buildings is to develop buildings which utilize the natural resources to the minimal at the time of construction and operational stage. Green buildings emphasize on the resource usage efficiency and also press upon the three R's - Reduce, Reuse and Recycle. Green Building is a team effort and the designing and construction includes consultants from architectures, landscaping, air conditioning, plumbing, energy and electrical field. These consultants assess the impact of the each and every design on the environmental condition, keeping in brain the capital involved. The final design needs to be practicable and should minimize the unconstructive impacts that the building would have on the environment.

Execution of the green building concept can lead to a decrease of carbon emission by thirty five percent, water handling by forty percent, solid waste decline by seventy percent and diminution in energy consumption by fifty percent. Green Building concept also calculates on the fact that an area with high bio-diversity should be avoided as a site for the construction of a building.

5.2. Principle:

Green Building principles includes a systematic and wide-ranging understanding of all the environmental impacts that occur throughout the building's life cycle and seek to get better the environmental performances throughout each stage of the life cycle. This approach is known as life cycle assessment which may be applied to products and services.

5.3. Different from conventional buildings

Both conventional and green buildings are poles apart though they are lookalike from outside, yet regarding type of technology used and benefits rendered. The main purpose of green buildings is to decrease energy and water utilization, recycling of ravage, using eco-friendly materials, etc. On the other hand, conventional buildings are typically not designed from the angel of view of energy, water, material and indoor environmental efficiency. It also minimizes the waste in construction by improving materials and reusing or recycling them.

In contrast to usual buildings, green buildings are additional energy efficient, have lower operational and maintenance costs, provide better placate and well-being for occupants, have lower risk potential and reduce negative impact on the environment. A green building is a building which represents the most well-organized and least disruptive way of using land, water and energy assets while ensuring the healthiest probable environment for the occupants.

5.4 India's Green Building Certification and Council

Indian Green Building Council (IGBC) has started IGBC Green New Buildings rating system to address the National priorities. This rating program is a tool which enables the designer to apply green concepts and reduce environmental impacts that are measurable. The rating program covers methodologies to cover diverse climatic zones and changing lifestyles.

6. SIMULATION RESULT

6.1. Introduction:

Now in this paper, to check the system efficiency simulation is being done by using HOMER software. The complete process of the integrating strategy can be understood from the figure below.

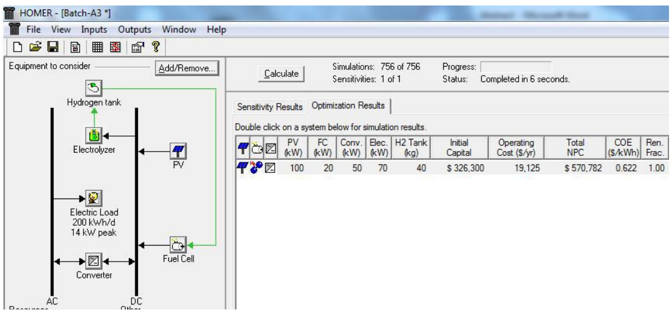

Fig -1: Simulation diagram of system

Here the electrolyzer will get the electricity from PV system for producing hydrogen to run fuel cell along with to meet both D.C and A.C loads. The produced hydrogen used in fuel cell to produce electricity. By this process the completely system becomes renewable. By this we will be able to run both A.C and D.C loads.

6.2 Cost summary

From the simulation report we analyzed the overall cost summary of the system i.e. the net present cost, levelized cost of energy, operating cost of the process. These figures are as follows. Again the graphical representation of the net present cost of PV, fuel cell, converter, electrolyzer, hydrogen tank with respect to capital cost, replacement cost, operating cost are done below.

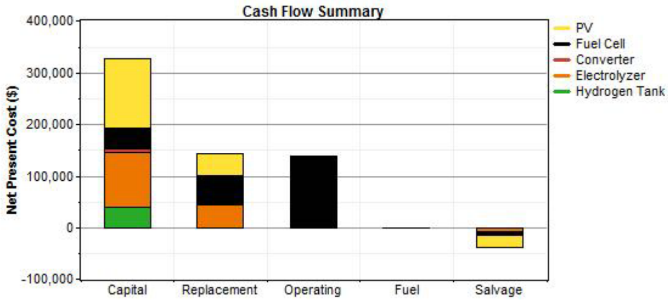

Fig -2: Cash flow summary

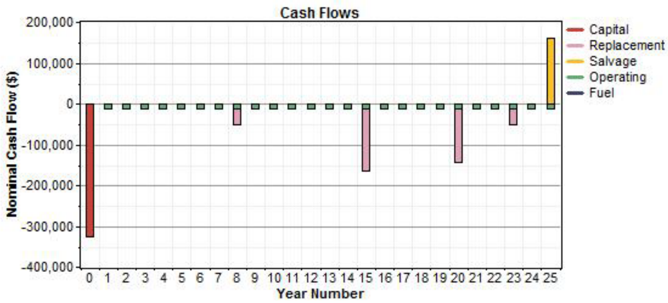

Fig -3: Year wise cash flow.

6.3 Electrical Output

To meet the electrical load demand here we are using both PV system and fuel cell. The production of the both system are given below in the table.

Component	Production (kWh/yr)	Fraction
PV array	177,552	84%
Fuel Cell	34,073	16%
Total	211,625	100%

Table 01 : Production rate

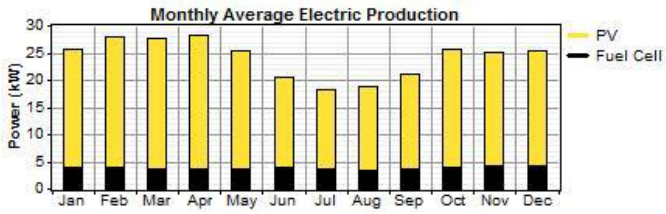

Fig -4: Average electricity production

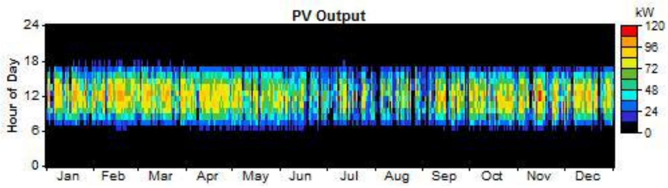

Fig -5: PV output

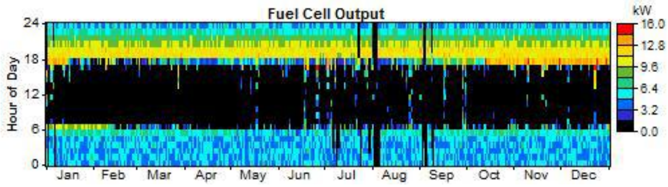

Fig -6: Fuel cell output

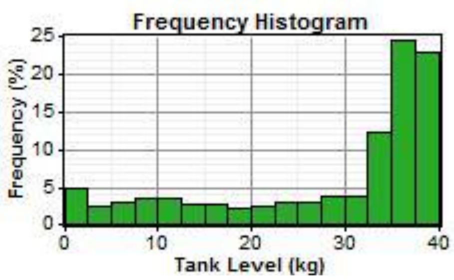

Fig -7: Hydrogen tank level

7. CONCLUSION

From the simulation report we got the result that how efficiently we can run the whole system by a solar plant and a fuel cell day and night without the help of any battery system. Thus here the cost, maintenance, and replacement of batteries are avoided. As the problems of batteries are avoided thus the payback period will reduce. The estimation of payback period is done and calculated to be 11 to 13 years. So from the report we can conclude that if we will go in this way we can create a green environment. Now one more thing is the cost of fuel cell and solar panel will reduce in the near future. Then obliviously the feasibility of the whole project will be more.

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