# Optimal Design of Grid-Tied Solar Electric Vehicle Charging Station Using HOMER GRID

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***Abstract*—This paper presents various charging schemes for solar powered electric vehicle charging stations. The optimum sizing of the station parameters and economic analysis has been done by using the optimization tool HOMER GRID. Various profiles of electric vehicles have been studied during the analysis. Use of electric vehicles and solar power generation are economically sound and environment friendly both. This helps in reduced consumption of fossil fuels, reduced carbon emission and integration of renewable energy resources into the conventional grid systems. The three combinations of grid and solar have been discussed in detail in this paper.**

**Keywords:** ***Carbon Emission, Electric Vehicles, Homer Grid, Solar Charging Station, Highway Chargers, Managed Office Charging***

## I. Introduction

Even today, most of the world's energy demand is met with fossil fuels. Almost 85% of the energy comes from natural gas, petroleum, coal, heavy oils etc. We all are aware of the environmental effects caused by them and therefore the renewable energy resources come into rescue. Though renewable energy resources also have their own limitations but they can be overcomed in the near future with proper research work. As far as energy consumption is concerned, the transportation sector is one of the major key energy consumers in the world. Therefore, electric vehicles are the need of the hour. Electric vehicles or hybrid electric vehicles help in lower consumption of fossil fuels, lesser carbon emissions and cheaper operational cost. Battery replacement cost and vehicle charging cost are still key cost factors that an electric vehicle user has to pay. In this paper, we will try to optimize the per unit electricity charges that a consumer has to bear for charging his electric vehicle. We will be designing a model using optimization tool HOMER GRID software where we will examine two electric vehicle charging schemes namely managed office charging and highway charger and examine the different profiles of electric vehicles that come for charging under respective schemes. Further, for the electric supply to charge these vehicles at the station, we will try different combinations of grid (called simple), solar and storage systems. We will be aiming at reducing the per unit electricity costs so that an electric vehicle owner has to pay a minimum amount for charging his Electric vehicle. Section 2 deals with System Description, section 3 deals with the results and Section 4 deals with the conclusion.

## II. System Description

We aim at designing such a system for electric vehicle charging stations that charges EVs with solar integrated grid connection and thus reduce the cost of electricity per unit that a consumer has to pay for charging his vehicle, also the carbon emissions. In the system design, we have taken generic flat plate PV of 3KW capacity each whose number is optimized by HOMER itself. This system is integrated with the nearby grid. Since this research is not done in any particular area, therefore, a generalized rate of ₹ 6.50 per unit of electricity is considered and similarly a sellback price of ₹ 2.25 per unit is considered as the export price. A system converter and Li-ion battery is also used for energy storage purposes. Two types of EV charging scheme has been studied i.e. Managed Office Charging and Highway Charging. The profile of the EVs for both schemes is given in Table 1.

The exact location from where the data for average global solar radiations, average wind speed and average air temperatures are taken is 1/124, Chanderi, Dhawlikar, Rakabganj, Agra, Uttar Pradesh 282001, India. The average electric energy consumption here is 835.1 KWh/day daily and 304.8 MWh annually with 190.32 KW as peak demand. The load profile for the day on which highest demand occurs can be depicted by graph 1.

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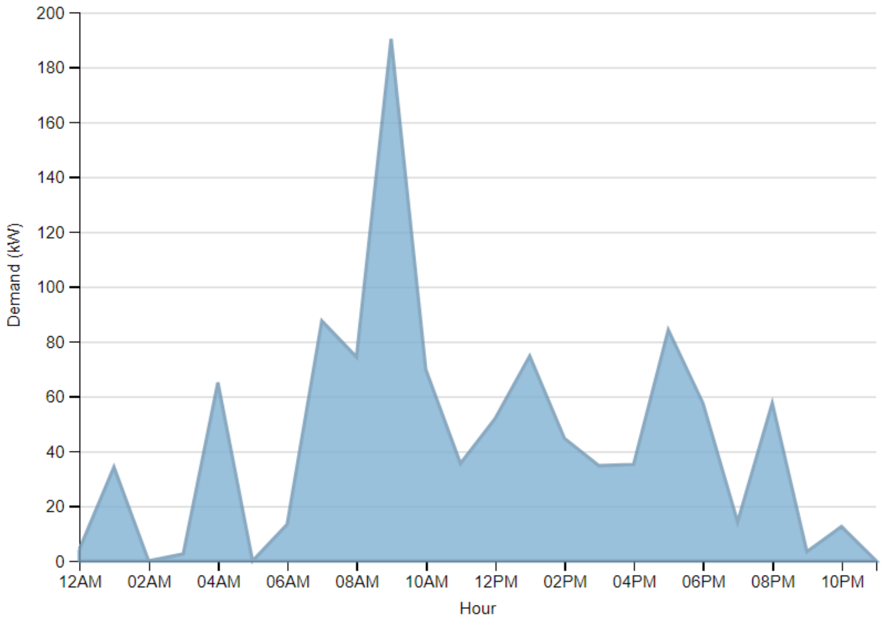
TABLE 1: PROFILE OF ELECTRIC VEHICLES

| Model | Proportion of EV Population | Maximum Charging power per EV (KW) | Required Charging Energy per EV(KW) |
|---|---|---|---|
| MFC: | | | |
| Leaf | 20 | 6.6 | 15 |
| Tesla Model X | 30 | 17.2 | 40 |
| Tesla Model 3 | 30 | 17.2 | 30 |
| BMW i3 | 10 | 7.7 | 12 |
| Chevy Bolt | 20 | 7.7 | 15 |
| HC: | | | |
| Large EVs | 30 | 150 | 20 |
| Small EVs | 70 | 50 | 20 |




Graph 1: Load Profile of Day With Highest Demand

The system model developed in HOMER GRID software is given in Figure 1.

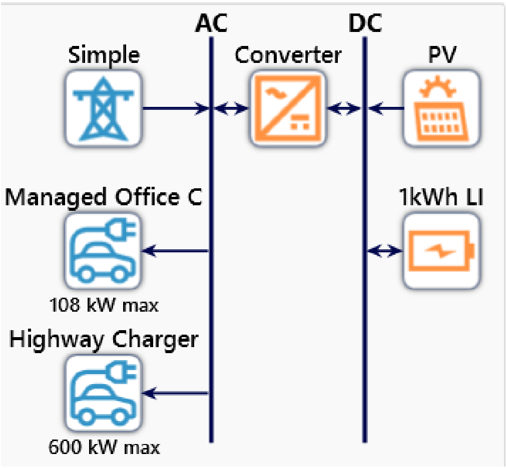



Fig. 1: System Model

As discussed earlier, we have taken 2 charging schemes for evaluation purposes namely:

1. Managed Office Charging
2. Highway Charger

The details of charger output power, mean time connected and number of chargers for both the schemes taken are given below in table 2.

TABLE 2: CHARGING SCHEME PARAMETERS

| Parameters | Managed Office Charging | Highway Charger |
|---|---|---|
| Charger Output Power (KW) | 18 | 150 |
| Mean Time Connected(hr) | 6 | 20mins |
| Number of Chargers | 6 | 4 |
| Scaled Avg Sessions/day | 10 | 20 |

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## III. Results

The HOMER GRID software simulated 277 feasible solutions out of which 84 were omitted due to lack of a converter or having unnecessary converters. Out of these solutions, 4 solutions have been picked up for our evaluation that are given in the following table 3.

The four cases taken are as follows:

1. Solar+Simple
2. Solar+Storage+Simple
3. Base Case
4. Storage+Simple

Table 3: Architectural Combinations

| | Architecture | | | | Cost | | |
|---|---|---|---|---|---|---|---|
| | | | | | NPC (₹) | COE (₹) | Operating cost (₹/yr) |
| | | | | | ₹ 19.1M | ₹ 4.84 | ₹ 1.01M |
| | | | | | ₹ 19.1M | ₹ 4.87 | ₹ 1.02M |
| | | | | | ₹ 21.7M | ₹ 6.50 | ₹ 1.68M |
| | | | | | ₹ 21.9M | ₹ 6.55 | ₹ 1.68M |

As depicted by this tabel, the base case is highlighted i.e. the cost of electricity per unit for charging when only grid is used, comes out to be ₹ 6.5 whereas after using solar PV panels along with the grid, the cost is reduced upto ₹ 4.84 per unit.

The summary of all the four cases is given in the below table 4.

The best case that comes out to be is the one in which electric vehicle charging is done with grid and solar both without using energy storage device i.e. "Case 1- Solar+Simple", in this case, the electricity charge is coming out to be ₹ 4.84. Further, comparison can be seen in table 5 and table 6.

The ROI (Return on Investment) for this system is calculated to be 7.2% and simple payback years comes out to be 8.5 years. Also the IRR (Internal Rate of Return) is coming out to be 10%.

The cash flow diagram of the system is shown in figure 2.

The performance summary of the system can also be obtained from the HOMER showing a plot of peak day PV and grid purchases for every month. The same for the hottest and coldest month can be seen in graph 2 and graph 3.

The total carbon emission using this system will be 94.6 tonnes/year whereas the only-grid system generates around 163.4 tonnes of carbon per year which is almost 1.7 times higher than the integrated system.

Table 5: Cost Summary

| | Base Case | Lowest Cost System |
|---|---|---|
| NPC | ₹ 21.7M | ₹ 19.1M |
| Initial Capital | ₹ 0.00 | ₹ 5.96M |
| O&M | ₹ 1.68M/yr | ₹ 1.01M/yr |
| LCOE | ₹ 6.50/kWh | ₹ 4.84/kWh |

Table 6: Savings

| | |
|---|---|
| Annualized Utility Bill Savings | ₹ 8,11,266/yr |
| Net Present Utility Bill Savings | ₹ 10.5M |
| Annualized Demand Charge Savings | ₹ 0.00 |
| Annualized Energy Charge Savings | ₹ 8,11,266 |

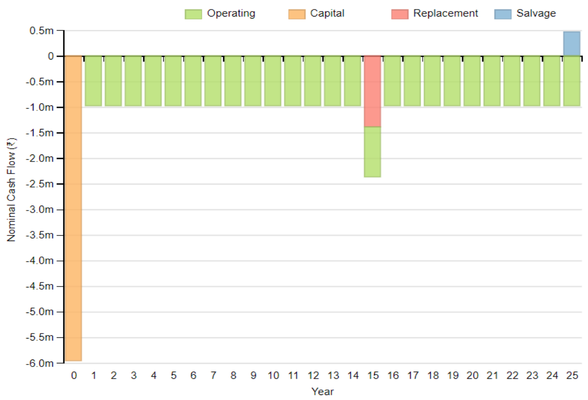


Fig. 2: Cash flow Diagram of the system

Table 4: Summary of all cases

| | Base Case | Solar + Simple | Solar + Storage: 1kWh LI + Simple | Storage: 1kWh LI + Simple |
|---|---|---|---|---|
| Costs and Savings | | | | |
| CAPEX | ₹ 0 | ₹ 59,58,830 | ₹ 59,12,088 | ₹ 1,25,729 |
| OPEX | ₹ 16,80,297 | ₹ 10,14,846 | ₹ 10,20,080 | ₹ 16,84,147 |
| Annual Total Savings (₹) | ₹ 0 | ₹ 6,65,451 | ₹ 6,60,217 | -₹3,850 |
| Annual Utility Bill Savings (₹) | ₹ 0 | ₹ 8,11,266 | ₹ 8,06,799 | ₹ 0 |
| Annual Demand Charges (₹/yr) | ₹ 0/yr | ₹ 0/yr | ₹ 0/yr | ₹ 0/yr |
| Annual Energy Charges (₹/yr) | ₹ 16,80,297/yr | ₹ 8,69,031/yr | ₹ 8,73,498/yr | ₹ 16,80,297/yr |


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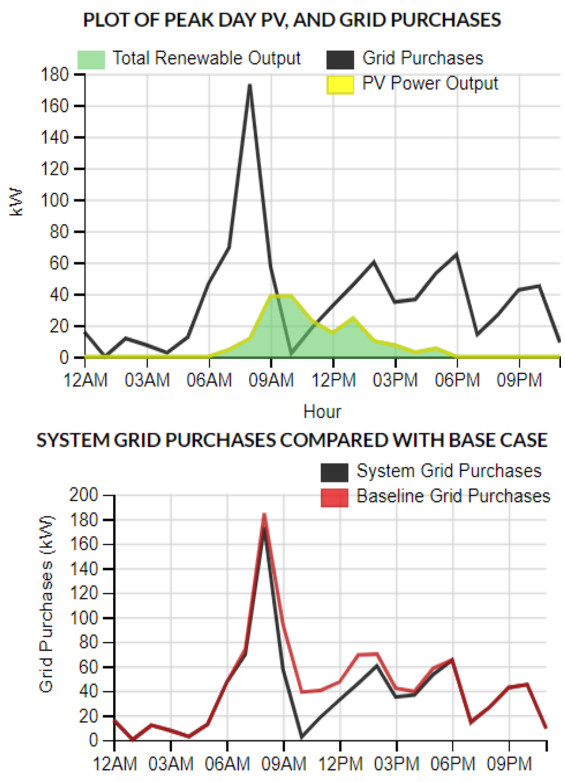
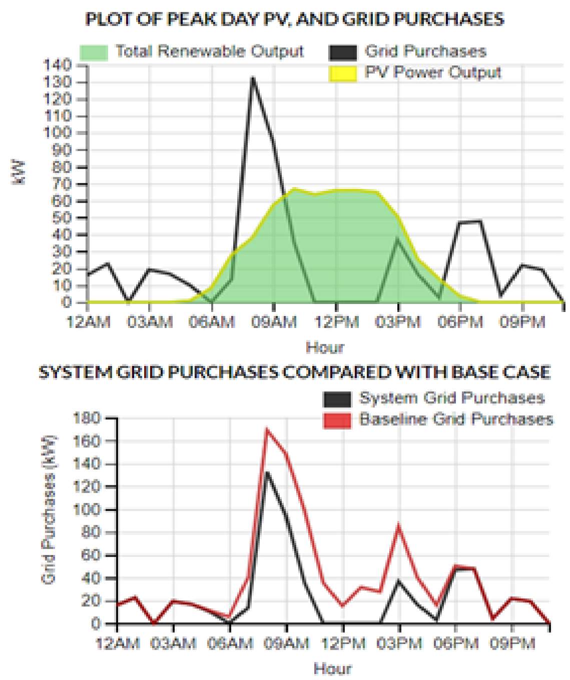



Graph 2: Performance summary for January




Graph 3: Performance Summary for May

## V. Conclusions

From the above design and analysis, it can be inferred that a solar integrated system is very effective when it comes to cost cutting. It serves many other benefits along with this. To meet the future electricity demands, renewable energy systems are a good alternative. Similarly, for reducing the carbon emissions and load on the fossil fuel demands, a variety of electric vehicles are available in the market now at an affordable price. The system that has been designed has proven to be both feasible in both technical and financial point of view.

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