International Journal of Emerging Technology and Advanced Engineering

Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 277-282

An ISO 9001:2008 certified Int. Journal, ISSN 2250-2459, available online at www.ijetae.com

Pre-feasibility analysis of solar-wind hybrid system potential in a complex hilly terrain

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ABSTRACT

A renewable energy hybrid system, is one of the cost effective and reliable options for power supply in remote areas of India. In this paper, a prefeasibility study is carried out to assess the potential for solar-wind hybrid systems for Hamirpur town located in Western Himalayan state of Himachal Pradesh (31.68° N, 76.52° E). The one year time series solar and wind data is analyzed using HOMER software (Hybrid Optimization Model for Electric Renewable) to carry out the prefeasibility analysis. The solar radiation data analysis shows that more than 800 W/m^2 is available for 250 hours, 600 W/m^2 to 800 W/m^2 of radiation is available for 550 hours, 200 to 400 W/m^2 of radiation is available for 1000 hours and 100 to 200 W/m^2 radiation is available for 700 hours during the year with average annual solar radiation of 432.5 W/m^2 indicating a potential site for setting up of a solar photovoltaic power plant. The wind data analysis shows that wind speed wind speed duration of 3700 hours for 1-2 m/s, 3050 hours for 2-3 m/s, 950 hours for 3-4 m/s, 300 hours for 4-10 m/s wind speed ranges.. The wind speeds less than 1 m/s wind speed is available for 760 hours in a year. The annual average wind speed for this site is found to be 2.094 m/s. The wind speed duration analysis shows that there is sufficient wind availability for short durations which can be utilized through micro wind turbines. The micro wind turbines with a lower cut in speeds ~ 1.5- 2m/s will be suitable for small power generation. The results of the study indicate that there is good potential for utilizing solar-micro wind hybrid systems to supplement the energy needs in hilly regions.

Keywords: Hybrid energy system; Solar Photovoltaics; Wind energy; HOMER

1. INTRODUCTION

The increasing energy consumption and rising public awareness about environmental protection have resulted in interest in the utilization of renewable energy sources. The solar, wind and biomass are being utilized for power generation both on large as well as on small scale in India. However, a renewable power system based on a single source may not be effective in terms of cost, reliability and efficiency for which hybrid systems offer a better option. A hybrid energy system is a better solution for electrification of remote rural areas where grid extension is both difficult and uneconomical. The hybrid systems that combine solar and wind generating units with battery backup can attenuate their individual fluctuations and reduce energy storage requirements significantly by integrating two resources in a proper combination[1].

There are a number of parameters which affect the efficiencies and functioning of hybrid power generation system, the most important parameters are solar irradiance and wind speed .

In order to determine the dimensions of a wind-solar stand-alone system, the assessment of solar and wind potential of the site, is necessary [2] For the estimation of solar and wind potential, at least one year accurate meteorological data for a particular location is essential. The solar and wind resource information is generally available often in terms of monthly averages of daily global irradiation falling on horizontal surfaces or monthly average wind speed data without the proper resource availability duration for a typical meteorological year [3]. In order to carry out the analysis for setting up a solar-wind hybrid power plant, the solar radiation and wind speed potential of the site along with duration of resources is essential.

Presented at International Conference on Energy Resources and Technologies for Sustainable Development, 07-09 February 2013, Howrah, India.

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 277-282*

The present research work focuses on pre-feasibility analysis for developing a Solar-Wind hybrid power generation system, with one year time series data analyzed using Hybrid Optimization Model for Electric Renewable (HOMER) .[4-5]

2. METHODOLOGY

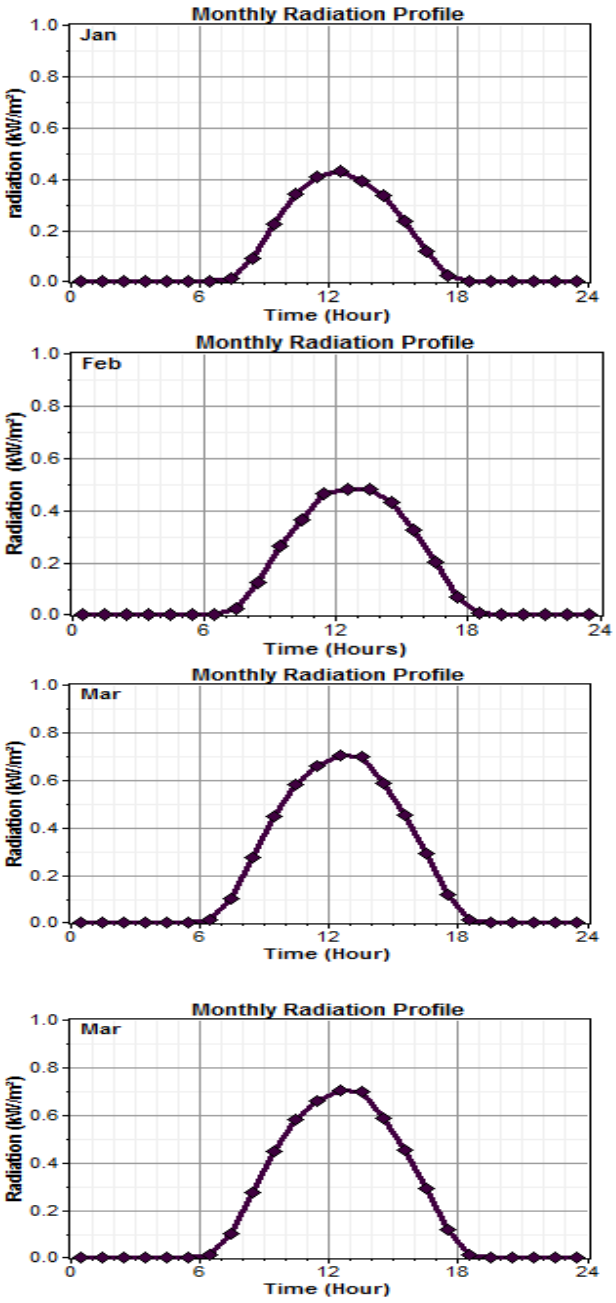
In order to determine, the wind and solar photovoltaic generation potential in the complex hilly terrain of Hamirpur, Himachal Pradesh, the solar radiation and wind speed for one typical meteorological year (Oct- 2011-September 2012) was measured using a Cambell automatic weather station equipped with anemometer, wind vane, pyranometer, rain fall, temperature, pressure, and relative humidity sensors. The data monitoring system stores data of solar radiation and wind speed every 1 minute of interval. The raw data are analyzed using HOMER software by importing time series data file. The monthly, yearly variation, duration curves for solar and wind characteristics, are studied. HOMER is a micro power optimization software used to evaluate designs of both off-grid and grid-connected power systems for a number of applications developed by Mistaya Engineering, Canada for the National Renewable Energy Laboratory (NREL) USA [6]. HOMER can simulate the operation of a system by making energy balance calculations and displays a list of configurations, sorted by net present cost that can be used to compare system design. Many tools are also available for sizing and simulation of a hybrid system but HOMER incorporates all the renewable as well as fossil fuel supply sources (eg: diesel generator).The HOMER inputs, solar radiation data and wind speed data loaded into program using a text file. After submitting solar radiation and wind speed data according to one minute of time step interval HOMER gives monthly and yearly variations.

3. RESULTS & DISCUSSION

The data analysis results are presented in the following sub-sections. It shows that the solar radiation varies almost in the same manner but wind speed varies more stochastically. These characteristics have a considerable effect on the proper sizing and successful operation of the hybrid system. The analysis of the measured monthly data for the period, indicates that the energy contribution from photovoltaic and wind generators, is expected to vary month wise.

3.1 Solar radiation characteristics

The measured global solar radiation is analyzed using HOMER software as an input text file of one minute time interval. Fig.1, shows monthly variation of solar radiation throughout a typical meteorological year.



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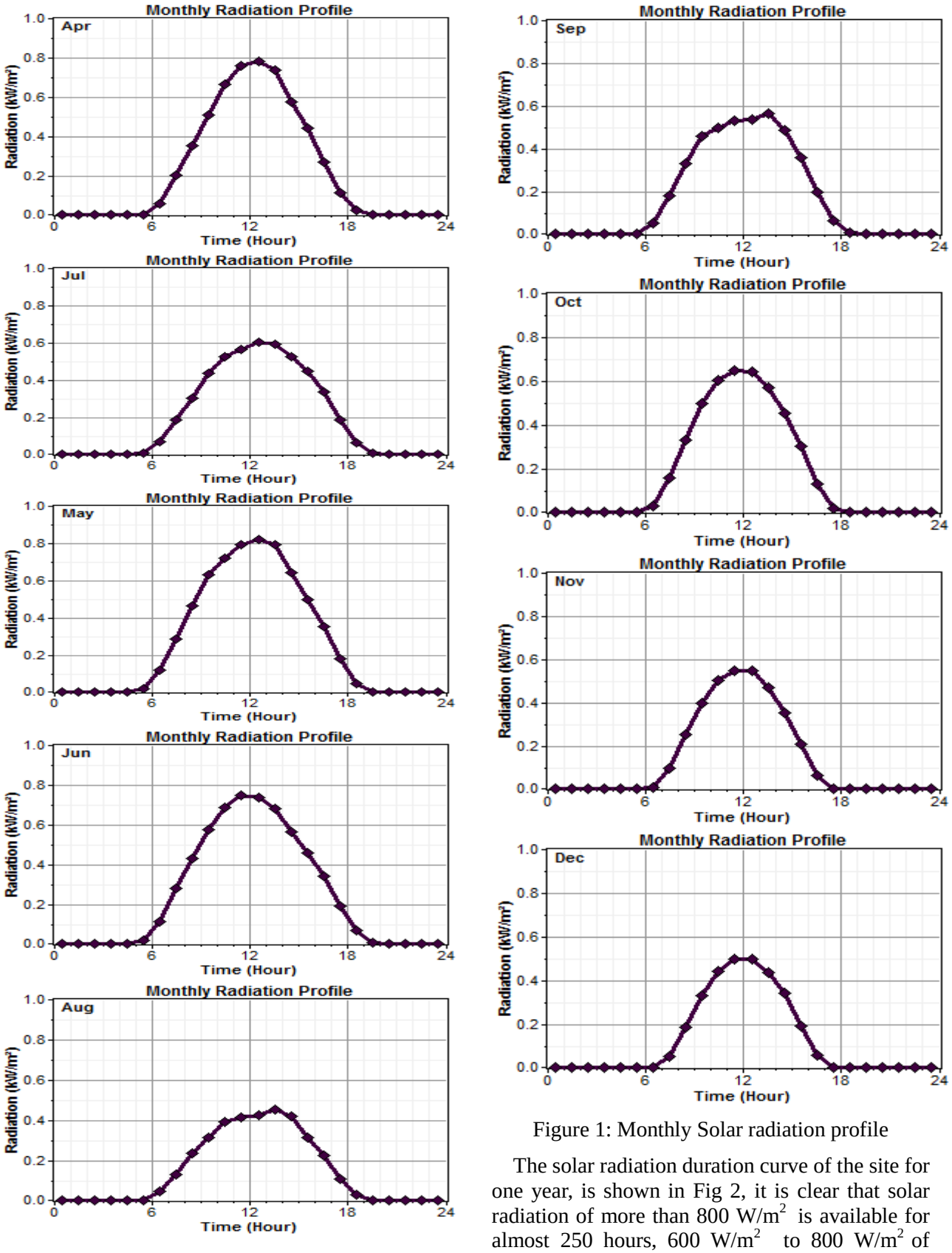

Figure 1: Monthly Solar radiation profile

The solar radiation duration curve of the site for one year, is shown in Fig 2, it is clear that solar radiation of more than 800 W/m^2 is available for almost 250 hours, 600 W/m^2 to 800 W/m^2 of radiation is available for 550 hours, 200 and 400 W/m^2 of radiation is available for 700 hours and 100 W/m^2 to 200 W/m^2 radiation is available for 1000 hours during the year.

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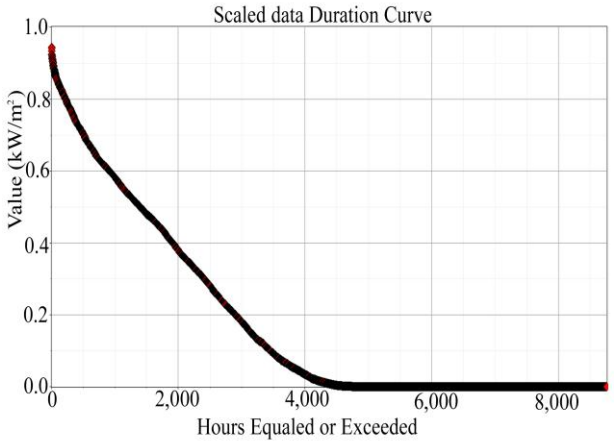


Figure 2: Global Solar radiation duration during a year

The annual variation of solar radiation shows that maximum radiation occurs during May and minimum in month of January with a yearly average radiation of 432.5 W/m^2 [Fig 3].

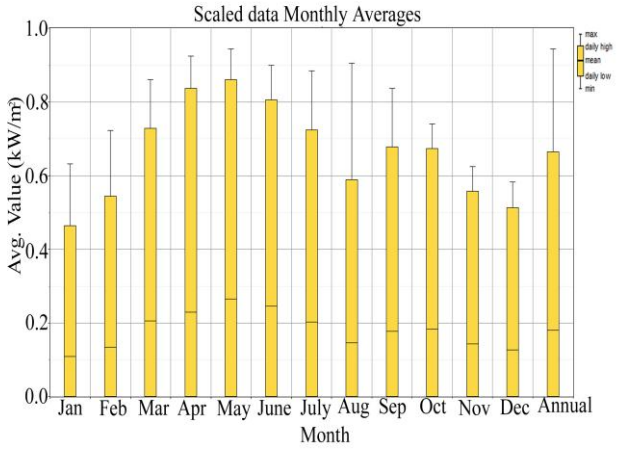
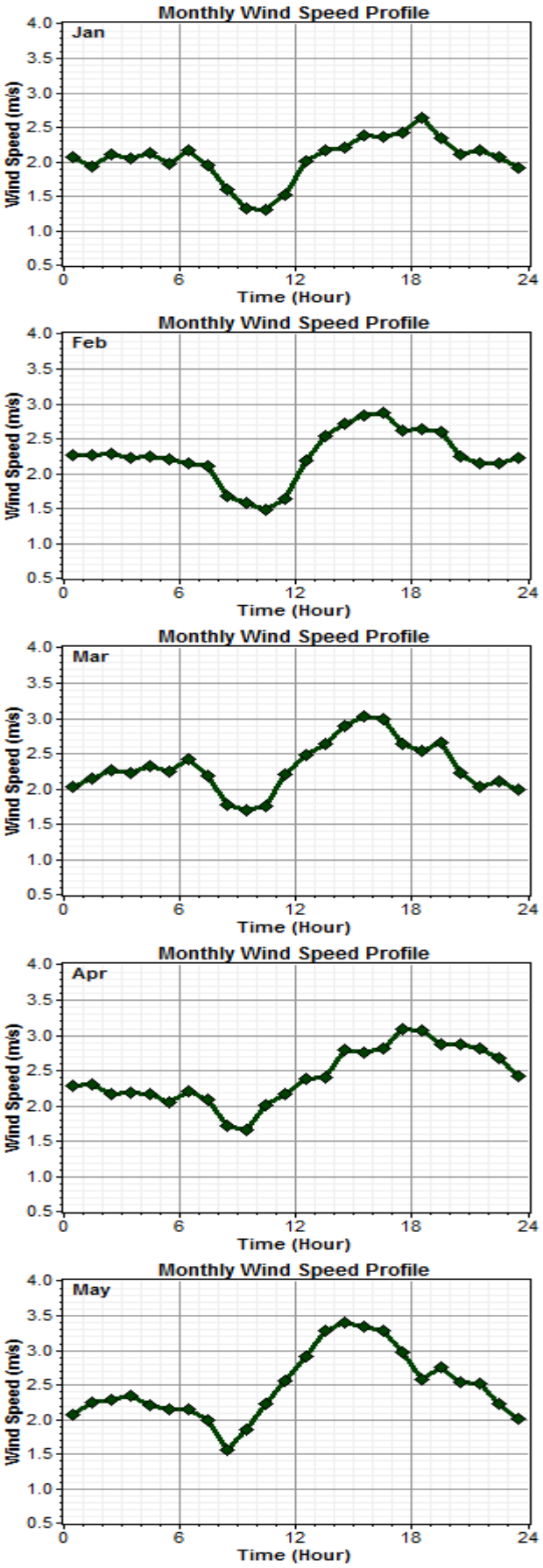


Figure 3: Monthly variations of Global Solar radiation

The results show that the location is a potentially good site for setting a solar photovoltaic power plant.

3.2 Wind speed characteristics

The monthly wind speed characteristics at the site are shown for each month in Fig 4.The general wind resource trend shows that there is a dip in wind speed between 6 am-12 noon and the wind speed increases after increase in speed during 12-18 hours.



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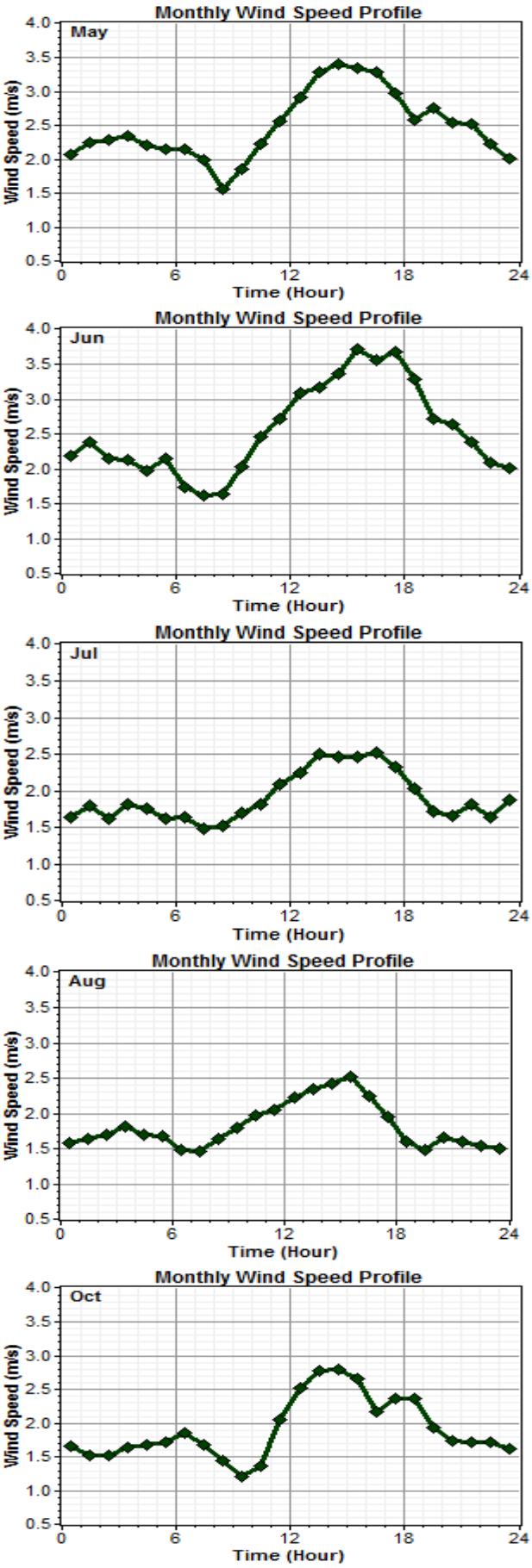

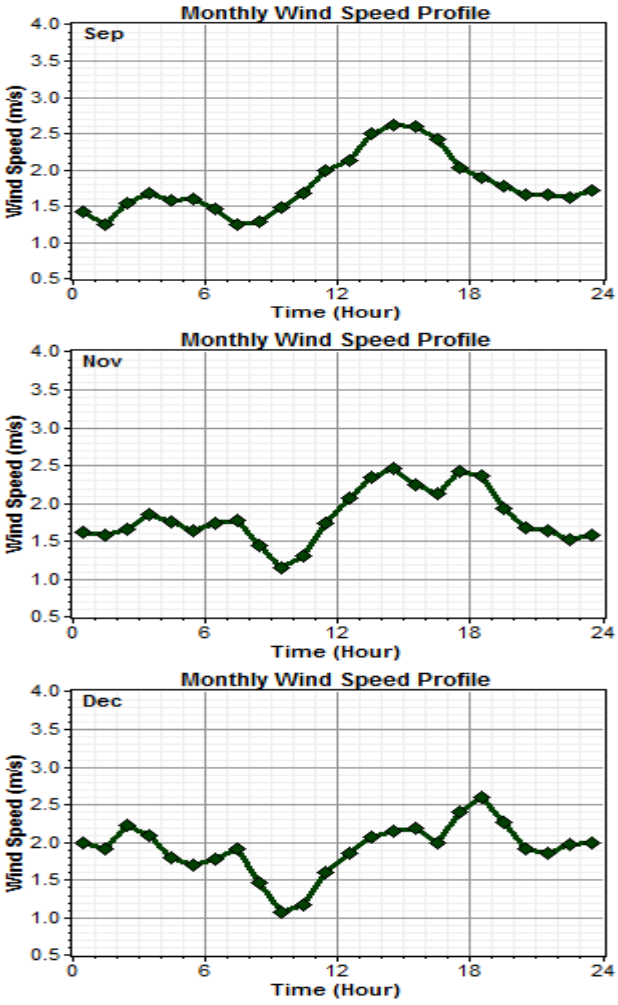

Figure4: Monthly variations of wind speed

Wind speed duration curve in Fig 5 shows that 1-2 m/s wind speed with a duration of 3700 hours yearly is most prevalent at the site. The 2-3 m/s wind speed has duration of 3050 hours and 3-4 m/s wind speed is prevalent for 950 hours and 4-10 m/s. is prevalent for 300 hours. The wind speeds less than 1 m/s wind speed are available during 760 hours in a year

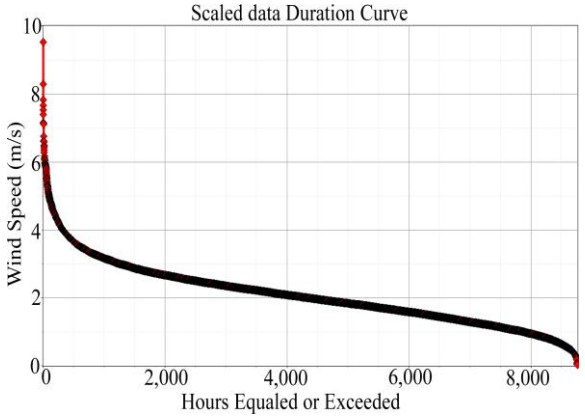

Figure 5: Annual wind speed duration profile

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The yearly variation of wind speed shows, that maximum wind speed occurs in month of May and minimum in month of January [Figure 6]. The analysis indicates that a micro wind turbine with a lower cut-in speed can be effective for small power generation.

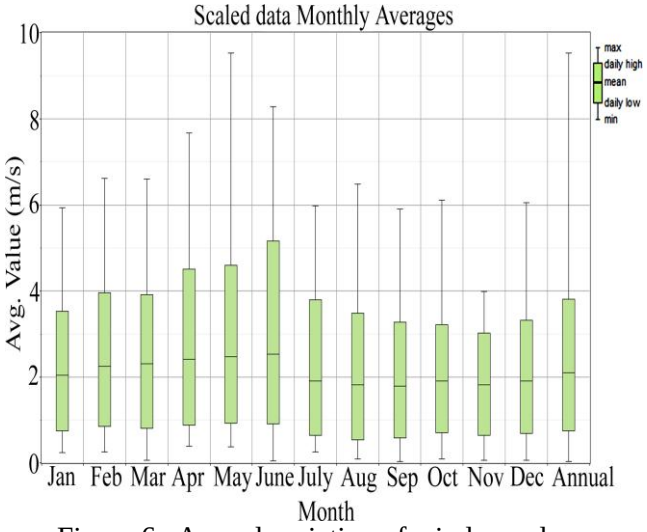

Figure 6: Annual variation of wind speed

4. CONCLUSION:

The solar and wind resource for the site in a complex hilly terrain is analyzed, to study the prefeasibility of establishing a solar-wind hybrid system. The site has an excellent solar resource potential for establishing solar PV plants. The wind speed characteristics of the region indicates a low wind speed zone with a low monthly wind speed averages of 2-3m/s. However, the wind speed duration analysis shows that there is sufficient wind availability for short durations which can be utilized through micro wind turbines. The micro wind turbines with a lower cut in speeds ~ 1.5- 2m/s will be suitable for small power generation. Our contention is that there is a sufficient unexploited wind resource available in the hilly region which needs to be utilized for small decentralized power generation and other applications like battery charging, oil extraction water pumping, grain grinding etc. The solar –micro wind hybrid systems will be effective and economical for these regions of India. The detailed analysis of the solar, wind resource of the hilly regions of India needs to be carried as these areas are neglected at present. Further follow up study on the feasibility of solar wind hybrid systems in hilly regions, is being carried out by the authors.

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