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COST BENEFIT ANALYSIS OF A ROOFTOP PV SYSTEM: A CASE STUDY AT BITS WARANGAL

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Abstract: Reliable grid integration is one of the important, if not the most important technical difficulty in the destiny. Rooftop solar is the most effective RE section that lags in the back of markedly in attaining the objectives set by almost all the nations. While in case of India this target is fixed to 175GW by 2022.In this paper to expedite the boom of rooftop, the gainsays (the fact) handling the rooftop is wish to be addressed and the generated green power is used within the campus. Case study is analyzed which was a ongoing project at **Balaji Institute of Technology&science, Warangal,** where all the building blocks are equipped with Solar panels and the power generated through them is directly fed to the different loads in the campus along with the classroom load. This paper also covers a techno economical analysis of currently installed solar PV rooftop system in the campus rooftops.

Key Words: ***Rooftop PV, Cost benefit analysis, Payback duration, environmental effect, Net metering***

NOMENCLATURE

RE Renewable Energy
MW Megawatts
GW Gega Watts
PV Photovoltaic
W_{day} Energy consumed per day
H_i No. of hours that i^{th}load is ON
P_i Wattage of i^{th}load
N_i No. of loads of i_{th} type
Psolar Power genr. by solar panels
I_r Light irradiation
d De-rating Factor
N_s No. of Solar panels
P_v Output of each panel
N_{bat} No. of batteries
V_{bat} Voltage rating of battery
I_{bat} Current rating of battery
DoD Depth of Discharge
W_{load} Load demand in Watts
W_{solar} Load supplied by PV in Watts
DF Diversity Factor
P_i Rating of the Inverter
C_{grid} Cost of power from the conventional grid
C_{pu} P.U cost of grid power
T Time in years
C_{pv} Cost of PV installation
C_{panel} Cost of PV panel
C_{bat} Cost of Battery
C_{bat} Cost of Inverter
C_{charge} Cost of charge controller
$C_{pv\ after\ subsidy}$ Cost of PV system

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after subsidy

I.INTRODUCTION:

Rooftop solar is the only renewable energy segment that lags behind markedly in achieving the targets set by the central government.

The main aim of national solar mission of India is

1. To create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022.

2.To ramp up capacity of grid-connected solar power generation to 1000 MW within three years – by 2013; an additional 3000 MW by 2017 through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff. This capacity can be more than doubled – reaching 10,000MW installed power by 2017 or more, based on the enhanced and enabled international finance and technology transfer. The ambitious target for 2022 of 20,000 MW or more, will be dependent on the 'learning' of the first two phases, which if successful, could lead to conditions of grid-competitive solar power. The transition could be appropriately up scaled, based on availability of international finance and technology.

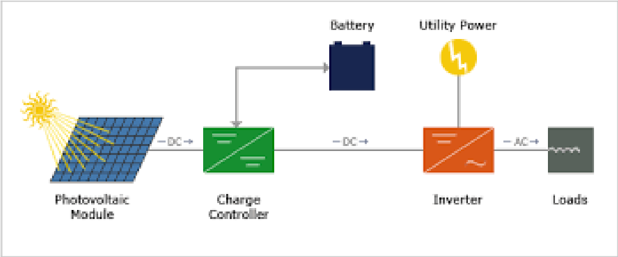
3. To create favourable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership.

4. To promote programmes for off grid applications, reaching 1000 MW by 2017 and 2000 MW by 2022.

5. To achieve 15 million sq. meters solar thermal collector area by 2017 and 20 million by 2022. To deploy 20 million solar lighting systems for rural areas by 2022

But the second side of the coin is following disadvantages, they are Two lacking items in rooftop are the residential part and agriculture part. The residential part faces some problems together with low cognizance, convenience of and delays in subsidies and a selection of troubles concerning person interface and patron expertise with Discoms. On the opposite hand, Discoms, who have very important role, because Discoms stand to lose sales from this type of movement. As on 31-03-2019 the total installed capacity in India is about 356.100GW.

Block diagram of proposed rooftop model is shown below



Grid connected installed capacity from all sources as of 31 May 2018.

Source	Installed capacity in MW	Share in percentage
Coal	**196,957.50**	**57.27**
Large Hydro	**45,403.42**	**13.20**
Renewable	**69,022.39**	**20.07**
Gas	**24,897.46**	**7.23**
Diesel	**837.63**	**0.24**
Nuclear	**6,780.00**	**1.97**
Total	**343,898.39**	**100.00**

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1.1. Problems with conventional Grid

1. Blackouts
2. Load shedding
3. T & D losses
4. Weak Interregional corridors due to multiple outages
5. Mal-operation of protective relays
6. under/Over Frequency,etc,
7. Pollution
8. Thefting of power on distribution lines (The only non-Technical loss) etc

The major contribution is given by Thermal plants which is the main cause of CO2 emisson,on of the best alternative for thermal plant is Solar power generation, which is a one of the most cleanest form of renewable energy source available. Light from the sun can be converted into either heat or electricity to help power to homes and commercial applications. Solar panels also known as PV modules, which contains photovoltaic (PV) cells, made from Silicon that converts the light from the sun into electricity.(Photovoltaic=Sun from the electricity. Photo=Sunlight, Voltaic=Electricity).The traditional read that the star electrical phenomenon strength is bigger expensive compared with the grid provided electricity at retail degree, it is being challenged by the non-stop fashion of lowering value the worth the value} of star technology and elevating price of fossil fuels

Typical household gets electricity from the local utility on the charges pre-determined within the tariff plans of the utility. However, because of lack of sufficient generation potential there are shortages and the utility can also should hotel to load losing leading to strength cuts for the stop purchasers. Moreover, because the prices of fossil fuels boom, the electricity tariffs are also elevating. In this state of affairs, some consumers may additionally need to discover and shift to trade resources for assembly their demand. However, moving to solar energy calls for upfront funding. The monetary benefit needs to be justified so that you can convince the purchaser to make the preliminary investment. A ordinary patron may not have the technical and industrial understanding to install and function the sun equipment. Consumer has to get expert advice from third party businesses which might not be dependable and custom designed to specific necessities.

The key benefits of solar generation are follows

1. Continuity of supply
2. Dependency on conventional grid decreases
3. Pollution is reduced
4. Less maintenance
5. No frequent purchase of Fossil fuels
6. Requires only capital investment
7. Free from Dynamic tariffs
8. Storage facility by means of batteries
9. No issue regarding transmission and distribution losses

The proposed approach is helping us in study of grid connected PV system where a fraction of energy is generated from renewable source. The capacity of the generation purely dependent on space and light irradiation. In this paper we consider a cost benefit analysis of a two building blocks of **BALAJI** group of institutions, where they were equipped with solar panels to support the demand of the institution.

On Site Investigation from the authors

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Operation:-When ever light irradiation starts drift currents are start accelerate which will build up some voltage which will combine with neighboring panel voltage in the array, leads to buildup the rated value, a charge controller is employed to control the fluctuations v& I before the battery set-up. A typical inverter is installed for the conversion DC-AC to serve the AC utilities in the home as well as in college.

Battery and Inverter set-up

II.MATHENATICAL ANALYSIS OF ROOF TOP SOLAR PV SYSTEM

While designing the rooftop PV system, we should take care about the appropriate sizing of PV-system, number of panels, Net metering equipment, and several multifunction meters.

In this section we are going to do mathematical model, that is depending up on the requirement of the load we are going to calculate number of panels, rating of each panel, inclination of panel to the current longitudinal conditions, placement of net metering equipment, and last but not the least calculation of load, generation of power by installed PV system.

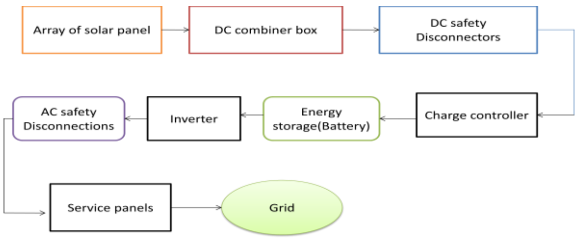

Fig.1 Block diagram of Rooftop solar system

I. Technical Analysis

a) Calculation of number of solar panels required:

$$W_{day}=\frac{\sum_{i=1}^{n} H_i P_i N_i}{1000}\text{Kwh} \qquad (1)$$

Depending up on the historical data available we are going to calculate the different types of load, how many hours the working and what is the rating of different types loads. After calculation of load we have gone through the daily & monthly loads and their respective tariffs, per day energy consumption is calculated by using the below equation.

Where i is the index of each type of load such as light, computer, fan etc,P_i=power rating of i^{th} load,H_i is number hours that type " i" device works per day,N_i is number devices of i^{th} type is used per day.

To meet the above calculated load we need to generate appropriate solar power, for which every factor of solar panel comes in to picture like efficiency,de-rating factor of panel with respect to atmospheric condition, Thus the total PV generation can be obtained by following equation.

$$P_{solar}=\frac{Wday}{I_{r*}d}\ \text{Kw} \qquad (2)$$

Where I_r average number of sunshine hours at installation (According to MNRE it is about 5.5 hours in Telangana), which will actually influence the solar power generation and also panel efficiency, and average de-rating factor is about 75%.

From the above consideration from MNRE and weather information available the number of panels required to install to satisfy the above demand is as follows.

$$N_s=\frac{P_{solar}}{P_V} \qquad (3)$$

Where P_v is out power of each solar panel.

b) Calculation of number of batteries required: let we shift our sight to bulk generation to established PV generation. Generation pattern from solar PV cell is completely mismatch from the existing load demand, such difficulty partly nullified by installing batteries

Size of a battery depends on

1. Source availability
2. Size of solar panel
3. Time of day price
4. Charging and discharging time of battery
5. Depth of Discharge

We need to store the power in battery either generation is higher than existing load demand or during low tariff time.

$$W_{load} \leq W_{solar} \quad (4)$$

Draw the power from battery either load is higher than generation or during high tariff time

$$W_{load} \geq W_{solar} \quad (5)$$

The number of batteries and size of each battery is obtained from the following equation

$$N_{bat} = \frac{W_{day} * Backup\ days}{V_{bat} * I_{bat} * DoD} \quad (6)$$

I_{bat} is battery current rating and DoD is Depth Discharge and V_{bat} is battery voltage rating.

C) Size of Inverter: Size and rating of inverter depends on

Generated voltage, peak voltage & diversity factor

Where

$$DF = \frac{\text{Maximum Demand on the system}}{\text{Peak demand on the installed generation}}$$

(7)

$$P_{inv} = \frac{\sum_i^N P_i N_i}{DF} \quad (8)$$

II.Cost benefit Analysis

a) Profit from Solar generation: This discussion completely involves how the investor gets returns for his capital investment, when he is interested to cut out from conventional grid and how he/she is directly helpful to the environment.

Let C_{grid} is the cost of power from the conventional grid,C_{pv} is the cost of power derived from rooftop generation along with the subsidy from both state and central governments for life time period of **T** years,C_{pu} cost per unit(Tariff) charged by respective state boards.

$$C_{grid} = 365 * W_{day} * C_{pu} * T \quad (9)$$

While coming to the rooftop solar plant installation major components are as follows

1. Solar panels
2. Batteries for storage
3. Inverter and
4. Charge controller.

So cost of PV generation will includes the individual cost above family members, so cost of PV generation is

$$C_{pv} = C_{panel} + C_{battery} + C_{inv} + C_{charge} \quad (10)$$

Various central and state government schemes are available to get solar panels with subsidies like KUSUM, Krishi jagan, Surya raitha and Suryashakthi Kisan Yojana etc., now various schems provides a maximum 30% subsidy.

Let Subsidy provided by various government bodies is $P_{subsidy}$ so the cost of installation of roof top is given by

$$C_{pv\ after\ subsidy} = (1 - \text{percentage of subsidy by the govt.}) C_{pv}$$

$$C_{pv\ after\ subsidy} = (1 - P_{subsidy}) * C_{pv} \quad (11)$$

Thus total profit by PV generation is given by

$$\text{Cost benefit (Profit)} = C_{grid} - C_{pv} \quad (12)$$

Along with profit for the installation we have following

Advantages

1. We have reconstructed power system
2. We can proudly save some fossile fuels for next

Generation

3. Pollution control
4. Transmission and Distribution losses are simply neglected
5. No possibility of non-technical loss
6. Cost for both transmission and distribution installation

and maintenance is neglected

6. Water wastage is controlled while in case of Thermal
plants, which is a primary natural resource we should save for our children.
7. Space Saving, i.e, no separate space is required.

God never made perfect things, i.e; the second side of the coin is disadvantages of PV system are as follows

1. What about the Toxic waste generated at the time of solar panel manufacturing
2. As the maximum lifespan of solar panel is about 25
Years, what about the disposal of panels once it's life time is over
4. What about the Radio emission (radiation) at the time of power generation.
3. Solar plant can't give any assurance that Iam going to generate X_{MW} of peak power whenever we require, because whose generation purely depends on atmospheric condition.
5. Firm Capacity is purely dynamic in nature.

b)Tailback period:

Tailback period is defined as the amount of time in which the invested capital amount bounces back, by selling/utilizing the generation.

Calculation of time required to make the savings equal to the capital investment

$$C_{pv}=W_{day}*365*T_{pay\text{-}back}*C_{pu} \quad (13)$$

$$T_{pay\text{-}back}=\frac{C_{pv}}{Wday*365*Tpay-back*Cpu} \quad (14)$$

b) Ecological Impact/Consequences:

we should concentrate mainly how much amount of CO_2 emission is mitigated. Central Electricity Authority(CEA) will take about advisory body on technical environmental matters in India, which is works under the Ministry of power(MoP).From the recent gazette released by CEA average CO_2 emission by thermal plant is about 0.82Tonns/MWh. From this data we can calculate average CO_2 emission mitigation from the following formula

$$CO_{2\ mitigation}=\frac{Wday*0.82*365*25}{1000} \quad (15)$$

On average one Acre of new forest can sequester about 205 tons of CO_2 annually.

Young trees absorb CO_2 at a rate of approximately 6 kgs per annum.

A middle age tree (about 10 years) absorbs CO_2 at a rate of approximately 22 kgs per annum.

ON SITE EXAMPLES:

i.House of 6 rooms:

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a)Energy consumed per day (W_{day}) =

$$\frac{(8*40*8)+(8*80*5)+(12*250*1)+(8*200*1)+(5*200*2)+(0.4*500*1)+(10*30*2)}{1000}$$

=13.16kwh

c) Total PV generation capacity required (P_{solar}) = $\frac{13.16}{5.5*0.75}$ =3.19kw

c) Number of solar panels required to meet the load demand (N_{solar})

=$\frac{3.19*1000}{255}$ **= 12.5 =13**

d) Cost of each panel (Panel cost) = 13*13,500 =1,75,000 /-

e) No. of batteries required (N_{bat}) = $\frac{W_{day}*Backup\ days}{V_{bat}*I_{bat}*DoD}$

V_{bat}.is battery voltage ratingV = 220

I_{bat} is battery current rating = 12 mah

DoD is Depth Discharge = 0.5

= $\frac{13.16*1000*3}{12*220*0.5}$ = 29.90 = 30 = 31

f) Cost of 13 batteries = 31*13500 = 4, 15,500/-

g) Size and cost of Inverter (P_{inv}) = $\frac{255*13}{1.7}$= 1950=2000 wtts

Let Inverter cost per watt would be Rs 7.4/- per watt

Cost of inverter = 7.4*2000 =14,800/-

Total cost of Entire set up = Cost of Panels+Cost of battery + cost of Inverter+ miscellaneous

= 1, 75,000 + 4, 15,000 +14,800 + 10,000

Total cost of Entire set up = 6, 15,700/-

Consider 30% subsidy = 6, 15,700*$\frac{30}{100}$ = 1,84,710/−

Net cost of installation is = 6, 15,700 – 1,84,710 =4,30,990 /-

Total electricity bill for 25 years at 7/- per watt = 365*25*7*13.16 =8, 40,595/-

Total profit by solar system = 8, 40,595 - 4,30,990 = 4,09,605/-

Total CO_2 emission mitigated = $\frac{13.16*0.85*365*25}{1000}$ = 102 Tons

Payback period = $\frac{4,09,605}{8,40,595} * 25 = 12.18$ years

Above Installation will approximately equal to plantation of 650 tress, which will be the actual profit to us which will saves our future India.

Case Study 2

Typical EEE Building at BITS: Existing Load

S. No	Name of the Device	Used hours per day	Power rating in watts	No.of devices of such type
1	Lights	8	40	8
2	Fans	8	80	5
3	Refrigerator	12	250	1
4	Computer	8	200	1
5	Television	5	200	2
6	Washing machine	0.4	500	1
7	Miscellaneous	10	30	2

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S. No	Name of the Device	Used hours per day	Power rating in watts	No.of devices of such type
1	Computers	5	200	42
2	Fans	6	80	97
3	Exhaust fans	6	60	3
4	LED Tubes	5	20	40
5	Projectors	2	150	4
6	LED bulbs	6	20	20
7	Florescent Tubes	6	50	40
8	Air Conditioners	6	3500	8
9	CFL	6	15	20
10	CC	24	50	10

Total cost of Entire set up = 1,30,93,600/-

Energy consumed per day (W_{day}) =

$$\frac{(42*200*5)+(97*80*6)+(3*60*6)+(40*20*5)+(4*150*2)+(2*20*6)+(40*50*6)+(3500*8*6)+(20*15*6)+(50*10*24)}{1000}$$

=291.04kwh

Consider 30% subsidy = 1,30,93,600*$\frac{30}{100}$ = 39,28,080/−

Net cost of installation is = **1,30,93,600**–39,28,080 =91,65,320 /-

Total electricity bill for 25 years at 7/- per watt = 365*25*7*291.04 =1,85,90,180/-

Total profit by solar system = 1,85,90,180 - 91,65,320 = 94,24,660/-

Total CO_2 emission mitigated = $\frac{291.04*0.85*365*25}{1000}$ = 2256 Tons

Payback period = $\frac{94,24,660}{1,85,90,180} * 25 = 12.67$ years

Total PV generation capacity required (P_{solar}) = $\frac{291.04}{5.5*0.75}$ =70.55kw

Number of solar panels required to meet the load demand (N_{solar}) =$\frac{70.55*1000}{255}$ = 276.66 =277

Cost of each panel (Panel cost)

= 277*13,500 =37,39,500 /-

No. of batteries required (N_{bat}) = $\frac{W_{day}*Backup\ days}{V_{bat}*I_{bat}*DoD}$

V_{bat}.is battery voltage ratingV = 220

I_{bat} is battery current rating = 12 mah

DoD is Depth Discharge = 0.5

$= \frac{291.04*1000*3}{12*220*0.5} = 661.4545 = 662$

Cost of 662 batteries = 662*13500 = 8,937,000/-

Size and cost of Inverter

(P_{inv}) = $\frac{255*277}{1.7}$= 41,550 wtts

Let Inverter cost per watt would be Rs 7.4/- per watt

Cost of inverter = 7.4*41500 =3.07,100/-

Total cost of Entire set up = Cost of Panels+Cost of battery + cost of Inverter+ miscellaneous

= 37,39,500 + 8,937,000 +3,07,100 + 10,000

Above Installation will approximately equal to plantation of 2502 tress, which will be the actual profit to us which will saves our future India.

Conclusions and Important observations:

The main aim of this paper is to calculate the Techno economical analysis of roof top solar power station, and also we try exploit the benefits of solar power to the society that is in terms of revenue, land ,and also environment by reducing the CO_2 emission.

1.For a typical household the installation cost of rooftop solar system is 4.30lakhs,with a life time profit of 4.09lakhs in 25years.

2.The payback period is 12.18 years, with average CO_2 reduction of 102Tons.

3.For a typical Engineering block of EEE the installation cost of rooftop solar system is 91.65 Lakhs, with a life time profit of 94.24 lakhs in 25years.

4.The payback period is 12.67 years,with average CO_2 reduction of 2256 Tons

5.The most dominant component in the installation are batteries because we have gone through 3 day backup period,i.e, cost and size of the battery depends up on backup period.

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