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# Study of Smart Home Energy System: A Case Study of a Household in Punjab

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***Abstract*—**The issue of global warming and energy deficit leads the state government of Punjab to take major steps in the favor of renewable resources. The smart home energy system is introduced as the major step for encourage the use of these renewable resources. The concept can be implemented to every household which results in clean and sustainable future. The government policy like roof top PV and incentives also motivate this concept. In this paper, the solar PV is used as renewable resource is integrated with power grid to reduce greenhouse gases and dependability on it. The whole design of this concept is simulated using homer software. The various configurations are simulated by the HOMER and best configuration selected on the basis of its cost effectiveness.

**Keywords**- homer; micro grid; renewable energy; roof top PV; smart home

## 1. INTRODUCTION

THE present energy crisis and problem of global warming provoke us to take different steps in the favor of renewable resources. The smart grid infrastructure is up gradation of the present grid. The one of main aspect of smart grid is smart home. The concept smart home is based on the smart use of distributed generation (DG). The use of DG can reduce carbon emission significantly and provide clean future as the energy resources are mostly renewable like Solar PV, wind etc [1].the special type of electrical meter is also installed on consumer premises known as smart meter which provides net metering. During low demand period the excess energy generated from solar PV can be sold to the utility grid. The smart meter registers both energy Punjab energy development agency (PETA). The various incentives and subsidies are provided by government. The whole study is simulated using software Homer (hybrid optimal model for electrical renewable) which is developed by NREL [2]. The HOMER professional version 3.5.0 is used in this study. The various configurations of the design are simulated and optimal results are determined. The sensitivity analysis is also done by taking specific sensitivity variables like cost, rating etc .The various energy storage technologies are also can be used for this purpose. The different constraints are also satisfied during simulation of various configurations.

## 2.1 SITE SURVEY

The site selected for implementation of smart home energy management system is surveyed the various specification are summarized below:

**TABLE-2.1 Site Specifications**

| **Location** | **$31^0$ 20.3`N latitude and $75^0$25`E longitude** |
|---|---|
| Average load | 1.24 kW |
| Peak demand | 4.19kW |
| Average energy demand per day | 32.83 kWh |

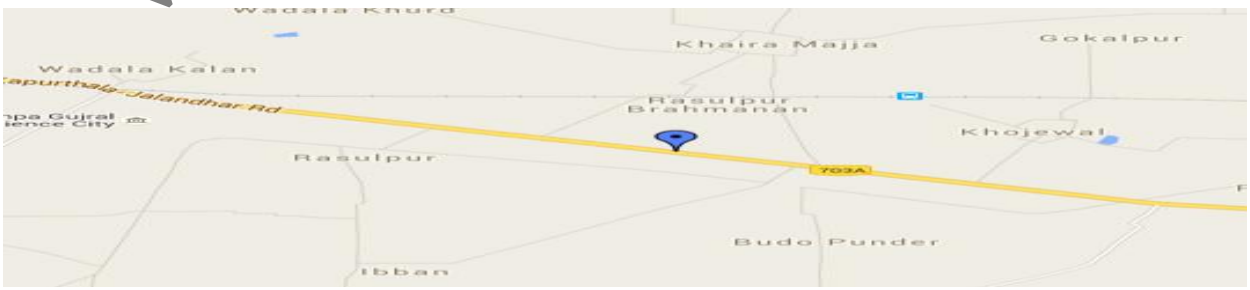



**Fig. 2.1 Location Site**

From location point of view the wind speed is very low for installing wind turbines. The solar radiations are abundant for this location and hence the solar PV can be installed as renewable resource strictly according to the roof top policy of government for getting benefits. The solar radiation data shown in fig. 2.2 below [1]:

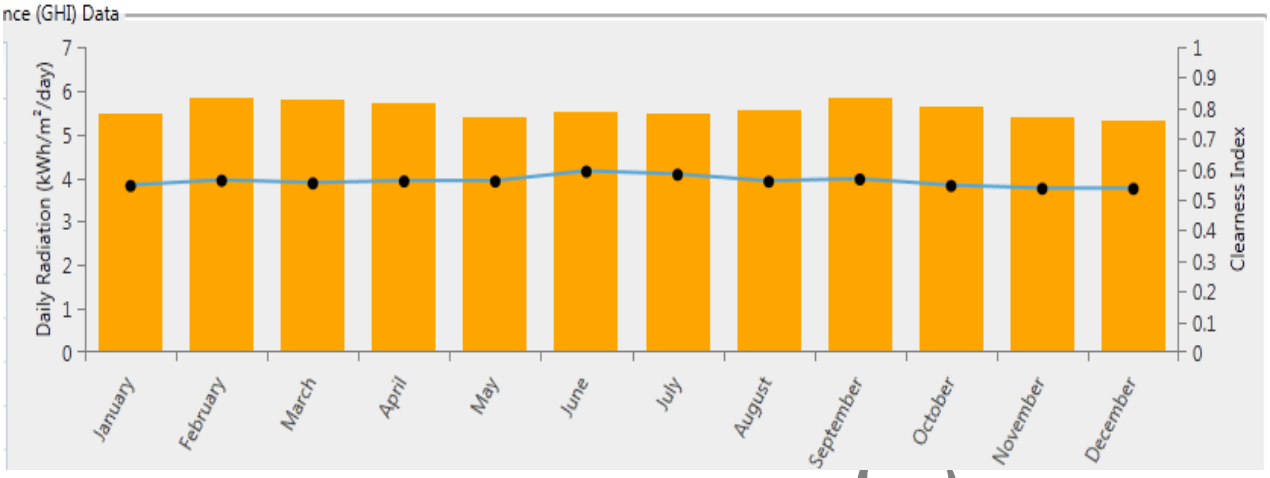



**Fig.2.2 Solar Radiation Data**

The solar radiation comes around 5.58 kWh/m2/day.The solar radiations are almost constant during the year.

## 3. LOAD PROFILE

The typical load profile for both daily and seasonal is shown in fig. 3.1 and 3.2 below respectively. From the daily profile it is clearly noticed that a lot variation occurs in a day due to heavy fluctuation in the use of appliances.

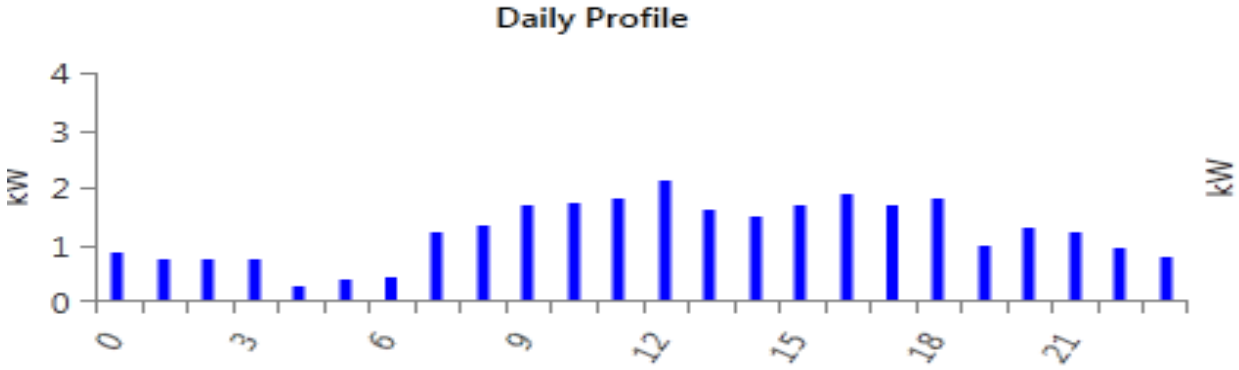



**Fig. 3.1 Daily Profile**

If the seasonal profile is also shown in fig 3.2 shows the variations with the changes in the seasons.

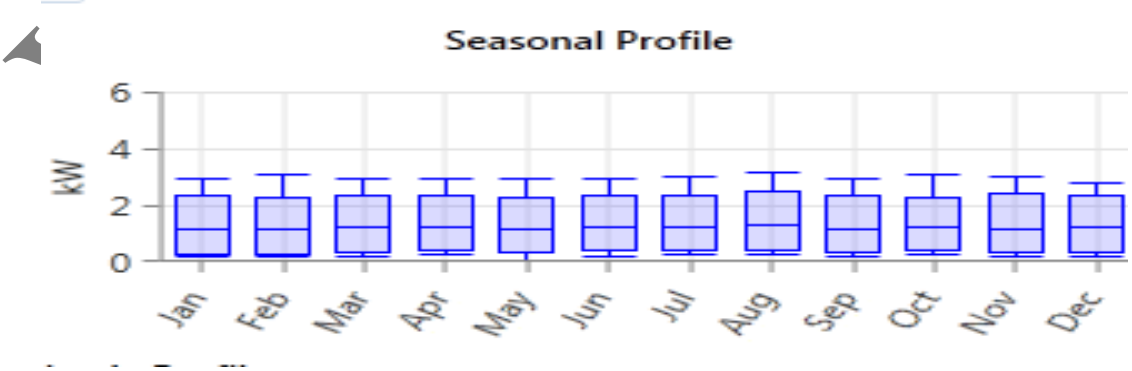



**Fig. 3.2 Seasonal Profile**

From the fig.4 we can noticed that the august is the peak month due to hot and humid weather.

## 4. PROPOSED MODEL

The designed model is proposed for the smart home energy system is shown in fig.4.1 below:

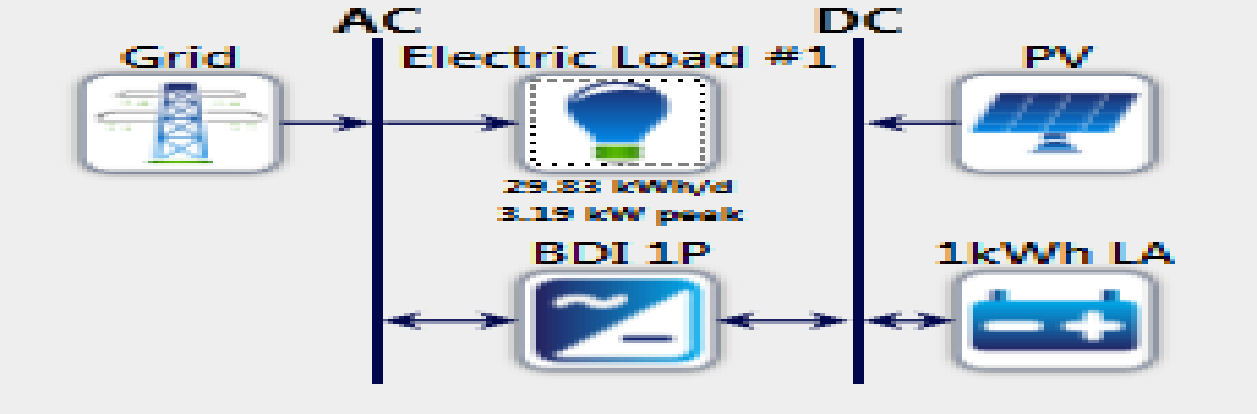



**Fig. 4.1 Proposed Model**

In the proposed model electrical load and renewable resource is shown which is connected to the grid. The rating of PV panel is 2 kW is taken and single phase converter (inverter) of 3 kW is also used.
The cost of tariff is Rs. 6/KWh and sell back price is also Rs 6 /KWh. The cost of solar PV is taken as Rs 1,20000 to Rs 1,00000 and the cost of converter is taken as Rs 19000/kW. The cost can be change by geographical location, government policies etc.

## 5. HOMER OPTIMIZATION AND SENSITIVITY ANALYSIS

The results of HOMER optimization is shown below the various configurations are simulated. The various configurations are simulated and the results are sorted according to how well it satisfied the constraints. The result of homer optimization are shown below in Fig. 5.1:

Export... Optimization Results: Left Double Click on a particular system to see its detailed Simulation Results Categorized Overall

| Architecture | | | | | | | | | Cost | | | | System | PV | | 1kWh LA | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PV (kW) | PVDC (kW) | 1kWh LA | Grid (kW) | BDI 1P (kW) | Dispatch | COE (Rs.) | NPC (Rs.) | Operating cost (Rs.) | Initial capital (Rs.) | Ren Frac (%) | Capital Cost | Production | Autonomy | Annual Throughput | Lifetime | Capital Cost |
| | 2.00 | 1.00 | | 999,999 | 1.00 | CC | Rs.5.82 | Rs.819,512 | Rs.50,784 | Rs.163,000 | 24 | 144,000 | 2,694 | | | | |
| | 2.00 | 1.00 | 1 | 999,999 | 1.00 | LF | Rs.5.87 | Rs.827,437 | Rs.51,088 | Rs.167,000 | 24 | 144,000 | 2,694 | 0.48 | 0.6 | 10 | 4,000 |
| | | | | 999,999 | | CC | Rs.6.00 | Rs.844,637 | Rs.65,336 | Rs.0.00 | 0.0 | | | | | | |
| | | | 1 | 999,999 | 1.00 | LF | Rs.6.28 | Rs.883,781 | Rs.66,585 | Rs.23,000 | 0.0045 | | | 0.48 | 0.6 | 10 | 4,000 |

**Fig. 5.1 Optimization Results**

From optimization results we can noticed that the cost of the energy reduced from Rs 6 to Rs 5.82 which shows that the installing solar PV is not only clean but also cost effective.

## 6. SENSITIVITY ANALYSIS

The sensitivity analyses can be also done by using homer software by choosing specific variables like cost etc. The sensitivity analysis is shown in Fig. 6.1.

Export... Column Choices... Sensitivity Results: Left Click on a sensitivity case to see its Optimization Results

| Sensitivity | Architecture | | | | | | | | | | | Cost | | | | System | PV | | 1kWh LA | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PV Capital Cost Multiplier (*) | | | | | PV (kW) | PVDC (kW) | 1kWh LA | Grid (kW) | BDI 1P (kW) | Dispatch | COE (Rs.) | NPC (Rs.) | Operating cost (Rs.) | Initial capital (Rs.) | Ren Frac (%) | Capital Cost | Production | Autonomy | Annual Throughput | Lifetime |
| 0.9 | | | | | 2.00 | 1.00 | | 999,999 | 1.00 | CC | Rs.5.82 | Rs.819,512 | Rs.50,784 | Rs.163,000 | 24 | 144,000 | 2,694 | | | |
| 1.1 | | | | | | | | 999,999 | | CC | Rs.6.00 | Rs.844,637 | Rs.65,336 | Rs.0.00 | 0.0 | | | | | |
| 1 | | | | | 2.00 | 1.00 | | 999,999 | 1.00 | CC | Rs.5.93 | Rs.835,512 | Rs.50,784 | Rs.179,000 | 24 | 160,000 | 2,694 | | | |

**Fig. 6.1 Sensitivity Results**

With changes in sensitivity results the results are changes significantly. In the search space the rating of different components can be taken which is shown below in the fig. 7.1:

Search Space

This table displays the values of all optimization variables. HOMER simulates the set of all possible combinations of these variables. You can also edit the search space for each component individually in the Component Input menus.

| BDI 1P Capacity (kW) | Grid Purchase Capac (kW) | 1kWh LA Strings (#) | PV Capacity (kW) | PV DC Capacity (kW) |
|---|---|---|---|---|
| 3 | 999999 | 0 | 0 | 1 |
| 2 | | 1 | 1 | |
| 1 | | | 2 | |
| 0 | | | 3 | |

Winning Sizes | Overall Winner | Category Winner | Calculate | OK | Cancel

| BDI 1P Capacity (kW) | Grid Purchase Capac (kW) | 1kWh LA Strings (#) | PV Capacity (kW) | PV DC Capacity (kW) |
|---|---|---|---|---|
| 3 | 999999 | 0 | 0 | 1 |
| 2 | | 1 | 1 | |
| 1 | | | 2 | |
| 0 | | | 3 | |

**Fig. 6.2 Search Space**

The different ratings of the components are used in the search space and best combination is determined.

## 7. ANNUAL ENERGY PRODUCTION SOLAR PV

The solar PV in combination with the grid reduces the cost of energy and also dependability on the grid. The annual average electrical energy production is shown in Fig. 9. The energy production from solar PV is dependent on the amount of solar radiation and clearness index.

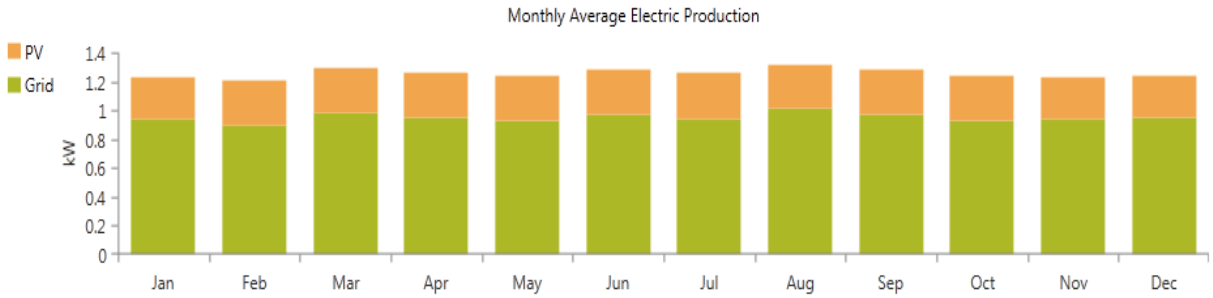



**Fig. 7.1 Average Energy Production**

The output from solar PV and the inverter annually is also shown in fig. 7.1 and 7.2.

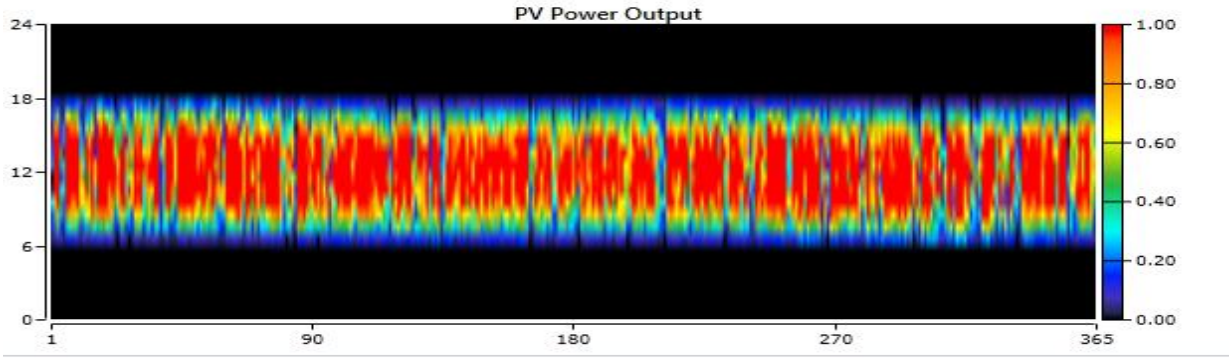
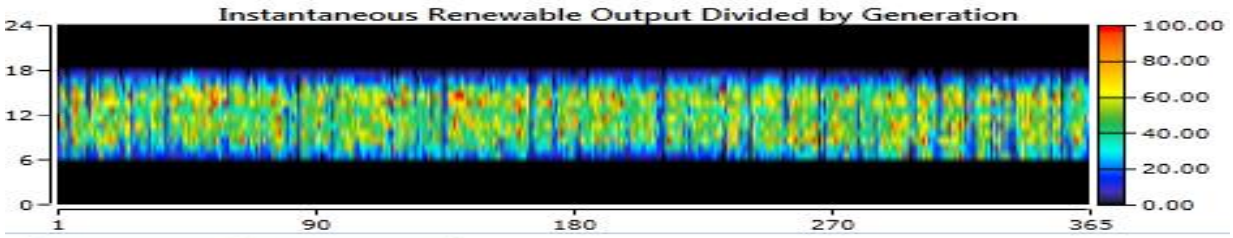
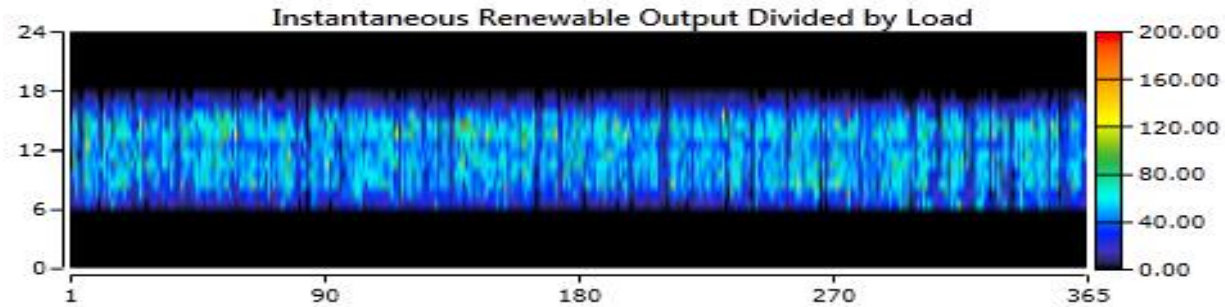



**Fig. 7.2 Solar PV Output**

## 8. RENEWABLE PENETRATION

The contribution of solar PV in the total energy production is the percentage of total energy output which is here 23.7%. The renewable penetration can be increased but will create the stability issues. The renewable penetration in the grid shown in the fig. 8.1.



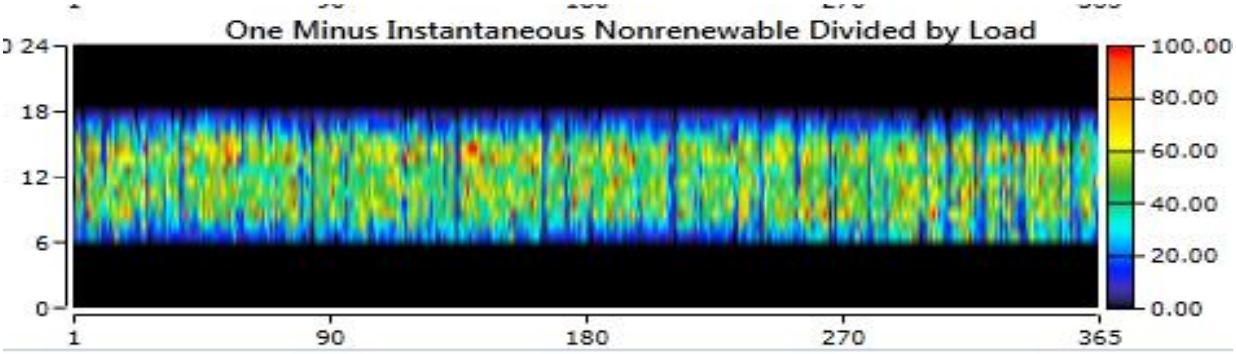



**Fig. 8.1 Renewable Penetration**

## CONCLUSION

In this study the concept of smart home energy system is studied. The small household load is taken and with homer the number of configurations is created and from these configurations the HOMER determined the most cost effective one. It is concluded that the implementation of smart home energy system on the different households can reduces the carbon emission and will be cost effective at the same time.

The solar PV's are installed strictly according to the government Roof top policy for getting various incentives and subsidies. These systems also have bright future as the cost of solar panels is expected to reduce in the future.

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