MONITORING SMALL OFF-GRID WIND TURBINE INSTRUMENTATION SYSTEM USING MICROCONTROLLER AND LABVIEW

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***ABSTRACT*—*Wind monitoring is essential for knowing the wind potential when setting up a wind farm. When the wind farm is in operation, all the parameters that affect a wind turbine are to be measured to know if the system is efficient. Inaccuracy in wind measurements lead to substantial economic loss. In this paper, a wind turbine instrumentation system is developed in software to measure parameters like, wind speed, wind direction, temperature, pressure and humidity. LabVIEW is used as the Graphical User Interface (GUI) for processing and monitoring all the parameters. The monitoring system developed measures current and voltage to compare the output power generated and the power factor with the actual data.*

Index Terms—LabVIEW, GUI

I INTRODUCTION

Assessing of potential wind farm sites and monitoring and maintaining existing wind farms is essential using a global standard and is the most accurate technology. Monitoring of wind is required for wind resource assessment, prior to setting up a wind farm [2]. The wind assessment is done for about a year and the data gathered at regular intervals is analyzed. For the site selection, wind shear, turbulence and acceleration are the factors that are to be considered. Since the energy from the wind is not constant, the minimum available energy at the site is to be calculated. Also, the measurement is done after setting up of the wind park to check the quality of the system. Under the Center for Wind Energy Technology, there are at present 327 wind monitoring systems. Using the long-term meteorological data and the new data, an accurate wind resource assessment is obtained. The comparison of the both helps in the determination of the wind power density of the site and also to decide whether the site is suitable for installation of a wind farm.

The wind resource assessment report statistics must include the following :Mean and annualized mean wind speed, wind shear, wind power, mean air temperature, turbulence intensity, wind rose, daily and hourly distribution, speed frequency distribution, etc. The wind power is directly proportional to the cube of wind speed on the site, to the square of thediameter of the rotor and to the air density. Using the wind site data, the rotor blades are designed to know if developing a wind farm at that site is profitable or not. A continuousmonitoring after the wind farm is in operation helps us to analyze if maximum output is generated by the generator and to know if the system is healthy or not. A monitoring system such as this, allows the operator to know if any maintenance is required. Often, pitch regulation is the most important factor for monitoring a wind turbine. This is necessary when wind speed is beyond the rated wind speed. The Wind Turbine Generator chosen for the site must be chosen according to the annual energy production and levelised cost of production.

The choice of appropriate measurement equipment and its correct installation are crucial. The equipment used for measurement must perform precisely to ensure the quality of data essential for producing accurate wind site assessments. A small discrepancy of even 5% in the evaluation of wind speed data drastically multiplies during assessment, calculations and results in a loss of seven digit economic figures. To evaluate whether a wind farm will be profitable, investors and banks require wind site assessments based on the most accurate measurement of data. Compared to the costs for the construction of a new wind farm, the costs for a high standard measuring system are minimal. The regulations IEC 61400-1201:2005 and TR6 are the most significant, describing the optimal installation of masts, traverse and sensors.

II WIND TURBINE SIZE AND WIND FARM SITE SELECTION

Turbines with a diameter of less than 15m and a power output below 50kW are classified as small. However, most small wind turbines have a diameter of around 7m or less and a power output ranging between 1kW and

10kW. For very small installations, such as a remote household, wind turbines can have a diameter smaller than 2m and output of kW or less [3]. A typical small wind turbine is shown in figure1.

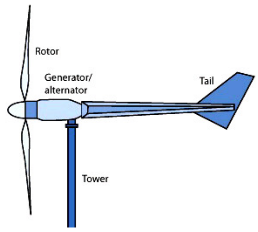

Fig.1 Basic parts of small Wind Turbine

Site selection for a wind turbine is of utmost importance in ensuring its reliability and appropriate performance. Wind turbines should be sited away from any major obstructions (such as trees, houses), with a clear exposure to the prevailing wind. Ideally, a wind turbine should be set up on a smooth hill top, where the air flow in general is reasonably smooth and free from excessive turbulence, which may cause damage and shorten the working life of a turbine. Alternatively, a wind turbine should be set on a tower as high as possible, since wind speed increases with height. Figure 2 shows the effect of height for selection of a proper site.

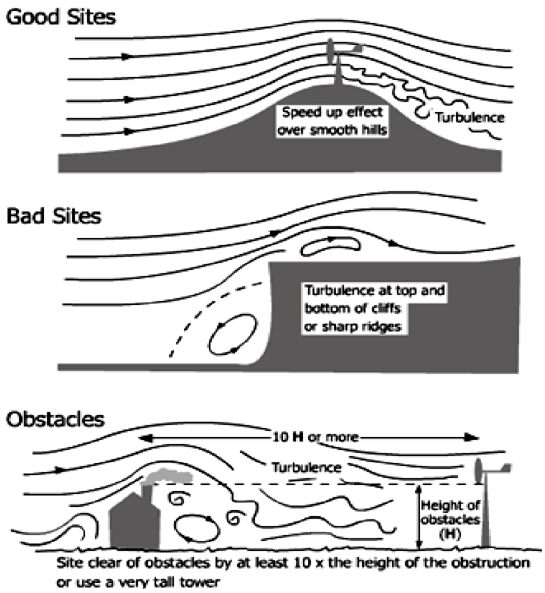

Fig.2 Wind Site Selection

III OVERALL INSTRUMENTATION SYSTEM

The instrumentation system consists of data acquisition (DAQ) hardware using PIC Microcontroller, the sensors and the LabVIEW software for the real-time monitoring of, wind speed, wind direction, temperature, pressure, humidity, AC and DC power waveforms [4][7]. The functional block diagram of the whole instrumentation system is shown in figure 3. The developed system has not only been used for data acquisition and instrument control applications, but also for database development and data analysis. The results are displayed and stored in real time. Signal conditioning hardware is required for these systems to condition and isolate the voltage and information signals before connecting to the DAQ board of the overall system.

The proposed instrumentation phase of the wind turbine monitoring unit includes LM35 temperature Sensor, wind speed measurement setup, HMC5883L direction sensor, HR 201 humidity sensor and SPD100G capacitive pressure transducer, signal conditioning circuits, LCD display, PIC16F77A IC and LabVIEW as shown in figure 3.

The data acquisition hardware proposed in the system is PIC16F77A Microcontroller, which is interfaced to the computer through a USB to Serial converter.The PIC16F877A features 256 bytes of EEPROM data memory, self programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions [5]. The synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I²C™) bus and a Universal Asynchronous Receiver Transmitter (USART).

USB to serial adapters are cables that convert the data sent by a serial-enabled device for use by a USB port [11][12]. The serial end has a DB9 connector, which plugs into the serial device. The USB connector plugs into the computer's USB port or a connected USB hub. The data that are transmitted by the serial device are sent directly to the USB port, where it is passed to software to interpret it.

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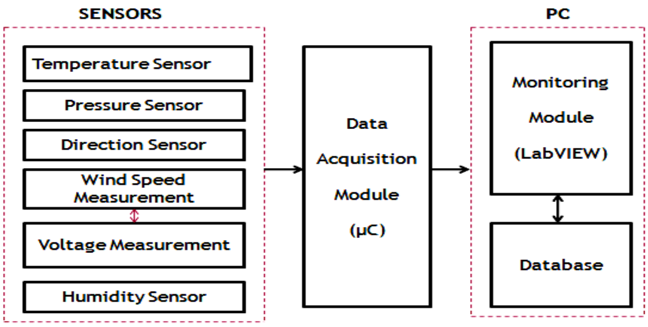

Fig.3 Overall Instrumentation System

LabVIEW is a graphical programming language created by National Instruments (NI)[1]. The LabVIEW programs are called virtual instruments. The front panel is the user interface. The block diagram includes the graphical code. Programming using LabVIEW is easy compared to other coding systems, thus consumes less time in programming [9]. Communication using LabVIEW to remote panel is possible by GSM, GPS or Ethernet, etc.

Pressure Measurement:

Barometric pressure is used with air temperature to determine air density. It is difficult to measure accurately in windy environments because of the dynamic pressures induced when wind flows across an instrument enclosure. An indoor or office environment is a preferred setting for a pressure sensor.

The Pressure sensor used in this case is the SPD100G capacitive transducer as shown in figure 4.The Smart Pressure Device SPD series of pressure sensors are silicon based and encapsulated in modified plastic Dual In Line packages, to accommodate six pins for through-board printed circuit mounting. The output voltages of both types are proportional to the pressure that is measured.

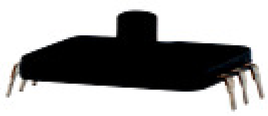

Fig.4SPD100G Pressure Transducer

Temperature Measurement:

As temperature is an important descriptor of a wind farm’s operating environment and is usually measured either near ground level (2 to 3m) or near hub height. In most locations, the average near ground level air temperature will be within 1°C of the average at hub height. It is also used to calculate air density, a variable required to estimate the wind power density and a wind turbine power output.

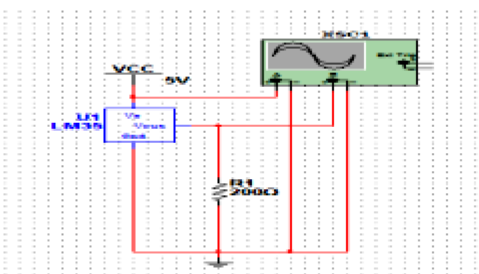

Fig.5 Circuit diagram of LM35 with load resistor

LM35 is the temperature sensor that is used for temperature measurement. It is a precision integrated-circuit temperature sensor, whose output voltage linearly varies with the Celsius temperature so there is no need for complex calibration of the sensor [10].

Every transducer or a sensor has its own relationship between its actual output and the voltage found in its output terminal. The temperature sensor LM35 maintains a proportional relationship with the voltage output. The relationship is shown in equation 1.

$$V_0(mV) = 10 \ldots. (1)$$

The load resistance is added for protection. When the LM35 device is applied with a 200-Ω load resistor, the device is relatively immune to wiring capacitance because the capacitance forms a bypass from ground to input and not on the output [8]. The circuit diagram is shown in figure 5.

Humidity Measurement:

Humidity sensor works on the principle of relative humidity and gives the output in the form of voltage. This analog voltage provides the information about the percentage relative humidity present in the environment. A miniature sensor consisting of a RH sensitive material deposited on a ceramic substrate. The AC resistance (impedance) of the sensor decreases as relative humidity increases.

HR201 is a new kind of humidity-sensitive resistor made from organic macromolecule materials. It has excellent linearity, low power consumption, wide measurement range, quick response, anti-pollution, high stability and high performance-price ratio. Figure 6 shows the HR 201 Humidity sensor.

HR201 sensor measures humidity by variation of output through resistance variation. As resistance varies, the voltage varies. This can be used to calibrate the sensor to measure the humidity.

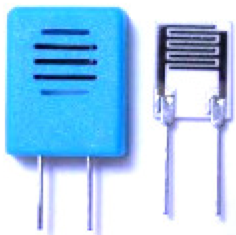

Fig.6HR201 Humidity Sensor

Wind Speed Measurement

Wind speed is the most important indicator of a site’s wind resource. In this paper, a small wind mill has been set up along with a motor. When the blades move, the rotational movement causes a small voltage in the motor [6]. This voltage is measured and calibrated to find the wind speed. The measurement set up requires a small torque for the blades to rotate and to produce voltage. Wind direction must be known for the system to work.

When the blades rotate, voltage is developed in the DC motor and can be measured using a voltmeter or a multimeter. Figure 7 shows a prototype of a small wind mill set up. The wind speed can be calibrated using the voltage developed by the system.

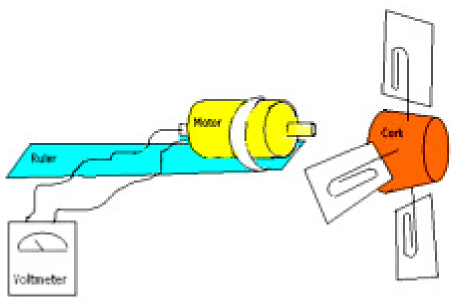

Fig.7 Small wind mill setup

Wind Direction Measurement

Wind direction measurements are a necessary ingredient for modeling the spatial distribution of the wind resource across a project area and for optimizing the layout of the wind turbines

A digital compass IC can also serve the purpose of a wind mill setup. The IC operates Anisotropic Magnetoresistive **t**echnology and allows us to measure both the direction and the magnitude of the earth's magnetic field. The current in the sensor is affected by the magnetic field and thus, the direction is sensed. Figure 8 shows the HMC5993L Digital Compass IC.

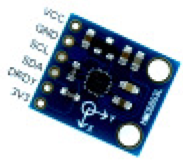

Fig 8 HMC5993L Digital Compass IC

IV SIMULATION AND RESULTS

There are 14 characters that are sent serially. The beginning is marked with '*' symbol. Only when the symbol is encountered, the data acquisition begins. The VISA begins with Open, Read and Close options required for data acquisition process.

Measurements in LabVIEW:

The blockdiagram for pressure measurement is shown in figure 9

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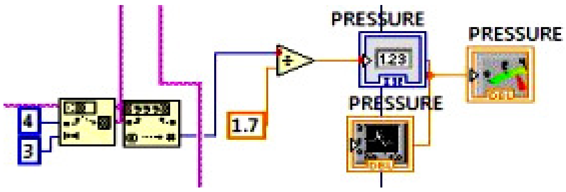

Fig.9Block diagram of Pressure Measurement

The pressure measurement is done by analyzing the characters 3 and 4. These characters receive the numerical value of pressure and the data is transmitted serially.

The subset is first taken from the string and then the string to number conversion is done. This number consists of the voltage output. For measuring the pressure, the voltage is divided by a constant.

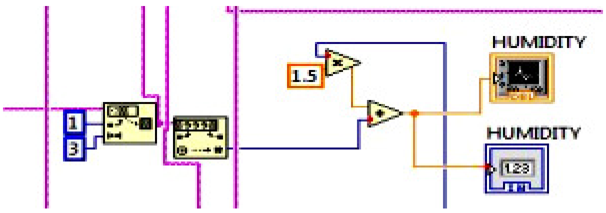

Fig.10Block Diagram of Humidity Measurement

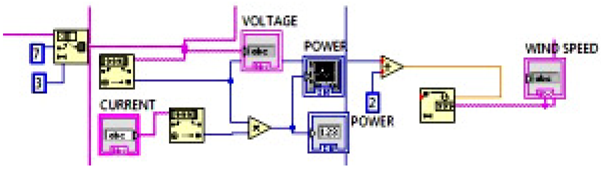

Fig.11Block Diagram of Power and Wind Speed Measurement

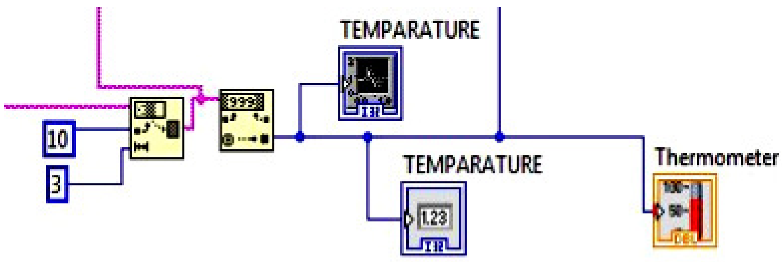

Fig.12Block Diagram of Temperature Measurement

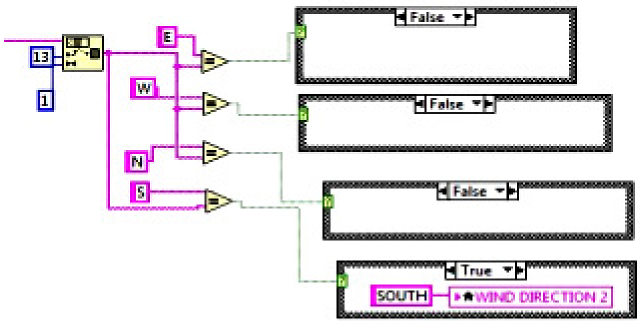

Fig.13Block Diagram of wind direction Measurement

In each case, the relevant characters are selected and used for analysis. Figures 10 to 13 shows the block diagram of each sensors in LAbVIEW. The data is logged to the system in the Microsoft Excel for future reference. The Front Panel of the overall system is shown in figure14.

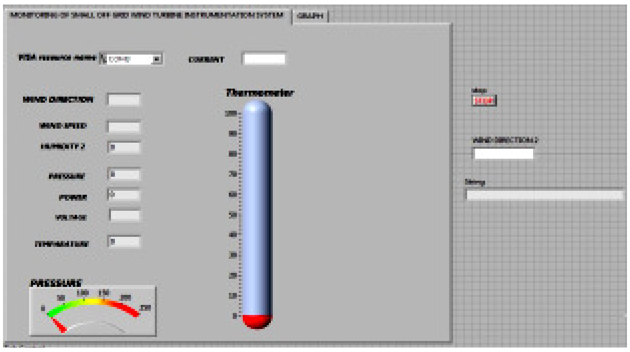

Fig 14 Front Panel of the Overall System

Hardware setup of the overall system:
The hardware part of the system consists of
1. Power supply region
2. Signal Condtioning Circuits
3. Sensor Cirucits
4. PIC Microcontroller
5. LCD Display Unit

The input voltage is limited to 5V and thus a step down tranformer is used in the power supply unit to provide the necessary input voltage to the PIC Microcontroller. The AC supply is then rectified using a bridge rectifier and a regulator provides protection for the overall circuit by limiting the voltage.

The HR201 Humidity Sensor is connected to the 1kΩ resistor to provide an output voltage which varies with humidity. The Pressure sensor detects the pressure and consists of a signal conditioning circuit to provide variable voltage according to pressure variation. Direction Sensor IC detemines the direction using the earth's electro magnetic field. LM35 sensor senses the temperature and provides an output voltage propoertionally. The windmill setup has a DC motor to produce voltage. Using this, wind speed is measured. All these sensors are connected to the PIC Microcontroller. The output is displayed in the LCD display board. The overall hardware setup is shown in Annexue I.

V CONCLUSION

Thus in this paper, the analysis of instrumentation system with parameters like Temperature, Pressure, Voltage, Humidity, Wind direction and Wind speed has been done using LabVIEW and PIC Microcontroller is used for its data acquisition. The chioce of components and its signal conditioning circuitry for developing the wind turbine instrumentation system has been discussed in detail. The system developed is economical and monitoring is done visually. The data is logged for future analysis

The analysis of instrumentation system can be further extended by using precise sensors and develop a small scale wind mill for testing. The effect of humidity can be studied in detail. The overall instrumentation system can be combined and a hardware system can be developed for monitoring and data logging. The setup can further be made as a single product.

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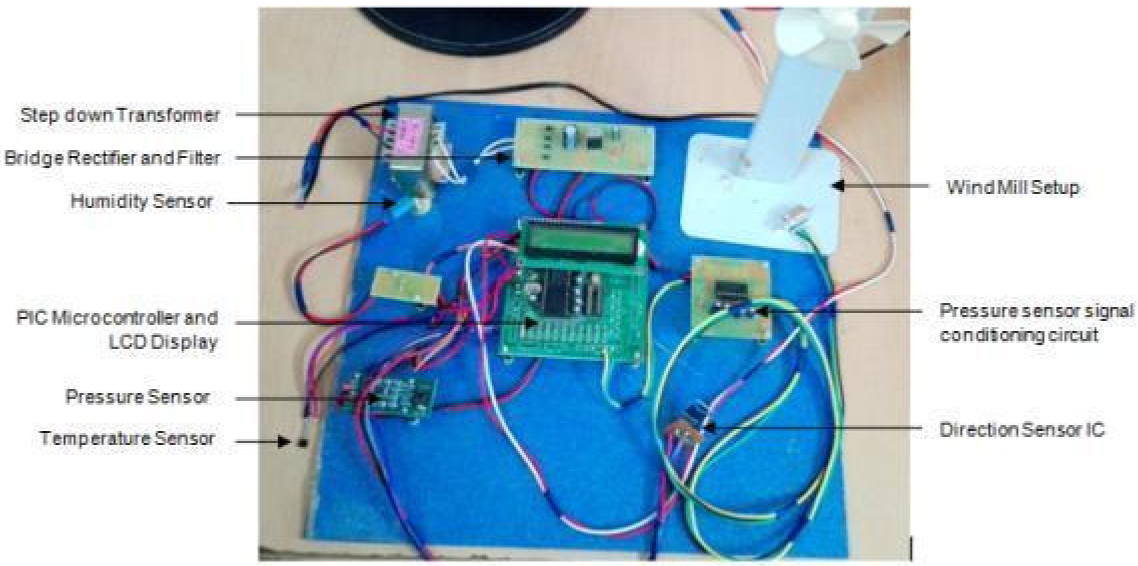
ANNEXURE I



Hardware setup of the overall system