Condition Monitoring and Control System for Small Wind Turbines

ABSTRACT

Real time monitoring and control is getting a boost now due to advent of newer generation of open source hardware and sensors. Wind turbines are one of the machines that require a lot of conditioning and monitoring as they are completely dependent on weather conditions and at times installed at remote areas like mountains and offshore. The task of monitoring wind turbines is something that requires a blend of remote monitoring and specifications based control. The control parameters are mostly analog and so we require to have a multitude of analog equipments which can help us in our pursuit. The data collection unit in our case will be an Atmega1280 based system which will house the sensors and the transmissions will be handled by esp8266/nrf240 or GSM modem's. The control mechanism on the client side will be metled out by Application Specific Java Software which will provide us real time parametric measurement and decision making on it. The decision making will be handled by fuzzy control. The application will host a control specifications compliant GUI which will make the monitoring easy.

Keywords*- wind turbine; condition monitoring and control system; data collection unit; graphic user interface*

I. INTRODUCTION

The wind turbines are a primary source of electricity generation in many parts of the world which have a great terrain and scenic shores where these giant turbines can be installed. India is one of those countries that has a variety of such systems, but the power generation suffers as the climate isn't really as stable as one would expect it to be. The problem is the models that have been deployed here have no means to adapt to the wind flow, humidity or air flow gradient so as to turn towards the best configuration for stable power generation. In effect it leads to potential difference losses. These losses are the compensated by the use of special transformers which boost the voltage bring it to a stable usable rating. This system overhead adds extra cost which makes the Purpose of renewable energy futile as it is more costly for maintenance than any of the conventional sources. So there needs to be a monitoring system through which can actually monitor the physical conditions or the parameters of the system.

Based on the parameters monitored we can change the direction of our blades based on the course of the wind. Different kinds of sensors available today might be helpful for our purpose. The different kind of sensors that can be deployed in our case can range from a small magnetometer to a fully fledged wind direction unit. The constraint that one should consider here in this case is the budget and efficiency of actually deploying the system. The system deployed must be such that it can be easily fixed and tuned into a real time system in operation with a little or no changes in the original configuration. Secondly the maintenance of the adhoc system for monitoring should have minimalistic interference in operation the original system designed. Also the maintenance should be very low as well.

The main aim of this paper is to actually design and calibrate a condition monitoring and control system for a very small-scale wind turbine. The system will consist of data collection units, data coordinator, data control unit, PC and smart android device(optional). The data collection units here are installed in the wind turbine side to collect sensing data from different sensors such as temperature, humidity, atmospheric pressure, wind direction, wind speed and vibration. The data coordinator node device receives the sensing data from data collection units and transmits it to our smart device via Bluetooth. Also, the coordinator communicates with a PC via CP2102 where the PC stores the sensing data in a database. To display the sensing data, Android and Processing are used to implement the GUI. The GUI based on Processing is used to control the wind turbine direction using control unit.

II. PROPOSED SYSTEM

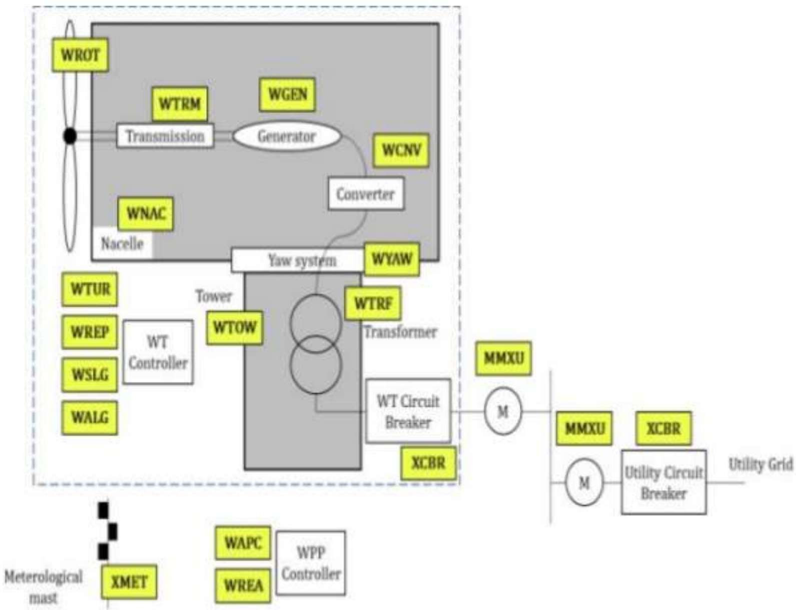

Fig .1.logical nodes of wind turbine

The proposed system is will have following components. Some of them are optional and some are mandatory

Table 1: Logical nodes of wind turbine

LN classes	Description	M/O
WROT	Wind turbine rotor information	M
WTRM	Wind turbine transmission information	O
WGEN	Wind turbine generator information	M
WCNV	Wind turbine converter information	O
WTRF	Wind turbine transformer information	O
WNAC	Wind turbine nacelle information	M
WYAW	Wind turbine yawing information	M
WTOW	Wind turbine tower information	O
WMET	Wind power plant meteorological information	O

M = Mandatory, O = Optional

Although some of the logical nodes are optional, but it is actually highly recommended for all the logical nodes to be available as shown in the fig1. The logical nodes are modelled by virtual model related to a real device.

- **Arduino Mega 2560**

The Arduino Mega is a microcontroller board in view of the Atmega1280. It has 54 computerized input/yield pins (of which 14 can be utilized as PWM yields), 16 simple data sources, 4 UARTs (equipment serial ports), a 16 MHz precious stone oscillator, a USB association, a power jack, an ICSP header, and a reset catch. It contains everything expected to help the microcontroller; essentially interface it to a PC with a USB link or power it with an AC-to-DC connector or battery to begin. The Mega is perfect with most shields intended for the Arduino Duemilanove or Diecimila.

- **ESP8266**

ESP8266EX incorporates a Tensilica L106 32-bit microcontroller unit (MCU), which includes additional low power utilization and 16-bit RSIC, achieving a most extreme clock speed of 160 MHz. With the Real Time Operation System (RTOS) empowered and a practical Wi-Fi stack, around 80% of the handling power is as yet accessible for client application programming and improvement.

III. FEATURES

- Two autonomously controlled CPU centres with customizable clock recurrence, extending from 80 MHz to 240 MHz
- Classic Bluetooth for heritage associations, additionally supporting L2CAP, SDP, GAP, SMP, AVDTP, AVCTP, A2DP (SNK) and AVRCP (CT)
- Integrates 4 MB streak
- Support for Bluetooth Low Energy (BLE) profiles including L2CAP, GAP, GATT,, SMP, and GATT-based profiles like BluFi, SPP-like, etc
- Bluetooth Low Energy (BLE) connects to smart phones, broadcasting low-energy beacons for easy detection
- Sleep current is less than 5 μA, making it suitable for battery-powered and wearable-electronics applications
- Integrates 4 MB flash
- Peripherals include capacitive touch sensors, Hall sensor, low-noise sense amplifiers, SD card interface, Ethernet, high-speed SPI, UART, I2S and I2C
- Fully certified with integrated antenna and software stacks

IV. RELATED WORK

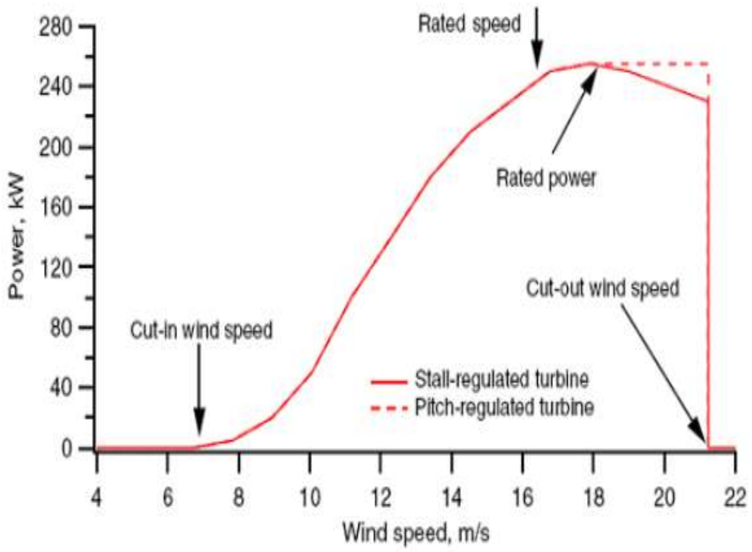

Fig. 2: Fuzzy Control:

In the stall control process, the rotor blade is fixed on the hub. The kinetic power from the wind is controlled or very limited depending on the profile of the blade and the rotational speed of the wind turbine is constant. So the output power of the WTGS is fluctuated seriously, especially when the wind speed exceeds the rated speed. This is harmful to both the mechanical part of the WTGS and the power system in which the WTGS is connected. While in pitch control, the blade can rotate around the axis of the blade, so the pitch angle of the blade can be changed according to the wind speed and the rotation speed of the wind turbine can also be changed. This variation can make the wind turbine absorb more wind energy when the wind speed is below the rated speed and store or deliver some surplus wind energy when the wind speed is above the rated speed. So this will make it possible to get maximum power from wind when the wind speed is between the cut in sped and the rated speed and keep the rated output power constant when the wind speed is above the rated speed but within the cut out speed.

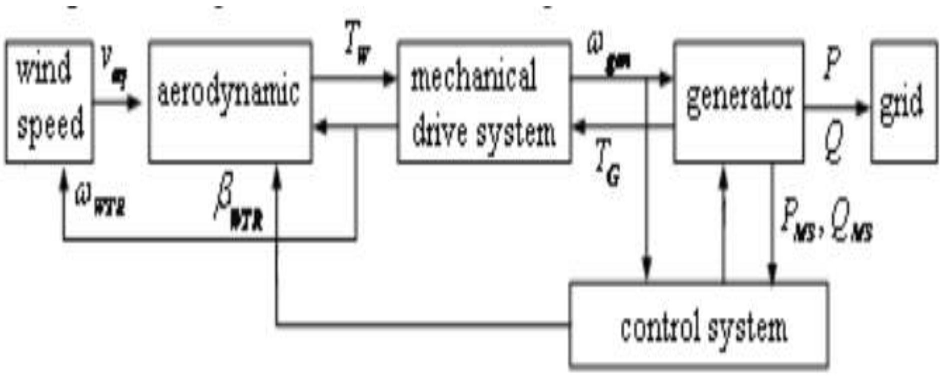

Fig. 3: wind turbine

$$T_e = \frac{p_1 m U_1^2 r_2}{(\omega_g - \omega_1)[(r_1 - \frac{C_1 r_2 \omega_1}{\omega_g - \omega_1})^2 + (x_1 + C_1 x_2)^2}$$

Where
p is the pole couple number of generator,
m is the phase number of the generator stator,
U is voltage of generator,
C is the adjusting coefficient,
ω is rotation angle speed of generator,
ω is the synchronous rotation speed of generator,
xr are the resister and inductor of stator respectively,
xr are the resister and inductor of rotor respectively.

In start stage, the WTGS does not need control. Under rated wind velocity, variable speed wind turbine generator system runs and turn the wind energy into electric energy. The rotation speed of the rotor blades should follow the variant of the wind speed and track the optimum power coefficient curve to get the maximum energy and so this stage needs variable speed control. In third stage, variable speed wind turbine generator system runs under rated power and higher wind speed, the rotation speed of the rotor and the output power needs to be maintained within a limited value because of the mechanical and electrical limitation.

When running of the variable speed wind turbine generator system under rated wind speed is not limited by power, the main control work is tracing the optimum power coefficient curve to get the maximum energy by controlling the rotation speed of the rotor blades and generally by controlling the rotation moment of the generator. But when the wind machine runs over the rated wind speed, the main control work is to limit the output power within an allowable range by adjusting the power coefficient of the wind machine.

V. CONCLUSION

In this paper, a condition monitoring and control system has been implemented for small scale wind turbine using data collection unit, control unit and coordinator. Various sensor nodes are installed at different parts of turbine and finally GUI based on JAVA is developed to show the received sensing data efficiently.

VI. REFERENCES

[1] Z. Hameed, Y.S. Hong, Y.M. Cho, S.H. Ahn, and C. K. Song, “Condition monitoring and fault detection of wind turbines and related algorithms: A review,” Renewable and Sustainable Energy reviews, vol.13, pp. 1-39, 2009.
[2] P. Tchakoua, R. Wamkeue, M. Ouhrouche, F. Slaoui-Hasnaoui, T.A. Tameghe, and G. Ekemb, “Wind turbine condition monitoring: state-of-the-art review, new trends, and future challenges,” Energies, vol. 7, pp. 2595-2630, 2014.

[3] R.A. Swartz, J.P. Lynch, B. Sweetman, R. Rolfes, and S. Zerbst, "Structure monitoring of wind turbines using wireless sensor networks," Workshop on Sensor Networks for Civil Infrastructure Systems, Cambridge, England, pp. 1-8, 2008.
[4] P. Joon-Young, K. Beom-Joo, and L. Jae-Kyung, "Development of condition monitoring system with control functions for wind turbines," World Academy of Science, Engineering and Technology, vol. 5, pp. 286-291, 2011.

[5] S. Grzegorz, A. Cruden, C. Booth, and W. Leithead, "A data acquisition platform for the development of a wind turbine condition monitoring system," in IEEE International Conference on Condition Monitoring and Diagnosis (CMD 2008), pp. 1358-1361. 2008.
[6] H.-H. Kim, S.-B. Ahn, S.-J.Choi, and J.-K. Pan, "ZigBee wireless sensor nodes and network for wind turbine condition monitoring," Journal of the Korea Academia-Industrial cooperation Society, vol. 13, pp. 4186-4192, 2012.
[7] M.A. Ahmed and Y.-C. Kim, "Communication networks of domestic small-scale renewable energy systems," International Conference on Intelligent Systems Modelling & Simulation (ISMS), pp. 513-518, 2013.