

**IBM NALAIYA THIRAN PROJECT REPORT**

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# **Predicting the Energy Output of Wind Turbine Based On Weather Condition**

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**TEAM ID: PNT2022TMID45145**

**BY TEAM MEMBERS**

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## **CHAPTER 1**

### **INTRODUCTION**

Wind is used to produce electricity by converting the kinetic energy of air in motion into electricity. In modern wind turbines, wind rotates the rotor blades, which convert kinetic energy into rotational energy. 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.

Extracting electricity from renewable resources has been widely investigated in the past decades to decrease the worldwide crisis in the electrical energy and environmental pollution. For a wind farm which converts the wind power to electrical energy, a big challenge is to predict the wind power precisely in spite of the instabilities. To solve this problem, the prediction of wind energy over the climate change can be an effective way. With the prediction being around, the energy can be obtained at a stable level so that it can be distributed evenly in a precise manner.

The prediction can be done with the help of past data of the wind turbine which helps in the predicting the future output of the wind energy effectively. Here we use the past wind turbine energy data and then Machine learning algorithms to make the prediction clear.

The ability to predict the output of a wind turbine benefits all the end users. It provides economic benefits such as direct employment, land lease payments, local tax revenue. The data collected from the weather stations can be accessed in real time easily.

## CHAPTER 2

### LITERATURE SURVEY

| S.NO | PAPER TITLE   | AUTHORS  | ADVANTAGES  | REFERENCELINK   |
|------|---|--|---|---|
| 1.   | Predicting the Energy Output of Wind Farms Based on Weather Data: Important Variables and their Correlation | <u>Ekaterina (Katya) Vladislavleva</u> , Tobias fedriech, Frank Neumann, Markus Wagner | wind energy output can be predicted from publicly available weather data with accuracy at best 80% R2on the training range and at best 85,5% on the unseen test data  | <a href="https://www.researchgate.net/publication/229812149_Predicting_the_Energy_Output_of_Wind_Farms_Based_on_Weather_Data_Important_Variables_and_their_Correlation">https://www.researchgate.net/publication/229812149_Predicting_the_Energy_Output_of_Wind_Farms_Based_on_Weather_Data_Important_Variables_and_their_Correlation</a> |
| 2.   | Current methods and advances in forecasting of wind power generation.                                       | A. M. Foley, P. G. Leahy ,A.Marvuglia, and E. J. McKeogh.                              | Firstly, numerical wind prediction methods from global to local scales, ensemble forecasting, upscaling and downscaling processes are discussed. Then the techniques used for benchmarking and uncertainty analysis of forecasts are overviewed, and the performance of various approaches over different forecast time horizons is examined. Finally, current research activities, challenges and potential future developments are appraised.This paper presents an in-depth review of the current methods and advances in wind | <a href="https://www.sciencedirect.com/science/article/abs/pii/S0960148111002850">https://www.sciencedirect.com/science/article/abs/pii/S0960148111002850</a>   |

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|  |  |  | power |  |
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|  |  |  |                           |     |  |
|--|--|--|---------------------------|-----|--|
|  |  |  | forecasting<br>prediction | and |  |
|--|--|--|---------------------------|-----|--|

|    |   |                                |  |   |
|----|---|--------------------------------|--|---|
| 3. | Short-term farm prediction of wind power: A data mining approach            | A. Kusiak, Zheng, and Z. Song. | This paper examines time series models for predicting the power of a wind farm at different time scales, i.e., 10-min and hour-long intervals. The time series models are built with data mining algorithms. Five different data mining algorithms have been tested on various wind farm datasets. Two of the five algorithms performed particularly well. The support vector machine regression algorithm provides accurate predictions of wind power and wind speed at 10-min intervals up to 1 h into the future, while the multilayer perceptron algorithm is accurate in predicting power over hour-long intervals up to 4 h ahead. Wind speed can be predicted fairly accurately based on its historical value | <a href="https://ieeexplore.ieee.org/document/4749292">https://ieeexplore.ieee.org/document/4749292</a> |
| 4. | Analysis of wind energy time series with kernel methods and neural networks | O. Kramer and F. Gieseke.      | This article shows how kernel methods and neural networks can serve as modeling, forecasting and monitoring techniques, and, how they contribute to a successful integration   | <a href="https://ieeexplore.ieee.org/document/6022597">https://ieeexplore.ieee.org/document/6022597</a> |

|  |  |  |  |  |
|--|--|--|--|--|
|  |  |  | <p>of<br/>wind into smart energy<br/>grids. First, we will<br/>employ kernel density<br/>estimation for modeling<br/>of wind data. Kernel<br/>density estimation<br/>allows a statistically<br/>sound modeling of time<br/>series data.<br/>The corresponding<br/>experiments are based<br/>on<br/>real data of wind energy<br/>time series from the<br/>NREL western wind<br/>resource dataset.<br/>Second, we will show<br/>how prediction of<br/>wind energy can be<br/>accomplished with the<br/>help of support vector<br/>regression. Last, we will<br/>use self-organizing<br/>feature maps to map<br/>high dimensional wind<br/>time series to colored<br/>Sequences that can be<br/>used for error<br/>detection.</p> |  |
|--|--|--|--|--|

|    |   |                          |   |   |
|----|---|--------------------------|---|---|
| 5. | The prediction and diagnosis of wind turbine faults | Andrew Kusiak, Wenyan Li | The rapid expansion of wind farms has drawn attention to operations and maintenance issues. Condition monitoring solutions have been developed to detect and diagnose abnormalities of various wind turbine subsystems with the goal of reducing                                      | <a href="https://www.sciencedirect.com/science/article/abs/pii/S0960148110002338?via%3Dihub">https://www.sciencedirect.com/science/article/abs/pii/S0960148110002338?via%3Dihub</a> |
|    |   |                          | operations and maintenance costs. This paper explores fault data provided by the supervisory control and data acquisition system and offers fault prediction at three levels: (1) fault and nofault prediction; (2) fault category (severity); and (3) the specific fault prediction. |   |

|    |  |   |   |   |
|----|--|---|---|---|
| 6. | Predicting the Wind Turbine Power Generation based on Weather Conditions | S.Preethi,H.Prit hika,M.Pramila, S.Birundha | In this paper, an end-to-end web application has been developed to predict and forecast the wind turbine's power generation based on the weather conditions. The prediction model has been developed using Bidirectional Long Short-Term Memory which is a unique kind of RNN (Recurrent Neural Network). It performs admirably in terms of capturing long-term dependencies along with the time steps and is hence ideal for wind power forecasting. |   |
| 7. | Machine learning ensembles for wind power prediction                     | Justin Heinnerman,Oli ver Krammer           | This paper propose the use of heterogeneous machine learning ensembles for wind power prediction.   | <a href="https://www.sciencedirect.com/science/article/abs/pii/S0960148115304894?via%3Dihub">https://www.sciencedirect.com/science/article/abs/pii/S0960148115304894?via%3Dihub</a> |

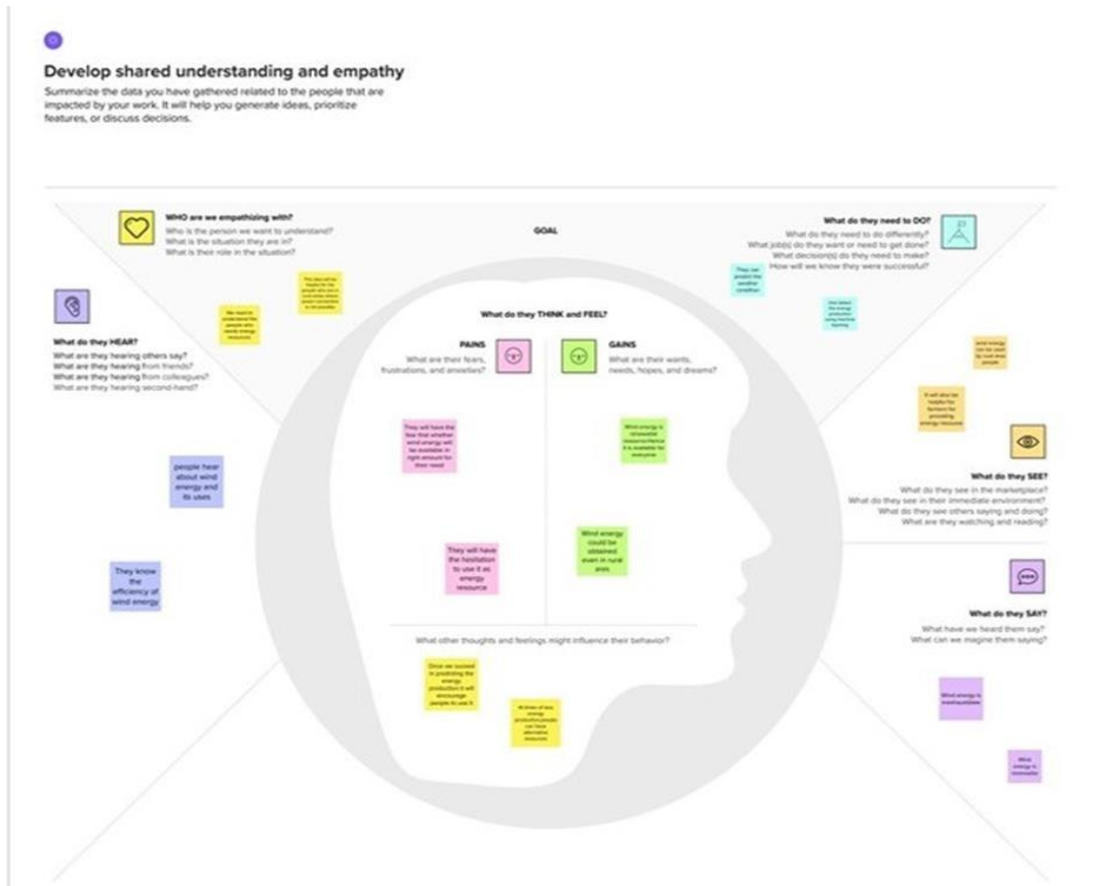
## CHAPTER 3

### 3.1 EMPATHY MAP CANVAS:

An empathy map canvas is a more in-depth version of the original empathy map, which helps identify and describe the user's needs and pain points. And this is valuable information for improving the user experience.

An empathy map canvas helps brands provide a better experience for users by helping teams understand the perspectives and mindset of their customers. Using a template to create an empathy map canvas reduces the preparation time and standardizes the process so you create empathy map canvases of similar quality.





### 3.2 IDEATION & BRAINSTORMING

Ideation may present itself in any one of a wide variety of ways and arenas. The book “Ideation: The Birth and Death of Ideas,” written by Douglas Graham and Thomas Bachmann, lists several different forms that ideation may take, including the following:

- **Solving Problems** – Ideation is often specifically aimed at problem-solving. For example, production managers at a company may be charged with coming up with ideas on how to reduce production costs.
- **Derivative Ideation** – Derivative ideation refers to building on an existing idea, such as developing complementary products or accessories to sell along with a company’s main product.
- **Innovation** – An example of innovation ideation is the process of a pharmaceutical company developing new medicines. Such a type of ideation often involves doing extensive research and experimentation as part of the ideation process.

- **Development of a “Revolutionary Idea”** – Ideation sometimes ends up creating a totally new line of thought or set of ideas, such as the development of a new philosophy.
- **Serendipitous Ideation** – Serendipitous ideation refers to situations where someone just happens to come up with a new idea even though they weren’t consciously trying to do so.
- **Combination Ideation** – Ideation often includes combining multiple ideas to create a new process or way of doing something.

## Step-1: Team Gathering, Collaboration and Select the Problem Statement

### Before you collaborate

A little bit of preparation goes a long way with this session. Here's what you need to do to get going.

🕒 10 minutes

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A

**Team gathering**  
Define who should participate in the session and send an invite. Share relevant information or pre-work ahead.

B

**Set the goal**  
Think about the problem you'll be focusing on solving in the brainstorming session.

C

**Learn how to use the facilitation tools**  
Use the Facilitation Superpowers to run a happy and productive session.

[Open article](#) →

1

### Define your problem statement

What problem are you trying to solve? Frame your problem as a How Might We statement. This will be the focus of your brainstorm.

🕒 5 minutes

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PROBLEM

To predict the wind energy production in order to plan for the energy needs of future in advance

### Key rules of brainstorming

To run an smooth and productive session

|                 |                         |
|-----------------|-------------------------|
| Stay in topic.  | Encourage wild ideas.   |
| Defer judgment. | Listen to others.       |
| Go for volume.  | If possible, be visual. |

## Step-2: Brainstorm, Idea Listing and Grouping

2

## Brainstorm

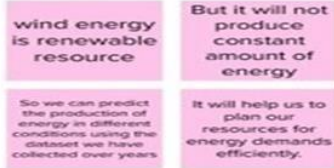
Write down any ideas that come to mind that address your problem statement.

10 minutes

### TIP

You can select a sticky note and hit the pencil (switch to sketch) icon to start drawing!

Antony Surya A



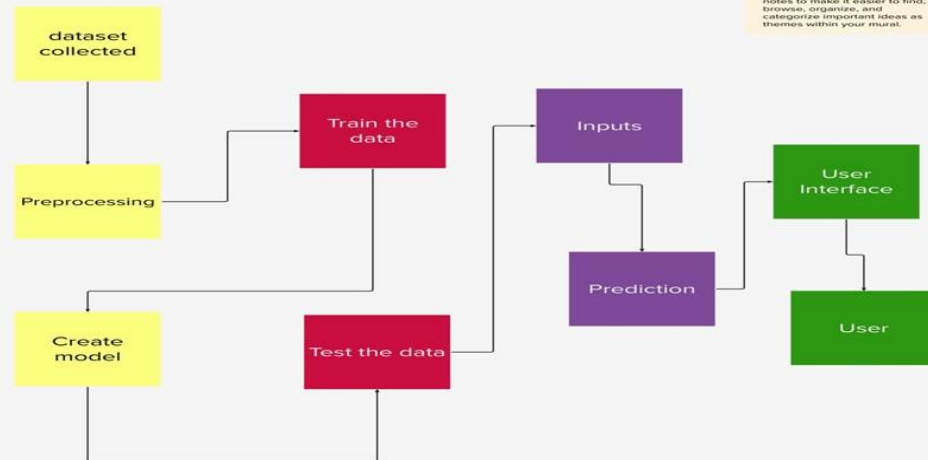
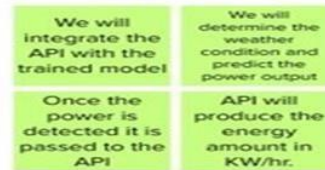
Gayathri A



Venkata Subramaniyan R



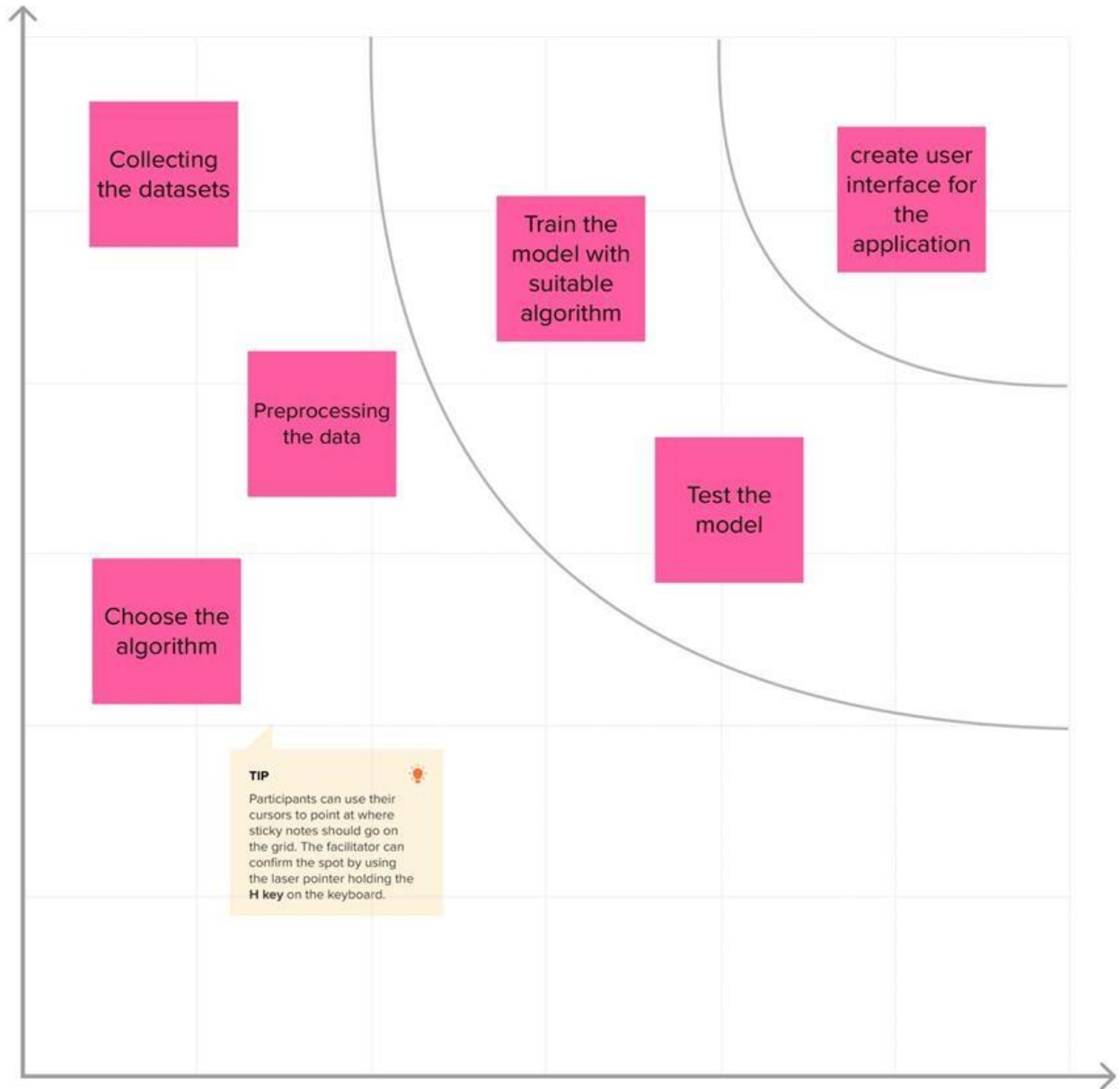
Venkataprasath



### TIP

Add customizable tags to sticky notes to make it easier to find, browse, organize, and categorize important ideas as themes within your mural.

## Step-3: Idea Prioritization



### 3.3 PROPOSED SOLUTION



miro

## CHAPTER 4

### REQUIREMENT ANALYSIS

#### Functional Requirements:

Functional requirements are product features or functions that developers must implement to enable users to accomplish their tasks. So, it's important to make them clear both for the development team and the stakeholders. Generally, functional requirements describe system behaviour under specific conditions.

The system sends an approval request after the user enters personal information. A search feature allows a user to hunt among various invoices if they want to credit an issued invoice. The system sends a confirmation email when a new user account is created.

Following are the functional requirements of the proposed solution.

| FR No. | Functional Requirement<br>(Epic)        | Sub Requirement (Story / Sub-Task)   |
|--------|---|--|
| FR-1   | User Registration (For App and webpage) | Registration through E-Mail or Mobile number.  |
| FR-2   | User Confirmation                       | Confirmation message sent to registered E-Mail id or mobile number.  |
| FR-3   | Essential details                       | <ul style="list-style-type: none"><li>o City name</li><li>o Wind speed</li><li>o Wind direction</li><li>o Temperature</li><li>o Humidity</li></ul> |
| FR-4   | Output                                  | Wind Energy will be shown in KW/hr   |

## **Non-functional Requirements:**

These are basically the quality constraints that the system must satisfy according to the project contract. The priority or extent to which these factors are implemented varies from one project to other. They are also called non-behavioral requirements.

They basically deal with issues like:

- Portability
- Security
- Maintainability
- Reliability
- Scalability
- Performance
- Reusability
- Flexibility

Following are the non-functional requirements of the proposed solution.

| <b>FR No.</b> | <b>Non-Functional Requirement</b> | <b>Description</b>   |
|---------------|-----------------------------------|--|
| NFR-1         | <b>Usability</b>                  | <ul style="list-style-type: none"> <li>o User-friendly.</li> <li>o Need not any special knowledge.</li> </ul>  |
| NFR-2         | <b>Security</b>                   | <ul style="list-style-type: none"> <li>o Data provided by the user will be protected from the unauthorized access.</li> <li>o Datas are secured in cloud.</li> </ul>                             |
| NFR-3         | <b>Reliability</b>                | <ul style="list-style-type: none"> <li>o Weather Information are up to date because it uses weather API for weather prediction.</li> <li>o It will provide the consistency in output.</li> </ul> |
| NFR-4         | <b>Performance</b>                | <ul style="list-style-type: none"> <li>o Website activity is quite faster and reliable.</li> <li>o Output values are so accurate.</li> </ul>   |
| NFR-5         | <b>Availability</b>               | <ul style="list-style-type: none"> <li>o Supports most of the device configurations.</li> <li>o Anyone can access the website with proper internet connection.</li> </ul>                        |
| NFR-6         | <b>Scalability</b>                | <ul style="list-style-type: none"> <li>o Often improving in technology and generating large amount of data, the website features also changes over a period.</li> </ul>                          |



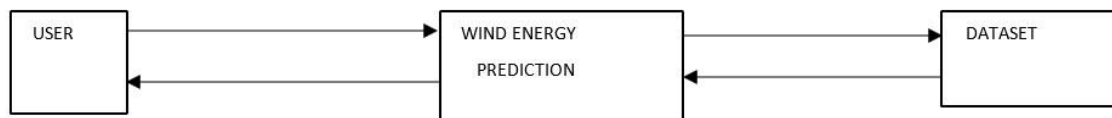
## CHAPTER 5

### PROJECT DESIGN

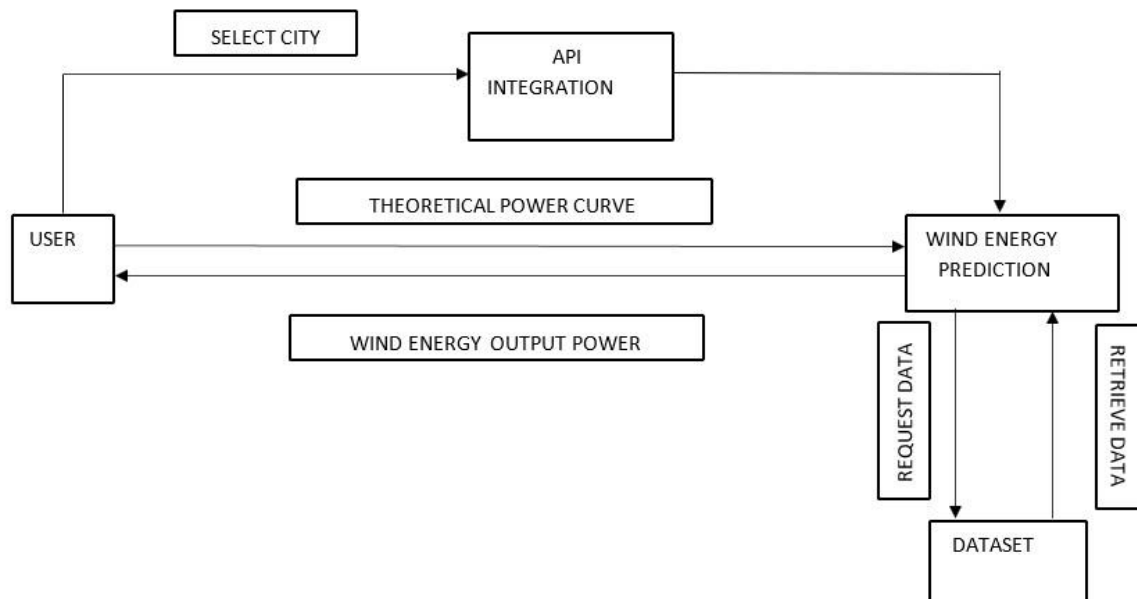
#### 5.1 DATA FLOW DIAGRAM

A Data Flow Diagram (DFD) is a traditional visual representation of the information flows within a system. A neat and clear DFD can depict the right amount of the system requirement graphically. It shows how data enters and leaves the system, what changes the information, what changes the information, and where data is stored.

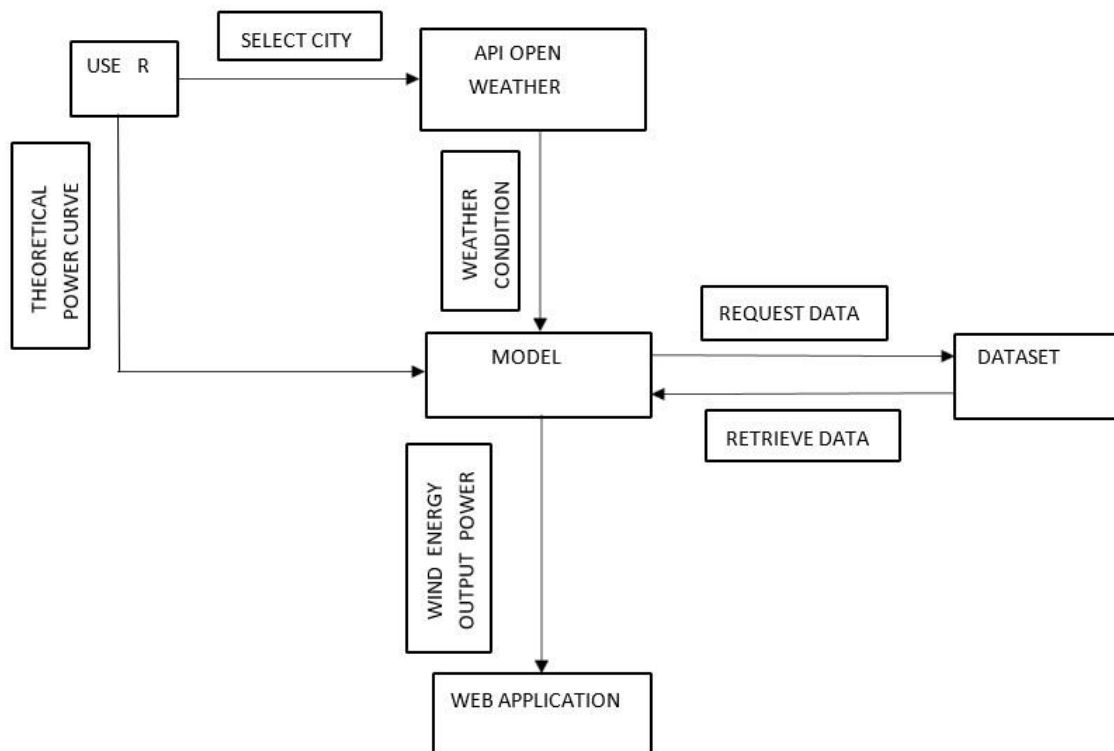
##### LEVEL 1:



##### LEVEL 2:



##### LEVEL 3:



## User Stories

Use the below template to list all the user stories for the product.

| User Type                 | Functional Requirement (Epic) | UserStory Number | User Story / Task   | Acceptance criteria                               | Priority | Release  |
|---------------------------|-------------------------------|------------------|---|---|----------|----------|
| Customer<br>(Mobile user) | Registration                  | USN-1            | As a user, I can register for the application by entering my email, password, and confirming my password. | I can access my account / dashboard               | High     | Sprint-1 |
|                           | Login                         | USN-2            | As a user, I can login to the application by entering email & password                                    | I can access my account/dashboard                 | High     | Sprint-1 |
|                           | Dashboard                     | USN-3            | As a user, I can see all the details raised by me   | I can get the information needed in the dashboard | Low      | Sprint-2 |

|                     |                 |       |  |   |        |          |
|---------------------|-----------------|-------|--|---|--------|----------|
|                     | Address column  | USN-4 | As a user, I can enter the address based on my query                   | I can get the weather report based on my address                      | High   | Sprint-2 |
|                     | Forgot password | USN-5 | As a user, I can able to reset my password                             | I can access my account again   | Medium | Sprint-2 |
|                     | Output          | USN-6 | As a user, I can get my weather report                                 | I can generate the wind energy after submitting the necessary details | High   | Sprint-2 |
| Customer (Web user) | Login           | USN-1 | As a user, I can login to the application by entering email & password | I can access my account/dashboard                                     | High   | Sprint-2 |
|                     | Dashboard       | USN-2 | As a user, I can see all the details raised by me                      | I can get the information needed in the dashboard                     | Low    | Sprint-3 |

|                         |                 |       |  |   |        |          |
|-------------------------|-----------------|-------|--|---|--------|----------|
|                         | Address column  | USN-3 | As a user, I can enter the address based on my query                         | I can get the weather report based on my address                      | High   | Sprint-3 |
|                         | Forgot password | USN-4 | As a user, I can able to reset my password                                   | I can access my account again   | Medium | Sprint-3 |
|                         | Output          | USN-5 | As a user, I can get my weather report                                       | I can generate the wind energy after submitting the necessary details | High   | Sprint-3 |
| Customer Care Executive | Login           | USN-1 | As an admin, I can see the queries raised by user                            | I can resolve the issues raised by the user                           | Medium | Sprint-4 |
| Administrator           | Login           | USN-1 | As an administrator, I can login to the application by using the admin login | I can access my account/dashboard                                     | High   | Sprint-1 |

|  |                     |       |   |   |      |              |
|--|---------------------|-------|---|---|------|--------------|
|  | Dashboard           | USN-2 | As an admin<br>I can see all<br>the orders<br><br>raised in the<br>entire<br>system and<br>lot more | I can assign<br>agents by<br>seeing<br>those order. | High | Sprint-<br>1 |
|  | Agent<br>creation   | USN-3 | As an<br>admin I can<br>create an<br>agent for<br>clarifying<br>the<br>customers<br>queries         | I can create<br>agents.                             | High | Sprint-<br>2 |
|  | Assignment<br>agent | USN-4 | As an<br>admin I can<br>assign an<br>agent for<br>each order<br>created by<br>the<br>customer.      | Enable<br>agent to<br>clarify<br>the<br>queries.    | High | Sprint-<br>1 |

## CHAPTER 6

### PROJECT PLANNING & SCHEDULING

#### Product Backlog, Sprint Schedule, and Estimation

| <b>Sprint</b> | <b>Functional Requirement (Epic)</b> | <b>User Story Number</b> | <b>User Story / Task</b>  | <b>Story Points</b> | <b>Priority</b> | <b>Team Members</b>                            |
|---------------|--------------------------------------|--------------------------|---|---------------------|-----------------|--|
| Sprint-1      | Registration                         | USN-1                    | As a user, I can register for the application by entering my email, password, and confirming my password. | 2                   | High            | Jeeva B, Dinesh Raja R, Dhinesh kumar R, Jegan |
| Sprint-1      | Data collection and pre-processing   | USN-2                    | Need to collect dataset for analysing and need to pre-process the data                                    | 1                   | High            | Jeeva B, Dinesh Raja R, Dhinesh kumar R, Jegan |
| Sprint-2      | Model Building                       | USN-3                    | We need to train the dataset and build model  | 2                   | High            | Jeeva B, Dinesh Raja R, Dhinesh kumar R, Jegan |

|          |                              |       |   |   |        |  |
|----------|------------------------------|-------|---|---|--------|--|
| Sprint-3 | Application Building         | USN-4 | We need to create a flask app with user interface built using HTML page   | 2 | Medium | Jeeva B, Dinesh Raja R, Dhinesh kumar R, Jegan |
| Sprint-4 | Train the Model on IBM Cloud | USN-5 | We need to train the model on IBM Cloud. At the end we should have a application that is able to predict the wind energy if we specify a city | 1 | High   | Jeeva B, Dinesh Raja R, Dhinesh kumar R, Jegan |

#### Project Tracker, Velocity & Burndown Chart:

| Sprint   | Total Story Points | Duration | Sprint Start Date | Sprint End Date (Planned) | Story Points Completed (as on Planned End Date) | Sprint Release Date (Actual) |
|----------|--------------------|----------|-------------------|---------------------------|---|------------------------------|
| Sprint-1 | 20                 | 6 Days   | 24 Oct 2022       | 31 Oct 2022               | 20  | 29 Oct 2022                  |



|                 |           |               |                        |                    |           |                    |
|-----------------|-----------|---------------|------------------------|--------------------|-----------|--------------------|
| <b>Sprint-2</b> | <b>20</b> | <b>6 Days</b> | <b>01 Nov<br/>2022</b> | <b>09Nov 2022</b>  | <b>20</b> | <b>09 Nov 2022</b> |
| <b>Sprint-3</b> | <b>20</b> | <b>6 Days</b> | <b>10Nov<br/>2022</b>  | <b>13 Nov 2022</b> | <b>20</b> | <b>13 Nov 2022</b> |
| <b>Sprint-4</b> | <b>20</b> | <b>6 Days</b> | <b>14 Nov<br/>2022</b> | <b>19 Nov 2022</b> | <b>20</b> | <b>19 Nov 2022</b> |

## **CHAPTER 7**

### **CODING & SOLUTIONING**

The source code is uploaded in the Github Sprint wise folders.

- **GitHubLink:** <https://github.com/IBM-EPBL/IBM-Project-43949-1660720792>

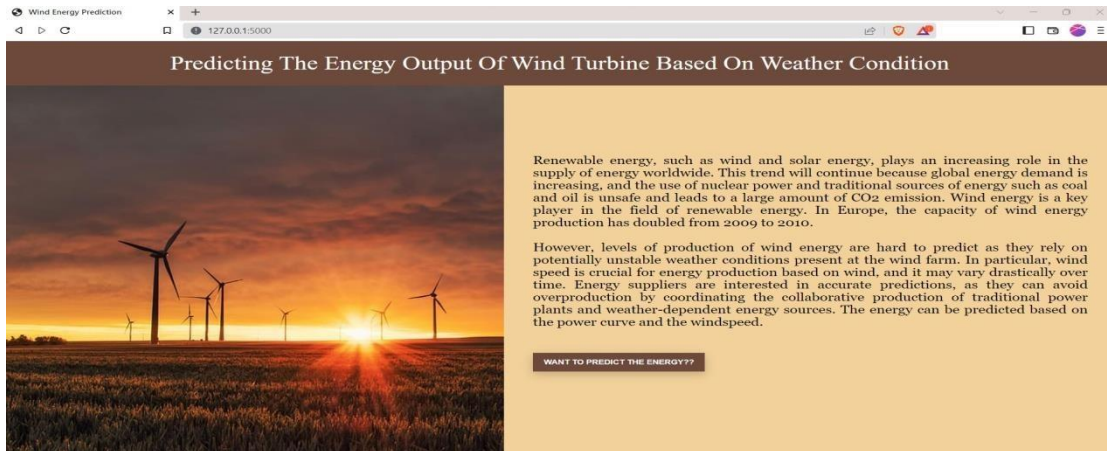
## CHAPTER 8

### TESTING

```
* Serving Flask app 'app'
* Debug mode: off
WARNING: This is a development server. Do not use it in a production deployment. Use a production WSGI server instead.
* Running on http://127.0.0.1:5000
Press CTRL+C to quit
127.0.0.1 - - [17/Nov/2022 22:00:35] "GET / HTTP/1.1" 200 -
127.0.0.1 - - [17/Nov/2022 22:00:37] "GET /predict HTTP/1.1" 200 -
127.0.0.1 - - [17/Nov/2022 22:00:37] "GET /static/css/main.css HTTP/1.1" 404 -
127.0.0.1 - - [17/Nov/2022 22:00:37] "GET /static/css/media.css HTTP/1.1" 404 -
127.0.0.1 - - [17/Nov/2022 22:00:37] "GET /static/css/items_grid.css HTTP/1.1" 404 -
C:\Users\HP\anaconda3\envs\IBM\lib\site-packages\sklearn\base.py:450: UserWarning: X does not have valid feature names, but RandomForestRegressor was fitted with feature names
warnings.warn(
[1739.4724141]
127.0.0.1 - - [17/Nov/2022 22:00:41] "POST /y_predict HTTP/1.1" 200 -
127.0.0.1 - - [17/Nov/2022 22:00:41] "GET /static/css/main.css HTTP/1.1" 404 -
127.0.0.1 - - [17/Nov/2022 22:00:41] "GET /static/css/media.css HTTP/1.1" 404 -
127.0.0.1 - - [17/Nov/2022 22:00:41] "GET /static/css/items_grid.css HTTP/1.1" 404 -
C:\Users\HP\anaconda3\envs\IBM\lib\site-packages\sklearn\base.py:450: UserWarning: X does not have valid feature names, but RandomForestRegressor was fitted with feature names
warnings.warn(
[1739.4724141]
```

## CHAPTER 9

### RESULTS



## **CHAPTER 10 ADVANTAGES AND DISADVANTAGES**

### **ADVANTAGES:**

- Ø Generating energy from the wind does not release any carbon emissions.
- Ø Wind energy lead to an overall reduction in carbon emissions.
- Ø The energy used for manufacturing and installing wind turbines can also be paid back relatively quickly.
- Ø It does not release any pollution or produce any waste during operation.
- Ø It is renewable and clean source of energy.
- Ø Efficient use of land space.
- Ø Wind energy is a job creator.
- Ø It does not result in any acid rains.

### **DISADVANTAGES:**

- Ø For the best wind source, turbines needs to be higher than the nearest surrounding structures.
- Ø Noise from wind turbines could be a concern for some rural locations.
- Ø While siting and designing for wind turbines, it can interfere with radar and aircraft navigation systems.
- Ø The electromagnetic radiation from wind turbines have been shown to be weak and do not present a health risk to local communities.
- Ø If wind turbines are inappropriately located, it could have an impace on birds through collision, disturbance and habitat damage.
- Ø Wind turbines are harmful to bats, in a similar way to bird populations.
- Ø Wind turbines are able to design only on remote areas.

## **CHAPTER 11**

## **CONCLUSION**

By doing the above project, we successfully created an interactive energy prediction dashboard using Watson studio, Watson Machine Learning and Weather Data. The experimental investigations showed the integration of different IBM cloud services. The results show that the responses from the Application were relevant and helpful. Although, the Web- Application demands complex integration of services it can be deployed easily to leverage the energy prediction and improve the energy production, effectively. In conclusion, this project helps in determining the wind energy production with change in weather condition. So that we can plan the energy resources accordingly.

## **CHAPTER 12**

### **FUTURE SCOPE**

For future research can be guided to improve relevant results and response time.

Simplification of integration of services can be achieved by normalizing the architecture. Also, a user feedback system can be incorporated to render the user queries and needs, but still we have given contact us portion for that part.