Techno-economic analysis by homer-pro approach of solar on-grid system for Fatehpur-Village, India

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Abstract. There are numerous locations available in rural regions of India, where essential electrical energy for load demand is not feasible. Individuals of those particular areas are facing problems, related to their social and economic development. To eliminate the energy crisis, uses of renewable sources are increasing day by day. In this study, we are analysis an On-grid solar energy harvesting system, which will provide necessary power requirement for the whole community of Fatehpur village located at 27°59'15"N and 77°44'07"E, to fulfil energy demand of the community load without much affecting environment. Here, the economic analysis using Homer-pro programme version 3.14.4, are examined, with Homer pro cycle charging as dispatch strategy. Load calculation and components pricing details are concluded through a local survey. Homer pro provides optimized results for selected site, through total present cost (NPC), the least cost of energy (LCOE) and operating cost etc. Based on simulation results by Homer pro, we obtained 1.77 RS/kWh as levelized cost of energy, which is much less than grid power price i.e. 5.6 Rs/kWh and 9,291,770.00 Rs as NPC. Main criteria of this software-package are NPC and LCOE to find out the best possible outcomes for the suited site.

1. INTRODUCTION

The energy is a basic, fundamental tool for any developing country like India. India has many rural regions, where power crisis is still present and becomes the part of concern. Because development of that particular area is also depends on the energy utilization. In various study of electrification of rural regions of India, solar energy is found to be the best one, which can provide power supply for ever-increasing load demand with reliability and can be an alternate way to replace conventional power sources, effectively. Various research works have been completed, based on renewable sources worldwide, in which hybrid system analysis is one of the versatile methods, which are using dominantly in India. Hybrid system technique includes many system configurations of renewable sources i.e. solar-wind, solar-wind-grid, solar-biomass-DG set, wind-biomass-PV system, PV system-wind-hydro-grid etc. Many locations around the world are present, where these hybrid systems have been installed as a power source due to energy crisis or unavailability of grid supply in that area. In previous study single source of energy was used i.e. solar or wind or biomass energy, which was not a reliable method due to limitations of operation based on weather conditions. With the advancement of technology, the making of hybrid system for remote areas becomes easy and hence the reliability of power supply also increases, accordingly. In this analysis, the village “Fatehpur” present at Aligarh-district of Utter Pradesh, India is selected for the analysis of grid-tied solar system with no power backup. The site for the evaluation of the proposed system is present in the outer area of the village.
has the coordinates 27°59'15''N and 77°44'07''E respectively. Various hybrid system combinations have been analysed for the site present at the village i.e. PV system-wind-battery, wind-solar-DG set, wind-grid-PV system and solar-grid with no power backup etc. by Homer-pro software. Out of many system configurations, solar-grid system with no power backup is found to be the best one due to the least cost of energy (LCOE) and NPC. Homer-pro software package is a tool which provides us a platform to allowed analysis of multiple sources of green energies at a single time and gives the result through NPC, LCOE, Operating cost & various calculations for energy, for any particular area of interest. For the proposed system, it is found that “LCOE” is 1.77Rs/kWh according to Homer-pro analysis report. Electrical energy becomes the part of our daily life routine. We wanted to design such a system that not only satisfied consumers load demands but also produces minimum or negligible effect to the environment. To design such a system, Homer pro software package works as a tool. The main advantage of this package is its financial analysis ability of the system. Homer-pro allows mathematical computation of the load in terms of feasible solutions. The step, done in [1], explains the technical economic prospectus by analysing of hybrid system for rural area in Pakistan. Development of hybrid system for a technical institute by Homer Pro is described in [2]. In the work of [3], a case study based on PV system with microgrid to obtain cost of energy with respect to variation in solar irradiance is elaborated. In [4], Techno-economic analysis for a hybrid system by using Homer Pro in Pakistan has been studied. For South Africa, renewable energy solution for the access of electricity in rural area is given in [5]. Design and analytic evaluation for remote regions of Arunachal Pradesh of a cost-effective model has been studied in [6]. In work of [7], Performance analysis has been done for solar energy harnessing system by Homer Pro and PVsyst software. In [8], economic and sensitivity analysis is given for hybrid renewable energy system by Homer pro. A simulation based analysis of rooftop on grid system has been studied in [9] by various software packages. The selected site is best suited for the installation of grid-tied system due to its good irradiance occurrence ability of sunlight during sunshine hours.

2. RESEARCH PROCEDURE

The structural outline of the procedure is given in Figure 2, which starts with community load calculation. Later on, available resources at that particular area of interest is analysed for an on-grid solar PV system examination, suitably.

![Figure 1. Site view.](image-url)
Program assessment is done by Homer-pro software. It is the trial software has version 3.14.4 type. With this software, many economic analyses are applied to obtain the best optimum results for the proposed system.

3. SITE SURVEY

In this work, the site selected for inspection is Fatehpur village in Aligarh district of Uttar Pradesh, India. The coordinates of the site are $27^\circ 59' 15''$ N and $77^\circ 44' 07''$ E. Average solar irradiance each year for the site is $5.22$ kWh/m$^2$/day according to National Solar Radiation Database by Homer-pro. Information regarding annual solar irradiance and clearness index is given in fig. 3. This site also has the enough amount of temperature availability annually, i.e. $26.18$ °C. According to 2011 census data, literacy rate of the village is $61.6\%$ and the rate of female literacy is about $25.3\%$. Working population is about $70.7\%$. It is a small village which comes under the Fatehpur panchayath. Fatehpur village is surrounded by Chandaus Block in north, Nohjil Block in west, Gonda Block in south and Lodha Block in east. Here, agriculture is the main source of income for their daily bread. Some peoples are also works outside of the village to create capital support for making their life more comfortable.
4. COMMUNITY LOAD COMPUTATION

Actual data of the village is collected via physical survey, in which calculation of electrical load for the community, number of habitation, overall status of village and other data are included. To calculate the exact load for the village, we calculate it for ten residences first. These residences exactly represent the load pattern of the entire community. It is available in Table-1. The overall population of this community is about 1000 resident. For their stay, there is a total of 200 habitations available, at present (5 persons/house are present). The kWh of habitations are obtained by multiplying the electric wattage of equipment with those hours that commoner considered to use. The total load of community is divided into two parts “winter and summer” load, to make estimation of electrical load trouble-free. In summer load condition time period between “March to September” months are considered, while in case of winter load calculations time slot between “October to February” months are examined. But during winter load estimation, complete fan loads are excluded to obtain the correct result [1]. In further process, we calculate the load of 10 houses for winter and summer season separately in kWh/day.

| S. no | Light (Q x W x H) | Fan (Q x W x H) | T.V. (Q x W x H) | Freeze (Q x W x H) | Water Pump (Q x W x H) | Mobile Charger (Q x W x H) | Washing Machine (Q x W x H) |
|-------|------------------|-----------------|------------------|-------------------|------------------------|-----------------------------|-----------------------------|
| 1     | 4x15x8 = 480     | 2x90x8 = 1440   | 1x80x4 = 320     | 1x350x12 = 4200   | 1x1000x0.5             | 1x7x2 = 14                  | 1x255x2 = 510               |
| 2     | 2x15x9 = 270     | 2x90x8 = 1440   | 1x80x5 = 400     | NA                | NA                     | 1x7x2 = 14                  | NA                          |
| 3     | 4x15x10 = 600    | 2x90x12 = 2160  | 1x80x5 = 400     | NA                | 1x1000x0.5             | 1x7x2 = 14                  | 1x255x2 = 510               |
| 4     | 5x15x6 = 450     | 1x90x10 = 900   | 1x80x3 = 240     | NA                | 1x7x2 = 14             | NA                          | NA                          |
| 5     | 6x15x8 = 720     | 1x90x10 = 900   | 1x80x4 = 320     | NA                | 1x7x2 = 14             | 1x255x2 = 510               | NA                          |
| 6     | 4x15x8 = 480     | 3x90x7 = 1890   | 1x80x6 = 480     | 1x350x12 = 4200   | 1x1000x0.5             | 1x7x2 = 14                  | NA                          |
| 7     | 2x15x12 = 360    | 4x90x5 = 1800   | 1x80x4 = 320     | NA                | NA                     | 1x7x2 = 14                  | NA                          |
| 8     | 5x15x6 = 450     | 2x90x6 = 1080   | 1x80x5 = 400     | 1x350x12 = 4200   | 1x1000x0.5             | 1x7x2 = 14                  | NA                          |
| 9     | 4x15x10 = 600    | 2x90x8 = 1440   | 1x80x4 = 320     | NA                | NA                     | 1x7x2 = 14                  | NA                          |
| 10    | 2x15x8 = 240     | 2x90x12 = 2160  | 1x80x5 = 400     | NA                | NA                     | 1x7x2 = 14                  | NA                          |
| Total | 4650 Wh/day      | 15210 Wh/day    | 3600 Wh/day      | 12600 Wh/day      | 2000 Wh/day            | 140 Wh/day                  | 1530 Wh/day                 |

Summer Load

| Total Wh/day for 10 habitations = 39.73 kWh/day kWh/day/house = 3.973 kWh/day Overall kWh/day for 200 houses = 200 x 3.973 = 794.6 kWh/day |
|---|---|

Winter Load

| Total Wh/day for 10 habitations = 24.53 kWh/day kWh/day/house = 2.453 kWh/day Overall kWh/day for 200 houses = 200 x 2.453 = 490.6 kWh/day |
|---|---|

Average daily energy consumption = (794.6 + 490.6) / 2 = 642.6 kWh/day
To calculate the per house kWh/day, we divided the summer and winter loads by 10. Later on, we multiply the per house kWh/day with the total no of available habitations, i.e. 200. In this way, overall community load is estimated. To explain the overall steps, all necessary mathematical data is shown in table 1. The annual average energy consumption of the entire circle is 642.30 kWh/day with the peak value of 58.14 kWp. Monthly and daily wise load details are given in the form of figure 4 and 5 respectively.

5. ENERGY AVAILABILITY

India has massive potential of non-conventional sources of energy. As on January 2021 renewable energy installed capacity in India is 92.55 GW, out of which, part of wind and solar power is about 38.68 GW and 38.79 GW respectively. In financial year 2020 electric power generation through renewable energy sources reached about 127.01 billion in India. With supporting policies regarding renewable sources along with future possibilities of 363 GW, Northern part of India is supposed to become the hub for Green energy.

5.1 Solar Energy Potential
The working site is present at Utter Pradesh have longitude-77°44'07" E and latitude-27°59'15" N. This site is perfect for the installation of grid tied solar system for whole community due to annual average solar insolation of 5.22 kWh/m²/day. This data can be seen in figure 2. Solar insolation data has taken from “National Solar Radiation Database” by using of Homer-pro software.
6. COMPONENTS DESCRIPTION

For designing and optimization for getting better results, we are using solar PV panels, solar convertor and the available utility power grid. It is given in fig. 6

![Schematic circuit diagram.](image)

**Figure 6**: Schematic circuit diagram.

What capacity of “component” and “quantity” required installing the system at community level is obtained by Homer Pro software.

**6.1 Solar PV Panel**

In this research, we are using Generic flat plat type PV panels due to its good efficiency and easy availability at the site location. Through market survey the price of 1kw panel is obtained i.e. 40000 Rs/kW. These panels have 25 years of life along with 80% derating factor. Above data is given in Table 2

| Constants                  | Worth          |
|----------------------------|----------------|
| Solar Panel                | 40000 Rs/kW    |
| Replacement Amount         | 40000 Rs/kW    |
| Derating Factor            | 80 %           |
| Life Time                  | 25 Years       |
| Operation & Maintenance    | 500 Rs / Year  |

**Table 2. Constants and worth of PV panels.**

**6.2 System Converter**

To design the solar on-grid system, converter is a very necessary component. Because without this we cannot convert solar PV panels output (DC) into AC supply so that proper communication between utility grid and solar system is achieved. A converter basically transforms the steady power into the sinusoidal power and vice-versa. For optimization, we are using system converter according to Homer pro. Per kW price of converter is 6000 Rs that is obtained from the market. Efficiency of the converter is 95% with the work period of 15 years. It can be seen in Table 3.

| Constants            | Worth          |
|----------------------|----------------|
| Solar Converter      | 6000/kW        |
| Replacement amount   | 6000/kW        |
| Life Time            | 15 Years       |
| Efficiency           | 95 %           |
| Relative Capacity    | 100 %          |
| Operation & Maintenance | 500 Rs/Year   |

**Table 3. Specifications of converter.**
7. OPTIMIZATION OUTCOMES

In this case we are using PV panels, Converter and utility grid to fulfil the requirements of the load which is present at community level via On-grid solar system. At last, we will see the financial analysis in terms of NPC, LCOE and operating coast, risky emissions, PV plate output analysis etc. And finally, excess amount of energy will be selling to the grid at suitable price.

![Figure 7. Optimized output for On-grid system.](image)

According to Homer pro results, If we use PV panels and Converter capacity of 173 kW and 124 kW respectively with utility grid than the community can access electric energy, for their needs at very low cost of energy i.e. 1.77 Rs/kWh. For accurate optimization, here we are using 5.6 Rs/kWh as a grid power cost, according to financial year 2018 and 2 Rs per kWh for grid net excess price. Other important results are given in table format.

### 7.1 Electrically Analysis Report

| Generation kWh/Annum | kWh/Annum |
|----------------------|-----------|
| Generic PV plate     | 291,739   |
| Grid purchases       | 134,799   |
| Total                | 426,538   |

| Consumption kWh/Annum | kWh/Annum |
|-----------------------|-----------|
| AC primary Load       | 234,549   |
| DC primary Load       | 0         |
| Deferrable Load       | 0         |
| Grid Sales            | 172,017   |
| Total                 | 406,566   |

| Quantity kWh/Annum | %     |
|-------------------|-------|
| Excess Electricity| 5,669 | 1.33  |
| Unmet Electric Load| 0    | 0     |
| Capacity Shortage  | 0     | 0     |

| Quantity | Gain | Unit |
|----------|------|------|
| Renewable Fraction | 66.8 | %    |
| Max. Renewable Penetration | 140 | %    |
Figure 8. Monthly electric production.

### 7.2 Report of Generic PV plate

| Quantity               | Gain | Units |
|------------------------|------|-------|
| Rated Capacity         | 173  | kW    |
| Mean Output            | 33.3 | kW    |
| Mean Output            | 799  | kWh/day|
| Capacity Factor        | 19.2 | %     |
| Total Production       | 291,739 | kWh/Year |

| Quantity               | Gain | Units |
|------------------------|------|-------|
| Min. Output            | 0    | kW    |
| Max. Output            | 174  | kW    |
| PV Penetration         | 124  | %     |
| Hours of Operation     | 4,371 | Hours/year |
| Levelized cost         | 2.14 | Rs/kWh |

Figure 9. Photovoltaic o/p power.

### 7.3 Financial Report

|                        |                  |
|------------------------|------------------|
| Net Present Cost       | 9,291,770.06 Rs  |
| Cost Of Energy         | 1.77 Rs/kWh      |
| Operating Cost         | 124,389.50 Rs/Year |
7.4 Converter Report

|                     | Inverter | Rectifier | Units |
|---------------------|----------|-----------|-------|
| Capacity            | 124      | 124       | kW    |
| Mean Output         | 31.0     | 0         | kW    |
| Min. Output         | 0        | 0         | kW    |
| Max. Output         | 124      | 0         | kW    |
| Capacity Factor     | 25       | 0         | %     |

|                     | Inverter | Rectifier | Units |
|---------------------|----------|-----------|-------|
| Hours of Operation  | 4371     | 0         | Hrs/yr|
| Energy Out          | 271,776  | 0         | kWh/yr|
| Energy In           | 286,071  | 0         | kWh/yr|
| Losses              | 14,304   | 0         | kWh/yr|

Figure 10. Output of the inverter.

7.4 Gaseous Emission

|                     | Gain     | Units             |
|---------------------|----------|-------------------|
| CO₂                 | 85,193   | Kg/Annum          |
| Carbon Monoxide     | 0        | Kg/Annum          |
| Unburned Hydrocarbons| 0       | Kg/Annum          |
| Particulate Matter  | 0        | Kg/Annum          |
| Sulphur Dioxide     | 369      | Kg/Annum          |
| Nitrogen Oxide      | 181      | Kg/Annum          |

8. OUTCOMES & DISCUSSION

Fatehpur village is an excellent site to install the proposed methodology due to increment in performance and reduction in cost of the mechanism. The value of solar insolation for this location is 5.22 kWh/m²/day, which is quite enough for the production of electric power through the proposed system approach. According to Homer pro results, if, we install this mechanism with PV panel capacity of 173 kW and converter capacity of 124 kW along with grid, than the cost of energy by is reduced to 1.77 Rs/kWh with respect to 5.6 Rs/kWh (FY18). The NPC of the system acquire is 9,291,770.06 Rs for 25 years of working time. This study focuses on to the performance analysis and economic viability evaluation examination of the proposed methodology for the rural area of Uttar-Pradesh, India.
9. CONCLUSION & FUTURE EXTENSION

India is facing energy crisis issues in their rural areas since long time. Due to failure of supplying sufficient electrical power to the rural region, peoples of that village suffering more for their self-development. Conventional energy sources are not capable to supply power to the residential load of that village for sufficient time duration due to load shading problem. At present trend, development of non-conventional power harvesting system with better reliability and efficiency increases rapidly. In this study, we are providing a simulation based analysis by Homer cycle charging for the Fatehpur-village in terms of LCOE i.e. 1.77 Rs/kWh, which is lesser than compared with grid power price i.e. 5.6 Rs/kWh. The NPC for the proposed system is 9,291,770.06 Rs and operating cost is 124,389.50 Rs/ Year, which is calculated by Homer-pro programme. The proposed methodology is environmental friendly & has potential to satisfy the load requirements for the community of Fatehpur village. Normally, this type of projects can be installed at remote location easily, because Indian government provides initiative to this type of work. The Indian government making useful policy, so that consumer can utilize the green energy for their daily load requirements and hence the dependency on the coal-fired power plants is reduced, accordingly. The villages, which have energy crisis or availability of grid electricity for fixed time, above proposed system are found to be the best one from low cost of energy and efficiency point of view.

10. References

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