Solar Energy Anomaly Detection System

Overview

The anomaly detection system runs as a background scheduler job. It processes incoming EnergyGenerationRecords in real-time to identify irregularities in solar unit performance. To ensure efficiency, the system only analyzes **new records** (processedForAnomaly: false) and marks them as processed immediately after analysis.

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1. Anomaly Types & Detection Logic

The system currently detects **4 distinct anomaly types**. Below is the breakdown of the logic used for each.

1. Zero Generation (ZERO_GENERATION)

Description: Detects when a solar unit is producing zero or negligible energy during active daylight hours.

- **Detection Logic:**
    - **Time Window:** 06:00 to 18:00 UTC (Daylight Hours).
    - **Condition:** energyGenerated < 1 kWh.
    - **Code Reference:** ZERO_GENERATION function.
- **Why this matters:** Indicates a complete system failure, inverter disconnection, or grid outage during peak production time.

2. Significant Generation Drop (GENERATION_DROP)

Description: Identifies when the current performance significantly deviates from the unit's recent historical average.

- **Detection Logic:**
    - **Historical Baseline:** Calculates average generation for the past 7 days (excluding the immediate last 24 hours to avoid partial data bias).
    - **Current Metric:** Calculates average generation for records created in the last 24 hours.
    - **Threshold:** Triggered if Current Average < (Historical Average * 0.5).
    - **Constraint:** Requires at least 10 historical records to establish a valid baseline.

- **Why this matters:** Indicates performance degradation due to environmental factors (heavy soiling, new shading) or component wear.

3. Abnormal Peak (ABNORMAL_PEAK)

Description: Detects energy readings that physically exceed the solar unit's rated capacity, suggesting sensor errors or dangerous surges.

- **Detection Logic:**
    - **Threshold:** Triggered if energyGenerated > (Unit Capacity * 1.2).
    - **Code Reference:** ABNORMAL_PEAK function.
- **Why this matters:** These readings are likely data artifacts (sensor calibration errors) or could indicate a voltage surge requiring safety checks.

4. Night Generation (NIGHT_GENERATION)

Description: Detects energy readings during hours when the sun is down.

- **Detection Logic:**
    - **Time Window:** 19:00 to 05:00 UTC.
    - **Threshold:** Triggered if energyGenerated > 0.5 kWh.
- **Why this matters:** Usually indicates a timestamp synchronization issue (server vs. device time) or "sensor drift" where the device generates noise signals.

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2. Severity Classification

We classify anomalies into two levels to help administrators prioritize their response.

Level	Color Code	Triggered By	Definition
CRITICAL	Red	ZERO_GENERATION	**Immediate Action Required.** The system is completely offline during production hours, resulting in direct financial/energy loss.
WARNING	Yellow	GENERATION_DROP ABNORMAL_PEAK NIGHT_GENERATION	**Investigation Needed.** The system is working, but data is inaccurate or performance is suboptimal. Does not usually require emergency intervention.

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3. Technical Implementation Notes

- **Scheduler:** The AnomalyDetection function is designed to be idempotent. It uses Promise.all to run checks in parallel for performance optimization.
- **Optimization:** A flag processedForAnomaly is used on EnergyGenerationRecords. The scheduler only fetches records where this is false, preventing the system from re-analyzing old records.
- **Timezones:** All logic currently assumes UTC time (getUTCHours).