In a real-life power station or industrial control system, the MPC (Model Predictive Control) controller would work with various actuators to eliminate anomalies. Based on code's context (voltage, current, and temperature control), here are the realistic control scenarios, required actuators, and how MPC would respond:

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1. Voltage Regulation (Vrms Anomalies)

Possible Anomalies: Overvoltage (>250V), Undervoltage (<210V)

Actuators Needed:

Tap-changing transformers (adjust turns ratio to regulate voltage)

Static VAR Compensators (SVCs) (inject/absorb reactive power)

Automatic Voltage Regulators (AVRs) (fine-tune generator excitation)

Switched capacitor banks (adjust reactive power compensation)

MPC Control Actions:

If **overvoltage** detected → Reduce tap position on transformer or command SVC to absorb reactive power.

If **undervoltage** detected → Increase tap position or switch in capacitor banks.

Example Scenario:

A sudden solar generation spike causes voltage to rise to 260V. MPC would:

Predict future voltage trajectory.

Calculate optimal tap change or SVC adjustment.

Send command to reduce voltage by 15V over 3 seconds.

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2. Current Control (Irms Anomalies)

Possible Anomalies: Overcurrent (>120A), Unbalanced currents

Actuators Needed:

Circuit breakers (trip if current exceeds safety limits)

Thyristor-controlled series compensators (TCSC) (adjust line impedance)

Load shedding controllers (disconnect non-critical loads)

Fault current limiters (superconducting/magnetic)

MPC Control Actions:

If **overcurrent** detected → Adjust TCSC impedance or shed 10% of loads.

If **asymmetry** detected → Rebalance phases using switched reactors.

Example Scenario:

A fault causes current to spike to 150A. MPC would:

Predict thermal overload risk.

Prioritize load shedding (e.g., disconnect HVAC systems).

Adjust TCSC to limit current to 110A within 2 seconds.

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3. Temperature Control

Possible Anomalies: Overheating (>80°C)

Actuators Needed:

Cooling pumps/fans (increase coolant flow rate)

Heat exchangers (activate additional cooling loops)

Load reducers (reduce current to lower Joule heating)

MPC Control Actions:

If temperature exceeds threshold → Ramp up cooling fans by 30% and derate power by 15%.

Example Scenario:

Transformer temperature hits 85°C due to prolonged overload. MPC would:

Predict thermal time constant.

Optimize cooling vs. power trade-off.

Command: `Cooling_Fan_Speed = 70%` + `Power_Limit = 85%`.

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4. Solar/Wind Integration (Renewable Fluctuations)

Actuators Needed:

Battery storage (BESS) (absorb/inject power)

Diesel generators (backup during low renewables)

Curtaiment controllers (reduce renewable output)

MPC Control Actions:

If solar drops suddenly → Dispatch BESS at 50kW for 5 minutes.

If wind gusts cause overvoltage → Curtail wind farm by 20%.

How Your MPC Code Maps to Real Control

Your code's adjustments (`ΔVrms`, `ΔIrms`) would translate to:

Code Output	Real-World Action	Actuator Command Example
`ΔVrms = -10V`	Lower transformer tap position	`Tap_Change = Tap_Position - 1`
`ΔIrms = -15A`	Shed 3 non-critical loads	`Load_Shed = [Load_12, Load_17]`

`ΔTemp = -5°C`	Increase cooling fan speed	`Fan_Speed = 60% → 75%`

Typical Anomaly Scenarios and MPC Response

Lightning Strike (Overvoltage):

- **Anomaly**: Vrms spikes to 280V.
- **MPC**:
    - Step 1: Trip surge arrestors (fast protection).
    - Step 2: Adjust SVC to absorb 50MVAR.
    - Step 3: Set transformer tap to -5%.

Short Circuit (Overcurrent):

- **Anomaly**: Irms = 200A (200% rated).
- **MPC**:
    - Step 1: Open circuit breaker in 50ms.
    - Step 2: Isolate faulted section.
    - Step 3: Restore power via alternate feeders.

Heat Wave (Overheating):

- **Anomaly**: Temp = 90°C (10°C above limit).
- **MPC**:
    - Step 1: Derate power to 80%.
    - Step 2: Activate auxiliary cooling.

Step 3: Notify operator for maintenance.

Key Requirements for Real Implementation

Hardware Actuators:

Programmable logic controllers (PLCs) to execute MPC commands.

Sensors with <1% error for feedback (PTs, CTs, RTDs).

Safety Layers:

Primary Protection: Fast-acting relays (independent of MPC).

Secondary Control: MPC for optimal adjustments.

Communication Protocols:

Modbus/TCP or **IEC 61850** to send commands to actuators.

OPC UA for sensor data aggregation.

Enhancing Simulation

To make demo more realistic:

Add actuator delay models (e.g., tap changers take 5s to respond).

Simulate communication latency (50-100ms for SCADA).

Include actuator saturation limits (e.g., `Fan_Speed ∈ [0%, 100%]`).