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The Assessment of Global Wind Power Generation at Jhimpir Pakistan: A Case Study

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Abstract

Energy is the key mover for any country's development. In today's era, the demand for energy is rapidly increasing and the cost of power is also increasing due to the lack of fossil fuels (coal, gas, and oil). To overcome the increasing demand and worst crises of non-renewable energy resources, the present solution is to move towards renewable energy. Sindh is a province of Pakistan that has the immense capability and prospect of neat and green energy production. The major locations for renewable energy resources are found in the city of Jhimpir, for wind power, in the district of Thatta, Sindh. Wind power generation is clean, eco-friendly, and easily maintainable. Different power companies are intensively taking part in investments to enhance wind generation and overcome the shortage of power in Pakistan. One of the quick promoting renewable energy is wind energy which is founded on freely available natural resources, in Jhimpir Sindh. This study aims to initiate the wind power analysis, total generating capacity, present scenario, and for wind energy present at different sites in Thatta Jhimpir. The comparison between daily data with six-hour data is carried out through statistical analysis at 10m to calculate the wind speed and direction. The private company has carried out the survey to measure the wind speed and compared data from the analysis, reanalysis, and forecast datasets. The geographical location where the mast was installed is 25.1330 N and 67.9950 E. The mast consists of five anemometers for wind speed measurement such as 85m, 60m, 30m, and 10m, and two wind vanes of 83.5m, and 28.5m for measurement of wind direction. The three years of data were used to evaluate the wind data from the datasets for this study. The researchers evaluated the NCEP-NCAR data in the Gharo region using the WRF simulated model at the height of 10m and 30m. In this study, we have analyzed the five datasets NCEP-NCAR, 20C, CFSR, GFS, and NCEP-FNL to measure the wind data at the height of 10m.

Index Terms: *Eco-Friendly, Fossil Fuels, Statistical Analysis, Wind Energy, Wind Turbines.*

I. INTRODUCTION

Energy is the key mover for any country's development. In today's era, the demand for energy is rapidly increasing and the cost of power is also increasing due to the lack of fossil fuels i.e., coal, gas, and oil [1]. Renewable energy is the best solution to meet the demand for energy in Pakistan. Presently Pakistan is facing financial problems due to that the new power generation plants based on coal, gas, and diesel cannot be installed [2]. Energy is the pillar of any country for development in order to run their industrial, commercial, and residential loads properly because all consumers of electricity are now demanding an uninterruptable power supply to run their loads properly [3]. Every country wants to run its industrial sector properly for development but due to the power quality problems and shortage of power, the required output is badly affected [4]. Power quality can be improved by installing the devices but the shortage of power is a serious problem for proper manufacturing in the industrial sector [5], and [6]. The shortfall of electrical power is increasing day by day in Pakistan, cities are facing 6 to 8 hours of daily load shedding, while villages are facing more than 12 hours daily, and some of the villages are without electricity [2]. Wind power is a clean, eco-friendly, and maintainable power-producing sector [7]. Different power companies are intensively taking part in investments to enhance wind generation and overcome the shortage of electrical power in Pakistan [8], and [9]. The utilization of oil and coal since 2015 has increased so we cannot rely more on oil and coal due to cost, also it will directly hit the economy of the country [10]. Natural gas is available in Pakistan but the Oil and Gas Development Company Limited (OGDCL) has declared that the natural gas reserves will decline from 2025 to 2030 so we cannot rely on natural gas for the installation of more power plants in Pakistan in order to meet the power demand [11]. Most countries are moving towards the production of power through renewable energy sources such as wind power generation which is the second large source of power generation and produces more than 6% of power globally [12]. China has installed wind power plants with a generation capacity of 282 GW up to 2020 and America has wind generation of 118 GW up to 2020 [13]. Pakistan is among the countries which produce power through wind sources. Sindh is a province of Pakistan with a huge potential to produce wind energy. The major locations for renewable resources are found in the city of Jhimpir, Thatta district, especially for wind power. The speed of wind is more than 7 m/s above 60m [11]. Different power companies are investing intensively to enhance wind power generation and overcome the shortage of power in Pakistan also founding freely available natural resources in Jhimpir Sindh [14].

The wind power plant at Jhimpir was developed by 'Zorlu Energy Pakistan', with an installation cost of 143 million having an installed capacity of 56.4 MW, for providing green and clean energy to the utility companies of Pakistan [10]. The 3.36 mean Weibull parameter and 8.94 m/s standard deviations are found and the performance of wind is evaluated for the two years [14].

This study aims to initiate the; wind power analysis, total generating capacity, and present scenario at the different sites in Thatta Jhimpir Pakistan. The comparison between daily data with six-hour data is carried out through statistical analysis by analyzing the wind speed and direction in order to produce the maximum power through wind. The private company has carried out a survey to measure the wind speed and compared the data from the analysis/reanalysis, and forecast the datasets [15]. The geographical location where the mast was installed was 25.1330 N and 67.9950 E.

The mast consists of five 'Anemometers' for wind speed measurements such as 85m, 60m, 30m, and 10m, and two 'Wind Vanes' of 83.5m, and 28.5m for measurement of wind direction [16].

The three years of data were used to evaluate the wind data from the datasets for this study [17]. The researchers evaluated the NCEP-NCAR data in the Gharo region using the WRF simulated model at the height of 10m and 30m. In this study, we have analyzed the five datasets NCEP-NCAR, 20C, CFSR, GFS, and NCEP-FNL to measure the wind data at the height of 10m.

II. WIND POWER PLANT

The Power which can be produced through wind sources is also known as renewable energy power [18]. Every country is now moving towards wind power generation due to the fact that this energy is both, environment friendly and less costly. Figure I shows the generation of power through wind globally up to 2020.

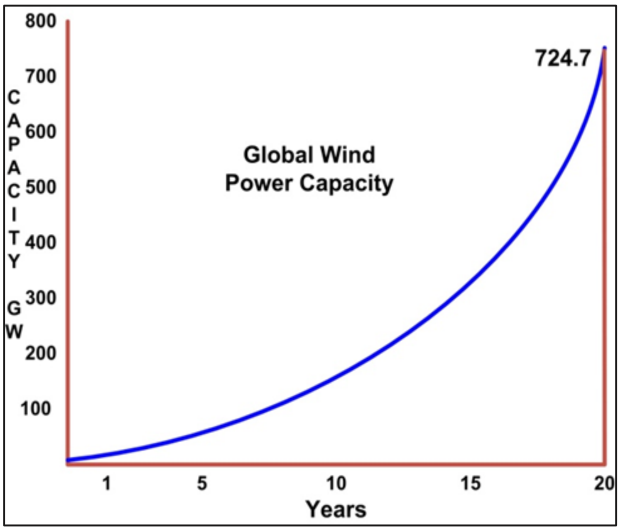


Figure I: Worldwide Wind Energy Installed Capacity

Table I shows the details of wind power generation in the different countries up to 2020 [19].

Table I: Wind Energy in the World

S. No.	Country	Capacity in GW
1	China	281.99
2	EUR	201.49
3	USA	117.74
4	Germany	62.184
5	India	38.889
6	Spain	27.09
7	UK	24.665
8	France	17.382
9	Brazil	17.198
10	Canada	13.377
11	Italy	10.839
12	Sweden	9.688
13	Australia	9.657
14	Turkey	8.832
15	Mexico	8.821
16	Netherland	6.6
17	Poland	6.267
18	Denmark	6.235
19	Belgium	4.692
20	Ireland	4.3
21	Pakistan	1287 MW

According to the report of ERNA, the generation capacity of wind energy has increased and reached 622,704 MW. The 60,400 MW was added only in 2020 [20]. The generation capacity of wind power in Pakistan was only 1287 MW in 2018 and the Government of Pakistan had planned to extend the wind power generation up to 3.5 GW in the later years [10].

A. Wind Turbine

The wind turbine is the main component of power generation through wind [21]. It consists of five major components such as foundation, tower, rotor, nacelle, and generator. Figure II shows the major components of wind turbines [22].

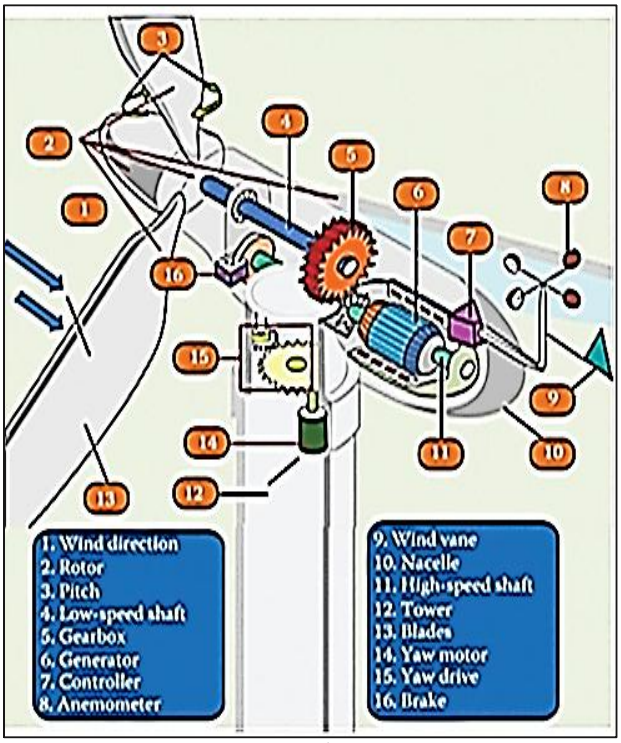


Figure II: Parts of Wind Turbine

The foundation of the onshore turbine is made underground and covered with soil. The foundation of the offshore turbine is underwater and cannot be seen [23]. The diameter of the tower is around 3-4 meters and the height is 75-110 meters depending upon the size of the turbine and its location [24]. The rotor is the rotating part of the turbine and it consists of three blades with a center hub [25]. It is not necessary for the turbine to have three blades but two and four blades systems are also available. The three blades systems have more efficiency than others comparatively [26]. The function of the hub is to hold the blades. The nacelle is built on top of the tower to accommodate all the components on the top [27]. Below, figure III shows the three-blade wind turbine; figure IV shows the typical curve for the wind turbine, and; figure V shows the power Vs velocity.

Figure III: Three Blade Wind Turbine

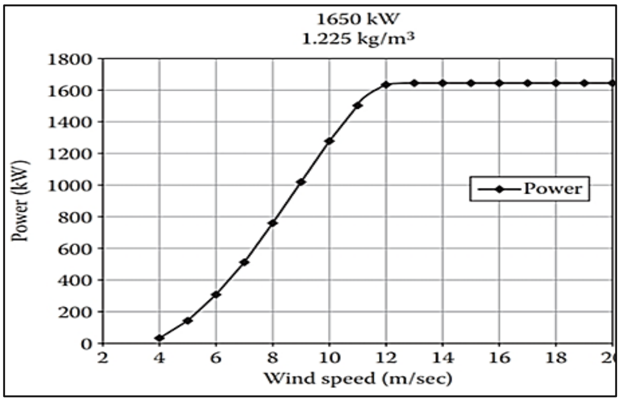


Figure IV: Typical Power Curve for a Wind Turbine

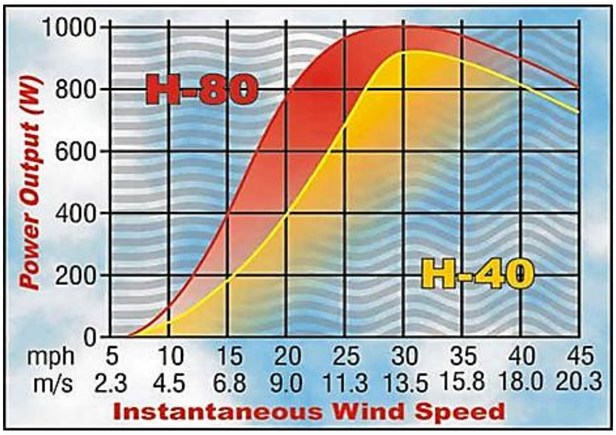


Figure V: Power Vs Velocity

In the past wind turbines required more space i.e., the formulation of wind turbines required thousands of acres, but after the development of onshore turbines, this space is reduced and produces 2-5 MW power [28].

Off-shore wind turbines are also used but they have a high installation cost due to that only small projects can be developed [12]. Due to the high initial cost of offshore turbines, the 30 MW project started work in 2020 [29]. The graphite-fiber in epoxy material was utilized for the development of wind turbines of a 60m radius, which is enough to produce a few MW of power [11]. Wind power captured by turbines is proportional to the square of their blade length. The maximum blade length of a turbine depends on the strength and stiffness of its material [27]. The speed of wind blows is higher at higher altitudes due to the pull of the land and air viscosity. Wind shear also called the change in velocity with altitude is more striking near the surface [14].

Typically change followed 1/7 of a power law, which is expected that the increase in wind speed is proportional to the 7^{th} root of altitude [21]. When we increase the altitude two times than the 10% speed of wind is increased. Turbines can be made with any number of blades, small scale wind turbines are made with whisper 175 with two blades because these turbines are easy to construct and ship. Three-blade wind turbines are more efficient but more complicated in construction at sites [20]. Table II shows the types of wind turbines.

Table II: Wind Turbines

S. No.	Types of Wind Turbines	
	VAWT	**HAWT**
1	Drag is the Main Force	Lift is the Main Source
2	The nacelle is Placed at the Bottom of the Tower	The nacelle is Placed at the Top of the Tower
3	YAW Mechanism is not Required	YAW Mechanism is Required
4	Difficult in Mounting	95% of HAWT Turbines
5	Unwanted Fluctuations in the Output and Low Starting Torque	Much Lower Cyclic Stresses

III. WIND POWER GENERATION AT JHIMPIR

Sindh province of Pakistan has good locations to install the wind power plant. The wind power plants are available in Gharo, Jhimpir, and Canister Qasim in the area of Sindh. The metrological department of Pakistan carried out a survey regarding the selection of potential areas for the production of power through wind.

After a survey, they have decided that the Jhimpir which is located in the Thatta district of Sindh 120 Km North-East of Karachi is the ideal location where wind power can be produced with a covered area of 9700 Km^2 and with a power potential of 43000 MW. The wind power plant at Jhimpir was developed by Zorlu Energy Pakistan with an installation cost of 143 million. Jhimpir power plant is located in the Sindh province with an installed capacity of 56.4 MW, providing green and clean energy to the utility companies of Pakistan.

In the initial stage, the German company provided six wind turbines that have the capability to produce 1.2 MW, and generated power was provided to the power utility company, Hyderabad Electric Supply Company (HESCO) Sindh in 2009. In the next stage, the 28 wind turbines were provided by Denmark with a capacity of 1.2 MW. The total generation of wind power at Jhimpir was increased to 56.4 MW and this project was completed in 2013. The 3.36 mean Weibull parameter and 8.94 m/s standard deviations are found and the performance of wind is evaluated for the two years. The real availability is calculated to be 90-97% subject to the non-availability of disturbances such as failure of turbine components, lower wind, and grid loss. Table III shows the wind power projects at Jhimpir with their respective generation capacity.

Table III: Wind Energy in Jhimpir

S. No.	Country	Capacity in MW
1	Zorlu Wind Energy	56.4
2	Metro Energy	50
4	TNB Power Plant	50
5	Sapphire Wind Power Plant	50.2
6	Three Gorges First Wind Farm	50
7	Artistic Energy (Pvt.) Ltd	49.2
8	Tricon Boston	150
9	FFC Energy Limited	49.5
10	Yunus Energy Limited	50
11	Master Wind Energy	52.8
12	Din Energy	50
13	Gul Ahmed Wind Energy	50
14	Sachal Energy	49.5
14	UEP Wind Power	100
15	Jhimpir Wind Power	49.7
16	Hawa Energy	49.7
17	Hartfort Alternative Energy	49.3

IV. METHODOLOGY

For the installation of the power project, it is necessary to compare the mast-measured data and datasets to evaluate the potential of the site. The four methods are proposed in this research to evaluate the speed of the wind at Jhimpir Sindh through analysis of dataset and mast measured data. The analysis is carried out through statistical methods. The statistical method helps in determining the different parameters such as wind speed. So we can calculate the Mean Absolute Error (MAE), Root Mean Square Error (RMSE), Correlation Coefficient (R), and Mean Bias Error (MBE), through statistical analysis. The wind speed data on the mast location was calculated through the nearby location of grid stations. They are available at a temporal resolution of three hours (20C) and six hours (NCEP-NCAR, CFSR, GFS, and NCEP-FNL), 20th-century data had been converted into six hours.

The reanalysis of wind speed data at the mast location was calculated from the four nearby grid stations by using bilinear interpolation. The data from datasets were converted to daily mean for comparison. The surface measured data has a resolution of ten minutes, so six hourly and daily data were calculated in this study.

V. RESULTS

The results obtained through the statistical analysis are tabulated in Table IV. The statistical analysis parameters MBE, MAE, RMSE, and R are computed from datasets and measured data of wind speed for the temporal basis on six hours and one day. The positive bias in wind speed represents the data from datasets is overestimated and lower values of error represent the high value of Correlation Coefficient (R) for wind speed. The overall wind biases are negative so they indicate the wind speed which is affected by satellite. CFSR data shows an overall good comparison of six hours daily.

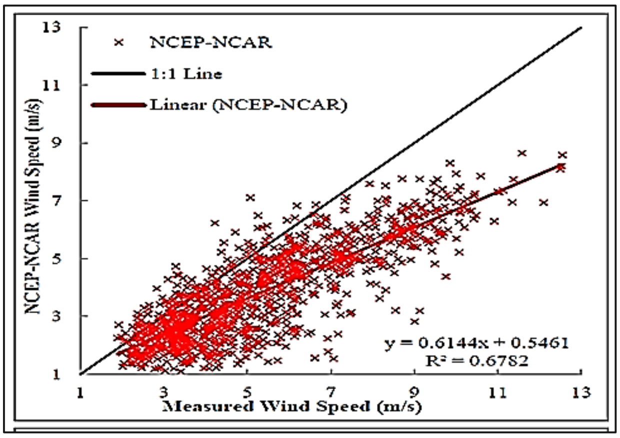
It has been seen in table IV that the statistical parameters on daily basis are better than the six-hour data. For six-hourly data, the 20C bias is smaller but a value of R is higher and CFSR has smaller MAE, MBE, MAE, and RMSE but a high value of R.

Figure VI shows the correlation between the surface measured and the dataset's wind speed. The correlation between the measured data and data from the dataset mean daily wind speed at 10m height is shown in figure VI.

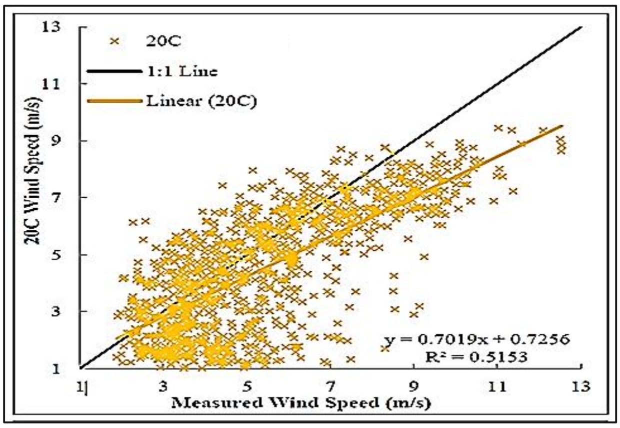
The horizontal axis in the scatter plot measured wind speed and the vertical axis shows the wind speed estimated by satellite. The best-fit line of correlation between both data sets along with 1:1 is presented. The equation best-fit line is also presented and the gradient is close to 1 and intercepts close to zero for better comparison. The highest gradients are in 20C and second best in CFSR, with the highest value of intercept in 20C and the lowest value for CFSR.

Table IV: Comparison between Measured and Wind Data from Datasets at 10m

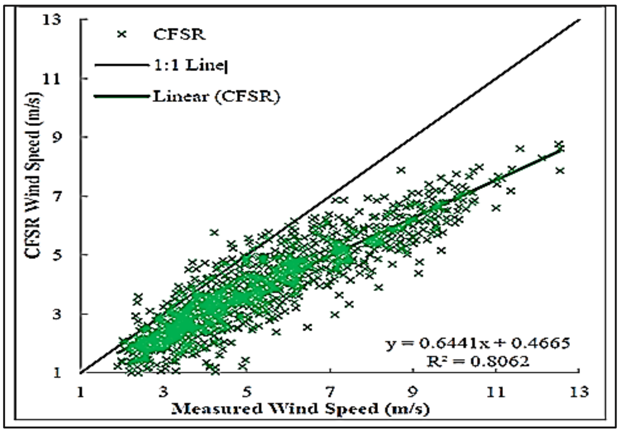
Temporal Resolution	Satellite Data	MBE	MAE	RMSE	R
		Speed m/s	Speed m/s	Speed m/s	Speed m/s
Six Hour	NCEP-NCAR	-1.51	1.85	2.33	0.700
	20C	**-0.86**	1.71	2.17	0.642
	CFSR	-1.42	**1.66**	**2.08**	**0.784**
	GFS	-1.59	1.90	2.40	0.681
	NCEP-FNL	-1.72	1.99	2.49	0.679
Daily	NCEP-NCAR	-1.52	1.60	1.94	0.822
	20C	**-0.86**	**1.43**	1.82	0.717
	CFSR	-1.43	1.48	**1.76**	**0.896**
	GFS	-1.60	1.64	2.03	0.820
	NCEP-FNL	-1.73	1.75	2.14	0.823



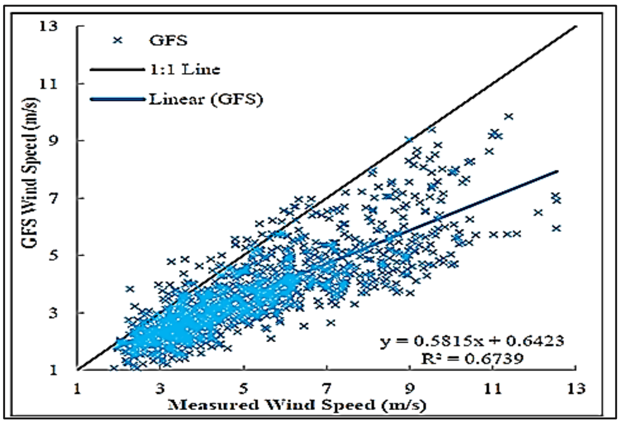
(a)



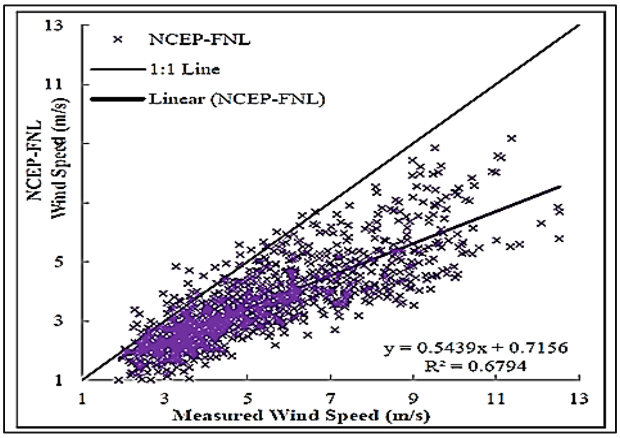
(b)



(c)



(d)



(e)

Figure VI: (a-e) Shows the Correlation between Surface Measured and the Dataset's Wind Speed

VI. DISCUSSION

Energy is the basic requirement for the development of the country. Fossil fuels are utilized for twenty years but nowadays the cost has increased and not easy for low-income countries to produce the energy at smaller rates. So renewable energy sources are the best solution to meet the demand for power at affordable rates. Wind energy is the key source from which we can get environment-friendly energy. The development of wind power plants is increasing day by day throughout the world and also Pakistan is one of them. Now a day's wind turbines are available for a large rating which can produce power in large amounts. There are two primary physical principles by which energy can be taken out from the wind; these are the creation of either 'Drag' or 'Lift Force' (or through a combination of the two), drag is in the direction of airflow, and lift is perpendicular to the direction of airflow. It has been seen that the statistical parameters on daily basis are better than the six-hour data.

VII. CONCLUSIONS

In this paper, the assessment of a local wind power plant has been carried out for a wind farm located at Jhimpir, Pakistan. It is concluded that the analysis and investigation outcome shows that the Sindh province selected for the said study has a massive wind potential with 10 m/s wind speed. The power coefficient is dropped if wind speed crosses the rated power. The efficiency of a wind turbine is decreased due to the increase in wind speed (m/s). Wind turbines work efficiently at wind speeds between 6 to 10 m/s. So it is concluded that we can produce the maximum power of up to 43000 MW in the area of Jhimpir, and also statistical analysis is carried out to analyze the different parameters. So the Pakistan government must give attention to the generation of power at a large scale to meet the demand of the consumers.

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Authors Contributions

The contribution of the authors was as follows: Abdul Hameed Soomro's contribution to this study was the concept, technical implementation, and correspondence. The methodology to conduct this research work was proposed by Maryam Abbasi along with facilitation in data compilation and validation. Data collection and supervision were performed by Saira Umer. Eman Shaikh's contribution was project administration, and paper writing.

Conflict of Interest

The authors declare no conflict of interest and confirm that this work is original and not plagiarized from any other source, i.e., electronic or print media. The information obtained from all of the sources is properly recognized and cited below.

Data Availability Statement

The testing data is available in this paper.

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