



Feasibility Study of Wind-Diesel Stand-Alone System for a Small Village in India

Irfan Anjum Badruddin

Department of Mechanical Engineering, College of Engineering,
King Khalid University, PO Box 394, Abha 61421. Kingdom of SAUDI ARABIA

*Corresponding author

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Abstract: The finite resources of energy like coal, oil, natural gas etc. are depleting day by day. On the other hand man is exploring new ways of utilizing energy and thus total energy requirement of the world is increasing continuously. With present rate of utilization, the underground deposits of coal, oil and natural gas are expected to last for approximately, 100 years, 50 years and 50 years respectively. To cope up with this problem, concerted efforts to generate renewable energy as an alternate source is increasing rapidly with passage of time. Among the available renewable resources, solar energy and wind energy are the prime candidates getting attention around the world for power generation. Wind energy is very good option for power generation but suffers due to variation in wind speed and thus the power contained in the wind, when considered on yearly basis. There are various methods to suppress this drawback of wind energy. One such option is wind-diesel system. This paper highlights, an analysis of wind diesel stand-alone system to meet the complete energy requirement such as house lighting, water pumping, laboratory operations for processing the salt, sealing machine operation etc., of a remotely located community in India.

Keywords: Wind, diesel, battery, electricity, remote village

1. Introduction

For hundreds of years man has been utilizing wind energy in one or the other form. It is well known that ancient people used wind energy for various purposes, which included ship sailing. As the time passed by new applications of wind energy were realized of which electricity generation is the most appreciated and accepted one. It is estimated that over 2 billion (nearly 33% of the world's total population) people across the globe are not having access to electric energy [1]. The reasons being, inadequate generation of energy, as most of the under developed countries have to depend on hydroelectric power generation which has several limitations and secondly lack of technology to reach homes located far away from cities with added difficulty of thin population. It is almost impossible to extend the grid to such places and bear the heavy losses incurred because of maintenances problems, voltage loses etc. Apart from this economic problem, there are many technical difficulties to reach out to these isolated places. This problem is more severe for countries like India where majority of the population lives in villages. The alternate solution for such places is to have area specific power generation system, which would satisfy electricity demand of the places at slightly higher but affordable cost. There has been renewed interest to use a hybrid system comprising of multiple conversion technologies to meet the energy demand of specific locations where a single conversion technology cannot meet the load demand [2-10]. One such system is wind-diesel stand-alone hybrid system. Wind energy is available free of cost and more importantly round the clock, which makes it an attractive option for power generation. Wind energy converter (WEC) based systems are modular in nature which makes it expandable as need arises. In order to reduce the dependence on fossil fuels, many countries with

moderate wind speeds are encouraging wind energy usage for power generation [11-16]. Wind energy association in Europe and UK have formulated strategies with an aim of utilizing wind energy to produce at least 10% of installed electrical power generation capacity in their countries of origin by 2025 and 2030 respectively. In the last few decades remarkable technological advances have occurred in wind energy converters (WEC), but still WEC do not generate enough power round the year because of wind speed variations. This problem is suppressed by adding back up power generation and energy storage systems. The wind-diesel systems are becoming a promising alternative energy source worldwide [17-19]. The WEC with diesel and various forms of energy storage device is a subject of interest among many researchers. Brown et al. [20] have reported field performance of a remote 10 kW wind turbine with battery storage. El-Hadidy and Shahid [21] have analysed use of wind-diesel system to meet the commercial loads in Saudi Arabia. Carta [22] has studied operation of wind-diesel system in Canary Islands. Francisco and Saenz [23] have discussed the integration of biomass power plant with WEC.

The focus of this paper is to investigate possibility of wind-diesel stand-alone system for a small community located at Khargoda in Gujarat state of India. The location under consideration is a wind rich area having a scarce population. A simulation is carried out to estimate wind power availability at Khargoda. The paper proposes a wind diesel system comprising of three wind energy converters with battery storage of ½ day requirement and a 7 kW Diesel generator as backup power generation system.

2. Analysis

Khargoda is a village located in Kutch area of Gujarat state in India. The latitude and longitude of place are 23.00 deg N and 70.22 deg E respectively. The wind speed data is available for the nearby region Kandla [24]. The region is blessed with high-energy content wind. Maximum wind speed in the region exceeds 100 km/h in stormy days during the month of May/June and attains a minimum of 40-60 km/h in Oct/Nov. The community may utilize this energy for storing, processing and dispatching salt produced in the region. There are 5 residential houses, a laboratory and machine shop for sealing the plastic bags. The population of the location is 35 with daily energy requirement as listed in table I.

Table 1 - Daily energy requirement at Khargoda

Electrical gadget	No	Capacity (in Watts)	Operation (Hrs)	Energy Requirement (kWh/day)
House lamp	10	50	12	6.0
Fan	05	68	10	3.4
Air Cooler	02	200	10	4.0
Water pump	01	400	3	1.2
Security lamp	10	50	12	6.0
Computer	01	250	4	1.0
Lab equipment	-	3000	2	6.0
Sealing machine	04	500	8	16.0
TOTAL				43.6

As shown in table 1, there are 20 lamps (House + Security), which consume 12 kWh energy. Applying energy management principles, the 50 W house lamp can be replaced by two 9 W compact florescent lamp (CFL) and that of security lights by 9 W (since the purpose of security lamp is to identify larger objects thus a single 9 W CFL serves the purpose) energy efficient lamp. After this replacement, the daily energy requirement of the location is reduced to 34.84 kWh. During windy days when power produced is more than actual load, an energy management program could be implemented and the society could be encouraged to utilize electricity for cooking, water heating and other purposes to make use of extra power available. With this program the revised load for 3 energy rich months i.e. May, June and July would be:

With 2 kW appliances for cooking and heating purpose on an average of 4 hrs per day
 Extra kWh per house : $2 \times 4 = 8 \text{ kWh}$
 For 5 houses : 40 kWh
 Revised load : 74.84 kWh

It is expected that plastic bag-sealing machine would work between 9:00 hrs to 18:00 hrs with one-hour rest in between. Air coolers are used when the heat is more during peak hours of the day. Fans are used partly during daytime and partly in the night. Water pump is used in off peak hours i.e. morning hours. CFL works between 18:00 hrs to 12:00 hrs in the night and early morning hours when sunlight is low. Laboratory equipment and computer may be used anywhere between 10:00 hrs to 17:00 hrs which are office working hours. The load profile is shown in figure 1.

2.1 Wind-diesel system components

The wind speed data for 15 years for the location under consideration is analysed that could give a good estimate of average wind speed over the next years to follow. Wind speed varies to some extent every year. For analysis purpose the mean hourly wind data per day per month is considered. The data is analysed in two distinct groups i.e. from 5:30 hrs to 18:30 hrs and 18:30 hrs to 5:30 hrs. Analysis of wind energy available at Khargoda shows that the following components are suitable to meet the load requirement.

Windmill	: 4.5 kW
Start up speed	: 12km/hr
Designed speed	: 60 km/hr
Rated power generation	: 4.5 kW at 45 km/hr
Propeller diameter	: 4.5 m
Weight of rotor	: 150 kg
Turbine blade design	: Aerodynamic profile with fiber-glass material
Diesel generator	: 7.0 kW /230V AC/Air cooled
Inverter	: 230VAC/50Hz/24V DC/7kW
Battery	: Lead acid, 5 units/48VDC/1750 Ahr

Windmill supplies energy to charge the battery on first priority basis. Once batteries are fully charged, windmill power is diverted to meet the load directly and surplus load is met by the battery bank. When there is no wind and battery is at its lowest level then Diesel generator (DG set) is started to charge the battery and to meet the load. DG set is always run at 80% of its full load capacity in order to have maximum fuel economy. In windy days excess power is fed to dump load after utilizing for additional purposes like cooking, water heating etc.

3. Results and discussion

The simulation is carried out for the power generation at the place under consideration for the load as given in table I. The daily power required for the months Jan-Apr and Aug-Dec is 34.84 kWh but it rises to 74.84 kWh during the wind energy rich months (May-Jul) due to use of electricity for cooking and water heating. It can be seen that the peak load period is between 11:00 hrs to 13:00 hrs as shown in figure 1. This is because the high power consuming electrical appliances such as lab equipment, air cooler, fan and cooking stove (in May, Jun Jul) are utilized during this time.

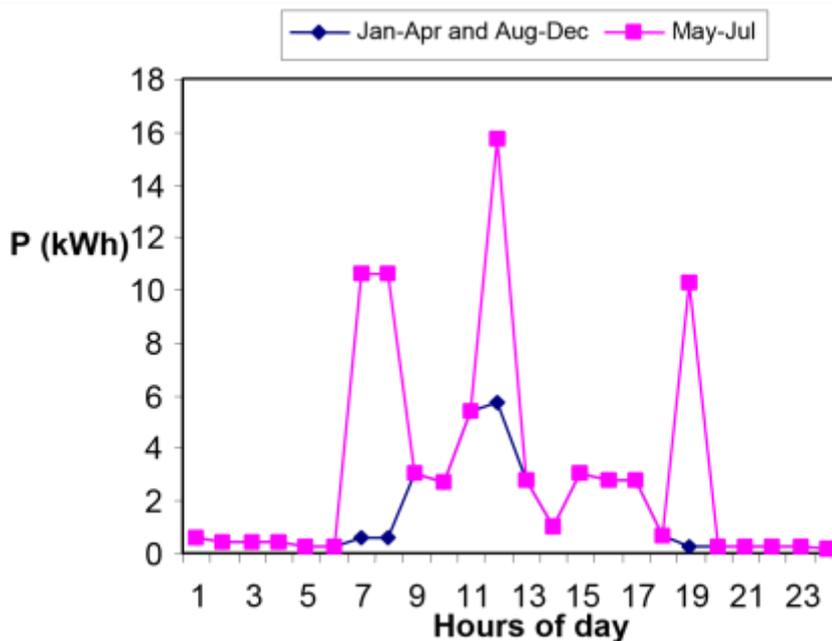


Fig. 1 - Load profile

Figure 2 shows the power generated by different combinations of windmills. Single windmill would generate only 30% of the required power and rest 70% has to be met by DG set. Single windmill would need the DG set to be operated throughout the year (figure 3). The maximum power required from DG set is 52 kWh in the month of Jul when operated with single windmill. The wind-Diesel power-sharing ratio makes single windmill undesirable for the location under consideration. 2-windmills can generate better amount of power and relies on DG set to supply 40% of the deficient load. With 2-windmills, maximum power needed from DG set reduces to 29 kWh. 3-windmill option can meet the load quite well since it can generate 14700 kWh power, as compared to 16396 kWh required power every year. Thus DG set has to take care of 10% power requirement. 3-windmills need the assistance from DG set in the months Jan-Apr, Jul-Aug and Oct-Dec. The maximum DG set energy requirement with 3-windmills is 24 kWh in the month of Nov. 4-windmills and 5-windmills can generate 19% and 49% more power than the requirement, respectively. When operated with 5 windmills DG set is needed only for 4 months i.e. Jan, Oct-Dec and the maximum power required from DG set is 17 kWh in Nov. As obvious from above discussion that 5 windmills could be the ideal choice for power generation throughout the year as it eliminates the need of DG set and requires minimum battery storage capacity (figure 4), but the location under consideration has high variations in wind speeds and during certain period of year (especially in May) the wind speed exceeds 100 km/h being detrimental to the blades of windmill. Under such circumstances a backup power generating systems is required which can meet the load completely if windmill breaks down. Thus 3-windmill with a DG set would be a safe choice to generate electricity for Khargoda and also economical as compared to 4 or 5-windmill option.

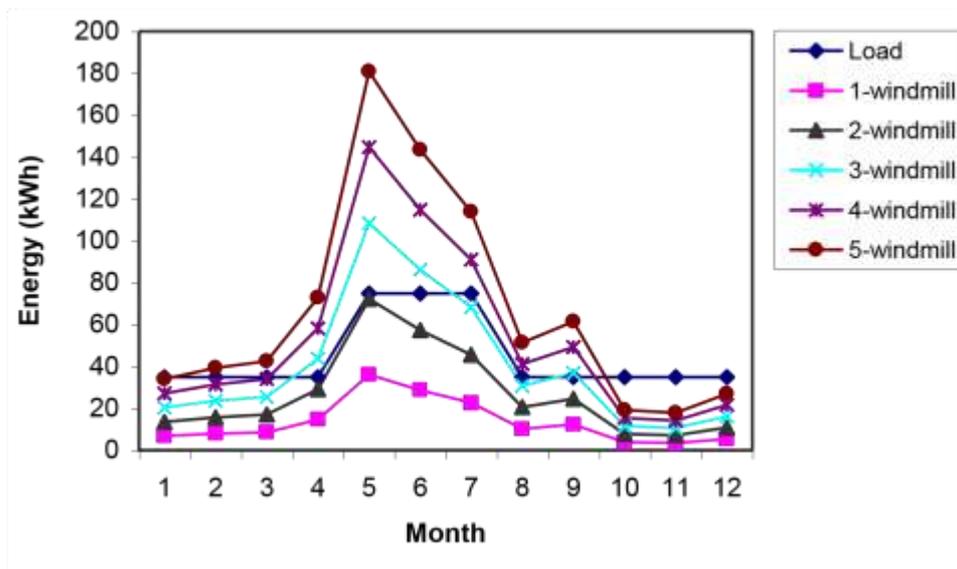


Fig. 2 - Power generated by different combination of windmill

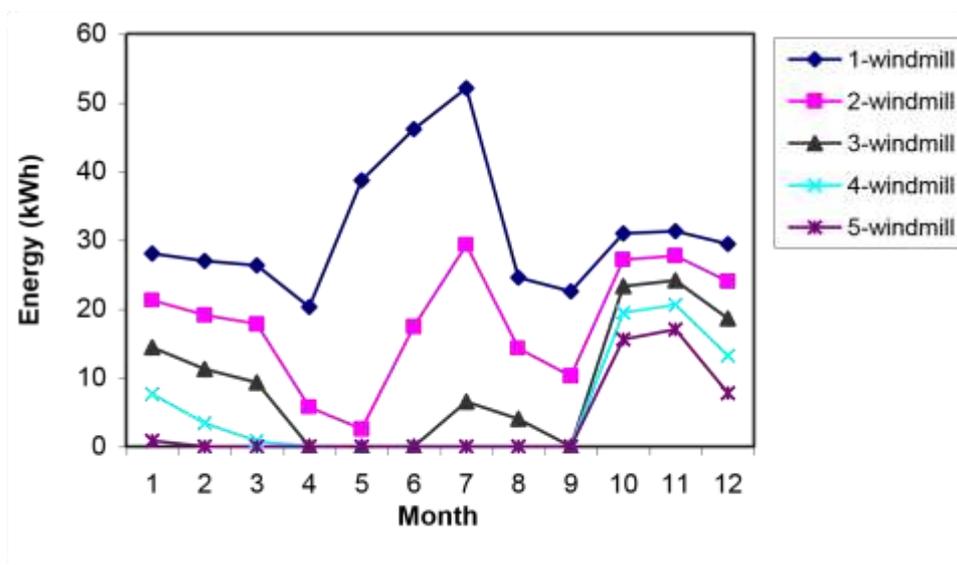


Fig. 3 - DG power required for different combination of windmill

Figure 4 shows the variation of DG set power with the number of days of battery backup for different windmill systems. It is evident from figure 4 that when battery backup increases to 3.5 days then 3-windmill system would generate sufficient power to meet the load, without using DG set. The battery backup of $\frac{1}{2}$ day would be good selection from economic point of view. With $\frac{1}{2}$ day battery storage the DG set need to supply 168 kWh of energy per year when operating with 3-windmills. Figure 5 shows the battery power variation during a day for $\frac{1}{2}$ day battery backup system.

It can be seen from figure 5 that battery power drops sharply around noon time which is peak load period due to usage of lab equipment, computers, fan, air cooler etc. Figure 6 shows the power developed by 3-windmills and the energy required by the society for first four months of the year i.e. Jan to Apr. During these months, power available is more than the demand between 18:00 hrs to 8:00 hrs of the day but the power generated is less than the required between 8:00 hrs to 14:00 hrs. The total windmill power/day is 15%, 25% and 114% more in the months of February, March and April respectively as compared to that of January. Figure 7 shows the windmill power and load during the months of May to Jul. It is clear from this figure that the windmill power is considerably high as compared to load requirement. Windmill power alone is sufficient to supply the energy required by society even though, these months have more power consumption due to usage of electricity for cooking and water heating purpose. In the month of May, wind power is 46% more than the requirement, which can be further used for any other purpose or can be fed to dump load. Jun is also wind energy rich month as the power produced is 14% more than what actually needed. However Jul is slight short of actual power required where in 9% of the load should be supplied from diesel generator. The power available in the wind is considerably high during 12:00 hrs to 20:00 hrs of the day.

In Aug, electricity would be just sufficient to feed the society with slight assistance from DG set as shown in figure 8. The amount of power generated by 3-windmills in Aug is 956 kWh and required power is 1080 kWh. In September 5% additional power is available compared to requirement. Oct to Dec is dry period so wind energy availability is concerned. Very less power is generated during these 3 months. During these months, DG set has to take care of more than 50% of the load. Among all months, Nov is the least energy available month. Total power available through windmill in Nov is only 10.68 kWh per day. Thus DG set has to take care of 70% of the load during this period. In Dec also DG set has to generate 52% of the total power needed by society.

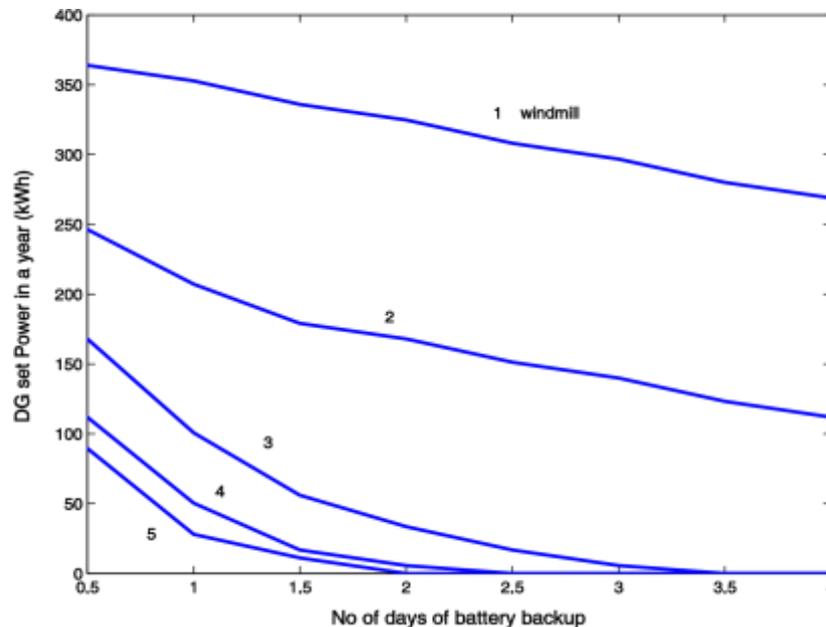


Fig. 4 -DG set power for different number of windmills and battery backup

4. Conclusion

A simulation study for a predefined load of a small community comprising a of 35 people with 5 residential houses along with a laboratory, in a village in INDIA, is carried out. Analysis of the effect of various parameters like, number of windmill systems and different battery backup systems is presented. The detailed month wise power generation by windmill and share of DG power is discussed. The study revealed that a hybrid of wind-diesel system is feasible to meet the load requirement of the village under investigation. The study shows that the village is suitable to have a combination of 3-windmill systems with a battery backup for $\frac{1}{2}$ day and a DG set of 7 kW capacity, to meet the load requirement. With above stated system, power requirement of the community could be met satisfactorily. It is shown that the battery backup of three and half days would remove the dependency on DG set, but it is desirable to have DG set as backup power generation unit in the case if windmill breaks down. Power generated by 3-windmill system is considerably high in the months of May, Jun and Jul. In the month of May 46% extra power is available in spite of using electricity for additional purposes like cooking and water heating by all 5 houses of the community. DG set is moderately required during Jan to Apr but it is not at all needed during May to Jul. However DG set is needed to maximum extent in the months of Oct to Dec when wind speed is lower compared to other months of the year.

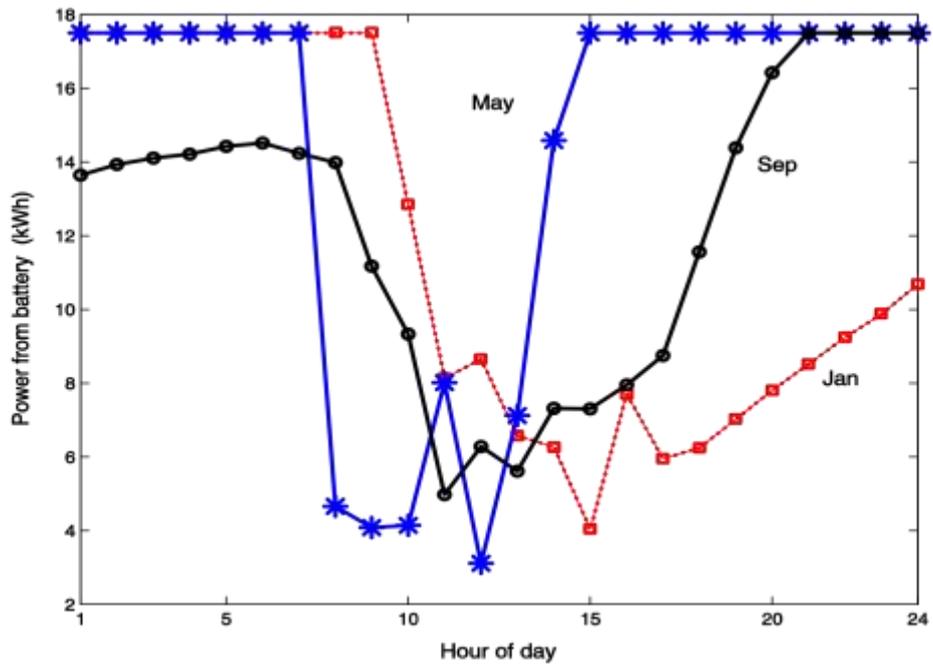


Figure 5: Battery power variation with time in a day

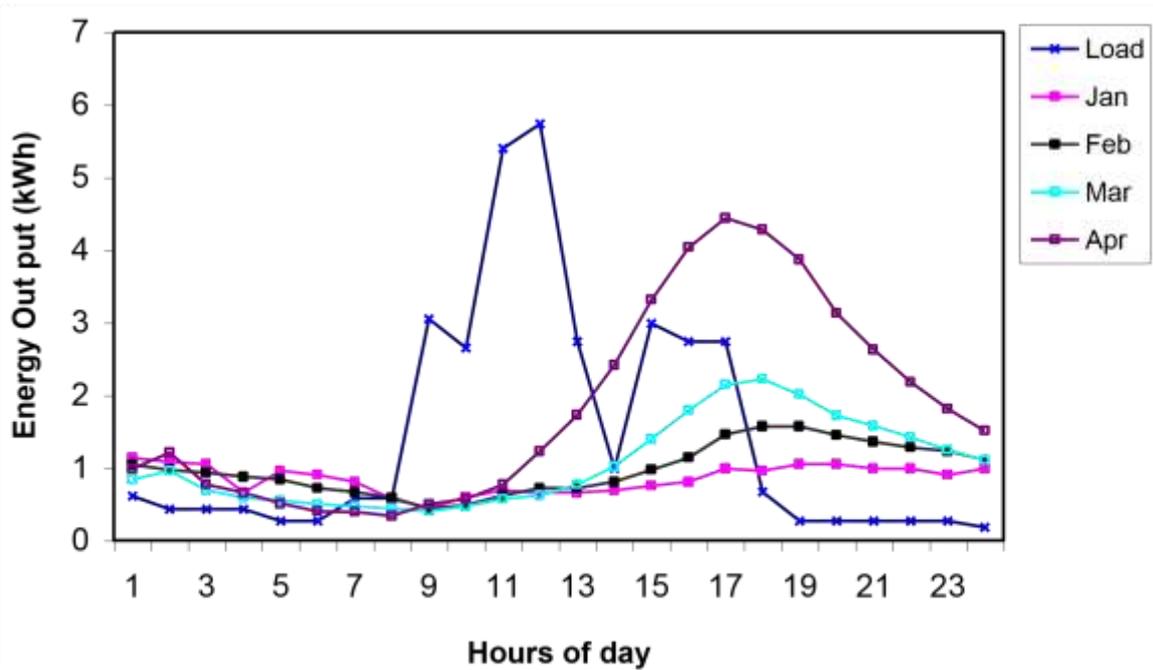


Figure 6: Hourly Energy generation During Jan-Apr

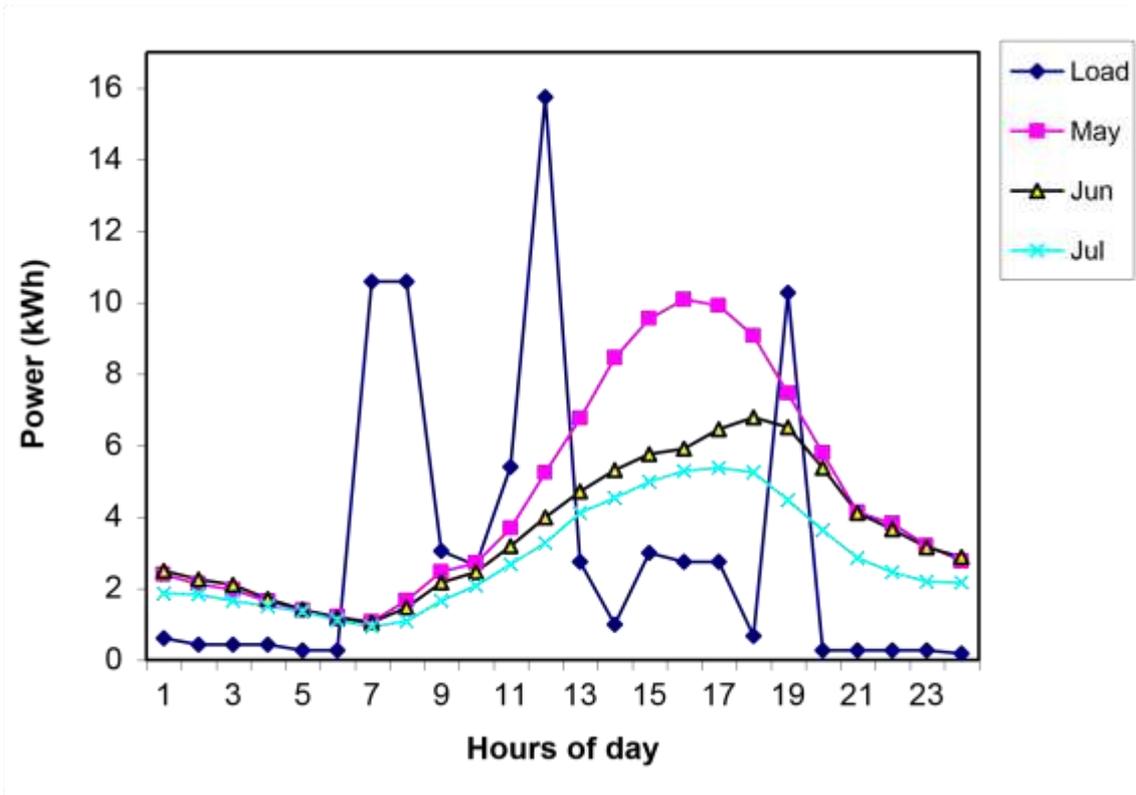


Fig. 7 - Hourly Energy generation During May-Jul

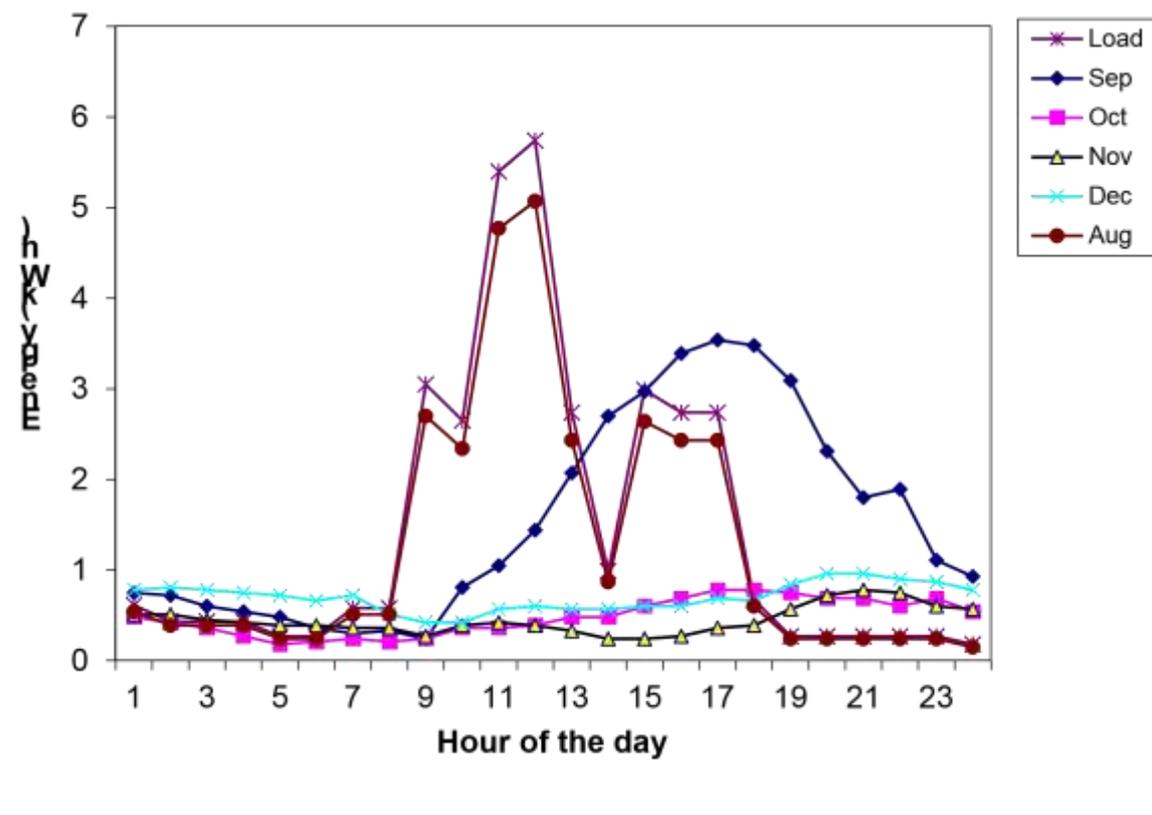


Fig. 8 - Hourly Energy generation During Aug-Dec

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