Life Cycle Costing of a 100kWp Solar PV System

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Abstract- Energy scarcity is one of the major problems every developing country is facing. With increase of power production in many developing countries, sectors like healthcare, education and technology can be developed and germinate even in the remote corners of the country. Renewable energy is a promising source to solve energy related problems of the developing nations and help to accelerate growth. Global installed capacity of renewable energy technologies is growing rapidly, however the renewable sources have a few constraints with respect to the geographical locations and the financial aspects .The present study is focused on the financial aspects of a 100 kWp solar PV system in India. Financial analysis has been performed with present cost of the system and energy cost on life cycle basis. Standard financial procedures have been used mainly focusing on various life cycle stages such as raw material acquisition, manufacturing and operation & maintenance.
Keywords- Break Even Point (BEP), Life Cycle Costing (LCC), Life Cycle Analysis (LCA).

I. INTRODUCTION

In India about 96.7% of villages have been electrified till May 2015 [1] out of which 30% of the households get less than 12 hours of electricity supply with 23% of the households getting less than 8 hours of supply and the balance of 11% had either not supply or were getting just less than 4 hours of supply every day [2]. The demand for electricity is increased by 28% from 2009 to 2015 [3] and is expected to increase at the rate of 1.2% per year [4].Fig 1 gives the details of the deficit electricity over past 6 years. Power generation in India was only 4.1 billion kWh in the year 1947-48 and in the year 2002-03 it was more than 600 billion kWh. Based on the growth rate per year, per capita electricity generation would reach about 5300 kWh per year in the year 2052 and the total about 8000 billion kWh [4].

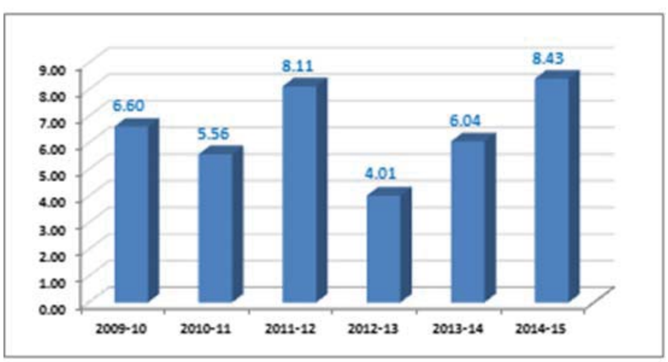

Figure 1: Trend of electricity deficit for past 6 years.

Majority of parts in India receives an average solar radiation of 4.85 kWh/m^2 per day and about 300-320 sunny days. The surplus solar energy can be utilized to in an effective way to optimize and solve the power crunch. The first commercial solar power plant in India was started in the state of Punjab with a capacity of 2 MW [5]. Over the capacity has grown, the present trend of the grid connected power capacities is shown in table 1 [6]. The State of Gujarat has commissioned Asia's largest solar park at Charanka village. The park is already generating 2 MW solar powers out of its total planned capacity of 500 MW [7].
The best suited solar system suited for Indian condition is Photovoltaic (PV) based panel. Generally there are two types of solar PV systems; Standalone system and a Grid connected. In grid interactive solar PV power systems, the DC power generated is converted to AC power using a inverter and is fed to the grid. The generated power during the sun hours are consumed by the load and excess is fed into the grid. In conditions where the system is dysfunctional due to cloudy weather the required power is drawn from the grid. The grid connected system works on net metering basis where in the consumer pays to the utility on net meter reading basis only.

Table 1: Electricity Generation scenario in India

Sector	**MW**	**%age**
State Sector	96,015	34.7
Central Sector	74,171	26.8
Private Sector	106,597	38.5
Total	**276,783**	
Fuel	**MW**	**%age**
Total Thermal	**192,535**	**69.6**
Coal	168,208	60.8
Gas	23,333	8.4
Oil	994	0.4
Hydro (Renewable)	41,997	15.2
Nuclear	5,780	2.1
RES** (MNRE)	36,471	13.2
Total	**276,783**	

Table 2: Latest installed capacities of renewables in India [6]

Sector	**share**
I. GRID-INTERACTIVE POWER (CAPACITIES IN MW)	
Wind power	24088.36
Solar power	4229.36
Small Hydro Power	4146.90
Bio-Power	4418.55
Waste to Power	127.08
Total	37010.25

II. LIFE CYCLE COSTING (LCC)

To carry out LCC, focus must be on Life Cycle Inventory which is in turn an important part of the LCA.

2.1 The Structure and components of LCA

Life Cycle Assessment (LCA) is the process of quantifying the material and energy flows and potential environmental impacts of technological systems. Roots of the life cycle concept can be traced back to the 1960s, when its forerunners, *net energy analysis, resource and environmental profile analysis*, were developed. Since the 1990s, LCA has developed further through efforts of the Society of Environmental Toxicology and Chemistry and, more recently, the International Organization for Standardization. Current international LCA standards are described in the ISO 14040.
LCA has some key distinguishing features. First, all analysis are based on a predefined quantity of product or service called the functional unit. As most LCAs are comparative in nature, the functional unit provides a logical basis for comparing the environmental performance of alternatives. For example, in the LCA of power generation systems a suitable functional unit would be 1 kWh of electricity. A second characteristic of LCA is that the both direct and indirect environmental effects of the system being studied and assessed. Major activities in the entire product chain – from the cradle to the grave – are included. In the case of electricity generation, for instance, environmental impacts arising from fuel extraction, storage and delivery are included along with direct power plant emissions. Finally, LCA relies on a multiple criterion perspective by quantifying different forms of environmental impact such as global warming, acid rain formation and ozone depletion.

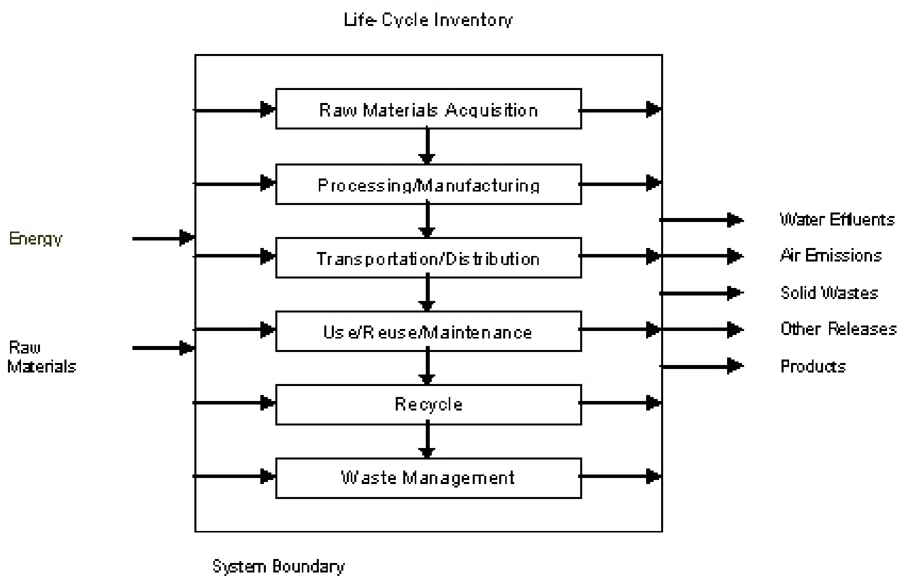

Figure 2.Life cycle system of a generic system

Figure shows the schematic of a generic life cycle. Although the stages shown apply to the case of a manufactured product, the concept is easily extended to include other products (such as heat or electricity) and services. The components of LCA are discussed below.

2.1.1 Goal and Scope Definition

Goal definition involves identifying the specific purpose of the LCA and the end-user of the information generated in the study. In most cases, LCA involves quantitative or qualitative comparison of alternative technologies. The results can be used to aid different levels of decision-making in scientific, corporate or public policy applications.
Scope definition involves identifying the system boundary (i.e., processes to be included as part of the entire life cycle system), the functional unit, and assumptions specific to the system being assessed. The level of detail of the LCA is also defined, for example by identifying the pollutants to be assessed. In practice it may also be possible to "streamline" or simplify the LCA.This section defines the scope of the analysis for the product's system. It offers guidance on what to include or exclude from the life-cycle inventory analysis. - Include in the

product's system the panels, the mounting system, the cabling, the inverters, and all further components needed to produce electricity and supply the grid. - Include the energy- and material-flows caused by manufacturing and storage, climate control, ventilation, lighting for production halls, on-site emissions abatement, and onsite waste treatments. - Commuting (transportation to and from work), administration, sales, distribution and research and development (R&D) activities are typically not included in the LCAs of conventional power generation systems. Such activities should therefore also be excluded from the LCA of PV systems, lest misguided comparisons are made; alternatively, if included, their contribution shall be analyzed and reported separately from that of the manufacturing phase. The assumptions are interest rates are not considered, Recycle and Waste management are not part of this study and cost per unit assumed same throughout the period of 25 years.

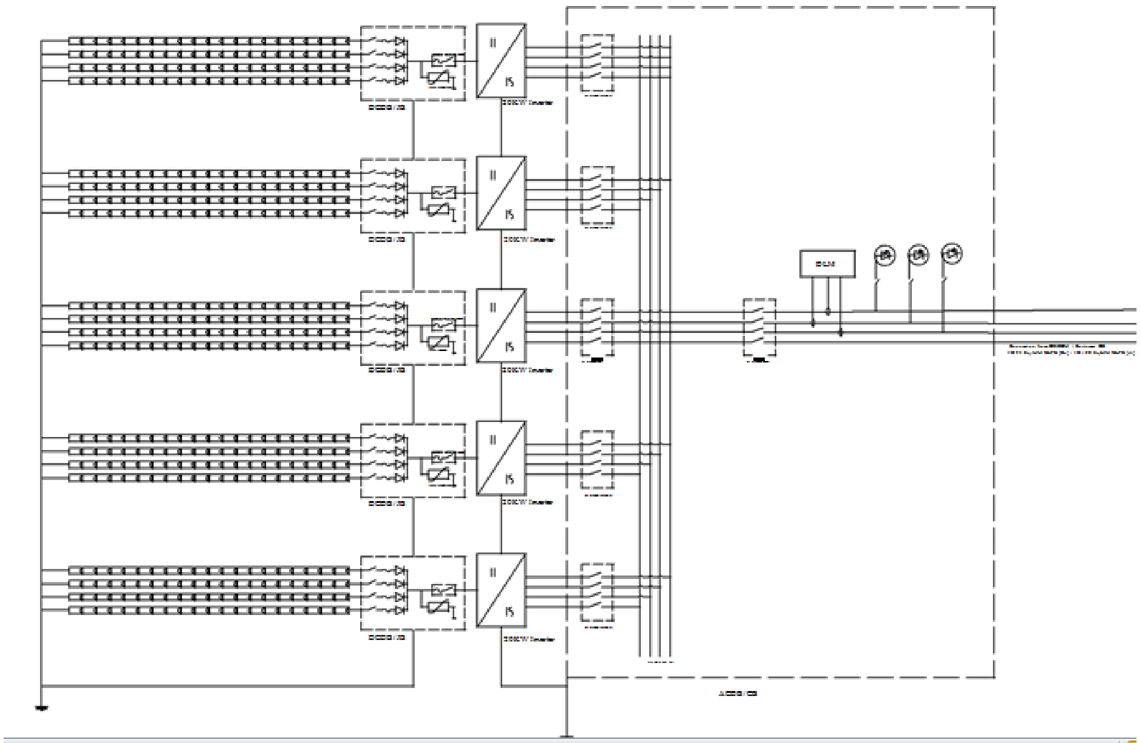

Figure 3: Line Diagram of SPV

III. ECONOMIC ANALYSIS

In this section, cost analysis and total revenue of solar power plant is studied. Cost analysis is related with expenses of an individual component of the plant and the total revenue indicates the total income of the solar power plant.

3.1 Cost Pay Back Time (CPBT) or Break Even Point (BEP)

The **break-even point** (BEP) in business and specifically cost accounting, is the point at which total cost and total revenue are equal: there is no net loss or gain, and one has "broken even." A profit or a loss has not been made, although opportunity costs have been "paid", and capital has received the risk-adjusted, expected return. In short, all costs that need to be paid are paid by the firm but the profit is equal to 0.

Table 3: Bill of materials including the cost of all components

S.No	Components	System Capacity	Quantity	Total Cost(Rs.)
1	PV Panels	250W each	400	40,00,000
2	PCU/String Inverters	20KW each	5	12,50,000
3	Module Mounting structure	100KW	-	9,00,000
4	Controls	100KW	-	3,00,000
5	Cables	100KW	-	2,50,000
6	BOS	-	-	2,35,000
7	Lightning Arrester	-	-	50,730

8	Cable Trey and Earthing	-	-	1,00,000
9	Transportation and logistics	100KW	-	2,00,000
10	Installation and commissioning		-	2,50,000
TOTAL				75,35,730

IV. RESULTS

4.1 Total Revenue

Total units produced by 100kWp system in one year = 150MWh (i.e 1, 50,000kWh)

(At a location in Huzarabad, Telangana, India.)

Revenue generated (at the rate of present selling price of Rs. 5.4) = 150000*5.4= =Rs. 8, 10,000.

The generation efficiency of the solar PV system is expected to decrease by 0.5% in every 5 years:

Total units produced in 25 years life time

=(1+0.995+0.99+0.985+0.980)*(150000*5) = 3712500 kWh

Average number of units consumed = 50*12*25=15000 kWh

(50 units per month of Electric Energy consumption for cleaning of modules)

Net units produced = 3712500-15000= 3697500 kWh

Total revenue generated by plant in 25 years life time (based on present selling price Rs. 5.4) = 3697500*5.4 = Rs. 19966500/-

4.2 Cost Pay Back Time

Hence, total revenue in 25 years = Rs.19966500

Installation cost of the plant =Rs.7535730

CPBT is the period in which ,we will be able to recover the investment cost of the plant.

So, CPBT = 25*7535730/19966500 = 9.43 years.

Life Cycle Cost for producing a kWh of electricity by a 100kWp Solar PV system over a life time of 25 years = 7535730/19966500= Rs. 0.377

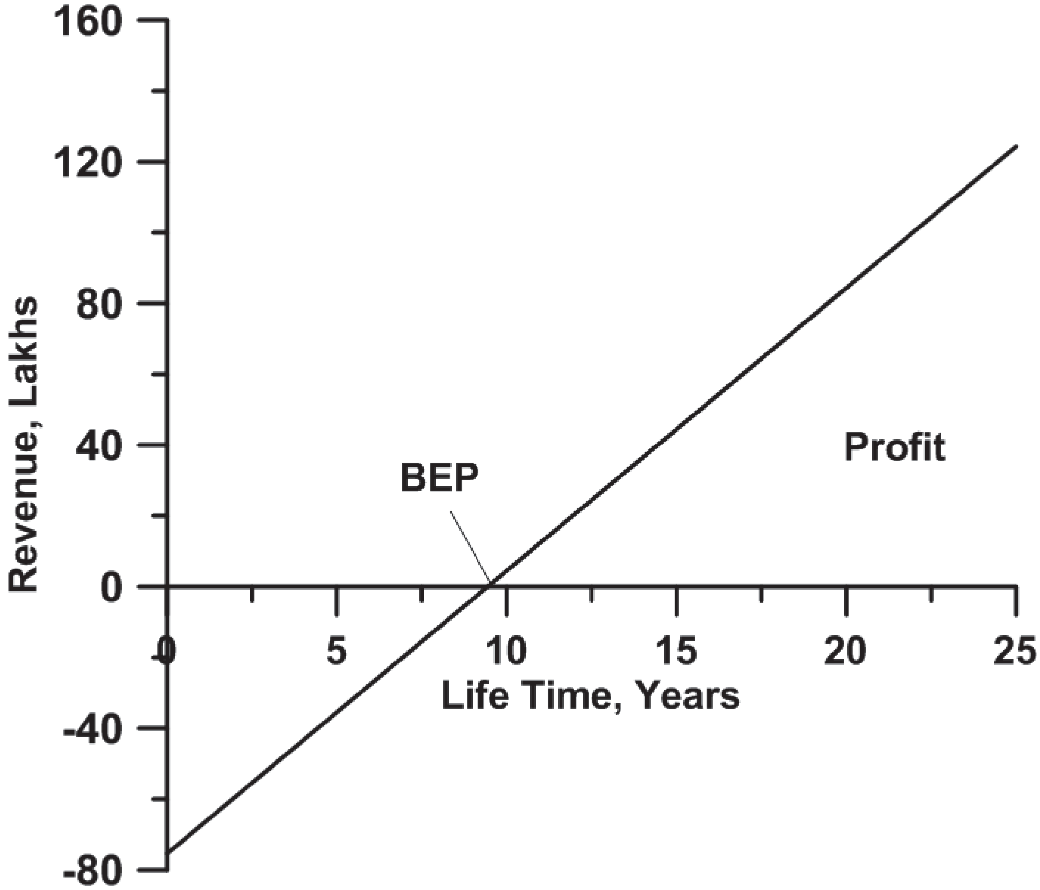

Figure 4: Graph showing BEP

V. SUMMARY

Since the plant includes all the components mentioned in the bill of materials, it has been seen that PV module cost (Rs.40, 00,000) is major in the establishment of a SPV plant. In Telangana, one unit is sold to grid at Rs. 5.4, and the total life of the plant is considered as 25 years, so total revenue generated for that 25 years is Rs.19966500 /- . Cost at the time of installation is Rs. 7535730 (without battery bank). So that the investment cost of the plant will be recovered in 9.43years. Variation in CPBT or BEP is dependent up on many factors such as the type of solar cell, irradiation at the location, capacity of the system and deterioration in the performance of Solar Modules.

VI. CONCLUSIONS

The stages of life cycle that incurred major investment in setting up a 100 kWp Solar PV plant are PV Panels, PCU/String Inverters and Module Mounting structure. The breakeven point has been found to be 9.43 years which is approximately same as BEP found in previous studies of world literature. Improvements in conversion efficiencies of Solar modules may reduce the BEP in future.

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