Predicting The Energy Output Of Wind Turbine Based On Weather Condition

PROJECT DOCUMENTATION

Team ID:PNT2022TMID20703

Submitted by

Tarun.H –Team Lead

Shasti Alagan.R

Monish Kumar S.S

Akash.R

Project Report Format

1. INTRODUCTION
    1. Project Overview
    2. Purpose
2. LITERATURE SURVEY
    1. Existing problem
    2. References
    3. Problem Statement Definition
3. IDEATION & PROPOSED SOLUTION
    1. Empathy Map Canvas
    2. Ideation & Brainstorming
    3. Proposed Solution
    4. Problem Solution fit
4. REQUIREMENT ANALYSIS
    1. Functional requirement
    2. Non-Functional requirements
5. PROJECT DESIGN
    1. Data Flow Diagrams
    2. Solution & Technical Architecture
    3. User Stories
6. PROJECT PLANNING & SCHEDULING

1.INTRODUCTION

In recent years, wind energy has become one of the most economical renewable energy technology. Today, electricity generating wind turbines employ proven and tested technology, and provide a secure and sustainable energy supply. At good, windy sites, wind energy can already successfully compete with conventional energy production.

Many countries have considerable wind resources, which are still untapped. The technological development of recent years, bringing more efficient and more reliable wind turbines, is making wind power more cost-effective. In general, the specific energy costs per annual kWh decrease with the size of the turbine notwithstanding existing supply difficulties.

1.1. Project Overview

Wind power generation differs from conventional thermal generation due to the stochastic nature of wind. Thus wind power forecasting plays a key role in dealing with the challenges of balancing supply and demand in any electricity system, given the uncertainty associated with the wind farm power output. Accurate wind power forecasting reduces the need for additional balancing energy and reserve power to integrate wind power. For a wind farm that converts wind energy into electricity power, a real-time prediction system of the output power is significant. In this project , a prediction system is developed with a method of combining statistical models and physical models. In this system, the inlet condition of the wind farm is forecasted by the auto regressive model.

1.2 Purpose

to predict/forecast wind energy production over a period of given time and location with respect to its legacy wind metrics.

2. LITERATURE SURVEY

[1] Uses the random forest regressor algorithm on the SCADA Dataset which is the data collected from a wind farm in France. It takes into consideration input factors such as wind direction, wind speed and outdoor temperature.

[2]'s major objective is to examine the viability of wind energy prediction using an off-the-shelf, industrial-strength non-linear modelling and feature selection tool called DataModeler.

The modelling objectives of this study are to:
(1) identify the minimal subset of driving weather features that are significantly correlated with the wind energy output of the wind farm;
(2) let genetic programming express these correlations in the form of explicit input-output regression models;
(3) choose model ensembles for improved generalisation capabilities of energy predictions and analyse the quality of produced model ensembles using an unseen test set.

[3] demonstrated that wind energy production can be predicted with an accuracy of up to 80% R2 on the training range and up to 85.5% on the unseen test data using publicly available weather data. They showed that symbolic regression trials, variable importance, variable contribution analysis, ensemble selection, and validation can all be carried out using a commercial data modelling and variable selection programme with mostly default settings. The framework they have presented is so straightforward that anyone can use it to forecast the generation of wind energy on a smaller scale—for individual wind turbines on private farms or urban buildings, or for small wind farms

[4] makes use of time series models in order to predict the power of a wind farm. The models were designed with the help of 5 data mining algorithms, of which 2 performed well.

The support vector machine regression algorithm achieved high accuracy of wind power and wind speed for smaller time intervals(10 minutes to an hour). A multilayer perceptron algorithm returned satisfactory results for time intervals between 1 to 4 hours

2.1 **Existing problem**

-The main limitation of random forest is that a large number of trees can make the algorithm too slow and ineffective for real-time predictions. In general, these algorithms are fast to train, but quite slow to create predictions once they are trained.

-It was noted at the end that the time series predictions brought about more stable results when compared to the integrated KNN based model. One of the drawbacks of time series models is the fact that they make use of predicted values as future inputs, and this would lead to the error factor increasing as the number of prediction steps increases

2.2 **References**

[1] Rashid, Haroon, Waqar Haider, and Canras Batunlu. "Forecasting of wind turbine output power using machine learning." 2020 10th International Conference on Advanced Computer Information Technologies (ACIT). IEEE, 2020.

[2] Webb, M., and S. Scuglia. "Wind power: A favoured climate change response." Global Economic Research: Fiscal Pulse (Scotiabank) (2007).

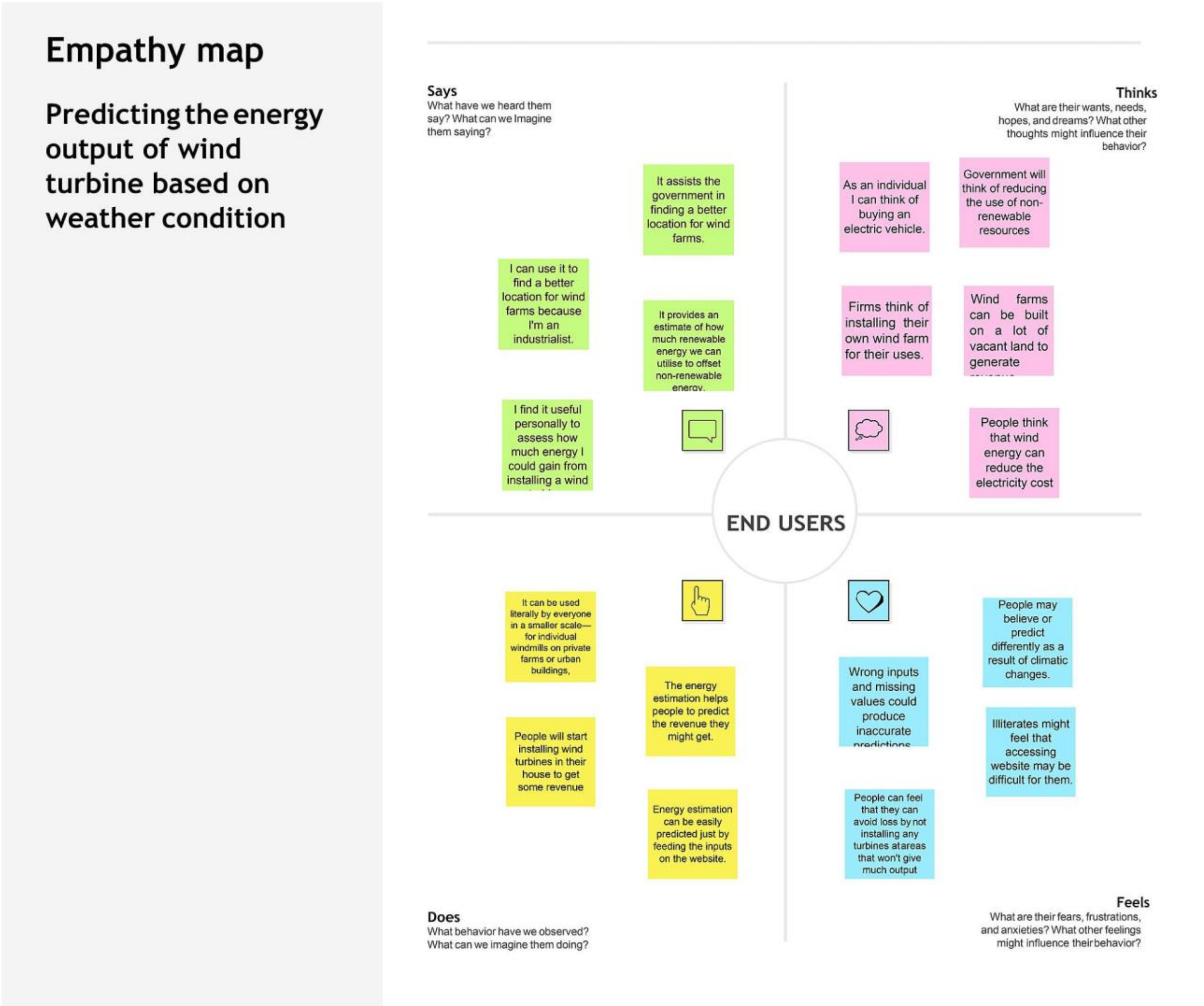
[3] "Vladislavleva, Ekaterina, et al. "Predicting the energy output of wind farms based on weather data: Important variables and their correlation." Renewable energy 50 (2013): 236-243.."

[4] Corchado, Emilio, Angel Arroyo, and Verónica Tricio. "Soft computing models to identify typical meteorological days." Logic Journal of the IGPL 19.2 (2011): 373-383.

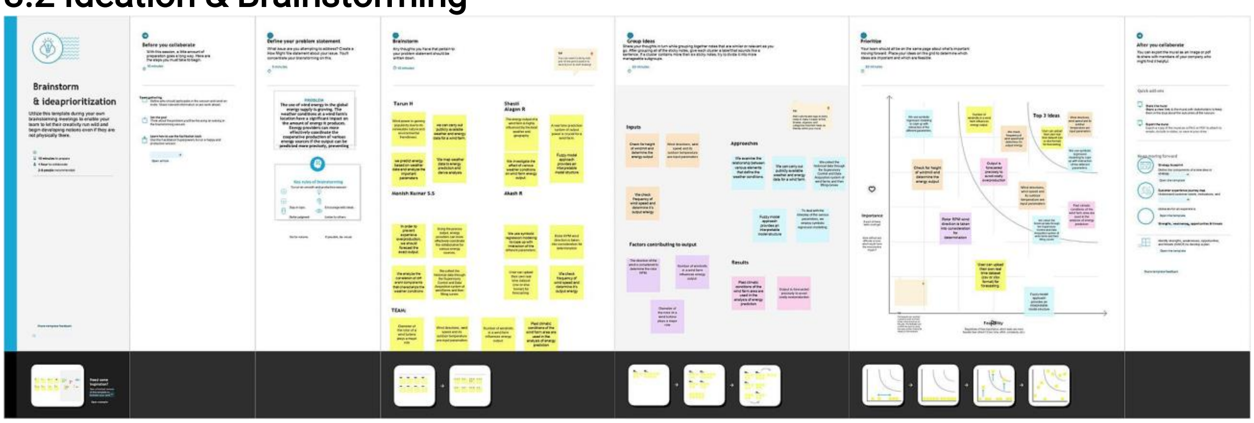
[5] Kusiak, Andrew, Haiyang Zheng, and Zhe Song. "Short-term prediction of wind farm power: a data mining approach." IEEE Transactions on energy conversion 24.1 (2009): 125-136

3. IDEATION & PROPOSED SOLUTION

3.1 Empathy Map Canvas



3.2 Ideation & Brainstorming



3.3 Proposed Solution

Problem Statement:

As wind is stochastic, wind power generation is different from traditional thermal generation. Given the unpredictability associated to the output of the wind farms, wind power forecasting is crucial in addressing the difficulties of balancing supply and demand in any electrical system.

Idea / Solution description:

Using a technique that combines physical models with statistical models, a prediction system is created. The auto regressive model in this system predicts the wind farm's inlet state.

Novelty / Uniqueness:

The energy outputs from the previous year are taken into account in this model, which also correlates them with the weather and other important factors. To obtain the energy output, we can input the weather conditions into this model. The algorithm is also adjusted dynamically based on the expected value and actual output value.

Social Impact / Customer Satisfaction:

A safe and environment-friendly alternative for the generation of electric energy, wind energy receives high levels of popular acceptance. In terms of the social aspect, unlike hydroelectric plants, wind power plants do not have significant negative environmental effects and allow for the coexistence of the production of electricity from the wind alongside the use of land for agriculture and animals.

Business Model (Revenue Model):

Wind utility companies will be able to make more money if they can increase energy output. Wind energy is a trusted source since we can predict the total power output at any given time.

Scalability of the Solution:

The data collected from the weather stations can be accessed in real time easily. The weather features can be easily obtained through the sensors installed that helps in predicting energy output.

3.4 Problem Solution fit

Project Design Phase-I - Solution Fit **Team ID:** PNT2022TMID52641

Predicting the energy output of Wind Turbine based on Weather conditions

Define CS, fit into CC

1. CUSTOMER SEGMENT(S) CS

Who is your customer?

- Individuals
- Electricity suppliers
- Industrialist
- Government

6. CUSTOMER CONSTRAINTS CC

What constraints prevent your customers from taking action or limit their choices of solutions? i.e. spending power, budget, no cash, network connection, available devices.

1. Illiterates may feel difficulty in accessing the website.
2. Network connection
3. Feeding missing or wrong inputs

5. AVAILABLE SOLUTIONS AS

Which solutions are available to the customers when they face the problem or need to get the job done? What have they tried in the past? What pros & cons do these solutions have? i.e. pen and paper is an alternative to digital notetaking

Manual calculations based on past climatic conditions which consumes large amount of time were tried in the past.

Pros:
Consumes less time
Cost-effective

Cons:
Network connectivity

Explore AS, differentiate

Focus on J&P, tap into BE, understand RC

2. JOBS-TO-BE-DONE / PROBLEMS J&P

Which jobs-to-be-done (or problems) do you address for your customers? There could be more than one; explore different sides.

Since there's no proper platform for wind energy prediction, we predict the energy output of wind turbine in order to earn some revenue and to locate a better place for wind farms.

9. PROBLEM ROOT CAUSE RC

What is the real reason that this problem exists? What is the back story behind the need to do this job?
i.e. customers have to do it because of the change in regulations.

Failures occur because of locating wind farms in unsuitable environment.

7. BEHAVIOUR BE

What does your customer do to address the problem and get the job done?

Since wind speed is constantly changing, so is the wind's energy content. The amount of fluctuation depends on the local surface conditions and obstructions as well as the weather.

Focus on J&P, tap into BE, understand RC

Identify strong TR & EM

3. TRIGGERS TR

What triggers customers to act?

Prediction of wind energy helps individuals and electricity suppliers to locate better location for wind farms and let them earn revenue.

4. EMOTIONS: BEFORE / AFTER EM

How do customers feel when they face a problem or a job and afterwards?

Before:
1. Stress, frustration
2. Fear of loss of investment

After:
1. Confidence, Happiness
2. Satisfaction, Relaxation

10. YOUR SOLUTION SL

A prediction system is developed with a method of combining statistical models and physical models. In this system, the inlet condition of the wind farm is forecasted by the auto regressive model.

Large turbine blades help capturing more of the available wind.

8. CHANNELS of BEHAVIOUR CH

8.1 ONLINE

What kind of actions do customers take online?

Checking on data updation

8.2 OFFLINE

What kind of actions do customers take offline?

Monitoring and maintaining wind farms.

4. REQUIREMENT ANALYSIS

4.1 Functional requirement

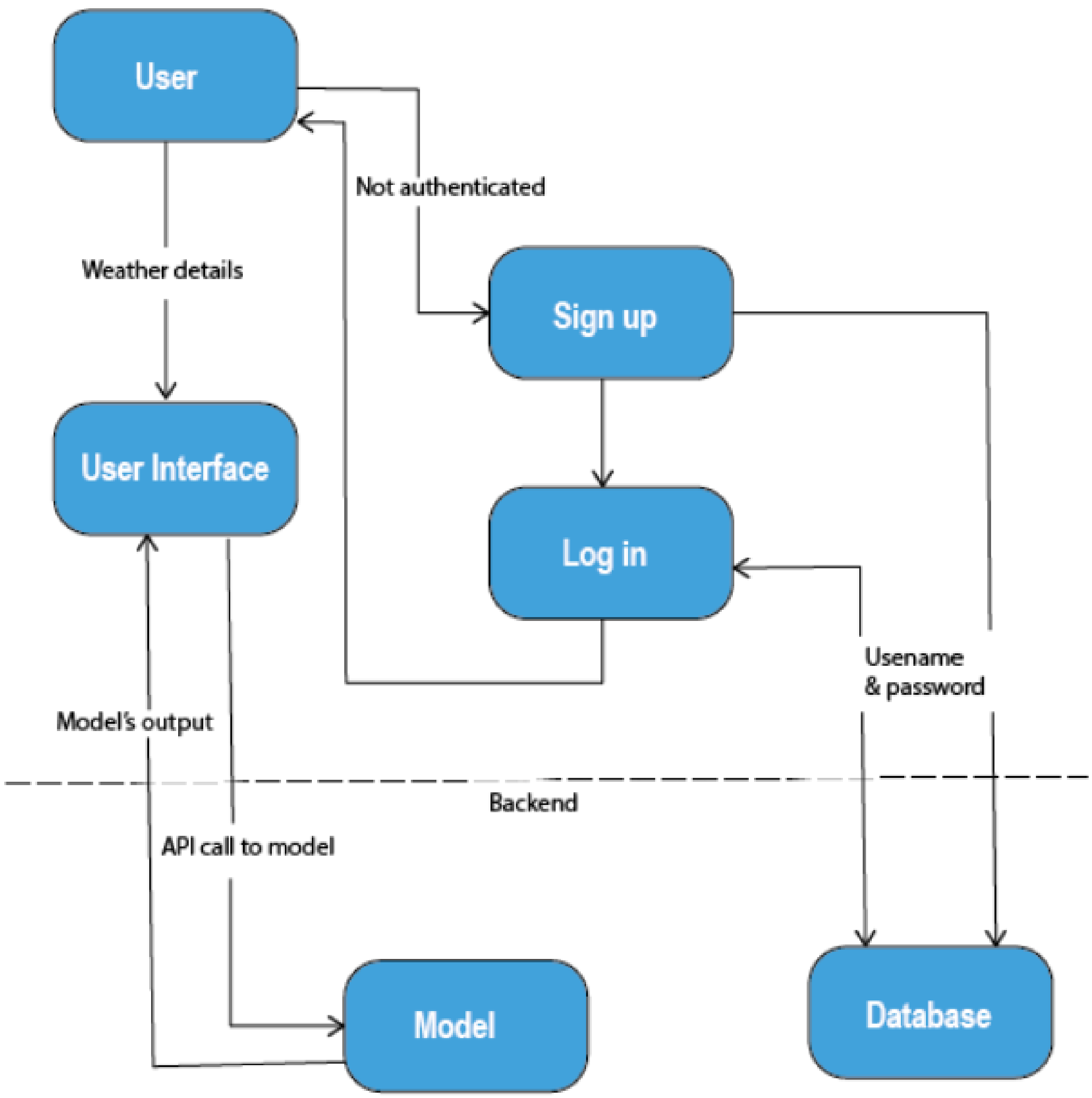
FR No.	Functional Requirement (Epic)	Sub Requirement (Story / Sub-Task)
FR-1	User Registration	Registration through Gmail Registration through form
FR-2	User Confirmation	Confirmation via Email Confirmation via OTP
FR-3	User login into website	Login using credentials Forgot password/change password for updating user credentials
FR-4	Displaying further information about the site	To know more about the site, user can click on the about button
FR-5	Enter required parameters	Inputs like city name, area and more
FR-6	Validating all required fields	System checks whether all the required fields are filled and those values are correct
FR-7	Displays weather conditions of entered city	Climatic conditions of the entered city will be displayed to the user
FR-8	Displays prediction results	User can view the results predicted
FR-9	Download prediction results	Download as jpg/png, download as pdf
FR-10	Logout from the site	User can log out from the site using the option provided

4.2 Non-Functional requirements

FR No.	Non-Functional Requirement	Description
NFR-1	**Usability**	The responsive website satisfies the user needs and is easy to use.
NFR-2	**Security**	Login credentials will be protected from attacks and of single use only. If it doesn't match the existing one, it shows error message. Number of attempts to login to the site is limited
FR-3	**Reliability**	User interface to guide the users throughout the website. User credibility is maintained by means of social proof System provides the precise output without generating errors
NFR-4	**Performance**	Site evaluates the user queries quickly
NFR-5	**Availability**	User can access the site from anywhere, anytime.
NFR-6	**Scalability**	With sufficient internet access, the system can be used as a web application to handle users from multiple users.

5. PROJECT DESIGN
5.1 Data Flow Diagrams

Data Flow Diagrams:



User Stories

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

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
Customer (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
		USN-2	As a user, I will receive confirmation email once I have registered for the application	I can receive confirmation email & click confirm	High	Sprint-1
		USN-3	User should verify the email once they have created their account.	I can register & access the dashboard with using my phone number and password	Low	Sprint-1
		USN-4	As a user, I can register for the application through Gmail		Medium	Sprint-1
	Login	USN-5	As a user, I can log into the application by entering email & password		High	Sprint-1
	Dashboard	USN -6	Once I have logged in, I can see my		Medium	Sprint-2

			dashboard .			
Customer (Web user)	Web access	USN -7	As a customer I can access the website to predict the turbine power	Customer can access the website once they logged in.	High	Sprint-2
	Prediction	USN - 8	As a customer when I enter the weather details, the website should predict the approximate turbine power		High	Sprint-2
		USN-9	Customer can also provide the latitude and longitude of any location, and our web app will predict the wind power based on the wind speed and wind direction of the location given.		High	Sprint-2
	Forecasting	USN-10	Customer can enter latitude and longitude of any location, our website will forecast wind speed , wind direction and wind power for next 6 days.		Medium	Sprint - 3
	Plotting	USN - 11	Website provides various charts to make the customer understand the speed, direction and power visually.			

User Type	**Functional Requirement (Epic)**	**User Story Number**	**User Story / Task**	**Acceptance criteria**	**Priority**	**Release**
	Security	USN- 12	As a customer I expect my data to be secured	Data should be encrypted	Medium	Sprint-3
Administrator	Database Access	USN - 13	As an Administrator, I should maintain the website. And update the website regularly.	I can manage the website	Low	Sprint-4

5.2 Solution & Technical Architecture

Technical Architecture:

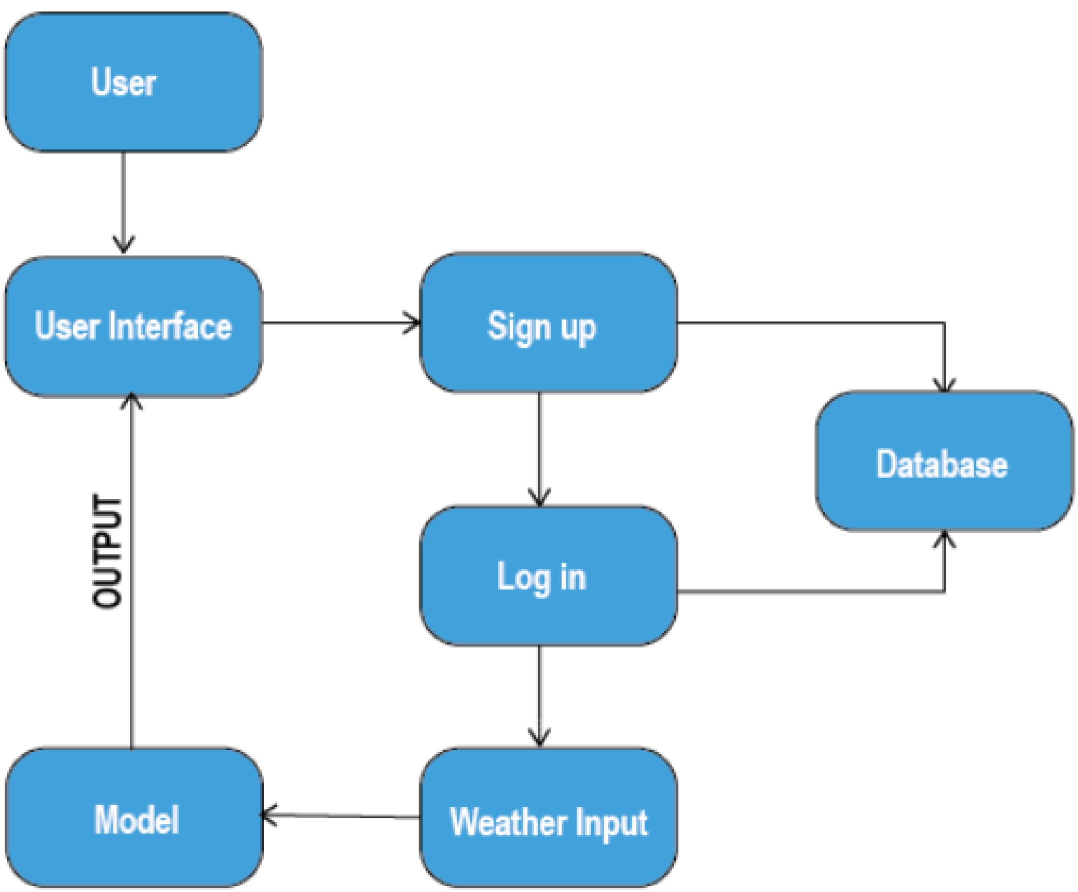


Table-1 : Components & Technologies:

S.No	Component	Description	Technology
1.	User Interface	User can interact with web application	React JS
2.	Application Logic-1	Using python to create API's	Python
3.	Application Logic-2	Creating a model to Predict the data	IBM Watson STT service
4.	Application Logic-3	Logic for a process in the application	IBM Watson Assistant
5.	Database	To store user details and dataset	NoSQL
6.	Cloud Database	Database Service on Cloud	MongoDB atlas
7.	File Storage	-	-
8.	External API-1	Encrypting the user name, password and communication details	NPM package encryption
9.	External API-2	Purpose of External API used in the application	Aadhar API, etc.
10.	Machine Learning Model	Predicting the out of wind turbine using weather data	Regression Model
11.	Infrastructure (Server / Cloud)	-	-

Table-2: Application Characteristics:

S.No	Characteristics	Description	Technology
1.	Open-Source Frameworks	Using open source for external packages	Technology of Opensource framework
2.	Security Implementations	For securing the details of the users	Encryption algorithms.
3.	Scalable Architecture	The architecture used here is a 3tier architecture where a middleware is present to carry out the communication between client and server.	3tier architecture.
4.	Availability	It's a web application	React JS

5.	Performance	100 request per second for the server. We can also make higher number of requests per seconds by upgrading	Server hosting

4.	Availability	it's a web application	React js
5.	Performance	100 request per second for the database.	mongoDB atlas

5.3 User Stories

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
						Akash R Monish Kumar S.S
Sprint-1	Login	USN-5	As a user,I can log into the application by entering email &password	5	High	Tarun H Shasti Alagan R Akash R Monish Kumar S.S Tarun H
Sprint-2	Dashboard	USN-6	Once I have logged in, I can see my dashboard.	6	Medium	Tarun H Shasti Alagan R Akash R Monish Kumar S.S Tarun H
Sprint-2	Web access	USN-7	As a customer I can accessthe website to predict the turbine power	7	High	Tarun H Shasti Alagan R Akash R Monish Kumar S.S

						Tarun H
Sprint-2	Prediction	USN=8	As a customer when I enterthe weather details, the website should predict the approximate turbine power	7	High	Tarun H Shasti Alagan R Akash R Monish Kumar S.S Tarun H
Sprint-3		USN-9	Customer can alsoprovide the latitude and longitude of anylocation, and ourweb app will predict the windpower based on the wind speed and winddirection of the location given.	10	Medium	Tarun H Shasti Alagan R Akash R Monish Kumar S.S Tarun H
Sprint-3	Forecasting	USN-10	Customer canenter latitude and longitude of any location, our website will forecast wind	5	Medium	Tarun H Shasti Alagan R

Sprint	**Functional Requirement (Epic)**	**User Story Number**	**User Story / Task**	**Story Points**	**Priority**	**Team Members**
			speed , winddirection and wind power for next6 days.			Akash R Monish Kumar S.S
Sprint-3	Plotting	USN-11	Website provides various charts to make the customer understand the speed, direction and power visually.	3	Low	Tarun H Shasti Alagan R Akash R Monish Kumar S.S
Sprint-3	Security	USN-12	As a customer I expect my data to be secured	2	Low	Tarun H Shasti Alagan R Akash R Monish Kumar S.S

Sprint-4	Database Access	USN-13	As an Administrator, I should maintain thewebsite. And update the website regularly.	20	High	Tarun H Shasti Alagan R Akash R Monish Kumar S.S

6. PROJECT PLANNING & SCHEDULING
6.1 Sprint Planning & Estimation

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Registration	USN-1	I can sign up for the application as a user by providing my email address, a password, and a password confirmation.	5	High	Tarun H Shasti Alagan R Akash R Monish Kumar S.S
Sprint-1		USN-2	When I register for the application as a user, I will get a confirmation email.	5	High	Tarun H Shasti Alagan R Akash R Monish Kumar S.S Tarun H
Sprint-1		USN-3	After creating their account, the user should confirm the email.	2	Low	Tarun H Shasti Alagan R Akash R Monish Kumar S.S Tarun H
Sprint-1		USN-4	As a user, I can register for the applicationthrough Gmail	3	Medium	Tarun H Shasti Alagan R

6.2 Sprint Delivery Schedule

Project Tracker, Velocity& Burndown Chart:(4 Marks)

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	22 Oct 2022	27 Oct 2022		
Sprint-2	20	6 Days	29 Oct 2022	03 Nov 2022		

Sprint	Total StoryPoints	Duration	Sprint Start Date	Sprint End Date(Planned)	Story Points Completed (as on Planned End Date)	Sprint ReleaseDate (Actual)
Sprint-3	20	6 Days	04 Nov 2022	09 Nov 2022		
Sprint-4	20	6 Days	11 Nov 2022	16 Nov 2022		

Velocity:

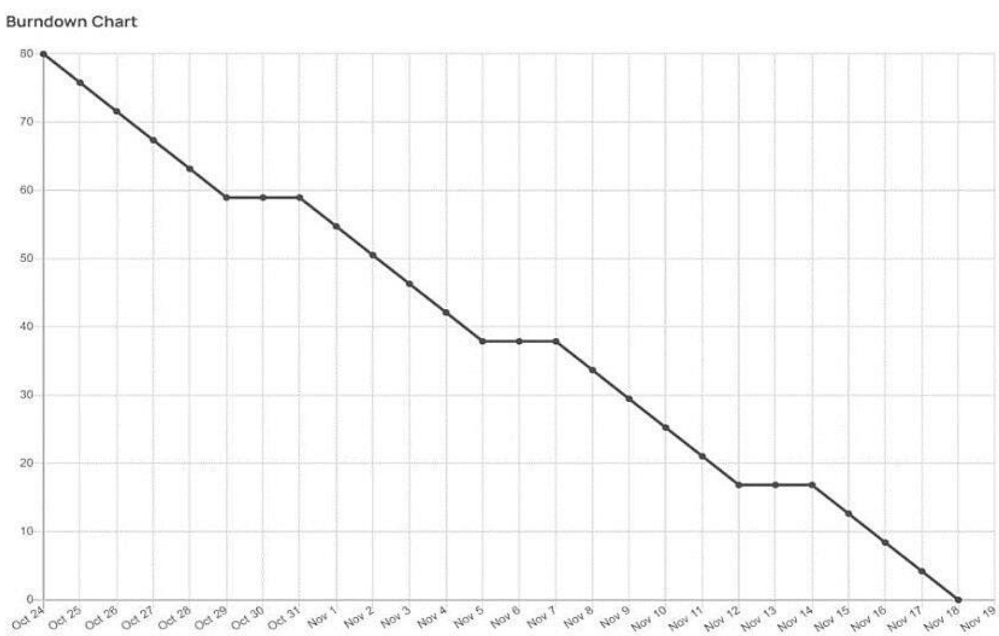
Imagine we have a 10-day sprint duration, and the velocity of the team is 20 (points per sprint). Let’s calculate the team’s average velocity (AV) per iteration unit (story points per day).

$$AV = \frac{sprint\ duration}{velocity} = \frac{20}{10} = 2$$

Burndown Chart:

A burn down chart plots the amount of work remaining to perform against the amount of time. In agile software development approaches like Scrum, it is frequently employed. Burn down charts, however, can be used for any project that makes observable progress over time.

6.3 Reports from JIRA



7. CODING & SOLUTIONING

7.1 Feature 1

We have developed a website which authenticates users and help them upload and check the seriousness of the diabetics.

7.2 Feature 2

We have developed a multilayer deep convolutional neural network that classifies the user image of a eye to which extense has the disease diabetics has been affected. The model will classify the images into 5 categories of diabetics and report them on asking for prediction. We have also developed a messaging service for receiving message for the type of diabetics.

8. TESTING

8.1 Test Cases

8.2 User Acceptance Testing

1.Purpose of Document

This document serves as a quick reference for the Predicting the energy output of wind turbine based on weather condition using Machine Learning.

Defect Analysis:

Resolution	Severity 1	Severity 2	Severity 3	Severity4	Subtotal
By Design	5	4	2	3	14
Duplicate	1	0	3	0	4
External	2	3	0	1	6
Fixed	9	2	4	15	30
Not Reproduced	0	0	1	0	1
Skipped	0	0	1	1	2
Won'tFix	0	5	2	1	8
Totals	17	14	13	21	65

Test Case Analysis:

Section	TotalCases	Not Tested	Fail	Pass
PrintEngine	9	0	0	9
ClientApplication	45	0	0	45
Security	2	0	0	2
Out-sourceShipping	3	0	0	3
ExceptionReporting	9	0	0	9
FinalReportOutput	4	0	0	4
VersionControl	2	0	0	2

9. RESULTS

9.1 Performance Metrics :- Model

10. ADVANTAGES & DISADVANTAGES

ADVANTAGES:

[1] Machine learning can automate the prediction of wind turbine energy output based on weather conditions, which can save time and improve accuracy.

[2] Machine learning can identify patterns in data that may be difficult for humans to discern. This can lead to more accurate predictions of wind turbine energy output.

[3] Machine learning can make predictions based on data from a variety of sources, including weather data, which can provide a more complete picture of the conditions that will affect wind turbine energy output.

DISADVANTAGES:

There are a few disadvantages to predicting the energy output of a wind turbine based on weather conditions using machine learning. First, the accuracy of the predictions may not be very high, since weather conditions can be quite variable. Secondly, the predictions may not be very reliable, since the weather conditions may change very quickly, and the predictions may not be updated in time. Finally, the predictions may not be very useful, since the energy output of a wind turbine is not directly related to the weather conditions.

11. CONCLUSION

Weather conditions have a significant impact on the amount of energy produced by a wind turbine. Machine learning can be used to predict the output of a turbine based on the weather conditions. This can be used to manage the power grid and ensure that the correct amount of power is being produced.

12. FUTURE SCOPE

There is a great potential for using machine learning to predict the energy output of wind turbines based on weather conditions. Currently, there are a number of machine learning models that have been developed and tested on various datasets. However, there is a need for further research to improve the accuracy of these models. In addition, there is a need to develop new models that can handle more complex weather conditions.

13. APPENDIX

13.1. Source Code

https://c4model.com/
https://developer.ibm.com/patterns/online-order-processing-system-during-pandemic/ https://www.ibm.com/cloud/architecture
https://aws.amazon.com/architecture
https://medium.com/the-internal-startup/how-to-draw-useful-technical-architecture-diagrams-2d20c9fda90d

13.2. GitHub Link:

https://github.com/IBM-EPBL/IBM-Project-6441-1658829016