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# Financial Analysis of Solar Photovoltaic Power plant in India

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***Abstract:*** *Solar photovoltaic (PV) power systems for both utility as well as roof mount applications growing rapidly in India. Solar power plants in India till date are mostly ground-mounted power plants. Most of the utility scale PV power plants are typically in the scale of 5 MW in size and connected to the electrical grid.*
*The objective of this study is to present the financial feasibility of 100 KW roof top solar PV power. State of art technology of solar PV modules, power electronics with fixed mounted array is considered for an educational institute. Presently the institute is using utility power and also diesel generator to backup for power outing. Financial analysis has been performed with present system cost based on life cycle cost of energy. Standard financial procedures have been used and the sensitivity parameters studied, mainly focusing on various factors, solar insolation variability at the site, the financial interest rates and operational and maintenance cost. The feasibility analysis results were discussed and presented in the conclusions.*
***Keywords:*** *Photovoltaic, Financial feasibility, Financial analysis, Insolation variability*

## I. Introduction:

The energy consumption of India is now soaring and may face severe electricity shortages in the near future. India needs a sustained growth rate of 9 to 10% over the next twenty years to meet ]its growth objectives. This implies that it will need to increase its primary energy supply buy a factor of three to four and to the electricity generation by a factor of five to six .India receives nearly 300-330 days of solar energy and there is a large potential available for generating solar power using unutilized space on rooftops of individual houses , industrial buildings ,commercial buildings, educational institutes or any other type of buildings can be used to moderately fulfill the requirement of the building occupants and excess , if any , can be fed into the grid . So the best suitable long term design solution for India would be highly distributed set of individual rooftop power generation systems connected through a local grid.

In grid interactive rooftop solar PV power systems , the DC power generated from solar panel is converted to AC power using power conditioning unit and is fed to the grid .The generated power during the day time can be utilized fully by powering locked upmany and excess can be fed to the grid as long as grid is available .In case , were Solar Power is not sufficient due to cloud cover or during the cloudy hours , the captive loads are served by drawing power from the grid.The grid interactive rooftop solar system can work on net metering basis where in the beneficiary pays to the utility on net meter reading basis only.

The main objective of present paper is to present the financial analysis of 100 KW rooftop solar PV power systems for both with and without battery support. The sensitivity analysis of the various cost elements have been studied and identified to look in for future reduction .The results were presented and the conclusions were drawn.

## II. Solar PV power system status in India:

In India, the solar market is undergoing changes from the incentive driven market to parity driven market. But this change is creating problem to policy makers and creating delays in policies.

One of the results of this transition is that Indian solar market is moving from utility market to generation market. Let us expect that 2014 will lay a strong ground for roof top solar market. To

understand the above statement we can take the delays that has been occurring in states like Andhra Pradesh, Tamilnadu, Karnataka, Punjab and Uttar Pradesh that has been continuing in delays different states are facing many litigations and no PPA`s have been signed.

On the other side, it is encouraging to see that many central and state governments have announced some policies, subsidies, Feed-in-Tariff`s (FITs) etc.. To promote rooftop solar power but there may also suffer some delays due to the election paralysis in India.

The solar energy corporation of India(SECI) was providing a capital subsidy for 100MW every year.

Due to all the above reasons, we can expect new solar PV capacity of 750 MW in 2014.

**Why off-grid roof top system:**
By using off-grid rooftop system the customer can have the following advantages.

- Have access to power continuously all the time.
- Not having any scheduled or unscheduled power cuts.
- No dependency on diesel
- The quality of this power is superior to the regular grid power.
- Investment against increasing fuel and grid charges.

**Application areas:**

- Hospitals
- Educational institutions
- Government offices
- Commercial buildings
- Petrol pumps
- Construction companies
- Water pumps

**Salient features of off-grid roof top system:**

- Low and optimum maintenance cost.
- Stable supply of power increases the overall efficiency of electronic components
- Can effectively manage usage of power based on requirements through smart electronics.
- Batteries designed for longer life.
- Minimum power loss with effectively designed DC cables and Junction boxes.

**What advantages educational institutes have with solar PV power system?**
**Self sufficient:**

By installing solar PV power plant in the educational institution it can get a benefit of producing its own and sufficient electrical energy without shortages or scheduled and unscheduled power cuts.

**Renewable Energy Corporation:**

Educational institutes can get a benefit of registering with Renewable Energy Certification which increases the goodwill about the institution.

**Training and Research:**

Students can be given some training programs and research projects which increases the capability of the students, which adds as a benefit to the institution.

**Green energy:**
Can reduce the carbon gases into the environment

## III. Functional Description:

Following figure show that various components of solar PV power plant for roof top system

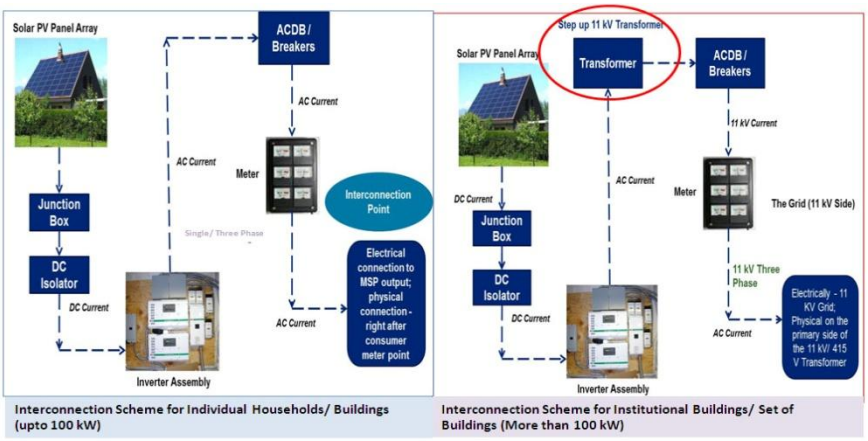



Figure: Interconnection Schemes

**Key components of solar rooftop system**

**Solar Panel** – A solar panel (photovoltaic module) is a packaged, linked group of photovoltaic cells and it is used as a component of a rooftop system to generate and supply DC electricity). Solar panels generally form a part of a vast solar array (multiple panels connected together). Each panel is graded by its DC output power under standard check conditions, and typically ranges between 100 - 350 watts. We have selected 200 watts panels for our system

**Junction box** - An electrical junction box is a connecting box for solar PV modules for series and parallel electrical connections, usually designed to conceal them from view and tampering. A small metal or plastic connection box may form part of an electrical conduit wiring system in a building, or may be covered in the plaster of a wall, hidden behind an access panel or spread into concrete with only the lid showing. It also includes terminals for combining cables. Its safety degree should be IP65.

**Inverter (Power Conditioning Unit)** - The Power Conditioning Units (PCU) used in grid connects SPV systems consists of an Inverter and other electronics for Maximum peak power tracking (MPPT), Synchronization and remote monitoring.

The inverter is the most complicated part of the PV system. It has to behave as the interface between the PV array and the Grid. As the PV array output fluctuates with the solar radiation the inverter has to cope with the same.

The major functions carried out by the PCU are as follows:

- Change the incoming DC received from PV modules into AC with suitable power quality. TheInverter creates sinusoidal AC waves forms with low harmonic distortion.
- The inverter also has to act as a protective device of the system. It requires tripping out if thevoltage, current or frequencies go beyond acceptable ranges.
- We have selected 5 numbers of 20kW each inverter for our plant.

**Manual/Automatic disconnect switch** - It is an automatically/manually operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Its vital function is to detect a fault condition and, by interrupting linkage, to immediately discontinue electrical flow.

**Step-up transformers** – The output from the inverters require a further step-up in voltage to reach the AC grid voltage level. This is the default case with our PV power plant installation, where the Low Tension (LT) infrastructure cannot handle the amount of power which may be generated by the rooftop plant. The step up transformer receives the output from the inverters to the required 11 kV grid voltage. Substation in our college is used for grid connection**.**

**Grid connection interface-** In our large rooftop solar PV plants the electricity is generally used for the college and remaining excess shall be exported to the grid network 11 kV voltage level. This interface is usually termed

as interconnection point and supply metering apparatus. Interconnection point and metering point are used to external to the PV power plant boundary and are typically located in the owner's premises.

## IV. Bill of materials:

**100 KW roof top systems with battery backup bill of materials:**

| S.no | Description | Quantity | Cost |
|---|---|---|---|
| | | | Rs |
| 1 | Solar panels,200W@STC | 500 | 35/W |
| 2 | Mounting structure | 100 | 8000/KW |
| 3 | Inverter | 20 | 50000/KW |
| 4 | Cables | 100 | 2000/KW |
| 5 | Battery, 12V/200Ah | 50 | 12000 |
| 6 | Combiner box | 20 | 10000 |
| 7 | Main junction box | 10 | 8000 |
| 8 | Fuses & Disconnects | Set | 3000 |
| 9 | Protection switches | 37 | 500 |
| 10 | Energy monitoring meter | 2 | 4000 |
| 11 | Remote control and monitoring system | 1 | 200000 |

**100 KW roof top system without battery backup bill of materials:**

| S.no | Description | Quantity | Cost |
|---|---|---|---|
| | | | Rs |
| 1 | Solar panels,200W@STC | 500 | 35/W |
| 2 | Mounting structure | 100 | 8000/KW |
| 3 | Inverter | 20 | 50000/KW |
| 4 | Cables | 100 | 2000/KW |
| 5 | Combiner box | 20 | 10000 |
| 6 | Main junction box | 10 | 8000 |
| 7 | Fuses & Disconnects | Set | 3000 |
| 8 | Protection switches | 37 | 500 |
| 9 | Energy monitoring meter | 2 | 4000 |
| 10 | Remote control and monitoring system | 1 | 200000 |

## V. Cost price of solar PV power system:

- Components
- Design and engineering
- Installation and commissioning
- Operational and maintenance

**Components:**

The components cost of solar PV power system with battery backup is shown in table 1

**Table 1: 100 KW roof top system cost with battery backup**

| Components | Cost/unit | | Total cost |
|---|---|---|---|
| | RS | | RS |
| Solar panels,200W @STC | 35/W | 500 | 3850000 |
| Mounting structure | 8000/KW | 100 | 880000 |
| Inverter | 50000/KW | 20 | 1000000 |
| Cables | 2000/KW | 100 | 200000 |
| Battery, 12V/200Ah | 12000 | 50 | 600000 |
| Combiner box | 10000 | 20 | 200000 |
| Main junction box | 8000 | 10 | 80000 |
| Fuses & Disconnects | 3000 | Set | 300000 |
| Protection switches | 500 | 37 | 185000 |
| Energy monitoring meter | 4000 | 2 | 8000 |
| Remote control and monitoring system | 200000 | 1 | 200000 |
| Total | | | 7303000 |
| VAT | 5.50% | | 401665 |
| Transport and Installation | 10% | | 730300 |
| Miscellaneous | 6% | | 438180 |
| Project management, Design and Engineering | 10% | | 730300 |
| Total cost | | | 9603445 |

Option 2 is 100KW roof top system without battery backup. The detailed cost of various components given in table 2

Table 2- Option 2 **100 KW roof top system cost without battery backup**

| Components | Cost/unit | | Total cost |
|---|---|---|---|
| | RS | | RS |
| Solar panels,200W @STC | 35/W | 500 | 3850000 |
| Mounting structure | 8000/KW | 100 | 880000 |
| Inverter | 50000/KW | 20 | 1000000 |
| Cables | 2000/KW | 100 | 200000 |
| Combiner box | 10000 | 20 | 200000 |
| Main junction box | 8000 | 10 | 80000 |
| Fuses & Disconnects | 3000 | Set | 300000 |
| Protection switches | 500 | 37 | 185000 |
| Energy monitoring meter | 4000 | 2 | 8000 |
| Remote control and monitoring system | 200000 | 1 | 200000 |
| Total | | | 6703000 |
| VAT | 5.50% | | 368665 |
| Transport and Installation | 10% | | 670300 |
| Miscellaneous | 6% | | 402180 |
| Project management, Design and Engineering | 10% | | 670300 |
| Total cost | | | 8814445 |

## VI. Financial analysis:

**Sensitivity analysis:**

Sensitivity analysis is done to study how the uncertainty in the output will be affected to different types of inputs.

Sensitivity analysis has been undertaken to determine how variations in the inputs impact the financial feasibility of installing and operating a PV solar system. The sensitivity analysis actually involves the changes/variations in the different inputs to the financial analysis and the result that is obtained by doing that financial analysis. This is an important for calculating the importance of various factors in getting the total financial results. The calculation of sensitivity analysis is done by considering the changes in following factors.

**Net present value:**

The difference between the present value of cash outflows. NPV used in capital budgeting to analyze the profitability of an investment or project.NPV analysis is sensitivity to the reliability of future cash inflows that an investment or project will yield.

$$\text{NPV} = \sum_{t=1}^{T} \frac{C_T}{(1+r)^t} - C_0$$

**Internal Rate of Return:**

The discount rate often used in capital budgeting that makes the net present value of all cash flows from a particular project equal to zero. Generally speaking, the higher a projects Internal Rate of Return, the more desirable it is undertake the project.

$$\text{IRR} = A + \frac{C - O}{C - D} * B - A$$

**Levelized cost of energy production (LCOE):**

The cost of energy production from the solar PV power plant is estimated taking into 25 years of plant life with 20% degradation for 25 years.

**100 KW Solar PV power plant financial analysis:**

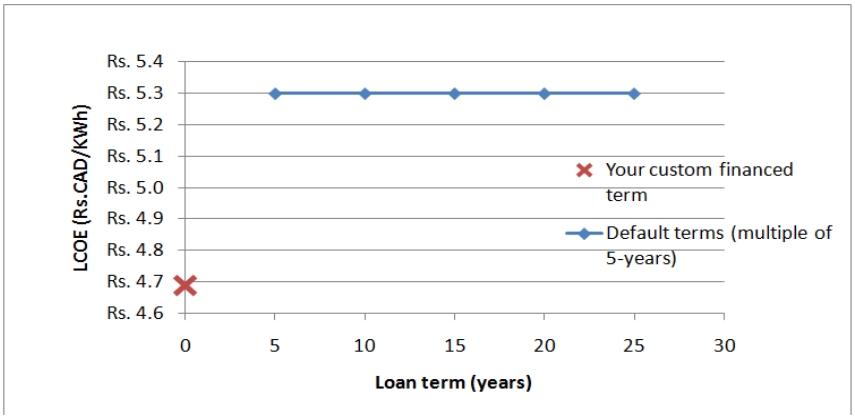
Total project cost:
With battery: 9603445
Without battery: 8814445

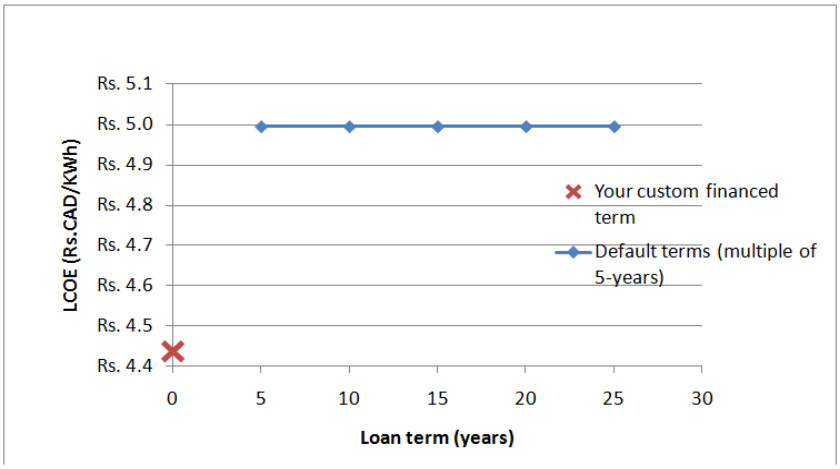
**Calculations**

Calculation of NPV, IRR, and LCOE values for Solar PV power systems (with and without battery) at different capital costs and Interest Rates.

| Capital cost | | | Interest Rates | | |
|---|---|---|---|---|---|
| | | | 0% | 10% | 13% |
| Original Capital cost | NPV | With battery | 0.16crores | 0.01crores | 0.06crores |
| | | Without battery | 0.20crores | 0.04crores | 0.01crores |
| | IRR | With battery | 31.81% | 14.92% | 10.59% |
| | | Without battery | 37.78% | 20.56% | 14.98% |
| 10% increase in capital cost | NPV | With battery | 0.51crores | 0.23crores | 0.13crores |
| | | Without battery | 0.80crores | 0.63crores | 0.57crores |
| | IRR | With battery | 41.28% | 26.67% | 21.60% |
| | | Without battery | 82.91% | 69.13% | 64.78% |
| 10% decrease in capital cost | NPV | With battery | 0.85crores | 0.70crores | 0.64crores |
| | | Without battery | 0.89crores | 0.75crores | 0.70crores |
| | IRR | With battery | 96.01% | 82.46% | 97.28% |
| | | Without battery | 107.07% | 93.66% | 88.88% |

| Capital Cost | | | Interest Rates | | |
|---|---|---|---|---|---|
| | | | 0% | 10% | 13% |
| Original capital cost | LCOE | With Battery | -- | 5.3 Rs.CAD/KWh | 5.3 Rs.CAD/KWh |
| | | Without Battery | -- | 5.0 Rs.CAD/KWh | 5.0 Rs.CAD/KWh |
| 10% increase in capital cost | LCOE | With Battery | -- | -- | 5.7 Rs.CAD/KWh |
| | | Without Battery | -- | -- | -- |
| 10% decrease in capital cost | LCOE | With Battery | -- | -- | -- |
| | | Without Battery | -- | -- | -- |



## VII. Conclusions:

- Total investment: 96 lakhs for 100kW roof top solar PV power plant with battery backup, 88 lakhs for without battery backup.
- The acceptable NPV cost with and without battery is 0.06 and 0.01 crores respectively with the interest rate of 13%.
- The acceptable IRR with and without battery is 10.59% and 14.98% respectively with the interest rate of 13%.
- The preferable LCOE with and without battery is 5.3 and 5.0 with the interest rate of 13%.

**7. Suggestions:**

- Installing of 100KW solar PV power system with battery (9603445) and without battery (8814445) can be undertaken at an interest rate of 13%.
- With increase/decreases in capital cost at 10%, also the solar PV system can be installed at the interest rate of 13%.

## Acknowledgements:

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## References:

[1] "India Solar Compass-January 2014", journal published on India Solar Market by Bridge to India-www.bridgetoindia.com.
[2] "Development of Financial Model of Bankable Feasibility Analysis of a 1MW Rooftop Solar PV Project in India"- a project report by Abhishek Chaudary-under NPTI (National Power Training Institute)-for LAHMEYER INTERNATIONAL.