EFFICIENT CONTROL OF WIND TURBINE USING INTERNET OF THINGS (IOT)

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ABSTRACT: Internet of things refers to a shared network of data and connectivity between devices, software, and sensors. The failures which occur in remote locations such as wind-farm systems result in interrupted power generation that can lead to increased system downtime and costs and overall decreased productivity. Fluctuating energy prices make optimal project efficiency and uptime critical to a wind farm's profit margins and bottom line. Through remote access, IoT can bridge the gap between a wind farm located several hours or even days away and a local control centre with access so attendants might adjust switches, software, or equipment from a distance. IoT gives wind-farm operators control to monitor and regulate much of a turbine's operation no matter how much distance separates the two.

INDUSTRIAL IoT FOR WIND TURBINES

The industrial IoT has got an advanced ability to access information and data from machines, sensors, and controllers which connected to the Internet [1]. Network connected systems and devices has got the special capability to collect, exchange, monitor, analyse, and intelligently act on information without or little human intervention.

IoT is possible in part because of a mass transition of industrial-grade equipment using an Ethernet data medium as a main link to networking infrastructures. Ethernet is the most widely installed local area network (LAN) that lets devices format data for transmission to other devices on the same connection.

Through access links such as Ethernet, but also fiber optics, wireless, and 4G, the Internet has become faster, more affordable, and more widely used [2]. The result is that even remote locations now have access and connectivity options.

An industrial-grade network infrastructure offers wind-farm operators many benefits, including improved operational management, access to real-time data, network security features, and automatic system warnings. These features provide real-time data, control, and secure access from remote locations.

IoT gives wind-farm owners or operators an ability to monitor and analyse onsite data on a daily, monthly, and even yearly basis, and can provide a detailed look at individual turbine performance. Based on this data, an optimized maintenance strategy can prioritize turbines that experience less than expected performance losses and therefore minimize downtime.

However, because wind farms are typically situated in extremely remote locations, equipment and networking reliability is critical. Transmission errors or delays could result in unnecessary maintenance delays [3].

Industrial-grade networking must be designed for rugged environments and support long mean times before failure rates — typically greater than 100,000 hours [4-5]. All controls and Ethernet equipment must withstand extreme temperatures, lightning strikes, and potential electrical interference from high power turbines.

Industrial-grade networking is key because keeping a network up and running at all times is imperative to successful wind-farm operations and production revenues [6].

CONNECTION TOPOLOGY

For networks containing multiple end devices (in this case, wind turbines), industrial-managed Ethernet switches with built-in fiber ports provide a ring-redundancy architecture. This design prevents loss of control and data to the wind farm in the event of an unexpected link failure.

Multiple fiber ports on the switch in the control cabinet are found at the base of a wind turbine, and provide at least two connections to the redundant ring. One or more additional fiber ports are usually available to run fiber to the nacelle to connect sensors and other devices.

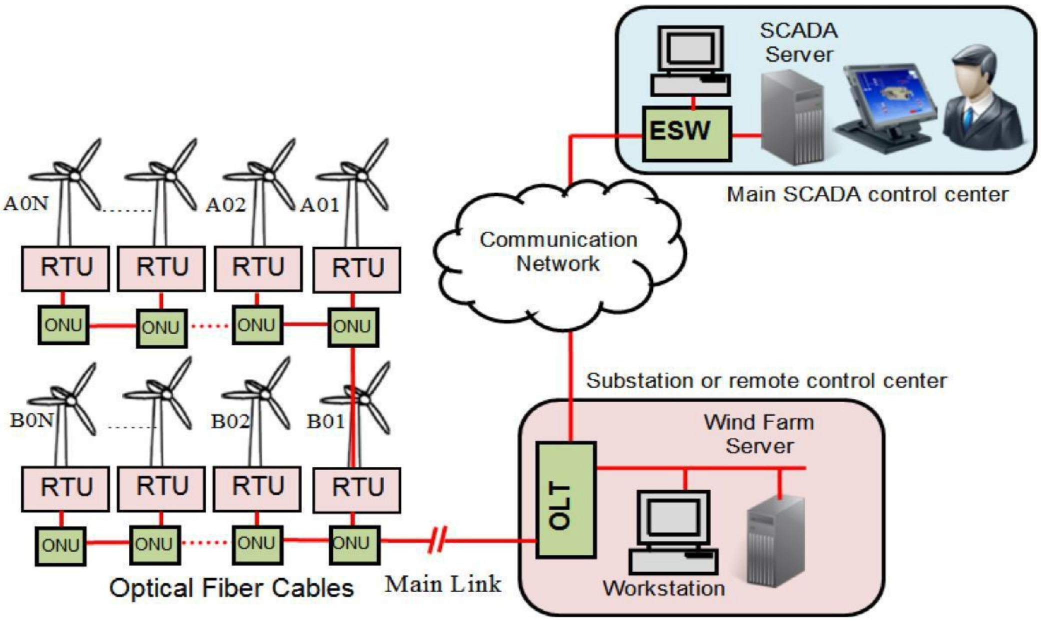

Fig.1: Connection of wind turbines in a network

If a switch fails, a connector disconnects, or someone cuts a cable, or if another unforeseen type of disruption occurs, the system automatically routes data around the problem using the redundant path. The design works to proactively safeguard against potential failures while assuring network uptime.

Network administrators can choose between multiple ring topology standards, depending on their application needs. For example, a wind-farm owner might choose between a Rapid Spanning Tree Protocol (RSTP) and an Ethernet Ring Protection Switching (ERPS) ring.

RSTP provides a mesh network topology where individual nodes relay data to the network. This means RSTP is resilient and capable of operating throughout multiple points of failure. But it also has a network recovery time of about 30 seconds. Should that outage delay generate concern for a wind-farm owner because it results in a gap in power production and data collection, ERPS provides another option.

Implementing an ERPS ring in a managed industrial Ethernet switch means it's possible to achieve recovery times of less than 50 milliseconds during a link failure. Impressive, but the downside is that an ERPS ring is only capable of having a single point of failure.

DATA TRANSMISSION PROCESS

Wind turbines are equipped with a control cabinet that holds a programmable logic controller (PLC), inverter power source, human machine interface (HMI), and I/O devices at the base of each tower. At the top of the tower or the nacelle, several sensors there detect wind speed, wind direction, and shaft rotation speed.

To maximize wind power, the data collected from sensors are analysed quickly and each turbine can adjust its settings accordingly, based on data it receives from the system. A reliable connection lets a turbine continually assess and account for changes in wind speed, temperature variations, and vibration to best optimize power generation.

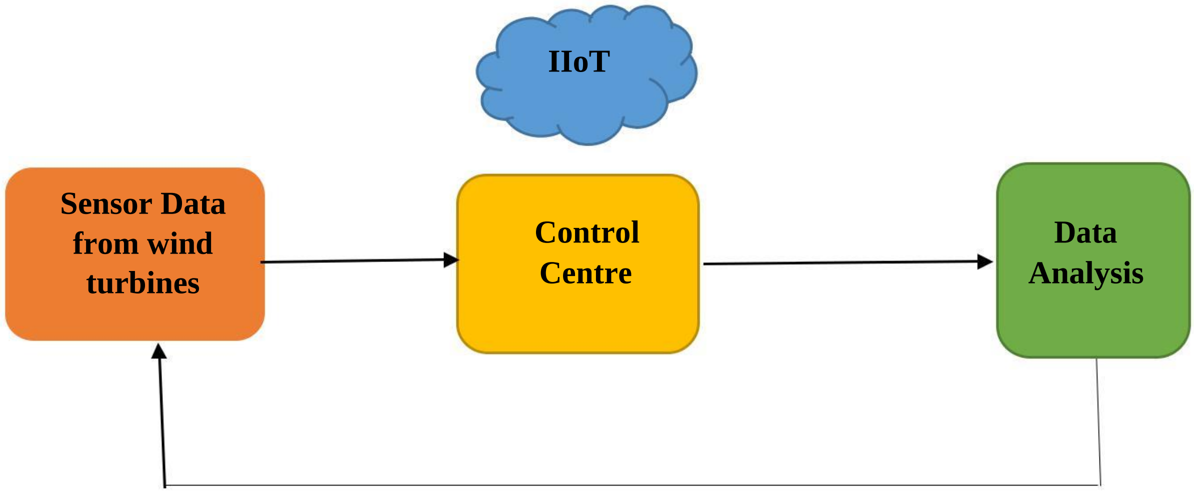

Fig:2: Wind turbine integration with IIoT

However, the communication path from a nacelle to the base of a turbine has some of the toughest communication challenges to overcome because of the distance. Sometimes it is possible to successfully use shielded Ethernet cables to provide a data link. Ethernet cables can provide communication links for about 330 feet, well within the range of most wind turbine heights.

A fiber-optic link can also offer electromagnetic interference or EMI immunity [7], which is important in turbines. Considerable EMI often exists in a wind turbine because of the ongoing generation of power. EMI can negatively impact communication and corrupt or completely lose data, especially if only Ethernet cables are used in a network.

Fiber-optic cables are also beneficial in mitigating potential damage caused by lightning strikes and can prevent strike effects from propagating to other pieces of equipment in the turbine [8].

ADVANCED MANAGEMENT & IOT

The size and remote location of most wind farms is no longer the issue it once was before the Internet of Things. An industrial networking system and remote data collection and communication provides real-time troubleshooting and advanced management at wind sites.

Also the detection and recovery time is reduced significantly in case of issues or equipment failures at wind farm. Apart from that, the data collection can lead to predictive operations and maintenance or advanced management of turbines so failures are caught before causing turbine downtime.

Implementing industrial-grade managed switches at wind farms makes additional software features available through the switch's Web interface. This improves data flow, network traffic, and equipment performance.

Some of the more commonly implemented features include:

- **IGMP snooping** which monitors traffic on a network, creating and maintaining a map of what pathways use multi-cast traffic streams. Some common pieces of equipment that send out multi-cast traffic are security cameras and PLCs. By learning where network traffic goes, the switch is able to filter multi-cast traffic and send it only to locations that require it rather than sending it all over the network, which greatly reduces bandwidth consumption.
- **Quality of Service (QoS)** prioritizes network traffic so that when congestion occurs, higher priority traffic takes precedence. QoS can help with error rates and transmission delays.
- **Network redundancy** is an important system safeguard where a component is duplicated so if it fails there is a backup.

- **VLANs** are virtual local area networks. These can divide or segment a network through software to create smaller and seemingly isolated networks for better management and security. For example, security and surveillance monitoring, control data, and management overview can flow through separate VLAN's that are then directed to the appropriate parties. This provides additional control over a site and prevents someone in the surveillance-monitoring department from accessing the control section of the network. VLANs also reduce the amount of network bandwidth consumed. Additionally, if a security threat or denial-of-service attack affects one VLAN, the threat will not spread to other VLANs on the network.
- **System warnings** from industrial-managed switches let users implement warnings and email alerts for various events so operators are alerted remotely and can respond faster to important networking issues.

CONCLUSION

Industrial-grade networking equipment provides a high degree of reliability and control pertinent to smart energy-management systems and offers a variety of solutions to the unique networking challenges at wind farms. Industrial-grade networking equipment is intended for rugged environments and used at many wind sites because it provides redundancy, fiber optic support, and advanced software management features that make a reliable and easily managed IoT network possible.

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