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Investigation of Small-Scale Wind Electricity Generation using Spline Interpolation Model

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ABSTRACT

The rapid increase in installed wind power across the globe requires a finest and comprehensive assessment of the potential to mitigate the intermittent effect of wind resources in electricity generation. To deal with this challenging issue, the cubic spline interpolation method is proposed in this study in a novel approach, for estimating the wind turbine power output across all the seasons of the year using the selected wind turbine power curve. The findings of the study revealed that sea breeze phenomenon and differential heating and cooling of land and water has not only a large effect on the formed winds in this region during the seasons but also on the wind energy availability. However, seasonal resource analysis was also introduced in testing the performance of the chosen wind turbine using a typical household electricity demand, and the results revealed that monsoon and summer equivalent seasons correspond to best periods for wind energy production at the studied site. Finally, it is concluded that the proposed method utilized in this study could be successfully used for assessing the wind power potential and identifying the viability of wind resources in electricity generation at any site of interest.

KEYWORDS: Renewable energy; Wind turbine; Typical household electricity demand; Electricity; Wind energy resources; Kasaragod; India

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1. INTRODUCTION

Utilization of fossil fuels in energy and energy-related activities is the major cause of global warming and climate change which are the top scientific and environmental issue of this century.[1, 2, 3]Greenhouse gases emission related energy use has already accounted for 90% of the global total greenhouse gas emission with heat and electricity generation responsible about 26% of the global energy-related greenhouse gas emission. It's estimated that about 16,000 people die annually because of global warming and climate change related issues, and about double of this number is expected by the year 2020, if fossil fuels remained the main source of energy across the globe.[4, 5, 6]The effects of global warming and climate change are already evident since previous centuries. Among the major evidence include extreme weather conditions (hurricanes, tsunami, extreme flooding), changes in precipitation and seasonal patterns, sea level rise and global average temperature rise across all the regions of the globe. The average global temperature rise is the effect of global concern as it is directly related to lower heat demand and higher cooling demand which is carbon as well as an energy-intensive process. [7]

Wind electricity technology is already identified as among the most promising technologies for the effective implementation of sustainable energy policies across the globe. Wind energy is becoming the fastest growing and most attractive renewable energy source among renewable electricity generation technologies. Wind electricity generation is realizing exponential growth in installed capacity due to the maturity of the technology, relatively low cost, effectiveness, and good infrastructures.[8,9,10]However, most of the development in wind poweris based on large scale wind power (i.e. wind farms). Large scale wind turbines are already pinpointed by the advocates across the globe for having environmental effects, insufficient production, and higher production cost. It is worth noting that, in the quest of utilising cleaner energy sources, all the pointed shortcomings of wind energy systems should not be enough reasons to avoid wind power penetration in the mix of electricity sources across the globe.

Like all other electricity generation sources, wind power is no exception in having rejection and agitations by the advocates across the globe. The major agitations that are hot in the current literature about wind turbines across the globe are mainly issues related to size, noise, issues related to flying animals and other wildlife.[11]To address these problems, huge developments in the shape, size, noise reduction are coupled in the design of micro wind turbines. In addition, because of the electricity transmission and distribution losses, small scale wind turbines are considerably gaining popularity in wind electricity generation across the globe especially with the development in electronic design, which has drastically reduced electronics power consumption to the extent that, one kilowatt is considered as typical daily household electricity consumption in the developing countries.[1,12,13,14]

Wind energy has witnessed tremendous development in India contributing 13.06% of the total installed capacity to the Indian national grid. Small scale wind turbines which can be located within the vicinity of our built environments, close to where the power is required, can contribute immensely in the India wind power sector. Unfortunately, massive penetration of wind generators in the traditional electric grids caused several side-effects, which determines the need for improving the robustness of system control and protection in addressing the intermittent nature of the wind power to the grid. To address this issue, huge improvement has been witness in recent time on the performance of small scale wind turbines which leads to steering their response in working effectively in low wind speeds and uneven wind directions, thereby, making them more competitive in serving the needs of the end-users and maintaining the standard of the grid.[15, 16,17]

At all scale of wind energy application (small, medium or large scale), finest wind potential studyisal ways required in establishing the viability of wind energy in electricity generation at any promising wind power site. Finest wind energy potential study is the first step in identifying the potential of wind resources in wind electricity generation at all time. In particular, optimum wind energy potential studies require the utilisation of long-term wind and other wind-related datasets, received at the particular site of interest where the WECs is planned to exist.[18]In this regard, critical analysis of wind potential of a location during yearly, monthly, seasons and other lower periods is required, and this is what most of the studies in the literature are sceptical to undergo, because of the time consumption. Several studies are conducted in the wind engineering field in the prediction of the wind power potential of sites of interest based on the available wind resources. An in-depthreview of the wind energy potential studies in the literature reveals the need for adopting more precise wind forecasting methods at all levels of potential investigations. This entails the utilisation of accurate methods for estimating the wind power density of a particular site of interest.[18]

Kavak and Akpiinar[19], analysed the wind energy potential of Manden-Elazig, Turkey using a five-year series of datasets. The findings of the study reveal that using the Weibull distribution method, the numerical values of the shape and scale parameters varied over wide range although the study was not able to provide diurnal analysis of the potential at the study site. Shata[20], studied the potential of wind power generation in south Egypt using two-year datasets and monthly Weibull parameters, standard deviation, and coefficient of variation. The modelling techniques utilised in the study was not able to address the gap in the diurnal potential analysis which is believed to furnish finest importations about the potential of renewable energy resources in electricity generation. Wais[21], performed wind power potential analysis of three locations using three-parameter Weibull distribution. The study revealed that the three-parameter Weibull distribution could effectively give better results compared with the two-parameter Weibull distribution. Anyway, it can be noticed that the Weibull distribution method can perform well in wind power estimation especially using probability approach which cannot give a clear picture of the potential at the diurnal level.

In particular, diurnal wind resources analysis is believed to be the simplest solution methodology that could be adopted to give a very clear picture of the volatility of wind resources in wind electricity generation. Hence, it can be said that a complete wind energy potential studies should always critically evaluate the potential at diurnal level of generation. To improve the wind potential estimation accuracy, several studies in the literature have successfully utilised different models in the assessment of wind power potential at diurnal level. In trying to address this issue, Maatalah et al.[22] analysed the wind power potential in the Gulf of Tunis, Tunisia using the statistical analysis method. The method successfully assessed the potential at the diurnal level and at different hub heights, although, a particular reference has not been made on the electricity demand dynamics. Diaf et al.[23] performed a potential and economic analysis of wind power at Adar in Algeria. The study confirms the well-proved effectiveness of the power curved fitting model in assessing the wind power potential of the studied site. Although the method adopted in the study allows the assessment of the potential at all level of generation including the diurnal analysis, unfortunately, demand dynamics is missing in the study.

In trying to address the intermittent effect of wind resources in electricity generation, any promising enabling methodology will never be complete if the diurnal analysis is missing. Although the application of some methodologies has been tested on several case studies, curve fitting models are among the most promising methods in diurnal wind power potential analysis. The diurnal analysis method allows the estimation of the power output from WECs based on the power curve made available by the WECs manufacturers. Although these methods are not fully developed in the literature, in most of the studies utilising these models, significant success in the estimation of power potential from the selected WECs has been achieved.[23, 24, 25]

This paper intends to fill the gap in wind energy potential studies by proposing a novel approach using a spline interpolation method, to estimate the wind energy potential in the coastal region of Malabar, Kerala, India. The main idea is to provide robust and finest analysis of the wind energy potential in electricity generation at the selected site. To the best of our knowledge, Even the government agencies that are responsible for the identification of renewable energy potentials of the districts of Kerala such as, The Agency for Non-conventional Energy and Rural Technology (ANERT), the State Nodal Agency responsible for implementing renewable energy programmes in the state hasn’t performed any previous study in the Kasaragod region of Malabar, Kerala.

The structure of the paper is organized as follows: in Section 1 of the article, the related background information on the needs and methods of evaluating wind energy potential based on the existing studies in the literature is presented. Section 2 describes the study site, the data used for the modelling and analysis of wind characteristics. The methods utilised in the wind power output estimations based on the selected WECs. Section 3 elaborates on the obtained results.Section 4 states the conclusions of the article.

2. MATERIALS AND METHODS

2.1 S*ite Description*

The Central University of Kerala is located in Periye, a town near Kasaragod city, the district headquarters of Kasaragod, Malabar region of Kerala, India. The Central University of Kerala is situated within the Latitude of 12° 39' 13" N and Longitude: 75° 09' 77" E. The universityis located in the rich biodiversity of Western Ghats, sharing a border with the Arabian Sea by the west as shown in Fig. 1. The entire Kasaragod district being a coastal location is experiencing a tropical monsoon climate under the Köppen climate classification.

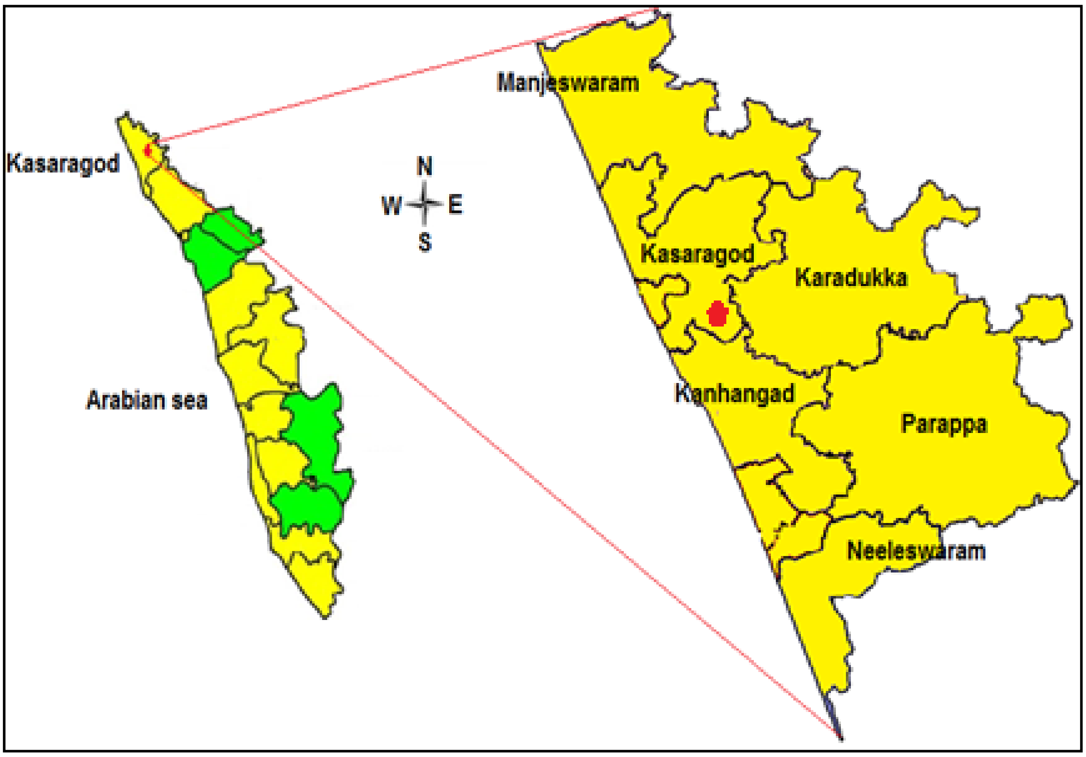


Fig 1. Geographic localization of Central University of Kerala, Periye, Kasaragod[26]

Malabar region of Kerala is endowed with abundant renewable energy resources. However, despite the abundant renewable energy resources, Kasaragod district is faced with an acute shortage of electricity. Due to the acute shortage of electricity far below the standard, the per capita electricity consumption of the district is 292units against 477units state average, with 778.63unitsof the national average. This acute shortage of electricity is the harsh reality leading to the overall backwardness of the district at large.[27]In the absence of any potential studies at the study site, there is a need for proper analysis of the wind resources at the site, to identify the viability of utilising wind power technology for the development of the district at large.

2.2 Meteorological Data

2.2.1 Wind speed data

Meteorological datasets play a very vital role in renewable energy potential studies sincethe power generation depends entirely on its availability. Wind speed, is characterised by high natural temporal variability because of direct dependence on climatic conditions.[1, 28]This fluctuating nature, is the major challenge of wind energy in electricity generation since the variation may not match the electricity demand on a continuous basis, and since renewable energy production and electricity demand are extremely variable changing on hourly, daily, as well as seasonal time scales depending on the region.[29, 30, 31]

In the absence of any responsible agency for weather monitoring and forecasting at the study site, the simplest solution methodology that could be adopted to achieve the objectives of this research is the adoption of satellite data measurements. The wind speed datasets utilised in this study were measured and recorded at 10m height above the ground with a resolution of 2x2km. Starting with the datasets, the ten (10) years (2006-2016) extracted hourly wind speed data obtained from PVGIS5 was subjected to a thorough analysis for conversion to one-year data having at least 100% of valid data. However, to study the seasonal behaviour of the wind resources at the site, the converted one-year datasets was grouped into seasons of the year: Winter (December, January, February), summer (March, April, May), monsoon (June, July, August, September) and post-monsoon (October, November) using Matlab Simulink data extraction script. Excel spreadsheets, Matlab Simulink, Origin and Oriana software's are employed at different points of the data processing and analysis.

2.2.2 Wind speed data adjustment

Wind speed at hub height is of special interest because a small increase in wind speed means a great increase in power output due to the cubic relation between wind speed and wind power output (Eq. 1). However, in most cases, wind speed measurements are recorded at a height much lower than the wind turbine hub height.

Wind speed increases logarithmically with height above the ground level. To address this natural issue, several models have been developed across the literature for extrapolating wind speed from the reference height to the required hub height. Though, power law (Eq. 2), is the common model adopted by several studies among which includesKhahro et al.[32], Ong'ayo et al.[33], Blumsac and Kerlsey[34], Mohammad et al.[35], Hailemariam et al.[36], González-Aparicio et al.[37]despite having several limitations and uncertainties that can sensibly compromise the results of a particular study. To improve the accuracy of estimating wind speed at hub height, more sophisticated models are required. To address these limitations and uncertainties, the Millward-Hopkins model (Eq. 3), is adopted in this study to extrapolate the reference wind speed from 10m height to 25m, the hub height chosen in this study. Millward-Hopkins modelling approach allows improving the modelling accuracy because it is integrated with all the terms in power law (Eq. 2), and it takes accounts of several boundary layer terms. This makes it on average a more realistic model compared to other models designed for this application.[1,38,39,40,41.]

$$P = \tfrac{1}{2}\rho\eta C_p A V^3 \qquad (1)$$

Where, ρ = density of air (kg/m^3), V = wind speed (m/s), C_p = Coefficient of Performance

η = gearbox efficiency and generator efficiency A = area of the wind turbine blades (m^2)

$$V = V_0\left(Z/Z_0\right)^{\alpha} \qquad (2)$$

Where, V= Wind speed at hub height Z in m/s, V_0 = Wind speed at reference height Z_0,

α= Wind shear exponent coefficient which varies from site to site.

$$V_{hub} = V_{ref}\frac{\ln\left(Z_{hub}/Z_{0-ref}\right)}{\ln\left(10/Z_{0-ref}\right)} \qquad (3)$$

Where, V_{hub}=Wind Speed at hub height (25m), V_{ref}= Wind Speed at reference height (10m), Z_{hub}= Reference height and Z_{0-ref} = Reference height roughness length(0.14m adopted in our calculations)

2.2.3 Wind speed data modelling

According to the standards, five-years datasets measurement at any promising site is sufficient to predict the long-term behaviour of wind speed.[41]The ten years (2006-2016) data utilised in this study, consist of several meteorological parameters in the form of metadata. Matlab Simulink script is designed and used in extracting the wind speed, as well as, sorting of the extracted data. The first step of the data analysis in this study is the conversion of the sorted wind speed data from 10m to 25m which is the hub height considered for the modelling. The next step is sorting and scaling the adjusted data to months of the year. The adjusted wind speed data is subsequently converted to a typical day across the seasons of the year (summer, winter, monsoon, and post-monsoon). Theapplication of interaction scripts for data extraction has been developed and utilised in several studies across all research areas in global scientific studies.[42, 43, 44, 45, 46, 47, 48]

2.3 Wind energy output modelling

Many models are available in the literature for estimating energy output from Wind Energy Conversion Systems (WECS). To estimate the electrical power of a wind generator based on the wind resources of the site, techniques such as Gamma, Lognormal, three parameter Beta, Rayleigh and Weibull distributions, are successfully been used by different studies in this regard. Although the application of these methodologies has been tested on several case studies, their deployment in the finest diurnal wind resources potential analysis is still not established in the literature.

Cubic spline interpolation technique is applied to Futurenergy 1kW wind turbine power curve values, to estimate the power output from the wind generator system based on the available wind speed values. Cubic spline interpolation method involves estimation of the wind turbine power output through interpolation of the data values in the turbine power curve as proposed by.[49, 50]MATLAB Simulink is used in this study in identifying the best polynomials for the spline. Though the proposed model in this study is applied to small scale wind turbines, the method can be scaled to any other WECs to predict the power output base on the power curve of the wind generator.

The analysis of the total energy is introduced in this study. The total estimated seasonal power output from the chosen wind turbine is computed using Eq. 4, based on the hourly wind speeds scaled to 25m hub height.

$$E_{total} = \sum P(v)t \qquad (4)$$

Where $P(v)$= estimated power output at wind speed v.t = total number of hours

3. RESULTS AND DISCUSSION

3.1 Monthly hourly mean wind speed modelling

Wind speed is characterised by high natural temporal variability because of its direct dependence on climatic conditions. This fluctuating nature is the major challenge of wind energy in electricity generation. To understand the potential of wind resources for electricity generation, a clear analysis of the variation at all levels is required. To address this issue, the first step is the finest potential studies which can be done by employing the accurate estimation models at the level of generation.

The overview of the mean monthly wind speed and the corresponding wind turbine power output at 25m (adjusted from 10m reference height) across Central University of Kerala, Periye, Kasaragod is depicted in Fig 2. The analysis of the monthly wind speed values at 25m demonstrates that the wind values remarkably differ from one month to another across all the months of the year. Although, it can notice that, the highest wind speed is observed in the month of June against the lowest value recorded in the month of November.The direct correlation observed on the turbine output and wind speed values distinctively portray the success of the adopted cubic spline interpolation method in estimating the wind power output from the selected WECs. It is obvious that the performance of the cubic spline interpolation method adopted in estimating the power output is promising in this application. Although many enabling interpolation methodologiesareexplored in the literature based on power curve estimation techniques, cubic spline interpolation is often preferred because the interpolation error can be made small even when using low degree polynomials for the spline. It should be noted that the results observed in this section show clearly the performance of the proposed model in estimating the wind power potential. This is because it is accepted by a clear analysis of the wind data and energy values predicted using this method are respectively the same with the values made available on the selected wind turbine power curve.

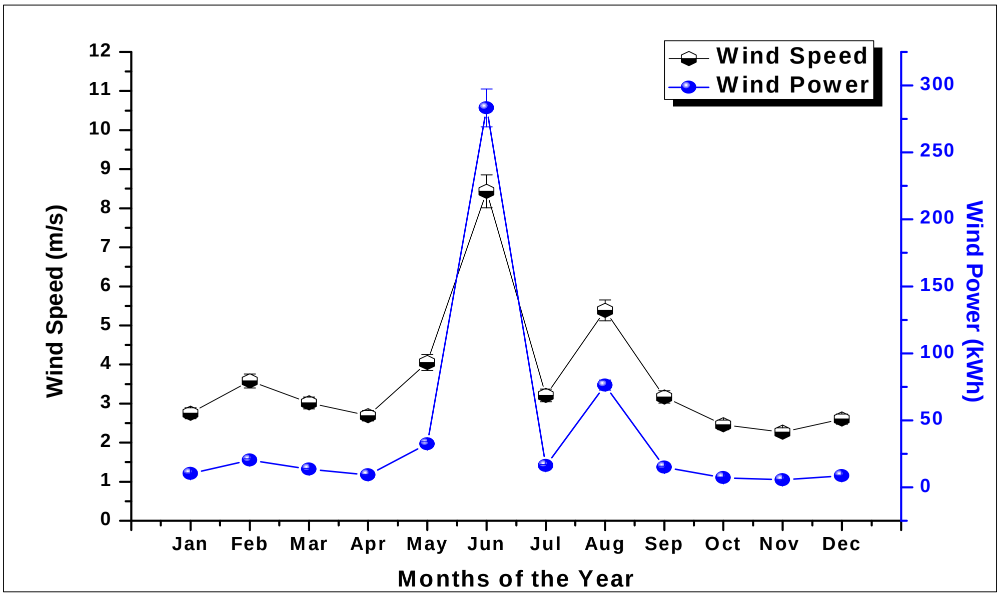
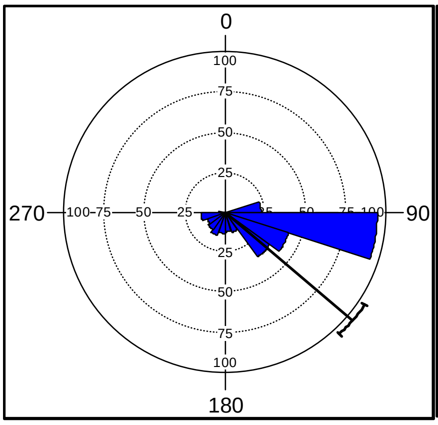


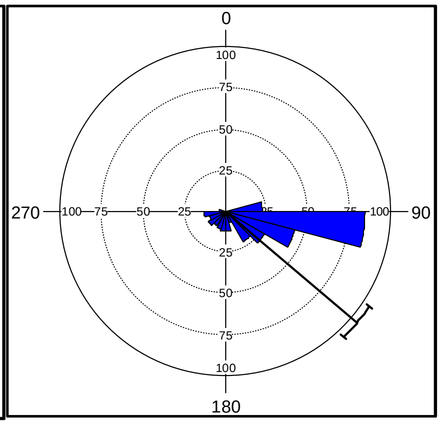
Fig 2. Monthly mean wind speed and mean power density for Central University of Kerala, Periye, Kasaragod (2006-2016)

Although one can argue that the proposed hub height (25m) suggested in this study is too high, but the justification of proposing the hub height lies on the proper analysis of the wind speed values for ten years (2006-2016) and the knowledge of the cut-in and cut-out wind speeds of the selected wind generator. Based on the specifications, so much as the long-time data of the study site is within the range of the selected wind turbine, and there are stable weather conditions at the site of interest, there will be no issue on selecting hub height within the turbine specifications.

3.2 Wind direction analysis

Wind direction analysis is very significant in any finest wind resources potential studies in electricity generation because it plays an optimal role in positioning the wind turbine at a given site. In most cases, the wind rose technique is the common approach usually adopted in presenting the distribution pattern of the wind direction of a processed wind speed data, over time-series. The wind rose diagram shows the magnitude of occurrence of the number of times which wind remained in particular wind direction in degrees from 0^{o} to 360^{o} clockwise.





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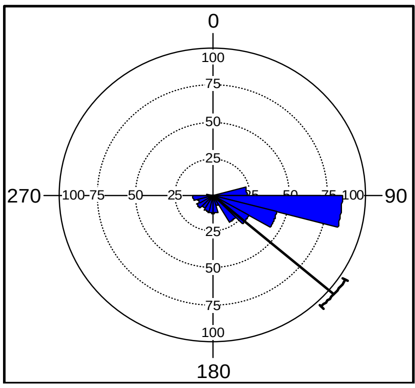

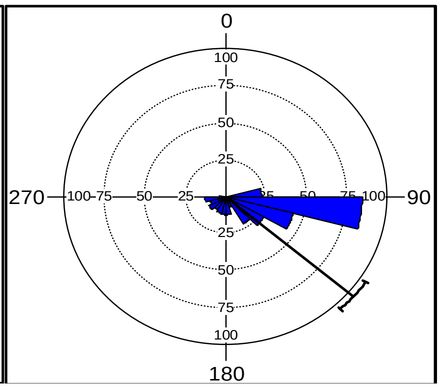

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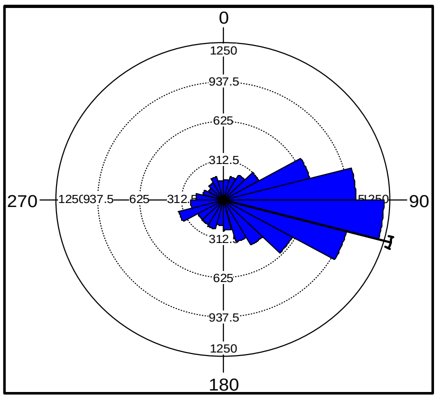

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Fig. 3. The wind rose diagram for the study period: a) winter; b) summer; c) monsoon; d) post monsoon; e) wind rose diagram for a typical year across the seasons

The analysis of the wind direction of the study site,using Oriana software for the period of (2006-2016) is depicted in Fig. 3.The uniform, wind direction observed is very advantageous to the study site because electricity loss associated with the change of direction of the wind in electricity generation can be very negligible. It is very important to note that, Easterly wind that dominated the wind flow of the study site, clearly indicates sea breeze, as an important factor in a location's prevailing wind, especially the coastal location. The wind rose generated for all the seasons of the year, revealed that the predominant wind direction at the site is ESE (East South East) direction which is revealing, stable weather conditions at the study site.

3.3Seasonal wind speed and power output modelling

A significant analysis of the seasonal wind resources at the site of interest is very useful in understanding the prospects of wind resources in electricity generation. The seasonal hourly wind speed trends generated from the scaled wind speed data (10m to 25m) are depicted in Fig. 4. The purpose of calculating the seasonal potential in each of the seasons based on the Köppen climate classification is to give a clear and finest analysis of the potential across all the seasons. Due to the topography, orientation and surrounding nature of the site, summer monsoonal flow has dominated the wind speeds of the study site. This helped in raising the wind speeds in monsoon and summer equivalent seasons in comparison to other seasons of the year. In addition, the points that have been considered based on the results is the importance of sea breeze phenomena. Sea breeze phenomena might have resulted in the high wind speed values as a result of the position of the study site in relation to the Arabian Sea.

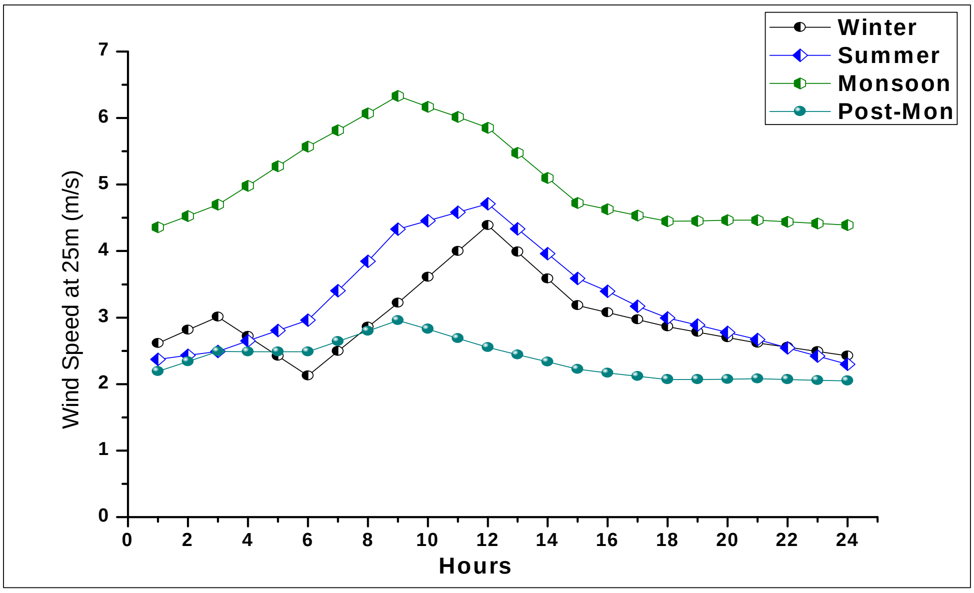


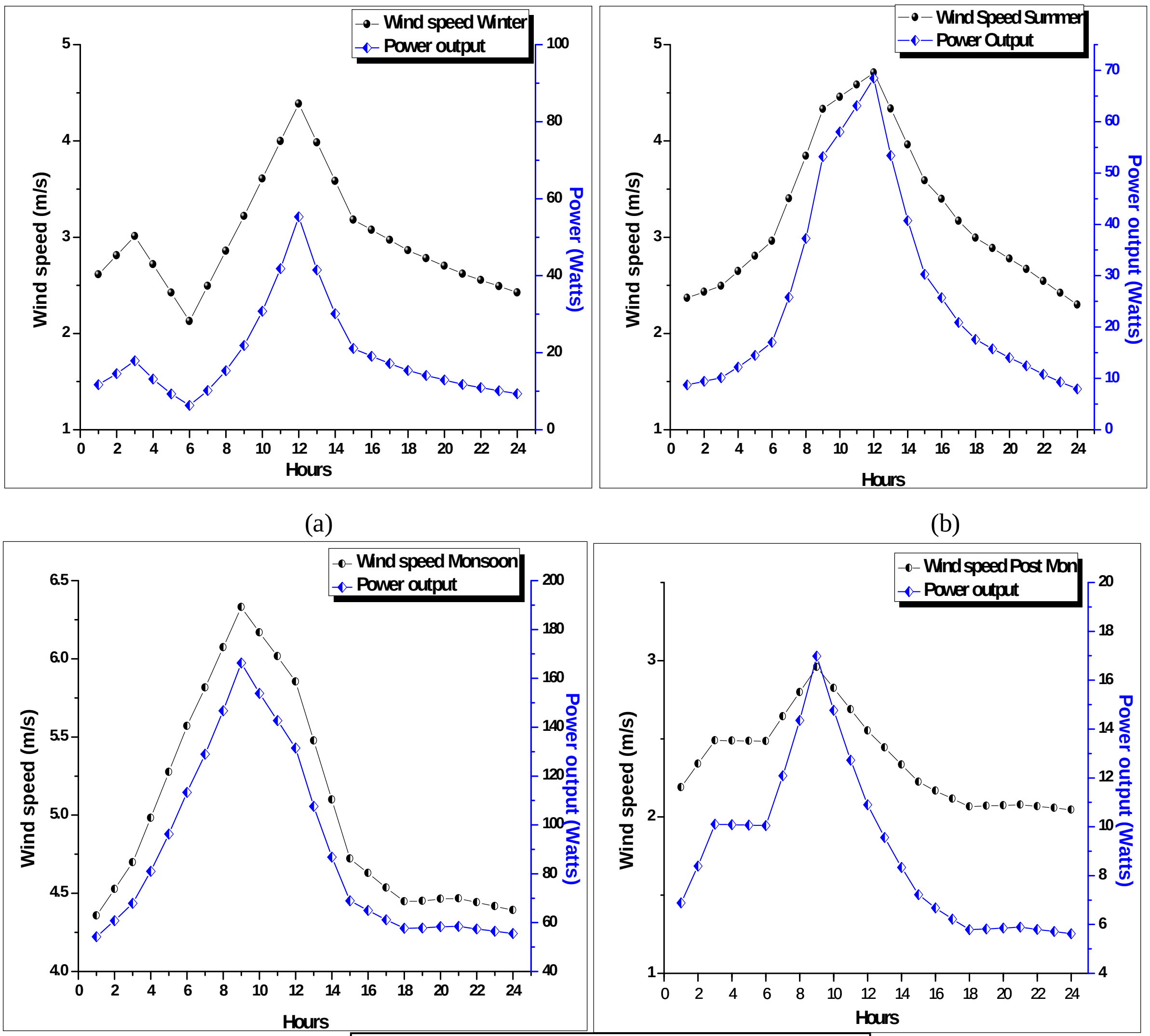
Fig. 4. Diurnal variation of wind speed at 25m

Generally, the wind resources across this region of Malabarshows a clear pattern of higher wind speeds during the sunshine hourswhen compared with night hours. This is not a complex issue, because the higher wind speed during the peak sunshine hours can be as a result of uneven heating of the earth by the sun. This heating causes buoyancy that is leading to circulation and movement of air parcels from the region of higher pressure to the region of the lower pressure of the earth. This is the driving factor for wind energy formation showing that wind energy depends heavily on solar radiation as supported by several studies conducted in the literature.[1, 51, 52, 53, 54]

The analysis of the wind speed data of the study site at 10m height revealed annual mean wind speed reaching 2.82ms^{-1} and it varies from 0.15ms^{-1} to 7.75ms^{-1}. Moreover, the performance of the proposed model in this study in scaling the wind speed data from 10m (reference height) to 25m hub height can easily be detected from the obtained results. The justification for employing the proposed model Eq. 3 lies on the several limitations associated with a power law. The limitations include the variation of the ground surface friction coefficient (α) with height above the ground level, time of the day, season of the year, nature of the terrain, temperature and wind speed across the site of interest.

Observation of the results in Fig. 5, on the generated values of wind power output values by the proposed spline interpolation model, shows that there is no reduction on the power rating of the wind generator at all level of wind speed. This means the model is incongruent with the original values in the turbine power curve. This can be observed on the overview of the diurnal wind resources and corresponding wind turbine performance estimated at 25m hub height, across the seasons. Despite the low cut-in wind speed of the selected wind generator, one can observe that the highest number of hours without generation from the selected wind generator are noted in the post-monsoon and winter seasons. It is also clear that monsoon and summer seasons correspond to the best periods for wind energy production. The results clearly revealed that using the proposed model in this study, the overall performance of any WECs can be established.

Although many models have been proposed in several wind energy potential studies, the proposed model adopted in this study is a promising enabling methodology that can allow the finest wind resources analysis any site of interest. This can be justified by considering the fact that, most of the promising methodologies recently explored in the literature are based on probabilistic-based techniques (mainly Weibull distribution method) in exploring the wind potential at the site of interest. Unfortunately, probabilistic-based techniques are usually restricted to a monthly analysis of the potential and as such, the effectiveness of their application in potential studies needs to be comprehensively assessed.



(c) (d)

Winter: Dec, Jan, Feb **Summer:** Mar, Apr, May

Monsoon: Jun, Jul, Aug, Sep **Post monsoon:** Oct, Nov

Fig. 5. Diurnal variation of wind speed and corresponding turbine performance across the seasons of the year in Central University of Kerala, Periye, Kasaragod (2006-2016): a) Winter; b) Summer; c) Monsoon; d) Post Monsoon

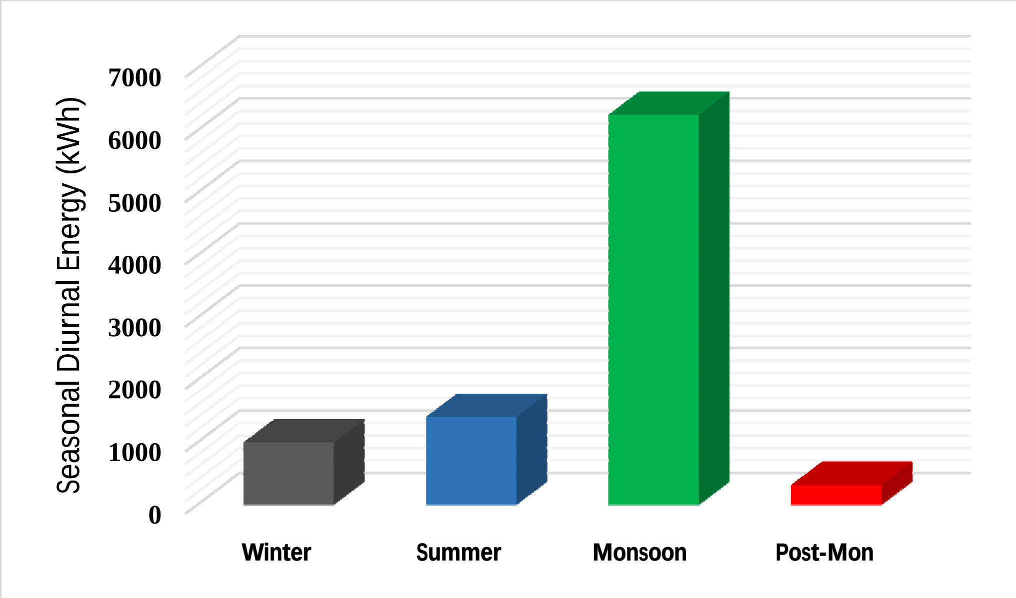


Fig. 6. Total seasonal energy generation

3.4Wind system performance modelling

Because of the intermittent nature of renewable energy sources in electricity generation, the hourly electricity demand profile is mostly having a preference in renewable energy potential studies. More specifically, in order to address the intermittent effect of wind power, a reference to the diurnal electricity demand of the end user is always required. Unfortunately, the hourly electricity demand profile is difficult in many cases, especially in highly traditional and erratic electricity dependent locations of the globe. For a proper benchmark test of the performance of the adopted model on the selected WECs, Photovoltaic Geographical Information System (PVGIS) typical household electricity demand profile is adopted. The electricity demand profile is based on the energy consumption of all the electrical equipment connected to a typical household during 24-hours of the day. The load profile assumes that the daily consumption is distributed in a way over the hours of the day, with most of the consumption during evening hours.[13]

Starting with the electricity demand data, the performance of the WECs at 25m hub height is evaluated across the seasons of the year as depicted in Fig. 7. The obtained results show the significance of the insolation reaching the earth surface on the wind resources of a location. As initially seen on this figure, sunshine hours are dominantly characterised with higher power output from the WEC system across all the seasons of the year. Such higher values are caused by the higher wind speed values which are generated as a result of the uneven heating of the earth by the insolation from the sun. Generally, during the noon hours the insolation heating, the atmosphere is strongest and hence it leads to the destabilisation of the atmosphere. This heating from the sun leads to the breaking of the inversion that's built in the atmosphere during the non-sunshine hours of the day.

Furthermore, by considering the nature of the trends, one can see thatsea breeze phenomenon has not only a large effect on the formed winds in this region during the summer season but also on the wind energy availability.

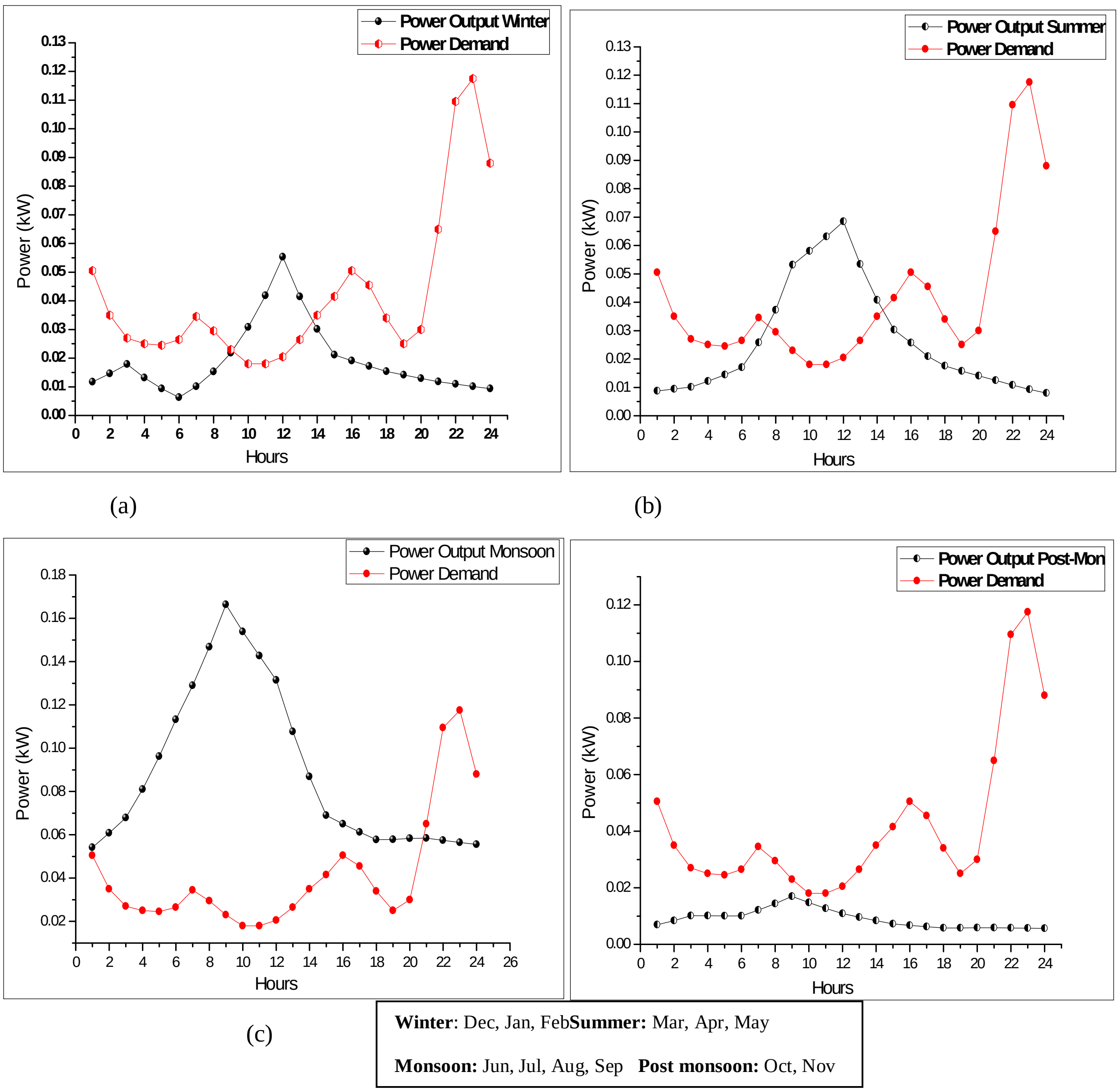


Fig. 7. Wind turbine performance at 25m against typical household electricity demand a) winter; b) summer; c) monsoon; d) post monsoon

The results also show that higher power output is observable across all the seasons of the year during the sunshine hours which results in the stable operation of the WECs. This results in the higher power output from the WECs exceeding the electricity demand except in the post-monsoon season. In addition, one can observe that, due to lower wind speeds during the morning and night hours, the system is unable to satisfy the demand because of the presence of an inversion in the atmosphere. Generally, in the presence of an inversion in the atmosphere during non-sunshine hours, the stable layer of cool air blowing in the atmosphere literally prevents the wind to move higher up in the atmosphere because the lowest part of the atmosphere is cooler than the air aloft. As it is shown in this figure, the insufficiency of the system in supplying the typical household electricity demand during those hours indicates the need for coupling storage options in the system design. Finally, the obtained results confirmed the effectiveness and novelty of the proposed method in providing the finest diurnal modelling performance of all types of wind turbines. One can also see the novelty of this study in furnishing comprehensive wind potential at the study site using long term wind speed datasets scaled to typical day across the seasons of the year.

4 CONCLUSION

To deal with the major issues of intermittent nature of wind resources in electricity generation, this paper adopted a cubic spline interpolation method based on the wind turbine power curve, in modelling the performance of micro wind generatorfortypical household electricity application across the seasons of the year. This study introduced utilisation of wind turbines at higher hub heights beyond the anticipations, because of proper analysis of the resources. Although it can argue that, the proposed hub height suggested in the study is too high, but it was proposed based on proper analysis of the wind speed values for ten years (2006-2016), which revealed stable weather conditions and wind speed values that fall within the cut-in and cut-out wind speeds of the selected wind generator. It is important to note that, this has not been highlighted in the wind literature. The results revealed that monsoon and summer seasons correspond to the best periods for wind energy production because of sea breeze phenomenon and differential heating, which has not only a large effect on the formed winds in this region during the seasons but also on the wind energy availability. The main conclusions drawn from this study are that the proposed model is a highly adaptive and novel approach that can be utilised explicitly in the evaluation of wind energy resources at the potential planning sitesof wind power around the world. The novelty of this method lies on its ability in taking account of all the major issues that the traditional wind assessment methods were not able to address, especially the diurnal potential analysis. This feature of the proposed method is particularly useful in accurate estimation of wind potential and identifying the viability of the wind resources in electricity generation at any site of interest. In the future, the research will look into real-time results validation in order to build more reasonable evidence under real case studies.

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