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Novel Design of Power Generation with Windmill Using National Grid

Ishfaq Ahmad Bhat
M.Tech, Power System, Department of Electrical Engineering, RIMT University, Mandi Gobindgarh, Punjab, India

Krishna Tomar
Professor, Department of Electrical Engineering, RIMT University, Mandi Gobindgarh, Punjab, India

Satish Saini
HoD, Department of Electrical Engineering, RIMT University, Mandi Gobindgarh , Punjab, India

ABSTRACT
When it comes to expanding its national grid and electrifying every corner of its land, India, a rapidly growing country, is always trying to do so. Most of India's energy is produced by large power plants, which are subsequently distributed through a number of grids and networks. India's energy infrastructure is the best in the world. Electricity dependability is a challenge in some of the most distant or hard-to-reach locations. It is common for power outages to occur in these areas, as well as low supply voltages. It is possible to create clean energy using windmills when the wind blows constantly at an extremely low cut-in speed.

Turbines and generators convert the stored wind kinetic energy into electricity in wind farms These facilities create electricity dependent on how fast the winds are blowing at them. As part of the investigation, a windmill was connected to the existing system to generate electricity. There is no need for external battery banks in order for the system to function properly. Once a specific threshold is reached, the windmill will take care of its load, and the extra energy will be sent back into the power grid.

Every time the windmill can't keep up, we'll have to turn to the grid. Net metering is used for electricity exchange. The model is used to analyze the study's validity and other technical features. To increase supply dependability, the size of windmills and other grid balancing elements will be adjusted as part of the initiative.

Keywords
Electrical energy, Grid, Threshold, Shortfall, Windmill, Balance of systems.

1. INTRODUCTION
A combination of population expansion and technical advancements has resulted in a fast increase in global energy consumption. A reliable and cost-effective renewable energy source must be selected to satisfy future energy demand[1].

The world's energy demands are increasing as a result of population growth and industrial development. Note that the world's population has increased by 2 billion people in only one generation. It's no surprise that emerging markets have accounted for much of this increase. To avert a worldwide energy catastrophe in the 21st century is one of the least important issues to be addressed. Since the world's population is increasing, so is its energy need. To develop themselves in the globe, various countries utilize a range of tactics and programs [2]. In the future, renewable technologies will have a greater proportion of the market (made up of solar, wind, geothermal, modern biomass, as well as the more traditional source i.e. hydro). [3]. Due to its variable output and time-dependent features, renewable energy poses several challenges. However, they are not enough to maintain the balance between power manufacturing and utilization. Renewable energy generation is intermittent, thus energy tragedies can be regarded as a solution. A surplus of energy is stored when production exceeds consumption. For inconsistent solar, It's important to have a way to store solar electricity due to the intermittent nature of solar energy output [4]. This may be done with a simple battery. Batteries, on the other hand, are not recommended due to the presence of sulphur oxide.

Rather of evaluating grid integration, batteries are withdrawn. To improve the supply's dependability, a hybrid PV-wind-grid system is being studied as a way to reduce dependency on grid electrical energy. To be reliable as a baseload and demand fluctuation source of power, it is required to store electricity.

1.1 Wind Energy System
For socio-economic development, energy is a critical input. The pace at which a nation consumes energy is frequently indicative of the amount of success that it may reach. When it comes to renewable energy sources, wind power is one of the most significant and has grown in importance in recent years. Numerous countries have announced plans to spend heavily in wind power in the foreseeable future. (3) Wind velocity dispersion throughout the wind regime. The total energy created over a period of time may be calculated by adding all possible wind speeds. The likelihood density of variable wind velocities must also be taken into account when computing energy. Knowing the wind speed in a specific region is crucial when it comes to establishing the cut-in speed, rated speed, and cut-out speed of a rotor. When using wind energy, it's also important to have a good grasp of the wind conditions at a specific location [5]. In contrast to solar energy, wind energy is difficult to assess since site circumstances and terrain have a major impact [6]. To stimulate wind energy use, several nations now have wind energy policies in place. Consequently, the importance of wind energy is expected to increase considerably in the next decades. There has never been a comprehensive review of wind energy that includes three aspects: status, potential, and policy studies and evaluations that the author is aware of. This study not only describes the current condition and potential of wind energy, but also covers current challenges and the newest research. Additionally, the current condition of the burgeoning industry is discussed, as well as its potential and future expansion.

1.2 Wind Grid Hybrid Energy System
Considering that wind turbines have become a source of power, wind forecasting has proved beneficial for network

management [7]. Wind energy forecasting is one of the most challenging meteorological phenomena to predict. Any given approach has its pros and cons. In certain instances, it may be useful while other times it may not be.. The technical standards of the energy grid, often known as grid code, are meant to provide a safe, secure, dependable, and cost-effective functioning of the energy grid's components. Those in charge of overseeing the integrity and functioning of the electricity grid are responsible for creating any grid code that is needed. According to its contributors, and especially its transmission businesses, a country's content might vary. That implies that all power generation, even renewable energy generation, must be connected to the power grid system. For all wind energy suppliers, this includes network frequency and voltage fluctuation needs, fault right-through and reactive power skills, as well as power factor control skills.

[9] Reduced intermittency of wind energy may be achieved by grid integration, as well as geographical and technical dispersion. They may be classified as gathering and distribution strategies, with the goal of minimizing the unpredictability of global wind power in a meaningful way. As a result of enhanced forecasting techniques, the system's effect can be reduced [10].

2. OBJECTIVES

- Transmission and distribution of power are the functions of the national grid.
- This grid power is a major source of electricity for most of India. To make up for this, the system relies on centralized facilities that burn fossil fuels to provide electricity. Consequently, the environment suffers. Occasionally, grid failures result in power outages, which are exacerbated if the site has a variety of geographical factors.
- As an alternative, renewable energy sources like as wind that are present on the installation site can avoid these issues. Wind power, on the other hand, is not a constant, but rather an intermittent source of energy. Some storage devices must be preserved in order to solve this problem, with batteries being the most commonly used. During its disposal and normal operation, the battery, on the other hand, emits pollutants like as NOx and SOx. As a result, sites that are sensitive to the environment may be harmed. As a result of the research, batteries have been replaced with grid integration.
- Energy provided by the windmill largely serves the needs of local residents and businesses. The extra power is sold to the grid after meeting the demand. During a power shortage, the grid will be used to purchase electricity. The system contains a net metering system, as well as power purchase and sale at a pre-determined price, among other components.
- This paper introduces the integrated wind-grid system and examines this alternative for reliable, cost-competitive electricity supply.

3. LITERATURE REVIEW

To offer an overview of the historical history of wind energy technology, Thomas Ackermann and colleagues published a report in 2000. They also reviewed the current state of grid-connected and stand-alone wind power generation across the world. A wide range of design approaches are discussed along with economics, the environment, and specialized system applications such as offshore wind generation, among other subjects. Nevertheless, due to the complexity of wind energy technology [11], the major objective of this study is to offer a brief assessment of the essential turbine and project concerns.

There is an abundance of wind energy in India, according to P. K. Chaurasiya and colleagues (2019). When it's time to install wind turbines, it's important to assess their ability to improve the country's energy position. 34605 MW of wind power have been built as of September 2018. India is now rated 4th in the world for wind energy conversion/use. The condition and growth of India's wind energy industry is examined. As well as wind energy, various strategies for enhancing and expanding wind resource utilization are covered in this study [12].

On the other hand, Tande (2003) provides an overview of grid integration of wind farms, including the influence on voltage quality and system stability. To determine if wind turbines affect the quality of electricity in distribution networks, a recommended technique is presented herein Electric grid influences such as sluggish voltage fluctuations, flickering, power dips and harmonics are determined by the power quality attributes of wind turbines, which are based on power quality characteristics. There is an example of a fixed-speed wind turbine that is shown. As a starting point for more complex models, the model is briefly discussed here. By incorporating dynamic wind farm models into power system modeling tools, it is feasible to analyze and develop new grid integration techniques. [13]

4. METHODOLOGY

4.1 Wind Performance Assessment

As a result of a lack of foresight, significant amounts of spinning reserves are required, which raises the cost of manufacturing. A prediction is also beneficial for network management when using wind turbines as a power source [14]. As wind energy is one of the most challenging meteorological phenomena to anticipate, there is no ideal approach for wind energy forecasting. When it comes to strategies, for example, some may be acceptable in particular situations, but not in others [15].

IEC-61400 standard. Basic design criteria for wind turbines are included in 61400. To offer an adequate degree of protection against harm from all risks during the length of its expected life. It follows that all modules, encompassing protection and control mechanisms and also the interior electrical and mechanical structural components of a wind turbine are covered by this standard and must comply with its provisions.

According to IEC 61400-2:2013 for small wind turbines (SWT), they must meet certain standards in terms of design, installation, service, and operation. There is a measure of security against harm caused by risks posed by such systems over their lifetime. In the case of wind turbines, it simplifies IEC 61400-1 [16] and makes substantial modifications. Balancing Equation of Energy.

As a result of this, the equations controlling the energy balance of different topologies of systems may be stated as follows:

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

For (Ein) and (Euse)phrases that have a utility link, the IEC Standard formulation should be used. For storage systems, there is no energy balance since the analysis period (often a year) is considered to be long enough to disregard global impacts of energy to or from this device. IEC Standard should contain the following formulation if analysis duration is not long enough: The subsequent energy balance equations were employed to compensate for these presumptions.

$$E_{in} = E_{Bu} + E_a \quad \& \quad E_{use} = E_L$$

4.2 Wind Energy Assessment

Essential metrics include the net amount of energy transported to and from the backup system, the overall system input and outgoing energy, the windmill's contribution to the overall

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amount of energy, and the efficacy with which the power from all sources is delivered. When wind flows at v m/s through an absorbing region A, the theoretical connection between the power of the wind (per unit time) is

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

Pressure and temperature, among other things, have a role in this. On Figure 1, you can see a wind turbine's so-called "machine power graph" (predictable maximum power as a function of wind input velocity) inside a wind tunnel. According to this machine slope, the wind turbine doesn't really produce energy below a specific minimum wind speed, known as a "connection speed". As the wind velocity increases after this connection speed, the power is increased. If you look at Figure 2, you'll see a similar trend of development. As soon as the wind turbine reaches its maximum speed, its output power is equal to the rated capacity. After the baseline wind speed, a specific range of wind speed is maintained. Wind turbines are disconnected when they reach their disconnecting speed to prevent severe wind breakage.

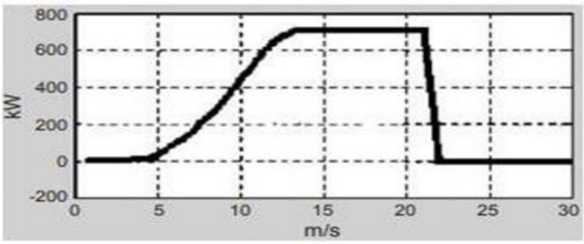

Figure 1: The power curve of a standard wind tunnel equipment

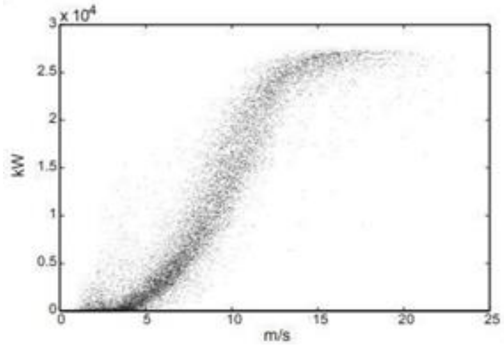

Figure 2: Empirical values of the velocity of wind and output power in a real wind farm.

4.3 Grid Assessment

Thereby allowing it to be linked to the national grid. There are several national and state agencies that provide and control grid values, so they cannot be changed during simulation. Because just the wind systems specified for the model are modeled, a fixed grid size is used. The grid has the following parameters: There are 50 Hz and 220 V +/- 10% ratings for single-phase connections. In the grid, there is a power capacity of 1000 kilowatts. A simplification was made by assuming that the energy cost for both delivered and bought power from a network is the same.

5. SIMULATION MODEL

An optimization tool for renewable energy-based power systems called the Hybrid Optimization Model for Electric Renewables (HOMER) [17], is used in this study to model and simulate power systems (NREL). This micropower optimization software has been extensively used in a number of prior hybrid energy system studies in other nations, and it was chosen here in this article to simulate a viable hybrid system for the location. Each system is modeled with a combination of traditional fuels and renewable energy to identify the most cost-effective architecture. This comprises electric load (primary energy demand), solar radiation, water resources, component technical specifications and prices, and the kind of dispatch technique, among other things. [18]

5.1 Modeling of Wind Energy

In order to synthesize the data, I gathered and inputted twelve average wind speed measurements between June 2018 and May 2019 [19]. I put 8760 data into HOMER, or one wind speed data each hour of the year. Daily and seasonal trends, as well as the Weibull distribution and correlation, are described in this sample data.

5.2 Tip Speed Ratio

Rotor blades moving through the air create instability. If it reaches a certain point when the air is still turbulent, it won't be able to effectively harvest power from the wind. While a slower blade span would lead in less turbulence, the opposite is also true. As a result, the tip speed ratio is also adjusted such that the blades don't have to pass through too much turbulent air. [20].

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

5.3 Betz Limit

In theory, a wind turbine generator may generate 59 percent of its power using a Betz Limit Power coefficient of 0.45 (= 45 percent) with a TSR of slightly below 6.

5.4 Height of Tower

Easy calculation and cost-effectiveness are the primary goals of roof-top windmills (40 feet). Thus, the overall height is about thirty metres.

5.5 Modeling Load Consumption

System modeling assumes two types of peak load:

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

A wind-turbine set produces PT(t), whereas GL(t) is the amount of power taken/supplied to grid.

5.6 Total Net Present Cost

Net present value is calculated by subtracting the entire lifetime earnings from all future expenditures. A few examples are construction expenditures, repair and maintenance costs, fuel prices, fines for pollution, and the cost of obtaining power off the grid. . Profits come from salvage value and grid sales, among other sources of income. The equation may be used to determine the system cost.

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

Where $C_{ann,tot}$ is the gross cost and R is the real interest rate.
R_{proj} is the project's lifespan, whereas CRF(i,N) is the high recovery factor.

5.7 Recovery Factor of Capital

An annuity's present value is calculated using a ratio known as the capital recovery factor (a series of equal annual cash flows). The following formula is used to determine the asset recovery factor.

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

In this case, N is the number of years, and A is the annual real interest rate. This research anticipated a real interest rate of 6% and a 25-year project duration.

5.8 O&M Cost

As the name implies, running and maintaining an element costs money. Operating and maintenance (O&M) expenses are determined by aggregating all system components. When it comes to the bulk of components, O&M expenses are estimated annually.

5.9 Project Lifetime

Costs accrue over a project's lifecycle. A year-based measurement, R Projand, represents its sign. In this example, the project's lifespan is set as 25 years.

5.10 Salvage Value

For electrical components, this is their worth at the end of their project life, which is their salvage value. As a result, the salvage value of an item is directly proportional to the remaining usable life of the object. We also estimate salvage value based on replacement cost instead of initial capital costs. There are two ways to represent it mathematically.

$$s = \frac{R_{rem}}{R_{comp}} C_{rep}$$

If you want to know how long the component has left to live, you can use *Rrem*.

$$R_{rem} = R_{comp} - (R_{proj} - R_{rep})$$

Rrep is the period of the replacement cost and it is calculated by:

$$R_{rep} = \frac{R_{proj}}{R_{Comp}} R_{Comp.} \cdot INT$$

In this case, *Crep* = replacement cost [$], *Rcomp* = element lifetime [year] and *Rproj* = project lifespan [year].

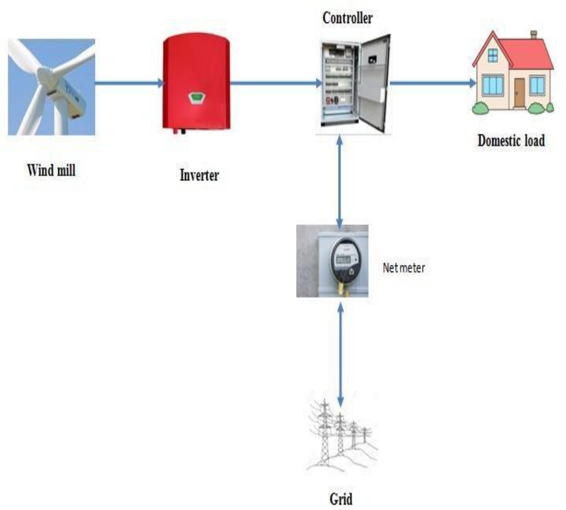

Figure 3: Wind-Grid Integrated system

5.11 Fraction of Renewable Energy

Percentage of energy generation from renewable sources in system (renewable fraction). This is determined by dividing the entire annual renewable energy output with the overall energy production..

$$f_{ren} = \frac{E_{ren}}{E_{tot}}$$

the overall electrical output in Kwh is equal to *Eren* sustainable electrical production in kWh.

5.12 Levelized Cost of Energy

Software defines it as the system's average cost per kilowatt-hour of electricity that may be used. In order to determine COE, divide the total amount of usable electric energy by the annualized cost of supplying power (total annualized costs minus cost of feeding the thermal load). Here is the COE formula.

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

What is the total yearly cost of energy [$/kWh], *Eprime,AC*= AC main load serviced [kWh/year] and Edef= dispatchable load served [kWh/year]?

6. SYSTEM ANALYSIS

Windmill with national grid, load, and command centre make up the system. This means that when the system is functioning in grid-integrated mode, it is considered to be in use. During the study, Gangadhar's domestic burden is considered. Figure 3 depicts the component arrangement of the device.

Hybrid wind-grid combined systems work as follows:

6.1 Windmill

Energy will be generated mostly by the wind mill. In order to fulfil the local need, windmill energy will be tapped. Surplus energy can be sold on a preset basis to the grid, while energy in low supply can be purchased off of it, if available. Using the net metre, each month's corrected financials are calculated. In this approach, a constant supply of energy would be maintained at all times. Key parts of the model are the wind mill, the National Grid connection, the inverter, converter, and controller.

6.2 Load Profile and Wind Resources

Power use per day is estimated as 1.75kWh/day, with peak usage at 269W per day. Figure 4 shows the hourly load. This is a graph that shows the average load demand for a system. En outre, as technology advances, more and more equipment will be required, increasing power consumption. Primarily, the system is meant to fulfill the needs of the domestic market only. It was unable to assess the real demand on-site, thus the simulation utilized an approximate approximation of the actual load. HOMER software incorporates the unpredictability of the day to create a load profile that's fair The whole simulation year is based on the assumption of a constant load. A modest wind speed is expected at the planned site for most of the year. Windmill simulation is done with a 1kW DC windmill. The lifetime of the windmill is 15 years. With a 10 metre tower, the average yearly wind speed is 4.956 metres per second. To construct a wind turbine costs INR 98,000, whereas to replace it costs INR 65,000. Wind resource pictograms are shown in Figure 5. Wind speed changes throughout a month are shown.

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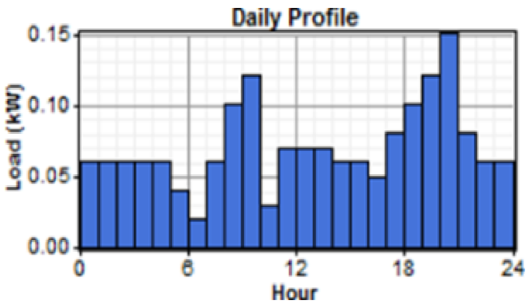

Figure 4: Hourly load

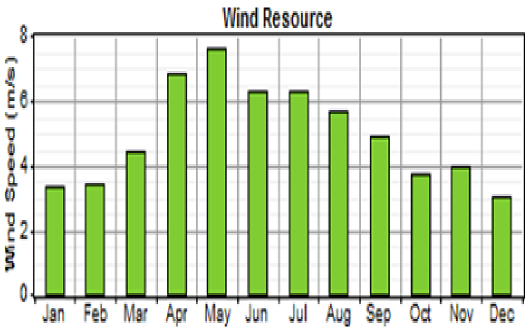

Figure 5: Wind Energy resources

6.3 National Grid

This study focuses on the use of wind turbines to increase the dependability of the current grid, despite the fact that the national grid plays a major part in the study. There is a grid, therefore the connections and standby costs are not included in the simulation because of this. For the grid to be able to meet future energy demand increases, the systems sell and buy capacity is highly valued. The price of energy acquired and sold is kept at the same level to make calculations easier**.**

6.4 Converter

To appropriately use Wind produced power, a subsystem is required, according to the proposed approach. BOS (Balance of Systems) is another name for this subsystem. The BOS does not include solar panels [21]. Inverters, battery banks, and battery chargers make up a solar power system's components. Use a safe method of transmitting or storing electricity. For a stand-alone system, balance-of-system equipment comprises batteries, a charge controller, power converter gear, protective gear, and metres and instrumentation, among other items of equipment.. BOS relies heavily on inverter and controller as a consequence of the research. Wind energy is intended to be DC, whereas loads are expected to be AC in the planned research. Instead of using a converter, this design uses an inverter. When it comes to efficiency, the converter is 90 percent efficient. If the inverter costs INR 13,600 initially, then INR 11,000 to replace it, the yearly running cost is INR 300.

7. Results and Observations

Wind power production varies based on output speed, as seen in Figure 6, while Figure 7 shows the power curve for a 1kW DC windmill in general. Calculated wind speed ranges from 3.3 to 7.6 m/s. 257% of the property is open to the wind. Installed wind power can create 1.584 kWh of energy per year from 1 kW of power.

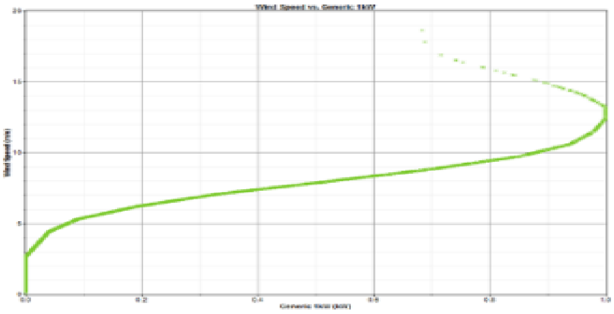

Figure 6: Wind speed and output power

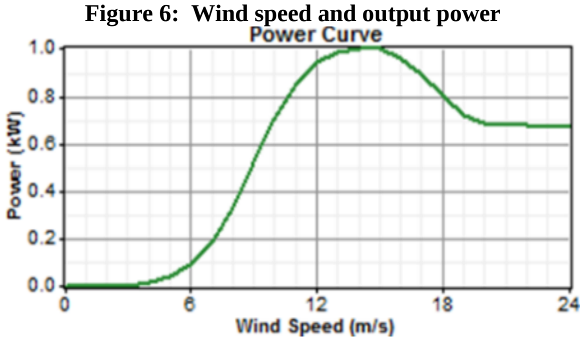

Figure 7: Power curve of generic 1 kW wind turbine

7.1 Wind Output and Grid Supply

Coastal Odisha is ripe for windmill development. 1 kilowatts of power are available. The research comprises a 1 kW DC type windmill that is general in nature. On average, it runs for 7,092 hours per week and has a capacity factor of 18.1. The total annual production is 1,584 kWh. According to Figure 8, a windmill's power output varies by month. It was decided to build a grid execution in order to evaluate the impact of such integration. Because of the grid, system batteries are not necessary. During the grid connection process, net metering will be used.. In times of high demand, energy purchases from the grid are recorded, but so too are energy exports back to the grid when there is an excess of energy to sell. In addition to ensuring supply dependability, grid integration will minimize pollution by delivering clean and green energy to the system. Amounts of energy bought and sold are shown in Figure 9. On the graph, power supplied to the grid is represented in orange, while electricity purchased is displayed in blue. This means that over the modeled year, 1,084 kWh of energy is sold into the grid, and 276 kWh of energy is acquired from it.

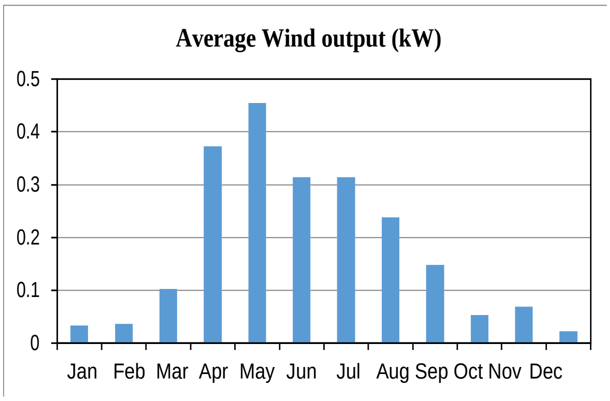

Figure 8: Output power of windmill

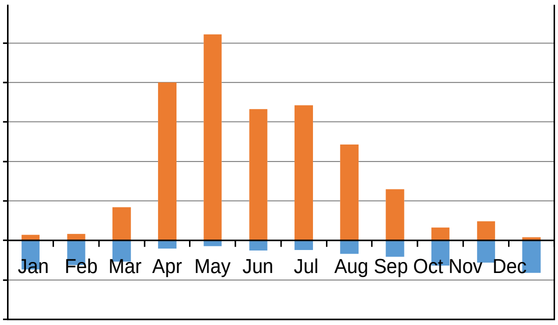

Figure 9: Grid energy purchase and sold

7.2 Renewable Energy Generation and Consumption on a Daily Basis

Figure 10 shows how renewable energy is produced. On this graph, you can see how much wind electricity is created and how much power is consumed on average. In January, February, October, and December, there is a deficit of energy, which is filled by purchasing electricity from the power grid. Each year, surplus energy is sold back to the grid at a pre-determined price to earn money.

7.3 Seasonal Demand and Energy Variation

Spring, winter, monsoon season and summer are the four diverse periods that India has to offer to its residents. In Figure 11, the 10th of March represents the spring season average load, the 10th of May represents the summer season average load, the 10th of July represents the rainy season average load, and the 10th of January represents the winter season average load. Windmill output is represented by the color orange, whereas grid sales are represented by yellow. The average load is shown by the navy blue bar. At all times this year, there was a greater supply of electricity than there was demand. As a result, energy must be acquired in the spring and winter to meet demand. Monsoon and summer seasons are used to sell energy to the grid when the windmill generates more than the load demand. Energy sold surpasses that purchased as a consequence.

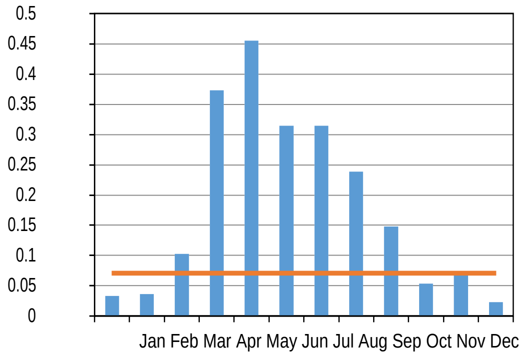

Figure 10: Demand for and production of renewable energy on a daily basis

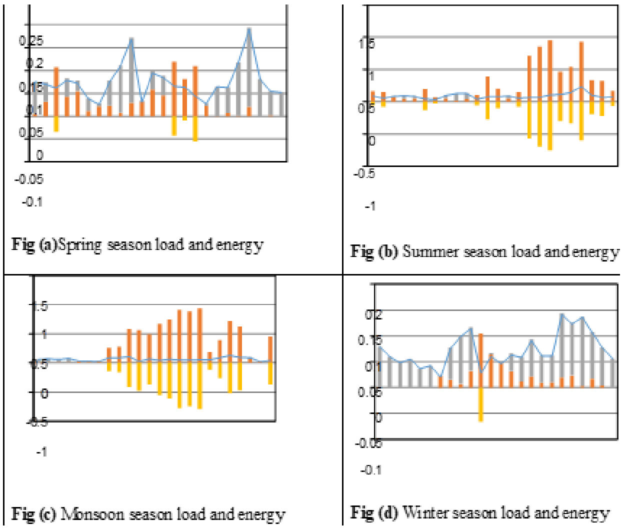

Figure 11: Seasonal energy variations

7.4 Sensitivity Analysis

Using a 10% capital decrease and a 15% replacement cost cut for wind turbines, LCoE and NPC drop 22,34 and 22,32 percent, correspondingly based on the assumptions above. An electrical charge surface map may be shown in Figure 10. When the converter cost is decreased by 10% and the replacement cost is cut in half, the LCoE and NPC both fall by 2.42 percent. A 24.77 percent and 24.75 percent price reduction is achieved when all key components are concurrently decreased in price. There is no capacity deficit in any of these situations, thus the operational expenses are reduced.

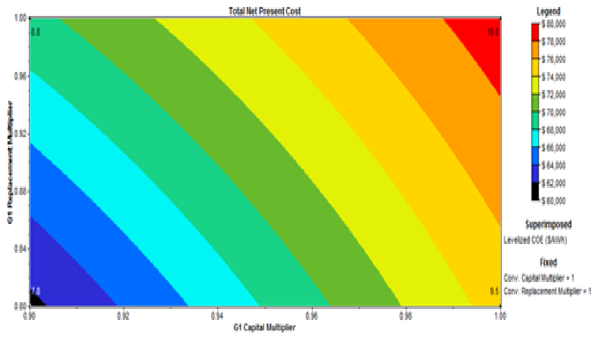

Figure 12: Surface plot of electricity charge.

7.5 Economic Analysis

Figure 13 shows the overall optimization result of a hybrid system using HOMER. A conceivable setup of the computer system is shown in each row of the table. Six columns of key modeling data follow, including Grid, Initial Capital, Operational Cost, Net Present Cost, COE Cost, and Renewable Percentage (RP). Symbols are displayed in the first four rows. Using a 1000kW grid with a 1kW wind turbine and a 2kW converter, for example, would be the ideal setup. The COE is found to be 10.045/kWh with an 85 percent renewable component. A yearly income of 2,534 rupees is feasible. For example, in Figure 14, you can see the cash flow overview dependent upon which components are selected on the system, which is utilized to calculate the NPC. The maximum capital and replacement costs for one-kilowatt wind turbines are the same.

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	G1	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
	1	2	1000	$ 111,600	-2,534	$ 79,208	10.045	0.85
	1	3	1000	$ 118,400	-2,238	$ 89,793	11.387	0.85
	2	2	1000	$ 209,600	-9,361	$ 89,932	11.405	0.94
	1	4	1000	$ 125,200	-1,942	$ 100,379	12.730	0.85
	2	3	1000	$ 216,400	-9,065	$ 100,518	12.747	0.94

Figure 13: Optimization result of wind-grid system

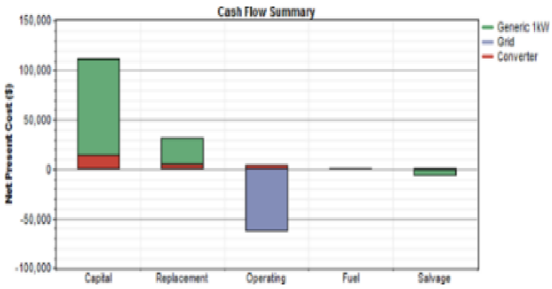

Figure 14: Project cash flow

Table 1: Performance summary of systems

Parameter	value	unit
Generic 1 kw		
Capacity total (rated)	1	kw
Mean output	0.18	kw
Factors of capacity	18.1	%
Whole production	1584	Kwh/yr
Output(min)	1	kw
Output(max)	0.18	kw
Penetration by wind	18.1	%
Working hours	1584	Hr
Reduced price	1	$/kwh
Capicity of converter	2	kw
Output(avg.)	0.16	kw
Output(min)	0	kw
Output(max)	0.9	kw
Capicity	8.1	%
Working hours	7092	Hours/year
Energy given	1584	Kwh/year
Energy taken	1426	Kwh/year
loss	158	Kwh/year

parameter	value	unit
Grid		
Energy purchased	1084	kwh
Energy sold	276	kwh
Net Energy	809	kwh
Peak demand	16	kw
Energy charged (income generated)	-4853	

8. CONCLUSION

In this study, the feasibility of the Wind-Grid integrated system is examined for a community load. The results are showing promising and inspiring. It concludes that with the integration of grid, the capacity shortage reduces drastically, the reliability of the system increases significantly, the levelised cost of energy is calculated as 10.045 INR/kWh, with a capital gain of INR 4,853 per annum, the proposed scheme is also having huge savings in pollutants and hence eco-friendly.

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