Solar Farm and Wind Farm Monitoring

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Utility-scale renewable energy installations present a monitoring challenge that LoRa mesh is well suited to address. Solar farms covering hundreds of acres and wind farms spread across tens of square miles both require communications between dozens to thousands of distributed sensor points and a central SCADA (Supervisory Control and Data Acquisition) system - often in locations where wired infrastructure is cost-prohibitive and cellular coverage is inconsistent. Note that LoRa mesh is a latency-tolerant, best-effort monitoring layer; it is not a substitute for the time-critical control, protection, or polling functions of a primary SCADA system.

The Distributed Energy Asset Monitoring Problem

As an illustrative example, a 50 MW solar farm might consist of roughly 150,000 individual panels arranged in around 3,000 strings across about 400 acres (actual panel, string, and acre densities vary by project and module type). Per-string monitoring (current and voltage at the combiner box level) is standard practice, but per-panel monitoring - which enables the fastest detection of soiling, shading, delamination, and connection faults - requires a communications infrastructure that can reach individual panel-level optimisers or microinverters. Running Ethernet or fibre to each panel location is economically unviable; typical outdoor WiFi access points provide reliable coverage on the order of ~100 metres. LoRa kilometre-scale range with low power consumption makes it a practical fit.

Typical Monitoring Payloads

LoRa-connected sensor nodes at a solar farm may carry:

- **Per-string DC current and voltage:** Sampled at combiner boxes, transmitted every 5-15 minutes. String-level anomalies (shading, soiling, failed panel) are detectable as deviations from expected current at a given irradiance level.
- **Inverter fault alerts:** AC inverters typically have RS-485 Modbus interfaces. A LoRa gateway node running Modbus-to-LoRa translation can relay fault codes, AC output power, and temperature readings from multiple inverters over the mesh.
- **Meteorological stations:** Irradiance (pyranometer), ambient temperature, module temperature (contact sensor), wind speed, and humidity. These readings are essential for performance ratio calculations and fault discrimination (is a string underperforming due to a fault, or due to cloud cover?).
- **Perimeter security:** Motion sensors, gate contact sensors, and camera trigger relays can be integrated into the same mesh, eliminating the need for a separate security radio system.

Wind Farm Applications

Wind farms present different geometry than solar farms - turbines may be spaced 500 metres to 1 kilometre apart across ridgelines or open plains - but the monitoring requirements are analogous. Key data points include vibration (to detect blade imbalance or bearing wear), nacelle temperature, yaw error (misalignment with wind direction), and blade pitch angle. LoRa nodes mounted in nacelles or at tower bases can relay this data over a mesh to the wind farm control building as non-safety-critical, supplemental telemetry. Turbine protection functions and primary condition monitoring must remain on the OEM SCADA/condition-monitoring system - the LoRa layer adds extra sensor modalities, it does not replace the protective or control instrumentation.

LoRa Mesh as SCADA Backhaul

In most installations, LoRa mesh serves as the last-mile communications layer connecting field sensors to the farm primary SCADA system, rather than replacing SCADA itself. A typical architecture places a gateway node at the SCADA server room that bridges LoRa mesh packets to the farm local network. After protocol translation, the SCADA system can receive latency-tolerant monitoring data from field sensors via the LoRa gateway much as it would from any other field device. This works only for non-time-critical monitoring data: LoRa's multi-second latency and best-effort delivery make it unsuitable for time-critical SCADA polling, real-time control, or protection functions, which must stay on the plant's primary instrumentation and control network.

Protocol translation is a key integration consideration. Many industrial sensors and inverters speak Modbus RTU (RS-485) or Modbus TCP, while SCADA systems may expect DNP3, IEC 61850, or proprietary protocols. Gateway nodes running lightweight protocol translation firmware (e.g., Node-RED running on a Raspberry Pi paired with a LoRa HAT) can handle Modbus-to-MQTT or Modbus-to-DNP3 translation at the edge.

Range Advantage Over WiFi

For a 500-acre solar farm, covering the entire site with WiFi would, as a rough estimate, require on the order of 20-30 access points with wired backhaul (Ethernet runs across acres of solar field; the exact count depends on AP placement and the site). A LoRa mesh covering the same area might require roughly 4-8 infrastructure nodes (an estimate that assumes line-of-sight, reasonable mounting height, and a suitable spreading factor), typically mounted on the fence perimeter or on elevated positions within the array. LoRa at SF10 often achieves roughly 1-2 km ground-level range in flat terrain - depending on antennas, mounting height, and clutter - enough to cover most farms with 2-3 hops, though real-world range varies and should be confirmed by on-site testing.

Integration Considerations

Renewable energy installations are subject to grid interconnection agreements and utility cybersecurity requirements. NERC CIP applies to the Bulk Electric System (generally larger generation and transmission assets); smaller behind-the-meter and distribution-interconnected solar (commercial and industrial rooftop, community solar) is typically below the applicability threshold and faces fewer compliance requirements. Before deploying a LoRa mesh on a utility-scale installation, operators should confirm that the mesh communications layer meets any applicable cybersecurity requirements, particularly regarding network isolation (the LoRa mesh should not be bridgeable to the plant control network without appropriate firewall controls), encryption (Meshtastic supports AES-256 encryption at the mesh layer), and access logging.

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