# Mathematically modeling of PV-Wind Hybrid system

Ranjana Khandare and Rubina Chaudhary\*

School of Energy & Environmental Studies, Devi Ahilya University,

Indore, MP, India

**Abstract:**

The study of hybrid (Photovoltaic and wind) generation is used system which is consist of 1 kW wind and 1 kW PV. The solar radiation data and wind data of the School of energy Environmental studies from D.A.V.V Indore are analyzed for sizing of the renewable energy system. A actual measurement for wind speed was recorded through a year of 2019. Also, the sun irradiance was through the year 2018 to 2020 period, to be considered for the output power calculations from the proposed crossbred renewable energy system.

**Keywords:** Hybrid system; Wind speed; Photovoltaic; solar radiation.

 *\*Corresponding Author: rubinachoudhary28@gmail.com,rubina\_chaudhary@yahoo.com*

*Address****:*** *Professor School of Energy &Environmental Studies, Devi Ahilya University,*

*Indore, MP, India*

 **1. Introduction:**

In the present scenario renewable power systems are becoming more and more popular, with the increase demand of energy and the concern of environmental pollution around the world. Photovoltaic energy and Wind energy have complementary characters. Combination of photovoltaic and wind energy in one system (hybrid system) become more reliable and reduces the storage batteries. The major advantage of the system is that it can satisfy the basic electrical energy requirements in remote areas, where grid power has not yet reached. The power generated from the hybrid system (solar and wind energy) stored in a battery bank which can be use whenever it is required **Chih-Ming Hong. et. al 2014** The solar radiation data and wind data of Indore, in India , are analyzed for determining the required capacity of the renewable energy system by use of mathematically modeling for this purpose. Crossbred renewable energy systems, which uses two resources of renewable energy, including wind and photovoltaic standalone system, which show superiority over implementation of single renewable energy source when it comes to the consistency, accuracy, efficacy and general cost of the system, **A.M. Hemeidam 2019.**

**2. Mathematically modeling of Photovoltaic generator:**

A Photovoltaic system converts sunlight irradiation into electrical energy. The tool responsible for this conversion is Photovoltaic cells, silicon is the most common material used in the manufacturing Photovoltaic cells. A silicon wafer is connected to electric terminals, and a circuit is formed. When the sunlight reaches the PV surface, the cells generate charge carriers and produce electric current that flows through short-circuit, **Diego B. et al. 2019.**

The output of PV generator (KWh) can be calculated based on the Eq. (1).This equation is used by many researchers related to mathematically modeling of Photovoltaic power generation (**Tao Ma. 2019, Muhammad Shahzad Javed 2019,** **Makbul A.M. Ramli 2016)**

 Power output of the PV array is expressed as

 PPV (t)=PR.fR.( GT(t)$ $/GS)…………………………………….. (1)

Where PRis PV module rated power (kW) output, fR is loss factor or derating factor (%) of PV module due to dirt, shadow and temperature etc., derating factor (fR) of 80% is employed in this study GT is hourly global solar radiation on PV module surface (KW/m2) GS is standard incident radiation (1000W/m2).

Table : 1 (Monthly average solar radiation 2019 by Solar electricity hand book 2019, Indore mp (India ) is 4.36 KWh/m2) and Fig.1 (Monthly average solar radiation 2019 by Solar electricity hand book 2019, Indore mp (India ) is 4.36 KWh/m2)

|  |  |  |
| --- | --- | --- |
|  | Months | Solar Irradiation KWh/m2 |
| P1 | Jan | 5.76 |
| P2 | Feb | 6.2 |
| P3 | Mar | 6.29 |
| P4 | Apr | 6.26 |
| P5 | May | 6.3 |
| P6 | Jun | 5.27 |
| P7 | Jul | 4 |
| P8 | Aug | 3.56 |
| P9 | Sep | 4.53 |
| P10 | Oct | 5.61 |
| P11 | Nov | 5.93 |
| P12 | Dec | 5.71 |

Table : 1

 Fig.1

**3.** **Mathematically modeling of wind turbine:**

The output power of a wind turbine at a specific location (School of energy Environmental studies from D.A.V.V Indore) depends on many factors, the amount of available energy increases with the increase in wind speed. It follows a cubic relationship between output of wind energy and wind speed. At high altitude the speed of wind is more and consistence .There is also an impact from the air temperature, given that cold air will result in higher levels of energy. The wind energy is used as a input source of a wind turbine and output is the mechanical power turning the generator rotor, **A.M. Hemeida 2019.**

The wind turbines output power can be expressed by Eq. (2).This equation is used in many works in the literature related to mathematically modeling of wind power generation **(S. Essalaimeh 2013, Chih-Ming Hong,2014, Hocine Belmili 2016, Danvu Nguyen 2016, A.M. Hemeida 2019, Diego B.2019**).

Pwind = $\frac{1}{2}$ CP ρ A V3 ………………………………… (1) Where Pwind output power of wind turbine,ρis the air density (approximately 1.225 kg/m3), A is the area swept by the rotor blades (m2) and it is perpendicular to the wind velocity, swept area can be calculated by A= π R D2 /4 where RD is the rotor diameter (m), Vis the wind speed in (m/s), and is CP the turbine power coefficient (dimensionless parameter) which varies between (0.2 to 0.5.)

Table: 2 represents the average wind speed of Indore, Madhya Pradesh,(India).which were recorded by world weather online between January -December 2018 (3.1m/s). From Table 2 the value of wind speed P6 is minimum and P11 is maximum and monthly average wind speed is 3.1 m/s. Figure: 2. Represents the monthly average wind speed pictograph which was recorded by world weather online between January to December 2018.

|  |  |  |
| --- | --- | --- |
|  | Months | Wind speed m/s |
| P1 | Jan | 2.2 |
| P2 | Feb | 2.4 |
| P3 | Mar | 3 |
| P4 | Apr | 3.3 |
| P5 | May | 4.4 |
| P6 | Jun | 5.2 |
| P7 | Jul | 4.1 |
| P8 | Aug | 3.7 |
| P9 | Sep | 2.3 |
| P10 | Oct | 1.6 |
| P11 | Nov | 2 |
| P12 | Dec | 2.3 |

Table:2 (Average wind speed value of January -December 2018 (3.1m/s))

Figure:2.

Table: 3 represents the average wind speed of Indore, Madhya Pradesh, (India). which were recorded by world weather online between January-December 2019 (3.1m/s). From Table 3 the value of wind speed P11 and P12 are minimum and P5 is maximum and monthly average wind speed is 3.1 m/s. Figure: 3. Represents the monthly average wind speed pictograph which was recorded by world weather online between January to December 2019.

|  |  |  |
| --- | --- | --- |
|   | Months | Wind speed m/s |
| P1 | Jan | 1.9 |
| P2 | Feb | 2.47 |
| P3 | Mar | 2.3 |
| P4 | Apr | 2.4 |
| P5 | May | 2.69 |
| P6 | Jun | 2.8 |
| P7 | Jul | 2.6 |
| P8 | Aug | 2.3 |
| P9 | Sep | 2.2 |
| P10 | Oct | 1.5 |
| P11 | Nov | 1.69 |
| P12 | Dec | 1.69 |

Table: 3 (Average wind speed value of January -December 2019 (3.1m/s))

Fig:3

Table: 4 represents the average wind speed of Indore, Madhya Pradesh, (India).which were recorded by world weather online between January -December 2020 (2 m/s). From Table 4 the value of wind speed P10 and P11are minimum and P5 is maximum and monthly average wind speed is 3.1 m/s. Figure: 4. represents the monthly average wind speed pictograph which was recorded by world weather online between January to December 2020.

|  |  |  |
| --- | --- | --- |
|   | Months | Wind speed m/s |
| P1 | Jan | 1.9 |
| P2 | Feb | 2.3 |
| P3 | Mar | 2.22 |
| P4 | Apr | 2.1 |
| P5 | May | 2.55 |
| P6 | Jun | 2.44 |
| P7 | Jul | 2.44 |
| P8 | Aug | 2.36 |
| P9 | Sep | 1.7 |
| P10 | Oct | 1 |
| P11 | Nov | 1 |
| P12 | Dec | 1.47 |

Table: 4 (Average wind speed value of January -December 2020 ( 2 m/s))

Figure:4

Table: 5 represents the average speed of wind comparatively for the year 2018, 2019, and 2020 (January –December). Indore, Madhya Pradesh, (India).which were recorded by world weather online). From Table 5 the value of wind speed P10 and P11are minimum and P5 and P6 are maximum. Figure 5 represents a pictograph of average speed of wind comparatively for the years 2018, 2019, and 2020 (January –December).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   | Months | Average wind speed value of January -December 2018 (3.1m/s) | Average wind speed value of January -December 2019 (3.1m/s) | Average wind speed value of January -December 2020 (2m/s) |
| P1 | Jan | 2.2 | 1.9 | 1.9 |
| P2 | Feb | 2.4 | 2.47 | 2.3 |
| P3 | Mar | 3 | 2.3 | 2.22 |
| P4 | Apr | 3.3 | 2.4 | 2.1 |
| P5 | May | 4.4 | 2.69 | 2.55 |
| P6 | Jun | 5.2 | 2.8 | 2.44 |
| P7 | Jul | 4.1 | 2.6 | 2.44 |
| P8 | Aug | 3.7 | 2.3 | 2.36 |
| P9 | Sep | 2.3 | 2.2 | 1.7 |
| P10 | Oct | 1.6 | 1.5 | 1 |
| P11 | Nov | 2 | 1.69 | 1 |
| P12 | Dec | 2.3 | 1.69 | 1.47 |

 Table: 5 (Comparative wind speed value of January 2018-Dec 2020)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Figure: 5 |  |  |

 Pwind = $\frac{1}{2}$ CP ρ AV 3 ……………………………………….. (2)

If CP the turbine power coefficient is assume that 0.2, ρis the air density (approximately 1.23 kg/m3), A is the area swept by the rotor blades assume that 1 m2and average wind velocity is place of Indore mp, India is 2 m/s on 2020. These values put in equation 2 to find 7.72 Watt wind power output. The wind output power is proportional to the turbine power coefficient, air density, area swept by the rotor blades, and wind speed. If the area swept by the rotor blades is changed the wind power output will also change.

Table: 6 represents monthly average wind speed value of January to December 2019 (3.1m/s ) by world weather online. From Table 6 the value of wind turbine output P10 is minimum and P6 is maximum.

 Table: 6 represents monthly average solar radiation value of January to December 2019 (5.41 kWh/m2) by Solar electricity hand book 2019, Indore mp India. From Table 6 the value of photovoltaic generator output P8is minimum and P2 is maximum.

From Table 6 the value of hybrid generator output P12is minimum and P6 is maximum.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|   | Months(2019) | Wind speed m/s (2019) |  Solar Irridation kWh/m2 (2019) | Output power of wind turbine on different wind speed (2019) | Output power of Photovoltaic generator on different solar radiation(2019)  | Output power of (wind turbine+ Photovoltaic generator) 2019  |
| P1 | Jan | 1.9 | 5.76 | 3.30 | 3.88 | 7.18 |
| P2 | Feb | 2.47 | 6.2 | 7.23 | 4.85 | 12.08 |
| P3 | Mar | 2.3 | 6.29 | 5.86 | 4.24 | 10.1 |
| ­­­­­P4 | Apr | 2.4 | 6.26 | 6.6 | 4.22 | 10.82 |
| P5 | May | 2.69 | 6.3 | 9.3 | 4.25 | 13.55 |
| P6 | Jun | 2.8 | 5.27 | 10.58 | 3.55 | 14.13 |
| P7 | Jul | 2.6 | 4 | 8.47 | 2.7 | 11.17 |
| P8 | Aug | 2.3 | 3.56 | 5.8 | 2.40 | 8.2 |
| P9 | Sep | 2.2 | 4.53 | 5.13 | 3.05 | 8.18 |
| P10 | Oct | 1.5 | 5.61 | 1.6 | 3.78 | 5.38 |
| P11 | Nov | 1.69 | 5.93 | 2.3 | 4.00 | 6.3 |
| P12 | Dec | 1.69 | 5.71 | 2.3 | 3.85 | 5.78 |
|  |  |  |  |  |  |  |

Fig: 6 Represents a pictograph of output power of Wind turbine, Photovoltaic generator and Hybrid generator for the year 2019 (January –December).

Fig : 6.

**6. Conclusion :**

Hybrid systems are the suitable solution for clean energy production. In this paper, a new Photovoltaic - wind hybrid generation system has been proposed and implemented. The photovoltaic and wind hybrid system of power generation was

developed by using mathematically modeling. Analyzing the solar radiation data and wind data of the School of energy Environmental studies from D.A.V.V Indore for sizing of the renewable energy hybrid system. The solar radiation is 5.27 kWh/m2 and wind speed is 2.8 m/s for particular location and maximum output of photovoltaic and wind hybrid system. Output of hybrid system is dependent on different parameters like solar radiation , PV module, loss factor of PV module due to dust, ρis the air density , swept area by the rotor blades (m2) , wind speed in (m/s), CP the turbine power coefficient. Finally it is concluded that by changing some parameters output of Photovoltaic - wind hybrid generation system can be changed.

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