PREDICTING THE ENERGY OUTPUT OF WIND TURBINE BASED ON WEATHER CONDITION

DOMAIN NAME: APPLIED DATA SCIENCE

TEAM ID: PNT2022TMID48318

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1. INTRODUCTION

Wind plant has lower cost of energy compared to other renewable energy source for large scale application. Due to the different geographical patterns, weather, and properties of the wind turbines, a wind turbine may have various performances given different situations. If the total output of a wind power plant can be predicted with high accuracy, more useful information can be provided to the power companies to help in scheduling the power generation. This information will allow a more flexible and intelligent control at a WPP (Wind power Plant).

Methods for predicting wind power generation can be categorized into physical methods, statistical methods, methods based on neural networks, and hybrid methods. The physical methods rely heavily on numeric whether prediction, which is confined by the sensors and monitoring devices placed within the WPP. The quality of hardware chosen, the parameters settings, the computation time, the time delay, and the sampling rates influence the accuracy of data collected from the WPP.

It is easier to predict a single wind turbines performance rather than a whole WPP power generation. Statistical and neural networks methods are based on the historical data and have a low prediction cost. The relationship between input data and output data based on the historical measured data is learned and then a nonlinear relationship model between them is built. But when new data not previously included in the training data set is used as input into this kind of model, the prediction error might be large, which is a disadvantage.

Different prediction methods mentioned above can be combined as hybrid methods to achieve better prediction results. But this will increase the complexity of the model. In this paper, multiple linear regressions are applied to predict the power generation at wind power plant.

1.1 PROJECT OVERVIEW:

Wind energy plays an increasing role in the supply of energy world-wide. The energy output of a wind farm is highly dependent on the weather conditions present at its site. If the output can be predicted more accurately, energy suppliers can coordinate the collaborative production of different energy sources more efficiently to avoid costly overproduction. In this paper, we predict energy prediction based on weather data and analyse the important parameters as well as their correlation on the energy output.

Solution: Our aim is to map weather data to energy production. We wish to show that even data that is publicly available for weather stations close to wind farms can be used to give a good prediction of the energy output. Furthermore, we examine the impact of different weather conditions on the energy output of wind farms. We are building an IBM Watson AutoAI Machine Learning technique to predict the energy output of wind turbine. The model is deployed on IBM cloud to get scoring end point which can be used as API in mobile app or web app building. We are developing a web application which is built using node red service. We make use of the scoring end point to give user input values to the deployed model. The model prediction is then showcased on User Interface to predict the energy output of wind turbine.

1.2 PURPOSE:

Wind energy plays an increasing role in the supply of energy world-wide. The energy output of a wind farm is highly depend on the weather condition present at its site.

If the output can be predicted more accurately, energy suppliers can coordinate the collaborative production of different energy sources more efficiently to avoid costly over production.

2. LITERATURE SURVEY:

(Niayifar & Porte-Agel, 2019)

Machine learning facilitates an alternative to existing analytical models for predicting the amount of energy generated or the performance of wind power installations. Traditional methods rely on complex differential equations systems requiring significant computational power and are slow to deliver results with acceptable accuracy. The use of machine learning to identify patterns in multidimensional data has proven to be an inspired decision, with the resulting models providing robustness, tolerance to outliers and errors, and success in dealing with noisy data. Therefore, support vector regression (SVR), regression tree (RT), random forest (RF), and artificial neural networks (ANNs) are selected to model this problem.

(De Giorgi, Campilon-go, Ficarella, & Congedo, 2020)

Based on these error intervals, the model's parameters can be selected and further used to fit the data. SVRs, similar to RT and RF, are sensitive to the selected input variables. Various data preparation steps must be completed before the data are input into these models. Wavelet transform is used to decompose time series data into components that are approximately stationary.

2.1 EXISTING PROBLEM:

There are several methods which are used for short-term prediction of wind generation at present:

The simplest ones are based on climatology or averages of past production values. One such naive predictor referred to as 'what you see is what you get' states that the future wind generation will be the same as the last measured value. Quiet good for 4-6 hours curve but very naive.

Advanced approaches for short-term wind power forecasting necessitate predictions of meteorological variables as input and make use of power curves. So to predict wind energy output one has to understand the power curve and plot the points in the curve, which is very tedious task .

2.2 REFERENCES:

[1]. O. Kramer and F.Gieseke. Analysis of wind energy time series with kernel methods and neural networks. In Seventh International Conference on Natural Computation, 2019.

[2].O. Kramer and F.Gieseke. Short-term wind energy forecasting using support vector re-gression. In International Conference on Soft Computing Models in Industrial . ronmental Applications, pages 271–280. Springer, 2011.

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[4]R. Poli, W. B. Langdon, and N. F. Mc Phee. A Field Guide to Genetic Programming. lulu.com, 2018.M. Schmidt and H. Lipson. Age-fitness pareto optimization. In Genetic Programming146. Springer, 2020.

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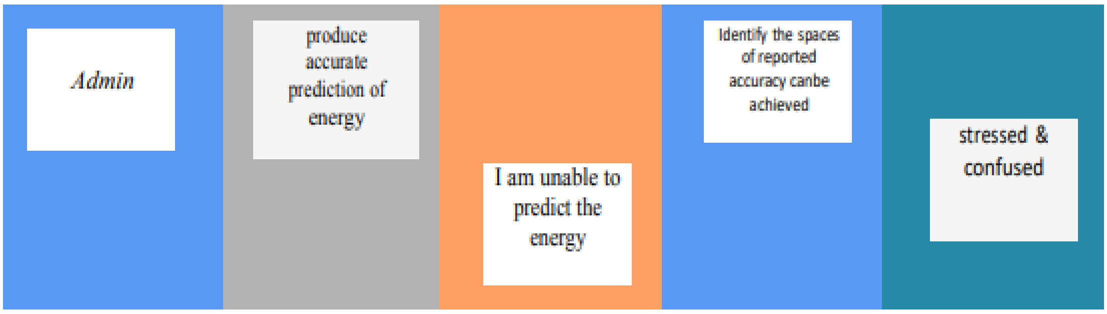
https://byjus.com/free-ias-prep/wind-energy-in-india/

https://flask.palletsprojects.com/en/1.1.x/

2.3 PROBLEM STATEMENT DEFINITION

A problem statement is a concise description of the problem or issues a project seeks to address. The problem statement identifies the current state, the desired future state and any gaps between the two. A problem statement is an important communication tool that can help ensure everyone working on a project knows what the problem they need to address is and why the project is important.

PROBLEM STATEMENT 1:



Admin

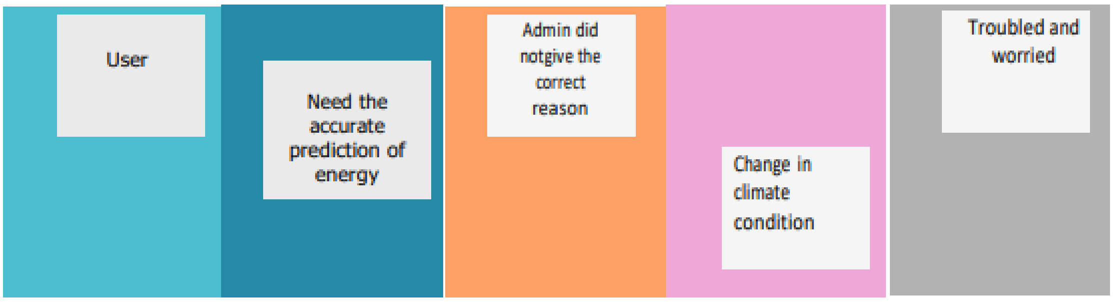
produce accurate prediction of energy

I am unable to predict the energy

Identify the spaces of reported accuracy canbe achieved

stressed & confused

PROBLEM STATEMENT 2:



User

Need the accurate prediction of energy

Admin did notgive the correct reason

Change in climate condition

Troubled and worried

Problem Statement (PS)	I am	I'm trying to	But	Because	Which makes me feel
PS-1	Admin	Produce accurate prediction of energy	I am unable to predict the energy	Weather condition	stressed & confused
PS-2	User	Need the accurate prediction of energy	Admin did not give the correct reason	Change in climate condition	Troubled and worried

3. IDEATION & PROPOSED SOLUTION

Ideation is the process where you generate ideas and solutions through sessions such as Sketching, Prototyping, Brainstorming, Brain writing, Worst Possible Idea, and a wealth of other ideation techniques. Ideation is also the third stage in the Design Thinking process.

3.1 EMPATHY MAP CANVAS:

An empathy map is *a* collaborative tool teams can use to gain a deeper insight into their customers. Much like a user persona, an empathy map can represent a group of users, such as a customer segment. The empathy map was originally created by Dave Gray and has gained much popularity within the agile community.

The empathy map represents a principal user and helps teams better understand their motivations, concerns, and user experience. Empathy mapping is a simple yet effective workshop that can be conducted with a variety of different users in mind, anywhere from stakeholders, individual use cases, or entire teams of people.

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.Empathy is important because it helps us understand how others are feeling so we can respond appropriately to the situation. It is typically associated with social behaviour and there is lots of research showing that greater empathy leads to more helping behaviour.

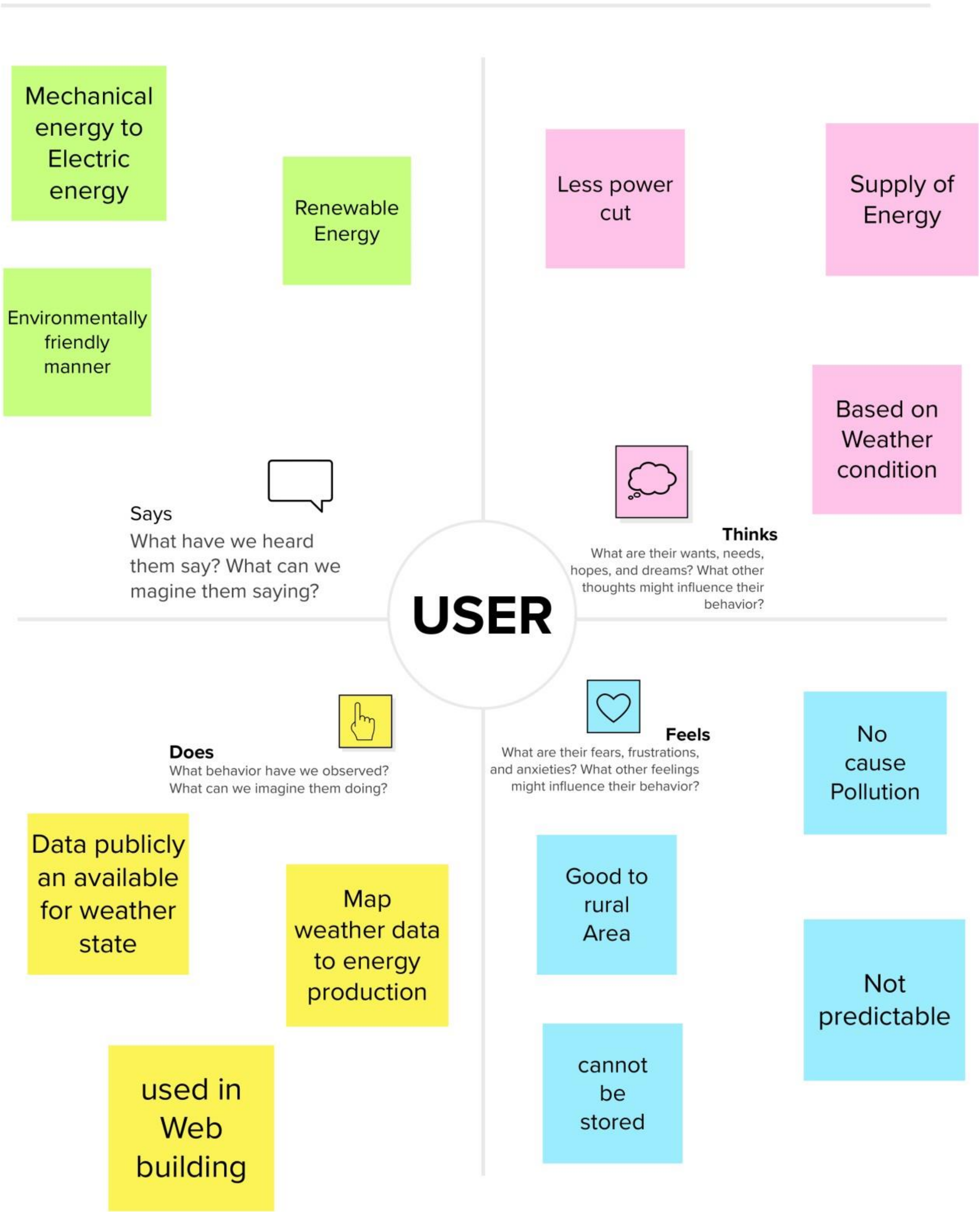

Mechanical energy to Electric energy
Renewable Energy
Environmentally friendly manner
Less power cut
Supply of Energy
Based on Weather condition
Says
What have we heard them say? What can we magine them saying?
Thinks
What are their wants, needs, hopes, and dreams? What other thoughts might influence their behavior?
USER
Does
What behavior have we observed? What can we imagine them doing?
Feels
What are their fears, frustrations, and anxieties? What other feelings might influence their behavior?
No cause Pollution
Data publicly an available for weather state
Map weather data to energy production
Good to rural Area
Not predictable
used in Web building
cannot be stored

Fig: Empathy map

3.2 IDEATION & BRAINSTORMING:

Brainstorming is usually conducted by getting a group of people together to come up with either general new ideas or ideas for solving a specific problem or dealing with a specific situation. For example, a major corporation that recently learned it is the object of a major lawsuit may want to gather together top executives for a brainstorming session on how to publicly respond to the lawsuit being filed.

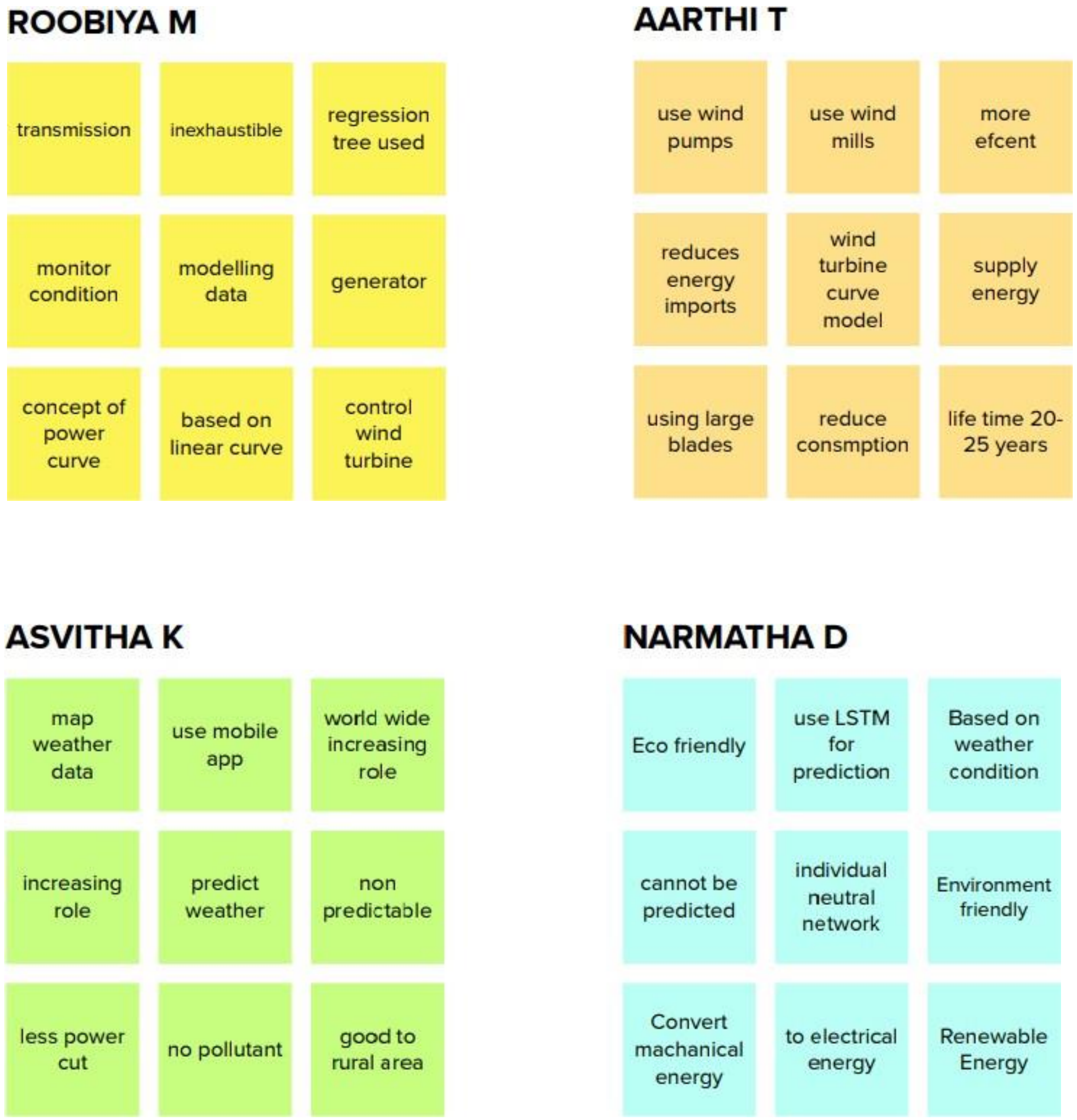


Fig: Brainstorm, Idea Listing and Grouping

3.3 PROPOSED SOLUTION

Problem Statement: Wind power consists of converting the energy produced by the movement of wind turbine blades driven by the wind into electrical energy. Wind power generation differs due to the stochastic nature of wind. The prediction of wind power plays an indispensable role in maintaining the stability of the entire power grid. This solution aims to forecast the wind power values efficiently by correlating the parameters of weather conditions and wind turbines.

Idea / Solution Description: Wind energy is a significant and eligible source that has the potential for producing energy in a continuous and sustainable manner among renewable energy sources. However, wind energy has several challenges, such as initial investment costs, the stationary property of wind plants, and the difficulty in finding wind-efficient energy areas. Hence, long-term wind power 16 forecasting is to be performed based on daily wind speed data using machine learning algorithms. With the process of applying machine learning models along with statistical models to historical wind speed data of a region, we can obtain long-term wind power values. This architecture integrated with a weather forecasting API, furthermore assists in the prediction in any location. The model is trained using IBM Watson's machine learning service and its scoring endpoint is fed to the application developed using the Flask framework to process the API's and energy prediction requests from the user to render the results on the UI.

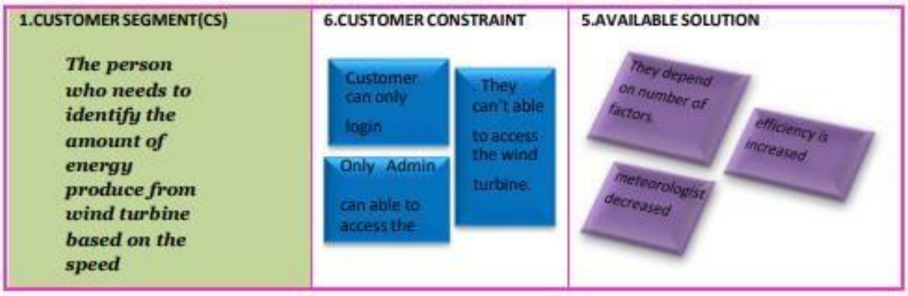
Novelty / Uniqueness: This solution is aimed to be architected in a way that makes it scalable and flexible in any kind of situations like unusual weather conditions, sudden influx of customers or users, analyzing in any type of location etc. This helps in dealing with the challenges of balancing supply and demand in any electricity system ,reducing the need for additional balancing energy and reserve power to integrate wind power by accurate wind power forecasting. Through statistical analysis combined with machine learning service over cloud as SAAS, the mentioned uniqueness are desired to be achieved.

Social Impact / Customer Satisfaction: By creating an effective machine learning model we will be able to increase the power produced hence the num and a clean technology, and this is one of the main impacts that makes it such an attractive and promising energy supply solution to predict the energy output of wind turbines based on weather conditions. Main social and environmental benefits includes reduction in CO2 emissions and fossil fuels imports. In areas where wind energy is employed, job opportunities are provided to many families and hence increases the employment percentage providing regional development. The customer will be able to get an overall picture of the output hence will get a clear picture on whether to invest more in that particular region or to rectify by investigation in another region. The customer will also be able to analyze and make changes based on the output to maximize the output making him/her a happy customer.

Business Model: (Financial Benefit) Opportunities to trade in the power produced are likely to expand significantly. Currently, it is possible for wind power producers to sell electricity to the grid, use it for captive consumption or sell it to third parties. With the emergence of independent power exchanges and with the likely liberalization and streamlining of power distribution across states, the opportunities to trade in power are likely to increase and become more lucrative.With the advent of the RPO/REC mechanism in India, there has been significant demand for non-solar (wind, small hydro, biomass etc.) over the past few months. Scalability of Solution 17 Energy trading in liberalized markets is particularly interesting from the perspective of wind energy producers because of the non-dispatchable nature of wind. This means that wind energy producers need to forecast how much they will produce in the future in order to place their bids. Hence customers can use our SAAS model to accomplish the task.

3.4. PROBLEM SOLUTION FIT:

Problem-Solution canvas is a tool for entrepreneurs, marketers and corporate innovators, which helps them identify solutions with higher chances for solution adoption, reduce time spent on solution testing and get a better overview of current situation.



1.CUSTOMER SEGMENT(CS)

The person who needs to identify the amount of energy produce from wind turbine based on the speed

6.CUSTOMER CONSTRAINT

Customer can only login

Only Admin can able to access the

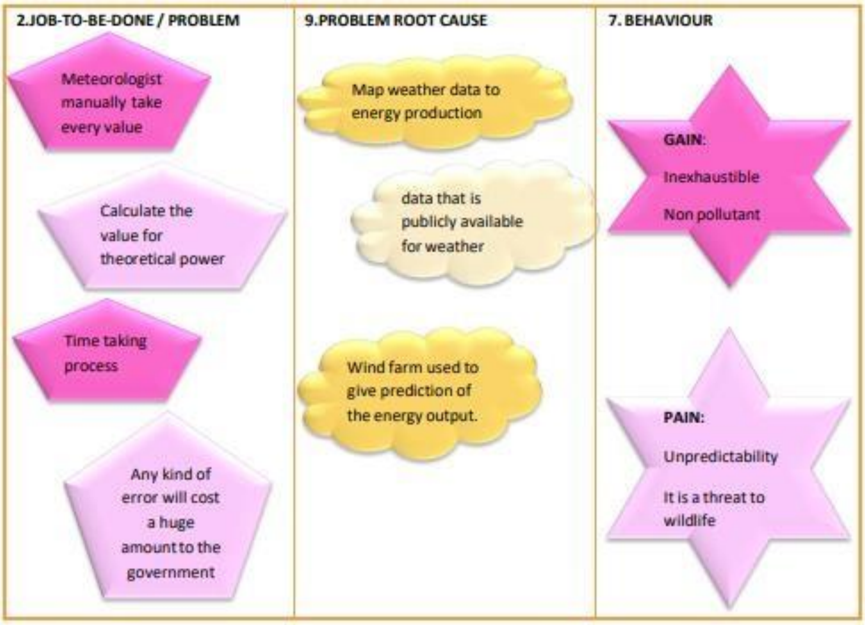
. They can't able to access the wind turbine.

5.AVAILABLE SOLUTION

They depend on number of factors.

efficiency is increased

meteorologist decreased



2.JOB-TO-BE-DONE / PROBLEM

Meteorologist manually take every value

Calculate the value for theoretical power

Time taking process

Any kind of error will cost a huge amount to the government

9.PROBLEM ROOT CAUSE

Map weather data to energy production

data that is publicly available for weather

Wind farm used to give prediction of the energy output.

7. BEHAVIOUR

GAIN:

Inexhaustible

Non pollutant

PAIN:

Unpredictability

It is a threat to wildlife

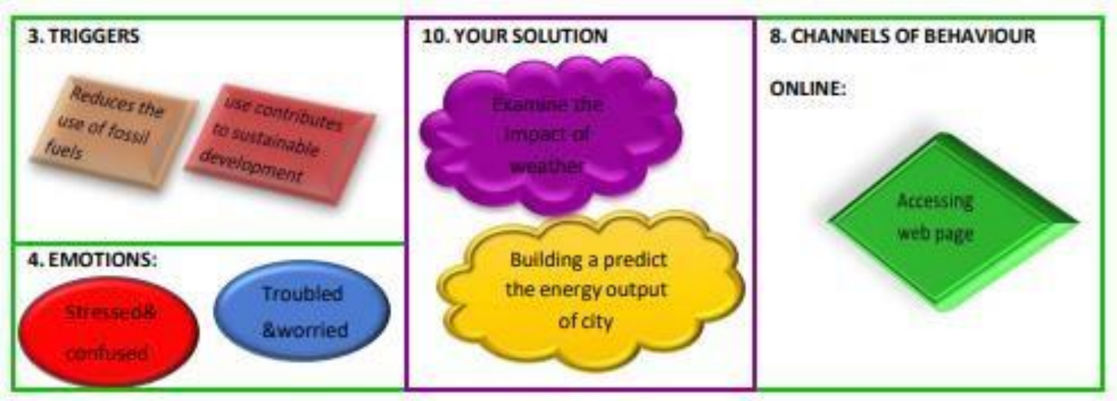

3. TRIGGERS
Reduces the use of fossil fuels
use contributes to sustainable development
4. EMOTIONS:
Stressed& confused
Troubled &worried
10. YOUR SOLUTION
Examine the impact of weather
Building a predict the energy output of city
8. CHANNELS OF BEHAVIOUR
ONLINE:
Accessing web page

Fig: Problem solution fit

4. REQUIREMENT ANALYSIS

Functional requirements are the desired operations of a program, or system as defined in software development and systems engineering.

1. Functional requirement.
2. Non-functional requirements.

4.1 Functional Requirements:

Following are the functional requirements of the proposed solution.

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 informationabout 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 ofentered city	Climatic conditions of the entered city will be displayedto 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:

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

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
NFR-3	Reliability	Wind Energy is reliable because it is both unlimited and domestic
NFR-4	Performance	Accuracy is high due to combination of multiple ML models to predict the output .
NFR-5	Availability	This is a web based application so we can access in any device that have a web browser with good Internet facility.
NFR-6	Scalability	It can be extended further to provide API which can be used by third party organizations such as Industries, Power suppliers , Governmental ,etc

5. PROJECT DESIGN

Project design is an early phase of a project where the project&#39;s key features, structure, criteria for success, and major deliverables are planned out. The aim is to develop one or more designs that can be used to achieve the desired project goals. importance of project designs are They help your team understand how to move through a project in the correct way. They help you avoid omitting important steps or items. They help you look more professional. They put the &#39;know how&#39; in the business, instead of in employees.

5.1 DATA FLOW DIAGRAMS

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, and where data is stored.

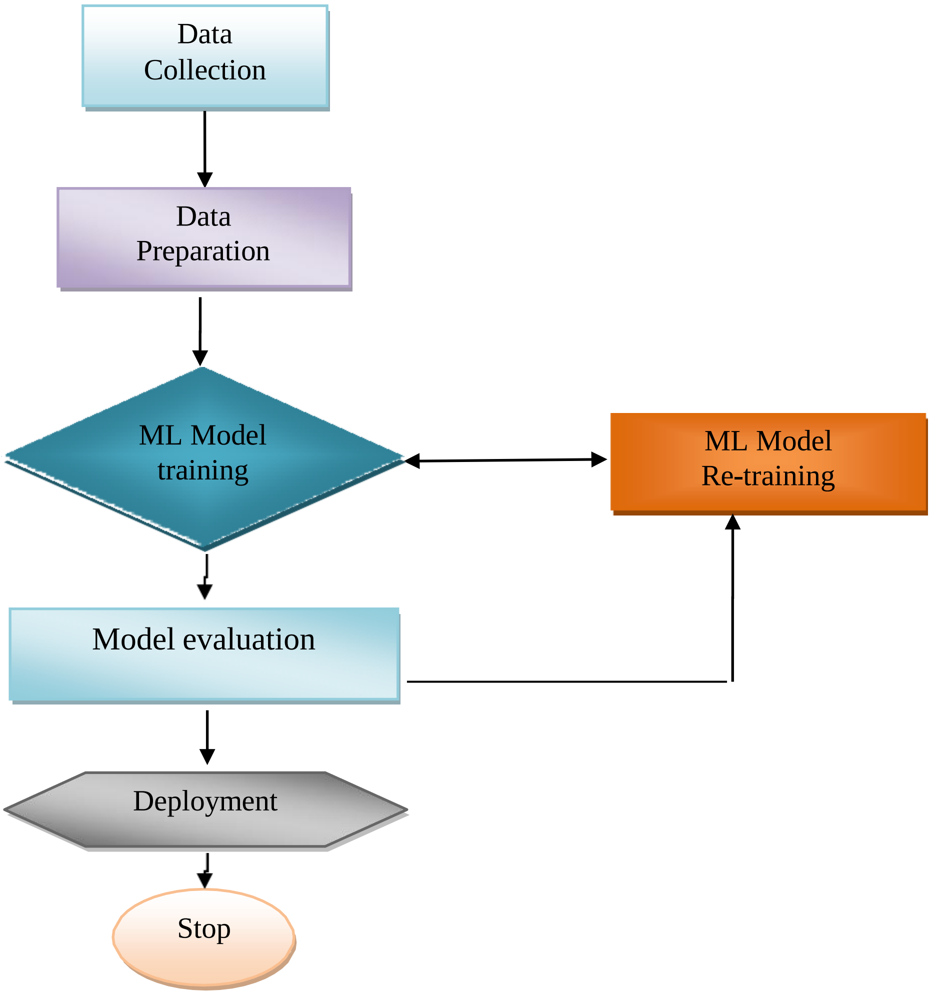


Fig : Data flow diagram

5.2 SOLUTION & TECHNICAL ARCHITECTURE :

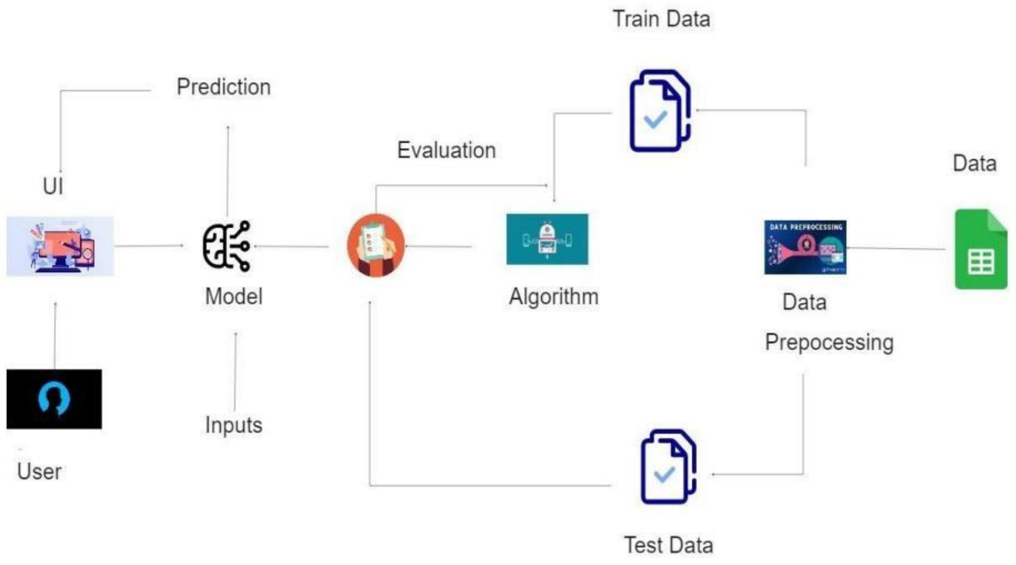
Solution Architecture:

Problem Statement:

Wind power consists of converting the energy produced by the movement of wind turbine blades driven by the wind into electrical energy. Wind power generation differs due to the stochastic nature of wind. The prediction of wind power plays an indispensable role in maintaining the stability of the entire power grid. This solution aims to forecast the wind power values efficiently by correlating the parameters of weather conditions and wind turbines.

Proposed Solution:

Long-term wind power forecasting is to be performed based on daily wind speed data using machine learning algorithms. A Minimal Viable Product is aimed to be built by integrating a machine learning algorithm with a front end UI to fetch the user inputs which will be evaluated and the wind power results are fed back to the UI. This architecture is further enhanced as the customer base expands by integrating with a weather forecasting API which assists in the prediction from any geographical location and by training the model using IBM Watson's machine learning service with its scoring endpoint fed to a Flask framework-built UI to process the API's and energy prediction requests from the user and rendering the results back to the UI.



5.3 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 customer, 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	Asacustomer,Icanlogintotheapplicationby enteringcorrectemailandpassword.Icanaccessmya	I can access my account/dashboard.	High	Sprint-1
	Dashboard	USN-3	As a customer, I can see all the orders raised by me	I get all the info needed in my dashboard.	Low	Sprint-2
	Order creation	USN-4	As a customer, I can place my order with the detailed description of my query	I can ask my query	Medium	Sprint-2
	Address Column	USN-5	Asacustomer,Icanhaveconversationswiththeassignedagentandgetmyqueriesclarified	My queries are clarified	High	Sprint-2
	Forgot password	USN-6	As a customer, I can reset my password by this option in case I forgot my old password.	I get access to my account again	Medium	Sprint-2
	Order details	USN-7	As a Customer, I can see the current stats of order	I get a better understanding	Medium	Sprint-2
Agent (web user)	Login	USN-1	AsanagentIcanlogintotheapplicationbyenteringCorrectemailandpassword.	I can access my account/dashboard	High	Sprint-2
	Dashboard	USN-2	As an agent ,I can see the order details assigned to me by admin.	I can see the tickets to which I could answer.	High	Sprint-3
	Address column	USN-3	As an agent ,I get to have conversations with the customer and clear his/her doubts.	I can clarify the issues.	High	Sprint-3
	Forgot password	USN-4	AsanagentIcanresetmypasswordbythisoptionincaseIforgotmyoldpassword.	I get access to my account again.	Medium	Sprint-4
Admin(Mobile user)	Login	USN-1	As aadmin,IcanlogintotheapplicationbyenteringCorrectemailandpassword	I can access my account/dashboard	High	Sprint-1
	Dashboard	USN-2	As an admin I can see all the orders raised in the entire system and lot more	I can assignments by seeing those order.	High	Sprint-1
	Agent creation	USN-3	As an admin I can create an agent for clarifying the customers queries	I can create agents.	High	Sprint-2
	Assignment agent.	USN-4	As an admin I can as sign an agent for each order created by the customer.	Enable agent to clarify the queries.	High	Sprint-1
	For go to password	USN-5	As an admin I can reset my password by this option in case I forgot my old password.	I get access to my account.	High	Sprint-1

6. PROJECT PLANNING & SCHEDULING

Project planning is a discipline addressing how to complete a project in a certain timeframe, usually with defined stages and designated resources. One view of project planning divides the activity into these steps: setting measurable objectives. identifying deliverables.

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	As a user ,I can register for the application by entering email, password and conforming my password.	5	High	ROOBIYA M AARTHI T ASVITHA K NARMATHA D
Sprint 1		USN-2	As a user, I will receive confirmation email once I have registered for the application	4	High	ROOBIYA M AARTHI T ASVITHA K NARMATHA D
Sprint 1		USN-3	As a user ,I can register for application through phone number	4	High	ROOBIYA M AARTHI T ASVITHA K NARMATHA D
Sprint 1		USN-4	As a user, I can register for the application through Gmail	3	Medium	ROOBIYA M AARTHI T ASVITHA K NARMATHA D
Sprint 1	Login(User)	USN-5	As a user, I can log into application by entering email& password	5	High	ROOBIYA M AARTHI T ASVITHA K NARMATHA D
Sprint 2	Dashboard	USN-6	Once I have logged in , I can see my dashboard.	6	Medium	ROOBIYA M AARTHI T ASVITHA K

						NARMATHA D
Sprint 2	Web access	USN-7	As a customer I can access the website to predict the weather conditions.	7	High	ROOBIYA M AARTHI T ASVITHA K NARMATHA D
Sprint 2	Prediction	USN-8	As a customer when I enter the weather details the website should predict the approximate weather conditions	7	High	ROOBIYA M AARTHI T ASVITHA K NARMATHA D
Sprint 3	Analysis	USN-9	As a customer, I wish to store my prediction and make analysis.	10	Medium	ROOBIYA M AARTHI T ASVITHA K NARMATHA D
Sprint 3	Security	USN-10	As a customer I expect my data to be secured.	10	Medium	ROOBIYA M AARTHI T ASVITHA K NARMATHA D
Sprint 4	Database Access	USN-11	An administrator I should maintain the website. And update the website regularly.	20	Low	ROOBIYA M AARTHI T ASVITHA K NARMATHA D

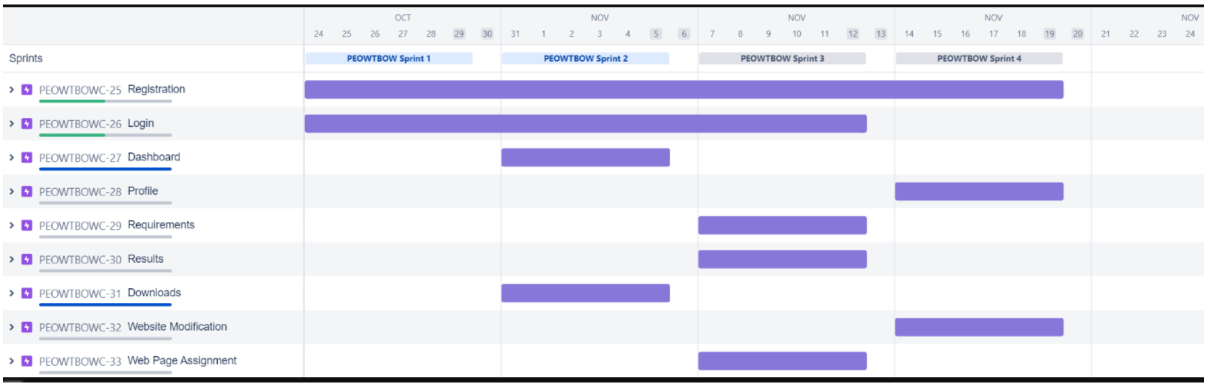
6.2 SPRINT DELIVERY SCHEDULE :

Sprint participants have produced sketches and drawings, writing, photographs, comic strips, videos and fully coded working prototypes. The answer is whatever&#39;s right to answer the problem**.**

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	29 Oct 2022	20	29 Oct 2022
Sprint 2	20	6 days	31 Oct 2022	5 Nov 2022	20	5 Nov 2022

Sprint 3	20	6 days	7 Nov 2022	12 Nov 2022	20	12 Nov 2022
Sprint 4	20	6 days	14 Nov 2022	19 Nov 2022	20	19 Nov 2022

6.3 REPORTS FROM JIRA:



7. CODING & SOLUTIONING

7.1 FEATURE :

Build the Flask app:

```
import numpy as np
from flask import Flask, request, jsonify, render_template
import joblib
import requests

app = Flask(__name__)
model = joblib.load('Power_Prediction.sav')

@app.route('/')
def home():
    return render_template('intro.html')

@app.route('/predict')
def predict():
    return render_template('predict.html')
```

```
@app.route('/windapi',methods=['POST'])
def windapi():
    city=request.form.get('city')
    apikey="a802b0f626c637d04185e582b5ad0d58"
    url="http://api.openweathermap.org/data/2.5/weather?q="+city+"&appid="+apikey
    resp = requests.get(url)
    resp=resp.json()
    temp = str((resp["main"]["temp"])-273.15) +" °C"
    humid = str(resp["main"]["humidity"])+" %"
    pressure = str(resp["main"]["pressure"])+" mmHG"
    speed = str((resp["wind"]["speed"])*3.6)+" Km/s"
    return render_template('predict.html', temp=temp, humid=humid,
pressure=pressure,speed=speed)
@app.route('/y_predict',methods=['POST'])
def y_predict():
    '''
    For rendering results on HTML GUI
    '''
    x_test = [[float(x) for x in request.form.values()]]
    prediction = model.predict(x_test)
    print(prediction)
    output = prediction[0]
    return render_template('predict.html', prediction_text='The energy predicted is {:.2f}
KWh'.format(output))

if__name__== "_main_":
    app.run(debug=False)
```

8. TESTING

The purpose of testing is to discover errors. Testing is the process of trying to discover every conceivable fault or weakness in a work product. It provides a way to check the functionality of components, sub-assemblies, assemblies and/or a finished product. It is the process of exercising software with the intent of ensuring that the Software system meets its requirements and user expectations and does not fail in an unacceptable manner. There are various types of test. Each test type addresses a specific testing requirement.

8.1 TEST CASES:

A test case has components that describe input, action and an expected response, in order to determine if a feature of an application is working correctly. A test case is a set of instructions on "HOW" to validate a particular test objective/target, which when followed will tell us if the expected behavior of the system is satisfied or not.

Characteristics of a good test case:

- Accurate: Exacts the purpose.
- Economical: No unnecessary steps or words.
- Traceable: Capable of being traced to requirements.
- Repeatable: Can be used to perform the test over and over.
- Reusable: Can be reused if necessary.

TYPES OF TESTS

1. Unit testing

Unit testing involves the design of test cases that validate that the internal program logic is functioning properly, and that program inputs produce valid outputs. All decision branches and internal code flow should be validated. It is the testing of individual software units of the application .it is done after the completion of an individual unit before integration. This is a structural testing, that relies on knowledge of its construction and is invasive. Unit tests perform basic tests at component level and test a specific business process, application, and/or system configuration. Unit tests ensure that each unique path of a business process performs accurately to the documented specifications and contains clearly defined inputs and expected results.

2. Integration testing

Integration tests are designed to test integrated software components to determine if they actually run as one program. Testing is event driven and is more concerned with the basic outcome of screens or fields. Integration tests demonstrate that although the components were individually satisfaction, as shown by successfully unit testing, the combination of components is correct and consistent. Integration testing is specifically aimed at exposing the problems that arise from the combination of components.

3. Functional test

Functional tests provide systematic demonstrations that functions tested are available as specified by the business and technical requirements, system documentation, and user manuals.

Functional testing is centered on the following items:

Valid Input : identified classes of valid input must be accepted.

Invalid Input : identified classes of invalid input must be rejected.

Functions : identified functions must be exercised.

Output : identified classes of application outputs must be exercised.

Systems/Procedures: interfacing systems or procedures must be invoked.

Organization and preparation of functional tests is focused on requirements, key functions, or special test cases. In addition, systematic coverage pertaining to identify Business process flows; data fields, predefined processes, and successive processes must be considered for testing. Before functional testing is complete, additional tests are identified and the effective value of current tests is determined.

4. System Test

System testing ensures that the entire integrated software system meets requirements. It tests a configuration to ensure known and predictable results. An example of system testing is the configuration-oriented system integration test. System testing is based on process descriptions and flows, emphasizing pre-driven process links and integration points.

5. White Box Testing

White Box Testing is a testing in which in which the software tester has knowledge of the inner workings, structure and language of the software, or at least its purpose. It is purpose. It is used to test areas that cannot be reached from a black box level.

6. Black Box Testing

Black Box Testing is testing the software without any knowledge of the inner workings, structure or language of the module being tested. Black box tests, as most other kinds of tests, must be written from a definitive source document, such as specification or requirements document, such as specification or requirements document. It is a testing in which the software under test is treated, as a black box .you cannot "see" into it. The test provides inputs and responds to outputs without considering how the software works.

7. Unit Testing:

Unit testing is usually conducted as part of a combined code and unit test phase of the software lifecycle, although it is not uncommon for coding and unit testing to be conducted as two distinct phases.

7.1 Test strategy and approach

Field testing will be performed manually and functional tests will be written in detail.

7.2 Test objectives

- All field entries must work properly.
- Pages must be activated from the identified link.
- The entry screen, messages and responses must not be delayed.

7.3 Features to be tested

- Verify that the entries are of the correct format
- No duplicate entries should be allowed
- All links should take the user to the correct page.

8. Integration Testing

Software integration testing is the incremental integration testing of two or more integrated software components on a single platform to produce failures caused by interface defects. The task of the integration test is to check that components or software applications, e.g. components in a software system or – one step up – software applications at the company level – interact without error.

Test Results: All the test cases mentioned above passed successfully. No defects encountered.

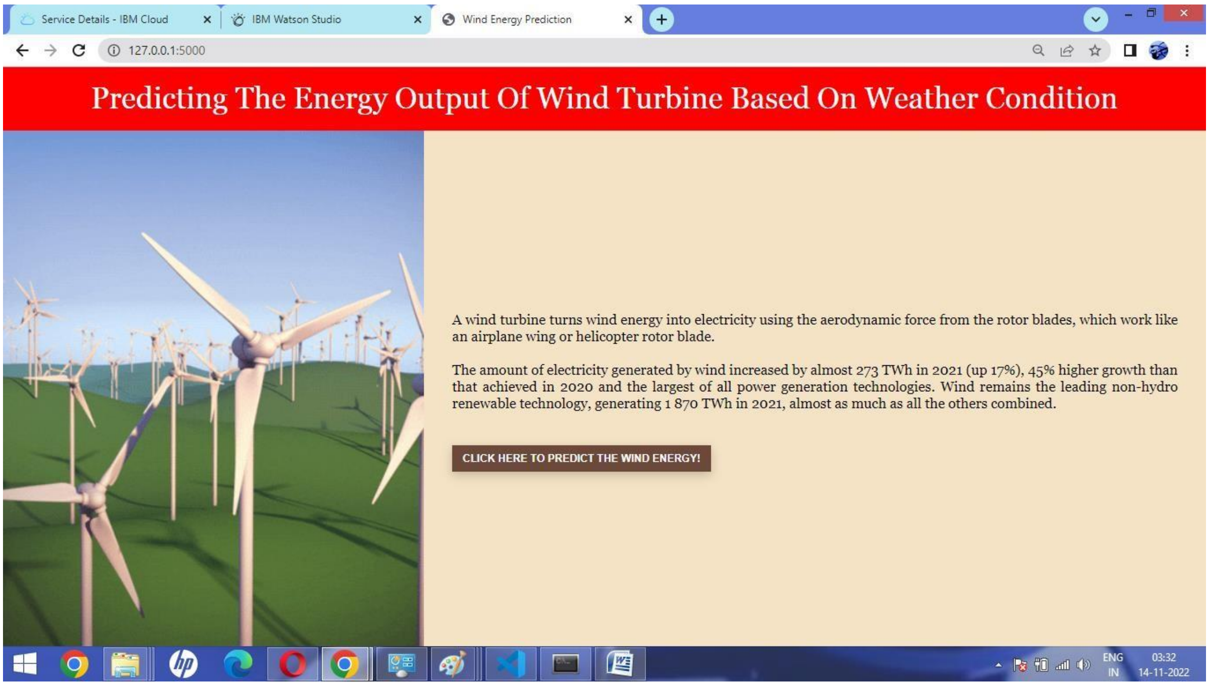
8.2 User Acceptance Testing

User Acceptance Testing is a critical phase of any project and requires significant participation by the end user. It also ensures that the system meets the functional requirements.

Test Results: All the test cases mentioned above passed successfully. No defects encountered.

9. RESULTS

9.1 PERFORMANCE METRICS:

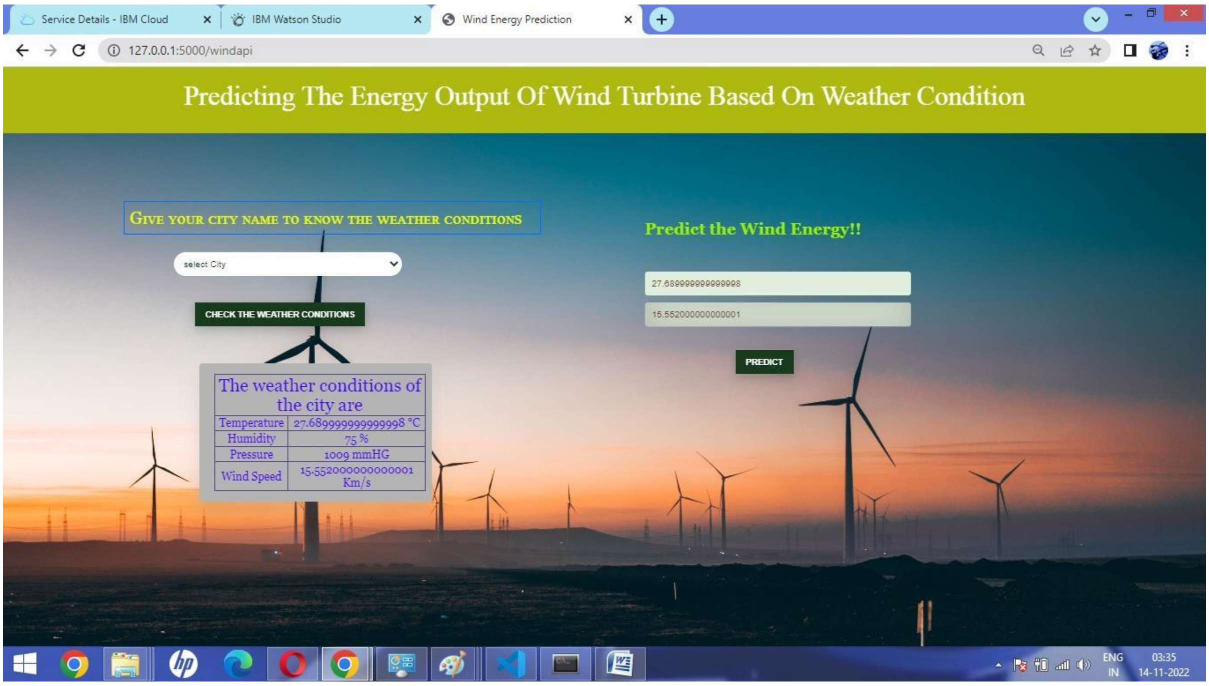


Predicting The Energy Output Of Wind Turbine Based On Weather Condition

A wind turbine turns wind energy into electricity using the aerodynamic force from the rotor blades, which work like an airplane wing or helicopter rotor blade.

The amount of electricity generated by wind increased by almost 273 TWh in 2021 (up 17%), 45% higher growth than that achieved in 2020 and the largest of all power generation technologies. Wind remains the leading non-hydro renewable technology, generating 1 870 TWh in 2021, almost as much as all the others combined.

CLICK HERE TO PREDICT THE WIND ENERGY!


Service Details - IBM Cloud
IBM Watson Studio
Wind Energy Prediction
127.0.0.1:5000/windapi
ENG IN
03:35
14-11-2022

Predicting The Energy Output Of Wind Turbine Based On Weather Condition

Give your city name to know the weather conditions

select City

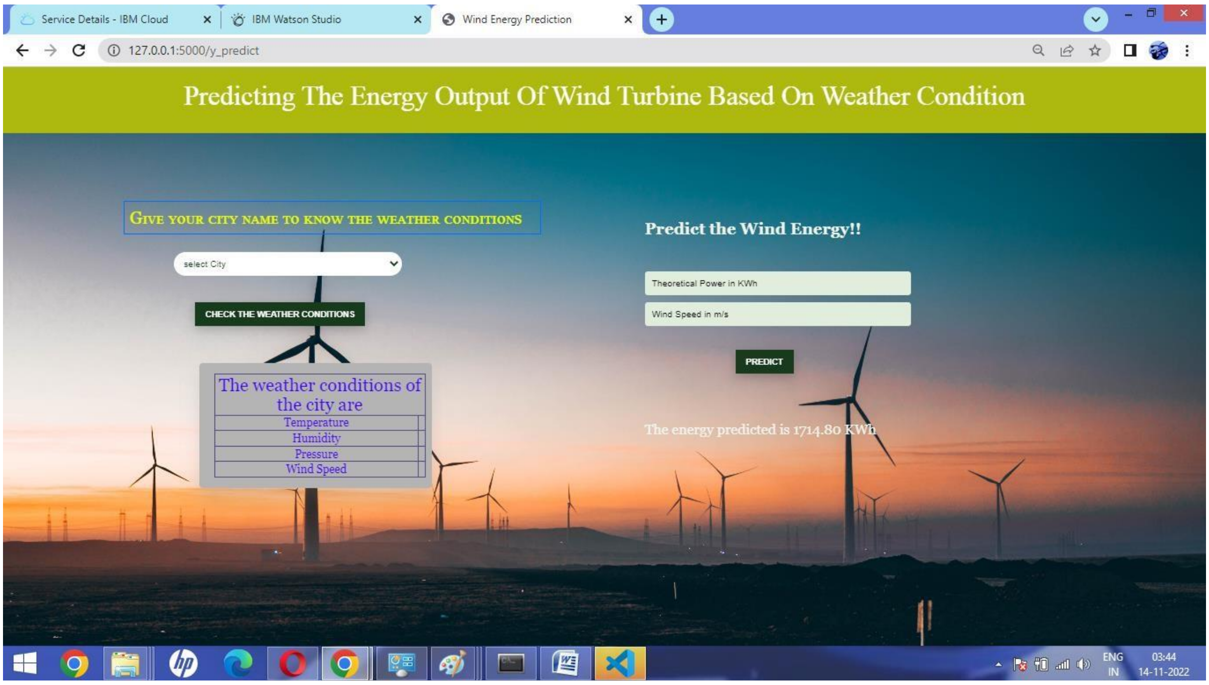
CHECK THE WEATHER CONDITIONS

The weather conditions of the city are	
Temperature	27.689999999999998 °C
Humidity	75 %
Pressure	1009 mmHG
Wind Speed	15.552000000000001 Km/s

Predict the Wind Energy!!

27.689999999999998

15.552000000000001



Predicting The Energy Output Of Wind Turbine Based On Weather Condition

Give your city name to know the weather conditions

The weather conditions of the city are

Predict the Wind Energy!!

The energy predicted is 1714.80 KWh

10. ADVANTAGES & DISADVANTAGES

ADVANTAGES:

- Weather Underground Services provide very accurate Historical Weather Data which increased the accuracy of model.
- On giving location permissions, web page can accurately predict power output at your live location.
- On the pros side, wind is a clean, renewable energy source, and is one of the most cost-effective sources for electricity.
- Turbines themselves run strictly on the power of wind generated, there is no need for fuel.
- The latest advances in technology have transformed preliminary wind turbine designs into extremely efficient energy harvesters.

DISADVANTAGES:

- Weather API is paid and the free version provide limited API requests per day.

- Android App can't be deployed on IBM Cloud.
- No free server available on IBM Cloud for deploying Backend.
- On the cons side, wind turbines can be noisy and unappealing aesthetically, and can sometimes adversely impact the physical environment around them
- Wind turbines are known to pose a threat to the wildlife. Flying birds and bats whose habitats or migratory paths could be injured or killed if they run into the blades that turn on the fanlike structure of wind turbines when they are spinning.

11. CONCLUSION

We started with the aim of improving the predictions of power generated using wind energy and we have achieved that using LSTM as machine learning model and performing model optimization on it. We have also observed that if the wind speed is less than 4 m/s the power generated by the system is zero. LSTM is not able to learn this pattern as this is not the part which it can understand in time series analysis. So, if a hybrid new model is created which can work as the combination of Decision Tree/Random Forest and LSTM we can improve upon these results as well.

12. FUTURE SCOPE

future work, we are planning further study of the possibilities for longer-term wind energy forecasting. Several forecasting models were discussed and a lot of researches on the models, which have their own characteristics, were presented. The major focus was on emphasizing the diversity of various forecasting methods available and also on providing a comparison of present mechanisms to determine the best available.

13. APPENDIX

SOURCE CODE

1.intro.html

```
<html>
   <head>
   <title>Wind Energy Prediction</title>
   <style>

      .header {
         top:0px;
         margin:0px;
         left: 0px;
         right: 0px;
         position: fixed;
         background: #fd0000;
         color: rgb(255, 255, 255);
         overflow: hidden;
         padding-bottom: 30px;
         font-family:Georgia, 'Times New Roman', Times, serif, serif;
         font-size: 2.5vw;
         width: 100%;
         padding-left:0px;
         text-align: center;
         padding-top:20px;
      }
      .second{
         top:90px;
         bottom:0px;
         margin:0px;
         left: 0px;
         right: 0px;
         position: fixed;
```

```
    padding: 0px;
    width: 100%;
    background-image:url(/static/image/aa.gif);
    background-repeat:no-repeat;
    background-size: contain;
}
.inside{
    top:90px;
    bottom:0px;
    margin:0px;
    left: 35%;
    right:  0%;
    position: fixed;
    padding-left: 40px;
    padding-top:15%;
    padding-right:40px;
    background-color:#f5e3c5;
    opacity: 100%;
    font-family:Georgia, serif;
    color:black;
    font-size:20px;
    text-align:justify;

}
.myButton{
      border: none;
      text-align: center;
      cursor: pointer;
      text-transform: uppercase;
      outline: none;
      overflow: hidden;
      color: #fff;
      font-weight: 700;
      font-size: 15px;
```

```
            background-color: #6c493a;
            padding: 10px 15px;
            margin: 0 auto;
            box-shadow: 0 5px 15px rgba(0,0,0,0.20);
        }
    </style>
    </head>
    <body>

        <div class="header">Predicting The Energy Output Of Wind Turbine Based On
Weather Condition</div>
        <div class="second">
            <div class="inside">A wind turbine turns wind energy into electricity using the
aerodynamic force from the rotor blades, which work like an airplane wing or helicopter rotor
blade. <br><br>
                The amount of electricity generated by wind increased by almost 273 TWh in 2021
(up 17%), 45% higher growth than that achieved in 2020 and the largest of all power
generation technologies. Wind remains the leading non-hydro renewable technology,
generating 1 870 TWh in 2021, almost as much as all the others combined.
        <br><br><br>
        <a href="{{url_for('predict')}}"><button type="button" class="myButton" >Click Here
To Predict The wind Energy!</button></a>
        </div>



        </div>
    </body>
</html>
```

2.predict.html:

```
<html>
```

```
  <head>
    <meta charset="UTF-8" />
    <meta name="viewport" content="width=device-width, initial-scale=1.0" />
    <meta http-equiv="X-UA-Compatible" content="ie=edge" />
    <link rel="stylesheet" href="https://use.fontawesome.com/releases/v5.7.2/css/all.css"
      integrity="sha384-
fnmOCqbTlWIlj8LyTjo7mOUStjsKC4pOpQbqyi7RrhN7udi9RwhKkMHpvLbHG9Sr"
crossorigin="anonymous" />
    <link href="https://fonts.googleapis.com/css?family=Dosis" rel="stylesheet" />
    <link rel="stylesheet" href="static/css/main.css"/>
    <link rel="stylesheet" href="static/css/media.css"/>
    <link rel="stylesheet" href="static/css/items_grid.css"/>



  <title>Wind Energy Prediction</title>
  <style>
#page {
 max-width: 80%;
 margin: auto;
}
body {
  background-image: url(/static/image/4.jpg);
  width: 100%;
  height: 100%;
  background-repeat: no-repeat;
  background-attachment: fixed;
  background-size: cover;
  overflow: hidden;

}
table {
    width: 100%;
    border-collapse: collapse;
```

```
}

.card {
        margin-right: auto;
        margin-left: 15%;
        width: 300px;
        box-shadow: 0 15px 25px rgba(129, 124, 124, 0.2);

        border-radius: 5px;
        backdrop-filter: blur(14px);
        background-color: rgb(180, 180, 180);
        padding: 15px;
        text-align: center;
      }
      .head {
        top:0px;
        margin:0px;
        left: 0px;
        right: 0px;
        position: fixed;
        background: #aeb90f;
        color: white;
        overflow: hidden;
        padding-bottom: 30px;
        font-size: 2.25vw;
        width: 100%;
        padding-left:0px;
        text-align:  center;
        padding-top:20px;
      }
      .second{
        top:80px;
        bottom:0px;
        margin:0px;
```

```
    left: 0px;
    right: 0px;
    position: fixed;
    padding: 0px;
    width: 100%;

    font-family:Georgia, serif;
    color:black;
    font-size:20px;
}
.inside{
    top:80px;
    bottom:0px;
    margin:0px;
    left: 51%;
    right:  0%;
    position: fixed;
    padding-left: 40px;
    padding-top:8%;
    padding-right:40px;

    font-family:Georgia, serif;
    color:#f3f5f0;
    font-size:20px;
    text-align:justify;

}
.myButton{
      border: none;
      text-align: center;
      cursor: pointer;
      text-transform: uppercase;
      outline: none;
      overflow: hidden;
```

```
            color: #fff;
            font-weight: 700;
            font-size: 12px;
            background-color: #183a1d;
            padding: 10px 15px;
            margin: 0 auto;
            box-shadow: 0 5px 15px rgba(0,0,0,0.20);
            margin-left:17%;
        }
    input       {
    width:50%;
    margin-bottom: 10px;
    background: #e1eedd;
    border: none;
    outline: none;
    padding: 10px;
    font-size: 13px;
    color: #6c493a;
    text-shadow: white;
    border: #6c493a;
    border-radius: 4px;
    box-shadow: white;
}
::placeholder {
  color: black;
  opacity: 1;
}

.left{
        top:80px;
          bottom:0px;
          margin:0px;
          left: 0%;
          right: 45.5%;
```

```
            position: fixed;
            padding-left: 10%;
            padding-top:5%;
            padding-right:40px;

            font-family:bold,Georgia, serif;
            color:rgb(238, 255, 0);;
            font-size:25px;

}
    select {
    width:50%;
    margin-bottom: 10px;
    background: white;
    border: none;
    outline: none;
    padding: 10px;
    font-size: 13px;
    color: #183a1d;
    text-shadow: white;
    border: #6c493a;
    border-radius: 40px;
    box-shadow: white;
}

input:focus { box-shadow: inset 0 -5px 45px rgba(100,100,100,0.4), 0 1px 1px
rgba(255,255,255,0.2); }



          table, th, td {
  border: 1px solid rgb(86, 72, 128);
  border-collapse: collapse;
  color: #3f00ff;
```

```
}

@media screen and (max-width: 500px) {

  .left,
  .second,
  .third {
      width: 70%;
  }
}




    </style>
    </head>
    <body>


        <header id="head">
        <div class="head">Predicting The Energy Output Of Wind Turbine Based On Weather Condition</div>
        </header>



        <div class="second">
        <div class="left">

            <p style="padding: 8px; border: 1px solid rgb(0, 110, 255); width: 575px;"> Give your city name to know the weather conditions</p>

        <div style="margin-left:10%">
        <form action="{{ url_for('windapi')}}"method="post" >
                <select name="city"  required >
                    <option value="" selected>select City</option>
```

```
<option value ="Ariyalur"  >  Ariyalur   </option>
<option value ="Andimadam"  >  Andimadam  </option>
<option value ="Coimbatore" >  Coimbatore  </option>
<option value ="Chengalpattu"  >  Chengalpattu   </option>
<option value ="Cuddalore"  >  Cuddalore  </option>
<option value ="Chennai"   >  Chennai </option>
<option value ="Dindigul"  >  Dindigul   </option>
<option value ="Dharmapuri" >  Dharmapuri  </option>
<option value ="Erode"  >  Erode   </option>
<option value ="Karur"  >  Karur   </option>
<option value ="Kancheepuram"  >  Kancheepuram   </option>
<option value ="Krishnagiri"   >  Krishnagiri </option>
<option value ="Kallakurichi"  >  Kallakurichi   </option>
<option value ="Madurai"   >  Madurai </option>
<option value ="Mayiladuthurai" >  Mayiladuthurai  </option>
<option value ="Nagapattinam"  >  Nagapattinam   </option>
<option value ="Kanyakumari"   >  Kanyakumari </option>
<option value ="Namakkal"  >  Namakkal   </option>
<option value ="Perambalur" >  Perambalur  </option>
<option value ="Pudukottai" >  Pudukottai  </option>
<option value ="Ramanathapuram" >  Ramanathapuram  </option>
<option value ="Ranipet"   >  Ranipet </option>
<option value ="Salem"  >  Salem   </option>
<option value ="Sivagangai" >  Sivagangai  </option>
<option value ="Tenkasi"   >  Tenkasi </option>
<option value ="Thanjavur"  >  Thanjavur   </option>
<option value ="Theni"  >  Theni   </option>
<option value ="Thiruvallur"   >  Thiruvallur </option>
<option value ="Thiruvarur" >  Thiruvarur  </option>
<option value ="Tuticorin"  >  Tuticorin   </option>
<option value ="Trichirapalli"  >  Trichirapalli   </option>
<option value ="Thirunelveli"  >  Thirunelveli   </option>
<option value ="Tirupathur" >  Tirupathur  </option>
<option value ="Tiruppur"  >  Tiruppur   </option>
```

```
        <option value ="Tiruvannamalai" >  Tiruvannamalai  </option>
        <option value ="The Nilgiris"   >   The Nilgiris    </option>
        <option value ="Vellore"    >  Vellore </option>
        <option value ="Viluppuram" >  Viluppuram  </option>
        <option value ="Virudhunagar"   >   Virudhunagar    </option>


      </select><br><br>
      <div style="margin-left:-15%"><button type="submit" class="myButton" >Check the Weather Conditions</button></div>

    </form>
    </div>
    <br>

    <div class="card">
    <table style="margin-left:2%; text-align:center; border-spacing:20px;">
      <tr>
        <td colspan="2" style="font-size:25px;">The weather conditions of the city are</td>
      </tr>
      <tr>
        <td>Temperature</td><td>{{temp}}</td>
      </tr>
      <tr>
        <td>Humidity</td><td>{{humid}}</td>
      </tr>
      <tr>
        <td>Pressure</td><td>{{pressure}}</td>
      </tr>
      <tr>
        <td>Wind Speed</td><td>{{speed}}</td>
      </tr>
    </table>
```

```
            </div>
        </div>
            <div class="inside">
            <div style="font-size:23px;font-weight:bold;">Predict the Wind Energy!!</div>
            <br><br>
            <form action="{{ url_for('y_predict')}}"method="post">
                <input type="text" name="theo" placeholder="Theoretical Power in KWh"
required="required" />
                <input type="text" name="wind" placeholder="Wind Speed in m/s"
required="required" /><br><br>
                <button type="submit" class="myButton" >Predict</button>

            </form>

           <br>
           <br>
           {{ prediction_text }}

        </div>



        </div>

    </body>

</html>
```

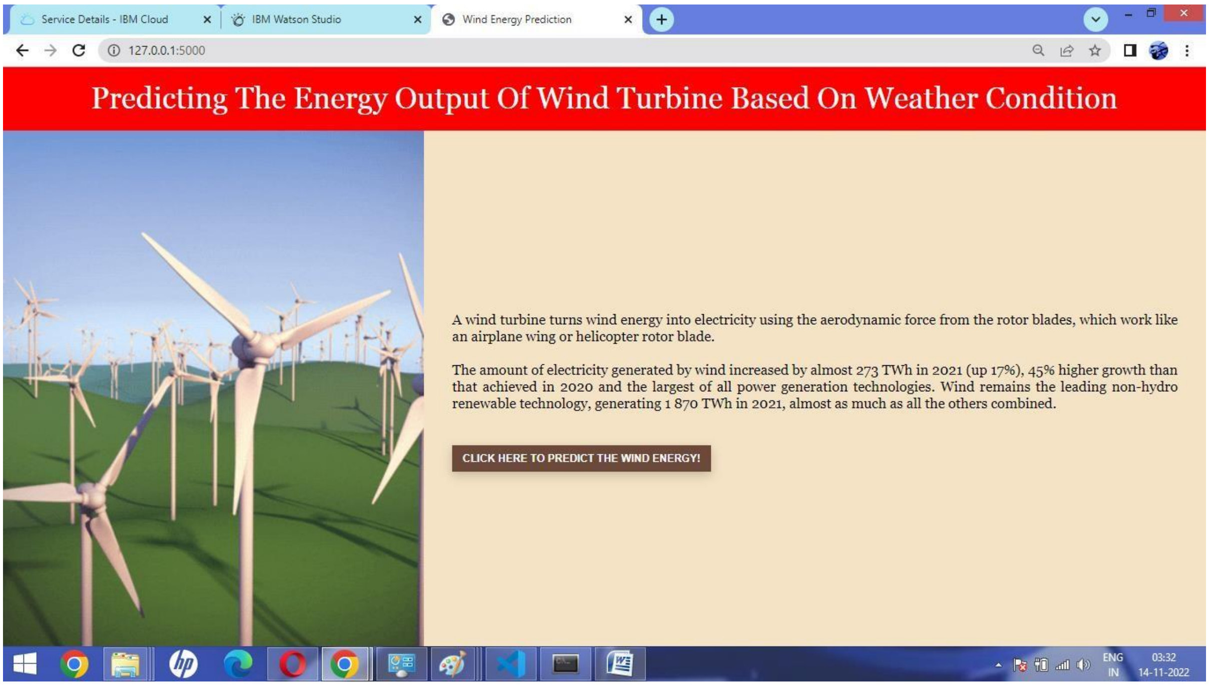
3.app.py(Flask app)

```
import numpy as np
from flask import Flask, request, jsonify, render_template
import joblib
import requests
```

```
app = Flask(__name__)
model = joblib.load('Power_Prediction.sav')


@app.route('/')
def home():
    return render_template('intro.html')


@app.route('/predict')
def predict():
    return render_template('predict.html')


@app.route('/windapi',methods=['POST'])
def windapi():
    city=request.form.get('city')
    apikey="a802b0f626c637d04185e582b5ad0d58"
    url="http://api.openweathermap.org/data/2.5/weather?q="+city+"&appid="+apikey
    resp = requests.get(url)
    resp=resp.json()
    temp = str((resp["main"]["temp"])-273.15) +" °C"
    humid = str(resp["main"]["humidity"])+" %"
    pressure = str(resp["main"]["pressure"])+" mmHG"
    speed = str((resp["wind"]["speed"])*3.6)+" Km/s"
    return render_template('predict.html', temp=temp, humid=humid,
pressure=pressure,speed=speed)
@app.route('/y_predict',methods=['POST'])
def y_predict():
    '''
    For rendering results on HTML GUI
    '''
    x_test = [[float(x) for x in request.form.values()]]
    prediction = model.predict(x_test)
    print(prediction)
    output = prediction[0]
    return render_template('predict.html', prediction_text='The energy predicted is {:.2f}
KWh'.format(output))


if__name__== "_main_":
    app.run(debug=False)
```

APPENDIX -2

Step 1: Login page - Wind Energy prediction



Predicting The Energy Output Of Wind Turbine Based On Weather Condition

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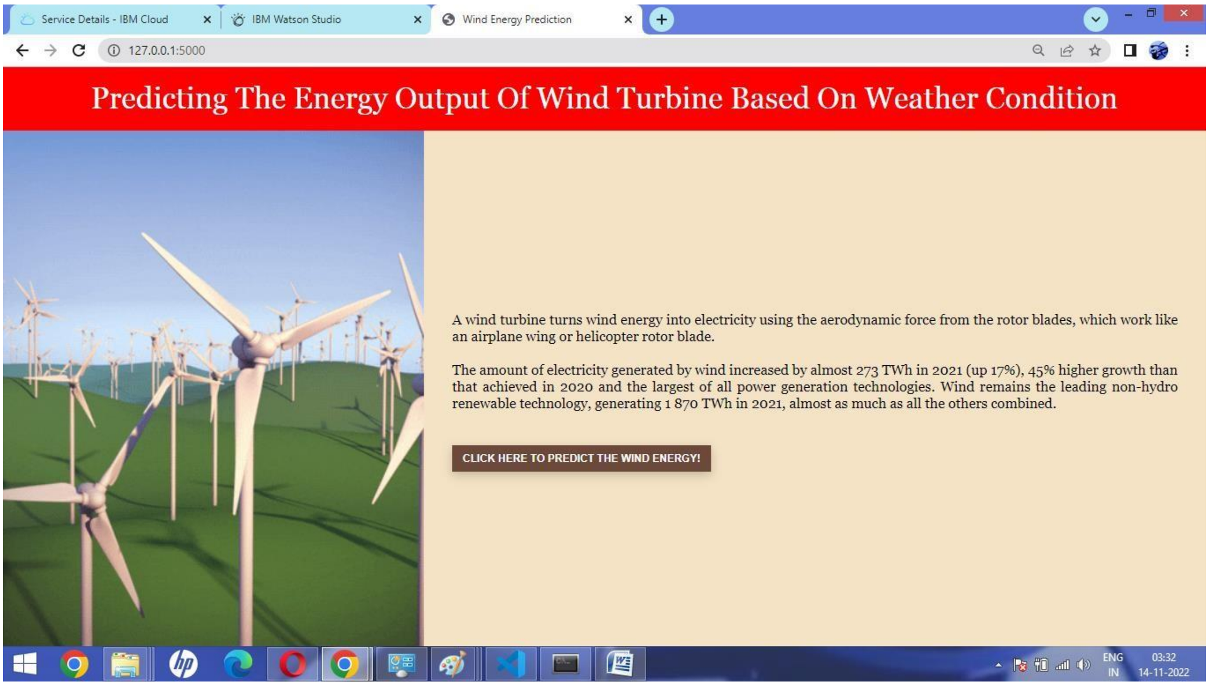
The amount of electricity generated by wind increased by almost 273 TWh in 2021 (up 17%), 45% higher growth than that achieved in 2020 and the largest of all power generation technologies. Wind remains the leading non-hydro renewable technology, generating 1 870 TWh in 2021, almost as much as all the others combined.

CLICK HERE TO PREDICT THE WIND ENERGY!

Step 2: Click the tab- Click here to predict the wind energy.



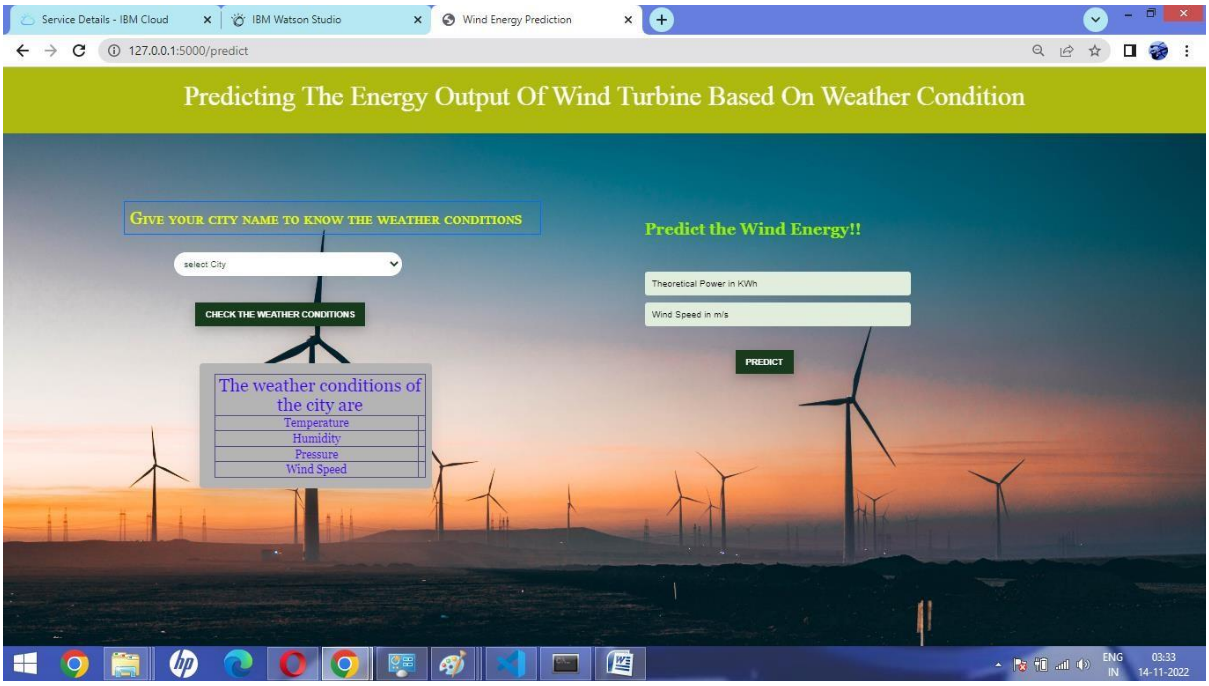
Predicting The Energy Output Of Wind Turbine Based On Weather Condition

A wind turbine turns wind energy into electricity using the aerodynamic force from the rotor blades, which work like an airplane wing or helicopter rotor blade.

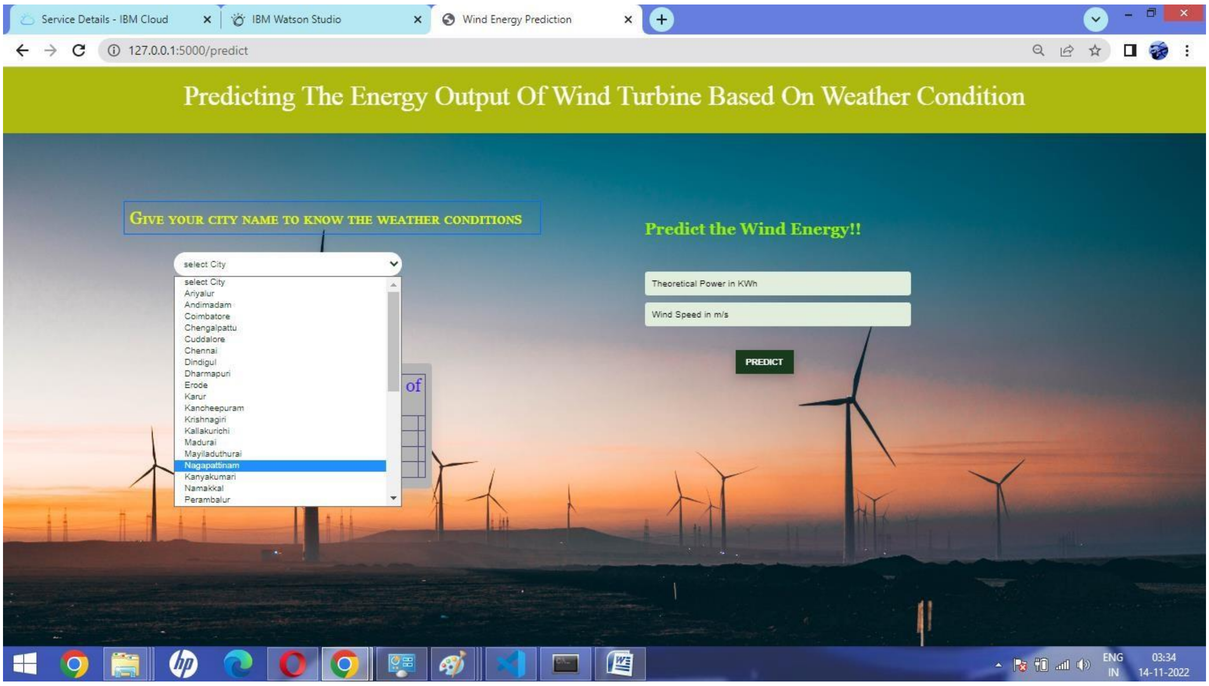
The amount of electricity generated by wind increased by almost 273 TWh in 2021 (up 17%), 45% higher growth than that achieved in 2020 and the largest of all power generation technologies. Wind remains the leading non-hydro renewable technology, generating 1 870 TWh in 2021, almost as much as all the others combined.

CLICK HERE TO PREDICT THE WIND ENERGY!

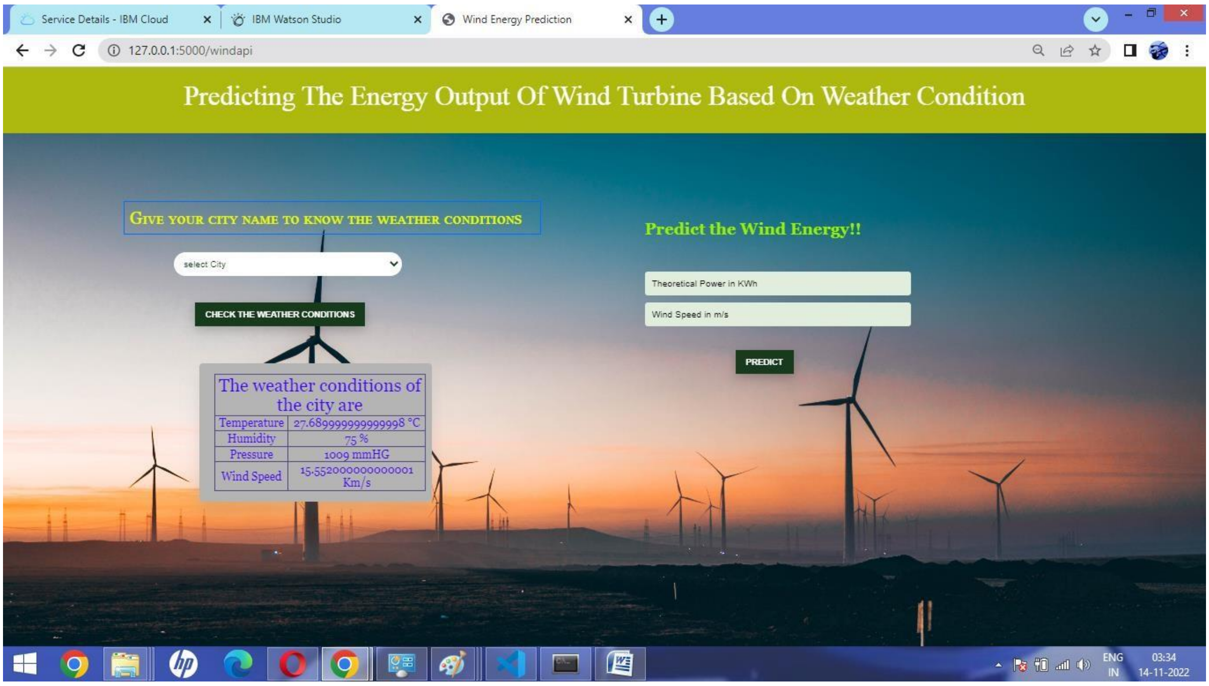
Step 3:A new page will appear


Service Details - IBM Cloud
IBM Watson Studio
Wind Energy Prediction
127.0.0.1:5000/predict
Predicting The Energy Output Of Wind Turbine Based On Weather Condition
Give your city name to know the weather conditions
select City
CHECK THE WEATHER CONDITIONS
The weather conditions of the city are
Temperature
Humidity
Pressure
Wind Speed
Predict the Wind Energy!!
Theoretical Power in KWh
Wind Speed in m/s
PREDICT
ENG
IN
03:33
14-11-2022

Step 4: Choose your city



Step 5: Then click – check the weather condition



Predicting The Energy Output Of Wind Turbine Based On Weather Condition

GIVE YOUR CITY NAME TO KNOW THE WEATHER CONDITIONS

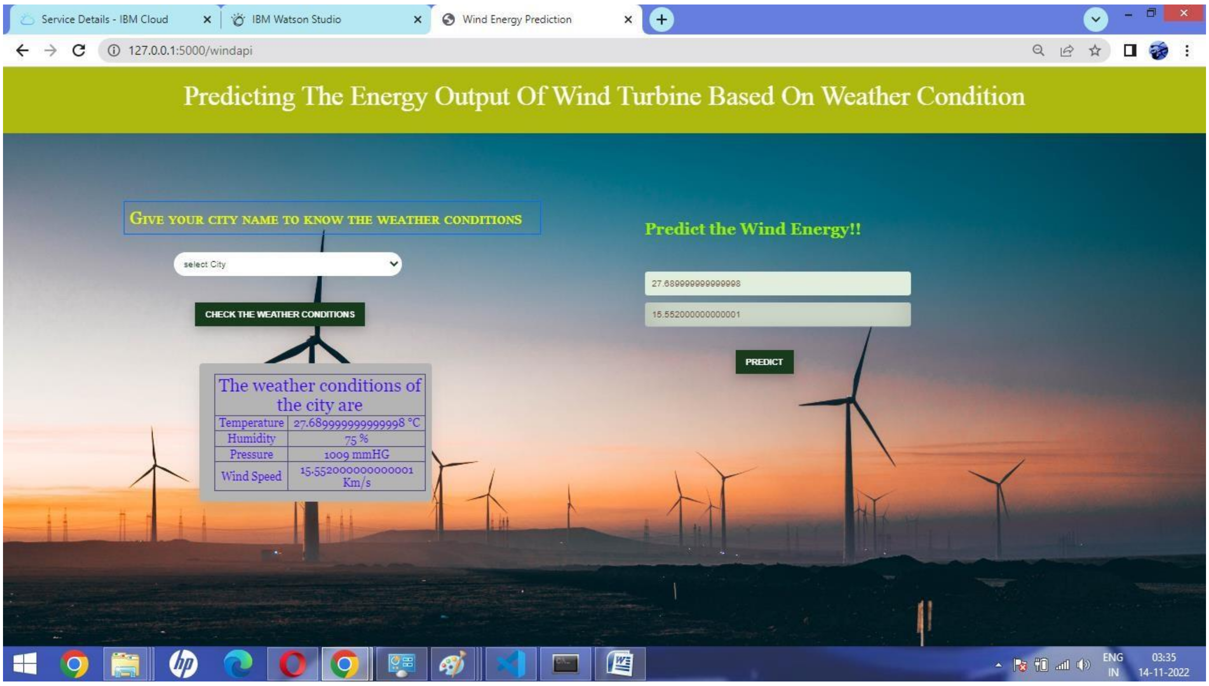
Predict the Wind Energy!!

Theoretical Power in KWh

Wind Speed in m/s

The weather conditions of the city are	
Temperature	27.689999999999998 °C
Humidity	75 %
Pressure	1009 mmHG
Wind Speed	15.552000000000001 Km/s

Step 6: Enter the fields – Theoretical power and Wind Speed



Predicting The Energy Output Of Wind Turbine Based On Weather Condition

GIVE YOUR CITY NAME TO KNOW THE WEATHER CONDITIONS

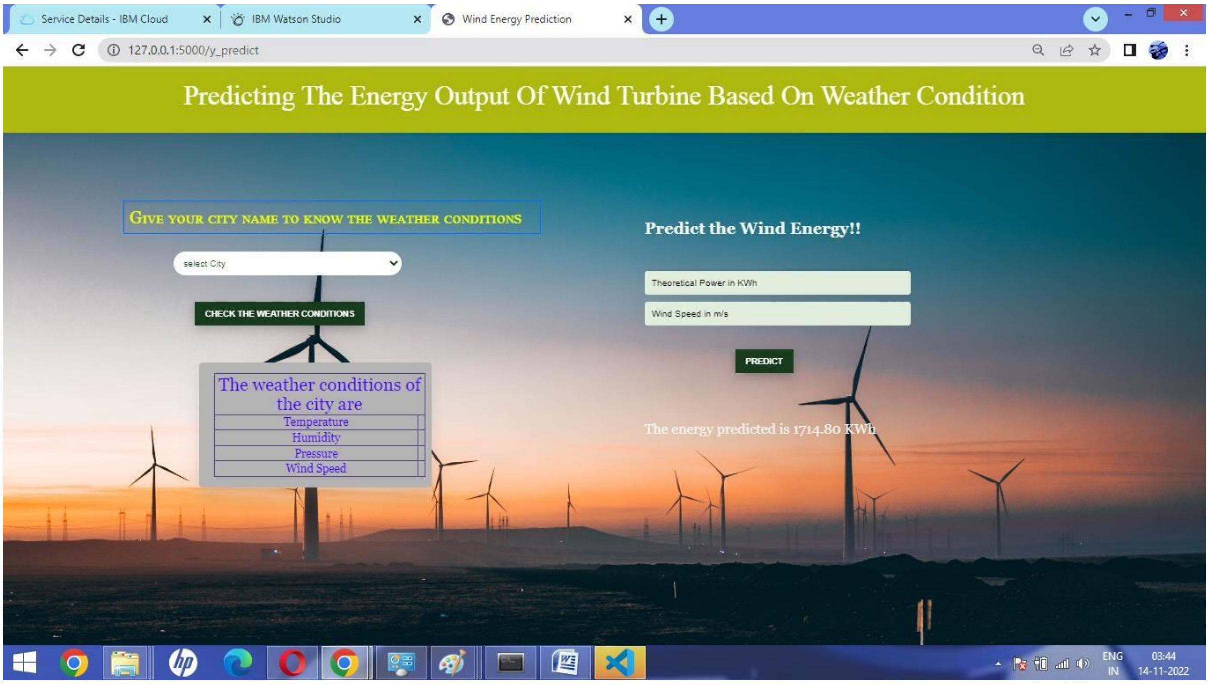
Predict the Wind Energy!!

27.689999999999998

15.552000000000001

The weather conditions of the city are	
Temperature	27.689999999999998 °C
Humidity	75 %
Pressure	1009 mmHG
Wind Speed	15.552000000000001 Km/s

Step 7: Then click pedict – the predicted output will appear as follows



Predicting The Energy Output Of Wind Turbine Based On Weather Condition

GIVE YOUR CITY NAME TO KNOW THE WEATHER CONDITIONS

Predict the Wind Energy!!

Theoretical Power in KWh

Wind Speed in m/s

The weather conditions of the city are	
Temperature	
Humidity	
Pressure	
Wind Speed	

The energy predicted is 1714.80 KWh

GitHub Link:

https://github.com/IBM-EPBL/IBM-Project-53058-1661270634

Demo link:

https://youtu.be/_LbA2BDHE-o