Valves, Pumps & Actuation

The **Actuation Layer** defines all AOFS-compliant devices that perform actions on the farm. This includes irrigation pumps, valves, gates, and optionally generator start/stop controls.

All actuators must comply with AOFS **safety, logging, and operational rules**, even if the system operates offline.

1. Core Actuators

- **Pumps**
  - Controls water delivery from sources to storage tanks or irrigation manifolds.
  - Must support:
    - Start/stop commands from Field Controller.
    - Safety interlocks (tank FULL/LOW, low voltage, pressure limits).
    - Optional energy-aware operation: integrate with Power & Energy Sensors to adjust schedule or warn operators.
- **Valves**
- Operate irrigation zones, distribution manifolds, or auxiliary water lines.
- Must support:
  - Open/close commands from Field Controller.
  - Flow or pressure monitoring feedback from Water Monitoring Sensors.
  - Fail-safe closure in case of errors, power loss, or critical alarms.
- **Optional Generator Start / Stop**
- See Optional Generator Integration.
- Can be automatic (remote start) or manual (operator alert).
- Must respect safety interlocks and event prioritization.

2. Actuation Control Principles

- **Local Authority:**
  - All critical actuation commands are decided by the Field Controller.
  - No remote system may bypass fail-safes or directly actuate pumps/valves.
- **Fail-Safe Operation:**
  - Hardware and software protections prevent flooding, over-irrigation, pump damage, or valve misoperation.
  - Actuators must respond to Sensors such as LOW/FULL tank switches, flow/pressure limits, and emergency stop signals.
- **Energy-Aware Operation (Optional):**
  - Actuators may integrate with Energy-Aware Operation Module.
  - Event execution can be:
    - Delayed or skipped if insufficient energy is available.
    - Prioritized based on urgency or operator-defined importance.
  - System may alert operators if an actuator is consuming **more power than expected**,

indicating possible maintenance needs (e.g., clogged pipe).

3. Scheduling & Automation

- **Event-Based Operation:**
  - Pumps and valves operate according to **scheduled irrigation events** defined in the Field Controller.
  - Can be triggered manually by operators or via automation rules.
- **Integration with Sensors:**
  - Actuators rely on Sensors & Environmental Monitoring for safe and efficient operation:
    - Soil moisture thresholds
    - Tank levels
    - Pressure and flow rates
    - Optional power measurements
- **Manual Override:**
  - Operators can manually actuate pumps or valves, respecting hardware safety interlocks.
  - Manual events are logged and visible to Farm/HQ controllers.

4. Logging & Documentation

- All actuator events **must be logged locally** on the Field Controller:
  - Event type (pump start/stop, valve open/close, generator start/stop)
  - Timestamp
  - Operator ID (if manual)
  - Relevant sensor readings at the time of actuation (flow, pressure, battery, energy)
- Logs are **synchronized with Farm and HQ Controllers** when connectivity is available.
- Supports analytics, energy assessment, and audit for compliance purposes.

5. Optional Modules & Extensions

- AOFS modules may define additional actuator types:
  - Greenhouse vents, fans, heaters, nutrient dosing pumps
  - Livestock feeders, water dispensers
  - Poultry egg collection or environmental actuators
- Any custom actuator must:
  - Integrate with Field Controller fail-safes.
  - Support logging and optional energy-aware prioritization.
  - Follow AOFS modular interface rules.

6. 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.
- All energy measurements, prioritization decisions, 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.
- Optional anomaly detection:
  - Alerts operators if an actuator consumes more power than expected (e.g., clogged pipe, stuck valve).

7. Manual Fallback Mode

AOFS supports **manual fallback operation** for farms without fully automated actuators.

- **Purpose:**
  - Ensure irrigation and critical farm operations can continue when automatic valves or pumps are unavailable.
  - Maintain safety, compliance, and event logging even with manual operation.
- **Operation:**
  - Field Controller generates **step-by-step instructions** for operators:
    - Which pump to switch on/off.
    - Which valve to set to open/closed or partial position.
    - Timing recommendations based on **irrigation schedule, soil moisture, tank levels, and weather conditions**.
  - Operators acknowledge each action in the system.
- **Energy-Aware Integration:**
  - If Energy-Aware Operation is active:
    - The controller calculates **available energy** for the scheduled events.
    - Alerts operators if performing the manual steps would **exceed available energy**.
    - Supports prioritization: some irrigation zones may be skipped or deferred according to urgency levels.
- **Logging & Documentation:**
  - All manual actions **must be logged**:
    - Operator ID

        - Action taken (pump/valve)
        - Timestamp
        - Relevant sensor readings at the time (tank level, flow, battery voltage, etc.)
    - Logs are synchronized with Farm/HQ controllers whenever connectivity is available.

- **Benefits:**
    - Allows farms to **comply with AOFS even with low-tech equipment**.
    - Ensures operators follow optimized schedules.
    - Enables full **auditing and analytics** later when automation is introduced.

8. References

- Sensors & Environmental Monitoring
- Electrical & Power Control Interfaces
- Operational Logic & Decision Hierarchy
- Hydraulic & Water Systems
- Optional Generator Integration
- Optional Energy-Aware Operation