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DESIGN AND ANALYSIS OF A STAND-ALONE PV SYSTEM FOR A RURAL AREA USING HOMER PRO SOFTWARE

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ABSTRACT: Among several renewable energy resources, Solar PV is the one of the most essential and sustainable resources. Photovoltaic system is the direct conversion of sunlight to electricity. This work focuses on the cost analysis and design of a stand-alone PV system to be set up in a rural village having a total load of 200kw. For that a rural area near Guwahati city namely Deepor Beel has been chosen in Chakardeo village. For this analysis HOMER PRO platform has been used. This system consists of an AC bus, a DC bus, both are interlinked by a converter. The PV system/array, battery backup and the load are on the DC bus. As a backup, a diesel generator is connected on the AC bus. The electrical energy produced from the PV system is 108,377 kWh/yr and a 22.8% of excess energy remained and the payback period has been found to be 1.7 yrs.

Keywords: Renewable energy resources, Stand-alone PV system, HOMER Pro

1. Introduction: The Sun provides the energy to sustain life in our solar system. In one hour, the earth receives enough energy from the sun to meet its energy needs for nearly a year. Photovoltaic is the direct conversion of sunlight to electricity. It is an attractive alternative to conventional sources of electricity for many reasons: it is safe, silent, and non-polluting, renewable, highly modular in that their capacity can be increased incrementally to match with gradual load growth, and reliable with minimal failure rates and projected service lifetimes of 20 to 30 years. Increased energy utilization and global pollution awareness have made green/renewable energy more and more valuable. Among several renewable energy resources, photovoltaic effect is the most essential and sustainable way. A photovoltaic system is a complete set of interconnected components for converting sunlight into electricity by photovoltaic process including array, balance-of-system, and load. The intensity of the sunlight that reaches the earth varies with time of the day, season, Location, and the weather condition. The total energy on a daily or annual basis is called irradiation and indicates the strength of the sunshine. Irradiation is expressed in Wh per meter square per day. Most of the rural areas in Guwahati city are still underdeveloped and in a chaotic state after the invasion, and there is a need to provide these areas with electricity. Small standalone PV electrification systems can play a strategic role in the region's development. The region enjoys a huge amount of solar radiation during the entire year. Although capable of providing plentiful and reliable electricity, this resource is largely untapped. The solar systems can satisfy the electrical needs of clinics, school, and other social places in a way that can positively affect healthcare and education, ensuring adequate services for the population. This project has been designed for the cost analysis of a stand-alone PV system to be set up in a rural village having a total load of 200kw. For that we have chosen a rural area near Guwahati city namely Deepor Beel (Chakardeo village). For this analysis we have used HOMER PRO platform since it is a global standard for optimizing microgrid design in all sectors, from village power and island utilities to grid-connected campuses and military bases. HOMER models a power system's physical behavior and its life-cycle cost, which is the total cost of installing and operating the system over its life span. HOMER allows the modeler to compare many different design options based on their technical and economic merits. It also assists in understanding and quantifying the effects of uncertainty or changes in the inputs. Our system consists of an AC bus, a DC bus, both are interlinked by a converter. The PV system/array, battery backup and the load are on the DC bus. As a backup, a diesel generator is connected on the AC bus.

Theoretical analysis: In a stand-alone system, the system is designed to operate independent of the electric utility grid and is generally designed and sized to supply certain dc and/or ac electrical loads. A bank of batteries is used to store the energy in the form of dc power that is produced by the photovoltaic (PV) modules to be used at night or in the no sun days. The dc output of the batteries can be used immediately to run certain low dc voltage loads such as lighting bulbs or refrigerators or it can be converted by an inverter to ac voltage to run ac loads that constitute most appliances. As output power of a solar array deviates with weather conditions, the rewarding activity of the standalone system is to find out the optimal size of a solar array and battery to meet load demand. The reliability of power supply to the load is described by the loss of power supply probability (LPSP). LPSP is the ratio of the number of hours that the system fails to supply a load to the total number of hours required by the load. Stand-alone PV systems should provide a good quality electricity service to be considered as an alternative to conventional grid extension, for places with no access to electricity. Basically, Stand-alone PV systems are ideal for remote rural areas and applications where other power sources are either impractical or are unavailable to provide power for lighting, appliances and other uses. In these cases, it is more cost effective to install a single stand-alone PV system than pay the costs of having the local electricity company extend their power lines and cables directly to the home.

A stand-alone photovoltaic (PV) system is an electrical system consisting of an array of one or more PV modules, conductors, electrical components, and one or more loads. These systems are not connected with utility power lines and these are self-sufficient systems. These systems could either be used to charge the batteries that serve as an energy storage device or could work directly using the solar energy available in the daytimes. These systems consist of the following:

- Solar panels mounted on the roof or in open spaces. Photovoltaic modules produce direct current (DC) electrical power.
- Batteries to store DC energy generated by the solar panels.
- Charge controller to prevent overcharging the battery.
- Inverter to convert electricity produced by the system from DC to AC power.
- Fuses and Isolation Switches: These allow PV installations to be protected from accidental shorting of wires allowing power from the PV modules and system to be turned “OFF” when not required saving energy and improving battery life.
- Wiring: The final component required in and PV solar system is the electrical wiring. The cables need to be correctly rated for the voltage and power requirements.

Hussein *et. al* in 2012 proposed a design of an optimal stand-alone photovoltaic system for a rural area in Oman which will help them grow will help them socially, economically, culturally and educationally. They cited that as all power generation facilities at present are dependent on nonrenewable fossil fuels and there is a risk of electricity shortages to occur in the near future, it is strongly advisable to seek alternative sources of energy. In case of Oman, it is found that if they continue electricity production using natural gas (which was the most used source for producing electricity domestically), then Oman will have to import, rather than export gas. According to the researchers, the three most important factors to be considered in selecting new resources are their availability, renewability and environment friendly and the solar source was found to fulfill all these conditions and Oman has a high solar energy density that is available in all parts of the country.

The team chose the roof of faculty of engineering building in Sohar University to install their system as roof is a more convenient location than ground. As method of designing, they found out the load profile of a typical house in that area at first which gave the consumption needs and in accordance to this the power capacity of the solar cell was defined using average daily number of sunshine hours. Then the number of PV modules, suitable types of PV panels (monocrystalline was taken), charge controllers, inverters, batteries, special cables, protection and other accessories are determined, respectively. After all these works are done, the simulation the model was done by using a computer software namely HOMER and the mean output production (in kWh/d), comparison between PV power generated and load power, total energy generated/day, life cycle cost etc. are found out by taking reference of the Comparison graph between PV and load power, monthly average electrical production graph, Cash flow diagram etc. The system was found to work to its maximum potential.

In 2016, Shahzad Ahsan *et. al* presented designing aspects and assessments of solar PV system based on field and actual performance. The study was based on design of solar PV system and a case study based on cost analysis of 1 kW off-grid photovoltaic energy system installed at Jamia Millia Islamia, New Delhi, India. In this project both monthly and weekly costs of energy produced by a 1 kW system was calculated. They also have briefly described the importance of search for renewable energy resources and the factors that can affect the production of solar energy. In this project a software viz. PVsyst has been used to evaluate the cost analysis and this software uses the information of solar radiation of the site to calculate generated power, used power and unused power.

Calculation of the total power consumption in one house and the cost of building the system was done after selecting the type and number of modules for the PV array (200 W Moserbaer (MBPV CAAP BC 200Wp) PV Si-Poly modules), batteries, inverter, controller etc. Then the performance of the system and monthly energy production were evaluated and calculated with the help of the same software. Comparison of energy generated and energy supplied and needed was also done in this paper.

Ali H A Alwaeli *et. al* 2017, aimed to study a stand-alone PV system in a village in Sipitang, Sabah of Malaysia in terms of principle of work, construction and operation. They also put forward and implemented a case study application. According to the authors of this paper also there is definitely a need to stop the dependency on fossil fuels which can cause many problems in long term and it should be replaced with renewable resources. But to compete with fossil fuels renewable energies needs to be cost-effective.

Providing electricity to communities in many rural areas in Malaysia is a hard task as connecting grid to those areas is technically impossible or economically expensive. Diesel generators are also not a suitable option. Finally going to establish stand-alone PV system design they explained about the principle of working of a PV cell in detail about which all of us are aware less or more. They also raised about the studied of hybrid wind-PV-Diesel-Battery system, finding suitable state of charge (SOC), hybrid photovoltaic-diesel systems in their paper. Then considering all the aspects to design the system of interest such as load profiling, calculating the size and number of PV panels, inverters, batteries, charge controllers and taking reference of the methods used in other projects they finally designed the system with 1 inverter, 1 charge controller, 2 batteries (250 Ah) and 4 PV panels (180 Watts)- all connected in parallel. The cost analysis concluded with a capital cost of 5,171.2 USD whereas it had an initial cost of 2,458 USD. Different applications of a stand-alone PV system were also discussed in this very paper.

Amjad Iqbal and M. Tariq Iqbal did a study on design and analysis of a Stand-Alone PV System for a rural house in Pakistan, in 2019. They tried to implement small PV systems to meet the domestic load demand of the people living in all the solar irradiance-rich areas of the world. Most of the remote communities of underdeveloped countries like Pakistan have high solar resource but are isolated from the main grid and they face long hours of load shedding. Taking the wind-speed data and solar radiation data in consideration they finalized to propose the PV system design.

They did the thermal modelling of their system using BEopt to observe the hourly load profile and with reference to that PV sizing had been done. An optimized and low-cost system was selected using HOMER Pro and the model was simulated in MATLAB-Simulink. The finalized design consists of a 5.8 kW PV with eight batteries of 12 V, 255 Ah, and a 1.4 kW inverter. The system costed $9650 and produced electricity at $0.199/kWh. The system was found capable of providing a stable voltage and frequency for the domestic load. They also added that a large-scale implementation of the PV system study could be done in future to explore the implementation of other combinations for energy storage systems along with the battery bank.

Ndagijimana, M. Tech, b. Kunjithapathan again in 2019, elaborately discussed on design and implementation of PV energy system for electrification of rural areas. They designed a standalone solar energy system to supply power to a single-family having load of 8006 W and experimented the implementation of solar energy system to supply a load of 180 watts as sample that can supply a room using

2 CFL bulbs, 1 mobile phone charger, one radio and one laptop. Taking into consideration different renewable energy resources, they discussed some advantages of solar resource over the rest.

The aim of this paper was to answer the questions such as how the energy can be achieved to satisfy our needs without environmental degradation at low cost, the basic elements required to design a standalone PV system. They explained the design methodology in 8 successive steps which were: site inspection, determining load requirements, PV module sizing, charge controller sizing, battery bank sizing, inverter Sizing, cable sizing and cost estimation. After choosing all the components, total power consumption demand in the chosen area is determined. Then the sizing and number of PV modules, battery sizing, inverter and controller sizing etc. are done using pre-defined mathematical formulae. After that calculating the capital cost and maintenance cost the overall cost is found out and finally the payback period was also calculated. The objectives cited within this study was achieved and the hypothesis had been confirmed. Also, they recommended the government to promote the solar energy system projects.

We did not find a project on PV system employing at any area of Assam. Therefore, we decided to do the same in our native place and to validate how efficient and cost effective it will be in the climate of Assam.

3. Design of the system:

I. <u>Site inspection in brief:</u> The selected area is a rural one in the periphery of Guwahati city, Assam with the coordinates of 26°6.0′ N and 91°38.9′E. This paper tries to propose a design of an optimal system to supply electrical energy to people of this area. At first, we briefly analyzed the renewable resources available in this area. Wind speed in this area is 0.89 mph. We have, the equation for wind power (P) given by $P=0.5\rho AC_pV^3N_gN_b$; where ρ= Air density in kg/m^3, A= Rotor swept area (m^2), C_p= Coefficient of performance, V= wind velocity (m/s), N_g= Generator efficiency, N_b= gear box bearing efficiency. As wind Power is proportional to cube of the wind velocity; such a small velocity results into a small amount of generated power. Again, this much velocity also does not remain constant all over the year which cannot ensure the generation of energy. We considered domestic and animal waste as the biomass generated in the area which is very less in quantity. As the process of generating electrical power from biomass (Biomass-Biogas-Electrical power) is already a very costly process, investing much for a small production is not a feasible option. There are no other renewable resources like geothermal, tidal etc. available in this area which eliminates those options automatically. The annual average solar global horizontal irradiance is 4.55 kWh/m^2/day. After all we decided to place a PV system to generate the required energy.

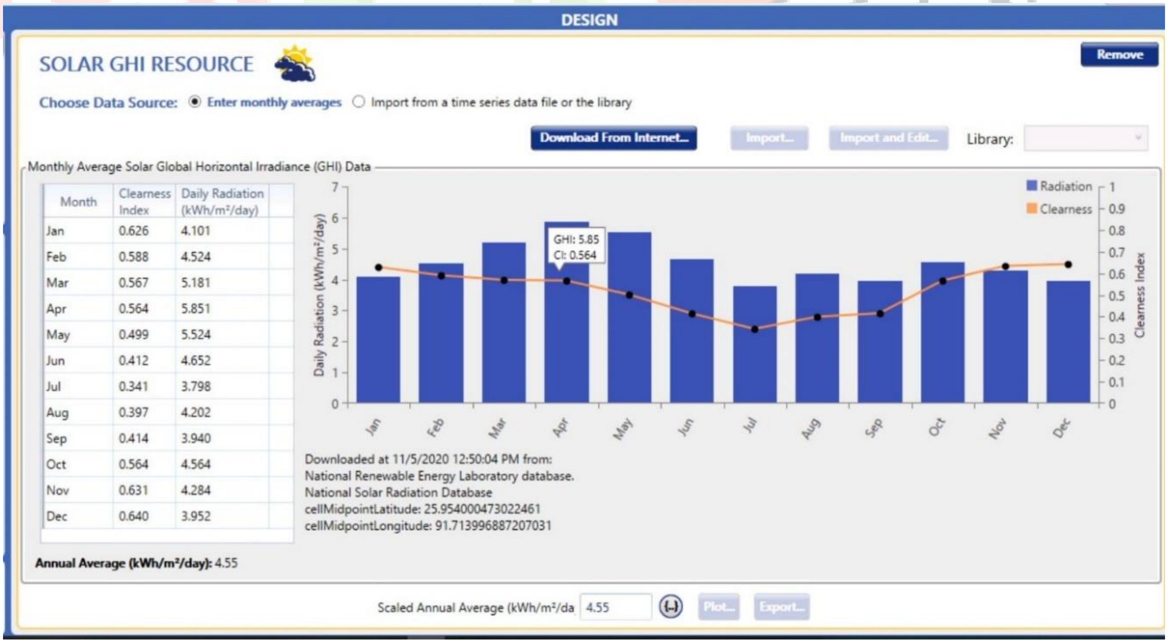


fig1: solar GHI resources

The modeling of this project has been initiated by considering the residential loads and hence the result of annual energy consumption. Table 1 shows an approximated calculation of the total energy consumption in a day per house by counting the number of active appliances and their power consumption mentioned on their packages.

Table1: Estimated energy consumption of a typical house in a day

Load	Qty	Volts	Power rating (Watts)	Run Hours per Day	Energy (Wh/Day)
Lights	7	240	15	7	735
Fans	4	240	48	12	2304
Television	1	240	50	3	150
Phone charging	4	240	5	3	60
Laptop	2/3 *	240	70	3	140
Miscellaneous					3309.66
Total					6698.66

*Assuming more than 65% of residentials have laptops.

Total power needed by 1 family in 1 day= 188 W

Total energy consumption by 1 family in 1 day= 6698.66 Wh

No. of families in the area= 30

Total energy consumption in the area= 6698.66x30= 200959.8 Wh/Day= 200.96 kWh/Day

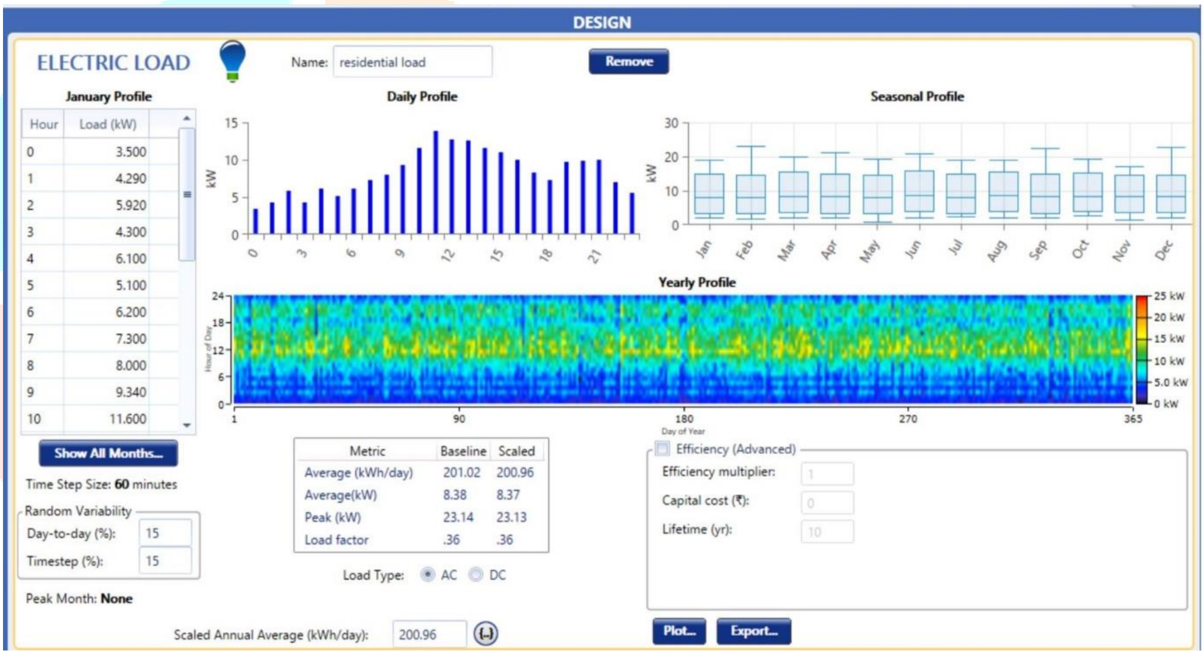


Fig2: Daily, Seasonal and Yearly Load Profile

In the rural areas, majority of people do not use air conditioners, washing machines or other such high power consuming non-essential commodities. The typical load is small, an approximate of 6-7 kWh/day of one typical house. The hourly, daily, seasonal and yearly load profile has been generated by the HOMER software (Fig 2) which shows that the energy consumption is relatively higher in the months of February, September and December. The hourly load profile for a year was also generated and it shows the total kWh consumption round the year by different load types (Lights, Fan, TV etc.). Miscellaneous load seems too high compared to others because it accommodates all different types of loads other than the list presented in Table 1.

Designing of PV system mainly consists of PV modules; large number of PV modules are connected in parallel and series combination called PV array. All PV modules are connected in parallel. This stand-alone PV plant is designed for a rural locality having requirement 200 kwh of electricity per day. The peak load on the system is 23.13 kw.

Block diagram:

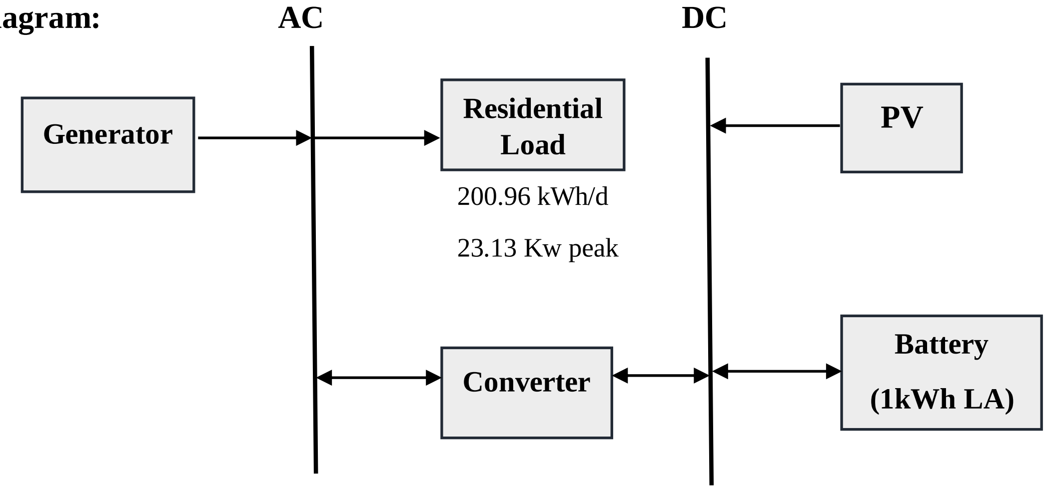


fig 3: block representation of the PV system model

II. Selection of components of the system:

a. **PV cell:** Solar panels (PV) are chosen as power generating source as and it is connected to the dc bus of voltage 36 volt. We have chosen Flat plate PV panel of Generic brand of rated capacity 1 kW. Its estimated lifetime is 25 years.

b. **Battery:** We have used a Generic 12 Volt lead acid battery with 1kWh of energy storage. Batteries are connected for backup battery to supply at night and to store excess energy. Its other specifications are:

Maximum capacity: 83.4 Ah
Capacity Ratio: 0.403
Rate constant (1/hr): 0.827
Roundtrip efficiency: 80%
Maximum charge Current (A): 16.7
Maximum Discharge Current (A): 24.3
Minimum storage life: 8 yrs

c. **Generator:** A Generic 25kW Fixed Capacity Diesel generator is used in this system. Minimum load ratio of the same is 45%. Generator is kept for no battery backup (minimum load ratio is 45%, i.e., generator will supply only 45%of total load in extreme situation).

d. **Converter:** As the residential loads mostly require AC, so load is in ac bus and a converter is also used between the both buses. This is a Leonics MTP 413F 25kW (Leon25) Converter which is about 96% efficient and has a lifetime of 25 years.

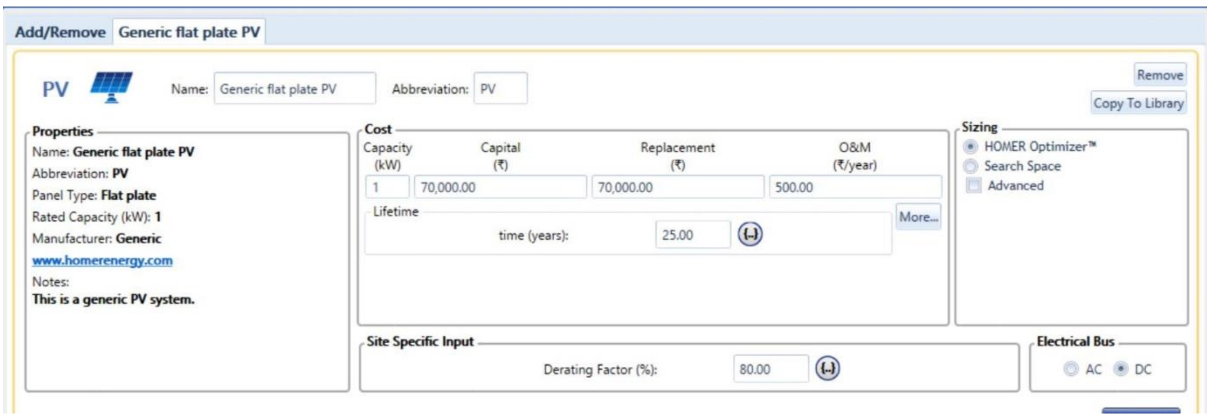


fig4: specification of PV panels

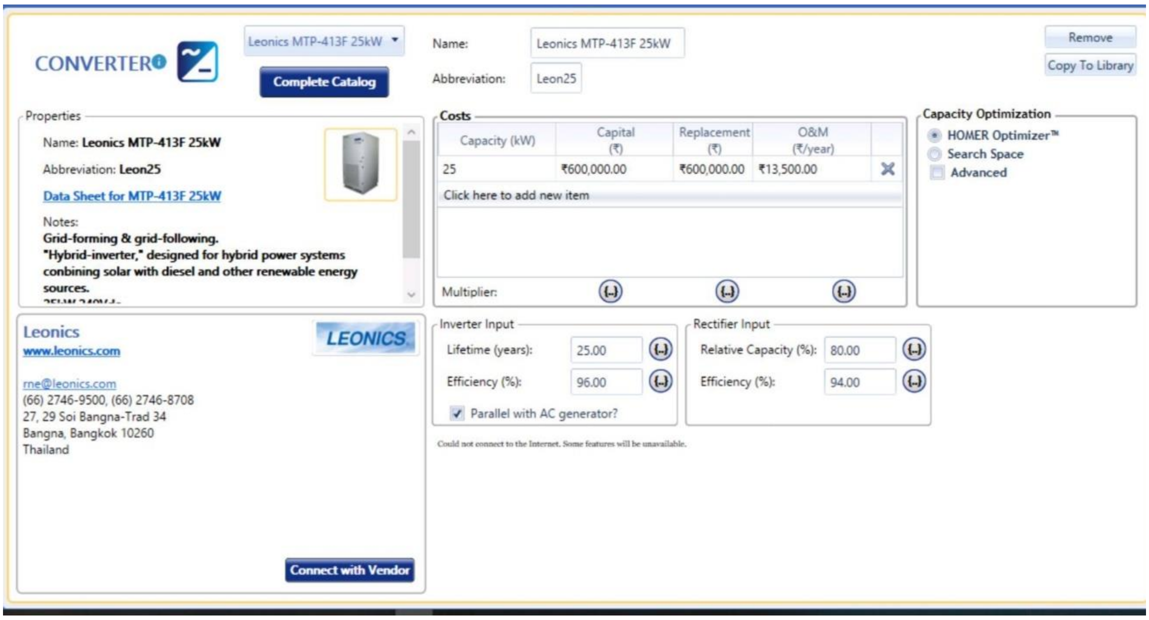


fig 5: specification of converter

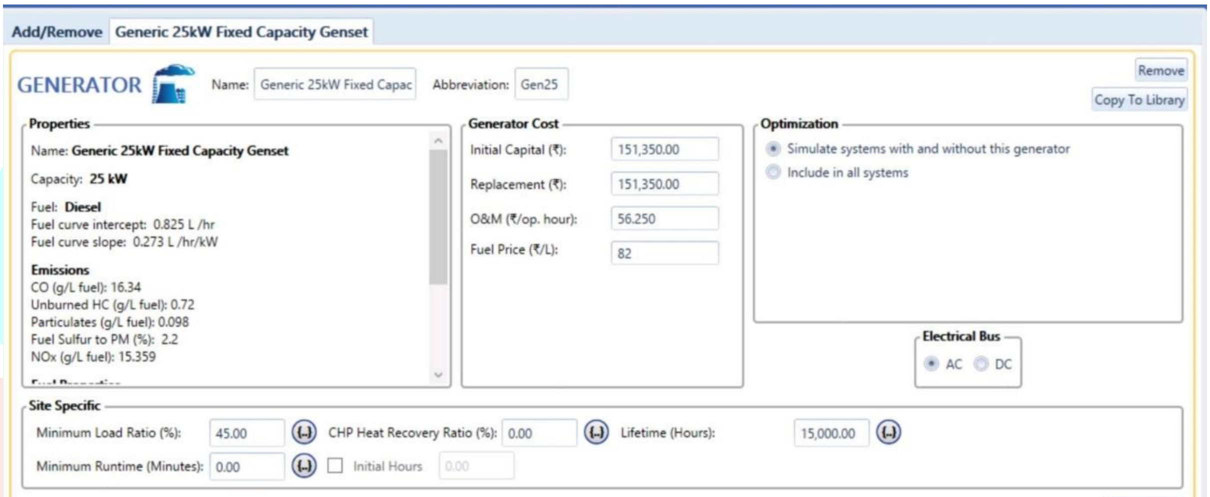


fig 6: specification of generator

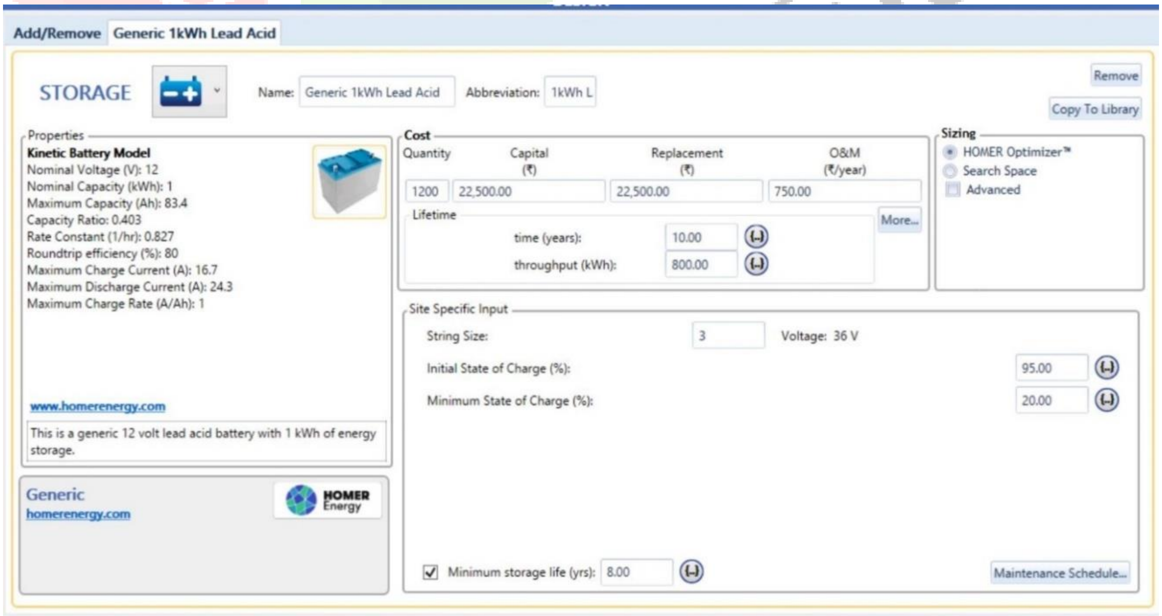
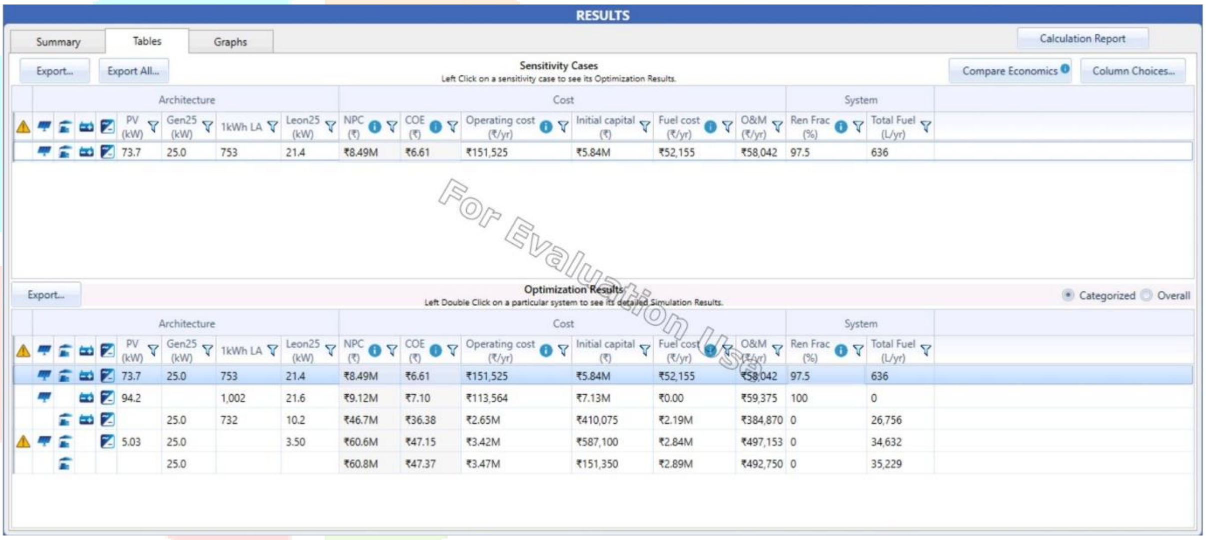


fig 7: specification of storage

fig 8: battery details

4. Simulation, Result and Calculation:



Sensitivity Cases

PV (kW)	Gen25 (kW)	1kWh LA	Leon25 (kW)	NPC (₹)	COE (₹)	Operating cost (₹/yr)	Initial capital (₹)	Fuel cost (₹/yr)	O&M (₹/yr)	Ren Frac (%)	Total Fuel (L/yr)
73.7	25.0	753	21.4	₹8.49M	₹6.61	₹151,525	₹5.84M	₹52,155	₹58,042	97.5	636

Optimization Results

PV (kW)	Gen25 (kW)	1kWh LA	Leon25 (kW)	NPC (₹)	COE (₹)	Operating cost (₹/yr)	Initial capital (₹)	Fuel cost (₹/yr)	O&M (₹/yr)	Ren Frac (%)	Total Fuel (L/yr)
73.7	25.0	753	21.4	₹8.49M	₹6.61	₹151,525	₹5.84M	₹52,155	₹58,042	97.5	636
94.2		1,002	21.6	₹9.12M	₹7.10	₹113,564	₹7.13M	₹0.00	₹59,375	100	0
	25.0	732	10.2	₹46.7M	₹36.38	₹2.65M	₹410,075	₹2.19M	₹384,870	0	26,756
5.03	25.0		3.50	₹60.6M	₹47.15	₹3.42M	₹587,100	₹2.84M	₹497,153	0	34,632
	25.0			₹60.8M	₹47.37	₹3.47M	₹151,350	₹2.89M	₹492,750	0	35,229

fig 9: sensitivity cases and optimization results

After simulating our model in HOMER, we get the optimization results as shown in Fig 9. Operating cost of the generator is least, so this is the base case.

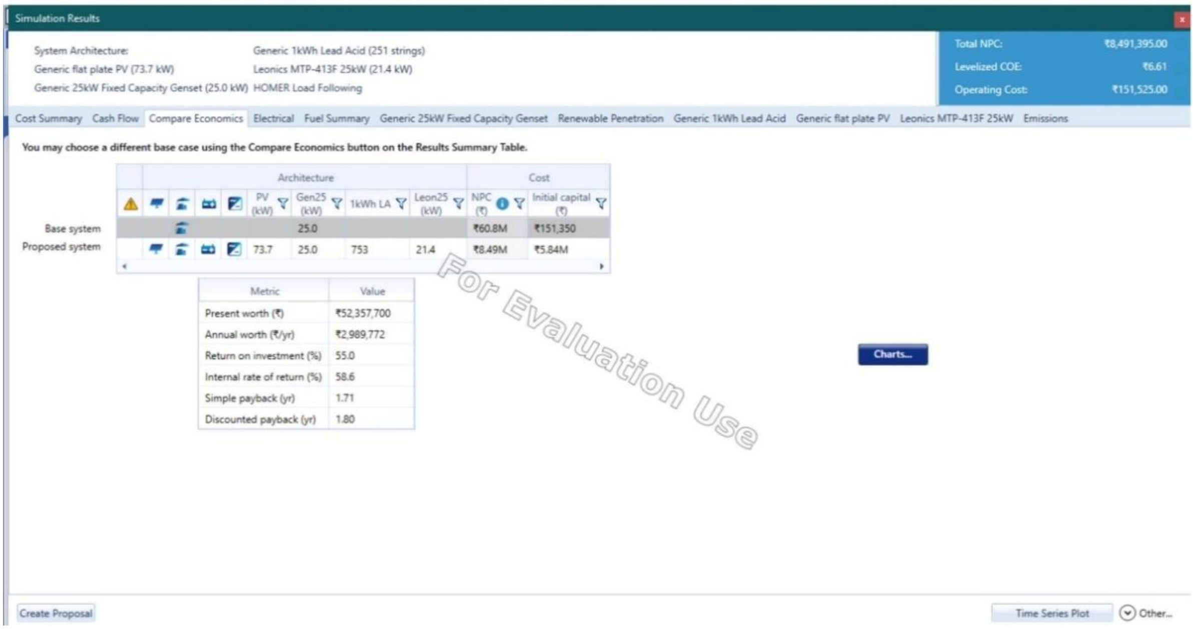


fig 10: base and proposed system, other economical values

Fig 10 shows the base and proposed cases. It also shows the present worth and annual worth which are Rs. 52,357,700 and Rs. 2,989,722, respectively. Return on investment is 55% and internal rate of return is 58.6%.

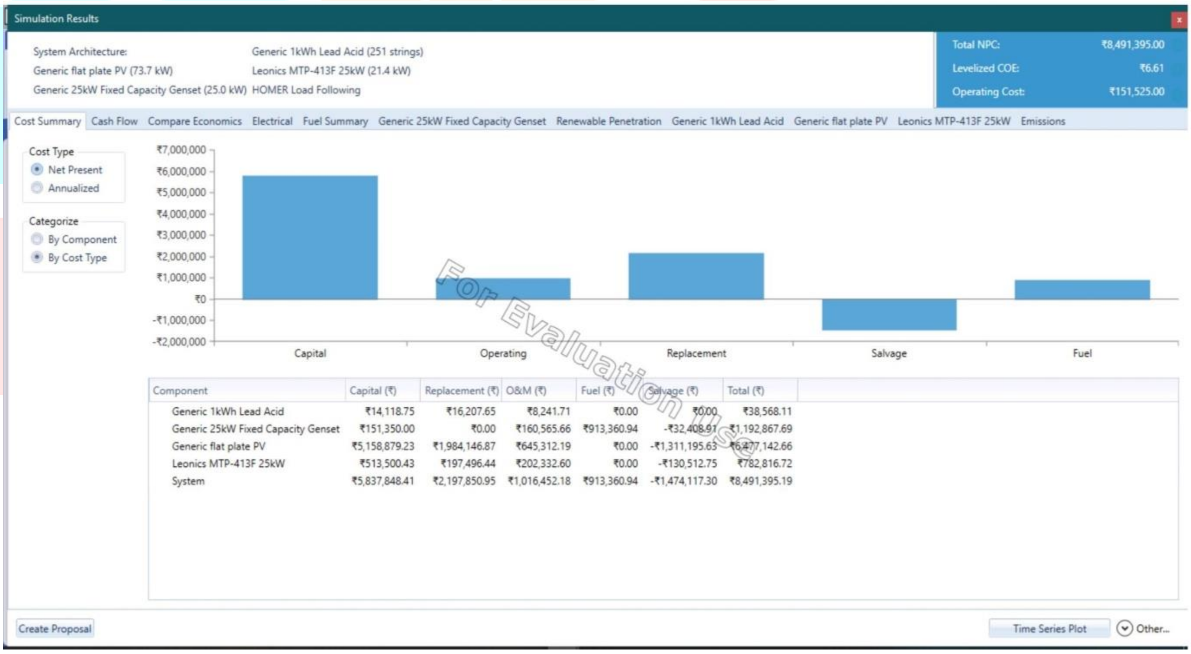


fig 11: net present cost by cost type

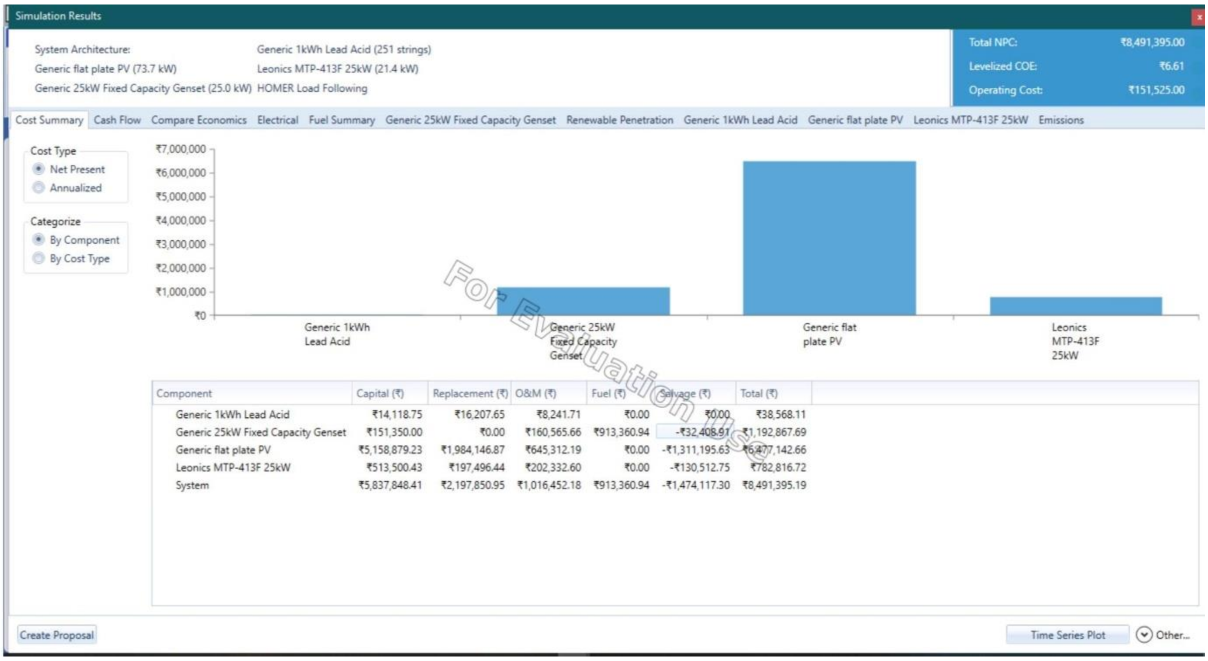


fig 12: net present cost by component

Fig 11 and Fig 12 present net present costs by cost type and components, respectively. The total NPC is equal to Rs. 8,491,395.00.

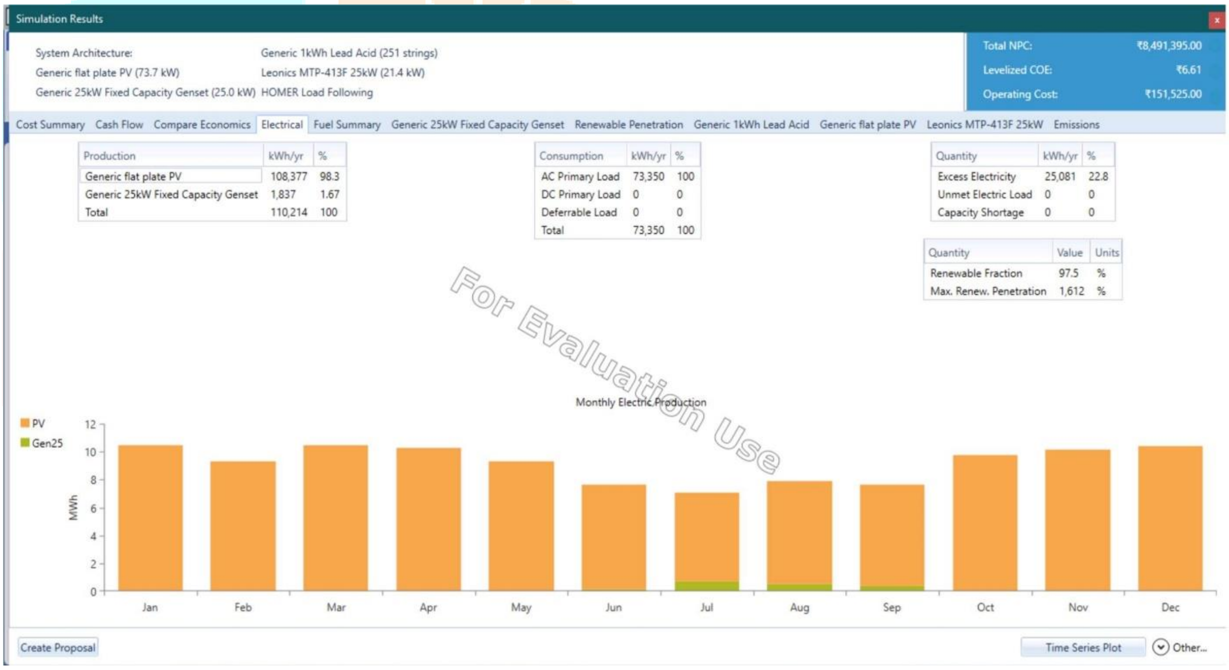


fig 13: monthly electric production

The electrical energy produced from the PV system is 108,377 kWh/yr and that from the generator is 1837 kWh/yr. Thus, the total generation is 110,214 kWh/yr. In the other hand the total consumption in a year is 73,350 kWh. There is no unmet load and an excess electricity of 25,081kWh/yr (22.8%) has remained. So, we can infer it as an optimal system.

We enclose the power output graphs of both PV and generator (Fig 14 and Fig 15).

fig 14: PV power output

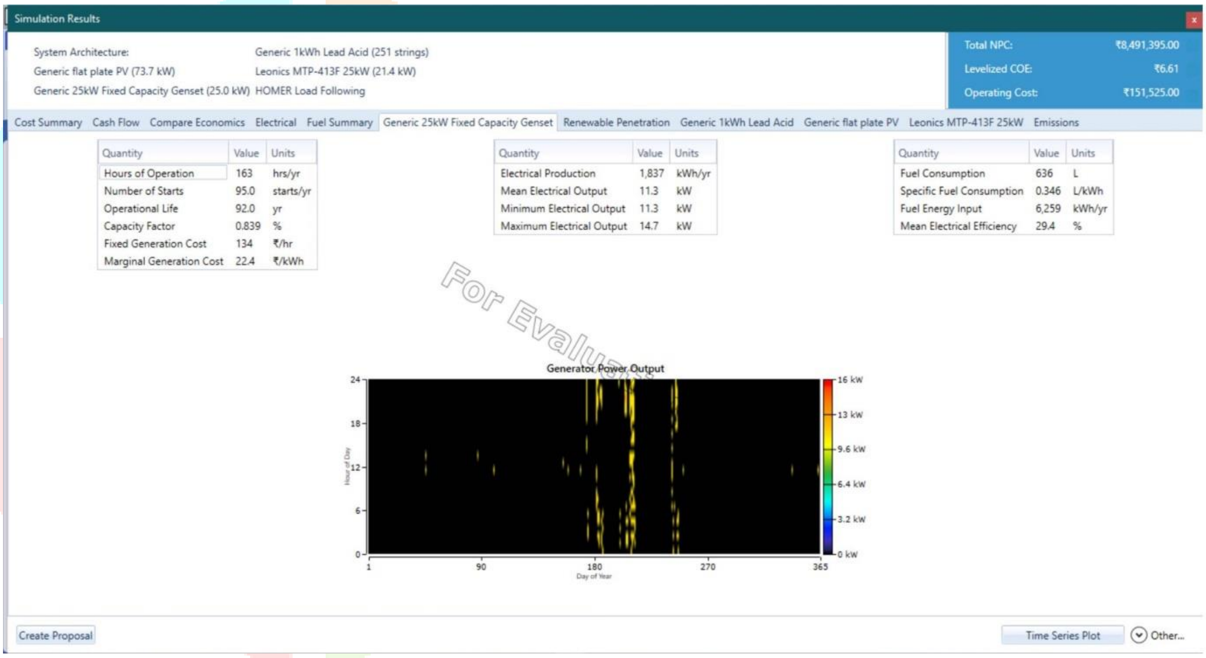


fig 15: generator power output

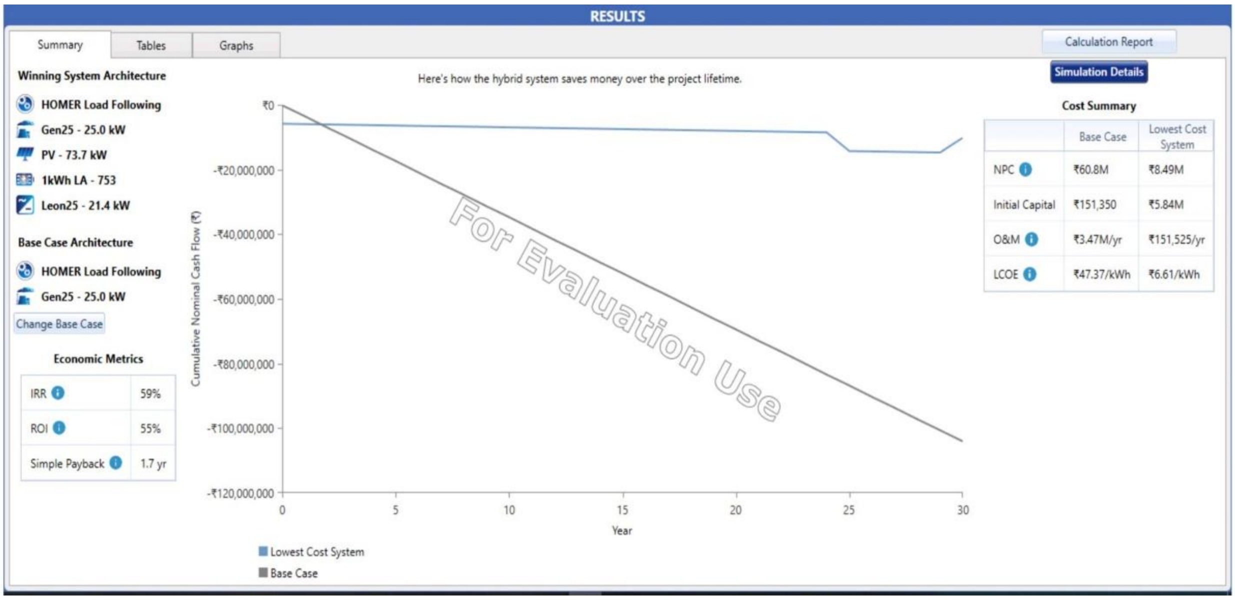


fig 16: how the system performs over the project lifetime

Fig 16 shows how the proposed system performs over years. The graphs of proposed system and base system intersect at a point of distance 1.7 from the origin along the x-axis (year). This means the proposed system will perform better after 1.7 years which is called the payback period.

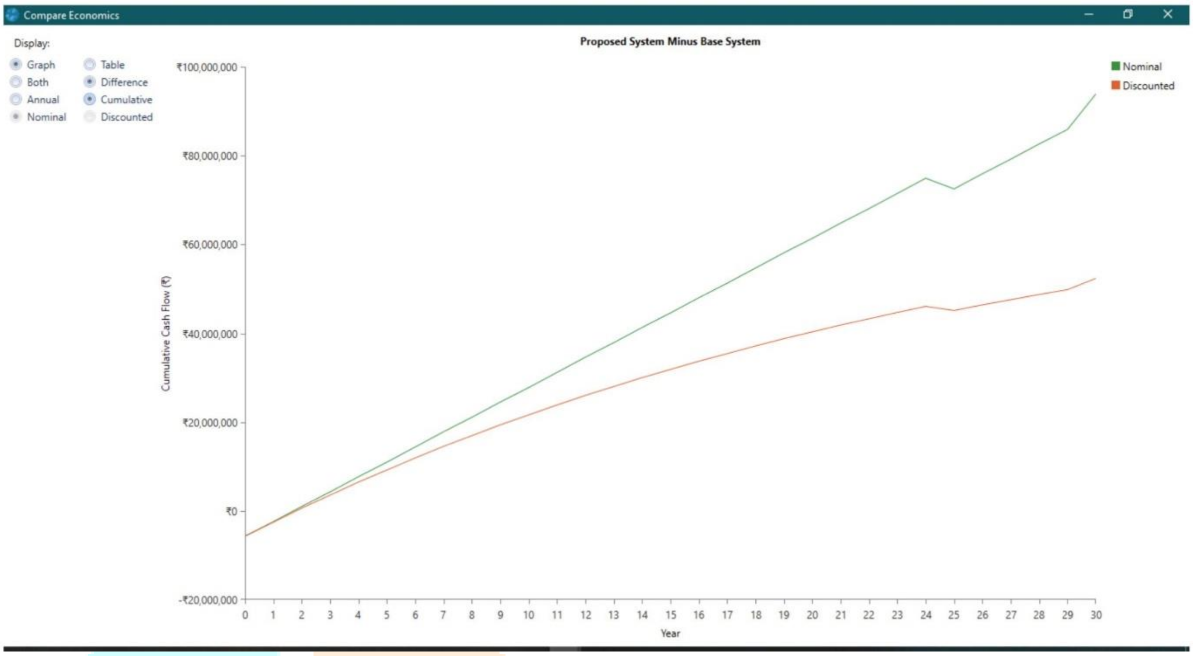


fig 17: difference of proposed system and base system

5. Conclusion: In this paper, a 200 kW PV system is studied for small homes in a rural area near Guwahati, India. Performance of the system and cost analysis for the designed system has been evaluated using HOMER software. The desired PV system generates 108,377 kWh/yr solar energy. The energy produced by the PV system is also calculated month wise.

6. References:

[1] Shahzad Ahsan, Kashif Javed, Ankur Singh Rana, Mohammad Zeeshan, 2016. "Design and cost analysis of 1 kW photovoltaic system based on actual performance in Indian scenario", *ScienceDirect journal.*

[2] Amjad Iqbal and M. Tariq Iqbal, 2019. "Design and Analysis of a Stand-Alone PV System for a Rural House in Pakistan", *Hindawi International Journal of Photoenergy Volume 2019, Article ID 4967148, 8 pages*.

[3] Dr. Radian G Belu, Dr. Richard Chiou, Ms. KETKI GHAISAS, Prof. Tzu-Liang Bill Tseng, 2014. "Teaching Renewable Energy System Design and Analysis with HOMER", *121st ASEE Annual Conference & Exposition, Paper ID #8779.*

[4] Anastasios Oulis Rousis, ID, Dimitrios Tzelepis, Ioannis Konstantelos, Campbell Booth and Goran Strbac, 2018. "Design of a Hybrid AC/DC Microgrid Using HOMER Pro: Case Study on an Islanded Residential Application", *Article Inventions 2018, 3, 55; doi:10.3390 by MDPI.*

[5] Ndagijimana, M. Tech, b. Kunjithapathan, 2019. "Design and Implementation PV Energy System for Electrification Rural Areas", *International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249-8958, Volume-8 Issue-5, June 2019.*

[6] Ehsanul Kabir, Ki-Hyun Kim* ID and Jan E. Szulejko, 2017. "Social Impacts of Solar Home Systems in Rural Areas: A Case Study in Bangladesh", *Article Energies 2017, 10, 1615; doi:10.3390/en10101615 by MDPI.*

[7] Ali H. Al-Hamdani, Abeer F. Dawood, Khudhayer N. Abdullah, Sayed M H Mousaui, 2016. "Optimal sizing of photovoltaic systems using HOMER for Baghdad", *Article in International Journal of Computation and Applied Sciences · June 2019.*

[8] Ali H A Alwaeli, Hussain Falih Mahdi, 2017. "Standalone PV systems for rural areas in Sabah, Malaysia: Review and case study application", *Article in International Journal of Computation and Applied Sciences · February 2017.*

[9] Ms. Shubhangi R. Mohije, Ms. Arti S. Bhongade, Ms. Vaishnavi D. Varma, Prof. Mangesh. J. Nemade, 2019. "Implementation of Solar Based System for Rural Area Development", *International Research Journal of Engineering and Technology (IRJET).*

[10] M.J. Khan, M.T. Iqbal, 2004. "Pre-feasibility study of stand-alone hybrid energy systems for applications in Newfoundland".

[11] Rohit Sen, Subhes C Bhattacharyya, 2016. "Off-grid Electricity Generation with Renewable Energy Technologies in India: An Application of HOMER", *OASYS SOUTH ASIA Research Project Peer-reviewed Published Papers (pre-publication version).*

[12] Hussein A Kazem, Feras Hasoon, Fawzi Al-Qaisi, Nabila Alblushi, Halima Alkumzari, Ahlam Alfora, and Ali H A Alwaeli, 2012. "Design of Stand-Alone Photovoltaic for Rural Area in Oman", *NCT 3rd Symposium.*