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A Model for Power Production Using a Solar-Grid Hybrid System

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ABSTRACT
Energy is frequently referred to as a country's backbone. The socioeconomic status of a country can be influenced by energy use and consumption habits. Most industrial and home operations are now performed by equipment that runs on conventional energy as a result of technological advancements. Thermal power plants are responsible for a large portion of India's conventional electricity. It has two consequences: first, it causes pollution, and secondly, it jeopardises India's energy sector, as the country imports the great majority of crude oil and coal. One of the most harmful factors is these power plants. India, with the nation's biggest national grid network, is frequently unable to supply the quantity of energy promised, and the system's dependability is a cause of worry.
Solar PV, on either side, is a long-term energy source that helps to reduce carbon dioxide emissions, despite the fact that it is weather-dependent and sporadic. Solar PV must be built with sufficient storage space to be dependable. In solar technology, a battery bank is typically utilised to store energy. Batteries are not used since they are harmful to the environment if discarded and eaten.
In this regard, a technology that combines solar PV with the present grid is discussed in order to provide suitable alternatives for achieving excellent electricity 24 hours a day, seven days a week is detailed. The system is designed to get its electricity from solar PV on bright days, and if there was a power outage, it may be pulled from the grid. The mechanism pumps power into the grid when excess power generation exceeds load demand. The method investigates the impacts of helps produce and attempts to determine the best model size and cost. The programme replicates the model to identify innovative ways to increase integration of renewable energy, reduce power outages, and preserve the quality of electricity provided. The suggested plan lays out some of the most practical and cost-effective strategy for providing a high-quality, dependable, and affordable supply of energy for home use.

Keyword
Grid networks, Conventional, Renewable, Biomass, Batteries, PV systems

1. INTRODUCTION
Fuels, nuclear energy, and renewables are the three main types of electricity-generating systems now in use across the world. Wood, coal, oil, and other fossil fuels have long been used as sources of energy. Nuclear power is not available to the great majority of the world's population for a number of reasons, and it has only been used in prosperous countries [1]. Calories, quintillions, and joules are all units of energy. The quantity of electricity or heat necessary to increase the temperature of 1 kilogram of water from 14.5°C to 15.5°C is measured in kilocalories. The quad unit is used to determine the amount of energy required by large countries. The joule [2] is the final energy measurement unit.
Nevertheless, the power generated should be held and delivered on the pressure in order for sporadic solar energy in becoming completely reliable as a power source for battery storage and subsequent demand changes. As a result, energy storage is required for self-generating PV power and looks to be the only solution to the problem of inconsistent solar power generation [3].

1.1 PV Solar Energy
Because they are infinite, ecologically harmless, reliable, effective, and cost-effective, freestanding renewable energy systems (RESs) are regarded as the most probable practical energy supply solutions in such places. Renewable energy is also seen as an important component of the economic future and healthy global ecology, as well as a way to solve to pollution issues. [4,5,6].
PV panels generate power that is both clean and renewable. During the energy-generating process, solar PV panels emit no damaging greenhouse gases, making them ecologically benign. Solar energy is both free and abundant since it is been produced naturally. It may be put nearly anyplace that receives sufficient sunshine. This energy is ideal for generating a variety of approaches in smart energy networks. DPG is without a question the power network architecture of the future! Furthermore, solar panel costs are rapidly decreasing and are likely to continue in the next years, suggesting that solar PV panels have a promising future path of both financial viability and ecological sustainability.. To improve supply dependability, a battery bank is employed in this study for freestanding solar PV systems. This hybrid approach combines well-known and conventional storage technologies to provide a one-of-a-kind solution to the challenging challenge of energy storage.

1.2 Solar PV based Micro Grid System
The rationale for this description because in the business, generators are frequently linked to the transmission network. Energy production, on either hand, is based on the idea of placing generating close to the load, whether it is on the distribution network or at the metre. Now that energy production is characterized as electric power generation at or below the distribution level, there is a need for a larger

separation between transmission networks. A difference in reference voltage levels, such as 220 kV and above being called transport and 110 kV being branded distribution, is unrealistic since distribution firms sometimes own and operate 220 kV lines while transmission businesses operate 110 kV lines. Because the voltage level doesn't create an economically meaningful distinction between distribution and transmission, another alternative is necessary. This study proposes a technique [7] that is based on a legal definition. This project's microgrid is intended to serve a Ladakh-based population. The capacity of this form of a microgrid is restricted. Because the grid is significantly smaller, the number of problems and their maintenance is minimized. In order to deliver a practical answer to the community, our study focuses on load reduction and synthesis.

2. OBJECTIVES

- The national grid of India stretches the length and width of the nation. However, in certain areas, extending such a grid is neither cost-effective nor viable. In some areas, good-quality power is in short supply. This research is based on one such group, which consists of five families that reside in the hilly terrain of India's Ladakh UT.
- A dispersed generation strategy is being investigated to serve this group. Solar PV produces electricity with the use of a cell as a reserve. The system is largely focused on the power supply's dependability and quality. Because the dispersion producing plant is so close to the load center, the strategy can improve supply reliability. Because the distance is less, the power quality is better. Moreover, by reducing carbon emissions, such a technique can reduce GHG emissions..
- In a microgrid system, solar panels produce energy, cells provide backup generators, and a charge controller balances the battery and load. Because of its tiny size, the microgrid has a very minimal possibility of generating a flaw. As a result, instead of system maintenance, a study now focuses on energy production, distribution, and supplier dependability.
- Installing a solar PV generation system on their house or balcony, as is done in India, can meet society's energy needs. Any surplus solar PV energy contained in a battery bank, which will enable it to meet load requirements. If PV power is insufficient to fulfill load requirements, the remaining load can be fulfilled by the large battery. The use of a battery bank removes the need for grid electricity, enabling the system to operate entirely on its own.
- As a result, the goal of this research is to create a Solar PV-based distributed energy system with a large battery to investigate if it can provide a town with a reliable, constant, and premium electrical supply.

3. LITERATURE REVIEW

Nema Et al. study the present status of stand-alone PV solar–wind hybrid energy plants with a typical backup device, such as diesel or grid, as well as their construction, administration and control requirements (2009). Future improvements that have the potential to increase the bids of such systems, as well as user acceptance, are also discussed in this study [8].

Pradhan et al. (2012) explore the applicability of the Hybrid Solar Wind Power System to use a test case. Hybrid solar and wind energy seem to be viable options for producing continuous electricity with improved system performance for hybrid self-contained uses in off-grid rural areas, among the different renewable resources available. The dependability of small freestanding hybrid solar/wind power systems was investigated using the approach suggested in this paper (HSWPS). The HSWPS reliability indices are calculated using the statistical durability evaluation technique [9].

Hafez et al. (2012) investigate the perfect idea, planning, scale, and management of a hybrid, renewable energy-based microgrid in order to reduce lifespan costs and carbon emissions. Four alternative microgrid configurations are built to examine and evaluate their economics, organizational effectiveness, and Environmental emissions: a diesel-only, a wholly renewable-based, gasoline mixed, and an outside grid-connected microgrid configuration. A grid-connected microgrid's break-even costs are also dissected. The study used HOMER, a well-known energy simulation tool for hybrid power systems. [10].

4. METHODOLOGY

4.1 Analysis of PV Performance

This can be beneficial for a variety of purposes, including tracking a guarantee, evaluating the system's health, displaying a productivity model similar to a future system, and so on. Despite the fact that the calculation and analysis of this measure appear to be simple, the procedure is complicated by weather volatility and insufficient data gathering. Despite the fact that performance assessments are most efficient when they are performed with the least degree of confusion and nuances handled systematically [11], there is presently no rule to govern this practice.

4.2 Standard for PV Systems

IEC-61724 is an internationally recognized standard. A new international standard establishes procedures for monitoring energy-related PV system characteristics such as in-plane brightness, array output, buffer input and output, and power converter input and output as well as sharing and analyzing the collected data. For example, the actual quality of a hybrid PV system with motor turbines and wind turbines, as well as a PV system linked to the utility grid [12], might be assessed.

4.3 Equation of Energy Balance

Ein = Energy IN System and Euse = Energy Used are two examples of energy balancing equations for different topologies of systems.

$$E_{in} = E_A + E_{BU} + E_{FUN} + E_{FSN} \quad (1)$$

$$E_{use} = E_L \quad (2)$$

4.4 Quantities of Electrical Energies

Energy from a backup generator, as well as energy transferred to or from a storage device or grid power link, are all included [13]. Knowing how much electricity a PV array delivers and gets to and from disk drives, as well as to and from power grid, may help assess its system performance.

4.5 Indicators of System Performance

By analyzing normalized systems quality metrics such as outputs, loss, and effectiveness, PV systems of diverse types and sites may be found to be comparable. Returns are energy quantities calculated for the rated array power of a solar panel. The efficiency of the system is related to the array size. When evaluating yields, losses are the gap between them.

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5. SIMULATION MODEL

We use HOMER, which is a modeling system. This article [14] covers electric load (primary energy demand), solar radiation, hydropower sources, constituent technical details/costs, and dispatch method kind.

5.1 Model of the Solar Geometry

A perpendicular axis connects Earth's North and South celestial poles, which is not parallel to the plane of Earth's orbit. The axial tilt or tilt of the Earth's axis with regard to a line perpendicular to its planet's orbit is roughly 23.5 degrees. "The Sun's Plane" is the plane that runs alongside to Earth's celestial equator and crosses its centre. The Earth accomplishes an elliptic cycle every year by traveling over and under this plane [15].

Keep the following in mind while thinking about how a solar array produces power.

5.2 Index of Clearness

To put it differently, it's a measurement of how clean the air is. To put it another way, it's the percentage of solar energy that travels into our air and reaches to the surface of the Earth. To get the value between 0 and 1, divide the surface irradiation by planetary radiation. In bright, sunny weather, it has a high value, while in dark weather, it has a low value. An average monthly clarity indicator is represented by the Kt sign. The Kt value varies from 0.25 (rainy month) to 0.75 (sunny month) (a very sunny month).

5.3 C. Point of Maximum Power

The efficacy in which the PV array converts sunlight into energy at greatest PowerPoint is evaluated under normal test circumstances. We employ the equation in order to calculate.

$$\eta_{mp,STC} = \frac{Y_{PV}}{A_{PV} G_{T,STC}} \quad (3)$$

Where, $\eta_{mp,STC}$ is the efficiency of the PV module under standard test conditions [%], Y_{PV} is the rated power output of the PV module under standard test conditions [kW], A_{PV} is the surface area of the PV module [m^2], $G_{T,STC}$ is the radiation at standard test conditions [1 kW/m^2]

5.4 Solar Declination Observation

Solar inclination, or the longitude at which the sun's rays are perpendicular to the earth's crust at noon time, is affected by the time of year. The equation below is used to compute the solar declination.

$$\delta = 23.45^\circ \sin\left(\frac{360^\circ\ 284+n}{365}\right) \quad (4)$$

where n is a day of the year [a integer between 1 and 365]

5.5 Load consumption modelling

There are two major sources of load demand in system modelling, which are as follows:

$$P_L(t) = P_{PV_L}(t) + P_T(t) \quad (5)$$

Where $P_{(PV\ L}$ (t)is the electricity delivered directly from the PV array, and P_T (t)is the power produced by the wind-turbine set. Because there is no net load, $P_{(PV\ L)}$ (t) is zero.

5.6 Parameters of the Economic Value

5.6.1 Net present cost

By deducting all of the system's lifetime expenditures and profits, the net present value is computed. The costs of obtaining electricity from the grid include capex, operations and maintenance charges (O&M), fuel prices, and ecological fines. Recoverable amount and grid sales are the two main sources of profit.

The equation may be used to calculate the system's cost.

$$C_{NPC} = \frac{C_{ann,tot}}{CRF_{(i,R_{proj})}} \quad (6)$$

$C_{ann.tot}$ is the annual real interest rate (discount rate); R_{proj} represents the project's lifespan, and CRF() is the capital recovery factor (CRF)

5.6.2 Capital recovery factor

This ratio is used to figure out how much insurance is worth (a series of equal annual cash flows). The capital recovery factor may be calculated using the equation below.

$$.CRF(i, N) = \frac{i(1+i)^N}{(1+i)^N - 1} \quad (7)$$

I and n denote the rate of an interest and the number of years, accordingly.

5.6.3 Levelized Energy Costs

They're estimated based on the system's average cost per kilowatt-hour of useful electrical energy produced. COE is calculated by multiplying total usable electric energy output by the cost of yearly power supply (total annualized costs minus cost of feeding the thermal load). Here's what we have**:**

$$COE = \frac{C_{ann,tot}}{E_{prim,AC} + E_{def}} (8)$$

Where $C_{ann,tot}$ = the total annualized cost of energy [$/kWh], $E_{prim,AC}$= AC primary load served [kWh/year] and E_{def}= deferrable load served [kWh/year

6. SYSTEM ANALYSIS

The proposed Distributed Generation system contains an end-user (load) and a control station, as depicted in Figure 1. A freestanding system is one that can function without the assistance of other systems. A microgrid was developed in Ladakh, India, to meet the demands of a population.

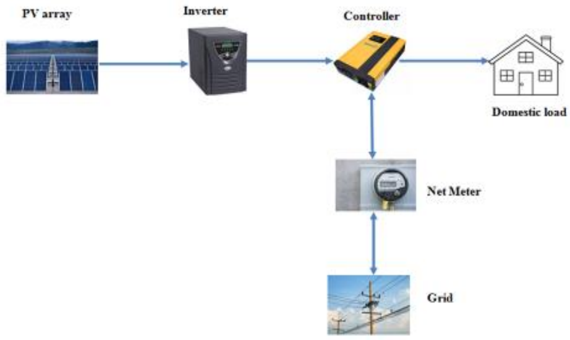

Figure 1: PV Based micro grid

There is just one power supply source when it comes to dispersed generating. Here's how a solitary solar cell works in a nutshell: This system produces power and sends it to the local grid daytime. A battery bank controls energy surpluses and shortfalls in a crisis. Charging and draining the battery bank at the same time can improve the power quality of a solar PV array. Charge and discharge rates, as well as capacity, must be acceptable in order to provide a reliable and affordable energy supply 24 hours a day.

The PV array, battery, inverter, and conversion are the most crucial parts of a DG system, with the PV array and rechargeable batteries being the most essential.

6.1 Load

The system recommended can manage a daily load of 34 kWh and a peak demand of 4.5 kW. Nevertheless, this is the average load requirement for a certain period of time. In addition, electricity consumption is expected to rise in the near future. The system is designed largely to fulfil the needs of domestic market. By introducing randomness to the day in HOMER software, a realistic load profile may be constructed. As a result, seasonal fluctuations in load are not taken into consideration. Figure 2 illustrates that the load will be the same for all of the projected year's months.

6.2 PV Energy Resources

The concept is mostly based on solar energy. The PV array's power production grows as technology advances. The ability of the PV array to generate power is influenced by the climate. India has an average of 4-8 kWh/m2/day, as seen in Figure 3. The study is taking place at 34.35 degrees north latitude and 77.45 degrees east longitude. A 9kWP PV array could be developed at the future site due to monthly average daily solar radiation of 5.481kWh/m2/day and a clearness index of 0.6566. The cost of a 9 kWp PV array is estimated to be INR 7,65,000, with low repair and maintenance expenses.

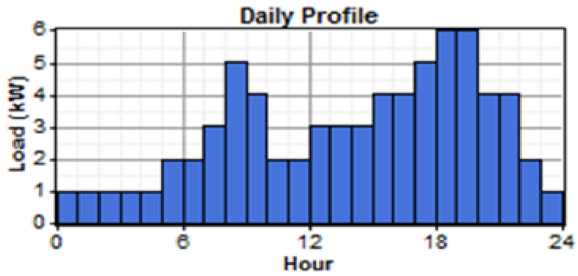

Figure 2: Hourly Load

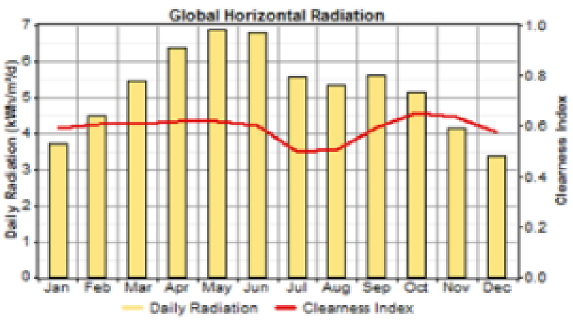

Figure 3: Solar resources

6.3 Battery Properties

All of the energy for the planned concept comes from solar PV panels. The amount of power generated by the PV array will fluctuate depending on the weather. A power source must also be built to supply the requirement for electricity during the night. PV panels are not capable of providing variable power. To lessen the PV system's intermittent characteristics, better battery quality is being developed. To imitate the scheme, a Surrette 4KS25P battery is utilised. The capital cost of the battery system is projected to be INR 1,17,000, with annual O&M costs of INR 5,400.

6.4 D. Importance of Converter

The approach requires a subsystem that allows PV-generated power to be supplied effectively to demand in order to be effective. The phrase "system equilibrium" is used to characterize this subsystem. "BOS" refers to everything in a solar system that isn't solar panels [2]. To get started, you'll need a solar panel converter, a battery bank, and a charger. Filtering electrical power for safe transmission and/or storing energy for future use are examples of BOS uses.

Batteries, a charge controller, power converter equipment, safety equipment, metres, and sensors are all part of a stand-alone system's balance-of-system. A photovoltaic system and an autonomous charger are crucial components of BOS for the research. PV solar panels provide changeable direct current (DC), which may be converted to utility-frequency (AC) and sent to the corporate electrical grid or used locally by off-grid devices.. In this analysis, demand is assumed to be AC, but solar PV production is assumed to be DC. In this method, an inverter or solar inverter is utilised instead of a converter. The 50 kW converters has a life expectancy of 15 years and a 90% efficiency rating. The capital cost is expected to be INR 20,340, with an additional INR 1,500 for maintenance and operation (O&M).

7. RESULTS AND OBSERVATIONS

7.1 DC Power Output from PV Arrays

Figure 4 shows the PV arrays' projected DC power. As a consequence, the data gathered year-round is computed using the 10 MW PV arrays. With a 115 W/m2 irradiation, it creates 1000kW of DC power. The highest temperature of 25°C and a solar irradiation rating of 1000W/m2 is suggested in their specs. Solar PV arrays with a power density of 1000 watts per square metre generate around 8.613 kilowatts. Every year, a multi-crystalline PV module loses 0.4 percent of its efficiency, and every degree above 25 degrees loses 0.5 percent. Additional to PV module pollution, there are other variables that might affect DC power output.

7.2 Solar Radiation and Output Power

The generation of PV electricity based on solar irradiance is represented in figure 5 below. It can be seen that the most extreme production of 22.07kWh happens during the day at a typical radiation of 0.333kW/m2.

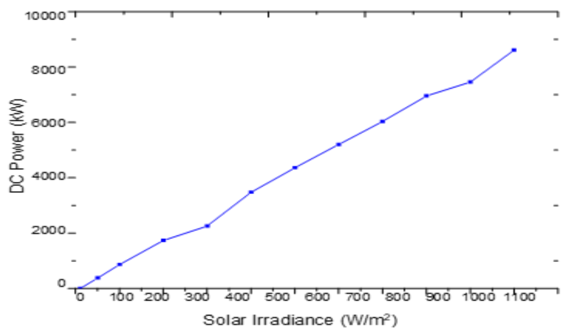

Figure 4: DC power output from PV array

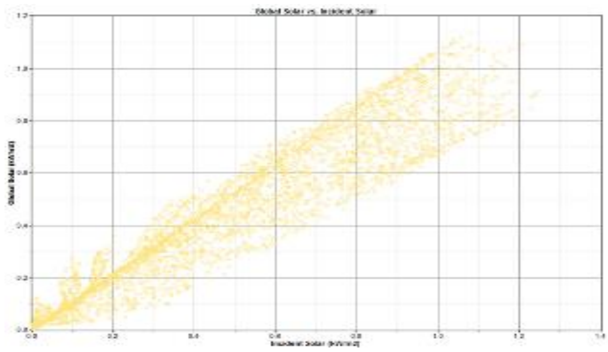

Figure 5: Solar radiation output power

7.3 Monthly Power Output from PV Array

The chart below shows the change in yield from monthly installments for the PV exhibit. The force yield of the PV display is typically high, with the highest values occurring

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between March and May and thereafter between September and October. At that moment, the PV exhibit might be able to provide a reasonable amount of force. Because the suggested site is bordered by downpours, the PV exhibit's force yield is reduced from June to August due to cloud cover. The PV cluster's force yield is expected to be 41,951kWh/yr based on current climate factors. Figure 6 illustrates this.

7.4 Grid Supply

In the study, the grid extension was assumed to be existent. As the hybrid system is connected to the present grid, the connection is visible. The grid connection is considered to increase reliability because the system avoids utilizing batteries owing to environmental considerations. The grid is connected to the solar PV system, as shown in Figure 7, and net metering is utilised to calculate the entering and exiting energy. Total outgoing energy in a year is 25,464 kWh (energy sold), and total received energy is 13,093 kWh, according to the system (energy generated). A total of 12,371 kwh of electricity is net transferred towards the grid, according to the system. Due to increased irradiation, the outbound energy is higher during the months of March to May and again in October to November. In July and August, the amount of energy expended is at its lowest.

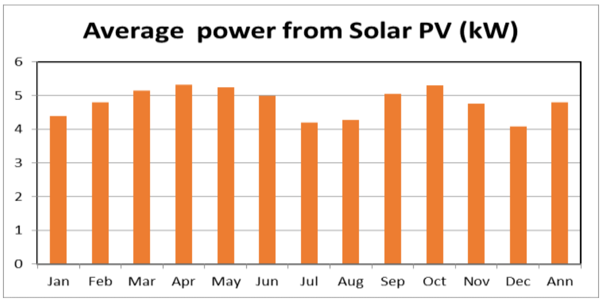

Figure 6: Monthly power output from PV array

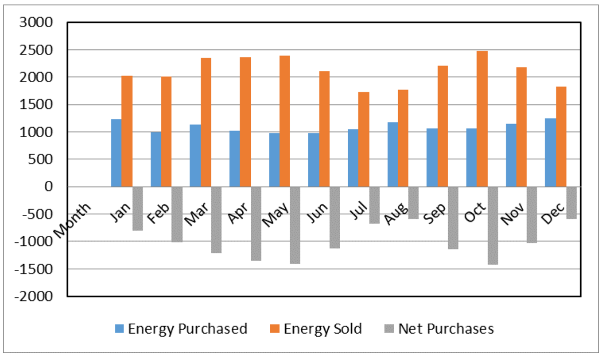

Figure 7: Energy exchange with the grid

7.5 Daily Energy Production and Load Demand

The daily average PV power output is represented by a blue line, the grid by an orange colour stack, and the average load by a grey line. After the regional load need is fulfilled, power is sent to the grid for sale at a predetermined price, enabling the program to profit. As a result of the daily load demand, Figure 8 demonstrates a higher production profit.

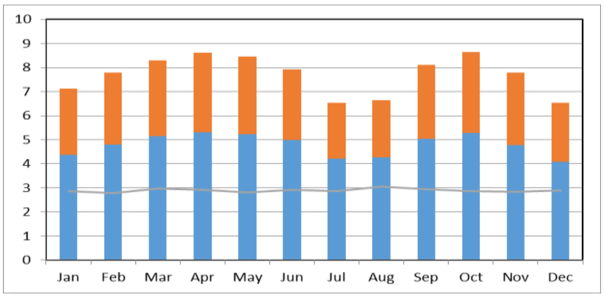

Figure 8: Daily energy production and load demand

7.6 Emission from the System

The system's emission level is shown in Table 1. Aside from being one of the system's best features, the system's pollutants are so low that, if we exclude a little bit of noise from the battery, they're essentially non-existent. Using this method, you may significantly reduce your carbon footprint and other essential pollutants that cause global warming.

Table 1: Emissions from the system

Pollutants	Emissions (kg/yr)
Co2	-7,818
CO	0
Unbumed hydrocarbons	0
Particulate matter	0
SO2	0
NO2	0

7.7 Economic Analysis

Figure 9 depicts the total optimization result of the Homer software-generated hybrid system. A sample computer system configuration is shown to the right of each row. Symbols occur in the first three columns of the table. In terms of numbers, the numbers in the next three columns reflect how numerous and how big each element is. System costs (capital vs. operational), Net present value (NPV) and COE (Levelized cost), renewable percentage (rf), capacity shortage (cs), and battery life are all listed in the following seven columns (lv) With a 9-kWP PV, 18 S4KS2P batteries, and a 3 kW converters, NPC will be the lowest possible. Although the output has been cut by 13%, the COE has increased to 7.430/kWh. A cash flow analysis is used to compute NPC. The most expensive alternative is to invest in batteries and converters. Figure 10 depicts the model that has been improved the greatest. (A quick rundown of NPCs.)

			PV (kW)	S4KS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Batt. Lf. (yr)
			9	18	3	$ 902,340	12,295	$ 1,059,505	7.430	1.00	0.13	12.0
			9	18	4	$ 909,120	12,975	$ 1,074,980	7.528	1.00	0.12	12.0
			9	20	3	$ 915,340	13,434	$ 1,087,070	7.511	1.00	0.11	12.0
			9	20	4	$ 922,120	14,114	$ 1,102,544	7.599	1.00	0.10	12.0
			9	22	3	$ 928,340	14,573	$ 1,114,635	7.645	1.00	0.10	12.0
			9	22	4	$ 935,120	15,253	$ 1,130,109	7.733	1.00	0.09	12.0

Figure 9: Optimization result of PV based microgrid

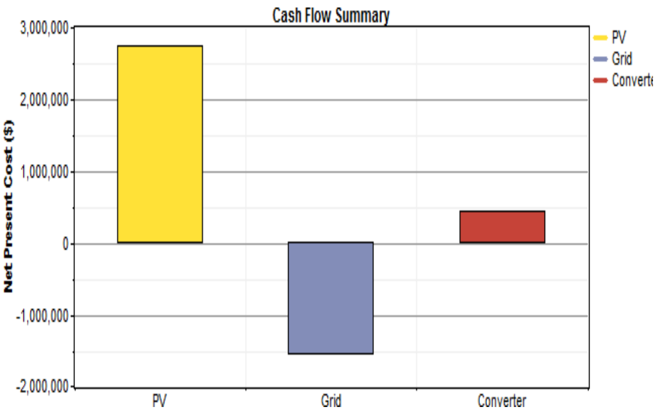

Figure 10: Cash flow outline of the project

7.8 Performance Summary of Different System Components

Table 2: Performance parameters of PV array, battery and converter

Parameters	Value	Unit
PV array		
Rated capacity	25	kW
Mean output	4.8	kW
Mean output	115	kWh/d
Capacity factor	19.2	%
Total production	41951	kWh/year
Minimum output	0	kW
Maximum output	24.9	kW
PV penetration	166	%
Hours of operation	4,379	hour/year
Levelized cost	5.13	$/kWh

Parameters	Value	Unit
Grid		
Capacity	20	kW
Mean output	4.3	kW
Minimum output	0	kW
Maximum output	20	kW
Capacity factor	21.5	%
Hours of operation	4379	hours/year
Energy in	41891	kWh/year
Energy out	37702	kWh/year
Losses	4189	kWh/year

Parameters	Value	Unit
Converter		
capacity	20	kW
Mean output	4.3	kW
Minimum output	0	kW
Maximum output	20	kW
Capacity factor	21.5	%
Hours of operation	4379	hours/year
Energy in	41891	kWh/year
Energy out	37702	kWh/year
Losses	4189	kWh/year

8. CONCLUSION

The feasibility of a PV-Grid coordinated architecture is investigated in this research. The results appear to be encouraging. It validates that with the framework's rapprochement, the limit defect decreases significantly, the new framework unwavering quality enhances completely, the plans used in the investigation are also essential in nature, the Levelized cost of energy is 5.078 INR/kWh, with an equity investment of INR 99,626 per year, and the suggested plot is also having huge investment fun.

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