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The Role of Continuous Thermal Imaging in Detecting Faults and Reducing Risks

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Improving Wind Turbine Maintenance

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Wind turbines are a critical pillar of renewable energy production, yet they routinely encounter significant operational risks, including overheating, electrical fires, and arc-flash incidents within their nacelle environments. These issues not only threaten the reliability of energy output, they also endanger maintenance personnel, increase operational costs, and contribute to lengthy downtime. Traditional methods of diagnosing these hazards, while long relied upon, are often dangerous, inefficient and prone to data inaccuracies. In response to these persistent challenges, Puget Sound Energy transitioned from conventional diagnostic methods to an advanced, fixed, bispectral infrared camera solution, fundamentally transforming its approach to wind turbine maintenance. This article explores how the adoption of this technology resulted in substantial improvements in technician safety, operational efficiency, real-time diagnostics, and proactive failure prevention, ultimately reshaping best practices for wind energy infrastructure maintenance.

Figure 1. The Sytis TC-90 magnetised to the panel door in the nacelle of a Vestas V80 power factor correction cabinet at Puget Sound Energy

Wind turbine maintenance has always presented challenges because of the high-risk environments in which these systems operate. Identifying overheating nacelle components requires extensive manual inspections, which can be time-consuming, hazardous and error-prone. Traditional tools often fail to provide real-time insights, leading to costly downtime and safety risks to maintenance personnel. The need for more effective diagnostic methods has driven the development of continuous thermal monitoring using advanced infrared camera imaging solutions such as the Sytis TC-90.

Traditional Methods and Their Limitations

Traditionally, diagnosing overheating and electrical component failures has required shutting down turbines, isolating electrical cabinets, and sending maintenance crews up towering structures, where they then conduct inspections on cold components using tools such as multimeters. This is time-consuming work and tedious. Often, single-use temperature indicators have been left in place to find areas of excess heat. While simple, they are unreliable because of their lack of time stamps, difficulty adhering to components, and inability to provide continuous monitoring. Additionally, technicians ascend and descend multiple times to place, retrieve and analyse these indicators, further increasing downtime and safety risks. Maintenance personnel often gather incomplete or inaccurate data, leading to prolonged turbine downtime. Moreover, unplanned shutdowns caused by unexpected electrical failures place additional strain on grid reliability. The cumbersome nature of these methods also limits the ability to conduct frequent inspections, leaving potential issues unnoticed until failure.

More Advanced Solutions

With traditional inspection methods failing to deliver actionable real-time insights, operators and maintenance personnel face ongoing uncertainty regarding the true health of their electrical systems, necessitating a more advanced solution with actionable data. Without continuous thermal monitoring of individual components, operators can only react to problems once they have already caused significant damage rather than preventing failures before they occur. While

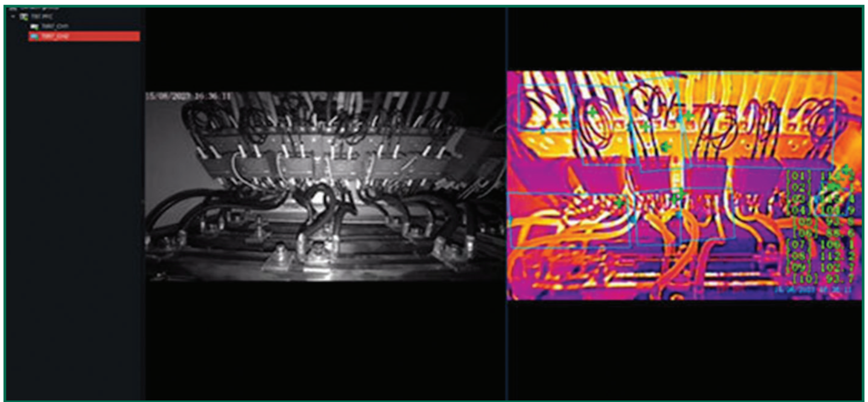

Figure 2. Rotated 90 degrees, a screenshot of the livestream showing side-by-side comparison from the Sytis TC-90 bispectral camera attached to the panel door inside a Vestas V80 power factor correction cabinet at Puget Sound Energy

thermalcouples with remote data loggers can report that a specific component is misbehaving and ambient temperature measurement tools can report that something is amiss in a certain enclosure or area of coverage, only infrared thermal imaging can holistically see the entire space in question and send images and alarms indicating that a component has a temperature issue. If there is an overheated wire, the image will highlight the specific wire that is of concern along with actual temperature data.

Implementing Fixed Infrared Technology

Recognising these challenges, Puget Sound Energy adopted an innovative fixed infrared imaging approach that fundamentally improved turbine maintenance and safety protocols. Unlike previous solutions, the bispectral TC-90 infrared camera system provided simultaneous thermal and optical imaging, enabling technicians to monitor critical electrical components continuously and remotely. The real-time monitoring capability meant that technicians no longer needed to power down turbines or physically access hazardous environments to assess electrical conditions. This advanced technology also featured automated software-driven alerts, triggering notifications whenever components exceeded predetermined temperature thresholds. These real-time insights allowed immediate interventions, preventing minor issues from escalating into major failures. Unlike traditional monitoring systems, which required lengthy set-up times and manual data retrieval, the fixed infrared camera powered via Power-over-Ethernet provided instant and ongoing visibility into turbine operations. By eliminating the need for repeated physical inspections, technicians could focus on analysing and addressing performance trends over time.

Early Detection and Prevention of Failures

The adoption of fixed thermal imaging technology yielded immediate and measurable benefits. Puget Sound Energy discovered that wires running to suspect contactors – critical electrical components within the nacelle – were routinely operating well above their manufacturer-recommended temperature limits, in some cases exceeding 180°C. The ability to identify these anomalies in real time enabled proactive maintenance measures that significantly reduced the likelihood of catastrophic failures such as fires and electrical malfunctions. With continuous monitoring, engineers could assess historical data to determine patterns of stress on components, allowing even more targeted preventive maintenance.

Deeper Diagnostic Insights

Beyond merely identifying overheating issues, the system provided deeper diagnostic insights that allowed technicians to implement targeted corrective actions. The actionable data gave maintenance the ability to send up the crews into the nacelle with a more targeted approach and with the correct replacement parts. In one case, after optimising component spacing for improved airflow, enhancing cooling mechanisms, and adjusting system configurations to reduce heat buildup, they eliminated arc flash and fires altogether. By leveraging this data-driven approach, Puget Sound Energy was able to mitigate operational risks, extend the lifespan of key turbine components, and enhance overall system efficiency. Moreover, the insights gained from this technology are now informing design improvements for future turbine installations, demonstrating its long-term value beyond immediate maintenance benefits.

Operational and Safety Benefits

One of the most significant advantages of implementing fixed thermal imaging was the reduction in the need for hazardous tower climbs. The real-time, remote monitoring capability of the system meant that technicians no longer had to perform routine inspections of low- to high-voltage cabinets manually. As a result, technician exposure to dangerous electrical environments was substantially minimised. Puget Sound Energy estimated that the new system would reduce the number of manual cabinet inspections by at least 50%, preventing hundreds of unnecessary tower ascents annually. This reduction not only improves worker safety and uptime but also increases overall workforce efficiency, allowing personnel to focus on higher-priority maintenance tasks.

Predictive Maintenance Planning

Additionally, the system's continuous monitoring capabilities enabled improved predictive maintenance planning. Instead of responding reactively to failures, maintenance teams could proactively schedule interventions

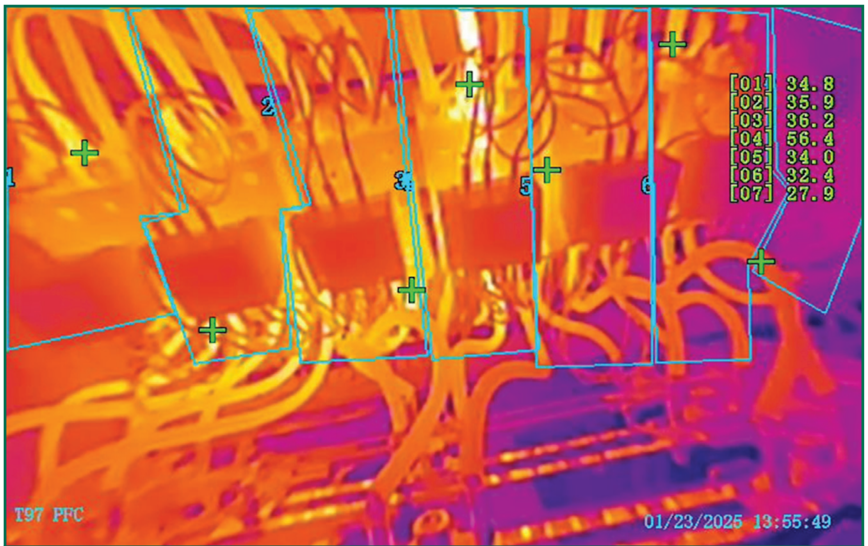

Figure 3. New anomaly identified by the TC-90 after retrofit: 20°C temperature differential

Troy Goss has nine years of experience within utility sectors as a thermographer and specialises in advanced imaging solutions. As a project manager at Sytis, he has contributed to safer, more efficient operations across utility projects worldwide. Dedicated to advancing industry practices, Troy continuously works to enhance innovative solutions.

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during planned downtime, reducing costly emergency repairs and improving overall wind farm efficiency. By streamlining diagnostic processes and minimising disruptions, Puget Sound Energy achieved significant cost savings while enhancing turbine reliability. The reduction in unscheduled maintenance also translated into fewer interruptions in energy production, supporting grid stability and sustainability goals.

Expanding Applications

Encouraged by the success of fixed infrared imaging within nacelles, Puget Sound Energy began exploring broader applications for this technology across its renewable energy infrastructure. Fixed thermal cameras are proving invaluable for monitoring and quickly diagnosing issues within other critical systems, such as power converters, inverters and switchgear installations. As analytics driven by artificial intelligence (AI) continue to evolve, these systems are expected to provide even deeper insights into mechanical stresses, vibration patterns, and predictive maintenance trends, further enhancing operational reliability.

Future Potential Applications

The potential applications of this technology extend beyond wind energy. In solar farms, for example, thermal imaging can be used to detect overheating in inverters and electrical connections, preventing potential fire hazards. In hydropower facilities, similar monitoring techniques can be applied to assess electrical equipment performance and identify inefficiencies. In battery energy storage system applications, targeted presets with alerting software settings will allow a specific battery to be identified and isolated prior to these temperature issues spreading heat to nearby batteries. These early-stage warnings will prevent thermal runaway long before it begins. As renewable energy technology develops, AI-powered thermal imaging solutions are expected to improve reliability, safety, and operational efficiency. As more operators see the benefits of real-time thermal monitoring, these solutions could help improve the sustainability and resilience of energy infrastructure.

The Sytis TC-90 is a trademark of Sytis

Further Reading

- Severe, R. 2025. Applying continuous infrared camera technology and software at Puget Sound Energy. 19 February. sytis.com/blog/success-applying-continuous-infrared-camera-technology-and-software-at-pudget-sound-energy/ ■