Final Project report

Predicting The Energy Output Of Wind Turbine Based On Weather Condition

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INTRODUCTION

- Overview:

Wind power generation is increasing rapidly and the availability of wind energy depends on wind speed, which is a random variable. This highly depends on the weather conditions at that place.

In our project, we propose an intelligent technique for forecasting wind speed and power output of a wind turbine from several hours up to 72 hours ahead. We will carry out this problem on publicly available weather and energy data sets correlating and considering different features in our project.

We will be able to predict the energy output of wind turbine.

Services (Cloud function , Watson Studio). By the end of the project, we'll learn best practices of combining Watson services, and how they can build interactive information retrieval systems with Cloud Functions + Watson Studio .

a. . **Project Requirements**:

Python, IBM Cloud, IBMWatson

b. . **Functional Requirements**:

IBM cloud

c. . **Technical Requirements**:

ML,WATSON STUDIO,PYTHON

d. . **Software Requirements**:

Watson assistant, PYTHON.

- Purpose:

Wind speed/power has received increasing attention around the earth due to its renewable nature as well as environmental friendliness. With the global installed wind power capacity rapidly increasing, the wind industry is growing into a large-scale business. Reliable short-term wind speed forecasts play a practical and crucial role in wind energy conversion systems, such as the dynamic control of wind turbines and power system scheduling. A precise forecast needs to overcome problems of variable energy production caused by fluctuating weather conditions. Power generated by wind is highly dependent on the wind speed. Though it is highly non-linear, wind speed follows a certain pattern over a certain period of time. We exploit this time series pattern to gain useful information and use it for power prediction.

LITERATURE SURVEY

- EXISTING PROBLEM:

There exist a number of technological, environmental and political challenges linked to supplementing existing electricity generation capacities with wind energy. Here, mathematicians and statisticians could make a substantial contribution at the interface of meteorology and decision-making, in connection with the generation of forecasts tailored to the various operational decision problems involved. Indeed, while wind energy may be seen as an environmentally friendly source of energy, full benefits from its usage can only be obtained if one is able to accommodate its variability and limited predictability. Based on a short presentation of its physical basics, the importance of considering wind power generation as a stochastic process is motivated. The conventional moving-average statistical models were proven to be less efficient in forecasting the wind energy, as the wind speed is inherently variable quantity.

- PROPOSED SOLUTION:

To overcome the disadvantages of conventional models, advanced deep learning models such as LSTM (Long Short Term Memory) , can be used to map the inherently variable attribute to a complex function. LSTM is well-suited to predict time series given time lags of unknown duration. Relative insensitivity to gap length gives an advantage to LSTM over alternative RNNs, hidden Markov models and other sequence learning methods. Since the wind speed and wind degree vary from place to place ,it is not possible to develop a generalized model which can predict the energy output of the wind farms located all around the world. As a part of our problem statement, Muppandal wind farm situated in Tamil Nadu at coordinates 8.2600 N 77.5475 E, is taken as a use case to train the LSTM model. The proposed LSTM model consists of four layers and computationally less expensive than other deep learning LSTM architectures.

The prediction problem was divided into two categories:

i. **Estimation**: Weather conditions like temperature, wind speed, pressure etc. determining the energy power prediction.
ii. **Prediction**: Without knowing any details about the weather conditions predicting the power generation using the pattern which it has followed in a certain period of time.

The architecture of deployed LSTM model :

Model: "sequential"

____ Layer (type) Output Shape Param #

===

lstm (LSTM) (None, 4) 96

____ dense (Dense)(None, 1) 5

===

Total params: 101

Trainable params: 101

Non-trainable params: 0

THEORETICAL ANALYSIS

a. Block diagram:

Long short-term memory (LSTM) units (or blocks) are a building unit for layers of a recurrent neural network (RNN). A common LSTM unit is composed of a cell, an input gate, an output gate and a forget gate. The cell is responsible for "remembering" values over arbitrary intervals of time; hence the word "memory" in LSTM. Each of the three gates can be thought of as a "conventional" artificial neuron, as in a multi- layer neural network: i.e., they compute an activation of a weighted sum. Moreover, they can be thought as regulators of the flow of values that goes through the connections of the LSTM; hence the denotation "gate". There are connections between these gates and the cell.

An LSTM is well- suited to classify, process and predict time series given time lags of unknown size and duration between important events. LSTMs were developed to deal with the exploding and vanishing gradient problem when training traditional RNNs. Relative insensitivity to gap length gives an advantage to LSTM over alternative RNNs, hidden Markov models and other sequence learning methods in numerous applications.

This just a introduction about LSTM, for more architectural and mathematical details you can read from the links provided in references.

b. Hardware/ Software designing:

The product designing involves training a model and deploying it using flask .The flask app is then deployed in PaaS infrastructure by Cloud Service providers. The flask app is designed as a RESTful API ,where the User Interface curls the result from server and displays it to the user.

Bootstrap

“The most popular HTML, CSS, and JS framework for developing responsive, mobile-first projects on the web.”

In layman’s terms: Bootstrap is a giant collection of handy, reusable bits of code written in HTML, CSS, and JavaScript. It’s also a front-end development framework that enables developers & designers to quickly build fully responsive websites.

IBM Cloud Functions

IBM Cloud Functions is a distributed computing service that executes application logic in response to requests from the web or mobile apps. You can set up specific actions to occur based on HTTP-based API requests from web apps or mobile apps, and from event-based requests from services like Cloudant.

ML/ DL Models:

ARIMA MODEL:

Using the ARIMA model, you can forecast a time series using the series past values. In this post, we build an optimal ARIMA model from scratch and extend it to Seasonal ARIMA (SARIMA) and SARIMAX models. You will also see how to build auto Arima models in python

LSTM MODEL:

LSTM Networks. Long Short Term Memory networks – usually just called “LSTMs” – are a special kind of RNN, capable of learning long-term dependencies. They were introduced by Hochreiter & Schmidhuber (1997), and were refined and popularized by many people in following work

Regressor MODEL:

IT uses random forest, linear regression, xg boost models. And we have combined them using Voting Regressor which takes the mean output of all the above models and improves the accuracy to a great extent

Data for LSTM Experiments

Historical wind energy data is taken from NREL to do this analysis. 6 years of wind power generation data is used in this experiment. The data after pre- processing have details about timestamp, air temperature (C), pressure (atm), wind direction (deg), wind speed (m/s) and Power generated by the system (kW). We have hourly data for about 6 years.

All the features are used for Estimation model and only time series features

i.e. Date Time and power generated by the system are used for prediction experiments.

Estimation

Estimation is all about predicting wind power generation given the current wind direction. Current wind and temperature conditions are given, this makes this problem a bit easy for a model like LSTM which looks at the current state of the weather and the previous trend which the weather is following to predict the power generated by the system Estimations models are useful if we get the weather information about the present day or the future publicly using machine learning with certain accuracy. Then this model can be used to be the perfect estimation of power generated by the system.

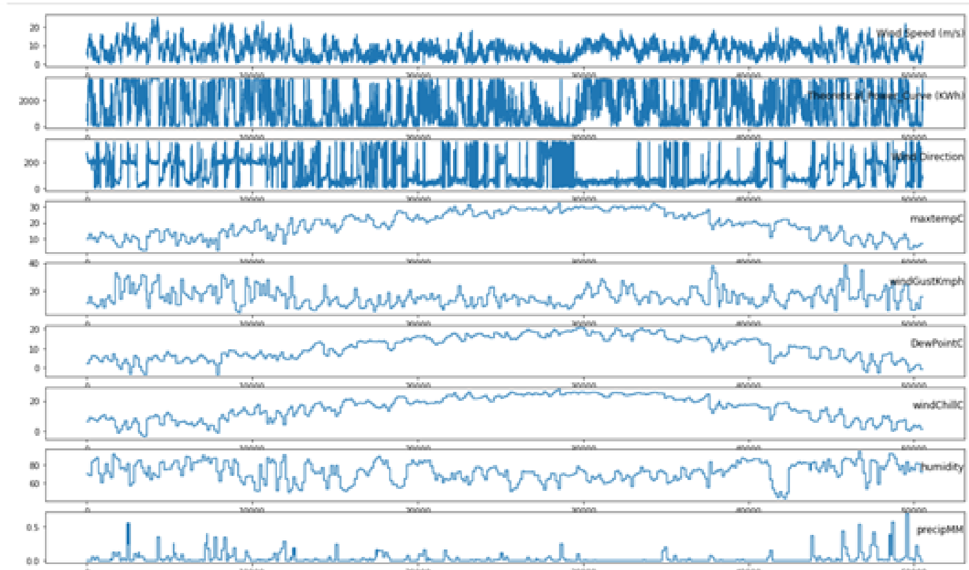
Experimental investigation

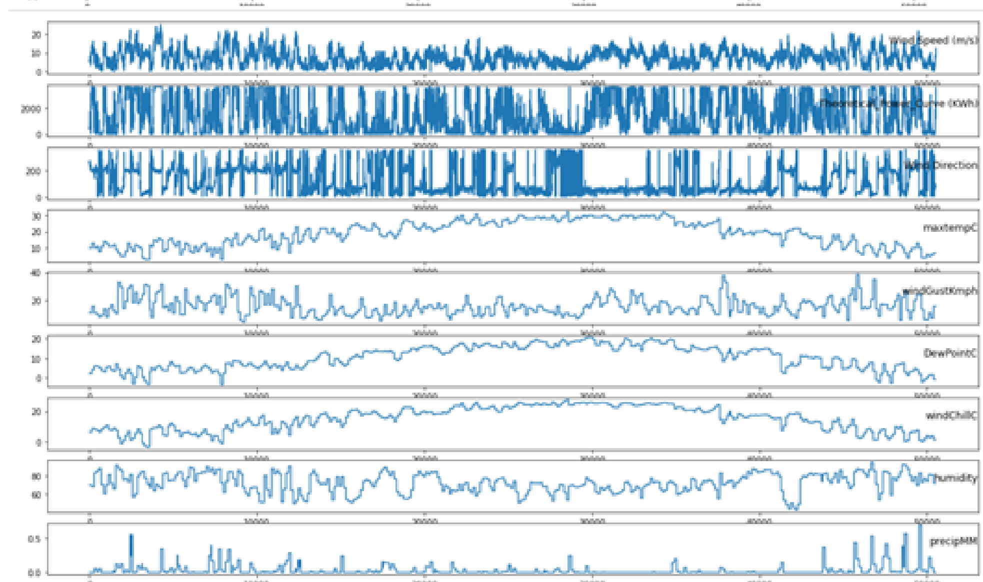
Estimation:

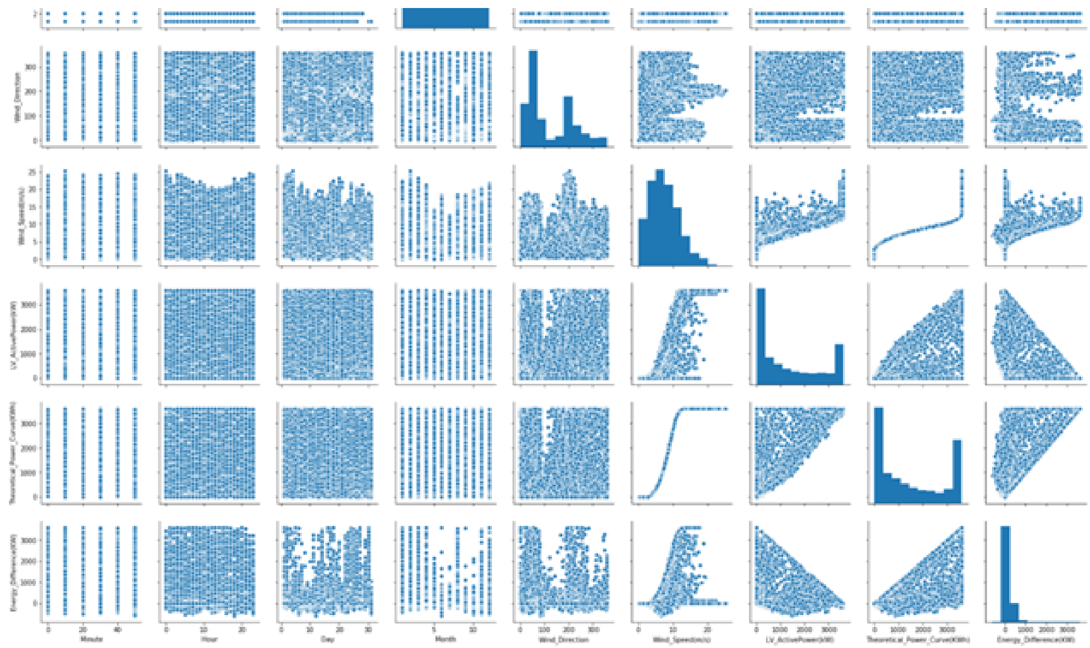
Data is represented in the following manner:

1 year of hourly data was divided into test batches for this experiment.

Results obtained from experiments (plots):

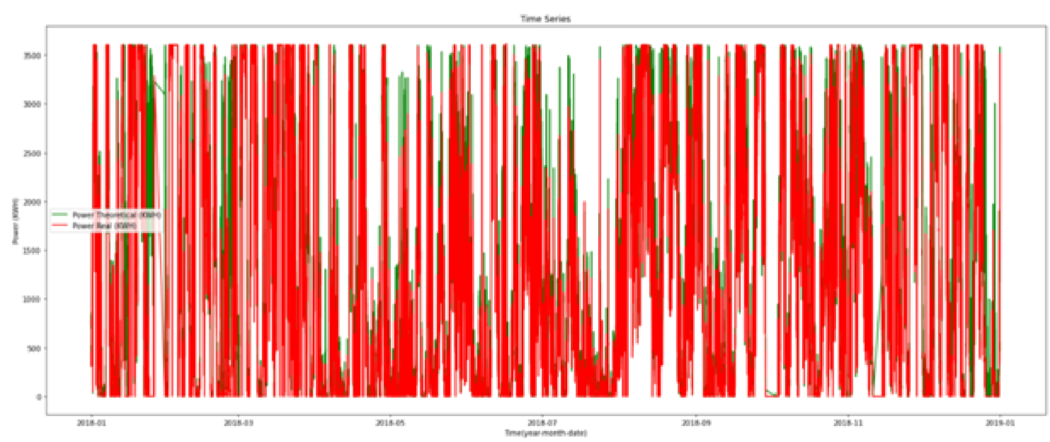


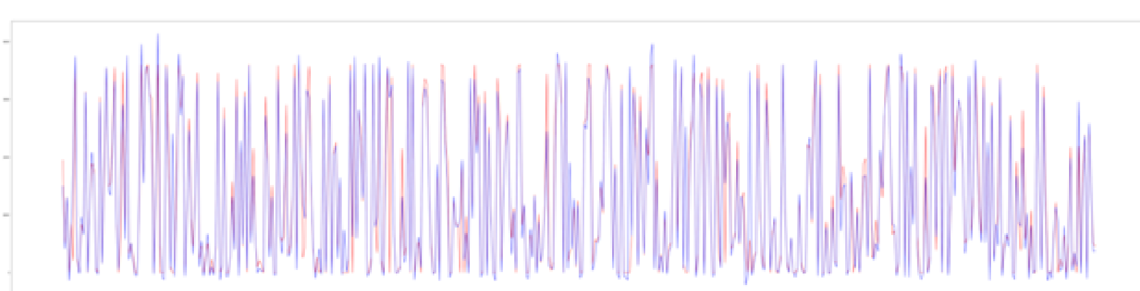


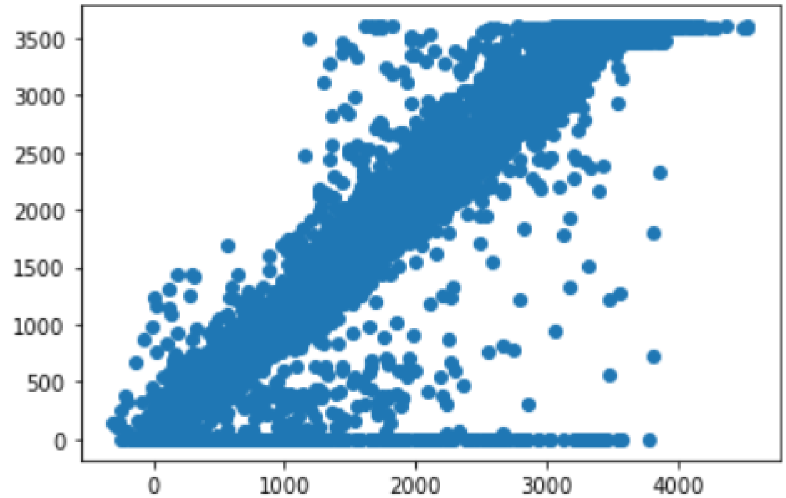


Results

Resultant plots of train and test:

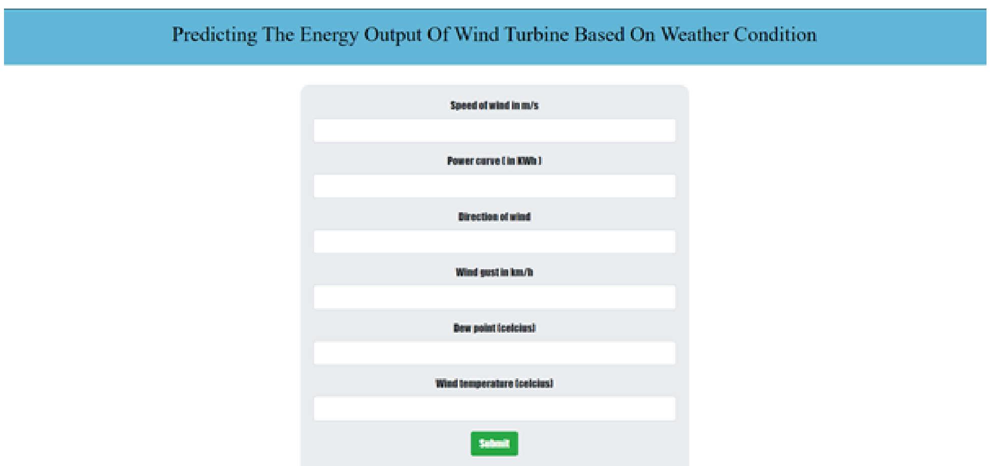


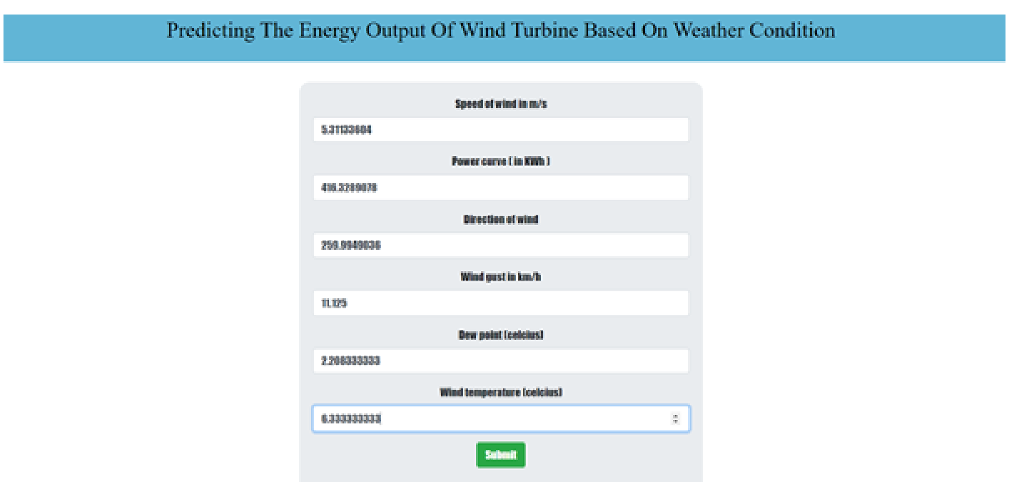




Front end:

Designed using HTML and CSS.





Advantages and disadvantages

Pros:

1. Accurate wind power forecasts are also important in reducing the occurrence or length of curtailments (which translate to cost savings), improved worker safety, and mitigating the physical impacts of extreme weather on wind power systems
2. Wind speed forecasting naturally has greater value where balancing markets are part of a competitive trading system for electricity, because the balancing market provides financial incentives to the generators and retailers for accurate output predictions.
3. ind turbines have a role to play in both the developed and third world.
4.

Cons:

5. The challenges to face when wind generation is injected in a power system depend on the share of that renewable energy.
6. For Denmark, which is a country with one of the highest shares of wind power in the electricity mix, the average wind power penetration over the year is of 16–20% (meaning that 16–20% of the electricity consumption is met wind energy), while the instantaneous penetration (that is, the instantaneous wind power production compared to the consumption to be met at a given time) may be above 100%.
7. Wind turbines are noisy. Each one can generate the same level of noise as a family car travelling at 70 mph.
8. When wind turbines are being manufactured some pollution is produced.

Applications

As we all know Renewable energy is the future of energy and wind mills is one that would be mostly used as a renewable source of energy because it takes less space as compared to others, more efficient and doesn't harm the environment in any way, that's why this system will be high in demand for cost reduction in construction and maintenance when constructing it according to the weather of the given place and will also help in increasing the efficiency of the energy output.

The same model mentioned above can also be applied to other data such as Solar energy, tidal energy etc.

The model can be transfer-learned for making predictions for other locations, instead of training from scratch. This reduces the time taken for training.

If we are able to achieve predicting the wind power output, then it will open up more avenues for efficient power production in this field. This will lower the dependence on conventional sources of energy like coal which can cause harm to our environment.

The service can be provided to users in application along with other features.

Could be helpful even in areas with less connectivity.

As the application is quite robust and resilient in its architecture, it allows one to easily navigate through different sections.

CONCLUSION

In this project, we have established the application to predict future wind power output values based on the regressor and deep learning models. The UI provides a great deal of information to anyone who would like to know about the future power output presented in the form of visualizations. Deploying it to the cloud makes it more scalable. The product can increase the accuracy of the forecasting the output from the wind turbine .Overall accurate wind power prediction reduces the financial and technical risk of uncertainty of wind power production for all electricity market participants

FUTURE SCOPE:

Our attempt would be to further improve the predictions using the ARIMA model and other models that are powerful. Imparting more features (like location, due level, humidity, etc) to our training set will enhance the predictions and will open up a new perspective on every front of wind prediction. India is the home of 1.25 billion people i.e. 17.5% of the total world population, which makes it second 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 [1]. 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 hydro-power 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'selectricity 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 [2]. 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.