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A PROJECT REPORT **(15CSP85)** ON

"IoT Assisted Solar and Wind Farm for Optimal Renewable Energy Generation"

Submitted in Partial fulfillment of the Requirements for the Degree of

Bachelor of Engineering in Computer Science & Engineering

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The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said Degree.

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DECLARATION

We, the students of Computer Science and Engineering, CMR Institute of Technology, Bangalore declare that the work entitled "**IoT Assisted Solar and Wind Farm for Optimal Renewable Energy Generation**" has been successfully completed under the guidance of Dr. Rijo Jackson Tom, Computer Science and Engineering Department, CMR Institute of technology, Bangalore. This dissertation work is submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Engineering in Computer Science and Engineering during the academic year 2019 - 2020. Further the matter embodied in the project report has not been submitted previously by anybody for the award of any degree or diploma to any university.

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ABSTRACT

Renewable energy comes from natural sources that are continuously replenished; increasing concerns over carbon emissions paired with decreasing costs due to innovation are two factors driving its importance today. Solar panels, Wind Turbines has been used to generate power for a long time, but we are not on track to meet the international climate goals established by International goals for sustainable development.

Renewable Energy has great potential as future energy source and it has been a welcome topic from a considerable time. For markets such as India, which has an evening peak load, Solar PV Generation isn't really commensurate with the demand as maximum solar generation occurs at noon while maximum demand is usually in the evening. We consider the use of micro grid system which is basically a local electrical grid that is capable of operating autonomously. It is a small energy system capable of maintaining stable service within a defined boundary thereby improves reliability.

Forecasting energy that will be produced the next hour, day or week will play an effective role in planning and managing the demand and supply of energy. We use LSTM algorithm to predict hour ahead prediction of solar irradiance and wind speed. The accuracy obtained through the RMSE value was 85 ghi for solar prediction and an RMSE value of 2 mph for the wind speed prediction for the data of 2 days.

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LIST OF ABBREVIATIONS

RE	**Renewable Energy**
LSTM	**Long Short-Term Memory**
UI	**User Interface**
UX	**User Experience**
ML	**Machine Learning**
DISCOMS	**Distributed Companies**
U.S	**United States**
OCR	**Optical Character Recognition**
IoT	**Internet of Things**
API	**Application Program Interfaces**
DOI	**Digital Object Identifier**
RMSE	**Root Mean Square Error**
GHI	**Global Horizontal Irradiance**
MPH	**Miles Per Hour**

CHAPTER 1

INTRODUCTION

Energy does things for us. It moves cars along the road and boats on the water. It bakes a cake in the oven and keeps ice frozen in the freezer. It plays our favourite songs and lights our homes at night. Energy helps our bodies grow and our minds think. Energy is a changing, doing, moving, working thing.

Energy is defined as the ability to produce change or do work, and that work can be divided into several main tasks we easily recognize:

- Energy produces light.
- Energy produces heat.
- Energy produces motion.
- Energy produces sound.
- Energy produces growth.
- Energy powers technology.

1.1 Fossil Fuels

Fossil fuels, which include coal, natural gas, petroleum, shale oil, and bitumen, are the main sources of heat and electrical energy. All these fuels contain—besides the major constituents (carbon, hydrogen, oxygen)—other materials including metal, sulphur, and nitrogen compounds. During the combustion process different pollutants like fly ash, sulphur oxides (SO2 and SO3), nitrogen oxides (NOx = NO2 + NO), and volatile organic compounds are emitted. Fly ash contains different trace elements (heavy metals). Gross emission of pollutants is tremendous all over the world. These pollutants are present in the atmosphere in such conditions that they can affect man and his environment.

When coal was used to produce heat for warming flats and for cooking in greater municipal agglomerations, disadvantageous influences on the environment from its combustion were observed. A Londoner coined the term “smog” in 1905 to describe the city’s insidious combination of natural fog and coal smoke. Smog in London predates Shakespeare by four centuries. Until the twelfth century, most Londoners burned wood for fuel. But with the city’s growth and the forest’s depletion, wood became scarce and increasingly expensive. Large deposits of “sea-coal” off the northeast coast provided a cheap alternative. Soon, Londoners were burning the soft, bituminous coal to heat their homes and fuel their factories. Sea-coal was plentiful, but it didn’t burn efficiently and much of its energy was spent making smoke, not heat. Along with these and various other fossil fuels which don’t combust completely release poisonous gas in nature resulting in pollutions and global warming.

1.2 Renewable Energy

Renewable energy is energy collected from sources that are naturally and constantly replenished, such as sunlight, wind, tides, waves and the earth’s heat. Recent innovations in technology, design and manufacturing are helping to lower costs of and increase the performance of these natural sources of electricity.

After paying for the costs of building a renewable energy facility, the electricity is free to produce. Unlike generating electricity from coal or natural gas, which requires paying for the fuel to burn to run the facility, solar and wind power facilities have no fuel costs. As a result, the cost of electricity from renewable resources is stable over a long period of time. With coal and natural gas, costs can fluctuate based on global and regional supply and demand.

Renewables are also gaining attraction due to widespread recognition that carbon emissions need to be reduced to avoid environmental impacts. There are a number of other benefits from renewable energy. For example, these energy sources are often more resilient during and after severe weather conditions. Since they are often spread out over large areas, a severe weather event in one location is less likely to cut off electricity to an entire region. Another key benefit is that renewable energy creates jobs. Solar panels need workers to install them, and wind farms need technicians for maintenance and repairs.

1.2.1 Solar and Wind Energy

Solar energy is that produced by the Sun's light – photovoltaic energy for the generation of electricity. Inexhaustible and renewable, since it comes from the Sun.

The primary technology used today to generate solar energy is the photovoltaic cell, commonly referred to as a "solar panel". This technology generates electricity from sunlight through a natural process that occurs in certain materials, known as semiconductors. Electrons in the semiconductors are freed when the sunlight hits the solar panel and then are made to travel through an electrical circuit, creating electricity that can be used directly by a device or sent to the power grid. 5 Scientists have seen significant improvements in the efficiency of solar panels over the last few decades and continue to explore new ways of generating solar energy, including perovskite solar cells , which could provide even higher efficiencies at very low production costs.

Humans have relied on the wind for hundreds of years to mill grain and pump water, but the modern technology used to generate electricity is more sophisticated. The wind turbines being installed today are capable of generating nearly four times the electricity produced by turbines in 2000.

In modern wind turbines, the point where the blades attach is about 80 meters off the ground, about the same height as a 25-story building and roughly twice as tall as turbines installed in 2000. Taller turbines can accommodate bigger rotors, which enables the turbine to generate more electricity, and are capable of producing electricity at lower wind speeds, meaning they are generating electricity for more hours of the day.

One of the main concerns that people voice about renewables is the question of what happens when the sun is not shining strong enough or the wind stops blowing. The simple answer is that a solar panel's ability to generate electricity diminishes when sunlight is blocked by a cloud or when it's dark outside. Similarly, if the wind isn't blowing, then a wind turbine isn't generating electricity (although as noted above, newer turbines are able to operate at lower wind speeds and still generate electricity).

However, this is only part of the story. The more complete answer is that along with a transition to renewable energy sources, there's an equally important transition taking place in the overall electricity system known as the grid. For the past 100 years or so, the electric grid has been a system characterized by large, centralized generating plants, usually powered by coal, hydro or nuclear power plants, along with a complex network of wires that transmit and distribute electricity from the generating plants to residences and businesses. Historically, there hasn't really been a way to store electricity; it must be produced as it is used. Increasingly, however, the grid is becoming a more diverse, decentralized system with different electricity sources, including wind, solar and natural gas, distributed over large regions, helping energy providers supply reliable energy year-round.

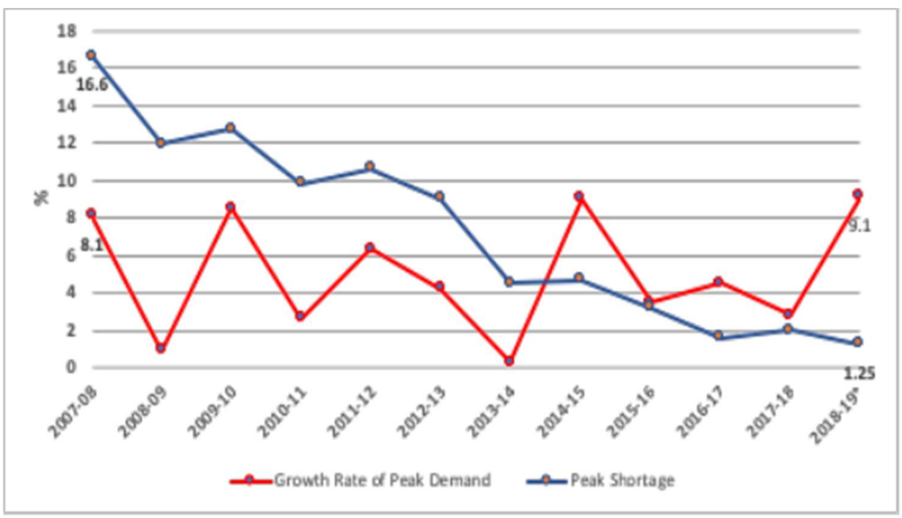
1.2.2 RE in India

India has set exceptionally ambitious renewable energy targets including 175 gigawatts (GW) of renewables by 2022, 275GW by 2027, and to achieve 40% of electric power installed capacity from non-fossil fuels by 2030. India seeks to tender another 80GW of renewables in total over the coming two years. In moving to meet those targets, total renewable energy installations in India reached 75GW by September 2018, representing 21% of total installed capacity and generating a record high of 11.9% of all electricity in the September 2018 quarter.

Such ambitious targets have invariably encountered various headwinds and challenges while renewable resources are earning their place due to the economics, today, most renewable energy including wind and solar are backed by fossil fuel generation like coal and natural gas in order to deliver reliable power to all consumers. Energy storage is emerging as a solution to reduce fluctuations in power produced at a given moment by renewables but further innovations in rates and technology are key to continuing adoption of renewables for consumers and energy providers

1.2.3 Trends in Energy and Peak Shortages

To meet growing energy demand, India has successfully added enormous new power generation capacity over the last decade, reducing the country's energy deficit from a massive 8.5% in 2010 to just 0.7% in 2017-18. Although peak power demand deficits have also dramatically reduced from 9.8% in 2010 to just 2% in 2018, they are still apparent. While the rate of increase in peak demand growth has fallen over the last decade, huge load variations during the day reflect people's requirements for electricity during different time periods, such as increased demand during early morning or evening. Fluctuating load variations require grids to provide additional peaking capacity, i.e. further energy generating capacity to meet peak demand. However, with the state of the existing tariff structure in India, it is not lucrative for power developers or investors to set up fast ramping capacity to meet peak demand.



Source: CEA, IEEFA. Note: For 2018-19, data is presented for 7 months (April to October 2018).

Fig 1.1 Growth Rate of Peak demand and Peak shortage

1.2.4 Current Trends in Electricity Requirements

The amount of electricity that needs to be generated at any given time to meet energy demand in India varies between states depending on population and occupation (i.e. domestic, agriculture, commercial, and industrial), temperature and seasonality, and cultural practices. A typical load curve illustrating the national variation in demand (aggregated electrical load of the different states in India) over a specific time is provided in Figure 1.2

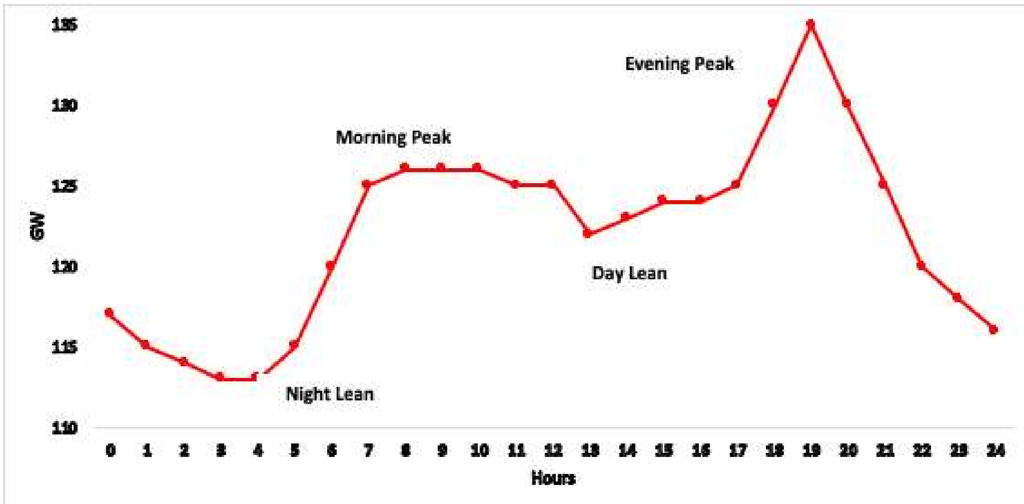


Fig 1.2 Typical All India load Curve

As illustrated in Figure 1.3 (below), India's load curves vary considerably between seasons:

- The month of May has a peak during the day, and later in the evening.
- August has a relatively flat profile during daylight hours, with a small peak in the evening.
- November shows a sharp evening peak; and
- January shows two distinct peaks: a sharp morning peak and a sharp evening
- peak.

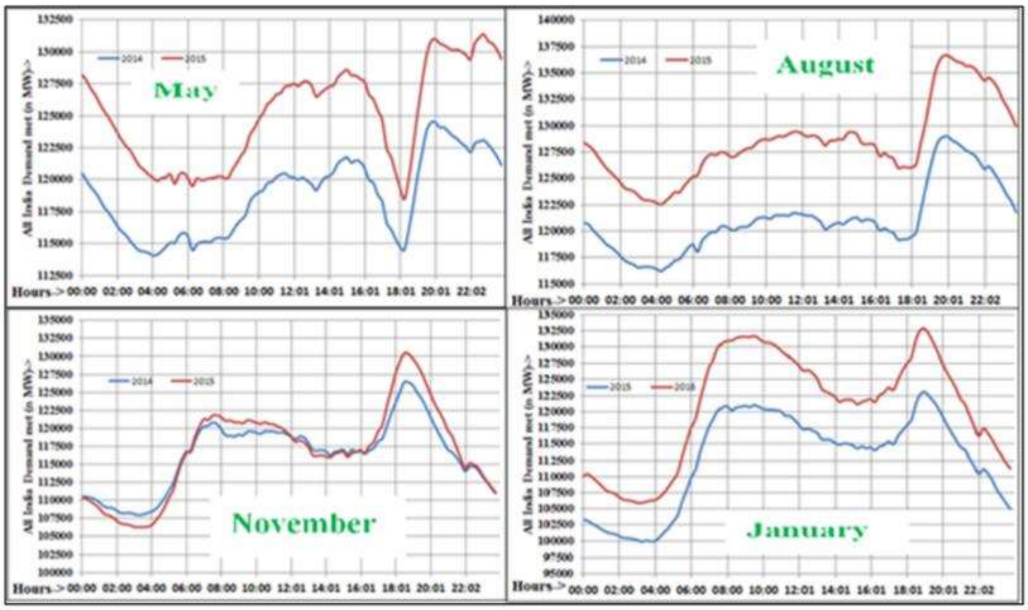
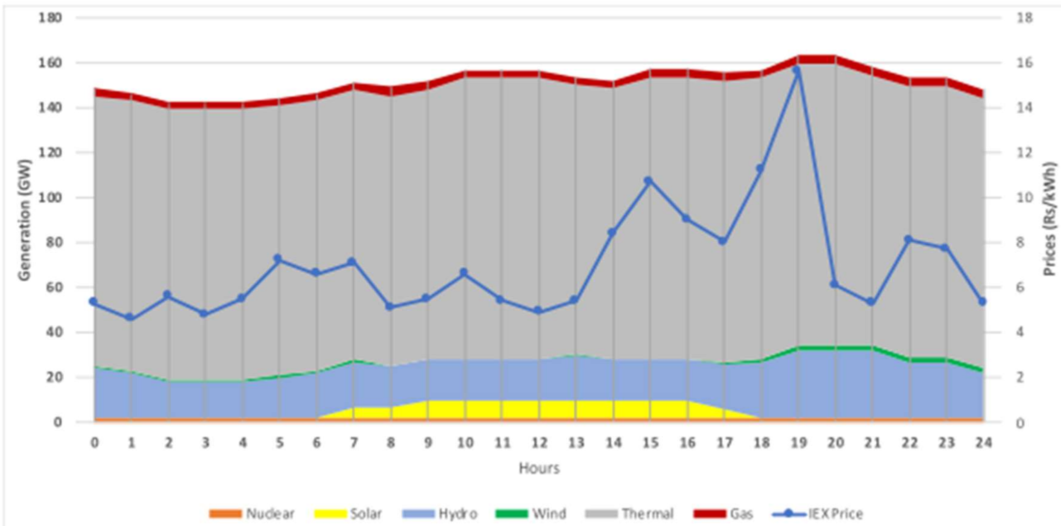


Fig 1.3 All India Daily Demand for Seasonally Different Months for 2014 and 2015

1.2.5 Current Trends in Electricity Supply and Prices

India's electricity supply has historically been largely coal dominated, with 196GW currently operational. Today, another 25GW of gas-based generation is also used primarily for meeting base load demand, the minimum level of demand required on the electrical grid.

In the last 2-3 years the share of solar and wind generation, although low, has been increasing rapidly. This focus on the deployment of more variable renewable energy generation - a result of India's transformation of the national electricity system to a more sustainable, lower cost, domestic generation – also brings additional load balancing pressures.



Source: NLDC, IEX, IEEFA.

Fig 1.4 All India Fuel Wise Generation Pattern and Prices at IEX on 3 October 2018

1.2.6 Current Trends in Capacity Addition

India continues to progressively deploy renewable energy generation within its total energy generation portfolio, as shown in Figure 6, thereby exploiting the rapid, Importantly, a greater off-take of renewable energy power in India requires grid strengthening, improved interstate transmission capacity, and ideally a stronger price signal for peaking power supply (such as time-of-day pricing) to reward fast ramping and flexible peak supply at least cost to producers, DISCOMs and consumers.

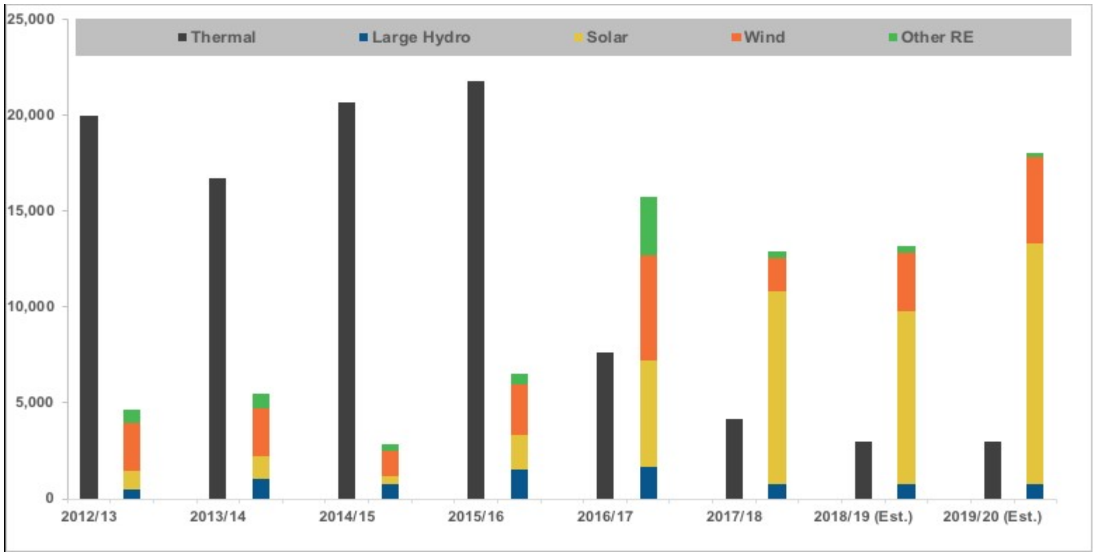


Fig 1.5 India's Electricity System Capacity and Generation by Fuel Type (2018/19)

In India, currently grid operations are decentralized at regional and state level. The responsibility of load and generation balancing lies with the state. Given the share of renewable energy will further increase in such states, a market needs to be developed that supports balancing capacity for improved flexing of the energy system.

Solar and wind energy are the two major types of renewable energy today which is the oldest and most well-established. Lesser-known types include hydropower, geothermal and tidal energy.

1.3 Micro Grid System

A micro-grid may be a localized cluster of electricity sources and sinks (loads) that usually operates connected to and synchronous with the standard centralized grid (macro-grid), however will disconnect and maintain operation autonomously as physical and/or economic conditions dictate.

According to the U.S. Department of Energy Microgrid Exchange cluster, the subsequent criteria defines a microgrid:

A microgrid may be a cluster of interconnected loads and distributed energy resources within clearly outlined electrical boundaries that acts as one operable entity with regard to the grid. A microgrid may connect and disconnect from the grid to allow it to work in each grid-connected or island-mode.

Microgrid definitions focus totally on 2 features:

- a microgrid may be a regionally controlled system
- a microgrid will perform each connected to the standard grid (megagrid) or as associate degree electrical island

The operation of microgrids offers distinct benefits to customers and utilities, i.e. improved energy potency, decrease of overall energy consumption, reduced environmental impact, improvement of dependability of supply, network operational advantages like loss reduction, congestion relief, voltage management, or security of energy supply and additional cost efficient electricity infrastructure replacement.

There is conjointly a philosophical fact, unmoving within the belief that regionally controlled systems are more likely to make wise balanced choices, like between investments in efficiency and supply technologies. Microgrids will coordinate these assets and offer them to the megagrid in a manner and at a scale that's per current grid operations, thereby avoiding major new investments that are required to integrate rising decentralized resources.

1.4 Machine Learning

Machine Learning is subfield of a computer science that evolved from the study of pattern recognition and computational learning theory in artificial intelligence.

Machine learning explores the construction and study of algorithms that can learn from and make predictions on data. Such algorithms operate by building a model from example inputs in order to make data-driven predictions or decisions, rather than following strictly static program instructions.

Machine learning is closely related to and often over-laps with computational statistics; a discipline that also specialises in prediction-making. It has strong ties mathematical optimisation which deliver methods, theory and application domains to the field.

Machine learning is employed in a range of computing task where designing and programming explicit algorithms is infeasible. Example applications include spam filtering, optical character recognition (OCR), search engines and computer vision.

Machine learning is sometimes conflated with data mining , although that focuses more on exploratory data analysis. Machine learning and pattern recognition “can be viewed as two facets of the same field”

When employed in industrial contexts, machine learning methods may be referred to as predictive analysis of predictive modelling

1.5 Forecasting

Forecasting is the process of predicting what will happen in the future based on the historical data collected. A model is created with the data collected by considering crucial parameters.

Forecasting plays in important role in planning. For instance, in weather forecasting, knowing tomorrows’ weather right now would help in preparing oneself based the forecasted details.

Accurate forecast is any field will have enormous economic, social benefits which will help us in overcoming hurdles.

Machine learning forecasting is an emerging field is and attracting an essential role in several significant data initiatives today. A lot of Organization today use machine learning forecasting to aid and improve in their organization growth.

Using these forecasting methods for the prediction of hourly energy generation from solar and wind farms would be highly beneficial for better planning for energy supply.

1.6 Existing System

As excessive use of fossil fuel results in emission huge amount of Carbon dioxide and many other hazardous gases into the nature, which resulted in a life threating global issue known as "Global warming".

Even after many steps being taken to reduce the carbon emission and to shift to renewable energy, it still hasn't been successfully to meet the requirements to fight this global disaster.

This is because the energy needed for the normal functioning of our life is still being generated from fossil fuels like coal. Due to the decentralized micro grid management we are not able to fully utilize the abundant amount of energy, renewable energy which is available to us.

The existing system to use solar and wind energy are capable but are still not efficient enough to extract the full potential of renewable energy due to the drawbacks in hardware. Further research and is needed to develop the hardware drawbacks we are facing.

1.7 Proposed System

Our focus is not to be demotivated by the drawbacks in hardware system which needs to be researched further but overcome this hurdle by using the advanced technology in the software field, one notable field being machine learning. Using machine learning to forecast is an immensely growing field and we are trying to use this technology to overcome our problems.

Hence this project proposes the use of micro grid system and forecasting using machine learning for optimal generation and utilization of renewable energy, which is a key step is fighting against global warming.

By providing hourly day ahead prediction of wind energy and solar irradiance, which is used to generate solar energy, effective planning can be formulate which can be useful in avoiding the fluctuation occurring due to lack/excessive energy generation which might result in damaging the appliances in houses and industry.

By solely depending upon the renewable energy we reduce the amount of fossil fuel being consumed during the process of energy generation.

These predicted values and decision making can be maintained and handled using web application built with advanced framework and technologies and by connecting them to cloud we will have a real time monitoring effective planning mechanism for the micro grid.

Hence our project "IoT assisted solar and wind farm for optimal renewable energy generation" will play an effective role in utilizing the available renewable energy and take one step further in solving the issue of global warming

1.8 Scope of the Project

This project aims to develop a web product which will act as a management system for the micro grid system and their involved authorities.

The Web application named "Smart Manager" would contain details about the working of the micro grid, which may include the demand of energy needed for the day and future forecast of the demand. The supply of energy will also be monitored using sensors and cloud technology.

The dashboard will have the hourly forecast details of the energy required for the next day, or for any number of days specified by the user. The representation would be in terms of graphs and details of the forecast will be available.

For the success of this project complete knowledge of time forecast and advanced web technology will be required.

Knowledge for time forecast is required so as to design a model which will provide accurate prediction of the energy forecast which will play a key role in planning.

Advanced web framework is needed to show have a better UX and UI design so as to achieve user friendly environment in the application.

The web application would contain the functionalities of a dashboard, having details of one or more micro grad which will be managed from any remote location.

The constraint is that we cannot provide hardware controls as that would go beyond the scope and knowledge of this project. As mentioned in the title this project is an assistant so to say, not entirely a controller.

The key element of this project is the prediction model. The accuracy of the model will help to plan out the necessary requirements for the energy supply for the future.

CHAPTER 2

OBJECTIVES AND METHODOLOGY

2.1 Objective

The main objective of this project is to create a web application which will act a monitoring and management system for the micro grid.

The application will focus displaying the day ahead hourly prediction of solar and wind energy. The prediction is done by the built model using the machine learning forecast algorithm, in this case LSTM which is one of a neural network model.

The dataset collected will trained using the LSTM model, prior to that the data has to be pre-processed in order to remove any outliers and erroneous data.

Once the model is prepared certain error calculation methods has to be applied to check for the accuracy. Necessary steps have to be taken in order to achieve maximum accuracy which will have a great impact on the outcome of the project.

The next step in the objective is to learn many web frameworks, libraries and API's which will help us in developing a Web application with exceptional features and functionalities, having a great impact on the users' experience.

The final step is the integration of the prediction model with the web application which will act a completion step, this is necessary in order to have a real time update on the model and will be reflected on the application.

Real time weather monitoring and weather forecast will also be helpful in the planning process of the operation of micro grid. Various APIs have to be used in order to extract data from different site to make the application look presentable

2.2 Methodology

The Smart Manager Web Application has a 3-level working layer. The prediction layer, integrating the front end to the web app and the UI layer.

The first step in our objective is to design a forecast model which will be the main component for this project. The output from this layer will act as the input for the upcoming layers.

As said before we are planning to use machine learning to forecast the solar irradiance and wind energy. This is a dual prediction model which will predict solar and wind energy in parallel.

The Solar irradiance is obtained from one of our guides' peer who work in similar field. The attributes are tentative as we are still working on the algorithm. The dataset is of hourly bases for solar and day basis for wind. The dataset amounts to around 4 years from the period of 2012-2016.

The Meteorological data for the prediction of windspeed is obtained from one of internets free weather service API. From this API we were able to obtain 10 years of meteorological data worth 10 years from 2010 to 2020.

The weather data for real time monitoring is also obtained from (name cannot be mentioned) the same website.

The idea is to predict the solar and wind speed on an hourly basis for the next day, and calculate the amount of solar energy and wind energy that will be produced, this is then compared to the demand of energy required for the next day. Decision has to be taken so has to how to balance the demand and supply.

Once the prediction is done, we integrate the output to a front end. The front end is a Web application; it acts like a dashboard showing the details of the output in Graph representation which will give a better User Experience.

As the results of the prediction model will be updated frequently the application will capture those changes and will be up to date, this will make the planning process an easier task.

2.3 Software development methodology

Agile Methodology and User Stories

Like all the successful projects this project our project was implemented in various phases and iterations.

First phase was to design a project plan which included brain-storming ideas to come up with a problem statement that would benefit the society and help a common cause which in our case is solely based on Machine Learning.

After the problem statement is designed the next step is to find a suitable dataset which helps us train and predict with high accuracy.

After the dataset has been collected the next step is to find the suitable algorithm which helps in predicting with good accuracy. There are different accuracy rates predicted for the same dataset with a different algorithm. Choosing up with the appropriate algorithm is the most crucial part of the project.

After many iterations of testing different algorithms LSTM algorithm proved to be the most appropriate of all. The algorithm id then implemented with the appropriate parameters.

The next step after implementing the algorithm is to test the accuracy, after many iterations of testing and tweaking both the solar and wind prediction models. For the prediction of wind speed for two days using the model, a RMSE of 2 (mph) was calculated for data ranging from 0-14 mph. And The result of the solar irradiance model showed exceptional accuracy with an RMSE of 85 W/m^2 . The data ranged from 0-900 ghi.

After the testing and with a satisfied prediction model is obtained the next step is to present it in a good web application with a good UI and UX through which the operator can easily use without hassle. Many designs were looked up and a constant re-designing considering users/customers input a beautiful Web Application was designed and the result from the prediction is showed with accuracy in the website in the form of graphs.

The last step is to verify all the above steps is working appropriately and fixing bugs getting input from the users/customers for a third eye view on the website and improving it.

Below is a table which describes the user stories and Agile methodology:

S No	Requirement Description	User Stories and Tasks	Description
1	Prediction of Solar panel Movement	As an energy farm Owner, I must be able to get the accurate position of solar panel so that solar panel is aligned with sun and optimum energy is generated	Neural Network
2	GUI Application	As an Energy farm Owner, I must be able to Monitor the Location, Movement of solar and wind panel, Energy generated as well as the number of active solar panel and wind turbine	Web Application
3	Prediction of Energy	As a Energy farm owner, I want the Information of how much energy is required per day.	Machine Learning Algorithm
4	Controlling Via Cloud	As a solar farm owner, I must be able to turn off one of the solar panel /Wind farm based on the energy requirement	Cloud Based

5	Prediction of Weather	As an Energy farm owner, I need to know the weather Prediction based on which I can switch between solar farm and wind farm	Machine Learning Algorithm

Table 2.1 Agile Methodologies and User Stories

The above table describes Requirement Description, User Stories and the Description of what domain the requirement belongs to.

The user stories are mainly focused towards the needs and wants of an energy farm owner as he makes up for the most of our user/customer base. The project is designed keeping mainly the energy farmers needs in mind

CHAPTER 3

LITERATURE SURVEY

3.1. Using Neural Network for Solar and Wind Power Forecasting

- In the paper "power forecasting using advanced neural network models" described in [1], the author proposes an advanced model, based on repetitive high order neural networks for the prediction of the power output profile of a wind park. Through this paper they suggested advantage of neural networks over other algorithm, is that fast learning algorithms can be derived for the weight estimation, enabling it to be appropriate for on-line applications.

- The paper "Short-term forecasting of wind speed and related electrical power" described in [2], proposes a model in which wind speed and the related electrical power of wind turbines are forecasted. The work is focused on the operation of power systems with integrated wind parks. Artificial neural networks models are proposed for forecasting average values of every hour. Input quantities for the prediction are wind speeds and their derivatives. The methods are tested using data collected over seven years at six different sites on islands of the South and Central Aegean Sea in Greece.

- In the paper "An aggregative machine learning approach for output power prediction of wind turbines Solomon" described in [3] proposed a model of performing a day ahead prediction of wind turbine power output using aggregative approach by combining Artificial Neural Network (Radial Basis and Conventional Feed forward Networks), Adaptive Neuro-Fuzzy Inference System (ANFIS) and Support Vector Machine (SVM). They found that the combination of techniques was able to outperform the individual models. They used Three techniques of combining (Simple Averaging, Regression and Outperformance) to test the result and was tested on recorded data of an operational 2.5 MW Permanent Magnet Direct Driven (PMDD) wind turbine in Goldwind Smart Microgrid in Beijing, China.

- The paper "Solar power forecasting using soft computing approach" described in [4] proposes a model using artificial neural network and generalized neural network with the help of different metrological data such as wind velocity, solar irradiation, and temperature as input to the model and predicted the changes in generated solar power, which they found to be very useful tool for a solar power plant and planning for storage battery which could provide stable power output from a PV system.

  Limitation: But the unknown working principle known as "black-box" of neural networks limits their applicability in predicting solar radiation. The irregularities in hidden layer becomes unpredictable.

3.2. Estimation and Forecasting Wind Speed and Solar Power using Soft Computing

- The paper "HF Skywave Radar Sea Black Scatter" described in [5] proposes that wind speed estimates are better obtained from HF radar spectra by first estimating the directional wind-wave spectrum from the second-order then computing wind speed from a wind-wave prediction model.

  Limitation: But the wind speed estimates are derived from the expressions that are highly dependent on the wave field. Hence these expressions are extremely difficult to obtain reliable estimation of wind speed.

- The paper "Solar power forecasting using soft computing approach" shown in [6] proposes a solar tracker system that uses a webcam as the main sensor combined with image processing technique that is embedded into Raspberry Pi board to locate the location of the sun in the sky. Raspberry Pi is the main board used replacing the big computer CPU to process the image. Two motor servo with design of pan and tilt were used to move the webcam to follow the direction the sun. It was shown that the system manages to catch the position of the sun even during the cloudy day. The system offers simple implementation of the tracker with the capability to locate the central coordinate of the sun on an image and the Raspberry Pi will send signal to the motor that will rotate in accordance with the movement of the sun.

- In the paper "Enhanced Performance of Solar Concentrators Using Soft Computing Techniques described" in [7] proposed a model suggesting that the efficiency of photovoltaic module is increased by covering an angle of around 180 degrees and the cost was reduced by use of cheaper glass materials. They have used Kalman filtering, also known as linear quadratic estimation (LQE), it is an algorithm that uses a series of measurements observed over time and the Bacterial Foraging Optimization Algorithm for minimizing a cost function

3.3. Analysis of Wind and Solar farms based on Cluster Analysis

- The paper "Critical Analysis of wind farms for sustainable generation" shown in [8], proposes a critical analysis on wind farms to improve the performance and reliability of wind energy system. The effect of its improvement has been studied with the Optimal Renewable Energy Mathematical (OREM) model which is developed for sustainable generation in India. The performance and reliability of the wind turbine generators have been evaluated in a demonstration windfarm (6 MW) in India. The average technical availability, real availability and capacity factor have been analysed from 1991 to 1995 and they are found to be 92%, 54% and 19% respectively. The analysis indicates that when grid drop failures are reduced by 50%, the overall reduction in the frequency of faults would be 35.2%, which is significant. The OREM model developed reveals that when the reliability factor of wind energy system is improved from 0.5 to 0.9 then the utilisation of wind energy would be increased by 82%.

- The paper "Day-Ahead Hourly Forecasting of Solar Generation Based on Cluster Analysis and Ensemble Model" described in [9] proposed a novel solar generation forecasting method based on cluster analysis and ensemble model. They first conduct cluster analysis based on solar generation to obtain a weather regime, which can improve the computational efficiency and avoids the difficulty in selecting weather variables

3.4. Using LSTM for Demand Prediction of Solar Irradiance

- The paper **"**Hourly day-ahead solar irradiance prediction using weather forecasts by LSTM" described in [10] is focused on residential and small commercial users deploying on-site photovoltaic generations. The proposed prediction model is trained by using long short-term memory (LSTM) networks taking considering the dependence between consecutive hours of the same day. They found that proposed LSTM algorithm is 18.34% more accurate than BPNN in terms of root mean square error (RMSE) by using about 2 years training data to predict half-year testing data. The paper has shown a superior ability to learn long-term dependencies by maintaining a memory cell to determine which unimportant features should be forgot and which important features should be remembered. Therefore, using the LSTM for modelling the hourly irradiance data, not only can the dependence between consecutive hours of the same day be captured, but the long-term (e.g. seasonal) behaviour can be learned. Once the LSTM network is trained and tuned, it can be used to predict the hourly solar irradiance values using the weather forecasts. Inspired by the work of references of this we propose a novel prediction scheme for hourly one-day ahead prediction of solar irradiance based on weather forecasts and long short-term memory (LSTM) networks.

3.5. Using Time Series based Demand Prediction

- The paper "Time Series ARIMA Model for Prediction of Daily and Monthly Average Global Solar Radiation" described in [11] focused on developing a seasonal auto-regressive integrated moving average (SARIMA) model to predict the daily and monthly solar radiation in Seoul, South Korea based on the hourly solar radiation data obtained from the Korean Meteorological Administration over 37 years (1981–2017). They found that the RMSE for this was equal to 33.18 for the monthly solar radiation model.

Limitation: The solar panels also exhibit a strongly non-linear I-V characteristic and a power output that is also non-linearly dependant on the surface insolation. But ARIMA model fails to identify such nonlinear dependency.

3.6. Solar Power generation using Random forest algorithm

- The paper "A Two-Step Approach to Solar Power Generation Prediction Based on Weather Data Using Machine Learning" described in [12] found that that most previous studies have only focused on using the measured weather records and very few studies have attempted to utilize both measured weather records and the forecasts. Thus, they proposed a two-step prediction process for PV power generation using both weather records and weather forecasts data. Their results also showed that the random forest regression algorithm performs the best for this problem achieving an R-squared value of 70.5% in the test data.

3.7. Research based around Energy Based Residential Application

- The paper "A Consistent Power Management System Design for Solar and Wind Energy-Based Residential Applications" described in [13] proposed an effective system which generates power for home appliances. They developed solar wind hybrid energy system, here the power is generated either by solar or wind. If both sources are insufficient, the load is fed from the grid. In this way, the power requirement of load can be supplied without any interruption. The system is developed with the help of only electrical components like inverter, batteries, relay etc.

- In the paper **“**Optimal Scheduling of Energy Supply Entities in Home Area Power Network”. Described in [14] proposed a model to solve the uncertain behaviour of producing renewable energy which is due to of varying wind speed and solar irradiations. In this paper they present a model of Nano-grid, representing a medium scale smart home. It integrates roof-top photovoltaic (PV) panels, energy storage devices (ESDs) and smart loads along with grid-supplied energy. So, they adopt a power scheduling scheme, establishing an optimal strategy of supplying cost-effective energy to the user's load demands. The scheduling scheme is based on mixed integer linear programming (MILP) framework, providing day-ahead optimal scheduling decisions for various energy supply entities.

- In the paper “Optimal Scheduling of Energy Supply Entities in Home Area Power Network” described in [15] the author developed a model of a smart grid, considering a smart home equipped with a rooftop photovoltaic (PV) system, flexible power load demands, ESDs including home battery storage (HBS) and electric vehicle storage (EVS), and an in-feed from the utility grid. Their main objective is to use a maximum of PV energy and reducing the cost of electricity by effective scheduling of various energy supply entities (ESEs), i.e., grid, PV, and ESDs, the model also reduces the cost of electricity by effective scheduling of various energy supply entities (ESEs), i.e., grid, PV, and ESDs.

3.8. Hourly Solar Irradiance Prediction using Support Vector Machine

- The paper “Hourly Solar Irradiance Prediction Based on Support Vector Machine and Its Error Analysis” described in [16] proposes a novel solar prediction scheme for one-hour ahead prediction of solar irradiance based on various meteorological factors including the cloud cover and support vector machine (SVM). A k-means clustering algorithm is applied to collecting meteorological data and the entire data are classified into three clusters based on similar daily weather types. They found that cloud cover as an input parameter, has the highest correlation with solar irradiance or PV output power.

3.9. Use of Hardware for Tracking and maintaining PV system and modules

- In the paper “360° sun tracking with automated cleaning system for solar PV modules” referred in [17], the author came up with a sun tracking-cum-cleaning system that has been designed, which not only tracks the sun but also cleans the modules automatically. This automated system is implemented using 8051 microcontrollers which controls the stepper motor coupled with the gear box (40:1 ratio). The presented tracking-cum-cleaning scheme provides about 30% more energy output as compared to the flat PV module (module kept stationary on ground) and about 15% more energy output as compared to PV module with single axis tracking.

- In the paper “Water cooling method to improve efficiency of photovoltaic module” referred in [18] the author proposed a model for Cooling of Photovoltaic in order to enhance the performance of the PV (Photovoltaic) system. Due to high temperature Photovoltaic module experiences short effect (efficiency loss) and long effect (permanent damage) degradation. Therefore, Cooling of Photovoltaic is one of the main concerns for enhancing the performance of the PV system. In this paper experiments have been conducted with water cooling arrangement to study the efficiency factor of the PV module. Results shows water circulation on the front surface of module decreases the temperature by 5°C whereas maximum power and efficiency increases by 2%.

- In the paper A smart IoT system for monitoring solar PV power conditioning unit described in [19] proposed a system designed a smart remote monitoring system based on internet of thing (IOT) for monitoring solar Photovoltaic (PV)

Power Conditioning Unit (PCU). This system had incorporated remote monitoring for solar PV PCU through internet using host, network GPRS (Global Positioning Radio Service), embedded system gateway and other components. The remote monitoring system can be installed for Solar PV PCU in order to solve management and maintenance problems. The result of their demonstration showed that the system can monitor store and manipulate data from solar PV PCU. Thus, the remote monitoring functions are realized in real-time.

- In the paper "Concentrating Solar Power Station Optimal Operation Model" described in [20] proposed large scale grid connection model for renewable energy, as a new technology for absorbing solar energy, concentrating solar power generation using a thermal storage system to make it a schedulable resource without increasing the uncertainty of the system. They suggested that concentrating solar power plants have certain advantages in dealing with solar energy uncertainty, prolonging production cycles, improving the utilization efficiency of heat storage tanks, and economic efficiency.

- In the paper "Enhancing Performances on Wind Power Fluctuation Mitigation by Optimizing Operation Schedule of Battery Energy Storage Systems with Considerations of Operation Cost" described in [21] designed the battery energy storage systems (BESSs) that are integrated into wind farms (WFs) to mitigate the wind power fluctuations. They proposed to solve the BESS switches between the charging and discharging states which significantly degrades the batteries, resulting in a high operation cost of the BESS. To address this issue, they divided BESS into two parts, which implement charging and discharging instructions, respectively. Sequential Monte Carlo simulation is applied to simulate the operation of the BESS-integrated WF on a typical day The simulation results validate that the solution can mitigate the output power fluctuations with better performance and a less operation cost than the existing solutions.

CHAPTER 4

SYSTEM REQUIREMENTS SPECIFICATION

The Micro grid management system is a user-oriented application. This is built and developed for the users' advantage. Its focus is upon how the user should feel comfortable using the application and make is planning with ease.

4.1 Functional Requirements

The functional requirement mainly focuses on the prediction modules, as predictions is the key to this project

- **Prediction of Solar and Wind energy**

  The user should get hourly day ahead prediction of wind energy and solar irradiance which is used to generate solar and wind energy which can be useful for effective planning.

- **Prediction of Demand Side Energy Requirement**

  The user should get accurate prediction of energy demand for the given locality with the smart grid.

- **Balance of Supply and Demand**

  The user should be able to analyse the extra requirement of energy needed at every hour of the next day when solar irradiance and wind energy is not sufficient enough to meet demand side energy requirement.

- **Real Time Monitoring of Micro Grid**

  The smart Micro Grid can automatically adjust based on the weather condition and demand side energy requirement for the given locality in Real Time.

4.2 Non-Functional Requirements

These are the additional features expected by the user without being told, for example, security of the application must be good.

- **User Friendly**

  The System must provide web interface which make it easy to monitor and analyze the supply and demand requirement with the help of simple UI and UX

- **Security**

  This system provides a login facility at the beginning of the web interface so that only authorized user can access it.

- **Time Efficiency**

  The system provides day ahead prediction output thereby Faster decision can be taken, increasing the time efficiency.

4.3 Hardware Requirements

- Processor: Intel i3 (or above) or AMD
- Processor Speed: 2.6Ghz or above
- RAM: 4GB
- Hard Disk: 10GB
- Keyboard
- Monitor
- Mouse
- Ethernet Connectivity

4.4 Software Requirements

- Operating System: Windows 8 and above
- Browser: Chrome or Mozilla
- Editors: Sublime or smart text editors
- Language used: Python, HTML, JS, CSS
- Machine Learning Framework: Scikit Learn
- Machine Learning Libraries: Numpy,Pandas,MatPlotLib
- Web Library: React, Node.
- Web module: Express, Nodemon, GoogleGraphs

CHAPTER 5

PROBLEM FORMULATION

5.1 Problem Formulation

"Are we even using the abundant amount of renewable energy that is available to us at free of cost? Are we taking necessary steps in order to fight the global warming?"

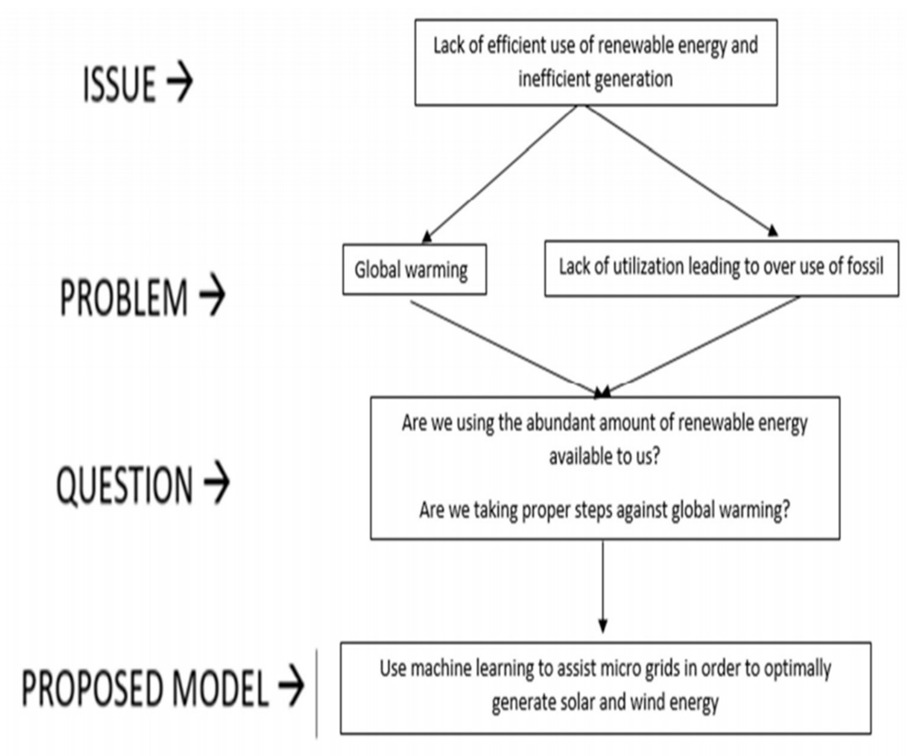


Fig 5.1 Problem Formulation

5.2 Problem Statement

The objective of this project is to identify a solution to the inefficient use of renewable energy by developing and implementing methodologies in assisting different renewable energy power plants such as Solar and Wind which are decentralized at the moment. We assist in such a way that with proper planning optimum generation of renewable energy is possible.

As mentioned previously, we are not on track to meet the international climate goals established under the international goals for sustainable development.

A step has to be taken in order to overcome this global disaster as continuing in this pace will never be enough to meet the objectives set by the UN Sustainable Development Goal 7 to change the system in order to increase renewable energy, it's access and efficiency.

To overcome this global issue efficient utilization of renewable source of energy plays a key factor and hence our idea of "IoT assisted Solar and Wind Power Plants for Optimal Renewable Energy Generation" would be helpful in reducing the consumption of fossil fuels and reduce carbon foot prints.

We can achieve this by introducing the concept of Prediction and IoT in controlling and efficiently managing the power plants by providing real time information through cloud communication.

By implementing this methodology, we can improve by utilizing the renewable energy, which is available to us in abundant thus, we take a small step in fighting global warming.

CHAPTER 6

SYSTEM ANALYSIS AND DESIGN

6.1 SYSTEM ARCHITECTURE

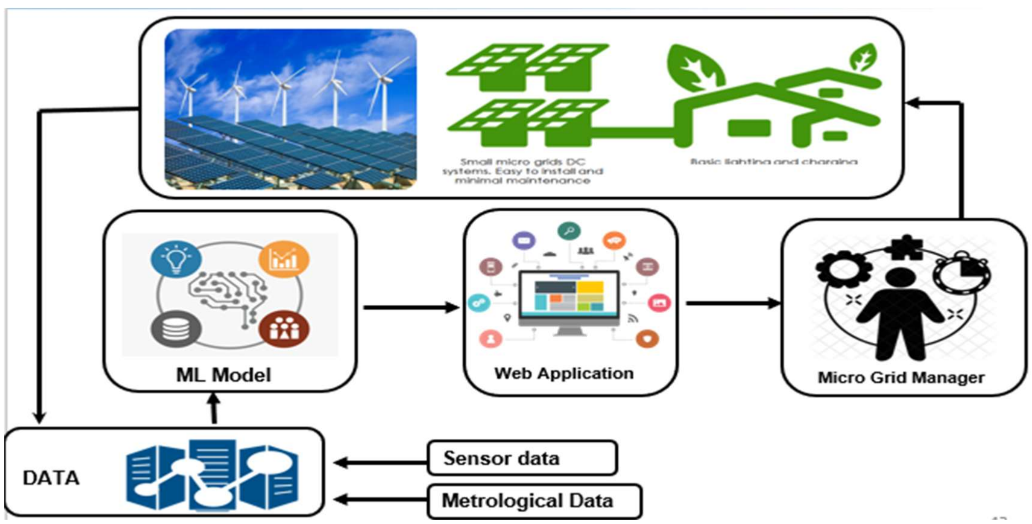


Fig 6.1 Architecture for Smart Grid

The system architecture follows one of the simple IoT architecture. The architecture consists of 4 layers. They are:

- The thing layer which consists of sensors and meteorological data from web sources
- The data network and data storage layer for storing of incoming data from various sensors
- The analysis layer where the data store in database is retrieved and is used for prediction of wind speed and solar irradiance

- The presentation layer which is web application which presents the predicted output and real time weather monitoring which is sent by the underlying server

These are the layers which we have introduced and the topmost layer, the presentation layer i.e., the web application is used by the Micro Grid manager to perform actions and take decisions.

Some level of controls for the power plants is also possible but it will be given in the future scope of this project. The microgrid manager can take decisions and perform action and the status of the power plants is monitored and the resulting data is stored in the database for future purposes.

6.2 DATASET

ATTRIBUTES	VALUES
Elevation Angle	5° - 9° (Degree)
Azimuth Angle	70° - 290° (Degree)
Temperature	25 °C – 35 °C (Celsius)
Humidity	50% - 95% (Percentage)
Pressure	990-1010 Pa (Pascal)
Global Horizontal Irradiance	20-900 W/m^2

Table 6.1 Attributes for Solar Irradiance Prediction

ATTRIBUTES	VALUES
Temperature	60 °F – 90 °F (Fahrenheit)
Humidity	50% - 95% (Percentage)
Pressure	25 – 26 in
Wind Direction	Directions (N,S,E,W..)
Wind Speed	0 – 10 Miles/Hour

Table 6.2 Attributes for Wind Speed Prediction

6.3 Activity/Data Flow Chart

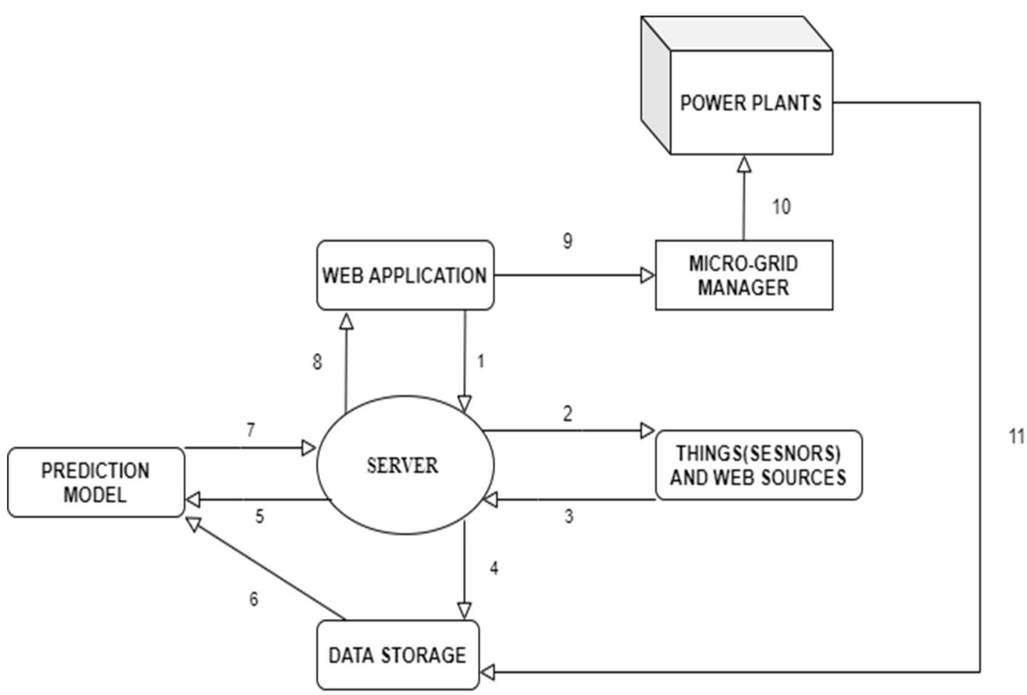


Fig 6.2 Activity/Data Flow Chart

The step wise explanation of Smart Grid Management

STEP 1:

The web application requests for predicted data and weather report to the server.

STEP 2:

The server then collects the data sent from sensors and other meteorological data from web sources.

STEP 3:

Upon receiving the request, the data is sent to the server.

STEP 4:

The received data is then stored on the database (currently is csv files).

STEP 5:

Then the model which is written in python is called upon using process creation for prediction of solar energy and wind speed.

STEP 6:

The data required for the prediction is then loaded and prediction of solar irradiance and wind speed proceeds.

STEP 7:

Upon successful prediction the predicted data is sent the server for further processing.

STEP 8:

The predicted data is processed and then sent to the web application to represent it in user friendly format

STEP 9:

The Micro Grid manager upon seeing the information has the option to perform required action for the proper working of the power plant

STEP 10:

The information (if present) is sent to the power plant for any further action (if required)

STEP 11:

The state of power plant and other data is stored in the database for further analysis.

These are the steps involved in the Smart Grid Management explained in brief. The project has been successfully implemented as a prototype and is in working condition and certain modification is needed when being used in real time.

6.4 USE CASE DIAGRAM

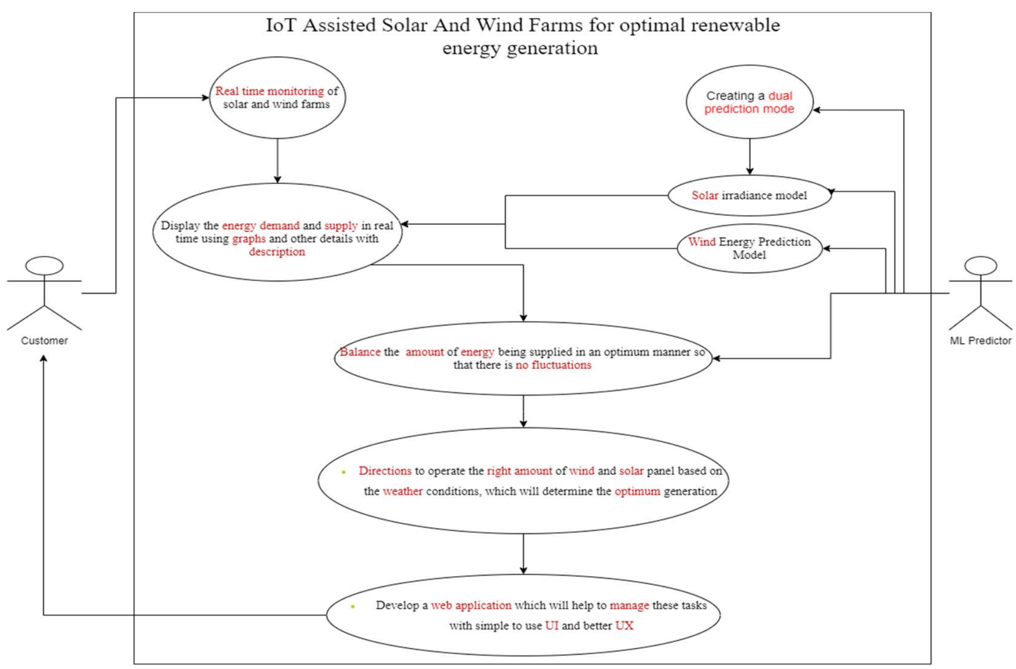


Fig 6.3 Use Case Diagram

The above use-case diagram provides a skeletal model of how the project works:

1. The customer or the operator visits our website to monitor his solar and wind farms.
2. The website then displays the energy demand and supply in real time with the help of graphs
3. The ML predictor is responsible for creating a dual prediction model I.e. both solar irradiance and wind energy prediction model
4. It also guides the operator for balancing the amount of energy to be supplied for optimal energy generation.
5. The website also provides directions for the operator to use the right amount of energy based on the weather data for optimal wind energy generation.
6. The development of a website which its easy to use UI and UX design help the operator in smooth operation of the above features and also for the operators to easily use without any hindrance or hassle.

CHAPTER 7

IMPLEMENTATION

7.1 LSTM Networks

Long Short-Term Memory networks – usually just called "LSTMs" – are a special kind of RNN, capable of learning long-term dependencies. They were introduced by Hochreiter & Schmidhuber (1997). They work tremendously well on a large variety of problems and are now widely used.

LSTMs are explicitly designed to avoid the long-term dependency problem. Remembering information for long periods of time is practically their default behavior, not something they struggle to learn!

All recurrent neural networks have the form of a chain of repeating modules of neural network. In standard RNNs, this repeating module will have a very simple structure, such as a single tanh layer.

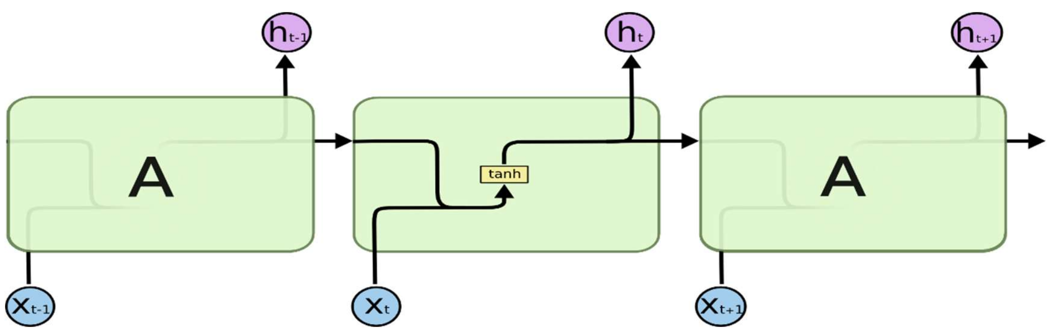


Fig 7.1 The repeating module in a standard RNN contains a single layer.

LSTMs also have this chain like structure, but the repeating module has a different structure. Instead of having a single neural network layer, there are four, interacting in a very special way.

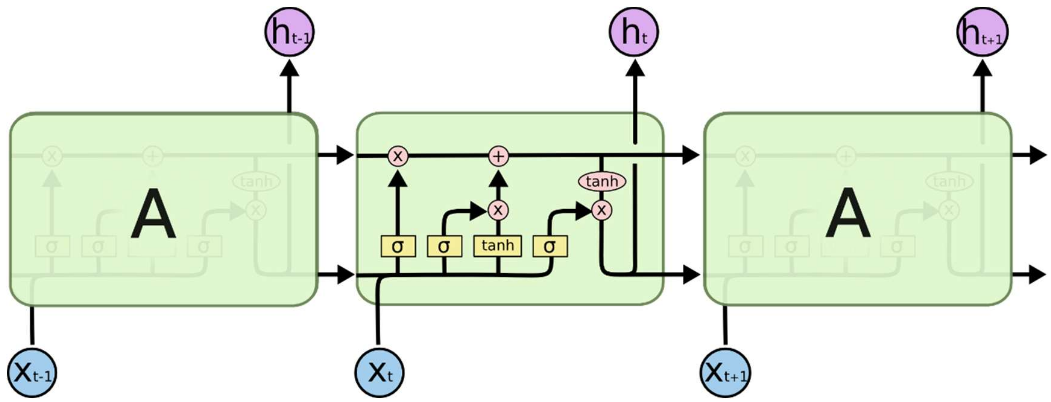


Fig 7.2 The repeating module in an LSTM contains four interacting layers.

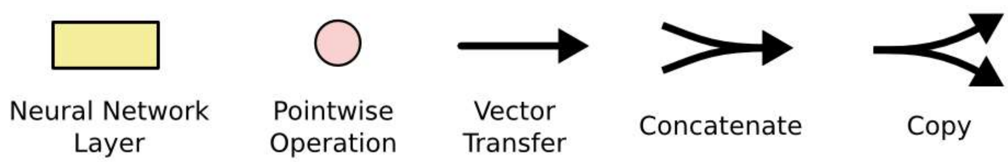


Fig 7.3 Notations used in LSTM

In the above diagram, each line carries an entire vector, from the output of one node to the inputs of others. The pink circles represent pointwise operations, like vector addition, while the yellow boxes are learned neural network layers. Lines merging denote concatenation, while a line forking denotes its content being copied and the copies going to different locations.

The key to LSTMs is the cell state, the horizontal line running through the top of the diagram.

The cell state is kind of like a conveyor belt. It runs straight down the entire chain, with only some minor linear interactions. It's very easy for information to just flow along it unchanged.

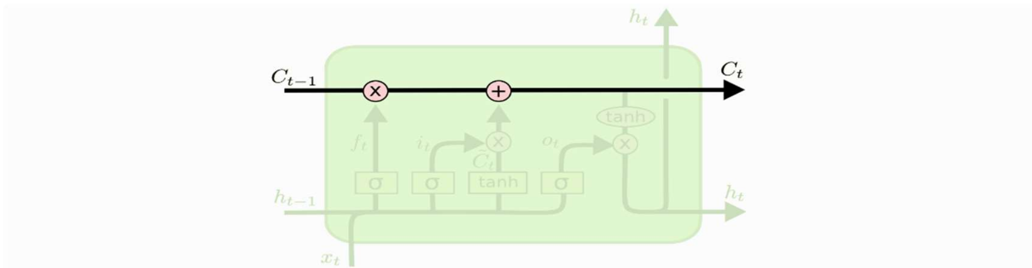


Fig 7.4 Cell State of LSTM

The LSTM does have the ability to remove or add information to the cell state, carefully regulated by structures called gates.

Gates are a way to optionally let information through. They are composed out of a sigmoid neural net layer and a pointwise multiplication operation.

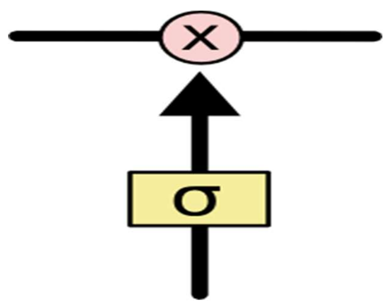


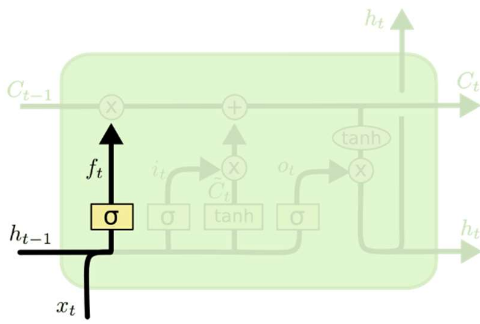
Fig 7.5 Neural network and Gate Operation

The sigmoid layer outputs numbers between zero and one, describing how much of each component should be let through. A value of zero means “let nothing through,” while a value of one means “let everything through!”

An LSTM has three of these gates, to protect and control the cell state.

7.2 Step wise explanation of LSTM

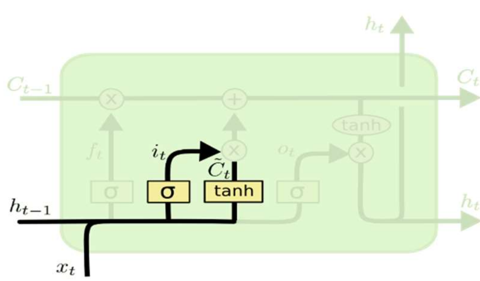
The first step in LSTM is to decide what information is going to be thrown away from the cell state. This decision is made by a sigmoid layer called the “forget gate layer.” It looks at h_{t-1} and x_t and outputs a number between 0 and 1 for each number in the cell state C_{t-1}. A 1 represents “completely keep this” while a 0 represents “completely get rid of this.”



$$f_t = \sigma\left(W_f \cdot [h_{t-1}, x_t] \ + \ b_f\right)$$

Fig 7.6 Step 1 of LSTM

The next step is to decide what new information it is going to store in the cell state. This has two parts. First, a sigmoid layer called the “input gate layer” decides which values we’ll update. Next, a tanh layer creates a vector of new candidate values, C_t, that could be added to the state. In the next step, we’ll combine these two to create an update to the state.

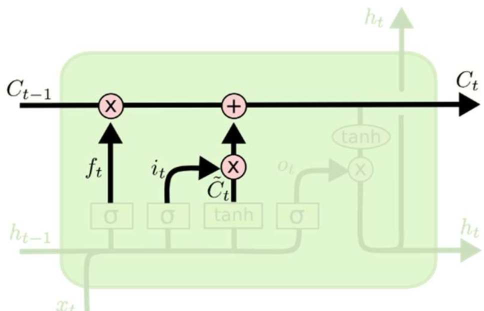


$$i_t = \sigma\left(W_i \cdot [h_{t-1}, x_t] \ + \ b_i\right)$$
$$\tilde{C}_t = \tanh(W_C \cdot [h_{t-1}, x_t] \ + \ b_C)$$

Fig 7.7 Step 2 of LSTM

It’s now time to update the old cell state, C_{t-1}, into the new cell state C_t. The previous steps already decided what to do, we just need to actually do it.We multiply the old

state by f_t, forgetting the things we decided to forget earlier. Then we add i_t*C_t. This is the new candidate values, scaled by how much we decided to update each state value.
In the case of the language model, this is where we'd actually drop the information about the old subject's gender and add the new information, as we decided in the previous steps.

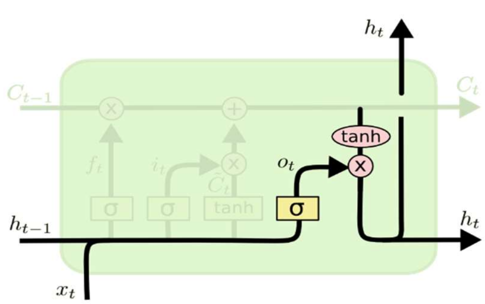


$$C_t = f_t * C_{t-1} + i_t * \tilde{C}_t$$

Fig 7.8 Step 3 of LSTM

Finally, it needs to decide what would be the output. This output will be based on our cell state, but will be a filtered version. First, we run a sigmoid layer which decides what parts of the cell state we're going to output. Then, we put the cell state through tanh (to push the values to be between −1−1 and 11) and multiply it by the output of the sigmoid gate, so that we only output the parts we decided to.

For the language model example, since it just saw a subject, it might want to output information relevant to a verb, in case that's what is coming next. For example, it might output whether the subject is singular or plural, so that we know what form a verb should be conjugated into if that's what follows next.



$$o_t = \sigma\left(W_o\ [h_{t-1}, x_t]\ +\ b_o\right)$$
$$h_t = o_t * \tanh\left(C_t\right)$$

Fig 7.9 Step 4 of LSTM

7.4 Algorithm/ Pseudo Code:

- Loading of Dataset: D_i
- Encode categorical feature
- Normalization of Dataset between 0 and 1 using the below formula
- Convert Series Data to Supervised Data by shifting all features by 1
- Split Dataset to training and testing data
- Convert the data from 2D [samples, features] to 3D [samples, timesteps, features]
- Choose the number of hidden layers, optimizer, epochs to define LSTM Network
- For each epoch:

  Train the LSTM model L for test Dataset

- Run Prediction for Training Data
- Calculate the RMSE for accuracy using below formula

Parameters initialized for LSTM Network

- Units = 100
- Dense Layer with Unit = 1
- Dropout Layer with value = 0.02
- Optimizer chosen is Adam with learning rate of 0.0001
- Total number of epochs between 10-20
- Batch size of length of training sample
- Time steps = 1

7.5 Angular

Angular is a platform and framework for building single-page client applications using HTML and TypeScript. Angular is written in TypeScript. It implements core and optional functionality as a set of TypeScript libraries that you import into your apps.

The architecture of an Angular application relies on certain fundamental concepts. The basic building blocks are NgModules, which provide a compilation context for components. NgModules collect related code into functional sets; an Angular app is defined by a set of NgModules. An app always has at least a root module that enables bootstrapping, and typically has many more feature modules.

- Components define views, which are sets of screen elements that Angular can choose among and modify according to your program logic and data.
- Components use services, which provide specific functionality not directly related to views. Service providers can be injected into components as dependencies, making your code modular, reusable, and efficient.

Both components and services are simply classes, with decorators that mark their type and provide metadata that tells Angular how to use them.

- The metadata for a component class associates it with a template that defines a view. A template combines ordinary HTML with Angular directives and binding markup that allow Angular to modify the HTML before rendering it for display.
- The metadata for a service class provides the information Angular needs to make it available to components through dependency injection (DI).

An app's components typically define many views, arranged hierarchically. Angular provides the Router service to help you define navigation paths among views. The router provides sophisticated in-browser navigational capabilities.

7.6 Python

Python is an interpreted, high-level, general-purpose programming language. Created by Guido van Rossum and first released in 1991, Python's design philosophy emphasizes code readability with its notable use of significant whitespace.

Its language constructs and object-oriented approach aim to help programmers write clear, logical code for small and large-scale projects.

Python is dynamically typed and garbage collected. It supports multiple programming paradigms, including structured (particularly, procedural), object-oriented, and functional programming. Python is often described as a "batteries included" language due to its comprehensive standard library.

7.7 ASP.NET Core

ASP.NET Core is the new version of the ASP.NET web framework mainly targeted to run on .NET Core platform.

ASP.NET Core is a free, open-source, and cross-platform framework for building cloud-based applications, such as web apps, IoT apps, and mobile backends. It is designed to run on the cloud as well as on-premises.

Same as .NET Core, it was architected modular with minimum overhead, and then other more advanced features can be added as NuGet packages as per application requirement. This results in high performance, require less memory, less deployment size, and easy to maintain.

ASP.NET Core is an open source framework supported by Microsoft and the community, so you can also contribute or download the source code from the ASP.NET Core Repository on GitHub.

ASP.NET 3.x runs only on .NET Core 3.x, whereas ASP.NET Core 2.x runs on .NET Core 2.x as well as .NET Framework.

Features of ASP.NET Core:

Supports Multiple Platforms: ASP.NET Core applications can run on Windows, Linux, and Mac. So, you do not need to build different apps for different platforms using different frameworks.

Fast: ASP.NET Core no longer depends on System.Web.dll for browser-server communication. ASP.NET Core allows us to include packages that we need for our application. This reduces the request pipeline and improves performance and scalability.

IoC Container: It includes the built-in IoC container for automatic dependency injection which makes it maintainable and testable.

Integration with Modern UI Frameworks: It allows you to use and manage modern UI frameworks such as AngularJS, ReactJS, Umber, Bootstrap, etc. using Bower (a package manager for the web).

Hosting: ASP.NET Core web application can be hosted on multiple platforms with any web server such as IIS, Apache etc. It is not dependent only on IIS as a standard .NET Framework.

Code Sharing: It allows you to build a class library that can be used with other .NET frameworks such as .NET Framework 4.x or Mono. Thus, a single code base can be shared across frameworks.

Side-by-Side App Versioning: ASP.NET Core runs on .NET Core, which supports the simultaneous running of multiple versions of applications.

Smaller Deployment Footprint: ASP.NET Core application runs on .NET Core, which is smaller than the full .NET Framework. So, the application which uses only a part of .NET CoreFX will have a smaller deployment size. This reduces the deployment footprint.

7.8 NodeMCU ESP826

NodeMCU is an open source LUA based firmware developed for ESP8266 wifi chip. By exploring functionality with ESP8266 chip, NodeMCU firmware comes with ESP8266 Development board/kit i.e. NodeMCU Development board.

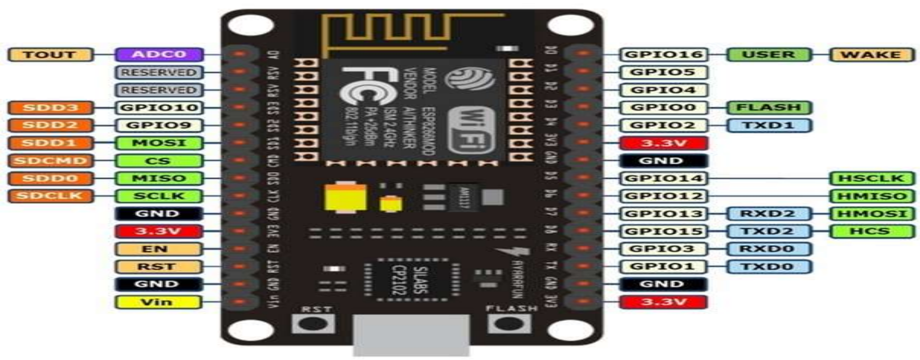


Fig 7.10 NodeMCU ESP826

NodeMCU Dev Kit/board consist of ESP8266 wifi enabled chip. The **ESP8266** is a low-cost Wi-Fi chip developed by Espressif Systems with TCP/IP protocol. NodeMCU Dev Kit has Arduino like Analog (i.e. A0) and Digital (D0-D8) pins on its board.

It supports serial communication protocols i.e. UART, SPI, I2C etc.Using such serial protocols we can connect it with serial devices like I2C enabled LCD display, Magnetometer HMC5883, MPU-6050 Gyro meter + Accelerometer, RTC chips, GPS modules, touch screen displays, SD cards etc.

7.9 ARDUINO NANO

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.x). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one.It has 14 digital I/O pins of which 6 provide PWM output. IT has 8 analog input pins.

The flash memory of board is 16KB or 32KB of which a KB used by boot loader. The clock speed of Nano is 16 MHz

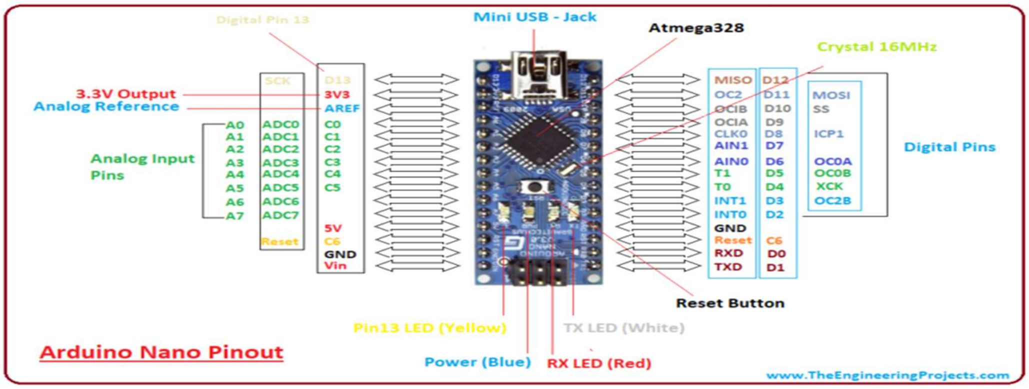


Fig 7.11 Arduino Nano

Arduino Nano is a microcontroller board designed by Arduino.cc. The microcontroller used in the Arduino Nano is Atmega328, the same one as used in Arduino UNO. It has a wide range of applications and is a major microcontroller board because of its small size and flexibility.

Basic Features of Arduino Nano

- It has 22 input/output pins in total.
- 14 of these pins are digital pins.
- Arduino Nano has 8 analogue pins.
- It has 6 PWM pins among the digital pins.
- It has a crystal oscillator of 16MHz.
- Its operating voltage varies from 5V to 12V.
- It also supports different ways of communication, which are:
    - Serial Protocol.
    - I2C Protocol.
    - SPI Protocol.
- It also has a mini USB Pin which is used to upload code.
- It also has a Reset button on it.

7.10 WE300 SOLAR IRRADIATION SENSOR

Global Water's WE300 Solar Radiation Sensor is a precision pyranometer that uses a high stability silicon photovoltaic detector (blue enhanced) to obtain accurate readings.

Fig 7.12 WE300 SOLAR IRRADIATION SENSOR

The WE300 includes a bubble level, leveling screws, and mounting hardware for a quality installation. The sensor is attached to electronics by 10 feet of cable, and the electronics are attached to 25 feet of marine grade cable, with lengths up to 500 feet available. The sensor's output is 4-20 mA with a two-wire configuration.

In addition, Global Water offers the GL500 Solar Radiation Recorder, which adds recording capabilities to the solar radiation sensors. The GL500 Solar Radiation Recorder connects to the pyranometer's 4-20mA output to record data.

- 4-20 mA output
- Marine grade cable with strain relief
- Mounting plate included

7.11 WE550 WIND SPEED SENSOR

The Global Water Wind Speed Sensor is constructed of high-impact materials, ensuring its durability and ruggedness even in severe weather conditions. The wind speed indicator has a very low threshold, and it responds accurately to subtle changes in wind speed.

Fig 7.13 WE550 WIND SPEED SENSOR

The wind speed transmitter is molded to 25 ft of marine grade cable, with lengths up to 500 ft available upon request. The wind speed sensor's output is 4-20 mA with a two-wire configuration. The wind speed transmitter's electronics are completely encapsulated in marine grade epoxy within a rubber sleeve.

Global Water's **PC320** Wind Speed Alarm and Controller uses the Wind Speed sensor's output to trigger motors and alarms. In addition, Global Water offers the **GL500** Wind Speed Recorder, which adds recording capabilities to the Wind Speed indicators. The GL500 Wind Speed Recorder connects to the anemometer's 4-20mA output to record data.

These are some of the major hardware which helps in the success of our project. These hardware are assumed to be present with the operator in working condition and in operable state.

7.12 How the Python Script work?

Our Python scripts are the major part of the project as this helps in training the wind speed and solar irradiance using past data and the prediction is done using current data obtained by APIs.

Below are the steps used to train the model:

- Step 1: Loading the necessary framework, in our case it is it is pandas which is most important
- Step 2: Loading the dataset which is both wind and solar data (5 years of data in case of solar and last 5 years in case of wind). The features for solar data include elevation angle, azimuth angle air temperature, humidity, pressure and ghi (which is the representation of sun's energy). The features for wind data include temperature, dew, wind direction, humidity, pressure and wind speed.
- Step 3: Feature Scaling the dataset which is essential for machine learning algorithms that calculate the distance between data. If not scaled the feature with the higher value range starts dominating.
- Step 4: LSTM as its name depicts is a Long Short Term Memory due to which it needs the previous data for predicting, hence LSTM uses all the features and also the previous value to predict.
- Step 5: The function series_to_supervised helps in converting the series data to supervised data. As we observe we find that the data is series and in order to convert it to supervised a new column is created which is a copy of ghi with the cells shifted up once.
- Step 6: This step is to split the column into 3 years of train and 2 years test data
- Step 7: In this step we import Sequential, Dense, LSTM, Dropout, from tensor flow which is a Google version of keras which is better.
- Step 8: In this step we separate the data into train x, train y, test x and test y train x and test x will contain all the features except ghi and train y and test y will contain ghi.

- Step 8: LSTM uses 3D data instead of the normal 2D data I.e. instead of only number of samples and number of features we have to add a time step which is a memory of 1 and by default is 1 and predicts next 1 hour in our case.
- Step 9: Building the neural model sequential helps in adding many models like LSTM, Dense and Adam in our case in one go. In our project we use LSTM with 100 hidden layers and the input shape which is the train x data. The output is not exactly the way we expect due to which we use Dense which is a weight multiplier and gives us the output in the range of 0-1.Adam algorithm is the learner algorithm which defines the learners rate I.e. how much the models learn in 1 iteration. At the end we compile the above network.
- Step 10: The next step is to train the data on train value and validate it on the test data. For each iteration the models need to update either by adding or dropping which is represented as loss for train data and val loss for train data. The prediction is good if the two values should match and if value of loss is greater than the value of val loss then it is called underfitting and if val loss is greater then it is called overfitting.
- Step 11: The next step is to plot the graph to check for loss as shown below. In the below graph we can see that the train and test value doesnt coincide from the start but it converges and are the same from the middle and end which depicts a good prediction model. As mentioned above if the loss and val loss values coincide it indicates a good prediction model.

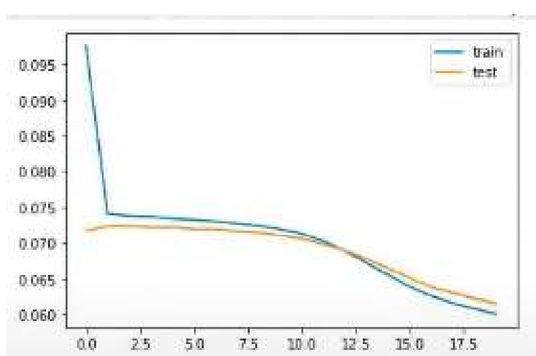


Fig 7.14 Graph for checking loss

- Step 12: The next step is to predict the model using test X and also convert back to 2D using inverse transformation back to its normal form from 3D and also to remove the FGHI column and replace it with the predicted data using python string concatenation.
- Step 13: Here we calculate the error in the prediction using the RMSE formula in our case the RMSE was calculated by below formula:

$$\textbf{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}}$$

The test RMSE was found out to be 85.323. This means the trained values have an error value of plus or minus 80. For example, if the trained value is 551 then either the true value can be 470 or 630.

- Step 13: The final step is to plot the graph for the predicted solar irradiance and wind speed values using matplotlib library.

7.13 How does the ASP.net core work?

The API being shown in the web page is being exposed by this code in the ASP.net core. The APIs major api used are:

1. weather-forecast-solar
2. weather-forecast-wind

First the above APIs get called if the request is a hit then another class is called which is called GetWeatherForecastSolar() and GetWeatherWind() for the above API respectively.

The class calls the website, and requests for data. Upon receiving the data, the class coverts, the data into JSON format and writes it into the solarData and WindData file respectively. If there is a success message, then the data stored in the file is shown in the web application and if there is a failure message then the data is discarded. The data won't be written in the csv file id it is open.

After the data has been written to the file the both solar and wind prediction model python scripts are called. The python Scripts are already compiled and ready for convenience. Calling a python code is creating a process and passing the file name, the c# code will then execute that code and return the process status. The status is the JSON file that is obtained from running the python script which helps us predict data stored in the SolarData and WindData file.

The predicted result is then printed on the console. The C# code then prints this data onto the web application. This is how the web application Interacts with the back end

CHAPTER 8

RESULTS AND DISCUSSION

8.1 Wind Prediction Model Result

The below graph shows the prediction of wind speed for two days using the model. The model had a RMSE of 2 (mph). The data ranged from 0-14 mph

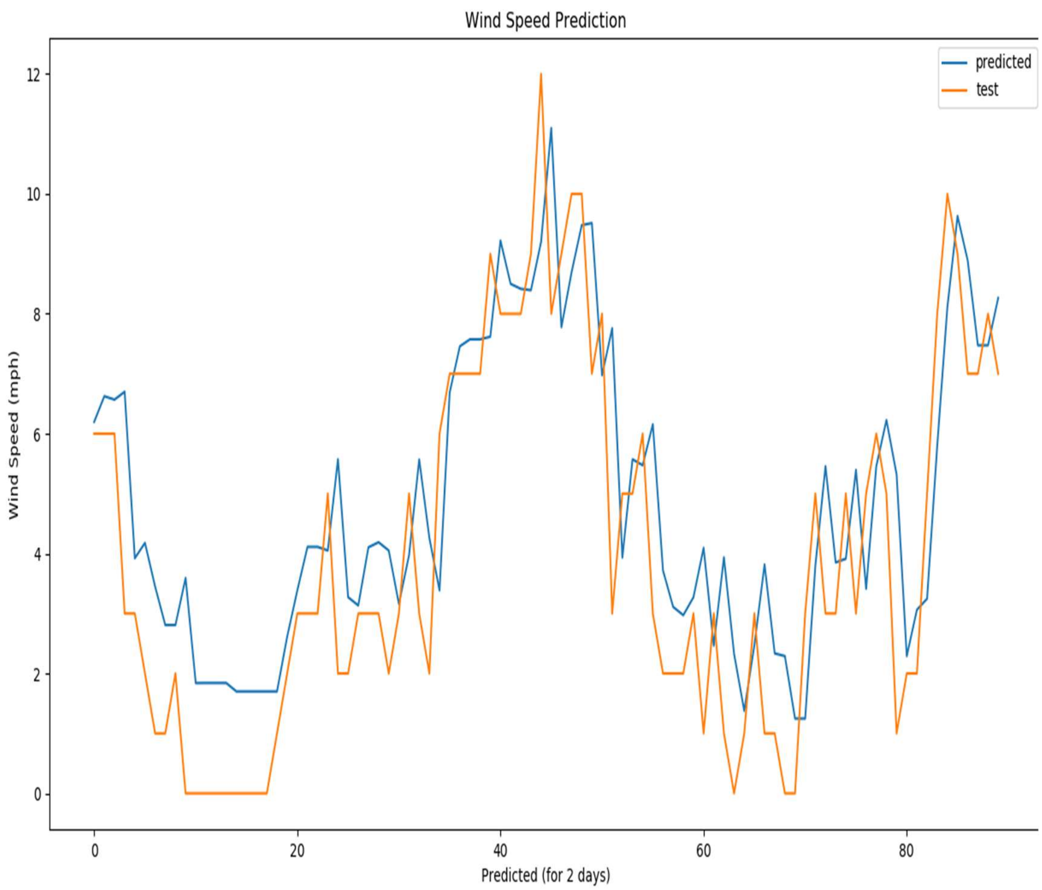


Fig 8.1 Predicted Result of Wind Speed

The test vs predicted graph shows exceptional result with the predicted data following the exact pattern of the test data.

The data which was used to train the model spanned up-to 10 years for Bangalore. The data was split into 8 years for training and 2 years for validation and prediction. As a result, the models showed tremendous learning pattern.

8.2 Solar Irradiance Model Result

The below graph shows the predicted result of Solar Irradiance model, value represented in terms of GHI (Global Horizontal Irradiance).

The result of this model is also exceptional with an RMSE of 85 W/m^2 . The data ranged from 0-900 ghi.

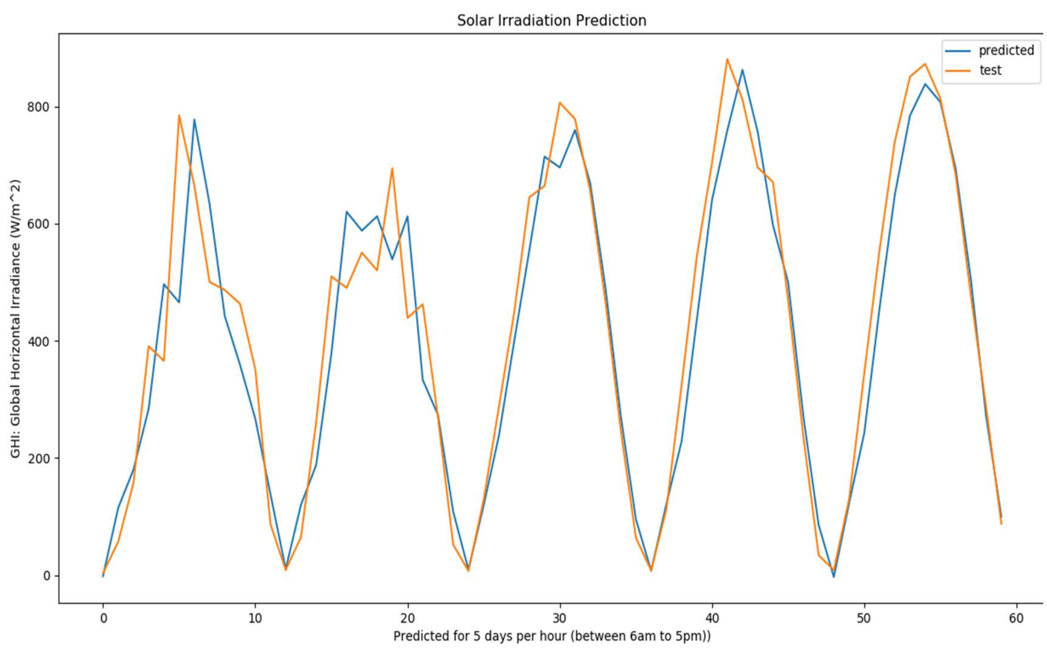


Fig 8.2 Predicted Result of Solar Irradiance

The test versus predicted graph shows few this model also followed the pattern of test data. The data used to model was of 5 years and was split into 3 years for testing and 2 year for validation and prediction.

The result obtained is also tremendous and has shown promising result for real time prediction

8.3 Web application screenshots

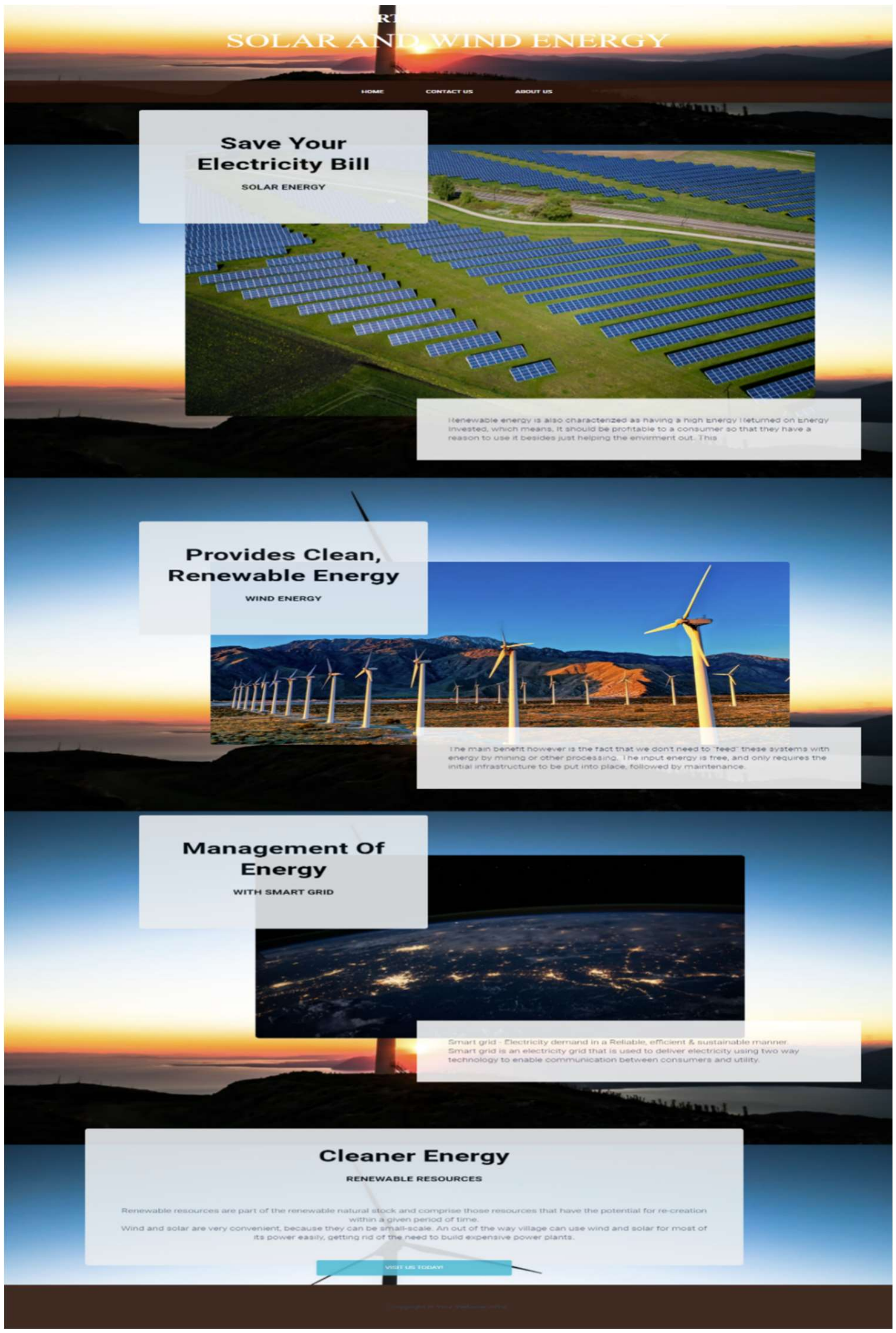


Fig 8.3 Home Page

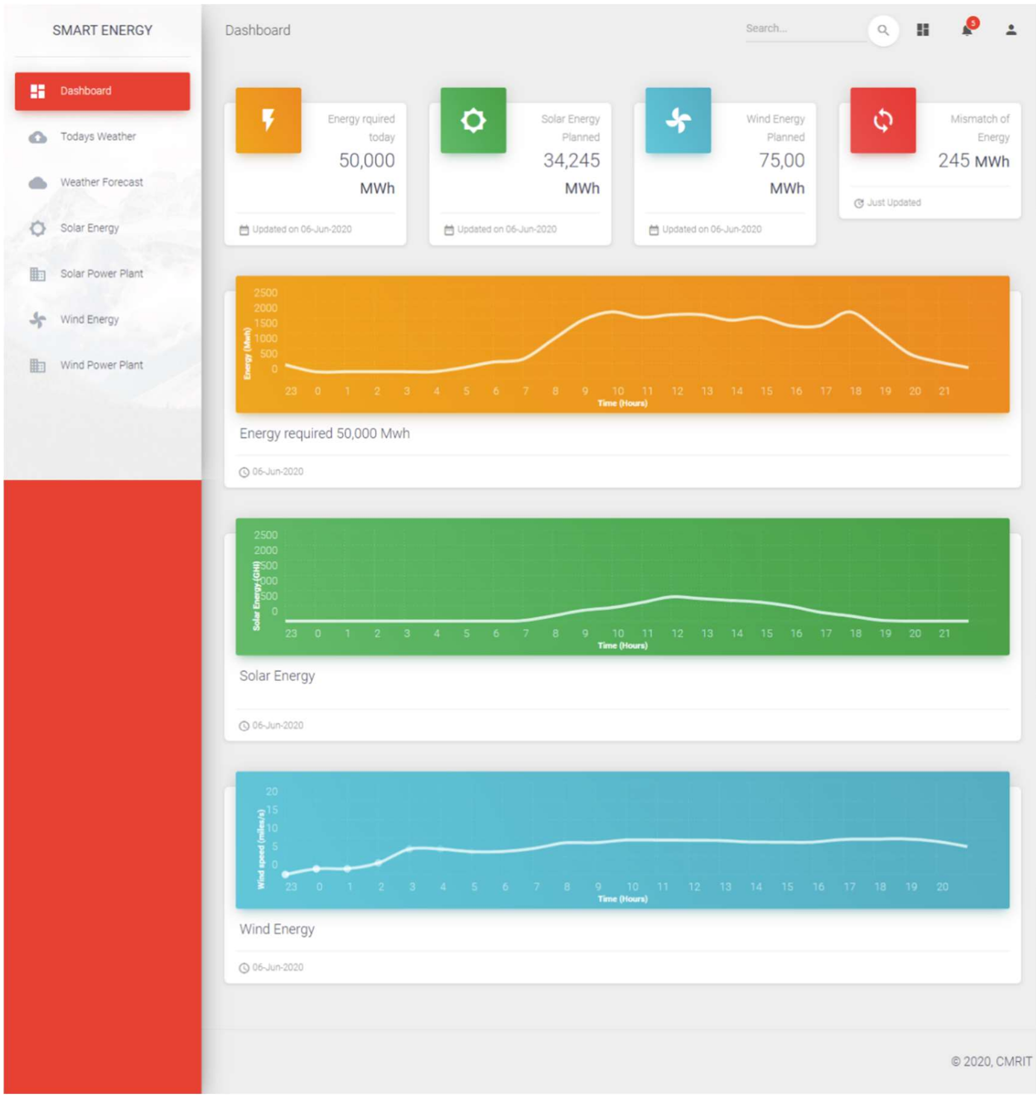


Fig 8.4 Dashboard

The dashboard contains the graph of Energy required for the next 24 hours. The also has the details of the predicted result, i.e., Solar irradiance and Wind speed for a rang of 24 hours. The graphs are updated at a one-hour interval.

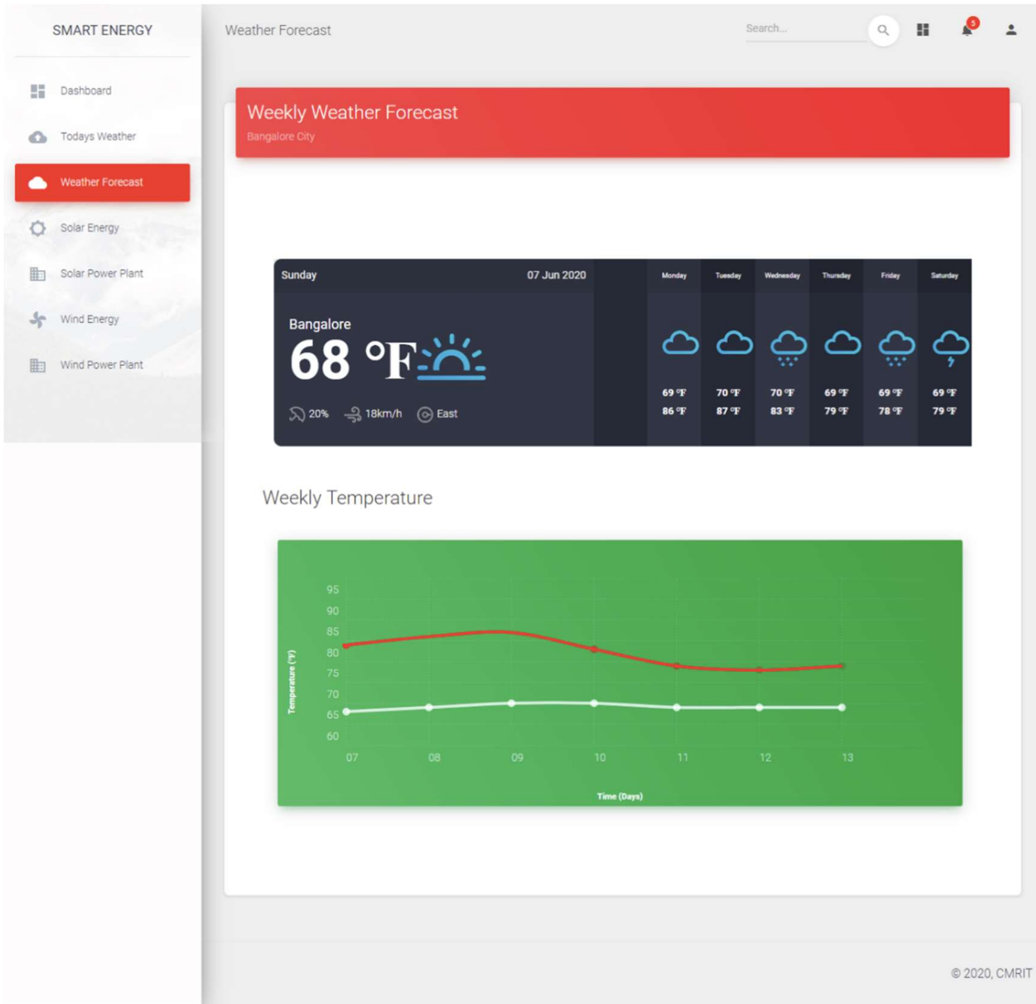


Fig 8.5 Weekly weather forecast

This page gives a description of weekly weather, the conditions and the minimum and maximum temperature.

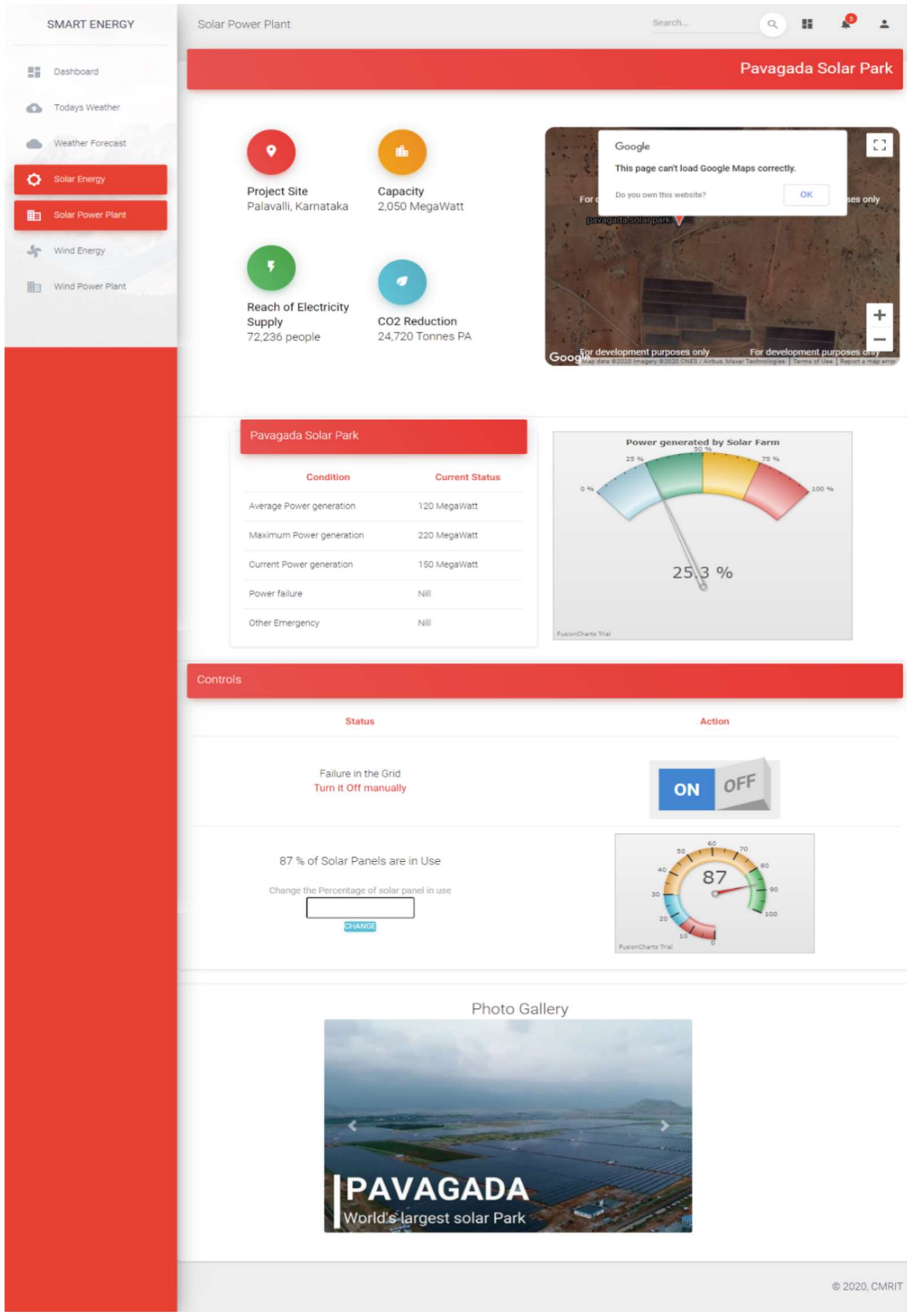


Fig 8.6 Solar Power plants details

This page contains the working condition of a given solar power plant. The energy being generated as well as efficiency of the production.

CHAPTER 9

TESTING

- **Unit Testing**

UNIT TESTING is a level of software testing where individual units/ components of a software are tested. The purpose is to validate that each unit of the software performs as designed.

A unit is the smallest testable part of any software. It usually has one or a few inputs and usually a single output. In procedural programming, a unit may be an individual program, function, procedure, etc.

In object-oriented programming, the smallest unit is a method, which may belong to a base/ super class, abstract class or derived/ child class. (Some treat a module of an application as a unit. This is to be discouraged as there will probably be many individual units within that module.) Unit testing frameworks, drivers, stubs, and mock/ fake objects are used to assist in unit testing.

We are mainly dependant on the API endpoints which performs various operations. Few important API endpoint testing was performed. They are:

- **API:** api/SmartEnergy/weather-forecast-solar. This api requests for solar weather data and writes into a csv file.
  - Testing for success
    - Input: None
    - Mocking: writing into csv file returns success
    - Output: Status code 200 OK
  - Test for failure cases
    - Input**:** None
    - Mocking: writing into csv file returns failure
    - Output: Status code 400 Bad Request

- **API:** api/SmartEnergy/predict/{modelName} This api returns predicted json data of model passed, either solar or wind.
  - Testing for success
    - Input: solar; Type: string
    - Mocking: prediction is success and returns predicted data
    - Output: Status code 200 OK with data of json type {"fullHour":"18:26","hour":[18,19,20,21,22,23,0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16],"value":[93.1,12.6,0,0,0,0,0,0,0,0,0,0,0,27.1,132.5,263,315.5,326.6,387.7,537.3,563,506.1,442,318.7]}
  - Testing for failure
    - Input: solar; Type: string
    - Mocking: prediction is unsuccessful and returns empty data
    - Output: Status code 400 Bad Request

- **API:** api/SmartEneegy/current-weather-report. This api returns a json data of current weather condition
  - Testing for success
    - Input: None
    - Mocking: respective web source returns expected data
    - Output: Status Code 200 OK with json data { "temperature": "80 °F", "dewPoint": "66 °F", "windDirection": "W", "windSpeed": "15 mph", "time": "17:25:36", "date": "17 Jun 2020" }
  - Testing for failure
    - Input: None
    - Mocking: No weather data from web source
    - Output: Status code 400 Bad Request

CHAPTER 10

CONCLUSION AND FUTURE SCOPE

10.1. Conclusion

This project develops a web product which will act as a management system for the micro grid system and their involved authorities.

The Web application named "Smart Manager" would contain details about the working of the micro grid, which may include the demand of energy needed for the day and future forecast of the demand. The supply of energy will also be monitored using sensors and cloud technology.

The dashboard will have the hourly forecast details of the energy required for the next day, or for any number of days specified by the user. The representation would be in terms of graphs and details of the forecast will be available.

For the success of this project complete knowledge of time forecast and advanced web technology will be required.

Knowledge for time forecast is required so as to design a model which will provide accurate prediction of the energy forecast which will play a key role in planning.

Advanced web framework is needed to show have a better UX and UI design so as to achieve user friendly environment in the application.

The web application would contain the functionalities of a dashboard, having details of one or more micro grad which will be managed from any remote location.

The constraint is that we cannot provide hardware controls as that would go beyond the scope and knowledge of this project. As mentioned in the title this project is an assistant so to say, not entirely a controller.

The key element of this project is the prediction model. The accuracy of the model will help to plan out the necessary requirements for the energy supply for the future.

10.2 Future Scope

Hardware integration can be done in an effective way to improve the efficiency of the project. Potential improvement can be made to our data collection and analysis methods.

Load balancing refers to the use of various techniques by electrical power stations to store excess electrical power during low demand periods for release as demand rises. Thus, would try to do it in an efficient way in future by using smart grids efficiently.

Identification, diagnosis and recovery of failure - If failure occurred, it must be identified quickly in the shortest possible time to avoid future damaging or cascading of event. In order to provide grid observability, controllability of assets, enhance power system performance and security, reduction in operating cost, maintenance and system planning, to accommodate a wide variety of generation centralized and distributed, intermittent and dispatch able, to communicate with energy management system in smart buildings to enable customers to manage their energy use and reduce their energy cost and lastly to predict and instantly respond to system problems in order to avoid power outages and power quality problems.

Smart Grids is not felt to be a necessity only for the integration of distributed generation, renewable energy sources and plug-in (hybrid) cars into the electricity grid but also for active participation of consumers for improvements in overall system efficiency, meet the peak demand without investment in generation and variable pricing system.

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