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IMPROVING STRUCTURAL INTEGRITY OF WIND TURBINE IN EXTREME CONDITIONS WITH THE HELP OF TELECOM NETWORKS

Abstract: *This paper describes a method of improving the life span of a wind turbine and optimizing its structural integrity by applying networking and telecommunication monitoring and real-time computation for an enhanced turbine design. The authors try to accomplish the goal of extending the lifespan of a wind turbine by applying networking equipment to provide real-time data and to establish decision making with the help of the computer results of data analysis and simulation.*

Key words*: structure optimization, wind turbine, telecom network*

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INTRODUCTION

A wind turbine, built on a utility scale in conjunction with other wind turbines to form a large powerplant for industrial scale, needs to be reliable and tolerant to fault in order to better serve the National Power Grid System.

In earlier work [1] the authors have designed several enhanced systems that can accomplish this using mechanical solutions integrated with better design principals as seen in figure 1.

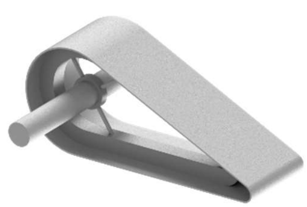

Fig. 1 Wind turbine blade with support system [1]

To enhance mechanical design is one method of obtaining a good result and a large number of cases have to be taken into consideration. Data information about the real-time state of the turbine must be available to be able to react to changes.

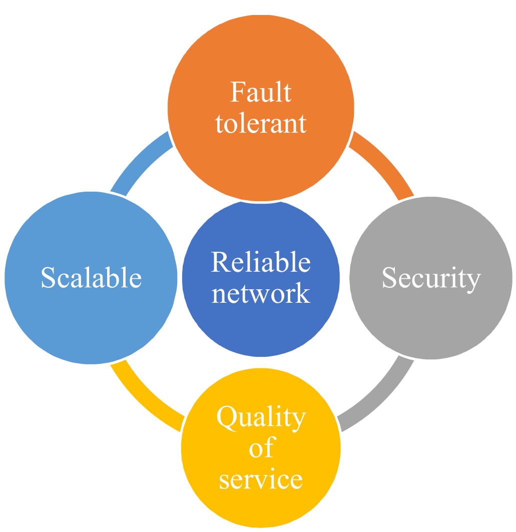

Fig. 2 Components of a reliable network

In the design process it is useful to consider, besides optimal efficiency, the possibility of extreme weather conditions and the resulting reactions of the equipment when such cases occur.

The equipment and the network have to follow standards and contribute to a reliable network. We can consider the network to be reliable when its state is defined by the attributes in figure 2.

The reliable network must be
- fault tolerant;
- secure;
- scalable;
- quality of service.

These 4 attributes of the network have to be simultaneously met in order for the network to function properly and provide accurate data and communications.

When considering the design of a modern wind turbine powerplant, one must thoroughly analyze all the parameters that are available in order to better optimize the device for better performance but also great durability and long-lasting life span.

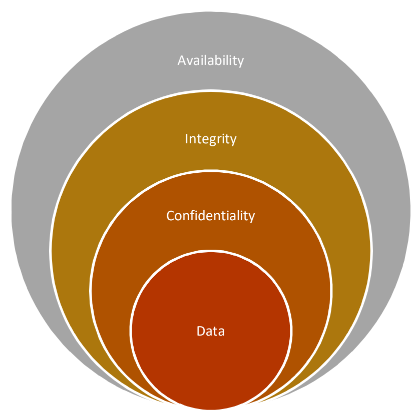

Fig. 3 Structure for data protection

All data extracted from the network for the purpose of better maintenance has to be available only to the intended equipment and devices. For this the network has to ensure the conditions for the data to be confidential. As shown in figure 3 the network has to be able to provide the layers:
- data;
- confidential;
- integrity;
- availability.

Provided that the network can deliver the required performance then the design may have a good outcome and improved performance.

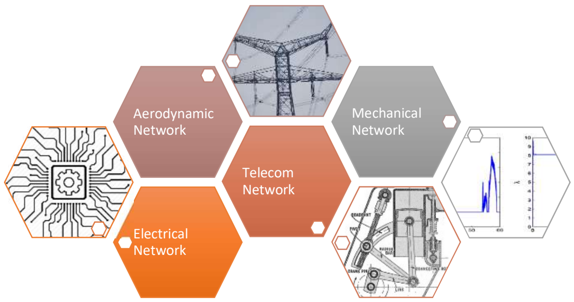

Fig. 4 Interconnected networks

In practice there are 4 main networks that provide the reliability, operation, life span extension of a wind turbine and these networks are as seen in figure 4 interconnected and rely on one another:
- the telecommunications network;
- the electrical network;
- the mechanical network;
- the aerodynamic network.

In earlier work [2] a solution for modularity was presented as a proposal for better management of the system as a whole. The design as seen in figure 5 was very elaborate.

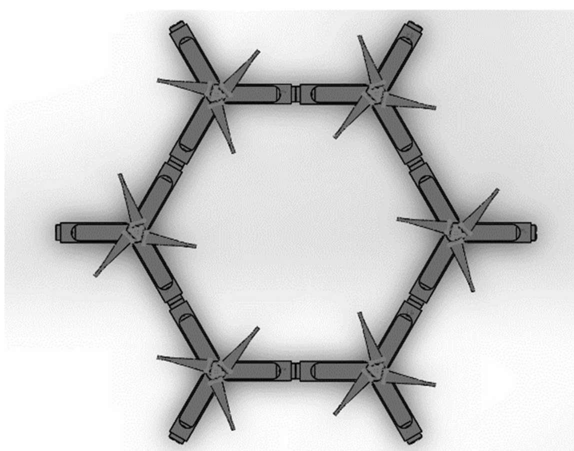

Fig. 5 Modular wind turbine design [2]

2. PACKET TRACER DEVELOPMENT OF A NETWORK FOR A WIND TURBINE

Packet Tracer [3] is a software application developed by Cisco Inc. to simulate a network with all the connections and devices contained in it.

In a network environment it is easier to simulate the process with the help of real-time simulation software to provide realistic results comparable to real world application then to install the equipment and realize its not properly working. Packet Tracer is such an application developed by Cisco for networking simulation.

System administrators can employ the use of Packet Tracer to setup a network and see whether or no its usable and after the simulation stage the system administrator can make the decision to implement the simulation scheme into real-life or not.

The software has a drag and drop interface and a command line interface built in that can aid the network engineer to add end nodes and intermediary devices and configure them.

In the application of networks for wind turbines we have to take into account several issues. The plant must be very well equipped with sensors and computers to extract data and make calculations based on the measurements to give solutions to problems in real-time.

Additionally, the need for HMIs (Human Machine Interfaces) is high. The computers allow the local dispatch engineer to interact with the equipment and take advantage of the network that is at his disposal in order to solve inbound problems.

Information is centralized and its no need for the system engineer to make phone calls or leave the office to visit the site in order to get an overview of the situation. It is sufficient to check his monitor to make a knowledgeable decision.

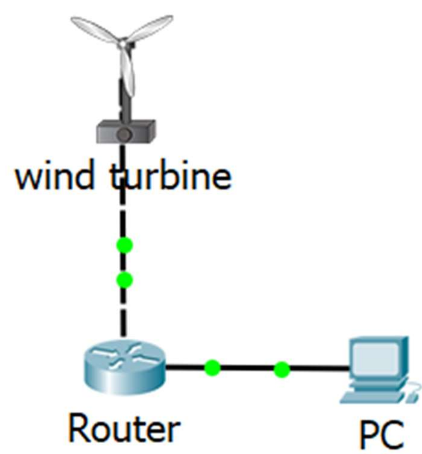

Fig. 6 Simple networking diagram

A simple network diagram as shown in figure 6 is designed as a start point for the wind turbine telecom network. The wind turbine can provide data to a local PC through a router and the dispatch engineer can see the results live. This method implies that the engineer is located near the site where the wind turbine is operating so he can reach the computer terminal.

Although the engineer can see the data, the measurements do not stay stored anywhere and get lost without the possibility for calculations to be computed and suggestions to be made for a better functioning wind turbine.

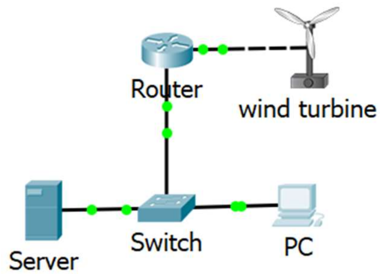

Fig. 7 Improved physical topology

The network topology has to be enriched in order to be able to store the data. As seen in figure 7 a server has been added so it can store data gathered from the wind turbine. The dispatch engineer can now operate with the data stored on the server. For convenience a switch has been added so the communication is easier to facilitate.

The complexity of the network has to be increased yet again in order to provide more data to the engineer and so we have to add more equipment.

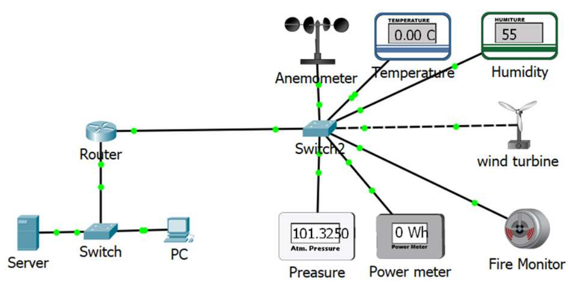

Fig. 8 Additional sensor data

As the need for more and more data rises the physical topology gets bigger and bigger. Data pulled from these sensors contributes to a better analysis of the system and results in a better coordination to ensure structure integrity improving and optimizing systems in real time.

As seen in figure 8 the additional sensor data is gathered and stored on the local server in order to get processed and as a result from the derived data we get instructions on what to change or maintain in the system for the equipment to run flawlessly.

The network topology is almost complete but in order to make it more useful to the engineer we have to provide access to all data from a remote distance via the internet so we continue to grow our network.

In a real-world scenario where an unexpected change in weather has started to influence the equipment in a local power station, the data provided by the equipment is indispensable.

For a gust that results in extreme weather conditions the wind turbine has a lot of implemented systems in order for it to survive the gust without much damage. Even though the systems are in place in the case of a failure the engineers have no way of realizing this until the end of the storm when it could be too late to do anything about it.

A wind turbine equipped with sensor systems that can provide an overview of the situation is present in most powerplants. The network provides data but this does not mean the data is also processed.

The proposed network is setup so that the systems also compute the data and can instantly provide several solutions. The engineers have to choose between the proposals and establish which solution option is better.

The anemometer sensor provides the wind speed and direction, the temperature and humidity are useful to provide accurate measurements on site.

The power meter indicates how much power, if any, is still produced in the case of a gust also we have a fire monitoring device included in our network meant to detect if any equipment has caught on fire.

The network includes a security section where motion detectors trip sensors and video surveillance are put in place in order to prevent physical access to both the network and wind turbine powerplant.

At the end of the network we can see a interface to connect the wind turbine to the Internet and provide access to its parameters via Internet access.

The Internet access is secure and can only be login by authorized personnel only providing security alongside convenience of use anywhere in the world.

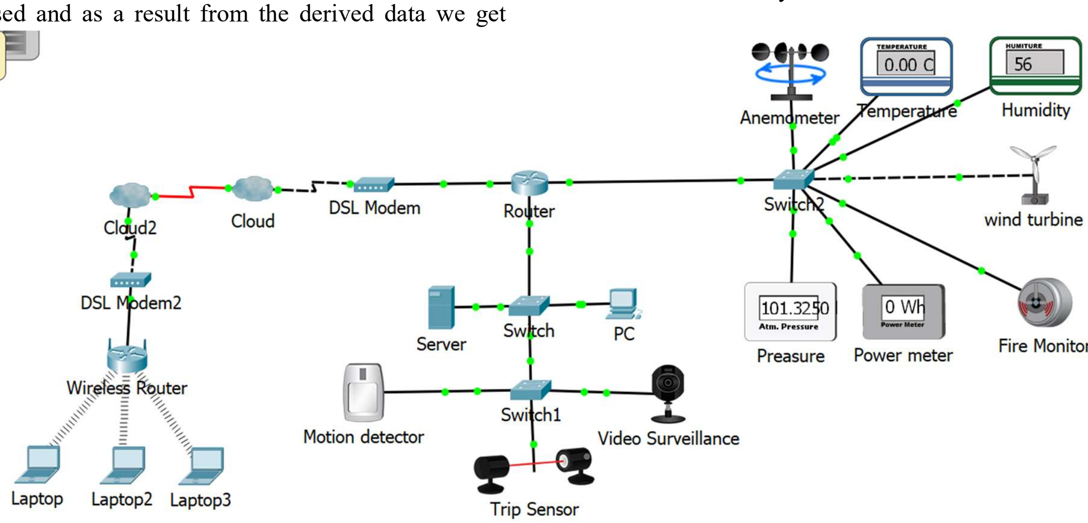

Fig. 9 Final network physical topology

In figure 9 we can see the final physical topology of the network [4]. We have a local network near the wind turbine site and we also have a user that can connect via the Internet from anywhere and interact with the network if need be.

The network is necessary in order to better control the equipment and it represents a mean to optimize the structural integrity of the wind turbine by prevention of unwanted faults in case of extreme conditions that may occur during the wind turbines lifetime.

3. FINAL RESULTS

The telecom network is useful for wind turbine structure optimization due to its reliable nature. We can interact with the system and make the right decisions having access to the set of data at all times. The engineers can better maintain and operate the wind turbine.

Considering an average of 2000 hours of total operation time in a year (8760 hours) [4] and the fact that faults can occur during these 2000 hours by adding the telecom network we can improve operability and reduce the fault time.

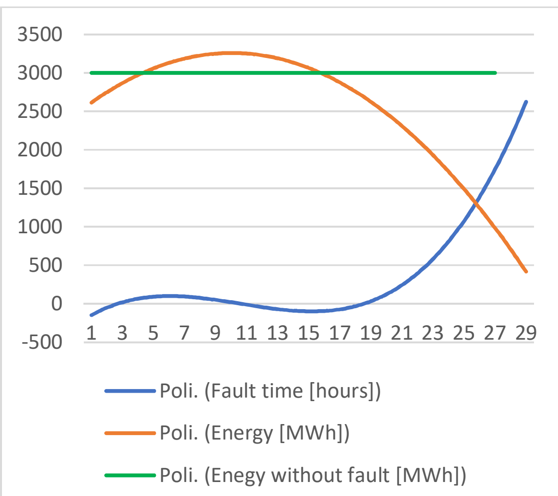

Fig. 10 Energy production change relative to fault time

Total energy production can be greatly influenced by fault duration as seen in equation 1 below.

$$E = P(a - f) \qquad (1)$$

Where E is the energy production; P is the power, a is the yearly average operation and f is the fault time. As seen in figure 10 as the fault time increases the energy production decreases but by adding the telecom network into the equation fault time decreases and energy production rises.

4. CONCLUSION AND DISCUSSIONS

The telecom network setup can improve the efficiency of the wind turbine and has an effect on the structure optimization by offering a range of data that the dispatch engineer can take advantage of and make the right decision in the case of an abnormal extreme condition for the wind turbine.

5. FURTHER RESEARCH

Additional work is being done to develop the other networks in order to integrate and corelate information. The result is a better functioning wind turbine with a larger life span and improved capabilities.

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