MAINTENANCE OF WINDMILLS WITH LoRa WAN

[1]Prof. Sushma Wankhede, [2]Sushant Namdev Mhatre, [3]Siddharth Sandesh Gurav, [4]Rajat Prakash Manohar, [5]Akhyar Asgar Gondekar
Dept. Instrumentation Bharati Vidyapeeth College of Engineering Navi-Mumbai[1,2,3,4,5],
sushama.wankhede@bvcoenm.edu.in[1], sushantmhatre17@gmail.com[2],
siddharthgurav21@gmail.com[3],manohar.rajat9@gmail.com[4], akhyargondekar97@gmail.com[5]

ABSTRACT

Windmill energy resource sector is booming which can mean only one thing more maintenance work & more jobs related to it, as well as dealing with it swiftly would be need of the hour. IoT which is new developing sector as well would be beneficial if it works hand in hand with the renewable energy resource sector. Sensor data acquisition is our first task, then data transmission is done by LoRa (Long Range Module) & GSM. LoRa is chosen for its ability to work under low to no internet coverage area & would be ideal due to its chirp spread spectrum. The third task is to get an accurate computer vision-based system to detect exterior flaws like windmill blade crack detection etc. The final task is to get graphical analysis of all the sensor data which would be obtained via ThingSpeak.

Keywords— (Windmills, IOT, LoRa & GSM, ThingSpeak)

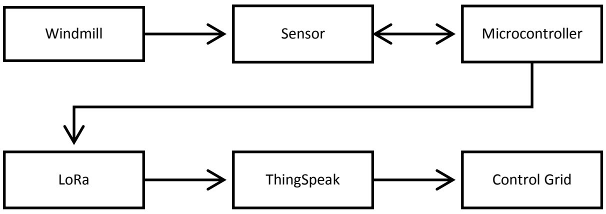
INTRODUCTION

The ever-growing energy resource sector, especially windmills are experiencing an exponential increase in terms of usage factor, as the race for replacing conventional fossil fuels due to extinction is picking up pace. This statement can be justified by statistical data, which shows growth up to 840.9 gigawatts till 2022 or in financial terms up to 47.5 Billion Dollars [1]. When there is so much growth in a certain sector, the responsibility to keep the resource running is also a crucial task. Our project focuses mainly on the task which is maintenance of windmills. The process starts with live sensor tracking from various sensors measuring different parameters such as temperature, humidity, air pressure, vibrations, current & voltage etc. This sensor data tracked then can be transmitted to the grid by LoRa WAN&GSM module. It can be plotted into graphical form by IOT based platform Thingspeak. We are also dealing with one of the significant anomalies which is windmill blade ejection by means of ultrasonic sensor & advanced computer vision also by using IOT based platform for this process instead of conventional wired technology will reduce the cost of wiring & wiring replacement as well as downtime of windmills which makes the system more reliable & efficient

SYSTEM OVERVIEW

Sensor Data Transmission & Graphical Analysis

This system in total comprises a lot of sensors & all the data should be sent to the control grid without hiccups & halts in the process. To accomplish this feat of measuring various parameters like atmospheric temperature, humidity, vibration, turbine temperature measurement, voltage & current output etc. The sensor integrated provide data to Raspberry Pi micro-controller [2]. These sensors are mounted based on their area of interest like in turbines to measure turbine temperatures by pyrometric temperature sensor, while others mounted outside such as to measure atmospheric humidity & temperature by DHT22. These sensors then should be able to transmit this crucial data to control grid [3]. To achieve this task instead of conventional wired technology we are going forward with recent development in IOT which is LoRa. This transmission module is ideal for the environment where windmills are located in remote locations where connectivity is scarce and transmission of data from such remote places can be a hassle. LoRa is based on chirp spread spectrum and relies on radio signals to transmit data up-to 10-20 Kms & this range can be extended by having a Network Gateway. The next feature providing a key advantage that it can work without internet connectivity. Along with-it GSM module is paired where private wind-farms have internet connectivity & it isn't the issue; it can deliver sensor data at a faster rate. This is how sensor data transmission takes place. To plot this data into graphical form we are using ThingSpeak, which is an IOT based platform designed specially to plot sensor data into graphical format. A block diagram representation show below will give a clear idea of the process.



Computer Vision Based Crack Detection

Machines which are placed in wild & harsh climatic regions do tend to suffer from wear & tear. Harsh climatic conditions such as lightning & thunderstorms poses a great threat to damage windmill ecosystem. In such environment windmills act like a lightning rod & more often times get damaged by it. The exterior structure though made up of Fiber-glass material, it sustains the damage. To Identify this damage & cracks we are using advanced computer vision. The micro-controller we are using is a Raspberry-Pi, which enables us to utilize the full-fledged power of machine learning & image processing. This is achieved with help of a high-definition camera which can monitor multiple windmills at a time, which provides the ability to monitor this wind-farms precisely.

In this project we are using YOLO V3 architecture. YOLO V3 is an improvement over previous YOLO detection networks. This model provides a lot of significant advantages over its predecessor such as high-speed detection and accuracy paired with multi-scale detection, strong feature extraction etc. [6]

The process takes place through a sequence. The first task it tackles is loading the data, the most common type for machine learning data is a CSV file. The task done before the loading data set is to split the data set in a specific ratio of training and testing, the main aim of deciding the splitting ratio is that all three sets should have the general trend of our original data-set. After splitting the data-set, one part of the data set is put through training while other goes through testing, training is the general term for the samples used to create the model, while the "test" or "validation" data set is used to qualify performance. Combining both the test and training models forms the trained and tested model which can then in-turn classify and distinguish cases, which in our scenario is if crack is detected or not detected and displays it as per required output.

This process can be explained in detail with help of accurate flowchart.

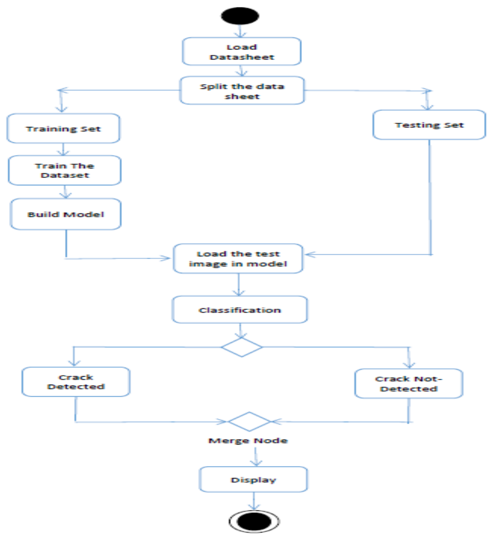


Fig 1. Flow Chart

Windmill Blade Ejection Anomaly Detection

The major halt in the production of windmill energy is due to this anomaly of blade ejection, as it can completely derail the working windmill. To tackle this problem, we are using integration of 2 sensors together, as the situation demands it. This system starts with ultrasonic sensors mounted on stem of windmill as well as the base which properly gives the overview of loosening of blades as they will move side to side or do up & down maneuvers, ultrasonic sensors work on principal of distance= speed x time. A distance threshold is set up, so if the blades move too much further apart the grid will be notified, this paired with vibration sensors to measure the vibration caused due to loosening of blades, both threshold if stepped-over for certain duration, the grid gets an update, then we can schedule a maintenance for this task.

REVIEW OF LITERATURE

This section provides a systematic literature review of system designed for monitoring & maintenance of windmills with help of LoRa WAN & summarizes all the research in last 12 to 14 years. The search for this review was limited to Global Journals publishing, YouTube, Safari Books Online, IEEE explore, Digital Library, Energy & Power Engineering, Science direct etc. The search we conducted consisted of keyword "maintenance of windmills" & it gave almost gave 20,70,000 results that included books, research papers, dissertations, retracted papers & technical reports & blogs, images.

A. Selection Criteria

Our focus was restricted to papers & articles that were published from 2006-2021, to have the clear ideas about development in each aspect of this monitoring & maintenance system, we narrowed down to English language-based papers that suited our title, purpose & shortlisted papers that mentioned in reference section

B. Title Based Selection

The first scan of each paper by their title gave us a rough idea about which papers should be kept for reference e.g., reports about manufacturing of windmills were rejected, the articles or papers which mentioned monitoring & IOT based solutions as well as nuances in the field were selected.

C. Final Assessment

The selected papers were scanned again to make a final list of papers, this was done by reading abstract of each paper selected from its title, we preferred any paper that has connection with wireless data transmission of sensor data, monitoring techniques, Wired & WIART technologies etc., out of which we selected 5 papers.

D. Derived Content

The IOT sector is quite a new development & use of custom-made micro-controllers & sensors is second nature to the field. Arduino & Raspberry-Pi for low-cost & real-time remote monitoring is quite beneficial which can continuously monitor the output performance & Operation [2]. Turbine Health Monitoring is also one of the more important issue. It is one of the most crucial components of windmill & maintaining its temperature to optimum working condition by means of Pyrometric Temperature sensor should be priority. Avoiding cost of wired installation which can further reduce maintenance of cost caused wire cuts/damages, ability to monitor the whole system from longer range [3]. The transmission techniques provided by actual industry grade quality also gave us an overview how some of those system work [4]. Computer vision-based detection [6][8] was also been looked into for crack detection for smart monitoring. Data transmission through LoRa & GSM modules were also taken into consideration [7], especially LoRa offering data transmission with no need for internet connectivity. Predictive maintenance can often stop situations from getting worse [9]. It can often avoid accidents & prevent loss of infrastructure, while also saving expenditure required for totally damaged parts.

WORKING & METHODOLOGY

The system is broken down to three phases as earlier seen in the overview. These three phases being sensor-based data transmission, computer vision-based crack detection & windmill blade ejection anomaly detection. These systems carry out each specific task to keep the resource running & well-functioning.

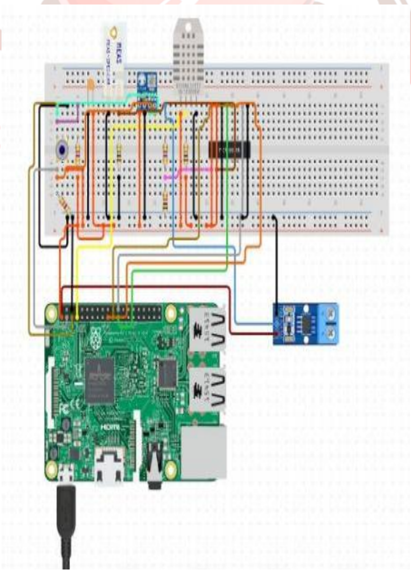


Fig 2. Circuit Diagram

A. Micro-Controller

While designing a system, the heart of the system is taken into consideration, prior to any other component selection, based on our requirement we have selected Raspberry Pi-4 as our micro-controller as it meets the what our system demands. It is well known & probably most renowned micro-controller which can almost handle anything with its great open-source capabilities, there's nothing this palm sized board can't achieve in terms of IOT, IIOT applications etc. [2]. It has a Quad-core CPU, paired with 4 to 8 gigabytes of ram depending on the model, also has 40 GPIO (General Purpose Input/Output) pins. Each pin has specific functionality, ranging from Vin pins which supply 5V or 3.3 V, PWM pins for motor drivers, TX & RX pins for communication related activities etc. Due to this varied amount of usage factors & versatility it provides we have chosen this micro-controller.

B. Sensors

There are various sensors measuring various parameters. First of many is DHT 22 which measures atmospheric humidity & temperature, so as to have better understanding of the climatic conditions on field where windmill is operating, this can also provide an overview on rusting factor. BMP180 is another sensor which provides data about atmospheric pressure on the windmill. Pyrometric temperature is used to measure turbine temperature, it is a non-contact type infrared sensor which has been set on threshold & notifies grid if the turbine is heating excessively while operating. This helps in better scheduling of maintenance as overheating can cause major issues going forward. Voltage & Current sensor measure output the windmill is providing. This helps in identifying if the windmill is operating efficiently & generating enough energy as per requirement. Vibration & Ultrasonic sensor does the task of detecting anomaly of windmill blade ejection. All this sensor data is transmitted to grid with help of Thing speak. It's an IOT based platform which helps in delivering sensor data in a graphical format.

C. Transmission Modules

To transmit the sensor data & to notify grid about the overstepping of thresholds is the task of the transmission modules. The two modules which can handle these tasks are LoRa & GSM modules. LoRa is a recent development in field of IOT, which works on chirp-spread spectrum. That is low bandwidth but longer transmission rang, LoRa has transmission speed of 256Kb/Sec, this might not look like a lot but it can deliver it areas deprived of internet connectivity, ideal for locations where windmills are situated [7]. The module we are using which Ra-02 which has transmission radius of 10-15Kms. This can be increased with help network gateway as an extension. GSM modules is for areas where internet connectivity isn't the issue i.e., private wind-farms where it can be done easily. The GSM module has higher bandwidth as it supports 4G LTE. Both of these modules have a year of battery backup on standby mode which can be seen as an added advantage. Both these modules provide serve the same purpose and output from these modules is provided to Thingspeak for graphical analysis. Data logging feature for historical analysis and providing benefit of predictive maintenance to prevent the system from sustaining further damage [5][9].

D. Camera

The camera is an essential component of the computer vision-based crack detection. To meet this purpose, we have selected a camera which supports our micro-controller i.e., Ras-pi Camera 2, its capable to deliver 1080p at 30 FPS, which is impressive & sufficient for our prototype. It also delivers 720p on 60FPS but clarity is crucial so we are sticking with 1080P. This camera will be used to identify cracks on the blade & will be situated at an ideal distance from the windmill, it will be trained under YOLO V3 model which will guide it in identifying cracks on the exterior structure.

E. Methodology

Problem	Solution	Technology
Turbine Health Monitoring	Can assign repair crew member to resolve the issue	Pyrometric Temperature Senor
Voltage/Current Measurement & Live Tracking	Sensor track Voltage and Current parameters.	Voltage, Current Sensor, LoRa WAN/GSM
Data Logging	Sensor data acquisition	Thingspeak
Efficient Use & Maximum Power Generation	On Real Time Monitoring	Thingspeak For Graphical Analysis
Optimize Maintenance	To detect any anomlaies like windmill blade ejection etc	Vibration Sensor, Ultrasonic Sensor
Data Transmission	In zero internet connectivity it can communicate to controller	LoRa & GSM modules
Physical/Structural Damage	Enhance computer vision technique has being use	Rasp Pi CAM V2 integrated with micro controller
Automating Wind Farms	Sensing & Controller	Pyrometric, Current, DHT11, Piezoelectric, Voltage etc
Maintenance	Use historical data, current data and suggest actions	Through Thingspeak, Cameras & LoRa/GSM Network Modules

The process is carried out in a specific way i.e., the task ranges from monitoring to data logging & on-site service. The first task handled by system is turbine health monitoring which can be done by Pyrometric infrared non-contact type sensor, which will be set on threshold & to assign repair crew members for on-site maintenance if the turbine is heating too much to frequently. Voltage & Current measurement, Live tracking will be done through voltage & current sensor. It will provide an overview on how efficient the system is. LoRa & GSM module transmit that data to thingspeak which will provide real-time graphical analysis. The sensor data acquired should be saved for historical analysis & predictive maintenance. Data logging is done with thingspeak as well which can keep record or all the data provided to it. Optimization of maintenance & to identifying structural damage with enhanced computer vision-based techniques with help of Raspi Cam V2 integrated with microcontroller. It can resolve this to avoid further damage to windmills. Data transmission & automating of windfarms is taken care by all the sensors as well as transmission modules. These modules can work in zero to no internet connectivity & communicate with control gird. These are some key highlights of our methodological structure, which has been explained with detailed chart earlier

V. Critical Review

This review provides total analysis, we made before finalizing our objectives & areas of interest we want to work while developing our system. Version developed by some industrial companies either relied on wired technology or WIART [4] which relied on either Sigfox & other transmission modules which either relied on internet connectivity or required wiring & rewiring costs much more. To reduce all this extra expenditure on either wiring or developing internet-based ecosystem, we used existing infrastructure & tried to make it smart by use of up & coming IOT technology which was suitable for all the task at hand. The structural analysis, as well as anomaly of windmill blade ejection anomaly was also taken into consideration while development which was another significant advantage considering earlier designed system models. Our whole system works in tandem & with less hiccups as possible.

VI. DISCUSSION

This discussion provides an overview of the design & functioning aspect of monitoring & maintenance system which has been proposed for windmills & some of the minor problems it faces & how we can tackle them.

The camera which does the structural analysis can be affected by weather conditions as well this can cause it to provide varied amount of false/garbage data, which can be disturbing for the whole system. The lens should be cleaned at a regular interval so wiping mechanism should be provided to clean the lens at regular interval. This will ensure the camera to record high resolution data & be precise as possible.

The Thingspeak IOT as well as LoRa are still developing platforms and will only get better with time. These resources would turn out to be beneficial once they get enough spotlight to shine. Working with these resources provided us an insight on how these systems can be further enhanced to utilize their potential.

This system is quite logically simple & easy to understand its principle about being able to monitor the windmills with help of sensor data acquisition & data logging for predictive maintenance. Also providing grid with deep analysis of sensor data which is transmitted through LoRa & GSM to Thingspeak. Accurate structural analysis provided by enhanced computer vision etc.

VII. Result

We selected few objectives before planning our approach towards the end goal. We divided some of these objectives into milestones. There are various parameters which will be monitored through the process of sensor data acquisition was done by integrating sensors with our raspberry Pi-4 micro-controller. To transmit this data with help of transmission modules in internet deprived areas was also achieved. This data then provided to thingspeak interface with help of API keys assigned for each sensor which will help in data logging & accurate graphical analysis. While accurate structural analysis with enhanced computer vision system with YOLO V3 for model training, which delivers what has been proposed to deliver. Blade ejection anomaly tackled by integrating ultrasonic & vibration sensor together works like a charm. Each milestone helped us reach our final destination. With all the upcoming updates to this system due to ever developing IOT sector will create a great thriving ecosystem.

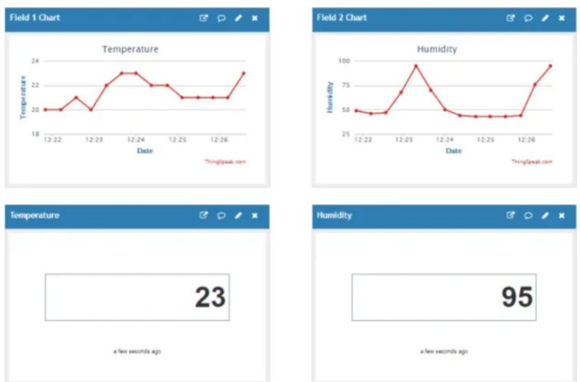


Fig 3.

VIII. CONCLUSION

From all the above results gathered, the final verdict on the system is that, it can acquire data accurately. Providing data to transmission modules with less hiccup as possible & transmitting it to grid with similar potential. Advanced computer vision used in the system providing substantial results with YOLO V3 model with trained & tested data set. Overall whole system is working together as a well-oiled machine.

IX. REFERENCES

1. Global wind turbine market article posted by Power Technology
2. IOT based Windmill Monitoring System by Vishal Kumar Singh, Department of Electronics and Communication, SIT, Tumkur.
3. Wind Turbine Condition Monitoring: State-of-the-Art Review, New Trends, and Future Challenges by Pierre Tchakoua, Gabriel Ekemb, Department of Applied Sciences, University of Quebec.
4. Maven Solution India PVT LTD.
5. State of the Art of Maintenance Applied to Wind Turbines, by Luis Barberá, Alejandro Guerrero, Adolfo Crespo Marquez, Vicente Gonzalez-Prida.
6. YOLOv3: An Incremental Improvement by Joseph Redmon, Ali Farhadi University of Washington
7. A Study of LoRa Low Power and Wide Area Network Technology, Umber Noreen, Ahcène Bounceur, Laurent Clavier .
8. Crack detection using image processing: A critical review and analysis, Arun Mohan, Sumathi Poobal
9. Damage mitigation techniques in wind turbine blades: A review, by Md Abu Shohag, Emily Catherine Hammel,David Olawale, O.I. Okoli.