WIND ENERGY POTENTIAL MAPPING IN INDIA

A PROJECT REPORT

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Abstract:

Renewable energies such as wind begin receiving remarkable popularity in accordance with the energy demand, expeditious expansion of solar and wind energy generation involves acute forecasting of wind, so in past and recent years it has become an intensive research area. An accurate forecast of wind power to maintain an affordable, secure, and economical power supply is most significant. Numerous investigations and research have been performed in this area in recent years.[2]

Wind energy is available without any cost and it does not emit any greenhouse gases. This makes it a great source of energy production for any developing state. The field of wind energy has tremendous scope for innovation, translating to real world applications and tremendous economic opportunity. It is crucially important for India, as our economy continues to evolve, and we must ensure every Indian has access to opportunity, decent jobs and livelihood. For that we will need greater resources. Clean, sustainable, renewable - and equally important, domestic sources of energy are essential to fulfill the potential of India in the coming years and it is certain that wind energy will play a major part in shaping India's future. .[6]

Wind energy is widely distributed in India as a renewable energy source. Aiming to alleviate the issues resulting from fossil fuel consumption faced by developing and developed countries (e.g., climate change) and to meet development needs, this study focuses on the location selection of wind farms and wind turbines in areas based on the various factors like wind speed , elevation ,distance from sea shore etc. Considering that the wind turbine location is crucial to wind power generation, this project focuses on areas we can set up wind turbines/farms.[1]

Introduction:

India is the home of 1.45 billon people i.e. 17.78% of the total world population, which makes it most populous country in world. India has the second fastest growing economy of the world. India’s substantial and sustained economic growth over the years is placing enormous demand on its energy resources. The electricity sector in India had an installed capacity of 253.389 GW as of August 2014.India became the world's third largest producer of electricity in the year 2013 with 4.8% global share in electricity generation surpassing Japan and Russia. Power development in India was first started in 1897 in Darjeeling, followed by commissioning of a hydropower station at Sivasamudram in Karnataka during 1902. Thermal power stations which generate electricity more than 1000 MW are referred as Super Thermal Power Stations. India's electricity generation capacity additions from 1950 to 1985 were very low when compared to developed nations. Since 1990, India has been one of the fastest growing markets for new electricity generation capacity. India's electricity generation capacity has increased from 179 TW-h in 1985 to 1053 TW-h in 2012. Wind energy is indigenous and helps in reducing the dependency on fossil fuels. Wind occurrence is due to the differential heating of the earth's crust by the sun. Approximately 10 million MW of wind energy is continuously available to India. India's Power Finance Corporation Limited projects that current and approved electricity capacity addition projects in India are expected to add about 100 GW of installed capacity between 2012 and 2017. This growth makes India one of the fastest growing markets for electricity infrastructure equipment. Of the 1.4 billion people of the world who have no access to electricity in the world, India accounts for over 300 million. The International Energy Agency estimates India will add between 600 GW to 1,200 GW of additional new power generation capacity before 2050. To fill the needs of the energy of this population, India have to look towards non conventional energy resource which can fill a huge demand of energy generated by the population of India. India is fulfilling its 85% of energy demand from the conventional recourses such as coal, nuclear energy, natural gas and petroleum which generate many greenhouse gases. Green houses gases- carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrous oxide (N_2O) etc. are produced in the energy generation process are not only harmful for people's health but it also deteriorates the environment vis-à-vis global warming and hole in the ozone layer. Thus it is the need of time that country should look towards the green & renewable methods for the generation of energy so that environment can be saved from those harmful effects. Wind energy, solar energy, biomass & other renewable methods can be used for the generation of energy to fulfill the energy demands of the country.[6]

With the continuous depletion of non-renewable energy sources, such as coal and oil, the shortage of fossil energy and the search for renewable energy have become new problems facing the development of the world. The primary sources of renewable energy are the sun, wind, ocean, etc., which have the advantages of large reserves and low emissions, among which wind energy is also considered as renewable energy with the most potential for development.[1]

Renewable energy is now becoming increasingly important as countries around the world seek to achieve carbon neutrality. Wind power generation increased by 10% globally in 2017. Denmark is the pioneer, with wind turbines providing 44 percent of its electricity. [2]

Based on a literature review, it is found that substantial research efforts by scholars have been dedicated to determining optimal locations for wind farms, which can be categorized into the locations of onshore or offshore wind farms. This dichotomy highlights the importance of considering distinct environments for developing wind energy projects.[1]

Objective of the Project:

The primary objective of this project is twofold:

1.Generation of Dataset for Wind Farm Site Selection: The second objective is to generate a dataset containing random geographic points for each state in India. This dataset will include key environmental variables such as wind speed, elevation, and distance to coastlines. The data will serve as a resource for optimizing wind farm site selection, ensuring that areas with the best conditions for wind energy generation are prioritized.

2.**Assessment of Wind Energy Potential**: The first objective is to assess wind energy potential across Indian states by analyzing wind speed, elevation, and proximity to coastlines using geospatial data. This analysis will help identify regions with high wind energy potential, enabling effective allocation of resources for wind energy development.

<u>Dataset Creation and Data Extraction Process:</u>

The dataset for this project was developed in Python, integrating geographic and meteorological data specific to India. Initially, a <u>shapefile (.shp)</u> served as a vector data format to store India's geographic features, including location, shape, and relevant attributes. This shapefile provided the structural outline within which various environmental data, such as elevation above sea level, wind speed, and other weather-related characteristics, were extracted.For the extraction of feature data, <u>TIFF[3]</u> (Tagged Image File Format) files were employed to manage raster graphics and image data. Using Python's Raster library, data were precisely extracted at latitude and longitude coordinates derived from the shapefile of India. Raster datasets, represented through arrays of cells or pixels, enabled accurate modeling of real-world entities like surface temperatures and digital elevation models.To calculate the "nearest distance from seashore," an additional shapefile for India's coastline was used, allowing for accurate computation of each data point's proximity to the shore. The project also incorporated a sampling approach in which 100 data points were randomly generated from each Indian state and union territory, ensuring a comprehensive geographic representation across the country. Finally, all extracted data were systematically stored in a CSV file, providing a structured format for further analysis and streamlined accessibility.The dataset used is shown below

STATE	longitude	latitude	wind_speed (m/s)	distance_to_seashore (km)	elevation (m)	temperature (C)	humidity (%)	air_density (kg/m^3)
JAMMU AN	75.81578	34.456748	5.4057374	1339.35001	3798	21	65	1.12
JAMMU AN	76.795108	33.479497	4.9437666	1293.852416	4303	21	65	1.12
JAMMU AN	75.439667	34.391441	3.78182	1319.563054	4338	21	65	1.12
JAMMU AN	75.793579	34.12264	8.870201	1304.484655	5037	21	65	1.12
JAMMU AN	77.46023	32.819307	3.263829	1246.270083	4624	21	65	1.12
JAMMU AN	76.593671	33.585248	8.518707	1299.334511	5581	21	65	1.12
JAMMU AN	76.684974	33.485512	6.921151	1291.372698	5199	21	65	1.12
JAMMU AN	75.458691	34.517125	3.7869701	1333.179858	4081	21	65	1.12
JAMMU AN	75.807141	34.425869	4.528658	1335.886372	3069	21	65	1.12
JAMMU AN	77.189485	32.919688	7.318989	1247.428044	5317	21	65	1.12
JAMMU AN	76.407198	34.121138	5.5047393	1328.050978	5161	21	65	1.12

FIGURE-1

Data Visualisation:-

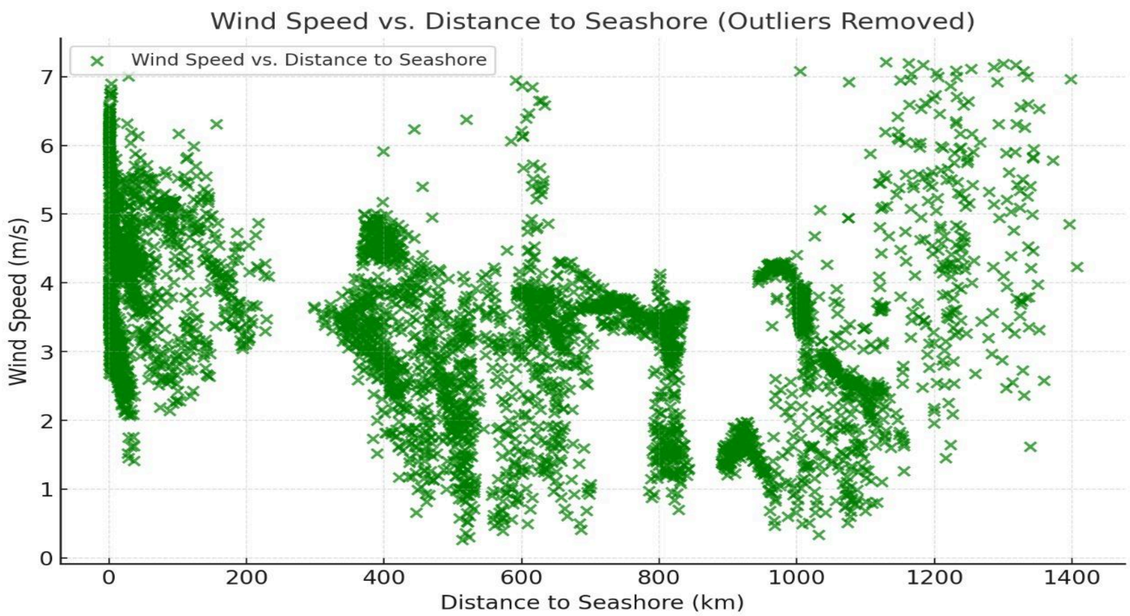

FIGURE-2

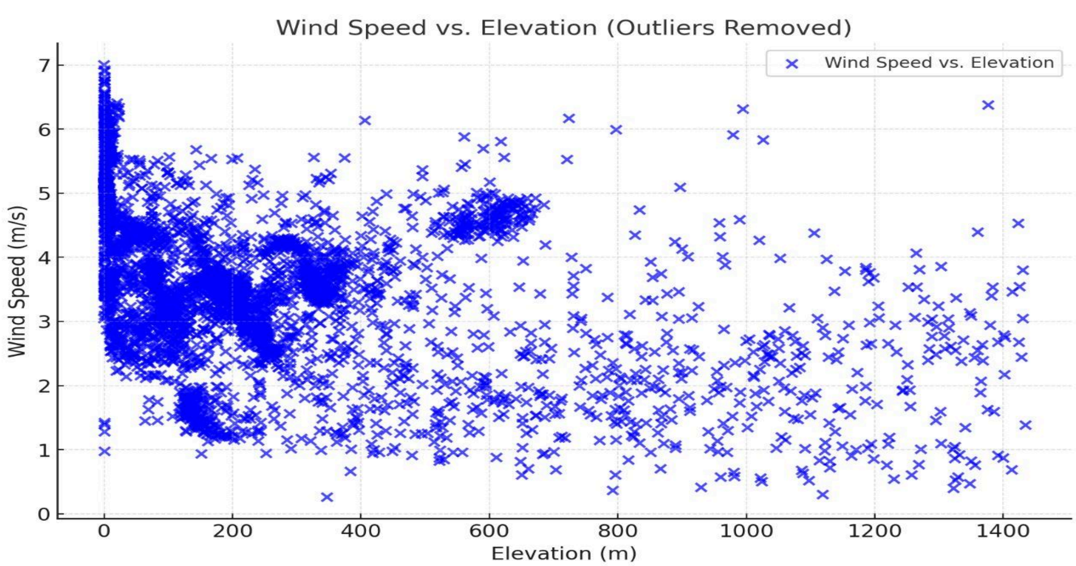

FIGURE-3

Experimental Procedure:-

Input Features: The model takes features like longitude, latitude, distance to seashore, elevation, temperature, humidity, and air density as input.

Feature Processing: These inputs are processed through hidden layers to learn patterns and relationships using non-linear transformations.

Output Prediction: The final layer outputs the predicted wind speed in meters per second.

Learning and Optimization: The model minimizes prediction errors during training using the Adam optimizer and Mean Squared Error loss.

Model Overview:-

This model is a feedforward neural network with three primary layers:

1.Input Layer: Specifies the input dimensions, matching the features in the dataset.

2.Hidden Layers: Two layers that extract meaningful patterns from the input data through a series of transformations.

3.Output Layer: Produces the final prediction as a single continuous value.

The model's design leverages the power of non-linear activations and robust optimization techniques to achieve high performance on regression tasks.

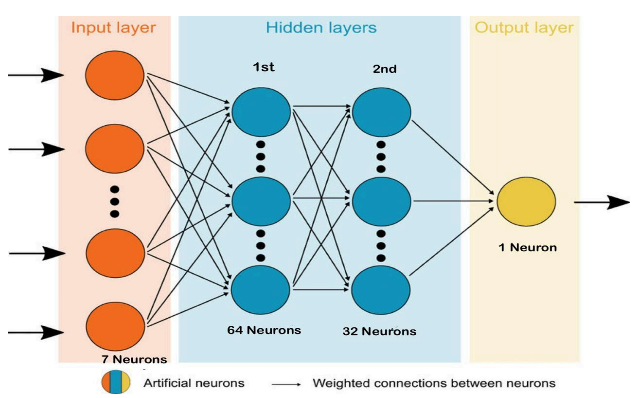

FIGURE-4

Layer-by-Layer Breakdown:

1. Input Layer

- Purpose: It defines the input shape of the data, which corresponds to the number of features in your dataset.
- This layer does not perform any computation but acts as an entry point, feeding the data into the subsequent layers for processing.

2. First Hidden Layer

- Neurons: Contains 64 neurons.
- Activation Function: Uses the ReLU (Rectified Linear Unit) activation function.

- ReLU introduces non-linearity into the model, enabling it to learn complex relationships in the data. It outputs the input directly if positive; otherwise, it outputs zero.
- Role: Processes the input data, learns high-level patterns, and passes these representations to the next layer.

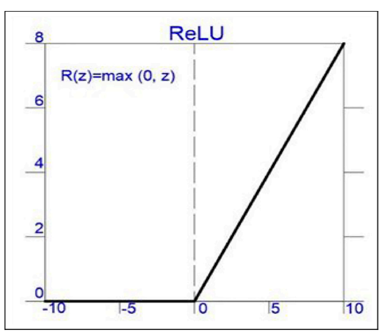

FIGURE-5

3. Second Hidden Layer

- Neurons: Contains 32 neurons.
- Activation Function: Also uses the ReLU activation.

- Role: Further refines and extracts patterns from the features learned by the first hidden layer, enabling deeper insights into the data.

4. Output Layer
- Neurons: Contains 1 neuron.
- Activation Function: No activation function is applied, resulting in a linear output.
- Role: Produces a single continuous value, which is the model's prediction. This makes it suitable for regression tasks where the target variable is continuous .

Model Compilation:-

- **Optimizer:** The model uses the Adam optimizer, which combines the advantages of AdaGrad and RMSProp. It adapts the learning rate dynamically for each parameter, ensuring faster convergence and effective handling of sparse gradients.
- **Loss Function:** The loss function is Mean Squared Error (MSE). MSE penalizes large errors by squaring them, making it suitable for regression tasks as it emphasizes accuracy.

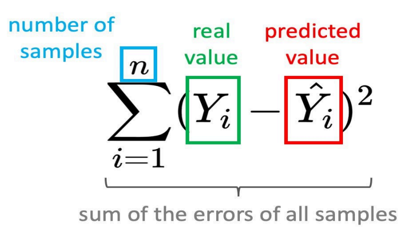

FIGURE-6

- **Evaluation Metric:** During training and testing, the model monitors Mean Absolute Error (MAE). MAE provides an intuitive understanding of model performance in the same units as the target variable.

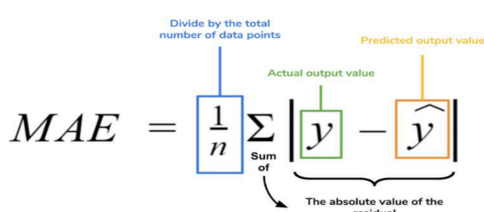

FIGURE-7

Training Process:-

- **Epochs:** The model is trained for 80 epochs, meaning it completes 80 passes through the entire training dataset.
- **Batch Size**: A batch size of 16 is used, meaning the model processes 16 samples at a time before updating its weights.
- **Validation Split:** 20% of the training data is set aside for validation. This ensures the model's performance is monitored on unseen data during training, helping to identify overfitting or underfitting.

Evaluation:-

After training, the model is evaluated on a separate test dataset. The evaluation process calculates:

- **Test Loss**: The Mean Squared Error on the test set.
- **Test MAE:** The Mean Absolute Error, which provides an interpretable measure of how close the model's predictions are to the actual values.

Key Features of the Model:-

1. **Non-linearity:** ReLU activations in the hidden layers allow the model to learn non-linear patterns, making it capable of handling complex relationships in data.
2. **Compact Design:** The architecture has two hidden layers with a reasonable number of neurons, balancing complexity and computational efficiency.
3. **Robust Optimization:** The Adam optimizer ensures efficient and stable learning across epochs.
4. **Regression Capability:** The final layer outputs a single continuous value, tailored for regression problems.

EXPERIMENTAL RESULTS:-

Accuracy	85%
Mean Absolute Error (MAE)	0.45
Mean Squared Error (MSE)	0.49
Root Mean Squared Error(RMSE)	0.70
R^2	0.78
Mean of target variable	3

FIGURE-8

Here in this work, we present an ML-based model that will predict the wind speed of a certain location based on the aforementioned features.

Experimental results are promising with **85% accuracy.**

Conclusion:-

This project explored the potential of wind energy in India and developed a machine learning model for wind speed prediction.It included

> **Dataset Generation:** A comprehensive dataset containing geographic points across Indian states was created. It incorporated critical environmental variables like wind speed, elevation, and distance to coastlines, providing a valuable resource for wind farm site selection.
>
> **Wind Energy Potential Assessment:** The analysis of wind speed, elevation, and proximity to coastlines revealed regions with high wind energy potential across India. This information can guide policymakers and renewable energy companies in prioritizing areas for wind farm development.
>
> **Machine Learning Model:** A feedforward neural network model was developed to predict wind speed based on various input features. The model achieved an accuracy of 85%, demonstrating its effectiveness in estimating wind speed for wind farm site selection.

India is a land of unlimited potential, but that potential is not getting used in effective manner. Wind energy is a great source to fulfill India's energy needs as well as develop its economy. Future and development of India depends upon many factors: one of them is being self dependent for its energy demands. It will free.India from its dependency on other countries for nuclear energy generation. Although Government's plans look ambitious now but it certainly aims to be self-reliant. Of all the major renewable sources they are primarily focusing on wind (generation and distribution). But, there are some limitations with implementation of this technology that must be considered. Wind turbines cannot be set up in many of the unused areas because it requires a huge amount of capital investment. Therefore, cost of wind turbines should be less so that they can be easily planted in more areas. Many research and development centers should be opened for the further enhancement and progress of wind power. Subject regarding to wind power technology and other renewable energy technologies must be introduced in colleges and schools which may increase its scope in future tremendously. In India, metros network can be a great source of wind power generation as it will need lighter equipment than conventional wind turbines to harness the wind generated by commute of metro trains. In some cities metro rails are already running and in several other cities government is planning to run it. So, lighter wind turbines can be installed at sites of the metro tracks so without much extra investment wind energy can be generated.Right now India's is headed on an increasing graph with a slower slope than before. Iit will have to keep the slope of this growth rate steeper if it wishes to achieve its targets in energy sector.[6]

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