

The Destructive Vibrations of a Wind Turbine

University of California, Santa Cruz Green Wharf Project

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Abstract - During severe wind conditions wind turbines have been known to have large amplitude vibrations that ware down the bearings of the turbine. To prevent the turbine from breaking down we plan on identifying the wind conditions that cause the deterioration of the bearing and cease operations during such wind conditions. Utilizing an accelerometer we were able to measure the amplitude of each vibration. After identifying the high amplitude vibrations we were able to determine the corresponding wind conditions.

INTRODUCTION

While wind turbines are operating they will often create vibrations caused by the rotating blades. Generally these vibrations are inconsequential to the health of the turbine, but during high and/or irregular wind conditions the wind turbines have been known to shake violently, causing the bearings of the turbine to deteriorate. When the bearings are sufficiently warren down the turbine becomes less efficient and eventually inert. In addition to the destructive qualities of the vibrations it is speculated that the vibrations reduces the rotational speed of the turbine, thus decreasing the power output.

In order to extend the lifespan of a wind turbine we have created a device that will monitor the vibrations of a wind turbine. Through comparing the vibration data to the wind condition data (including wind direction, wind speed, and frequency) we can determine the destructive wind conditions. Once we have identified the malicious wind conditions we will be able to configure the turbine to cease operations during the flagged wind cycles, thus extending the life span of the turbine.

BACKGROUND

The University of California, Santa Cruz Greenwharf Project utilizes a solar panel and wind turbine to generate clean, renewable

energy. The wind turbine has the unique placement on top of a building at the Santa Cruz Municipal Wharf, which overlooks the Monterey Bay. At this location wind funnels into the bay and travels up as it reaches the Santa Cruz Municipal Wharf, this causes the wind turbine to experience lift. The unique wind conditions of the Municipal Wharf causes the wind turbine to vibrate on the X, Y, and Z-axes. The turbine's rapid movements have caused the bearings to breakdown, consequently reducing the efficiency of the turbine. To prevent further damage to the turbine breaks have been permanently installed. Once the destructive wind conditions have been identified the breaks will be removed and the wind turbine will resume operations.

METHOD

The project focused on developing the device that could monitor measure the amplitude of the turbines vibrations and reported the measurements back to a computer using a mesh network.

1. SOFTWARE

Each device is equipped with an ATmega 88PA chip that is responsible for reading the measurements from the accelerometer. The device uses an i2c protocol to communicate.

The program begins by establishing communication between the microcontroller and the accelerometer. Once communication had been established the microcontroller sends a write command that sets a pointer at the accelerometers' X-axis address. Next the microcontroller sends a read command that retrieves the X-axis data from the accelerometer and stores the data in a buffer. After the X-axis data is stored the microcontroller will write and read the data from the accelerometers' Y-axis and Z-axis addresses.

Once all the data is received, the microcontroller will apply a time stamp to the data and transmit the data to the computer. The

computer receives the data in the following format:

'Device Address' 'Time' "X = ..."
'Device Address' 'Time' "Y = ..."
'Device Address' 'Time' "Z = ..."

The device attaches its address and a time stamp with each transmission of data so that the data can be organized even when a mistake is made. Mistakes that can be encountered are the failure to receive or the failure to transmit data, incorrect order of received data, and mixed data (since there are multiple devices the data being received can intermixed).

The received data is parsed by the computer and organized. Each incoming message is organized based upon the address of the transmitting device, the time at which the data was taken, and the associated axis of the data. The data is then graphically displayed showing the amplitude of the vibrations at a particular time. Using comparative analysis the destructive winds will be easily identified.

II. COMMUNICATION

The system uses a mesh network to communicate. More specifically the system is configured in a star formation. The star formation defines each device to be an end node and the computer to be the coordinator. Each end node only communicates with the coordinator and the coordinator communicates with all end nodes.

The star network was constructed using XBee chips. Each XBee device was configured with a unique address and a common pan ID. Every device had an XBee chip incorporated in its overall design. The XBee chip attached to the computer is coordinator and API mode enabled. API mode allows the coordinator to wirelessly configure chips within the network and receives the address of the transmitting device each time a data is received (which allows the user to organize incoming data when multiple devices are used).

III. POWER

Each device uses two AA batteries to power the entire device. The XBee chip requires 3.3 volts to operate, the atmega chip requires at least

2 volts, and the accelerometer requires the same voltage as the microcontroller. For simplicity the entire system operates at 3.3 volts. Since the AA battery packs only supply 3 volts a voltage buck converter is used to increase the voltage to 3.3 volts. The voltage converter has a sensitivity down to 1.3 volts, which maximizes the use of each battery pack and the lifespan of each device.

IV. IMPLEMENTATION

The system utilizes three devices attached to the stem of the wind turbine. One device is placed at the top of the stem, the second device is placed in the center, and the last device is placed at the base of the stem.

The base device establishes the neutral position of the wind turbine; using the top device we can apply simple trigonometric analysis to determine the exact amplitude of each vibration.

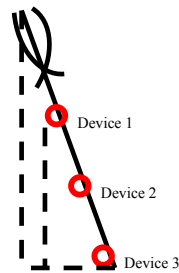


Figure 1: Shows the method used to determine the amplitude of each vibration.

To find the amplitude of each vibration we apply simple trigonometry. First we find the angle of the turbine stem.

$$\cos(\theta) = (x1 - x2)/y$$

The value reported from device 1 is x1, x2 is the value reported by device 3, and y is the distance from device 1 to device 3. Using the angle and the entire length of the wind turbine we can find the total amplitude of the vibration.

CONCLUSION

The implementation of the system described above on the Municipal Wharf turbine will allow researchers to identify toxic wind conditions and will extend the lifespan of the turbine. Once enough data has been collected a safety feature can be included that will enable the system to automatically cease operation when the unwanted wind conditions are detected.

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