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# Design and Simulation of monitoring system for windturbine using low power wireless sensor network

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**Abstract**

*The wind turbine can be seen as alternative source of energy generation as nowadays we are going for green energy generation. It is also a natural source of energy generation. So monitoring of wind turbine becomes essential and crucial. The parameters like blade position, vibration, wind speed, rotor condition, and power output are to be monitored continuously. The system consists of low power wireless sensor nodes assembled on wind turbine which forms the WSN and are controlled through embedded system and IoT. In case of errors the system reacts accordingly and tries to avoid the fault.*

***Key Words***: *Wireless Sensor Network, Wind Turbine, Renewable energy, Python*

## I. INTRODUCTION

To address the climate change, gas emission reduction, biodiversity protection and renewable technology development nowadays the world wide priority is to improve the energy conversion and efficiency. Wind energy is fastest growing sector in terms of installed capacity in all renewable energy sources. Wind turbines are located at remote place, unmanned. [9] They are always exposed to harsh environment, weather conditions as compared to conventional power generators. Due to this changing external environment the wind turbine undergo constant load changes giving rise to mechanical stress. The wind turbine is a three blade system driven by the wind. The blade and rotor transmit energy via the main shaft through gear box to generator. The maintenance costs approx 10 to 20 % of total cost of energy. The wind turbine requires a high degree of maintenance to provide reliable and cost effective power output. The maintenance of the wind turbine can be classified as predictive maintenance, preventive maintenance,and corrective maintenance. Under preventive maintenance category the condition monitoring of wind turbine is used which will determine optimum point between corrective and scheduled maintenance. While doing condition monitoring the most popular method used is SCADA (Supervisory Control and Data Acquisition) system. In this system the condition monitoring is carried out using documented data. The different parameters are monitored on regular basis. The system is good in practice but does not necessarily provide warning for the operators to carry out the maintenance. The maintenance is carried out only after fault has occurred. So an online remote monitoring system is designed and developed using wireless sensor network, embedded system and IoT infrastructure.

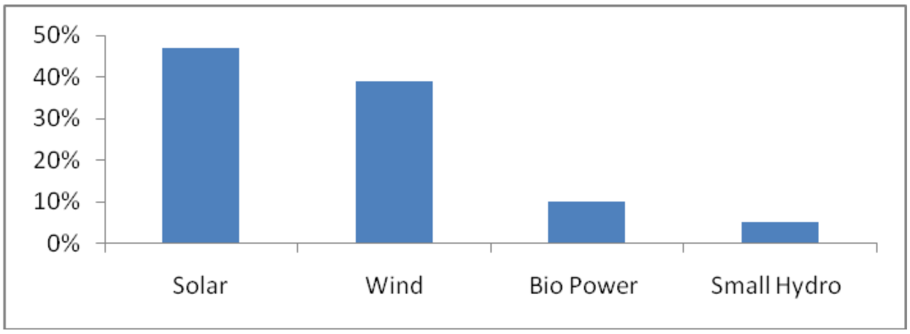


**Fig 1: Installed Capacity of Renewable Energy Sources in India 2021**

## II LITERATURE SURVEY

The condition monitoring system consists of combination of different sensors and digital signal processing equipments. The data acquisition and signal processing the faults can be detected and appropriate actions can be taken or planned for working of the components. The different techniques and methods for condition monitoring are discussed by many authors. The qualitative fault tree analysis is discussed by Fausto Pedro GarcíaMárquez[1] along with different techniques. A general review of different techniques along with recent trends and future challenges are discussed by Pierre Tchakoua[2]. Hehas also discussed the strength and weakness of current wind turbine condition monitoring system and discussed the research priorities required to meet the different challenges in wind industry technological evolution and market growth. A systematicreview of machine learning methods applied to condition monitoring system using vibration information and SCADA data is been published by InnusMurdo Black [ 3]. The major issue in data driven approaches is it requires preprocessing data. A noval method used for condition monitoring using adaptive multivariate control charts and SCADA system is developed by Qinkai Han[4].Three SCADA based monitoring methods signal trending, physical model and self-organizingmaps arebeen reviewed by Michal Wilkinson [5] using five operational wind farms. Condition monitoring system using embedded system and WSN is developed by Dr.R.UMAMAHERWARI [6] using simulation model using energia tool software.All the authors have contributed a lot in condition monitoring method using SCADA system and different techniques involving data driven approach. The major parameters in condition based monitoring involves 1) selection of the number and type of sensors2)Selection of effective signal processing methods associated with the selected sensors and 3) design of combination of sensors and signal processing methods which give an improved performance. In this paper the condition based monitoring system is developed using low power wireless sensor nodes and IoT infrastructure.

### III HARDWARE OF THE SYSTEM

The wireless sensor node consists of microcontroller, a transceiver, power supply and an antenna. The fig 2 gives the detailed block diagram of wireless sensor node[12] .The wireless sensor nodes are mounted on the wind turbine at various locations to monitor the parameters of the wind turbine. As we want to achieve low power consumption the controller used in wireless sensor node is MSP 430 from Texas instrument having power dissipation 18 mW in low power mode. The transceiver used is CC 2500 from Texas Instrument which generally dissipates 70 mW during transmission. Fig 3 gives the power breakdown of sensor node. The fig shows that the transmitter is consuming highest power. So if we are able to reduce the data transmission, then we can achieve low power consumption for the entire system. Thewireless sensor node will process the data and will be finally send to server computer. This will reduce the data transmission and will achieve low power consumption. An interrupt driven system will wake up the sensor node periodically and the node will process the data and will send it to the server computer. The acoustic emission sensor is used to monitor the events continuously [11]. This sensor will monitor acoustic events continuously, at that time the wireless sensor node is in sleep mode. The acoustic emission sensor consists of piezoelectric transducer mounted on the plate and connected to electrical connector. The minimum displacement detected by the sensor is in terms of picometers. If any event is detected, the acoustic sensor will send interrupt to the wireless sensor node which will wake up. The diagram for acoustic emission sensor is shown in fig 4. The node will perform the operation and the result will be transmitted to the node at receiving end server computer. This method decreases the frequency of operation as compared to conventional time based wake up method, resulting in small transmission time and hence low power is consumed.

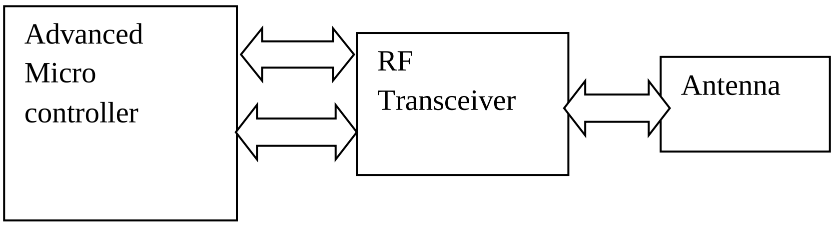


**Fig 2: Typical wireless sensor node hardware**

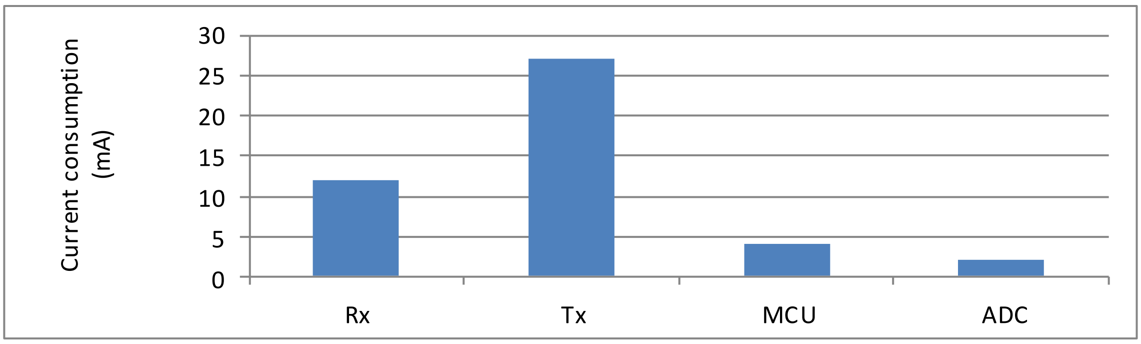


**Fig 3: Power breakdown of the sensor node.**

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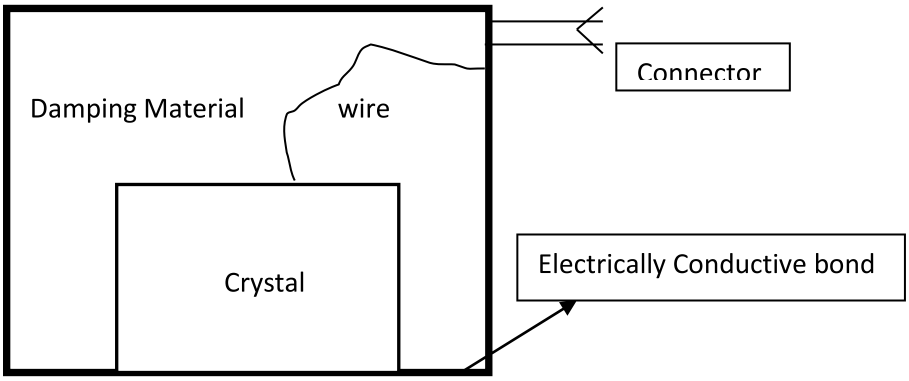


**Fig 4: Block diagram of acoustic emission sensor**

The sensor node located at server computer called as master node consists of MSP 430 MCU and CC2500 transceiver (TRx). It is connected to PC (server) through Zigbee emulator which monitors the data of WSN and controls the system and displays the result. [10] The AE sensors are mounted on blade of wind turbine. The sensor nodes are connected to AE sensors. The node also contains an analog interface along with MCU and transceiver. A maximum of 10 nodes can be connected to the system. The AE sensor monitors the event continuously.Whenever an event occurs signal is sent to the node through interface to MCU. The node which is in sleep mode wakes up and data is processed. This data is send to master node at the host computer through cloud. When data is received at the master node it is again processed and is given to host computer which is displayed on the screen.

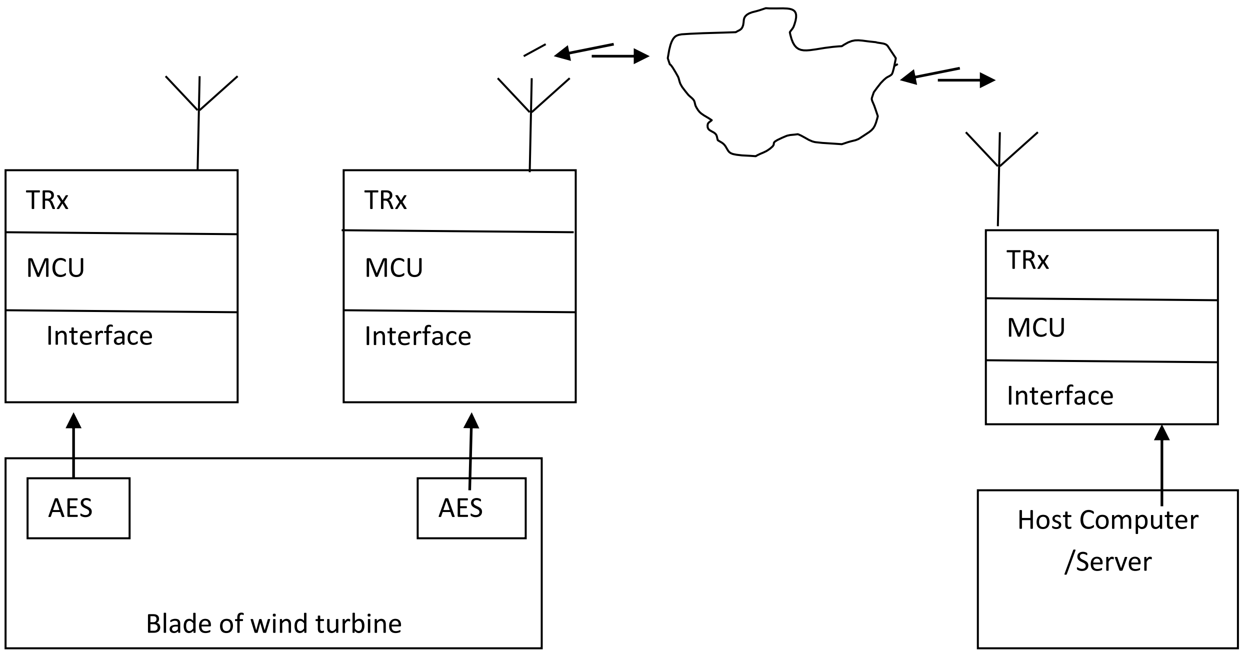


**Fig 5 block diagram of the system.**

## IV SOFTWARE MODULE

The software module is used to simulate the prototype of the system. Python language is preferred for simulation. Another software MATLAB can also be used for simulation purpose. As python is open source it is preferred over MATLAB. The main modules involved are

1) Communication controller module
2) Transceiver Module
3) I2C bus module
4) Wind turbine module.

The wind turbine module consists of 4 sub modules namely i) aerodynamic module ii) Parameters of turbine iii) Geometry of Blade iv) Normal values. The following fig 6 shows the interconnection of these modules.

The detail description of modules is as follows

1) Communication controller module: This module sets the initial condition of all the registers, stack pointers, flag etc. Assigns the input port and output port of the controller. It handles the interrupt and interrupt service routine.
2) Transceiver module:This module does the calibration of transmit and receive mode. It checks and read the content of config register during the receive mode. During the operation set the mode of the transceiver to low power mode and puts the transceiver to transmit mode.
3) I2C module: It initializes the port and the registers. It also handles I2C state machine ISR.
4) Wind Turbine module :
   i) Aerodynamic module : The aerodynamic parameters are air density and power loss factor

**Table 1: Aerodynamic model**

| Name | Parameter symbol in Python | Units |
|---|---|---|
| Air density | Rho | Kg/ sq. m |
| Power factor loss | Kp | --- |

   ii) Blade geometry :

**Table 2: Blade Geometry**

| Name | Parameter symbol in python | Unit |
|---|---|---|
| Radial position | R | meter |
| chord | C | meter |
| Twist | Thetat | deg |

iii) Turbine parameters : The parameters of wind turbine are as follows :[8]

**Table 3: Turbine parameters**

| Name | Parameter symbol in python | Units |
|---|---|---|
| No. of blades | Nb | ---- |
| Rotor radius | R | meter |
| Inertia of the blade | Jb | $Kgm^2$ |
| Total Mass of tower | Mt | kg |
| Transmission ratio | Nu | ---- |
| Inertia Rotor | Jr | $Kgm^2$ |
| Generator Power | Pn | W |
| Efficiency Generator | Eta | ---- |

iv) Normal Values :

**Table 4: Normal Values**

| Name | Parameter symbol in python | Unit |
|---|---|---|
| Wind speed | Vn | m/s |
| Blade pitch angle | thetan | Deg |

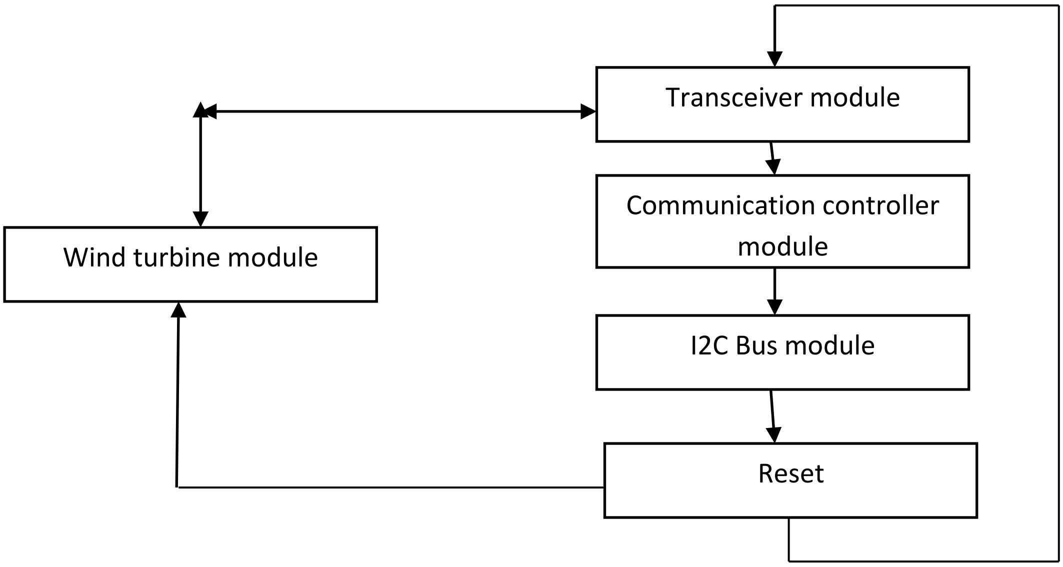


**Fig 6 Interconnection of Software modules**

## V EXPERIMENTAL RESULTS

There are two parts in the results. The first is computer based simulation testing and the second is testing of real prototype. The computer simulation is done through python language and the duration of the simulation is considered as 100 s. The transmission ranges of all nodes are same and aredeployed randomly. The bit rate is constant and the packet size is 70 bytes. As the number of nodes increases the transmission hops increases and end to end delay increases.In the simulation test 1.5 kW wind turbine is simulated to verify the effective simulation of the system. Fig 7 and fig 8 shows some simulation results related to rotor speed, power generator,and both these parameters versus time in sec.

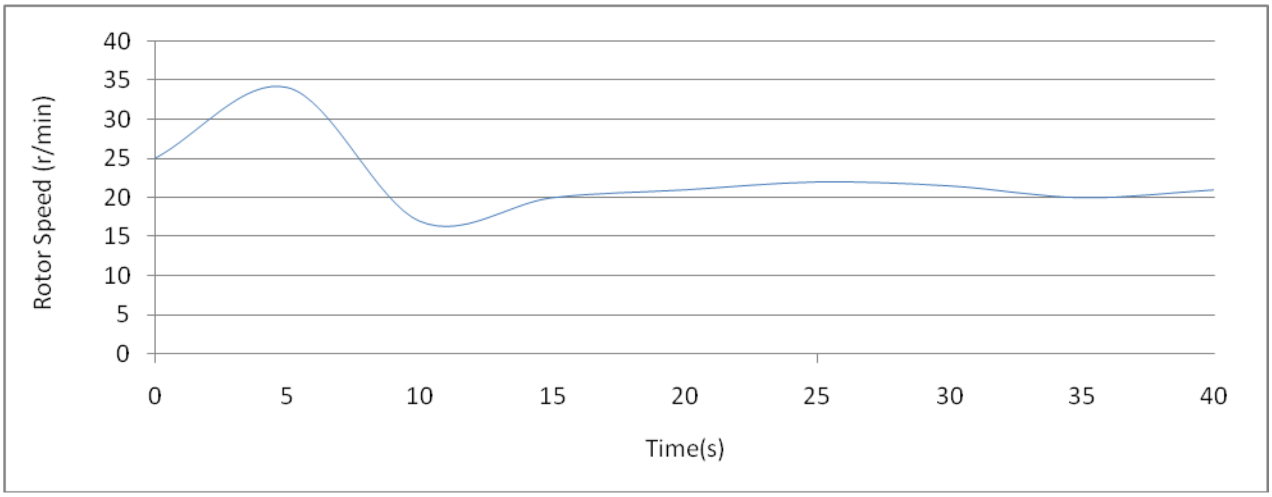


**Fig 7: Rotor Speed Vs Time**

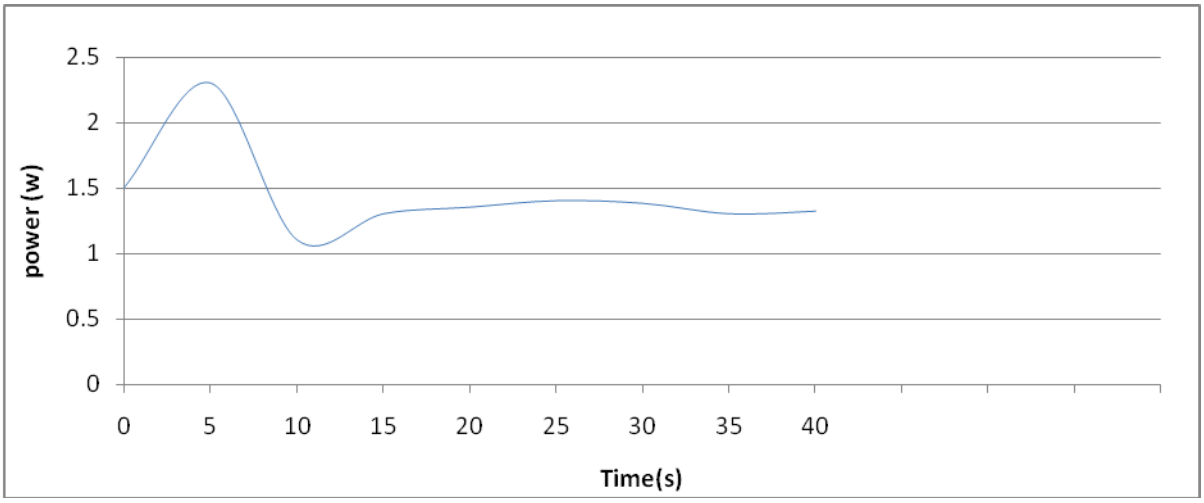


**Fig 8: Power Vs Time**

The node is supplied with AA battery with 2.6 V .The power consumption in actual prototype is measured while testing. The table below shows the power consumption of the node in three different modes i) sleep mode ii) active mode iii) Transmission mode. It is observed that the power consumption is very less in the transmission mode. So using low power wireless sensor node it becomes economically feasible to design the system.

**Table 5: Power consumption of node in various modes**

| Mode | Power ( mW) | Time |
|---|---|---|
| Sleep Mode | 0.3 | --- |
| Active Mode | 10.2 | 4s |
| Transmission Mode | 74.4 | 1ms |

## VI CONCLUSION

The system is designed using low power wireless sensor network for remote monitoring of wind turbine instead of traditional method to reduce the cost as well as maintenance. The advantage of proposed system is it identifies the fault promptly and avoids further major maintenance. The system also decreases the power consumption which is the need of the hour. In future the system can be build with adaptive network topology for reliable and cost effective monitoring of the wind turbines.

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