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Vibration and Over Speed Control of Wind Mill based on Power Line Communication

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***Abstract*— This paper focuses on power line communication based control of wind turbine using embedded system. The concept of power line communication is so far implemented in the field of home automation, farm management. Renewable energy systems play an important role in generation of electrical energy. Researchers are focusing now a day's mainly on the renewable energy security systems. One such security system has been implemented in this project for the control of wind turbines from over speed and vibration. By measuring the speed and the vibration for the closed loop control the security of wind mill is assured. Using of power line adds advantage of controlling of wind turbines from some remote station which eliminates the manual monitoring of the adverse condition that could affect the windmill operation. In addition to that operating periods of the wind mill can be extended by this proposed scheme which eliminates the continuous monitoring of the wind speeds. Also since power line communication uses the same transmission line for message transmission, additional equipment installation for this purpose is totally eliminated. Thus the proposed idea eases the method of wind turbine maintenance and enhances the security over adverse climatic conditions.**

Index Terms— Communication System, Grid, Renewable energy, Power line, Wind mill and control system.

I. INTRODUCTION

The main objective of wind turbines is to produce electrical energy as low as possible. Wind power accounts nearly 10% of India's total installed power generation capacity and generated 34,615.1 million kWh in India. Wind turbines are designed to yield maximum output at wind speeds around 15 metres per second. By eliminating over vibrations and over speed in the wind mill, wind turbine is protected from damage. Various methods are available to protect the wind turbine. Here power line communication was used to protect the wind turbine. A wind turbine is a device which converts the wind's kinetic energy into electrical power. Wind turbines are categorized into wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging, auxiliary power for boats and power traffic warning signs. Medium turbines are used for making a domestic power supply while selling unused power back to the utility supplier through the electrical grid. Most of the countries use large turbines to reduce their reliance on fossil fuels. Wind turbine blades rotate either in a horizontal axis or in a vertical axis. The horizontal axis wind turbine is most commonly used with wide number of blade types. Vertical wind turbine produces lesser ratings of power and is less common in usage. Horizontal-axis wind turbines (HAWT) consist of main rotor, shaft, and electrical generator at the top of a tower, and must be pointed into the wind direction. Small turbines are pointed towards wind flow direction by using simple wind vane, while large turbines preferably use a wind sensor coupled with a servo motor. Gearbox turns the slower rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator. For communication, power line digital subscriber line (PDSL) or power line networking (PLN) make use of the existing electricity network. Thereby the cost of installation is much lesser than any other communication system. The electrical power supply is used for communication purpose and high, medium and low voltage supply is used for internal communication of electrical utilities, remote measuring and control task. Power line communication modem act as both transmitter and receiver and is used for turbine vibration and over speed control of the wind turbine.

II PROBLEM DESCRIPTION

At present in case of emergency such as over vibration in the wind turbine or during the time of any natural calamities such as earthquake, there is a chance for the wind turbine to get damaged. So, it is important to control the operation of the wind mill. But the control of wind mill can be done only in the generating station manually. So it consumes more time and requires lot of human power to control the wind mill. The main objective is the wind turbine automatic control from sub-station in the case of over vibration and over speed in the wind turbine. In meeting out the objective, two PLC modem are used as communication path between the generating station and the sub-station. One PLC modem will act as a transmitter and another PLC modem will act as a receiver and vice-versa. The control of wind mill has to happen from the sub-station and the time consumption for man power can be reduced. The communication technology ,Power line communication enables sending data over existing power cables .By running the power cables to an electronic device one can both power it up and at the same time control/ data retrieve can be made possible from it in a half-duplex manner.

Using Power line communication method, electrical wiring is done to simultaneously carry both data and alternating current (AC) electric power transmission or electric power

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distribution. Thus power line communication is also called as power-line carrier, power-line digital subscriber line (PDSL), mains communication, power line telecommunications, or power line networking (PLN). A large variety of power-line communication technologies are required for different applications which includes such as home automation and internet access which is often categories as broad over power lines (BPL).Most of the power line communication technologies apply themselves to one type of wire such as premises wiring within a single building. But some can cross between two levels for example, both the distribution network and premises wiring. Typically transformers prevent propagating the signal which needs multiple technologies to form very large networks. Wide range of data rates and frequencies are used at different situations. Spread spectrum radio signals operating in crowded environment create difficult technical problems which are more common between wireless and power-line communication. The barrier in most of the amateur radio group is radio interferences.

III. METHODOLOGY

The proposed system uses power line communication technology in controlling vibration and over speed of wind turbine. Both the power and the data can be sent through the same cable. In this system parameters such as speed and vibrations are measures using proximity sensor and vibration sensor and the corresponding analog values are sent to the PIC microcontroller and then it is processed. Proximity sensor and the vibration sensor is used to sense the speed and the vibration in the wind turbine respectively. Power line communication modem will act as a transmitter and receiver in both the substation and the generating station. Based on the values of the sensors, the wind turbine is controlled and the speed of the turbine is shown in the LCD display. The advantages are reduction in overall cost of the wind, one cable is enough to send both the data and the power, wind turbine can be operated from the substation itself, man power usage can be reduced and requires less maintenance.

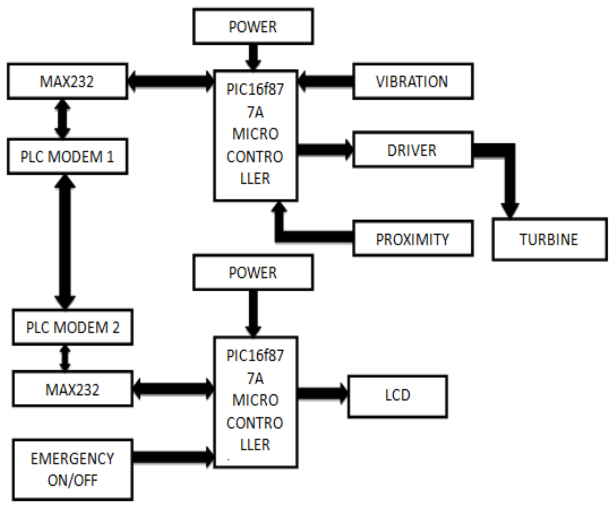

Figure 1 Block Diagram

The paper aims at automatic control of wind turbine in case of natural disorders. The control of wind turbine is mainly performed with the help of two signals produced in the two controllers. The two controllers, one in the generating station and another one in the sub-station is used. The overall operation of the proposed system can be clearly known from the block diagram shown in Figure.1.The power supply unit supplies required power (+5V) to the micro-controller. There are two micro controllers are used in this project one act as master (Sub-station) and another act as slave (Generating-station). This micro controller acts as a heart of this paper.PIC16f877A is a sixteen pin micro controller. Here two micro controllers are used one in the generating station and another one in the substation. The output of the vibration sensor and the proximity sensor are connected to the micro controller in the generating side. Emergency switch is also connected to the micro controller in the substation. Two PLC modem will be connected to the two micro controllers respectively to transmit the power and the data. During transmission from slave to master PLC modem1 will act as transmitter and PLC modem2 will act as a receiver. While transmission from master to slave PLC modem2 will act as transmitter and PLC modem1 will act as receiver. The vibration sensor is used to sense vibration occurs in the wind turbine. If there is over vibration in the wind turbine then the vibration sensor senses it and gives the corresponding analog value to the slave and then the slave transmits the signal to the master through the two PLC modem. The proximity sensor is used to sense the speed occurs of the wind turbine. If the speed exist the constant value of 55 miles per hour then the proximity sensor senses it and gives the corresponding analog value to the slave and then the slave transmits the signal to the master through the two PLC modem. When the analog values from the corresponding sensors are sent to the slave, the slave then transmits the data to the master then. Here both the power and the data are transmitted through the same power line by using Power line communication modem. Two max232 circuits are used which act as communication data path between PLC modem and the micro controller. The main purpose of max232 is for transmission and receiving the data from the two PLC controllers. The driver circuit is used to control operation of the turbine. The output of the micro controller (slave) gets the data from the master. The output of the slave is connected to the driver circuit. When a vibration exists in the wind turbine due to any external disturbances the master transmits corresponding data to the driver circuit. The output of the driver circuit is connected to the wind turbine. Now the circuit breaker is switched on and the brakes are applied to the blades thus the wind turbine is stopped. The LCD is used as an output display unit. The output unit displays the speed of the turbine in rpm, status of the wind turbine (on/off). Emergency on/off switch is provided in the master circuit. In the case of any emergency or any fault period the turbine can be manually controlled with the help of emergency switch to protect the wind turbine from damage. Hence with the help of these two sensors the data's are sent to the controllers. Thus micro controller controls the wind turbine with the help of the driver circuit. The speed of the wind turbine can be viewed in the LCD display.

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IV. SYSTEM DESIGN

The hardware components used are Power supply unit, PIC Microcontroller 16F877A, LCD display, Vibration sensor, Proximity sensor, Driver circuit, Power line communication modem, Push button, Generator, MAX232, Rotor, Rotor blades and Gearbox. The AC voltage, typically 220Vrms, is connected to a step down transformer, which steps that AC voltage down to the level of the desired 12V DC output voltage. A diode rectifier then provides a full wave rectified voltage 5V that is initially filtered by a simple capacitor filter to produce a DC voltage. This resulting ripples in DC voltage or AC voltage variation. A regulator circuit is used to remove the ripples and also remains the same DC value even if the input DC voltage varies. The voltage regulation is usually obtained by using the popular regulator IC units as illustrated in Figure 2.

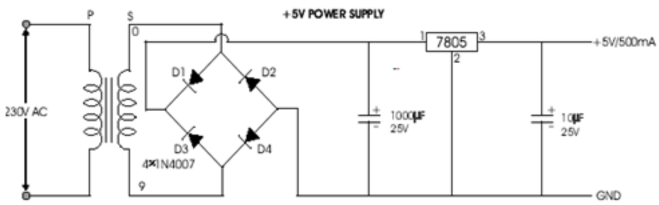

Figure 2 Circuit Diagram of Power Supply

The main purpose potential transformer will step down the power supply voltage (0-230V) to (0-6V) level. Then the secondary of the potential transformer will be connected to the precision rectifier, which is constructed with the help of op–amp. The advantages of using precision rectifier are it will give peak voltage output as DC; rest of the circuits will give only RMS output.

The operation of bridge rectifier is as shown in Figure 3.When four diodes are connected, the circuit is called as bridge rectifier. The input to the circuit is applied to the diagonally opposite corners of the network, and the output is taken from the remaining two corners. Let us assume that the transformer is working properly and there is a positive potential, at point A and a negative potential at point B. the positive potential at point A will forward bias D3 and reverse bias D4. The negative potential at point B will forward bias D1 and reverse D2. At this time D3 and D1 are forward biased and will allow current flow to pass through them. D4 and D2 are reverse biased and will block current flow. The path for current flow is from point B through D1, up through RL, through D3, through the secondary of the transformer back to point B. After one-half cycle the polarity across the secondary of the transformer gets reversed, forward biasing D2 and D4 and reverse biasing D1 and D3. Current flow will now be from point A through D4, up through RL, through D2, through the secondary of T1, and back to point A.

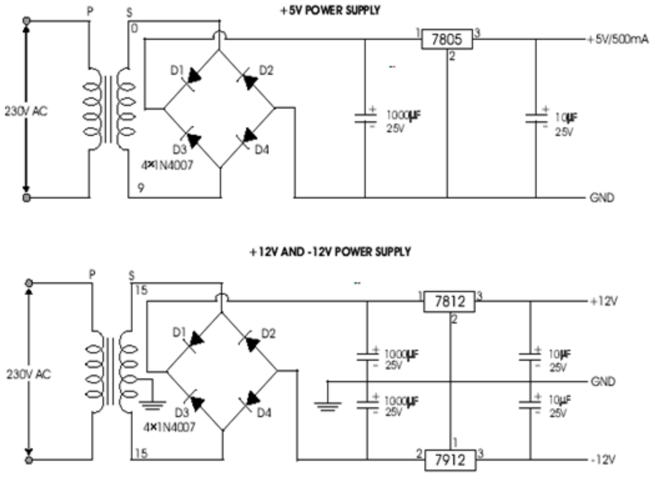

Figure 3 Bridge Rectifier

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, the synchronous serial port. Transmitter (USART). All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

Liquid crystal display(LCD) comes in many sizes 8x1 , 8x2, 10x2 , 16x1 , 16x2 , 16x4 , 20x2 , 20x4 ,24x2 , 30x2 , 32x2 , 40x2 etc . Many multinational companies like Philips, Hitachi, and Panasonic make their own special kind of LCD'S to be used in their own products. All these LCD'S performs the same functions such as displaying characters, numbers, special characters, ASCII characters etc. The programming is same among manufacturers and they all have either 14 pins (0-13) or 16 pins (0 to 15). Alphanumeric displays are used in a wide range of applications such as palmtop computers, word processors, photocopiers, point of sale terminals, medical instruments, cellular phones, etc. The LCD display requires data in a serial format. The display also requires a 5V power supply. The 5V is best generated from a 5V fixed regulated power supply.

Accelerometers operate on the piezoelectric principal a crystal generates a low voltage or charge when stressed as for example during compression. Motion in the axial direction stresses the crystal due to the inertial force of the mass and produces a signal proportional to acceleration of that mass. This small acceleration signal can be amplified for acceleration measurements or converted (electronically integrated) within the sensor into a velocity or displacement signal. This is commonly referred as the ICP (Integrated Circuit Piezoelectric) type sensor. The piezoelectric velocity sensor is more rugged than a coil and magnet sensor, has a wider frequency range, and can perform accurate phase measurements. Most industrial piezoelectric sensors used in vibration monitoring today contain internal amplifiers. The sensitivity of industrial accelerometers typically ranges between 10 and 100 mV/g; higher and lower sensitivities are also available. To choose the correct sensitivity for an application, it is necessary to understand the range of vibration amplitude levels to which the sensor will be exposed during measurements.

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An Inductive Proximity Sensor consists of an oscillator, a ferrite core with coil, a detector circuit; an output signal is used to drive the coil. The coil in conjunction with ferrite core induces a electromagnetic field. When the field lines are interrupted by a metal object, the oscillator voltage is reduced, proportional to the size and distance of the object from the coil. The reduction in the oscillator voltage is caused by eddy currents induced in the metal circuit, housing, and a cable or connector. The oscillator generates a sine wave of a fixed frequency. This interrupts the field lines. This reduction in voltage of the oscillator is detected by the detecting circuit.

Relays are electromechanical devices that use an electromagnet to operate a pair of movable contacts from an open position to a closed position. Here relay is used as a circuit breaker. In order to turn on and off the wind turbine the relay circuits is used to trip the wind turbine. By tripping the circuit breaker the power supply to the will turbine is stopped hence it will stop the entire process. Normally this tripping is done during an abnormal condition.

PLCC modem is a power line carrier communication (PLCC). The PLCC modem is in the form of a ready-to-go-circuit module, which is capable of transferring data over the power cable at the low voltage end of the power transformer of a 3-phase/ 4-wire distribution network. A pair of embedded PLCC modems connected on the power line can provide low speed bi-directional data communication at a baud rate of 9600 bps. The embedded PLCC modem is based on the differential code shift keying (DCSK) technology in power line carrier communication (PLCC) is well known for its high immunity to electrical noise persistent in the power line.

The output of the PLC modem is connected to the max232 transmitter receiver and then this max232 transmits the signal to respective master and slave. The drivers provide TIA-232 voltage level outputs which is about ±7.5 volts from a single 5-volt supply by on-chip charge pumps.

The components of wind turbine are generator,rotor ,blades,gearbox and shaft.. The purpose of generator in a wind turbine is to convert mechanical energy into electrical energy. In high power wind turbines, doubly-fed asynchronous generators are most frequently used. The operating rotation speed can be varied with this type of doubly-fed asynchronous generator. In synchronous generators, grid connection is only possible through transformers; due to its fixed rotation characteristics. A simple generator consists of magnets and a conductor. The conductor is typically a coiled wire. Inside the generator, the shaft connects to an assembly of permanent magnets that surrounds the coil of wire. The rotor is the component which helps the rotor blades to converts the energy in the wind into rotary mechanical movement. Usually the three-blade horizontal axis rotor dominates the rotational movement. The rotor blades are mainly made of glass-fiber or carbon-fiber reinforced plastics. They use the principle of lift force on the lower side of the wing the passing air generates higher pressure, while the upper side generates a pull. These forces cause the rotor to move forward and make it rotate.

The gearbox converts the rotor motion of 18-50 rpm into the approx. 1,500 rpm which the generator requires. The gearbox thus takes on the task of matching the rotation speeds of the slow-moving rotor and the fast-moving generator, and generally has several steps to cover for various wind conditions. If a specially developed multi-pole ring generator is used, the gearbox is no longer required (best-known manufacturer of direct drive turbines).

The wind-turbine shaft is connected to the center of the rotor. When the rotor spins, the shaft spins as well. In this way, the rotor transfers its mechanical, rotational energy to the shaft, which enters an electrical generator on the other end. The emergency on/off switch is provided in the substation. In case of any emergency period such as any fault, structural failure or some other problem this emergency switch can be operated manually in order to control the wind turbine thus damage in the wind mill can be avoided. This push button will stop the entire process or it will start the process.

The overview of prototype system is shown in Figure 4.

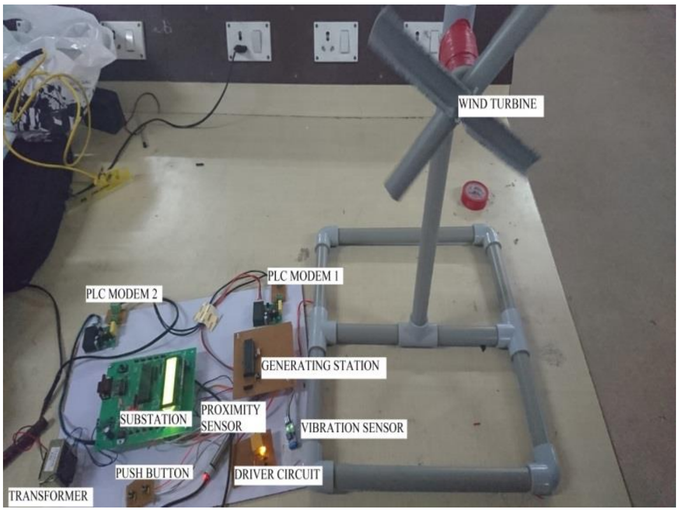

Figure 4.Overview of prototype system

V. RESULT AND CONCLUSION

This paper uses two PIC micro controllers for substation and generating station. Before implementing the hardware, the results are verified using proteus software. The oscillator frequency of two microcontrollers is 10 MHz. The components are selected from the components mode. The power supply and the ground are selected from the terminals mode. The LCD display is connected to the substation PIC microcontroller for displaying the data. The turbine is connected to the generating station microcontroller through the relay. The connections are given as per the circuit diagram. The proteus file is simulated and the results are verified.

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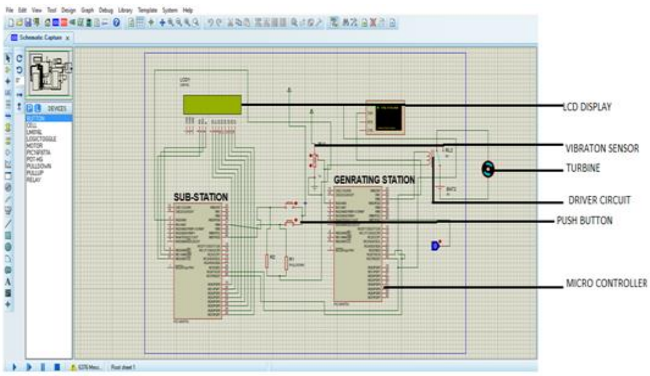

Figure 5 Simulation Block

The figure 5 shows the output of the simulation. Initially the value of the vibration sensor will be high. As soon the vibration occurs in the wind mill, the vibration sensor value will be decreasing. When the value reaches zero then the vibration in the turbine may cause damage to it. So the turbine is stopped automatically from the substation.

NORMAL OPERATION

The data is transmitted when the push button is pressed. At this speed the turbine is operating at normal condition. When the speed exceeds normal operating value (55miles/hour) the proximity sensor senses the speed and the turbine is automatically stopped with the help of driver circuit.

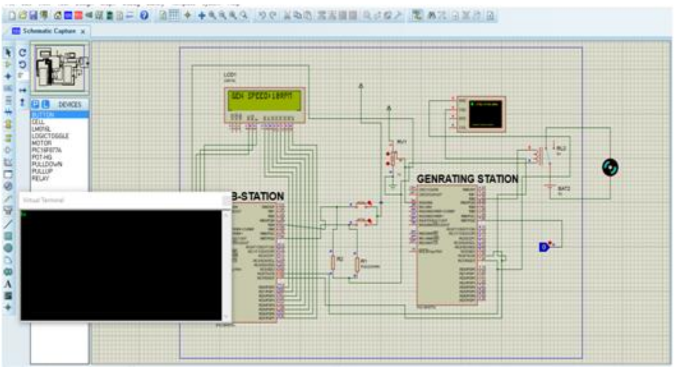

Figure 6 Normal operation

STOP CONDITION

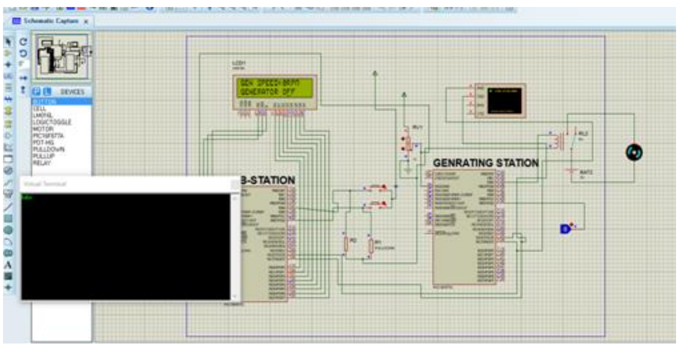

Figure 7 Stop condition

From the figure 6 it is clearly understood the speed of the turbine is 0rpm i.e. the turbine has stopped. Hence the overall generation is stopped. Thus during the time of any natural calamities, the turbine can be controlled from the substation with the help of proximity sensor, vibration sensor, PLC modem and a micro controller. When all the conditions are normal, the turbine can be again start it process. With the help of push button in the substation the turbine can be started. The push button is used to send the data. In the figure 7 it clearly understood that the vibration sensor value has become minimum i.e the vibration in the turbine is very high. Hence the data is send from the substation to stop the turbine. The speed of the turbine is zero it is clearly seen in the LCD display. Thus the turbine is stopped and the generation is also stopped for a certain period of time.

The prototype of the paper “Wind turbine control using power line communication” is fully ready and functional. Real time implementation of this paper has a great scope and it will save large amount of time and man power. This will be more suitable for the countries like India where they largely depend upon wind energy for electricity. Power line communication is used in this project thus the data and power both are transmitted in the same cable. In the modern era everything has become automation so it is necessary to make things as easy as possible. As the time goes on automation place a large role in human life. Taking this in to account power line communication system can be implied in many real time applications. Thus the difference between the actual value and the obtained value can be minimized.

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