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A Power Generation Study Using a Hybrid Model of Solar and Wind Energy

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ABSTRACT
With a large number of cities and villages, India is the second highest populated country in the world. In India, villages still house a sizable percentage of the people. To better their socioeconomic situation, small cottage businesses that may employ local residents should be developed. The industries included in the programme are small cottage businesses that operate during the day and close at night. These businesses need a steady supply of electricity. However, due to its geographic constraints, the area has seen a significant loss of supply and has frequently finding electricity inadequate to run the equipment. As a result, industry expansion would be impeded, and local residents' development would be affected. Renewable energy, on the other hand, may be produced and utilized on-site, enhancing supply reliability. They have a cheap operating cost because they are renewable in nature. However, because renewable energy output is entirely dependent on weather conditions, a battery bank must be used as a backup.. This backdrop describes a way for combining solar PV with wind energy. The system considers integrating solar PV and wind energy to satisfy demand because they compliment each other in nature. The software may be used independently. The system runs several permutations of the model to find the most optimum model capable of providing consistent, acceptable quality, and cost-competitive electricity. The strategy also researches and analyses the degree of renewable penetration to minimize carbon footprint, investigates combinations to reduce capital investment, and focuses on decreasing the levelized cost of energy.

Keywords
Carbon footprint, Outage, Hybrid Renewable Energy, Battery Bank, Standalone, PV.

1. INTRODUCTION
Around the world, electricity generating systems are divided into three types: fossil fuels, nuclear power, and renewable energy. Other resources like, wood, coal, and oil are all recognized as fossil fuels in natural state. For a number of reasons, nuclear power is out of reach for a large portion of the world, and it is only used in industrialized countries. [1]. A facility that turns heat into electricity is referred to as a "thermal power plant" [2]. It's no secret that renewable energy is outperforming the rest of the energy industry.. Renewable technology is likely to play a bigger role in some long-term scenarios If the right regulations and new technologies are implemented, renewables may account for up to 50% of global energy consumption by the middle of the twenty-first century [3]. A storage system is necessary for intermittent solar energy to be a viable choice for satisfying both base load and variable needs. PV power generation requires energy storage due to the fluctuation of solar energy output [4]. PV systems featuring battery storage assist to sustain the value proposition of home solar by reducing economic uncertainty when utility energy rates fluctuate.. Client load profiles can be changed using charge control systems and batteries. It's a one-of-a-kind method since it employs an antiquated kind of energy storage. [5].

1.1. Photovoltaic Solar Energy (PV)
PV technology is attractive and environmentally friendly, with a number of major benefits over traditional power generating techniques. Because solar energy comes from the sun, it is abundant and free. Almost wherever there is sunshine, sunlight can be made available. [6]. The majority of solar PV systems are intermittent, unreliable, and weather-dependent. The only way to assure an uninterrupted and stable power source is to use energy storage. Extra power can be stored and released when net load is present when power supply exceeds demand, providing a steady backup to intermittent renewable energy sources [7]. A battery unit is placed to enhance the reliability of a standalone solar PV system. This hybrid methodology gives a unique answer to the hard problem of energy storage by employing the most traditional storage strategy.

1.2. Energy from the Wind
When the PV array creates more energy than is needed, it is sent to a battery bank (which stores chemical energy), and when the PV array is inadequate, the battery bank fills the gap. In this situation, wind energy provides a dependable and potential renewable source [8]. Several nations are considering a range of policies to stimulate the use of wind energy for electricity generation [9]. As a result, wind energy's relevance is expected to rise in the next decades.. As far as the author knows, the research looks at wind energy from three perspectives: status potential, policy analysis, and policy assessments. This article examines wind energy's current state, prospects, and policies, as well as the problems it faces and the most recent research. This emerging phenomenon's current state of affairs, potential, and future are also explored. This study makes recommendations for expanding installed wind power capacity.

1.3. PV-Wind Hybrid Energy System
When several sources are combined, the system gains balance and stability, as well as the complementary strengths and limits of each source type. The major goal is to provide grid-quality electricity to remote villages 24 hours a day, seven days a week. Not only are hybrid energy systems pollution-free, but they are also cost-effective, user-friendly, and socially responsible [10]. Such systems, especially in distant regions, are essential energy sources for local stores, schools,

and clinics [11]. The proposed model seeks to give a generic model for selecting the optimum hybrid system for a rural cottage business and residential load among various renewable energy combinations, while minimizing overall life cycle cost and maintaining system dependability. The model contains solar PV, wind, and rechargeable battery, as well as a simulation but no actual verification. The goal of an integrated energy system is to determine what component sizes and operating techniques are best for the system. The findings will be utilised to design and plan an optimal hybrid energy system that will offer a reliable and cost-effective power supply to the required load.

2. OBJECTIVES

- In India, small and medium-sized businesses account for a substantial portion of rural employment (SME). They are often decentralised and modest in size, allowing them to be managed in local groups. Grid electricity is used to power the majority of their equipment.
- Small and medium-sized enterprises (SMEs) employ the vast bulk of India's rural population (SME). Because they are decentralised and modest in size, they may be dealt with on a regular basis by small groups. The great majority of their equipment is supplied by grid electricity provided by the city...
- The targeted location receives a lot of sunshine because it is south of the Cancer Tropic. Because of its proximity to Odisha's eastern shore, the wind pressure at the location is mild all year..
- In this study, a hybrid combination is taken into account. A small industry with an interest in the site will be explored in this study to discover if such a model is possible.
- In addition, our research attempts to optimise the system so that power can be delivered reliably and at a reasonable cost.

3. LITERATURE REVIEW

Using annualised life cycle costs, Kandpal et al. (2010) compare solar home and microgrid on the basis of identical types of loads and load patterns for varying numbers of residents, as well as altering length and costs of distribution networks (ALCC). According to the study, microgrids are more cost-effective in cities with flat terrain and more than 500 households when 3–4 low-power appliances (e.g. 9W CFLs) are used for an average of 4 hours each day. Both options are viable from the standpoints of the consumer, an energy service provider, and society, according to the study [12].

Using a sectorial systems of innovation framework,

To assess the link between technical policy and industrial growth, K Kari et al. (200) examine the development of the wind energy sector in India. For more than two decades, wind energy has been Denmark's primary source of electricity. Wind energy accounted for 18.8% of Denmark's total power consumption in 2004. Despite being late to the game, India has risen to become the world's fifth-largest wind energy producer. India's "interactive learning" technique is unrivalled in the globe. The success of India's wind energy sector may be ascribed in great part to the country's unwillingness to copy foreign technology, laws, and institutions. [13]

In distant rural regions where grid extension is difficult and expensive, a hybrid energy system is a good option. Solar photovoltaic, wind, micro-hydro, and conventional generators can all be used in a hybrid system. This article examines the various components of hybrid energy systems in attempt to identify the best possible mix of energy elements for a normal farming village while keeping the life cycle cost as low as possible. When it comes to sizing hybrid renewable energy hardware and establishing operating parameters, the model developed will be quite useful! According to a case study, microhydro-wind systems are excellent for powering rural villages in India's Western Ghats (Kerala). The microgrid adopted has a unit cost of Rs. 6.5/kW/h, eliminating the requirement for a traditional diesel generator. [14].

4. METHODOLOGY

4.1. Performance Evaluation of the Photovoltaic System

Assessment of the PV system's performance. This information may be used to determine the system's health, assess a performance measure that will be applied to a new Photovoltaic, and conduct a variety of other activities. To make a performance review as beneficial as possible, it must be performed in a way that minimises ambiguity and takes into account the situation's complexity. However, there is currently no standard in place to control this practise. [14]

4.2. Standard for Photovoltaic Systems

The IEC-61724 standard was developed by the International Electrotechnical Commission. The processes for monitoring energy-related PV system characteristics such as in-plane light, array output, store input and output, and power converter input and output, as well as transmitting and evaluating sensor readings, are outlined in a new international standard. These methods are used to evaluate the actual quality of stand-alone applications. or u-shaped PV arrays. [15]

4.3. Equation for the Balance of Energy

Ein and Euse, where Ein represents energy IN a system and Euse indicates energy utilised, are two equations that govern energy balance in systems[16]:

$E_{in} = E_A + E_{FUN} + E_{BU+} E_{FSN}$

$E_{use} = E_L + E_{TSN+} E_{TUN}$

In IEC-61724, the terms EFUN and ETUN stand for Net Energy From and To the Utility, correspondingly, whilst EFSN and ETSN stand for Net Energy From and To a Storage Facility, respectively. EA and EBU are the total power from the grid generating and backup sources, accordingly, whilst EL is the Energy to the Load (ETL) assessment..

In this study, the following assumptions have been made:

The formulae for Energy IN the System (Ein) and Energy Used (Euse) have been streamlined in the lack of a utility link; if a linkage is present, the IEC Standard calculation should be used. The worldwide effect of the energy that flows to or from this item on the system's long-term efficiency is neglected since the research period is believed to be long enough (usually a year); if this supposition is incorrect, the IEC Standard must be revised to add the following.:

$$E_{in} = E_A + E_{BU} \ \& \ E_{use} = E_L$$

4.4. Indices of System Performance

By analyzing standardized system performance characteristics such as yields, loss, and effectiveness, PV systems of various designs and localities may be found to be comparable. The yield is calculated using the maximum output power of a solar panel. The system's efficiency improves as the array size grows. When evaluating yields, losses are the disparity among them.

4.5. Assessment of Wind Energy

PV systems of varying styles and settings can be easily compared by evaluating standardized system performance parameters like as yields, loss, and efficiency. The yield is determined using a solar panel's maximum output power. As

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the array size rises, the system's quality has improved. When comparing yields, losses are the difference between them.

$$power = \frac{1}{2}\rho v^3$$

Temperature and pressure are two more things to think about. According to the manufacturer's information, The so-called equipment and power curve of a given wind turbine is seen in Figure 1. (deterministic output power based on the input velocity of the wind). The wind farm does not create power below a certain minimal wind speed, called as connectivity, as seen by this device power curve. As the wind speed increases, the power rises after this internet speed... As shown in Figure 2, there is a comparable development trend that is dependent on the type of wind turbine technology used. The power output of a wind turbine achieves its rated capacity when it reaches its nominal speed. There is a variety of wind speeds after the nominal wind speed. When a wind turbine reaches its disconnection speed, it is unplugged to prevent catastrophic wind damage.

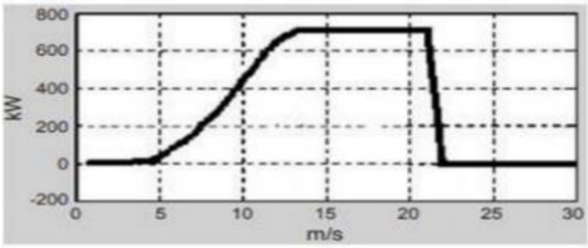

Figure 1: Example of a typical machine

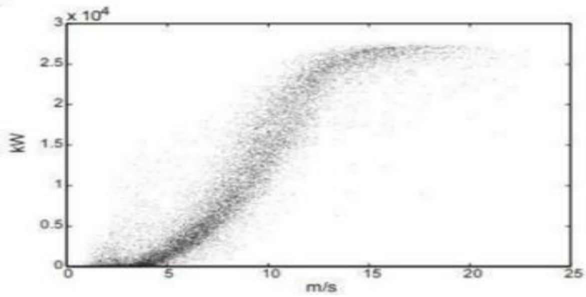

Figure 2: In an actual wind farm, theoretical figures for wind velocity and power output

5. SIMULATION MODEL

This work employed the NREL's Hybrid Optimization Model for Electric Renewable (HOMER) software [17], a renewable energy-based performance optimization tool, as a simulation and analysis tool.. This micro power optimization techniques have been extensively utilised in past hybrid energy system studies in many countries, and it is also suggested here for simulating a feasible hybrid system for the site's energy demands. The programme calculates the most cost-effective system design for each system by simulating a combination of traditional and renewable energy sources. You need to provide the latest details as an input: Electric load (primary energy demand), renewable resources (solar radiation), hydro resources, component technical details/costs, dispatch mechanism (for example), and other factors are all considered. [18]

5.1. A Solar Geometric Model

It is parallel to the celestial poles but not perpendicular to the Earth's daily rotation around its axis (North and South). On the other hand, the tilt or obliquity of the Earth's orbital plane is presently about 23.5°. According to astronomy, the plane of the sun is a plane that runs parallel to Earth's celestial equator and goes through the sun's centre of gravity. Over and under this plane, the Earth completes a full year's cycle.

5.2. The Clearness Index

You may choose time intervals of an hour or a month. These numbers may be found in the solar resource inputs box. Kt is a monthly average clarity indicator. A bad month, for example, has a Kt of 0, whereas a good month has a Kt of 0.75. To compute, we utilise the equation.

$$:\eta_{mp,STC} = \frac{Y_{PV}}{A_{PV} G_{T,STC}}$$

5.3. Solar Declination

The time of year has an impact on declension, or the longitudes at which the sun's rays are parallel to the earth's surface during noon time. The equation below is used to calculate the solar steady decline.

$$\delta = 23.45° \sin\left(\frac{360°\ 284 + n}{365}\right)$$

Where η_ (mp STC) stands for the PV capsule's maximum power output under standard test conditions [kW], APV stands for the PV device's total area [m2], and GT,STC stands for the radiation under standard test conditions [1 kW/m2]. The value n denotes the number of days in a year (from 1 to 365).

5.4. Modelling of PV Power Generation

The number of modules required for photovoltaic (PV) systems is determined by the load demand and PV array output under ideal working circumstances (current and voltage). The PV array's power output is calculated using the model described in [19, 20]. The following diagram depicts the relationship between PV array output current I and voltage V:

$$I = N_p I_{ph} - N_p I_0 \left(e^{\frac{1}{V_t}\left(\frac{V}{N_s} + \frac{I_{RS}}{N_p}\right)} - 1\right) - \frac{N_p}{R_p}\left(\frac{V}{N_s} + \frac{I_{RS}}{N_p}\right)$$

Photocurrent (A) Iph; Saturation current of diode (A) I0; resistance in series (Ω); Shunt resistance (Ω); Thermal voltage (Vt); Boltzmann's constant (K); electron charge (q); series PV cells (Ns); Cell temperature (K) T; Boltzmann's constant 1.381 1023 J/K; electron charge (q); and number of PV cells in series (Ns). N is the number of PV modules connected in series. As a result, the PV array's power output is

$$P=VI= N_p I_{ph} V - N_p I_0 V \left(e^{\frac{1}{V_t}\left(\frac{V}{N_s} + \frac{I_{RS}}{N_p}\right)} - 1\right) - \frac{N_p}{R_p} V \left(\frac{V}{N_s} + \frac{I_{RS}}{N_p}\right)$$

Where, $I_{ph} = I_{ph,STC}[1 + \alpha I_{sc}(T - T_{STC})]\frac{G}{G_{STC}}$, $I_0 = I_{0,STC}\left(\frac{T}{T_{STC}}\right)^3 \exp\left(\frac{E_{g,STC}}{kT_{STC}} - \frac{E_g}{kT}\right)$, $P_{PV} = Y_{PV} f_{PV}\left(\frac{\bar{G}_T}{\bar{G}_{T,STC}}\right)[1 + \alpha_P(T_c - T_{c,STC})]$, $V_t = V_{t,STC}\frac{T}{T_{STC}}$, $R_p = \frac{R_{p,STC}}{G/G_{STC}}$, $R_{sh} = R_{sh,STC} + 3 \times R_{sh,STC} e^{-5.5/G_{STC}}$, $T = T_m + \frac{G}{G_{STC}}\Delta T$

Also, the PV generator's energy balance model at time t is stated as:

$$P_{PV}(t).f_{PV}.\eta_{inv} = P_{PV_L}(t) + P_{PV_P}(t) + P_{PV_D}(t)$$

η_{inv} is the inverter efficiency, f_{PV} is the PV derating factor and $P_{(PV L)}$ (t) is the PV power given to the load; $P_{(PV P)}$ (t) is the power to load; and $P_{(PV D)}$ is the PV power wasted on the dump load (t).

5.5. Simulation of Wind Energy

I obtained and inputted twelve average wind speed readings from June 2018 to May 2019 to synthesise the data [20]. As a result, HOMER generated 8,760 different values. Seasonal and daily patterns, as well as the Weibull distribution and autocorrelation, are all described in this sample data.

5.6. Tip Speed Ratio

When a rotor blade rotates through the air, it creates turbulence. If it reaches this stage, the air will be unable to collect wind energy efficiently as long as it is turbulent. While it is true that a larger rotor span reduces turbulence, the opposite is also true. To avoid the blades travelling through too much turbulent air, the tip speed ratio is also chosen. [21]

$$Tip\ speed\ ratio = \frac{Tip\ speed\ of\ blade}{Wind\ speed}$$

5.7. Betz Limit

The Betz Limit Power coefficient for this sample turbine is 0.45 (= 45 percent) with a tip speed ratio of slightly less than 6.

5.8. Tower Height

Rooftop windmills were designed to make computations more simple and cost-effective (40 feet). As a result, the entire height of the structure is about thirty metres.

5.9. Load Consumption Simulation

System modelling assumes two types of load demand.:

$P_L(t) = P_T(t) \pm G_L(t)$

In this equation, $P_T(t)$ is the power by a wind set, and $G_L(t)$ is the power taken/supplied to the grid.

5.10. Economic Parameter

5.10.1. Present net cost

By deducting all of the system's lifetime expenditures and revenues, the net present value of the system is determined. Capital expenses, cost of repairs, sustainment costs, fuel costs, ecological fines, and fuel costs, as well as any other costs connected with obtaining electricity from the grid, are all included. Scrap value and grid selling revenue are the two sources of revenue..

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

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

where$C_{ann,tot}$total annual cost;; R_{proj}represents the lifetime of project; and CRF() is the capital recovery factor.

5.10.2. *Factor of capital recovery*

This ratio is used to measure the value of an annuity (a series of equal annual cash flows). The present value factor may be calculated using the following equation:

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

the interest rate i and the years n.

5.10.3. Lowering of Cost of Energy

It is described as the system's average cost per kilowatt-hour of useable electrical energy generated, according to software. COE is calculated by multiplying the entire quantity of accessible electric energy by the annualised cost of power delivery (total annualised costs minus cost of feeding the thermal load). For the COE, we have the following equation:

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

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 system contains a power generator (photovoltaic array, wind turbine, and battery), a load, and a control station, as illustrated in Figure 3. The system is described as operating in a stand-alone mode in this description. Data from a small factory in Ganga dharprasaddia, India, was used in the study. Here's a summary of how the hybrid solar PV-wind system works. During the day, the solar PV system creates power, while the mill produces power at high wind speeds. The batteries is used to retain surplus energy above the load need, and it is emptied when there is a power deficit to meet the load requirement. A steady and sustainable energy supply may be assured 24 hours a day if the charging and discharging rates, as well as the capacity, are sufficient. A PV array, windmill, and battery, as well as an inverter, converter, and charge controller, are the main components of the system.

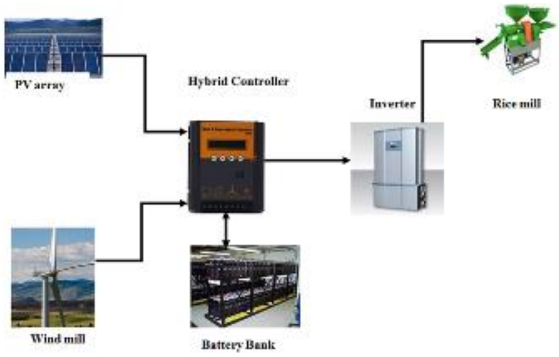

Figure 3: PV wind hybrid system

6.1. Load Profile

As shown in Figure 4, the proposed system will have a daily load of 11kWh and a maximum load of 23kW. In any event, this is the overall average demand over a specific time period.. Because of the increased number of machines, electricity consumption will rise in the near future. The system was designed primarily to meet the needs of small cottage industry enterprises, who account for the vast majority of users. Even if there isn't a physical site visit, a lot of assumptions are formed. After that, a realistic load profile was created using HOMER.

6.2. Solar Energy Resource

Solar energy is an important component of the suggested plan. The PV array's power output improves as technology advances. Weather conditions have an impact on the PV array's ability to generate electricity. Solar radiation in India ranges from 4 to 8 kWh/m2/day on average. The research takes place at a latitude of 20.59 degrees and a longitude of 86.59 degrees. The PV array has a capacity of 3 kWP and a clarity index of 0.57, with a monthly average daily solar radiation of 5.42 kWh/m2/day and a monthly daily solar radiation of 5.42 kWh/m2/day. A 3 kWp PV array costs INR 2,43,000, with little replacement and O&M costs, as shown in Figure 5.

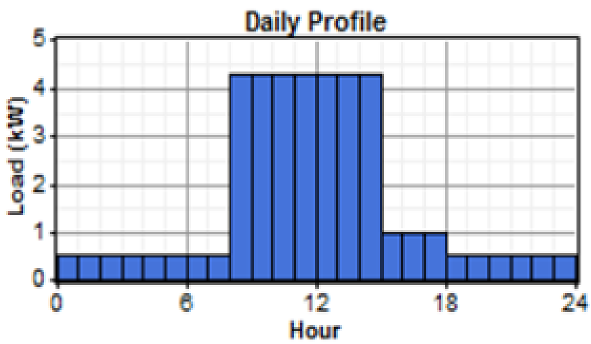

Figure 4: Hourly load

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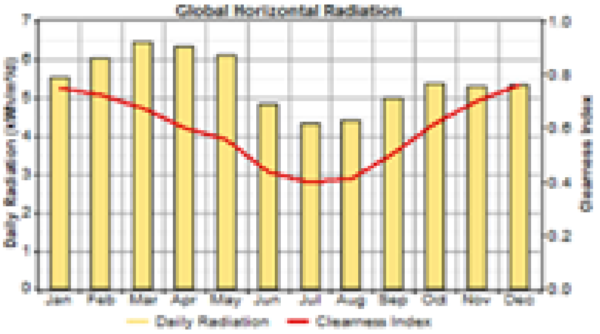

Figure 5: Solar energy resource

6.3. Battery Performance

In the proposed proposal, solar PV panels are the only source of energy. Weather conditions have an impact on the electricity generated by solar panels. A power supply must be accessible for the length of the night. As a result, PV arrays are unable to provide variable power. The batteries' quality is being enhanced in order to decrease the PV system's intermittent nature.

The model is powered by two Surrette 4KS25P batteries. The proposed plan estimates that the battery sub-system capital cost will be INR 42,000, replacement costs will be Rs. 30,000, and annual O&M expenses would be INR 400.

6.4. Converter

The photovoltaic system and independent charge controller are the two most important BOS components in this research.

The balance of system (BOS) component of a solar system is essential because it allows AC-powered equipment to be used. Solar power inverters have distinctive features like mpp tracking and anti-islanding prevention that make them ideal for solar arrays. The study's assumed demands are AC, whereas solar PV output is DC. This design employs a solar or inverter as an alternative to a converter. Two-kilowatt converters with a 15-year lifetime and 90% efficiency were utilised. The capital cost is INR 13,600, the replacement cost is INR 11,400, and the annual O&M cost is INR 400 if you follow the recommended strategy.

7. RESULTS AND OBSERVATIONS

7.1. Solar radiation with estimated output

The connection between PV power output and variations in global solar radiation is seen in Figure 6. At an average radiation of 0.333kW/m2, a maximum output of 8.448 kWh is observed throughout the day.

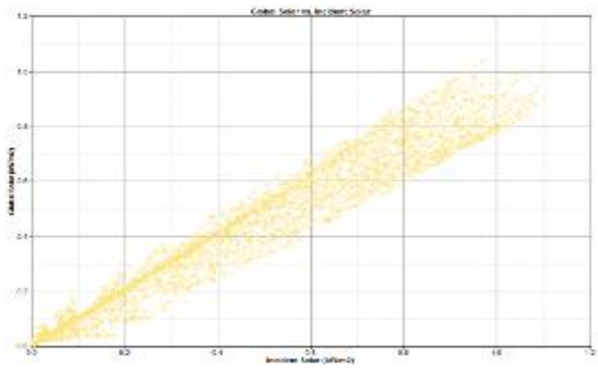

Figure 6: Estimated Solar Radiation and expected PV Output Power

7.2. Wind Speed with Estimated Output

Figure 7 depicts the relationship between wind speed and wind power output. Throughout the year, the proposed location suffers low to medium wind speeds. The wind turbine on the mount revolves at a speed of 3 to 8 metres per second. Wind penetration was recorded at 2.13 percent at the proposed site.

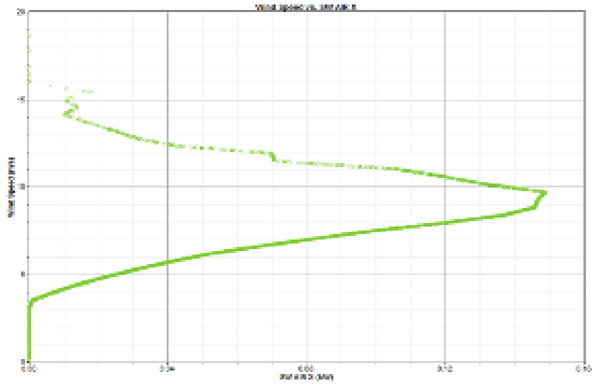

Figure 7: Estimated Wind velocity and expected wind mill power

7.3. Monthly Power Output from PV Array

The monthly output variation from the PV array is seen in Figure 8. The PV array's power generation is satisfactory throughout the year, with a peak from November to March. As a consequence, a PV array may generate a significant amount of energy throughout the year. The electricity output fluctuates from March to September due to the fact that the intended site is dominated by monsoon weather. Depending on the conditions, the PV array is expected to produce 18,965 kWh/year. Figure 9 shows the average daily power production over the course of a simulated year, as well as its variation over time.

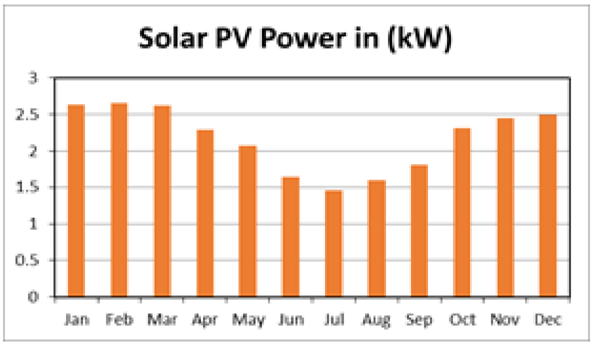

Figure 8: Monthly power output from PV array

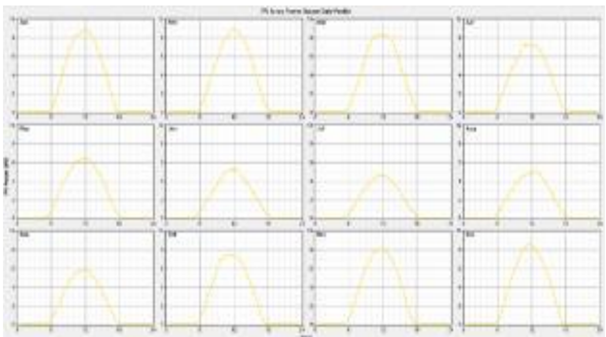

Figure 9: PV array power output variation

7.4. Wind Energy Production

The wind mill is included in this research to determine its feasibility and influence on the system's dependability. Figure 10 shows the monthly windmill power input. A wind turbine installation's capacity is limited to 1 kW for economic reasons. The study makes use of an AIR SWX wind turbine. It runs for 6,461 hours per year, with an 8.84 percent capacity factor. It has a 3720 kWh overall capacity. The windmill produced a decent amount of electricity from March to September, making it compatible with solar PV, even if PV power output fell due to cloud cover during that month. Figure 11 depicts the variation in windmill power output across the months.

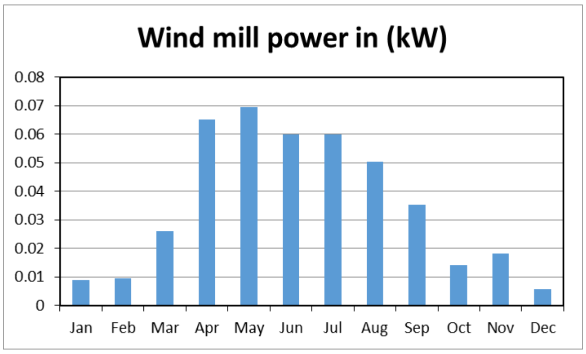

Figure 10: Monthly windmill power input

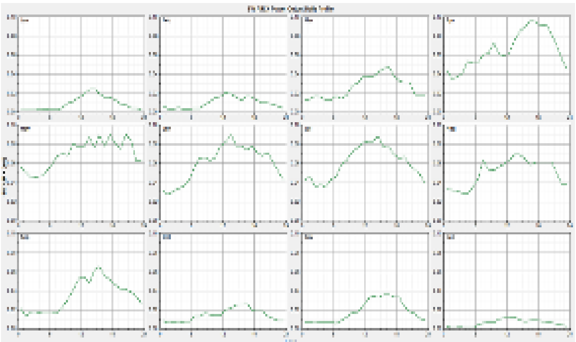

Figure 11: Energy output and load on a daily basis

7.5. Daily Mean Energy Production and Load Demand

Two active energy sources are presently used to power the system. Figure 11 shows the output of a 3kW SPV as a blue bar. The red bar represents the Windmill's power output. According to HOMER estimations, solar energy supplies 86 percent of the load. When used together, the SPV and windmill can meet the energy-generating needs. Achievable is a quality, and integration helps you attain that quality.

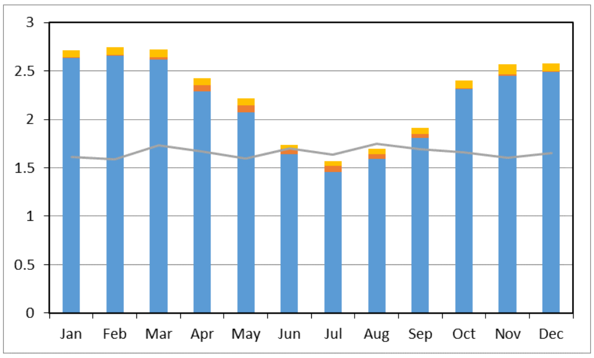

Figure 11: Daily mean energy production and load

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 emissions are so low that, if we exclude a little bit of pollution from the battery, they're virtually non-existent. Using this method, you may significantly reduce your carbon footprint and other critical pollutants that contribute to global warming.

Table 1: System emissions

Pollutants	Emissions (kg/yr)
CO_2	0
CO	0
hydrocarbons	0
Particlesr	0
SO_2	0
NO_2	0

7.7. System Parameters' Performance

Table 2: Performance of PV array and Generic

Parameters	Value	Unit
PV array		
capacity	12	kW
outputAverage	2.2	kW
output	52.0	kWh/d
Factor of capacity	18.0	%
Production total	18965	kWh/year
Min output	0	kW
Max output	2.92	kW
PV penetration	126	%
Hours of working	4,387	hour/year
Optimized cost	3.66	$/kWh

Parameters	Value	Unit
AIR SWX		
Capacity rated	0.400	kW
Output average	0.04	kW
Factor of capacity	8.84	%
Production total	310	kWh/yr
Min output	0	kW
Max output	0.15	kW
Wind penetration	2.13	%
Operation hours	6,461	Hr
Optimized cost	49.3	$/kWh

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Table 3: Performance parameters of Battery and converter

Parameters	Value	Unit
Battery		
nominal capacity	38.0	kWh
usable capacity	22.8	kWh
autonomy	13.7	hr
throughput	52,843	kWh
wear cost of battery	0.592	$/kWh
energy cost average	0	$/kWh
In put energy	3,137	kWh/yr
output power	2,524	kWh/yr
storage depletion	16	kWh/yr
losses	597	kWh/yr
throughput	2822	kWh/yr
expected lifetime	12	Yr
Parameters	**Value**	**Unit**
Converter		
Capacity	6	kw
Average Output	1.49	kw
Min outpit	0	kW
Max outputt	6	Wh
Capacity factor	24.9	%
Hours of operation	8604	h/yr
Energy in	14517	kWh/yr
Energy out	13065	kWh/yr
Losses	1452	kWh/yr

8. CONCLUSION

In this study, a PV-Wind system is studied for a small business. The results are promising. It concludes that integrating a battery increases the system's power output, that the schemes used in the study are complementary in nature, that the capacity shortage is 0.15 percent, increasing the scheme's reliability, and that the levilised cost of energy is estimated to be 8.118 INR/kWh, which is likely to decrease in the near future due to technological advancement and deregulation. The suggested technique also emits little pollutants, making it ecologically friendly.

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