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Potential of Wind and Solar Energy using Weibull and Hargreaves Method Analysis

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***Abstract*—This paper presents an analysis of wind speed characteristics and solar radiation received in Perlis, Northern of Peninsular Malaysia. The characteristic of wind and solar is recorded per hour for a month using Davis Vantage Pro2 Weather Station. Recorded data is analyze using Wiebull distribution function and Hargreaves method for wind and solar respectively. The analysis through Davis Vantage Pro2 Weather Station is then used to compare wind and solar data collected from Chuping station, Malaysian Meteorological Department. From overall of this work, the authors found that the potential of wind and solar energy through out Weibull and Hargreaves method is successfully analyzes.**

***Index Terms*—Wind, Solar, Weibull, Hargreaves.**

I. Introduction

ENERGY from wind is derived largely from solar radiation. Motion of the air mass in the atmosphere is caused by solar insolation and is reproduced as jet streams. These affect the ground speed of high flying jet aeroplanes. The disturbance of atmospheric air is reproduced at ground level as wind. Like solar energy, the wind energy is free, environmentally clean and is infinitely renewable. There is no pollution and no direct use of fossil fuels in the energy gathering process. Unlike solar energy, the wind availability is not cyclic and diurnal but intermittent, unpredictable and is not limited to daylight hours [1].

Solar energy in one form or another is the source of nearly all energy on the earth. Solar radiation can be converted into electrical energy directly, without any intermediate process by the use of solar photovoltaic (PV) cells. Photovoltaic generation of power is caused by radiation that separate positive and negative charge carriers in absorbing material. In the presence of an electric field, these charges can produce a current for use in an external circuit [2].

The movement of air masses in the atmosphere is perceived as wind and has various causes. The first and most important of these is the heating of the earth by the sun. Wind energy utilization is, therefore, an indirect form of solar energy utilization. The radiation from the sun is absorbed by the earth's surface and then returned to the atmosphere above. Since the earth's surface is not homogeneous, the absorption of the solar energy varies both with respect to geographic distribution and with respect to the time of the day and the annual distribution. This non-uniform heat absorption produces great differences in the atmosphere with respect to temperature, density and pressure so that the resultant forces will move the air masses from place to another [3].

Several publications have been proposed in using Weibull and Hargreaves method or equations in determine the wind speed and solar radiation [4-8]. The main purpose of this paper is to examine the potential of wind and solar energy in Perlis through out this method. The main parameter applied in the equations is collected and recorded using Davis Vantage Pro2 Weather Station. This weather station is successfully installed at Electrical Energy and Industrial Electronic (EEIES) Research Cluster located at Kangar, Perlis. The purpose of weather station installations is to improve the study in assessment of wind and solar energy especially in northern area of Peninsular Malaysia. Even though the weather station only installed about 2 month but through Weibull and Hargreaves method can support the data with mathematical analysis.

II. Analysis Methods

Both wind and solar are related to each other. The combination of this two source energy is a perfect match as electricity generation. Since the solar energy is only available during day time hour, through additional of wind energy able to overcome the unavailability of sun intensity during night time. However the wind is unpredictable and not available all the time. Through this paper, the Weibull and Hargreaves method is highlighted to analyze the potential of these two sources in Perlis.

A. Weibull Distribution

In practice, the problem is frequently that insufficient data about the frequency distribution of the wind speeds at a particular location are available. In such a case, there is no alternative but to use a mathematical approximation for the distribution curve. In normal wind regimes, a Weibull function will provide a good approximation. The Weibull function is defined as:

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$$\Phi = 1 - e^{-\left(\frac{v_w}{A}\right)^k} \quad (1)$$

where:
Φ = distribution function
v_w = wind velocity (m/s)
e = logarithmic base (normally the natural log, e = 2.781)
A = scaling factor
k = form parameter

If nothing besides the mean wind velocity is known and an "usual" frequency distribution can be assumed, this is characterized by a form factor of k = 2. In this case, the Weibull distribution is called a *Rayleigh distribution*. The relative frequency is obtained mathematically from the cumulative frequency by differentiating with respect to the wind speed v_w [3].

The power available in the wind varies with the cube of the wind speed. A common unit of measurement is the wind power density, or the power per unit of area normal to the wind direction from the wind is blowing:

$$Pw = \frac{1}{2}\rho v_w^3 \quad (2)$$

where ρ is an air density at standard atmosphere (kg/m^3) [3].

B. Hargreaves Method

The orientation of the earth's orbit around the sun is such that the sun-earth distance varies only by 1.7 percent and since the solar radiation outside the earth's atmosphere is nearly of fixed intensities, the radiant energy flux received per second by a surface of unit are held normal to the direction of sun's rays at the mean earth-sun distance, outside the atmosphere, is practically constant throughout the year.

This is termed as the solar constant I_{sc} and its value is now adopted to be 1367 W/m^2. However, this extraterrestrial radiation suffers variation due to the fact that the earth revolves around the sun not in a circular orbit but follows an elliptic path, with sun at one of the foci. The intensity of extraterrestrial radiation I_{ext} measured on a plane normal to the radiation on the *n*th day of the year is given in terms of solar constant (I_{sc}) as follows:

$$I_{ext} = I_{sc}\left[1.0 + 0.033\cos\left(\frac{360n}{365}\right)\right] \quad (3)$$

Various equations are available for estimating Reference Crop evapotranspiration (ET_0) and most important parameters in estimating ET_0 are temperature and solar radiation [4]. From the equations define for ET_0, Hargreaves Samani has recommended a simple equation to estimate solar radiation (R_s):

$$R_s = (K_T)(R_a)\sqrt{T_D} \quad (4)$$

where:
T_D = maximum daily temperature minus minimum daily temperature (°C) for weekly or monthly periods
R_a = extraterrestrial radiation (mm/day)
K_T = empirical coefficient

Extraterrestrial radiation is the solar radiation incident outside the earth's atmosphere. On average the extraterrestrial irradiance is 1367 W/m^2. This value is varies by ±3% as the earth orbits the sun.

$$R_a = \frac{1440}{\pi} \times SC \times \left(1 + 0.033\cos\frac{360n}{365}\right) \times (\cos\pi \times \cos\delta \times \sin\omega_s + \omega_s \sin\varphi \times \sin\delta) \quad (5)$$

where:
SC = solar constant (1367 W/m^2)
n = number day of year (DOY)
δ = solar declination
ω_s = sun set hour angle.

The extraterrestrial radiation is differing for each of latitude.

III. Results Analysis

A. Weibull Distribution

From the both equation state in Wiebull and Hargreaves, the characteristic of the wind and solar are represent in this section respectively. According to Seyit and Ali, they are proposed four different method for estimating Weibull parameter which are graphic method, maximum likelihood method, moment method and power density method [4]. From these author, this paper only present the fourth method in determine the Weibull distribution.

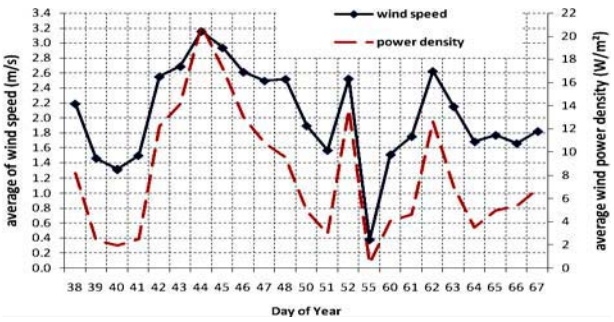

Figure 1: Relations of wind speed correspond with power distribution.

The power density plotted in the Fig. 1 is determine from the equation 2 above. However, the collected data in early of year 2011 between February and March is the illustrated based on the previous data collected in year 2005 until 2009 for the same month.

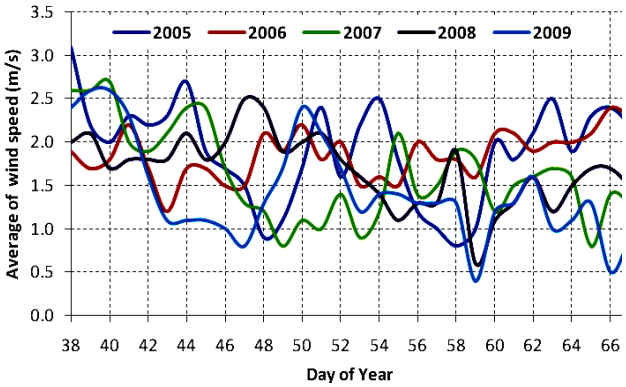

Figure 2: Total of wind speed collected from MMD for February to March of year 2005 until 2009.

As references of the Weibull distribution for power density of year 2011, the collection of wind speed from past five year is used. From the both graph plotted in Fig 1 and 2 shows that the pattern of wind speed almost sequences. The slightly different for year 2011 is the data collected is more efficient using Davis Vantage Pro2 Weather Station even displayed for a month of recording data.

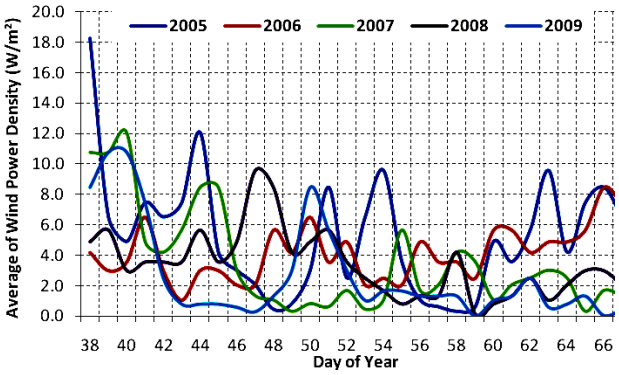

Figure 3: Average of wind power density of past five year collected.

As discussed in the wind speed pattern, the average of wind power density of past five year also shows the trend pattern as determine using Weibull distribution of year 2011.

B. Hargreaves Method

Unlike Weibull, the Hargreaves methods can apply to determine the solar radiation for certain area is enough to have the temperature value. This method is able to estimate the solar radiation and slightly to determine the potential of PV system installation.

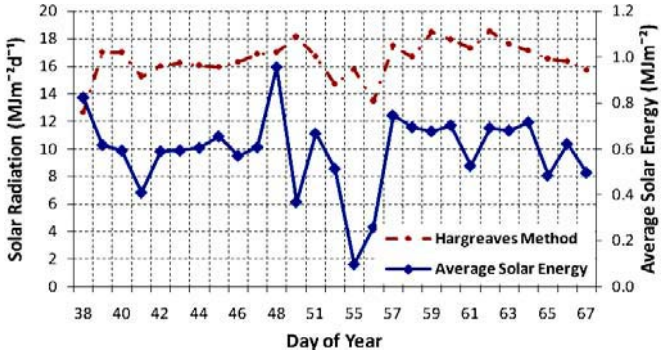

Figure 4: Solar radiation through Hargreaves method and average of solar energy.

Through Hargreaves method, the plotted graph shows the pattern of the solar radiation is illustrated on average. While the second line in the Fig. 3 is the average of solar energy recorded using weather station. From the both line plotted illustrates the potential of solar energy available in Perlis.

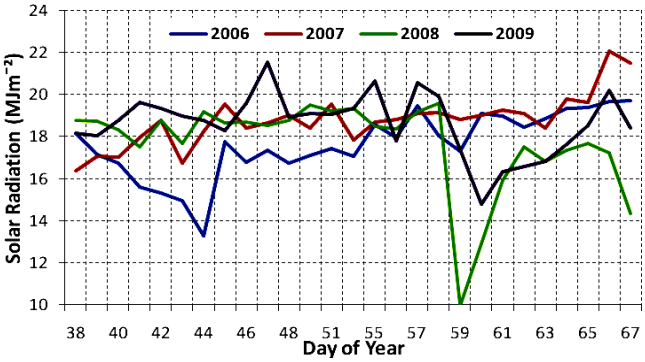

Figure 5: Solar radiation using Hargreaves method of 2006 until 2009.

Fig. 5 show the graph plotted the pattern of solar radiation over four year past. However, the recorded data for year 2005 is not available due to several error occur. From the obersevation above, the current solar radiation pattern indicated that only 9.3% different with the past four year.

IV. Conclusion

From the overall of the observation and discussion, this paper concludes that the potential of both wind and solar radiation is highly suitable to assess in Perlis. This is supports by the Weibull and Hargreaves method that implement in this paper. However, some modification and recommendation of the characteristic and type for the system is needed. Through the installation of Davis Vantage Pro2 Weather Station at EEIES Research Cluster has improved the current recording of weather changes as research purpose.The next step will continue with further improvement and analysis in other related method to estimate the wind and solar energy.

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