Electrical & Power Control Interfaces

AOFS defines the electrical and power control architecture to **safely operate pumps, valves, and irrigation loads** under any power source. It is designed to **ensure fail-safe operation, energy efficiency, and compliance with AOFS standards**, independent of whether the farm uses grid, generator, or solar power.

1. Core Power Principles

- AOFS is **power-source agnostic**: it works with grid, generator, solar, or hybrid systems.
- Controllers must enforce **fail-safe operation** for irrigation and actuation regardless of the power source.
- Systems must support **safe shutdowns** in case of power anomalies or failures.
- AOFS may track **energy consumption of pumps and actuators** to support optional logging, reporting, and operator awareness. **Recommended for off-grid or weak-grid farms, but not required** for farms with stable grid power.

2. Optional Solar Integration

AOFS supports optional solar monitoring for farms that want to optimize energy usage:

- **Level 1 – Minimal Monitoring (Recommended for off-grid / weak-grid farms)**
  - Field Controllers may monitor battery voltage and current.
  - Supports reliable irrigation operation when solar/battery power is used.
  - Fully optional for farms with stable grid or generator power.
- **Level 2 – Integrated Monitoring (Optional Advanced Module)**
  - Controllers can read solar generation metrics from panels/inverters via standard protocols (e.g., Modbus, MQTT, RS485).
  - Enables dynamic irrigation scheduling based on energy availability.
  - Supports advanced PUE analytics and reporting.
  - Completely optional — AOFS compliance does **not depend** on it.

3. Optional Energy-Aware Operation

- AOFS controllers **may** measure power consumption of pumps, valves, and other actuators while running.
- Controllers **may** estimate battery drain or energy availability for upcoming scheduled irrigation events.
- AOFS supports **event prioritization**:
  - Each scheduled irrigation or actuator event can be assigned an **urgency or importance level** by operators.
  - If insufficient energy is available:
    - Low-priority events can be **delayed or skipped**.
    - High-priority events are executed **as soon as sufficient energy is available**.

        - Optional alerts notify operators of skipped or delayed events.
- AOFS can provide **proactive scheduling guidance** (optional):
    - When the operator attempts to schedule an irrigation or actuator event, the system **may simulate expected energy usage and availability**.
    - The controller can then **warn the operator**: "Based on current energy estimates, you will most likely not have enough power for this event."
    - Operators may then adjust **priority, timing, or load** before committing the schedule.
- AOFS can provide **real-time anomaly detection** (optional):
    - If an event starts drawing **more power than usual**, the controller can alert operators.
    - Examples include:
        - Clogged pipes increasing pump load.
        - Valves partially stuck or leaking.
        - Unexpected actuator malfunction.
    - Provides actionable insight so operators can **investigate, correct issues, or adjust schedules**.
- All energy measurements, prioritization decisions, anomaly alerts, and resulting operational logs **may be recorded** for later analysis:
    - Enables visualization of energy usage and event execution history.
    - Helps operators determine if **additional batteries, solar panels, or load rescheduling** are needed.

4. Optional Generator Integration

AOFS supports optional generator-based backup to supplement energy supply for irrigation and other actuator events.

- **Automatic Generator Start (Optional)**
    - If a compatible generator with remote start/stop interface is available, the system **may automatically start** it when energy is insufficient for scheduled events.
    - Remote interfaces can include: relay, Modbus, CAN, or other compatible protocols.
    - Automatic start **requires safety interlocks**:
        - Prevent start during maintenance.
        - Prevent overload or dry-run conditions.
    - All starts/stops are logged for audit and analysis.

- **Manual Alert Generator Start (Optional)**
    - If a generator exists but cannot be automatically started, AOFS can **alert operators** when battery or energy is insufficient.
    - Example alert: "Warning: scheduled irrigation may fail. Turn on generator now!"
    - Operators can then **manually start** the generator.
    - The system continues to monitor energy availability and advise operators on priority and schedule adjustments.

- **Integration with Event Prioritization**
    - Both automatic and manual generator options respect **event urgency**.
    - Low-priority irrigation can be delayed, while high-priority events trigger generator use.
    - Energy logs and operator actions are **recorded** to support farm management decisions and future optimization.

- **Optional Analytics**
    - Tracks generator runtime, energy supplied, and efficiency.

    - Helps farm managers decide if **additional batteries, solar panels, or load rescheduling** are needed.

4. Implementation Guidelines

- AOFS compliance does **not require any specific power source, monitoring, or energy-aware operation**.
- Optional monitoring modules should follow AOFS **data logging and offline-first principles**.
- All controllers and modules, regardless of power source, **must enforce local fail-safes** for pumps, valves, and critical irrigation operations.

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