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Feasible Size Ratio Prediction of Wind and PV Module for Energy Generation of Different Climatic Zones in India

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ABSTRACT

Solar and wind are renewable energy resources that are non-exhaustible, freely available, ecofriendly and capable for providing solutions to the power problems, which are recently being faced by India and all over the world. With increasing demand of generating electricity, wind and solar energies are not available all the time, the combined implementation of renewable resources such as wind and solar can meet the increasing demand of electricity. This Paper presents study about the Photovoltaic-Wind Hybrid System (PWHS) under six climate zones of India. The study is based on the size ratio of Average Solar Irradiation Energy (ASIE) and Average Wind Speed Energy (AWSE). Annually, the ASIE varied form 5.00 KWh/m^2 to 6.50 KWh/m^2 whereas the values of AWSE varied between 0.1 m/s and 2.4 m/s. After analyzing different climatic conditions, PWHS was designed. Through mathematically modeling and learning programming techniques, different size ratios were conformed. Linear programming was applied on average annual value of photovoltaic (PV) and wind, to determine the size ratio of PV wind among different climate zones.

Keywords: *Hybrid System; Wind Speed; Photovoltaic; Solar Irradiation*

1. Introduction

The availability of solar and wind energy resources is determined by the climatic conditions at specific location. Pre-feasibility studies depend upon the climatic data such as the wind speed, solar irradiance and load demand for that particular location. In order to calculate the performance of a system, an appropriate weather data is required. The weather conditions may vary from one location to another. Because of the large variation of weather conditions in different parts, India needs to focus on hybrid power projects, which support optimizing the production and power at competitive prices as well as to reduce the variability. Also, to formulate the mandatory standards and regulations for hybrid systems which are not included in the previously announced policy (wind-solar hybrid policy on May 15, 2018). The hybridization of two or more renewable systems along with conventional power source battery storage can increase the performance of the renewable technologies as reported earlier [1]. Advantage of the hybrid energy systems is that the energy can be exploited from several sources at the same time which will raise the overall efficiency of the system as reported by Das et al. earlier [2]. In the past few years, increasing sustainable growth in the industrial sector and global population has increased the energy demand all over the world. Presently, conventional power systems mainly rely on the usage of nonrenewable resources such as oil, gas, and coal. Therefore, utilization of these fossil fuels contribute to several negative effects on the environment due to the emission of greenhouse gases as reported by Sharvini [3].

The aim of this study is to propose the Photovoltaic-Wind Hybrid Systems (PWHS) which are applicable all over the India as suggested by Luthra, et al. [4]. Meteorological data of six different locations of India which come under different climatic zones was utilized. The main idea behind this study was to find the size ratio of photovoltaic and wind system (PVWS) by using linear programming algorithms [5].

1.1. Meteorological Data

Global solar irradiance and possible wind speed data was utilized for this study which is available for the year 2022. The solar irradiation data was collected from the online website wetherspark.com and wind speed data from the world weather online.com [6]. This data of six different locations in India was used to complete this work. The data was compiled on monthly average values of the global solar irradiance (KWh/m^2) and wind speed (m/s) that was utilized for the size ratio of photovoltaic and wind under the present study [7].

1.2. Climatic zones characteristic of India

The climate classification system divides the country into six major climatic zones. These zones are: (1) hot and dry, (2) warm and humid, (3) moderate, (4) cold and cloudy, (5) cold and sunny, and (6) composite. From each of the climatic zone, a representative location was selected as reported by Bhatnagar et al. [8]. The selected locations under the present study along-with their respective climatic zones and geographical data are presented in Table 1.

Table 1: Geographical parameters for selected locations in India

S.No	Climate Zone	Name of Place	Latitude	Longitude
1	Composite	Indore (Madhya Pradesh)	22^o 71''	75^o 85''
2	Hot and dry	Jaipur (Rajasthan)	26^o 92''	75^o 77''
3	Warm and humid	Dibrugarh (Arunachal Pradesh)	28^o 21''	94^o 72'
4	Moderate	Bangalore (Karnataka)	12^o 97''	77^o 59''
5	Cold and cloudy	Shimla	31^o 10''	77^o 13''
6	Cold and sunny	Jammu	32^o 72''	74^o 85''

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2. Methodology

2.1. Mathematical calculation of the output power of photovoltaic generator

A photovoltaic system converts sunlight radiation into electrical energy. The system used for this conversion is the photovoltaic cell in which silicon is the basic material used for manufacturing the photovoltaic cells [9]. An electric circuit is formed when silicon wafer is connected to the electric terminals. When light from sun reaches the photovoltaic surface, the cell generates charge carriers, resulting in the electric current that flows through the short-circuit as discussed by AL-Ezzi et al. [10]. The output of PV generator (KWh) can be calculated based on Eq. (1). This equation is used by many groups working on mathematical modeling of photovoltaic power generation as reported by Ramli et al. [11]. The power output of the PV array is expressed as:

$$P_{PV}(t) = P_R . f_R . [G_T(t)/G_S] \quad (1)$$

Where P_R is PV module rated power (KW) output, f_R is loss factor or derating factor (in %) of PV module due to dirt, shadow and temperature variation etc. Derating factor (f_R) of 80% was employed in this study. G_T is the hourly global solar radiation on PV module surface (KW/m^2), and G_S is the standard incident radiation (1000W/m^2).

2.2 Mathematical calculation of output power of wind turbine

The output power of a wind turbine at specific location depends on many factors, including the amount of available energy that increases with increasing wind speed. It follows a cubic relationship between the wind energy output and its speed. At high altitude, the speed of wind is high and consistence. There is also an impact of the air temperature at high altitude. It has been noticed that cold air will result in the higher level of energy. The wind energy is used as an input source of the wind turbine and output is the mechanical power turning the generator rotor**.** The wind turbine output power can be expressed by equation (2). This equation is used in many reports in the literature related to mathematical modeling of the wind power generation system**.**

$$P_{wind} = \frac{1}{2} C_P \rho A V^3 \quad (2)$$

Where P_{wind} is the output power of the wind turbine, ρ is the air density (approximately1.23 kg/m^3), A is the area swept by the rotor blades (m^2) perpendicular to the wind velocity that can be calculated by $A= \pi RD^2/4$. Where RD is the rotor diameter (m), V is the wind speed in (m/s), and C_P is the turbine power coefficient (dimensionless) that varies between 0.2 and 0.5.

3. Predicting the best size ratio of PV-Wind hybrid system for different climate zones

3.1 Monthly average solar radiation (KWh/m^2) of six different climate zones

The first location is the composite climate of Indore, the city of Madhya Pradesh in India. Second location deals with hot and dry climate of Jaipur, the city of Rajasthan. Third location includes the warm and humid climate of Dibrugarh, the city of Arunachal Pradesh. Fourth location is the moderate climate of Bangalore, the city of Karnataka. Fifth location is comprised of cold and cloudy climate of Shimla and sixth location contains cold and sunny climate of Jammu. All these cities belong to India. Table 2 represents the monthly average solar radiation of these designated locations measured in KWh/m^2 in 2022.

3.2. First location (Indore city with composite climate)

Table 3 represents the average wind speed of Indore, Madhya Pradesh that was recorded by the world weather online between January and December 2022. The data has also been plotted in Fig.1. Indore has composite climate, which was studied in this work. Fig. 2 represents the average annual solar irradiation of the location, which comes out to be 5.80 kWh/m^2. This data along with Table 4 show the average annual wind speed that was 2.4 m/s, and the output electric power of photovoltaic generator was 0.93 W. Similarly, the output electric power of wind generator was 0.6 W. According to the linear programming, the output Photovoltaic-Wind Hybrid System (PWHS) was 1.5 W. It has been found that the size ratio of photovoltaic and wind are 40% and 60%, respectively.

Table 2: Monthly average solar radiation measured in KWh/m^2 in 2022 in different cities of India

Months	Indore	Jaipur	Dibrugarh	Bangalore	Shimla	Jammu
Jan	4.9	4.4	4.1	6.0	6.0	3.3
Feb	5.9	5.4	4.9	6.7	6.6	4.1
Mar	6.8	6.4	5.7	7.0	6.9	5.3
Apr	7.3	7.2	6.1	6.6	6.4	6.7
May	7.5	7.6	6.4	5.7	5.6	7.1
Jun	6.3	7.3	5.9	5.0	4.8	7.8
Jul	5.1	6.1	5.6	4.9	4.8	7.0
Aug	4.9	5.8	5.4	5.1	5.2	6.4
Sep	5.7	6.1	5.0	5.1	5.4	6.1
Oct	5.7	5.6	4.8	5.2	5.3	6.1
Nov	5.0	4.6	4.4	5.4	5.4	3.9
Dec	4.6	4.1	3.9	5.6	5.5	3.2

Table 3: Monthly wind speed during 2022 with an average speed of 2.4 m/s at the city of Indore

Months	Wind speed (m/s)
Jan	2.3
Feb	2.1
Mar	2.0
Apr	2.2
May	4.3
Jun	4.0
Jul	3.5
Aug	3.2
Sep	2.4
Oct	2.1
Nov	1.5
Dec	2.2

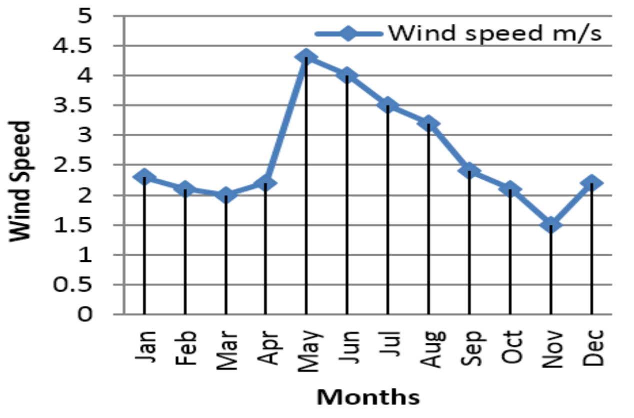

Fig. 1: Monthly average wind speed of Indore, Madhya Pradesh which was recorded between January to December 2022

Table 4: Output power of wind generator, photovoltaic, and hybrid generator at Indore for the year 2022

Months	Wind speed (m/s)	Solar irradiation (kWh/m^2)	Wind turbine on different wind speeds	Photovoltaic generator on different solar radiation	Wind turbine photovoltaic generator
Jan	2.3	4.9	2.3	0.91	3.21
Feb	2.1	5.9	1.7	1.1	2.8
Mar	2	6.8	1.5	1.2	3.2
Apr	2.2	7.3	2.0	1.3	3.3
May	4.3	7.5	15	1.4	16.4
Jun	4.0	6.3	12	1.17	13.17
Jul	3.5	5.1	8.0	0.95	8.95
Aug	3.2	4.9	6.29	0.91	7.2
Sep	2.4	5.7	2.6	1.06	3.66
Oct	2.1	5.7	1.7	1.06	2.76
Nov	1.5	5.0	0.6	0.93	1.53
Dec	2.2	4.6	2.0	0.86	2.86

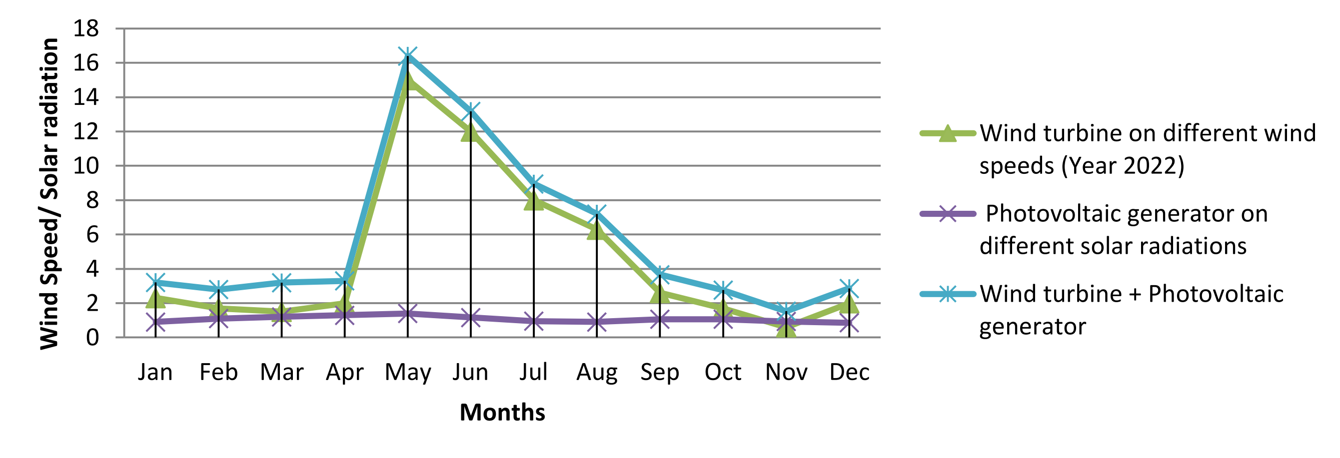

Fig. 2: Output data of wind generator, photovoltaic hybrid generator graph of Indore, Madhya Pradesh (India) as recorded by linear programming from January to December 2022

3.3. *Second location (Jaipur city, hot and dry climate)*

The city of Jaipur (Rajasthan) with hot and dry climate was analyzed. The average annual solar radiation recorded in 2022 was 5.80 kWh/m^2 and average annual wind speed was 2.27 m/s. Table 5 and 6 along with Fig. 3 and 4 represent the relevant data at the city of Jaipur. It is noticed that the output electric power of photovoltaic generator was monitored as 0.86 W. Similarly, the output electric power of wind generator was 0.42 W. According to the linear programming, the output

Photovoltaic-Wind Hybrid System (PWHS) was 2.15 W. It has been seen that the size ratios of photovoltaic and wind were 30% and 70%, respectively.

Table 5: Average wind speed at Jaipur & Rajasthan recorded on monthly basis in 2022

Months	Wind speed (m/s)
Jan	1.9
Feb	2.2s
Mar	2.1
Apr	2.2
May	3.4
Jun	3.4
Jul	2.4
Aug	2.7
Sep	2.5
Oct	1.8
Nov	1.3
Dec	1.4

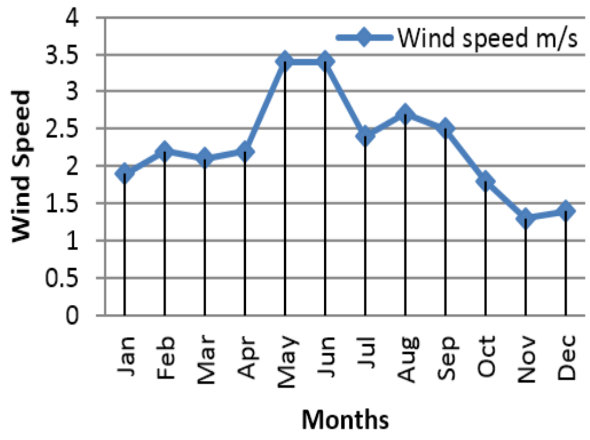

Fig. 3: Monthly average wind speed graph of Jaipur & Rajasthan which was recorded by world weather online in 2022

Table 6: Output values of wind generator, photovoltaic, hybrid generator recorded in 2022

Months	Wind speed m/s	Solar irridation kWh/m^2	Wind turbine on different wind speeds	Photovoltaic generator on different solar radiations	Wind turbine photovoltaic generator
Jan	1.9	4.4	1.3	0.748	2.04
Feb	2.2	5.4	2.0	1.01	3.01
Mar	2.1	6.4	1.7	1.19	2.89
Apr	2.2	7.2	2.0	1.34	3.34
May	3.4	7.6	7.54	1.4	9.04
Jun	3.4	7.3	7.54	1.3	8.84
Jul	2.4	6.1	2.65	1.1	3.75
Aug	2.7	5.8	3.77	1.0	4.77
Sep	2.5	6.1	3.0	1.14	4.14
Oct	1.8	5.6	1.11	1.04	2.15
Nov	1.3	4.6	0.42	0.86	1.28
Dec	1.4	4.1	0.52	0.7	1.22

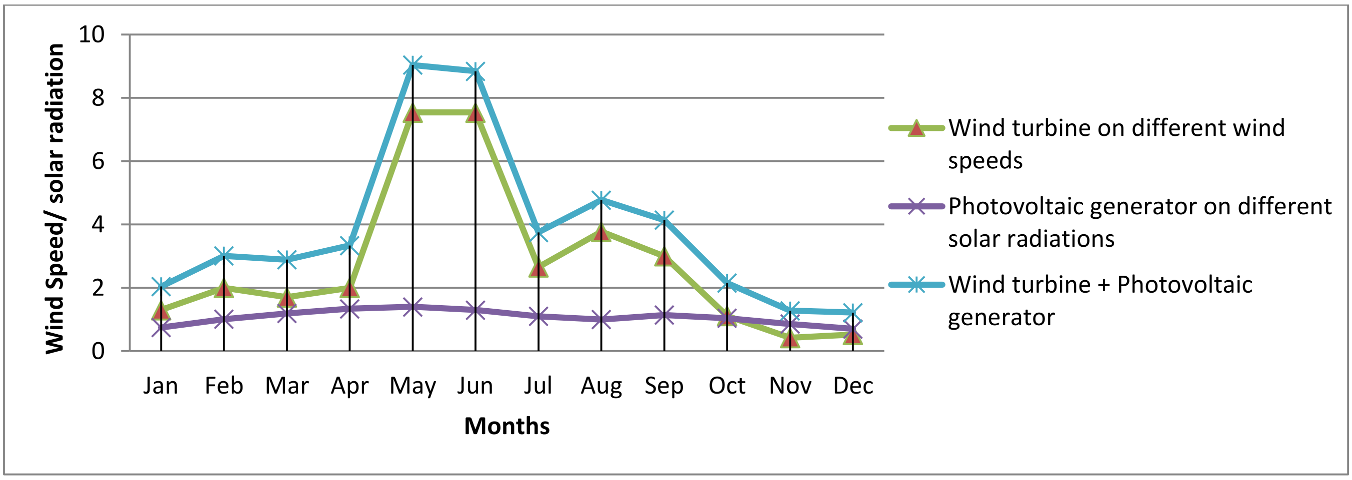

Fig. 4: Output solar radiation of wind generator, photovoltaic, hybrid generator graph recorded from January to December 2022

3.4. Third location (Dibrugarh city, warm and humid climate)

The Dibrugarh (Arunachal Pradesh) in India possessing warm and humid climate was analyzed. The average annual solar wind generator was 0.42 W. Irradiation was 5.1 kWh/m^2 and average annual wind speed was 1.77 m/s. The output electric power of photovoltaic generator was 0.89 W.

Table 7: Average wind speed of Dibrugarh (India) recorded in 2022

Months	Wind speed m/s
Jan	1.4
Feb	1.9
Mar	1.9
Apr	2.4
May	2.2
Jun	2.2
Jul	1.8
Aug	1.8
Sep	2.1
Oct	1.3
Nov	1.2
Dec	1.1

According to linear programming the output Photovoltaic-Wind Hybrid System (PWHS) was 1.31 W. It was found that the size ratio of photovoltaic and wind were 30% and 70%, respectively. Table 7 and 8 along with Fig. 5 and 6 represent the relevant data discussed in this section.

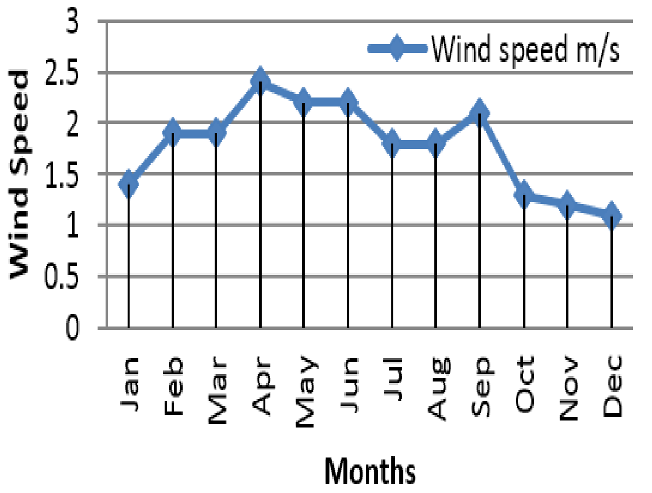

Fig. 5: Monthly average wind speed graph of Dibrugarh that was recorded by world weather online

Table 8: Output power of wind generator, photovoltaic, hybrid generator in 2022

Months	Wind speed m/s	Solar Irridation kWh/m^2	Wind turbine on different wind speeds	Photovoltaic generator on different solar radiations	Wind turbine Photovoltaic generator
Jan	1.9	4.4	1.3	0.748	2.04
Feb	2.2	5.4	2.0	1.01	3.01
Mar	2.1	6.4	1.7	1.19	2.89
Apr	2.2	7.2	2.0	1.34	3.34
May	3.4	7.6	7.54	1.4	9.04
Jun	3.4	7.3	7.54	1.3	8.84
Jul	2.4	6.1	2.65	1.1	3.75
Aug	2.7	5.8	3.77	1.0	4.77
Sep	2.5	6.1	3.0	1.14	4.14

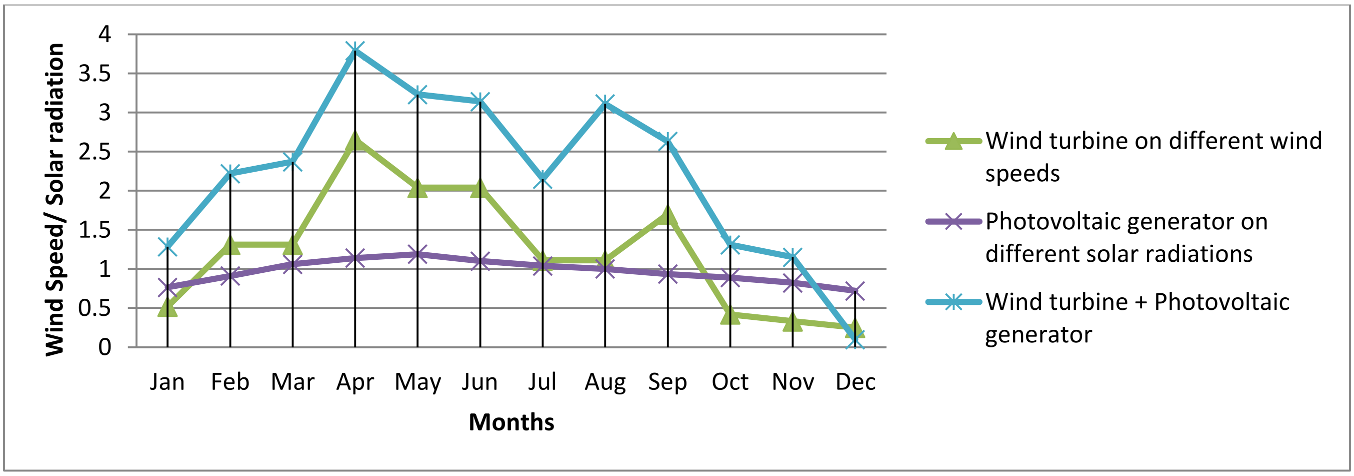

Fig. 6: Output values of wind generator, photovoltaic, hybrid generator graph of Dibrugarh (Arunachal Pradesh), recorded by linear programming between January to December 2022

3.5 Fourth location (Karnataka city, moderate climate)

Analysis of Bangalore (Karnataka) with moderate climate was presented. Table 9 and 10 along with Fig. 7 and 8 represent the relevant data collected at Karnataka. On the basis of this data, the average annual solar radiation was 5.6 KWh/m^2 and average annual wind speed was 1.8 m/s. The output electric power of photovoltaic generator was 1.30 W.

Table 9: Represents the average wind speed of Bangalore (India) recorded between January-December 2022

Months	Wind speed m/s
Jan	1.4
Feb	1.9
Mar	1.9
Apr	2.4
May	2.2
Jun	2.2
Jul	1.8
Aug	1.8
Sep	2.1
Oct	2.0
Nov	1.5
Dec	1.4

Similarly, the output electric power of wind generator was 1.33 W. According to the linear programming, the output Photovoltaic-Wind Hybrid System (PWHS) was 2.58 W. It was found that the size ratio of photovoltaic and wind are the same as 50%.

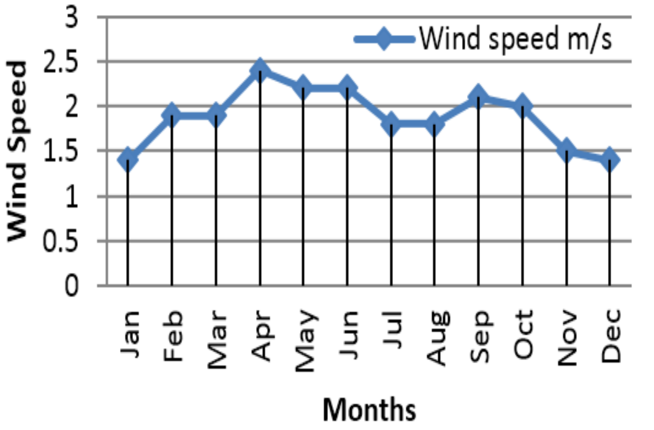

Fig. 7: Average wind speed graph of Bangalore (India) recorded by world weather online between January and December, 2022

Table 10: Output values of wind generator, photovoltaic, hybrid generator for 2022

Months	Wind speed m/s	Solar Irridation kWh/m^2	Output power of wind turbine on different wind speed	Output power of Photovoltaic generator on different solar radiation	Output power of wind turbine Photovoltaic generator
Jan	1.4	6.0	0.52	1.12	1.64
Feb	1.9	6.7	1.33	1.25	2.58
Mar	1.9	7.0	1.33	1.30	2.63
Apr	2.4	6.6	2.65	1.23	3.88
May	2.2	5.7	2.0	1.06	3.06
Jun	2.2	5.0	2.0	0.935	2.93
Jul	1.8	4.9	1.11	0.91	2.02
Aug	1.8	5.1	1.11	0.95	2.06
Sep	2.1	5.1	1.77	0.95	2.72
Oct	2.0	5.2	1.53	0.97	2.50
Nov	1.5	5.4	0.64	1.00	1.64
Dec	1.4	5.6	0.52	1.04	1.56

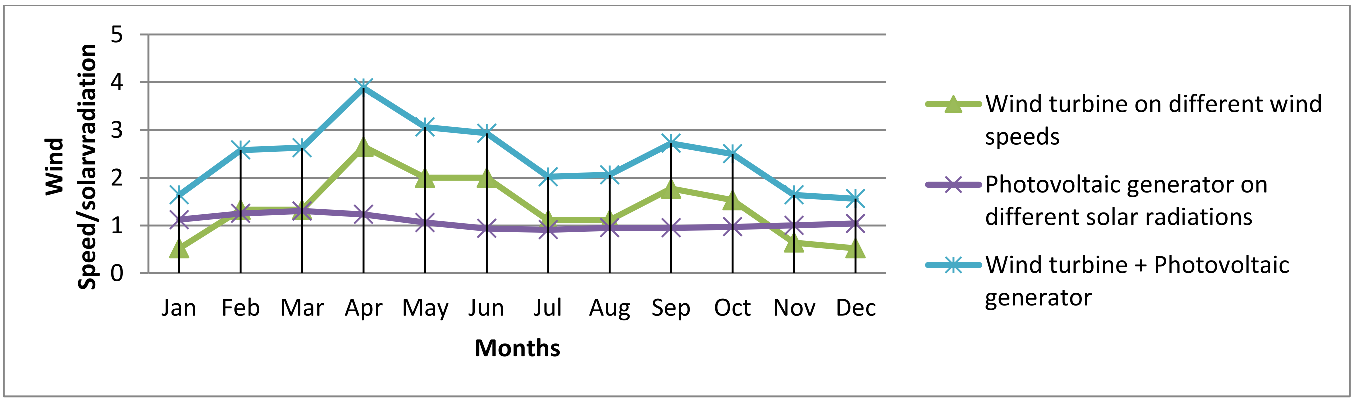

Fig. 8 Output value of wind generator, photovoltaic, hybrid generator graph of Bangalore (India) for the year 2022

3.6 Fifth location (Shimla city, cold and cloudy climate)

Shimla is having cold and cloudy climate which is analyzed. It is seen that the average annual solar radiation was 5.6 KWh/m^2 in 2022 and average annual wind speed was 0.1 m/s. The output electric power of photovoltaic generator was 1.29 W. Similarly, the output electric power of wind generator was 0.0015 W. By linear programming the output of Photovoltaic-Wind Hybrid System (PWHS) was 1.29 W and it is expressing that sizing and ratio of photovoltaic wind hybrid system in this location is not possible because the wind speed is very low. Table 11 and 12 along with Fig. 9 and 10 represent the relevant data discussed in this section.

Table 11: Aaverage wind speed of Shimla (India), which was recorded from January to December 2022

Months	Wind speed m/s
Jan	0.1
Feb	0.2
Mar	0.2
Apr	0.4
May	0.2
Jun	0.3
Jul	0.0
Aug	0.0
Sep	0.1
Oct	0.0
Nov	0.1
Dec	0.1

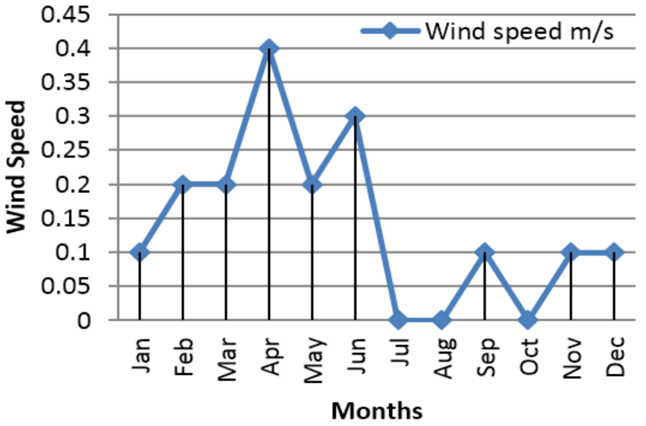

Fig. 9: Monthly average wind speed at Shimla (India) which was recorded by world weather online in 2022

Table 12: Output values of wind generator, Photovoltaic, hybrid generator

Months	Wind speed m/s	Solar Irridation kWh/m^2	Wind turbine on different wind speeds	Photovoltaic generator on different solar radiations	Wind tu rbine + Photovoltaic generator
Jan	0.1	6.0	.0001	1.122	1.122
Feb	0.2	6.6	.0015	1.234	1.235
Mar	0.2	6.9	.0015	1.290	1.291
Apr	0.4	6.4	.0122	1.196	1.208
May	0.2	5.6	.0015	1.047	1.048
Jun	0.3	4.8	.0051	0.897	0.902
Jul	0.0	4.8	.0000	0.897	0.897
Aug	0.0	5.2	.0000	1.028	1.028
Sep	0.1	5.4	.0001	1.009	1.009
Oct	0.0	5.3	.0000	0.991	0.991
Nov	0.1	5.4	.0001	1.009	1.009
Dec	0.1	5.5	.0001	1.028	1.028

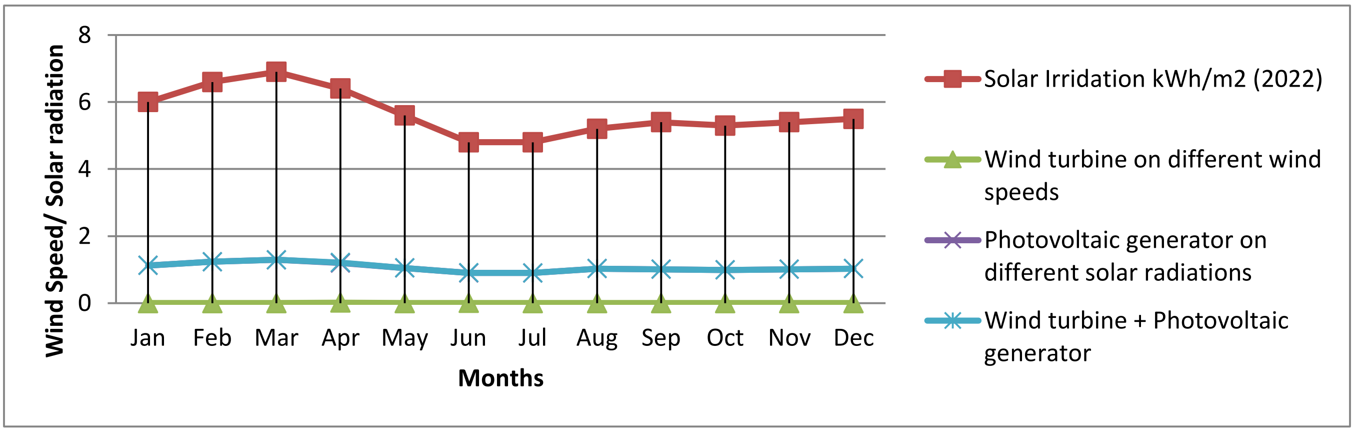

Fig. 10: Output value of wind generator, Photovoltaic, hybrid generator graph of Shimla (India) recorded between January to December 2022

3.7 Sixth location (Jammu, city, cold and sunny climate)

The city of Jammu has cold and sunny climate that was analyzed in this section. On the basis of average annual solar irradiation (5.0 kWh/m^2) and average annual wind speed was 0.3 m/s and the output electric power of photovoltaic generator was 1.3 W. Similarly, the output electric power of wind generator was 0.005 W and the output Photovoltaic-Wind Hybrid System (PWHS) was 1.30 W. It was also seen by the linear programming that size ratio of photovoltaic and wind system was not possible due to the low wind speed. Table 13 and 14 along with Fig. 11 and 12 represent the relevant data collected at Jammu.

Table 13: Average wind speed of Jammu (India) recorded by world weather online between January-December 2022

Months	Wind speed m/s
Jan	0.3
Feb	0.3
Mar	0.3
Apr	0.3
May	0.3
Jun	0.3
Jul	0.3
Aug	0.0
Sep	0.3
Oct	0.3
Nov	0.3
Dec	0.3

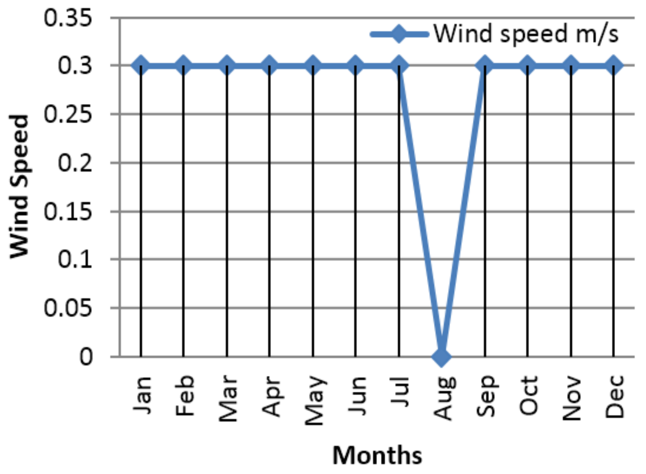

Fig. 11: Monthly average wind speed graph of Jammu (India) which was recorded between January to December 2022

Table 14: Output value of wind generator, Photovoltaic, hybrid generator (year 2022)

Months	Wind speed m/s	Solar Irridation kWh/m^2	Wnd turbine on different wind speeds	Photovoltaic generator on different solar radiations	Wind turbine + Photovoltaic generator
Jan	0.3	3.3	0.005	0.617	0.6175
Feb	0.3	4.1	0.005	0.766	0.7665
Mar	0.3	5.3	0.005	0.991	0.996
Apr	0.3	6.7	0.005	1.25	1.255
May	0.3	7.1	0.005	1.32	1.325
Jun	0.3	7.8	0.005	1.45	1.455
Jul	0.3	7.0	0.005	1.30	1.305
Aug	0.0	6.4	0.00	1.19	1.195
Sep	0.3	6.1	0.005	1.14	1.145
Oct	0.3	6.1	0.005	1.14	1.145
Nov	0.3	3.9	0.005	0.72	0.725
Dec	0.3	3.2	0.005	0.59	0.595

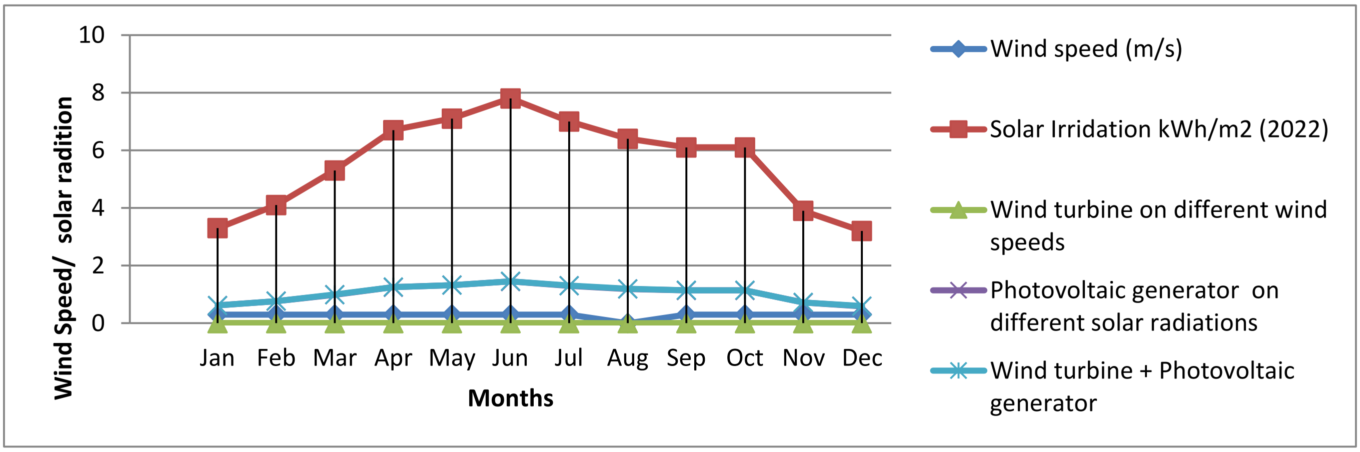

Fig. 12: Output value of wind generator, Photovoltaic, hybrid generator graph of Jammu (India) in 2022

Fig.13 shows the output values of wind generator, photovoltaic, hybrid generator of the first location (Indore) which is the composite climate. Second location is the hot and dry climate of Jaipur. The third location is the warm and humid climate of Dibrugarh and fourth location is the moderate climate of Bangalore, the city of Karnataka. Fifth location is the city of Shimla with cold and cloudy climate and sixth location is cold and sunny weather of Jammu. These values were recorded from January to December 2022.

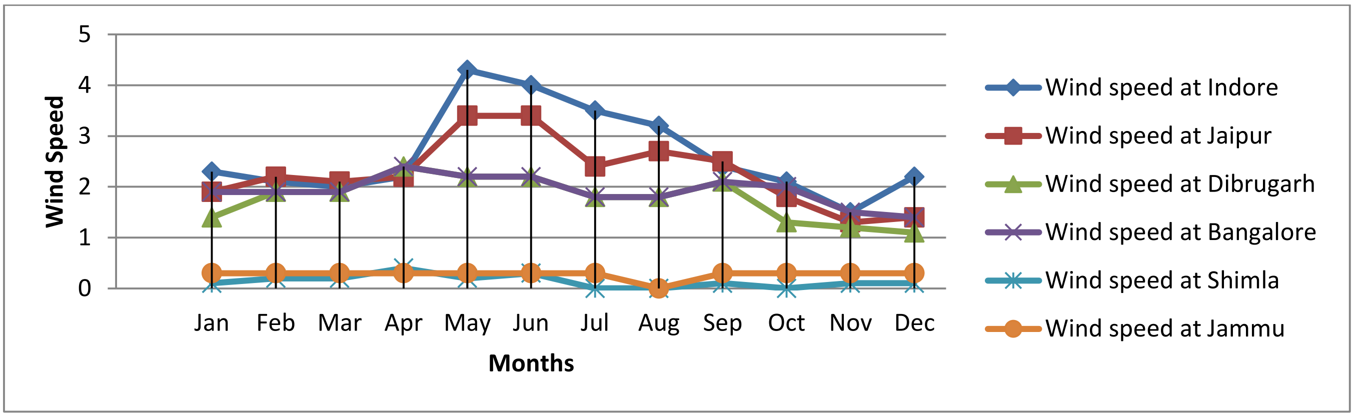

Fig. 13 Output values of wind generator, photovoltaic, hybrid generator graph at different locations of India

4. Result and Discussion

On analyzing Photovoltaic-Wind Hybrid Systems in different climatic zones, it was observed that the selected city of Indore with composite climate has suitable size ratio of PV wind that is 40:60. Jaipur with hot and dry climate having suitable size ratio of PV wind was 30:70. Dibrugarh possessing warm and humid climate with suitable size ratio of PV wind was 30:70. The photovoltaic output of Jammu with cold and is better than Shimla with cold and cloudy climate but output of the wind turbine is negligible over there because of the very low wind speed at both places. Therefore, the size ratio of PV wind was not determined.

5. Conclusion

Six different climactic locations of India were analyzed to find the size ratio of photovoltaic and wind PWHS on the basis of global solar irradiance and wind speed. Bangalore is said to be perfect location for PWHS with highest output in comparison with other locations of India. The size ratio of PWHS was 50:50 and it can be used for better understanding of the meteorological features characteristic of India. This study can help the domestics and industries to decide the location and size ratio of PV wind hybrid system for best utilization of the economy and availability of electrical energy. The result showed that solar radiation of Indore and Japur was 5.80 KWh/m^2 followed by Bangalore, Dibrugarh, and Shimla which was 5.6 KWh/m^2. On the other hand, the speed of wind at Indore was 2.4 m/s, Jaipur was 2.27 m/s, Bangalore was 1.8 m/s, Dibrugarh was 1.77 m/s, and wind speed at Jammu and Shimla were 0.3 m/s and 0.1 m/s, respectively. These locations are not recommendable for the wind energy production. If the energy production system was combined as photovoltaic wind hybrid system, we will get almost the same power output in Indore Bangalore that is followed by Jaipur and then Dibrugarh in accordance of the available data and calculations.

References

[1] C.R. Kumar. and M.A. Majid, "Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities," *Energy Sustain. Soc.*, vol. 10, no. 1, 2020.

[2] A.K. Das, "An evaluative study of some selected libraries in India undergoing the process of digitization*", Doctoral dissertation*. India, pp. 1–374, 2008.

[3] S.R. Sharvini, Z.Z. Noor, C.S. Chong, L.C. Stringer, and R.O. Yusuf, "Energy consumption trends and their linkages with renewable energy policies in East and Southeast Asian countries: Challenges and opportunities," *Sustain. Environ. Res.*, vol. 28, no. 6, pp. 257–266, 2018.

[4] S. Luthra, S. Kumar, R. Kharb, M.F. Ansari, and S.L. Shimmi, "Adoption of smart grid technologies: An analysis of interactions among barriers," *Renew. Sustain. Energy Rev.*, vol. 33, pp. 554–565, 2014.

[5] B. Bora, R. Kumar, O.S. Sastry, B. Prasad, S. Mondal, and A.K. Tripathi, "Energy rating estimation of PV module technologies for different climatic conditions," *Sol. Energy*, vol. 174, pp. 901–911, 2018.

[6] Y. Kwon, A. Kwasinski, and A. Kwasinski, "Solar irradiance forecast using naïve Bayes classifier based on publicly available weather forecasting variables," *Energies*, vol. 12, no. 8, pp. 1–13, 2019.

[7] B. Navothna and S. Thotakura, "Analysis on large-scale solar PV plant energy performance–loss–degradation in coastal climates of India," *Front. Energy Res.*, vol. 10, 2022.

[8] M. Bhatnagar, J. Mathur, V. Garg, and J. Iqbal, "Development of a method for selection of representative city in a climate zone," *Ashrae.org.*, vol. 8, pp. 510–517, 2018.

[9] A.K. Berwal, "Development of Statistical Model to Evaluate the Effect of Meteorological Parameters on the Performance of PV-Cell/Module," *Journal of Advanced Research in Alternative Energy, Environment and Ecology*, no. 1, pp. 1–7, 2020.

[10] A.S. Al-Ezzi and M.N.M. Ansari, "Photovoltaic solar cells: A review," *Appl. Syst. Innov.*, vol. 5, no. 4, p. 67, 2022.

[11] M.A.M. Ramli, A. Hiendro, and Y.A. Al-Turki, "Techno-economic energy analysis of wind/solar hybrid system: Case study for western coastal area of Saudi Arabia," *Renew. Energy*, vol. 91, no. C, pp. 374–385, 2016.