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SUPERVISORY CONTROL FOR FLEXIBLE AR OPERATION

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Advanced Reactor and the Need for Advanced Control Systems Workshop

INTRODUCTION

Flexible Operation of Advanced Reactors

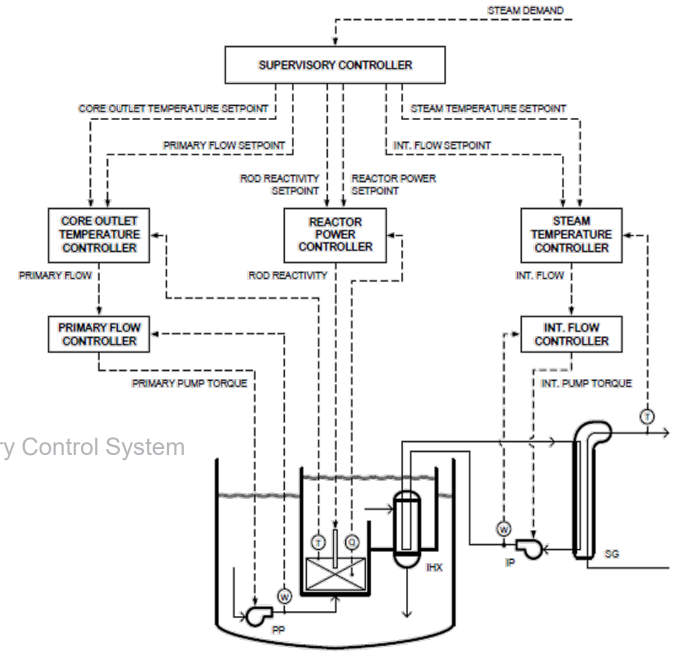
- ARs will be deployed to meet the diverse demands of the power grid in future energy markets, including:
  - Base load
  - **Load fluctuations**
  - **Changes in operation modes**
    - Power generation, refueling, shutdown, heat up & cool down, etc.
  - **Unexpected events**
    - Such as sudden grid disconnections upon request
- Flexible operation of ARs might be successful with:
  - Supervisory control for the load-following operation
  - Requirements & procedures for the mode changes
  - Strategic actions for the events

SUPERVISORY CONTROL SYSTEM

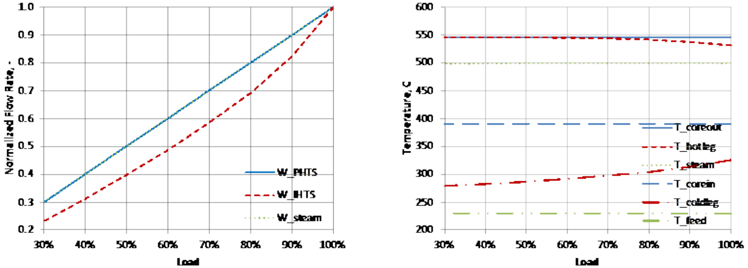
Load-following Operation

- Provides overall coordination of the actuators to automatically regulate the process variables so that the performance goals are safely met during the operation

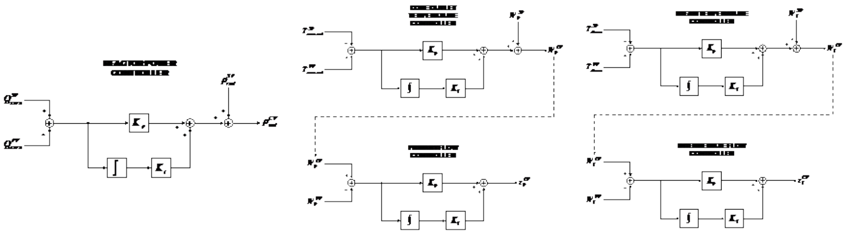
- Operates through the **hierarchical structure**:
  - Demand
  - Set-points, or **load schedule** (steady-state)
  - **Controllers** (dynamic)



Supervisory Control System



Load Schedule

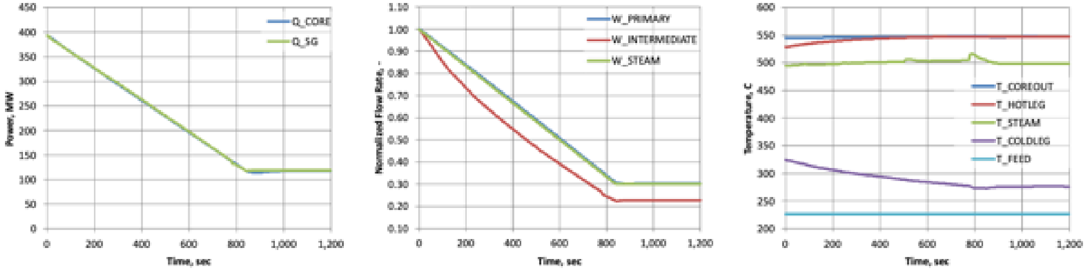


Controllers

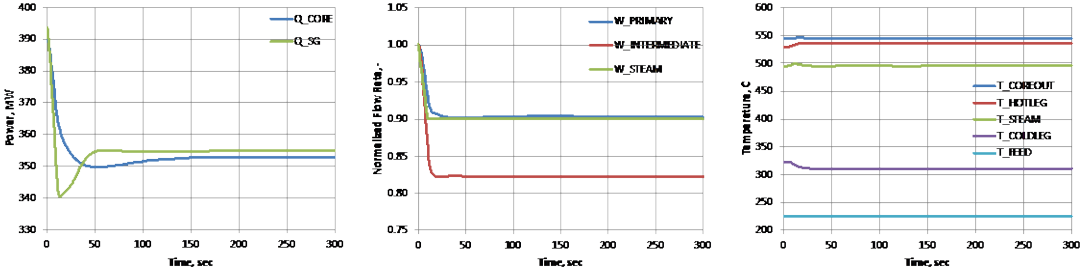
SUPERVISORY CONTROL SYSTEM

Example – Power Operational Transients

- System responses for **5%/min ramp** and 10% step load changes



5%/min Ramp Load Change



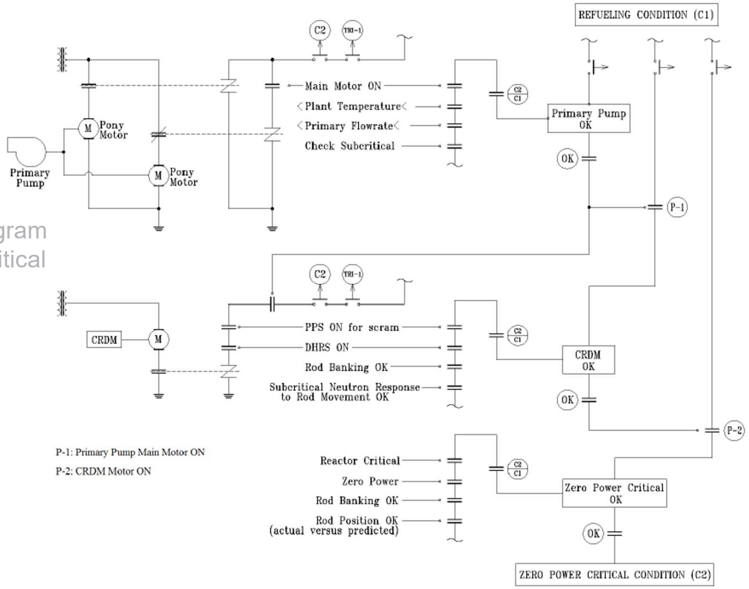
10% Step Load Change

OPERATING REQUIREMENTS & PROCEDURES

Mode Changes

- Over the plant lifetime, transitions may occur regularly or irregularly to meet the mission of plant
- PCS shall include the dedicated control system and logic to accomplish the mode change
- An example:

Procedure Logic and Wiring Diagram from Refueling to Zero-power Critical



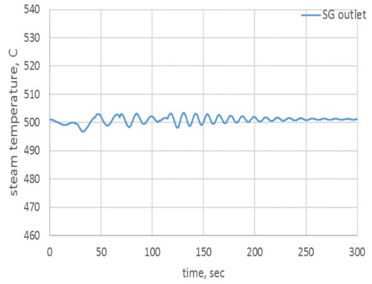
Stage	System	IF Condition	THEN Condition
1	Primary Pump	If operator push the buttons TR1-1 and C2	Then main motor is energized for the primary pump
		If main motor is energized	Then pony motor is de-energized
		If pony motor is de-energized	Then plant temperature is checked
		If plant temperature is within the allowed limit	Then primary flowrate is checked
		If primary flowrate is within the allowed limit	Then reactor criticality is checked
		If reactor is subcritical	Then the automated procedure asks for operator manual confirmation to proceed to Stage 2
2	Control Rod Drive Mechanism	If the operator issues a manual OK	Then PPS is checked
		If PPS is ready for SCRAM	Then DHRS is checked
		IF DHRS is working	Then CRDM motor is energized
		If CRDM is energized	Then control rods banking is checked
		If control rods banking is OK	Then subcritical neutron response to control rod movement is checked
		If subcritical neutron response is OK	Then the automated procedure asks for operator manual confirmation to proceed to Stage 3
3	Reactor Core	If the operator issues a manual OK	Then control rod withdrawal moves to make the reactor critical
		If reactor critical is achieved	Then check the reactor power
		If reactor power is zero	Then check the actual control rod position
		If difference between actual and predicted control rod positions is within the allowed limit	Then the automated procedure asks for operator manual confirmation to C2

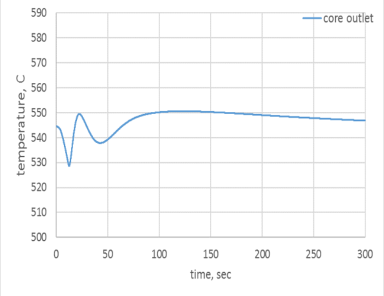
STRATEGIC ACTIONS FOR UPSET EVENTS

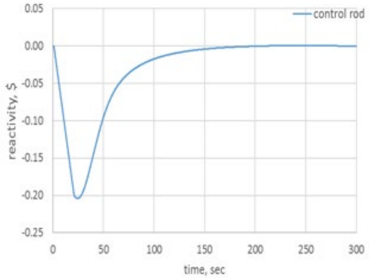
Sudden Grid Disconnection (Large Load Rejection)

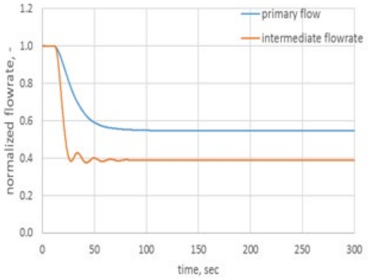
- Provides capability to continue electric power generation without scram in the event of load rejection up to and including a disconnect from the grid
  - Through coordination of RPCS, SBCS, and TCS

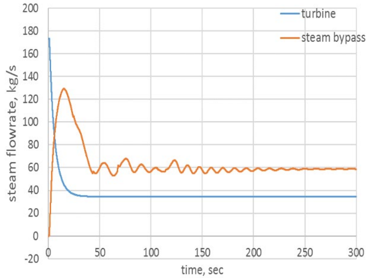
- Provides capability to run back to house load for the complete load rejection event, then quickly resume full load electric generation.
- Serves to improve plant availability, provides an added level of insurance against the station blackout.

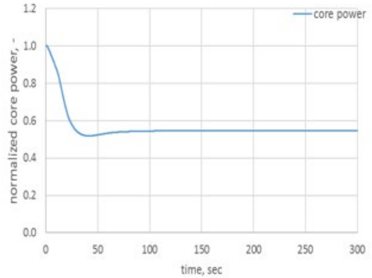












Full Load Rejection

CONCLUSION

- ARs will be deployed to meet the diverse demands of the power grid in future energy markets, including *base load*, *load fluctuations*, *change in operating modes*, and *unexpected events*.

- For the flexible operation of ARs to meet the diverse demands, the plant control system should operate with the supervisory control feature, dedicated control logic for mode changes, and prepared procedures to be performed in case of upset events.

BACKUP SLIDES