Assessment of Greenhouse Emission of a Typical PV Power Station

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***Abstract*- The energy generation by a photovoltaic power plant seems as nonpolluting method of energy generation. Therefore, LCA methodology is applied to analyze the environmental impact created in span of complete life of a PV power plant. The GHG emission, that is one of the impact indicators is analyzed in this paper. Energy consumed in manufacturing, assembling, transporting and in installing a PV power plant contribute to the GHG emission. From the LCA methodology, it is found that the profit of 120 ×10^6 kg CO2-eq/yr is earned by the PV power generation setup. The GHG emission saving further be improve if the energy consumption in manufacturing stage could be reduced.**

***Keywords*– Greenhouse emission, environmental impact, LCA.**

1. INTRODUCTION

The simple mechanism of producing electricity popularizes the PV system so widely. The on-spot electric generation is a major advantage of a PV system specially in the remote locations where it is difficult to disperse the transmission channel. It is a favorable choice at noise sensitive areas like residential, institutional and hospital buildings.

A typical PV system consists photovoltaic modules installed open to solar radiation that generate direct current (DC) and then it is fed to the charge controller which regulates the current according to the connected storage devices and load. An inverter is also connected in the circuit to convert the DC to alternating current (AC). Other monitoring and regulated devices are fuse box, switches, meters also connected in circuit to support the generation of electricity.

PV system have the most compatible mechanism can be categories as according to supporting system namely standalone photovoltaic, grid-connected, and hybrid photovoltaic systems [1]. Classification and configuration have shown in figure 1,2,3 respectively. Standalone systems are not connected to the utility grid and rely on battery storage to provide electricity when solar production is insufficient. These systems are common in remote areas without access to the grid.

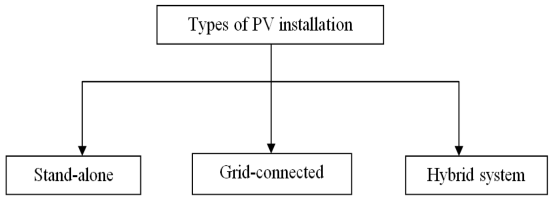

Figure 1: Classification of PV installation

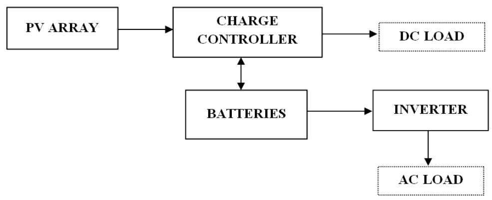

Figure 2: Configuration of Standalone PV system

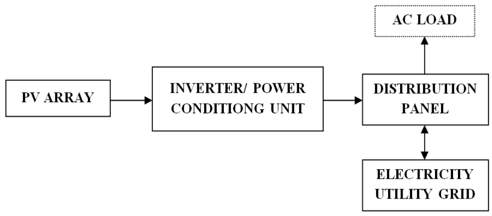

Figure 3: Configuration of Grid Connected PV system

Grid- Connected systems are connected to the utility grid, allowing users to draw electricity from the grid when solar production is low and sell excess electricity back to the grid.

Energy generation method using the photovoltaic panel system looks clean energy generation since it generates electricity without any emission. But for any system it is necessary to evaluate the complete life phases of that system in aspect of energy consumed. A LCA system is a tool which systematically evaluate environmental impact of a process, product or service throughout the lifespan [2]. It is a method to identify and quantify the usage of energy and material with the environmental release. LCA considers various stages, including resource extraction, manufacturing, distribution, use, and end-of-life treatment. The process involves compiling an inventory of all relevant inputs and outputs associated with each stage of the life cycle, such as energy consumption, raw material usage, emissions to air, water, and soil, and waste generation [3]. These inputs and outputs are then quantified and assessed based on their environmental impacts, often using impact assessment methods to analyze factors like greenhouse gas emissions, acidification, eutrophication, and more. This helps in decision making and comparing the environmental performance of the system. The international standard organization has a structured methodology for applying life cycle analysis approach to a product [4]. The structure of LCA is shown in figure. 4.

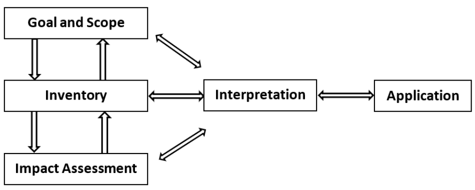

Figure 4: LCA Methodology **[5]**

LCA helps identify opportunities for environmental improvement and inform decision-making by comparing different product designs, materials, manufacturing processes, and other factors to determine which options have the least environmental impact. It's widely used in industry, policymaking, and research to promote sustainable development and reduce environmental burdens.

2. LCA OF PV SYSTEM

Many scholars have performed LCA for different configuration and at different location. Kumar et al. [6] suggested proposal of a 1 MW solar PV power plant at Malaysia, which can generate around 1390 MWh of electricity per annum with a GHG emission reduction of 818.71 tCO2 per annum. Luo et al. [7] applied the LCA methodology to compare the impact of module structure on energy payback time and greenhouse gas emission on different types of silicon technology in Singapore. The greenhouse gas emission for conventional module Al-BSF, PERC and frameless double-glass PERC solar cells are found as 30.2, 29.2, and 20.9 gCO2-eq/kWh respectively, which shows that using PERC cell technology without frame double glass module reduces EPT and GHG emission significantly and offer more environmental benefit over convectional module design. Magrassi et al. [8] studied environmental impact generated by the photovoltaic and hybrid gas turbine power plant of 100kWp operated with solar energy in Almeria, Spain. Author considered three scenarios as a full load, variable load depending on weather condition and variable load depending on solar irradiation level represented the greenhouse gas emission values as 0.236 kg CO2eq/kWh, 0.117 kg CO2/kWh and 0.043 kg CO2eq/kWh respectively. LCA of present PV station has been performed in following manner:

2.1 Goal and Scope:

In a PV power station, the main objective is the generation of a certain amount of electricity over a specified period thus the method is compared with the conventional method of electricity generation.

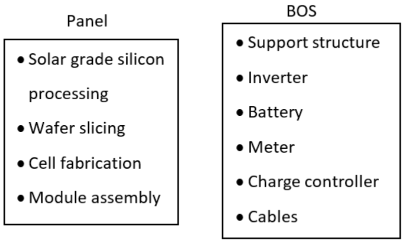

Figure 5: System Boundaries of LCA of PV station

2.2 Life Cycle Inventory:

For PV panels, the system boundaries as shown in figure 5, typically encompass the entire life cycle, from raw material extraction and manufacturing to transportation, installation, operation, and end-of-life disposal or recycling.

2.3 Life Cycle Impact Assessment

This section reviews the diverse environmental impact from the PV panels installation, generation and end of life stage. The assessment involves calculating the greenhouse gas emissions associated with the production, transportation, and operation of PV panels.

2.4 Interpretation:

In the final stage, the results of the LCA are interpreted and used to draw conclusions and make recommendations.

In this paper LCA of a typical PV station is analyzed on basis of energy generation and consumption. Since PVS offer no emission of pollutant gases or matter during the operational phase, its manufacturing and installation is included in the analysis.

3. METHODOLOGY

3.1 Specification of Plant

For the current study a solar photovoltaic of 62kWp is considered with the specification of following PV module in table 1. The location of the plant is considered Rajasthan where the yearly average global horizontal irradiation is 5.68kWh/m^2/day and the average ambient temperature and wind velocity remain in a range of 25ºC and 3 to 10 km/h respectively.

Table 1: Specification of PV Power plant

Component	Specification
Module	Poly-c
Module area	1.94 m^2
Total no. of module	200
Total area of module	388 m^2
Rated Power	310 Wp
Module efficiency	15.8%

A PV system should assume positive for the environment if GHG emitted by this system is less than the GHG emission generated by the conventional system i.e. coal fired system. The GHG emission is computed at each stage of manufacturing and installation of PV system**.**

3.2 Energy input

Energy requirement in installing a photovoltaic power generation unit includes mainly two components: energy in manufacturing of Photovoltaic panel and energy consumed in making and installing a PV system i.e. BOS and it includes inverter, supports cables and meter.

Table 2: Consumption of energy [9]

Component	Energy Consumption (kWh/m^2)	Energy Input (kWh)
Module manufacturing	976	3786×10^3
BOS	233	90×10^3
Miscellaneous (10%)	120	46×10^3

3.3 Energy output

The annual solar irradiation for the Indian subcontinent is 1200 to 2100 kWh/m^2 [10]. The power conversion efficiency of the module is found as 15.8%, performance ration of system is 77% [11] and the effective area of total modules are 388 m^2, total energy output is obtained by this equation

E_{ouptut} = I_{annual} × Area of module × power conversion efficiency (1)

E_{output} = 1700 × 388 × 15.8% × 0.77

E_{output} = 80247 kWh/yr

3.4 GHG emission of PV plant

Since coal is the major source of electricity generation in India, the GHG emission by any other generation method should be compared with this conventional method.

The GHG emission of the coal power plant is reported as 0.98 kg of CO_2-eq/kWh and with consideration of transmission and distribution losses, this value is taken as 1.58kg [12] [13]. The PV station benefits only when the GHG emission will be lower for the complete life cycle of the PV plant.

GHG generated in system installation = Energy consumed* GHG emission by conventional method (2)

- GHG emission in installation = 3922×10^3 ×1.58 kg CO_2-eq
- GHG emission saved = 80247×10^3 ×1.58 kg CO_2-eq
- GHG emission profit = 120 $\times10^6$ kg CO_2-eq/yr

4. RESULT

The LCA methodology is applied to analyze the environment impact produced by the energy generation form PV power plant. The energy consumed in manufacturing and installation phase is considered for the analysis. The GHG emission generated in installing a 62kWp power station is obtained as 6.2×10^6 kg CO_2-eq. The annual output generated is obtained as 80247 kWh and with this output annual saving of GHG emission is obtained as 120×10^6 kg CO_2-eq/yr. For life of a PV module is considered as 25 years, total 3×10^9 kg CO_2-eq is saved for the complete life of power plant.

5. CONCLUSION

A typical PV power plant is analyzed with the LCA methodology for the Greenhouse emission saving perspective. It is found from the analysis that:

- Total of 6.8 $\times10^6$ kg CO_2-eq GHG emission is generated in installing this PV power plant.
- The annual output generated is found as 80247 kWh with assuming 1700 kWh/m^2 insolation.
- PV power plant offer considerable saving in GHG emission as 126 $\times10^6$ kg CO_2-eq/yr.
- The GHG saving directly depends on the output generated from the PV panel that mainly depends on the specification of module and location of the plant.
- The embodied energy might get reduced with the technology upgradation, that further reduce the energy input.
- The efficiency of energy conversion changes over lifetime of module, that also affect the energy output.

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