Winds of Change

IIoT-Enabled Transformations in the Wind Energy Sector

Introduction

Since the early industrial revolution, the world economy has been thriving on fossil fuels with deleterious consequences. Two centuries of economic development has near depleted high-carbon energy reserves formed over geological times and precipitated the global crisis of climate change. The ground realities demand a transition to a clean, low-carbon energy system which, by global consensus, is now being realized across the world through large-scale harvesting of solar, wind, and hydropower.

Today, wind is a key component of the renewable energy mix of many countries and its share in total power production is on the rise. The years between 1992 and 2007 recorded 25% growth (from 2.5 GW to 94 GW) in the global installed capacity of wind power. New installations worth 60 GW were expected in 2017 alone. With advances in turbine technology, wind energy is set to become more cost-competitive compared to expensive biofuels.

The prospects for wind energy production are also bright in terms of financial incentives and investments as well as favorable policies and legislation. However, several challenges exist on the ground that prevent wind farms from evolving into reliable powerhouses of the 21st century and wind businesses from realizing their growth potential.

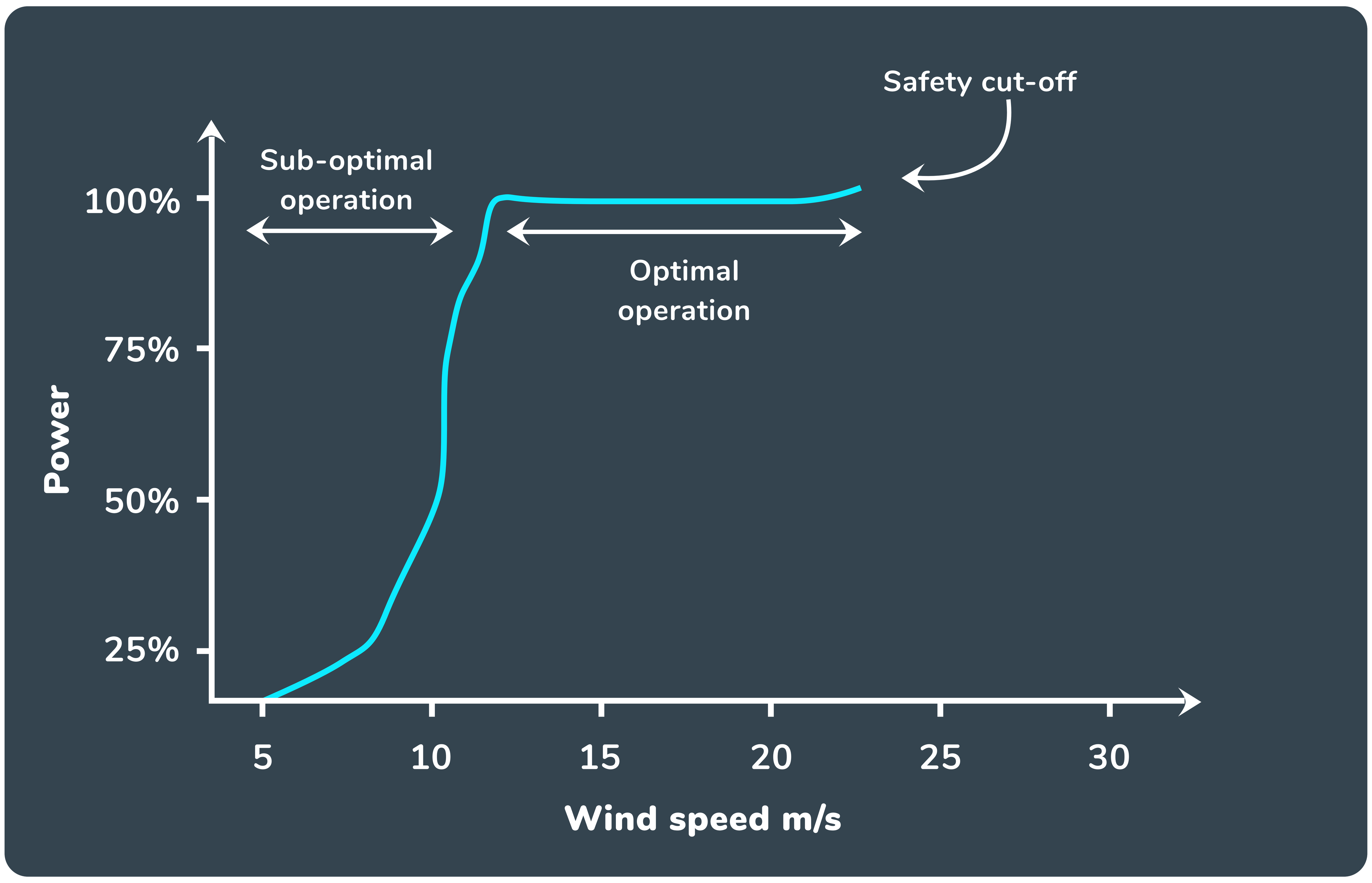
Wind farm monitoring and maintenance is a major problem area in operations. Sensor-based and IIoT-driven big data technologies, however, are now turning the tide in favor of business owners, giving them unprecedented control and oversight of their wind farms.

Wind Power: Features & Challenges

Varying and Intermittent Power Resource

Wind is an intermittent resource and its speed varies throughout the day and year. When there is no wind, there is no power either. Wind is therefore not the readily available or uninterrupted resource that biofuels are.

Wind turbines start producing power only at a designated wind speed (typically close to 10 mph) and as the wind picks up, the output increases in cubic relation to the speed. At the same time, at higher wind speeds (over 55 mph), turbines are turned off to avert damage. The optimum wind speed for turbines to achieve their nameplate capacity or maximum output is 9 mph to 27 mph. These are some of the basic constraints within which wind turbines operate.



To borrow a figure of speech, it takes a fair wind to hoist the sails. For wind farms, fair wind means high potential for power. To leverage this wind for energy conversion, every turbine should be shipshape, free of defects in its parts or in whole.

Remote and Geographically Dispersed Locations

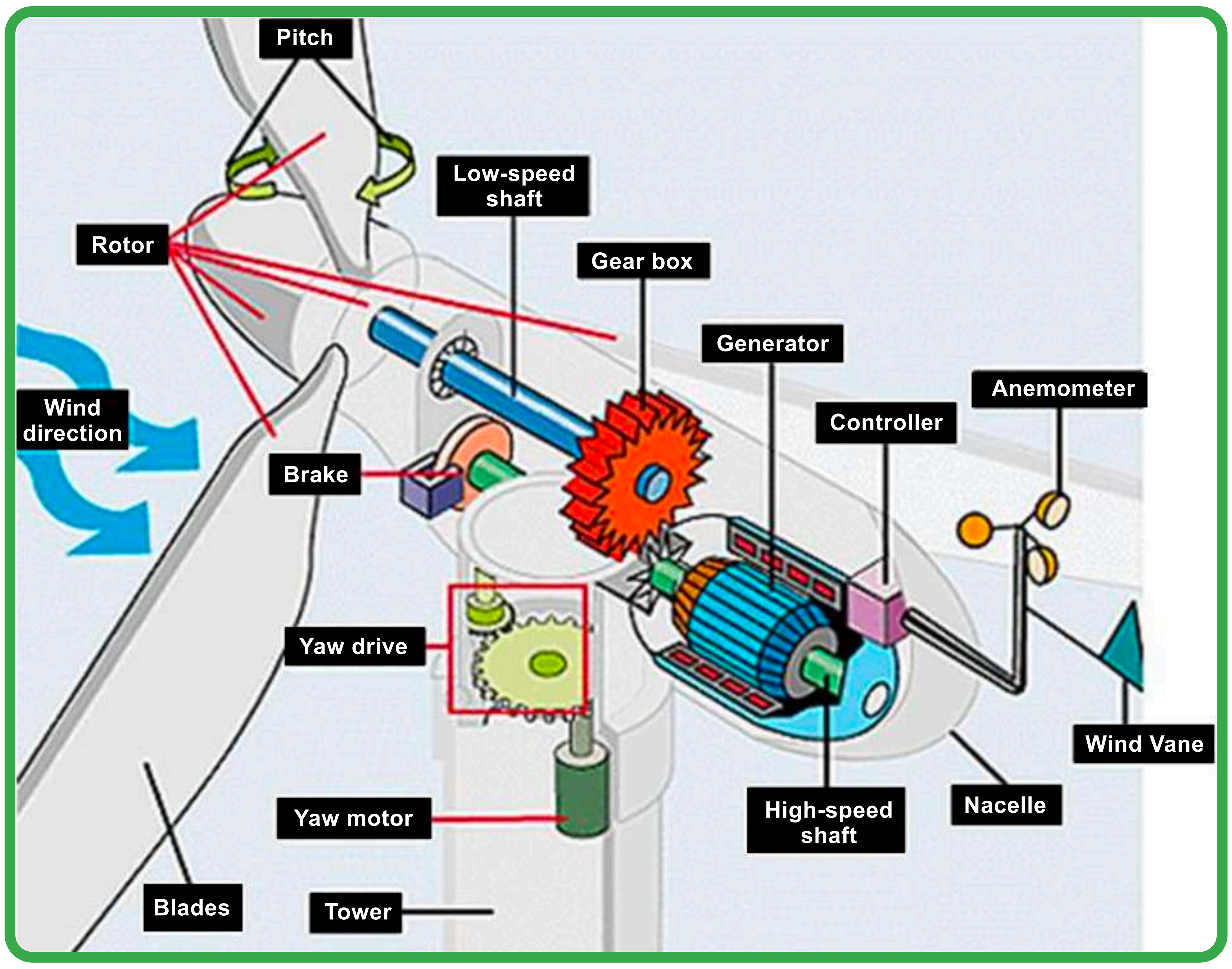
Wind turbines require unobstructed wind. For this reason, they are located far away from cities and towns, either in mountainous or agricultural areas or, in the case of offshore farms, in oceans. Turbines located closer to human settlements are usually smaller, of lower capacity (100 kW or less), and more suited for local off-grid applications.

Utility-scale wind farms are typically spread over a large area of land (or ocean) to permit the free flow of air. Thus a 25-MW onshore project could span 1500 acres, that is, every megawatt of power production could involve 60 acres of land. And depending on the size of the projects, the number of turbines installed could vary from a few tens to a few thousand.

Again, wind farms are not always concentrated in one location. Many wind farm businesses are geographically dispersed, owing to the nonuniform nature of wind. The remoteness and wide dispersal of wind farms add to the logistics and management challenges in optimizing wind farm operations.

Multiple Components and Parameters

The wind turbines dotting a landscape may look like uncomplicated machines with massive propeller-like blades mounted on lofty towers. Behind these formidable structures, there are finer components—generator, gearbox, brake, yaw drive, among others—whose synchronized and fault-free operations turn wind to power. Needless to say, wind production is constrained by the health of each component, monitoring which is a gargantuan task given the inaccessible location and scale of deployment.



A host of components go into the making of a wind turbine and their collective efficiency reflects on turbine performance.

Although the average lifespan of a wind turbine is 20 years, the potential for failure begins to grow the further you move from the commissioning date. With it grows the risk of incurring high operations and maintenance expenditure or OPEX. It could amount to as much as 11%-30% of the Levelized Cost of Electricity of an onshore wind project.

Main Gear Box	Generator	Main Bearings	Rotor Blades
32%	23%	11%	<10%

Technologies that are currently available do not give an incisive view of the turbine so as to verify the exact condition of individual components and mitigate the risks on time. There are problems with relying on a SCADA-only system. The operation status records could be inconsistent, acquisition rate may vary, and there are no maintenance records.

Wind Turbine Maintenance

There are different maintenance strategies, predominant ones being reactive (corrective) and preventive (scheduled). In the first instance, repairs are done when machines break down. In the second, repairs are time-based or run-based. Most often, it is a mix of both strategies, but sometimes adaptive strategies are taken as a stopgap arrangement, whereby operators make do with what they have.

As a strategy, reactive maintenance is fundamentally flawed. Quick fixes can be faulty in themselves, particularly if the technicians are inexperienced. Reactive maintenance does not sufficiently address the root cause of the failure, which may trip up the machine for future failure. It is not economically viable either, not just because of the incremental cost of fixing the same problem again and again but also because of the expensive downtime it entails every time the problem occurs.

The standard industry practice is scheduled maintenance, whose frequency and scope is determined by service warranties. It assumes that wear-out failure is the most common type of failure. Unlike in reactive maintenance, there may not be an actual degradation during a scheduled inspection. While such consistent maintenance schedules are useful to regulate machine downtime and availability, they do not safeguard owners from unplanned downtime caused by parts failure.

IIoT-Driven Smart Wind Farm Management

The convergence of industrial-scale Internet, advanced sensors, and processing systems has opened up a new world of opportunity for industries. The wind energy sector too is a beneficiary of these evolutionary technological changes. Some of its longstanding challenges are being resolved through these technological breakthroughs, enabling wind farm businesses to stave off losses and gear up operations to contribute to a sustainable energy system.

Remote Equipment Monitoring

As discussed earlier, remoteness of turbines and the complexity of the machinery pose practical difficulties in achieving the required efficiency. The Internet of Things with its ability to connect to distant objects and collect and interpret data concerning those objects provides a pathbreaking solution whereby visibility into operations is now possible without physical proximity.

Most modern turbines come with some kind of built-in condition monitoring system, which can vary from vendor to vendor. These systems capture a few condition parameters such as the temperature of bearing, oil, or winding and transmit it to a Supervisory Control and Data Acquisition (SCADA) system for monitoring and analysis.

Since most projects involve multi-vendor or EPC contracting, turbine condition monitoring is fragmented across multiple systems. Therefore, obtaining a holistic or aggregated view of the entire wind farm is difficult for large farms. Although generation of wind power is not centralized, it is critical for monitoring to be centralized so speedier and more reliable decisions can be made on time.

Predictive Maintenance

Another game-changing technological development is predictive maintenance—an advanced function that allows wind farm owners to predict maintenance problems and proactively resolve them before they lead to breakdowns. Rather than firefight every failure, failure can be prevented through judicious action. This is a huge technological leap from reactive or corrective maintenance where machine deterioration is dealt with after it snowballs into irreversible failure.

Time series models are used in forecasting performance variables by identifying aberrations or anomalies in data. Statistical analysis techniques like Autoregressive Moving Average Model (ARMA) help in predicting future values. For example, analysis of the time-series data of gearbox vibration can be used to predict at what point in future the gearbox could fail.

Data mining techniques offer even greater possibilities for a more accurate interpretation of multivariate turbine data. Sophisticated machine learning algorithms can parse the vast amounts of accumulated data into meaningful information by correlating events and identifying patterns. Algorithms can identify patterns in data that preceded a failure and alert users of impending failures when it detects a similar pattern in data.

Predictive analytics affords a more sophisticated and stringent maintenance regime for wind farm owners, which minimizes long-term maintenance costs and improves machine availability and reliability. Business owners who aim for long-term performance (rather than short-term cost reduction) can only benefit from predictive maintenance as it is estimated to reduce maintenance costs at least by 50%.

Business Optimization

Given the high capital expenditure (84% of it consumed by turbines) and annual maintenance (1%-3% of turbine installation) costs, wind farm owners have to fine-tune operations to realize value from their investments. The sweeping and deep insights provided by the Internet of Things empowers owners to take much more informed decisions than before in real time and minimize the risk of loss.

One of the greatest barriers has been siloed data, which makes data discovery and decision-making difficult and error-prone. IoT and big data technology-enabled platforms facilitate data sharing and data-intensive computations and the extracted insights can be accessed literally from anywhere in the world.

Precise data collected from turbines helps compare actual output with the baseline provided by the vendor by means of power curve to check if the turbines are producing their rated capacity. Significant variations between the two could signify two kinds of issues: aging or non-compliance both of which can be quickly followed up.

Since there are variations in wind speeds, assessments become reliable only when they are carried out over a period of time. By storing massive amounts of data, IIoT-enabled platforms can provide a historical view of data. The variation in output can also be evaluated in comparison with the seasonal changes. This big picture is essential for business owners to see power production in its real context.

Production improvements can also happen with sensor inputs. In large farms, turbines can align themselves to leverage the wind better based on the information gathered before the wind reaches them. By aligning the turbine towards the wind proactively, power production can be pumped up.

SeeMyMachines: Real-Time Remote Wind Farm Monitoring Platform

SeeMyMachines, a powerful industry-grade IoT solution from QBurst and PlanetG, delivers actionable insights in real time from wind farm machines, giving businesses dynamic decision-making capability. It leverages best-in-class Internet, big data, cloud, and mobile technologies to provide an end-to-end IIoT solution for optimizing wind farm operations.

Its real-time condition monitoring, predictive maintenance, and wind farm performance monitoring capabilities equip wind farm businesses to prevent costly system failure, ensure turbine availability, and make the right decisions to ramp up Overall Equipment Effectiveness (OEE). User-friendly data visualization employed in SeeMyMachines further speeds up problem discovery and user response.

As a fully equipped Computerized Maintenance Management Information System (CMMIS), SeeMyMachines streamlines maintenance planning, scheduling, and coordination. By ensuring compliance and the timely resolution of turbine issues, the platform helps businesses reach new levels of efficiency in operations and maintenance.

Components of SeeMyMachines Integrated Monitoring System

SeeMyMachines affords an individual view of turbines as well as a consolidated view of wind farms. This intelligent system consists of a few key components.

At one end of this system are sensors embedded in turbines. These continuously capture data on turbine status and ambient conditions (refer table below). The size of data grows proportionally large as more sensors are tacked to the turbine components.

Performance Parameters Captured by Sensors

Speed	Wind, rotor, generator
Temperature	Ambient, bearings, gearbox, generator, nacelle
Pressure	Gearbox oil, cooling system, pitch hydraulics
Angle	Pitch and yaw
Movement	Vibrations and nacelle oscillation
Data	Voltage, current, phase
Wind Direction	

Its cloud-based processing platform extracts intelligence from this massive pool of data and relays it to the end users via mobile or desktop applications in real time or close to real time.

With information on their remote turbines and farms ready at their fingertips, users can monitor turbine availability and track down malfunctions from unusual data values. With built-in anomaly detection algorithms to trigger alerts, users don’t have to manually pour through the data to check those values.

Architecture Highlights

Highly Scalable

Ingests data from hundreds of sensors and other data sources. Executes data-intensive computations efficiently and reliably even as data surges in volume or speed.

Highly Intelligent

Leverages advanced machine learning technologies to extract crucial insights from large-volume sensor data. Supports predictive modeling and helps offset risks.

Interoperable

Connects to a wide range of data sources. Standardized connectors pull and push data to various systems including enterprise platforms, sensor networks, and databases.

Open Technology Stack

Consists of robust open technologies: Kafka (data ingestion), Spark (data processing), HDFS (real-time and historical data analysis), MongoDB (aggregated data storage).

Conclusion

Commercial-scale wind power production is an absolute necessity to meet the rising need for energy and speed up the switch to renewable energy. Wind farm businesses, which were previously saddled with heavy costs and difficult operating conditions, are now better positioned to tide those difficulties with the help of technology. The evidence for this is visible in their contributions to the total energy share.

Cutting-edge Industrial Internet of Things technologies are further turning the wind in their favor by allowing them to connect to their disconnected and scattered wind farm machinery, track turbine condition, measure important variables, and predict undesirable outcomes.

This real-world example of a wind farm business is a point in case. Not only did the company reduce monitoring hassles and inefficient inspections, it cut down related costs and overhauled operations using critical understanding generated by IIoT. Leveraging the real-time, comparative, and predictive analytical insights generated by IIoT, every wind farm business stands to gain tremendously in their productivity, efficiency, and profits.

Schedule a consultation to know more about this centerpiece technology and how it can transform your wind farm business.

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