| Lesson Title: Integrated Control System | Lesson Number: 326-9 |
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1.0     References
       1.1     B&W Cross Training Manual – Chapter 9
       1.2     ICS Technical Manual
       1.3     WNP-1 Training Material
2.0     Training Aids
       2.1     Transparency Package for Lesson 326-9
       2.2     Simulator (ICS Stations)

A-9

3.0 Objectives
- 3.1 Explain the function of the following ICS subassemblies
  - 3.1.1 Unit Load Demand
  - 3.1.2 Integrated Master
  - 3.1.3 Feedwater Demand
  - 3.1.4 Reactor Demand
- 3.2 Define the following terms:
  - 3.2.1 Track
  - 3.2.2 Runback
  - 3.2.3 Cross limits
- 3.3 With the use of a block diagram of the ICS, discuss the following:
  - 3.3.1 Normal power increase and decrease
  - 3.3.2 Runbacks
  - 3.3.3 Placing any ICS hand/auto station in manual
  - 3.3.4 Load rejection
  - 3.3.5 Turbine trip
  - 3.3.6 Reactor trip

4.0 Presentation
- 4.1 Introduction
  - 4.1.1 Function of ICS – matches generated Electrical megawatts with demanded electrical megawatts.
  - 4.1.2 Accomplishes its function by simultaneous control of four subassemblies
    - 4.1.2.1 Unit Load Demand – Set point generation
    - 4.1.2.2 Integrated Master – Steam header pressure control
      - 4.1.2.2.1 Turbine governor valve control
      - 4.1.2.2.2 Turbine bypass valve control
      - 4.1.2.2.3 Atmospheric valve control
      - 4.1.2.2.4 Translation of MW demand into FW demand and RX demand
    - 4.1.2.3 FW Demand
      - 4.1.2.3.1 Startup and Main FW valve control
      - 4.1.2.3.2 MFP speed control
    - 4.1.2.4 Reactor Demand
      - 4.1.2.4.1 Reactor power control
      - 4.1.2.4.2 $T_{avg}$ control
  - 4.1.3 Basic Control Loop
    - 4.1.3.1 Set point
    - 4.1.3.2 Actual value of parameter
    - 4.1.3.3 Error signal
    - 4.1.3.4 Control Device

4.2 Unit Load Demand

    4.2.1 Function – Set point generation for remainder of ICS (**Objective #1**)

    4.2.2 Manual/Automatic station (Unit Master)

        4.2.2.1 Automatic – originally intended for automatic control by dispatcher – not used.

        4.2.2.2 Manual – Operator inputs value of desired load

            4.2.2.2.1    0 to 100% of MW transmitter output

            4.2.2.2.2    At full load, ULD may not indicate 100%

            4.2.2.2.3    WNP-1, ULD is MW input from 0 to 1350 MWe

    4.2.3 Rate Limiter

        4.2.3.1 Operator Input

        4.2.3.2 ½% to 5 %/minute of full load value (i.e., 6.75 MWe/minute to 67.5 Mwe/minute.

        4.2.3.3 Limit is reduced to ¾ % per minute if the output of the ULD is less than 15% demand

    4.2.4 Low Load Limit

        4.2.4.1 Both the low and high load limits were originally intended to limit the control range of the dispatcher.

        4.2.4.2 Operator Input signal

        4.2.4.3 Low load limit is normally set at 15% because the unit is at operating $T_{avg}$, the turbine is on line, and the plant is approaching stability.

        4.2.4.4 Some plants set the Low Load Limit at zero which allows automatic control of turbine load at lower power levels.

        4.2.4.5 If the out put of the ULD is less than the Low Load Limit, a + 100% signal is supplied to the $\Sigma$, the output of the ULD is returned to the Low Load Limit at the operator selected (input) rate. The output of the Unit Master "tracks" the load via the dotted line, so the $\Sigma$ does not change when the condition clears.

        4.2.4.6 High Load Limit

        4.2.4.7 Operator Input signal.

        4.2.4.8 Normal set point is 100%

        4.2.4.9 Can be used to limit load demand, e.g., with one main feed pump in service, the high load limit may be reduced to 60% to limit demand to within the capacity of one pump.

        4.2.4.10      If the output of the ULD is greater than the high load limit, a –100% signal is input to the $\Sigma$, the output of the ULD is returned to the high load limit at the operator selected (input) rate. The output of the Unit Master "tracks" the load via the dotted line, so the $\Sigma$ does not change when the condition clears.

4.2.5   Trace signal from the output of the ULD to the Integrated Master
        4.2.5.1 Operator inputs desired rate of load change setpoint into the rate unit.
        4.2.5.2 Operator initiates by pushing buttons on the Unit Master load increase or decrease.
        4.2.5.3 Assuming that the signal is > than the LLL and < HLL, the value of load passes through the Summer ($\Sigma$) to rate unit.
        4.2.5.4 The output of the rate unit is an increasing or decreasing signal, which is changing at the operator input value.
        4.2.5.5 The load demand signal enters the Integrated Master.

4.2.6   Track
        4.2.6.1 Definition – the full automatic control of the ICS has been inhibited. **(Objective #2)**
        4.2.6.2 In Track, Mwe becomes MWd.
        4.2.6.3 Tracking Conditions – Table 9.2, page 9-25
                4.2.6.3.1   Reactor trip – cannot control reactor power or $T_{avg}$
                4.2.6.3.2   Generator Output breakers open – cannot control generator load
                4.2.6.3.3   EHC in manual
                        4.2.6.3.3.1 Turbine in other than ICS control – cannot control governor valves
                        4.2.6.3.3.2 Turbine trip – cannot control turbine governor valves – EHC station reverts to manual on turbine trip.
                4.2.6.3.4   Diamond rod control in manual – cannot control reactor power or $T_{avg}$
                4.2.6.3.5   Major hand/automatic control stations in manual
                      4.2.6.3.5.1 Reactor Demand
                      4.2.6.3.5.2 SG/Rx Demand (part of IM)
                      4.2.6.3.5.3 Both FW demands in manual
                4.2.6.3.6   Feedwater flow greater than feedwater demand by 5% (205 units only)
                4.2.6.3.7   Reactor or Feedwater cross limits
        4.2.6.4 In track, the rate of load change is 20% per minute
        4.2.6.5 Track drives the ULD output to the current value of generated Megawatts.
        4.2.6.6 When tracking condition clears, the demanded load value must be re-entered by the operator.
        4.2.6.7 Tracking Indications
                4.2.6.7.1   Annunciator in the control room
                4.2.6.7.2   Both the manual and automatic lights on the Unit Master are energized.

4.2.7 Tracking Example

    4.2.7.1 Place turbine in manual

    4.2.7.2 Open the governor valves ☞ steam flow through the turbine increases ☞ MW (e) increases.

    4.2.7.3 Increase in MW(e) is supplied to FW demand and RX demand at a rate of 20%/minute

4.2.8 Runbacks

    4.2.8.1 Definition – the automatic reduction in load due to a loss of necessary generation equipment **(Objective #2)**.

    4.2.8.2 List runbacks – Table 9.1, page 9-24.

    4.2.8.3 Runback inputs

        4.2.8.3.1 Variable rates

        4.2.8.3.2 Runback input into Unit Master – prevents MW demand from exceeding runback limit.

    4.2.8.4 If the ULD output exceeds the runback limit, a second runback signal will be immediately generated.

    4.2.8.5 Runback Example

        4.2.8.5.1 Assume the unit is at 100%

        4.2.8.5.2 A rod drops generating the asymmetric rod runback.

        4.2.8.5.3 A value of $-100\%$ will be transferred into the $\Sigma$, so its output will drop to zero.

        4.2.8.5.4 A rate of 30% per minute will be automatically transferred into the rate unit

        4.2.8.5.5 MW demand will start to decrease at a rate of 30%/minute.

        4.2.8.5.6 The output of the Unit Master "tracks" the load via the dotted line, so the $\Sigma$ does not change when the condition clears.

        4.2.8.5.7 The ICS will reduce load to 60% at 30% per minute.

4.2.9 Frequency Correction

    4.2.9.1 Compensates for speed error signal in EHC

    4.2.9.2 Increases or decreases demand as long as load limits are not in effect.

    4.2.9.3 Frequency error not in effect during runbacks or tracking conditions.

    4.2.9.4 Circuit operation

        4.2.9.4.1 Setpoint of 60 hertz

        4.2.9.4.2 If frequency drops below 60 hertz, a + output from the $\Delta$ will result.

        4.2.9.4.3 The + signal will be added to the output of the rate unit in the $\Sigma$ to increase demand signal.

        4.2.9.4.4 Frequency > 60 hertz, opposite signals.

4.2.10 ULD Operations
        4.2.10.1      Load Increase
        4.2.10.2      Load Decrease
        4.2.10.3      Track
        4.2.10.4      Runbacks

4.3     Integrated Master

4.3.1    Functions (**Objective # 1**)

    4.3.1.1 Controls turbine load

    4.3.1.2 Controls 22 turbine bypass and atmospheric dump valves.

    4.3.1.3 Compensates for changes in plant efficiency.

    4.3.1.4 Performs 1 through 3 by monitoring steam header pressure

    4.3.1.5 Translates MWd into FWd and RXd.

4.3.2    Turbine Load Control

    4.3.2.1 The turbine is treated like a BACK PRESSURE REGULATOR.

    4.3.2.2 Circuitry.

        4.3.2.2.1   MW error – Actual MWs are compared with MWd in a $\Delta$ amplifier.

        4.3.2.2.2   MW error is summed with header pressure setpoint in a $\Sigma$ amplifer. Header pressure setpoint is an operator input = 1035 psig

        4.3.2.2.3   The setpoint, as modified by megawatt error is supplied to the pressure error circuit ($\Delta$) which compares setpoint and actual header pressure

        4.3.2.2.4   Output of pressure error circuitry controls turbine governor valve position.

    4.3.2.3 Load Increase

        4.3.2.3.1   MWd from ULD is increased

        4.3.2.3.2   MWd > MW generated ☞ - MW error

        4.3.2.3.3   –MW error is summed ($\Sigma$) with header pressure setpoint. Header pressure setpoint is reduced. (1% MW error results in a setpoint change of 12 psi).

        4.3.2.3.4   The pressure error amplifier ($\Delta$) compares the reduced header pressure setpoint with actual header pressure resulting in a + output.

        4.3.2.3.5   A + output causes the turbine governor valves to open to reduce "header pressure."

        4.3.2.3.6   Load increases because steam flow through the turbine has increased.

4.3.2.4 Load Decrease

        4.3.2.4.1   MWd from the ULD is decreased.

        4.3.2.4.2   MWd < MW generated ☞ + MW error

        4.3.2.4.3   + MW error is summed ($\Sigma$) with header pressure setpoint. Header pressure setpoint is increased.

        4.3.2.4.4   The pressure error amplifier ($\Delta$) compares the increased header pressure setpoint with actual header pressure resulting in a − output.

        4.3.2.4.5   The − output causes the turbine governor valves to close to increase header pressure.

        4.3.2.4.6   Load decreases because steam flow through the turbine has decreased.

4.3.3    Turbine load control during tracking conditions.

    4.3.3.1 Header pressure setpoint modifications are prevented by Transfer Relay, $T_2$, after 100-second time delay.

    4.3.3.2 The purpose of the 100-second time delay is to allow enough time for runback signals to be completed should a tracking condition occur during a runback.

    4.3.3.3 Tracking example

        4.3.3.3.1   Diamond Station to manual ☞ TRACK

        4.3.3.3.2   Pull rods ☞ increase in reactor power.

        4.3.3.3.3   Increased reactor power ☞ more energy deposited into OTSGs.

        4.3.3.3.4   With fixed turbine valve position, the increased energy ☞ header pressure increase.

        4.3.3.3.5   The pressure error amplifier ($\Delta$) now compares an unmodified setpoint with the increased header pressure, and a + error results.

        4.3.3.3.6   The + error opens turbine valves to lower header pressure, and load increases.

        4.3.3.3.7   The ULD, via Transfer Relay $T_1$, sends MW(e) as MWd to remainder (FWd) of ICS.

4.3.4    Megawatt Demand Modification

    4.3.4.1 Function − to allow the rapid achievement of turbine load.

    4.3.4.2 Circuitry − Pressure error modifier ($\Delta$) which receives unmodified header pressure setpoint and actual header pressure as inputs. It sends an output to a summer($\Sigma$) in the Integrated Master.

    4.3.4.3 Circuitry will allow "excess" energy removal during up power maneuvers and "decreased" energy removal during down powers. Called a "kicker" signal by some.

4.3.4.4 Load Increase
    4.3.4.4.1  Turbine reaches new load value first, at the sacrifice of header pressure.
    4.3.4.4.2  Header pressure < setpoint results in a + pressure error modifier output to the $\Sigma$.
    4.3.4.4.3  The + error is added to MWd in the $\Sigma$ to increase the signal to the Rx and FW to restore header pressure.

4.3.4.5 Load Decrease
    4.3.4.5.1  Turbine reaches new decreased load value first ☞ header pressure increases.
    4.3.4.5.2  Header pressure > setpoint ☞ - pressure error modifier output to $\Sigma$.
    4.3.4.5.3  The − error is subtracted from MWd in the $\Sigma$ to decrease the signal to the Rx and FW to restore header pressure.

4.3.5  Bypass and Dump valve control
    4.3.5.1 Controls 22 valves
        4.3.5.1.1  Bypass valves – 6 valves- 18.5% capacity
        4.3.5.1.2  Bank 2 Atmospheric Dumps – 4 valves – 19.6%
        4.3.5.1.3  Bank 3 Atmospheric Dumps – 4 valves – 19.6%
        4.3.5.1.4  Bank 4 Atmospheric Dumps – 4 valves – 19.6%
        4.3.5.1.5  Bank 5 Atmospheric Dumps – 4 valves – 19.6%
    4.3.5.2 Circuitry
        4.3.5.2.1  Unmodified header pressure setpoint and actual header pressure supply the Pressure Error (valves) $\Delta$ amplifier.
        4.3.5.2.2  Bias values which are subtracted from error signal
        4.3.5.2.3  Transfer Relays (3 through 7) which control the value of bias.
        4.3.5.2.4  Hand/Auto station for the bypass valves (used during plant cooldowns)
        4.3.5.2.5  Condenser interlocks.
            4.3.5.2.5.1 Low Vacuum
            4.3.5.2.5.2 Low Circulating Water flow
    4.3.5.3 Bias Values
        4.3.5.3.1  Turbine trip values
            4.3.5.3.1.1 Maintain 0% power $T_{avg}$ prior to criticality
            4.3.5.3.1.2 Dissipates Reactor and RCP energy prior to turbine loading

4.3.5.3.2 "Normal" values – allow for an independent relief function for valves. Normal bias selected when:

4.3.5.3.2.1 Turbine bypass valves are closed ~~AND~~ *AND* *Pressure*

4.3.5.3.2.2 ~~Pressure error < 10 psi and~~ ULD > 15%   *Error < 10*

*OR*

4.3.5.3.3 Reactor Trip Biases

4.3.5.3.3.1 Minimize cooldown following a reactor trip by increasing header pressure.

4.3.5.3.3.2 Normal pressurizer level is 220 inches

4.3.5.3.3.3 5 inches level decrease per 1°F temperature change

4.3.5.3.3.4 601°-550° = 51°F X 5 inches = 255 inch contraction

4.3.5.3.3.5 220 inches – 255 inches = -35 inches in pressurizer.

4.3.5.3.3.6 Increase bias on reactor trip so that RCS temperatures decrease to only 567°F

4.3.5.3.3.7 601° - 567° = 34° X 5 inches = 170 inches contraction

4.3.5.3.3.8 220 inches – 170 inches = 50 inches in the pressurizer.

4.3.6 *Summary of Valve Bias Operation –* *when the plant reaches 550°F during a heatup, the turbine bypass valves will open to maintain header pressure at 1035 psig. The reactor is taken critical, and power is escalated. As the energy in the RCS is increased, the bypass valves open wider to dissipate the energy to the condenser. At approximately 8% power, the turbine is accelerated to 1800 rpm and loaded. This parallel steam flow path tends to decrease header pressure which, in turn, decreases the error signal to the bypass valves, and the valves start to close. When the turbine bypass valves are closed, the turbine is placed in ICS control. If ULD output is > 15% and the header pressure error is < 10 psi, then the "Normal" bias values are selected.*

4.3.7 Plant Efficiency Compensation

4.3.7.1 Compensates for small MW(e) errors during steady state operation.

4.3.7.2 Circuitry

4.3.7.2.1 Calibrating integral receives MW error.

4.3.7.2.2 Integral output to variable gain and summer.

4.3.7.2.3 Summer is dominant at low loads, variable gain dominate at high loads.

4.3.7.2.4 Blocked when load is changing > 2% per minute.

4.3.8 SG-RX Master Hand/Auto Station

      4.3.8.1 Gives manual control of both FW and Rx

      4.3.8.2 Manual selected ☞ Track

      4.3.8.3 Blocks runback signals to FW and Rx

4.3.9 Feedwater/Reactor Signal Translation

      4.3.9.1 One to one translation for FW demand

      4.3.9.2 15% limit for the Rx demand

4.4 Feedwater Demand Subassembly

  4.4.1 Basic control loop

      4.4.1.1 Demand signal from Integrated Master

      4.4.1.2 Compared with FW flow in a $\Delta$ amplifier

      4.4.1.3 Flow error controls pump and valves

  4.4.2 Feedwater Temperature Correction

      4.4.2.1 Functions to maintain a constant Btu/lbm in exit steam

      4.4.2.2 Temperature program versus FW flow (Figure 9-5) is compared with actual FW temperature.

      4.4.2.3 If actual temperature < FW temperature limit (desired value), the gain of the variable gain unit is reduced to less than unity.

      4.4.2.4 If flow is reduced, the available energy in the OTSG will ensure superheated steam.

  4.4.3 $T_{avg}$ Modification

      4.4.3.1 Purpose – to allow FW to control $T_{avg}$ if the reactor is in manual.

      4.4.3.2 Circuitry

          4.4.3.2.1 Tavg error from Rx demand

          4.4.3.2.2 FW demand $\Sigma$

          4.4.3.2.3 FW Tavg control is prohibited if:

              4.4.3.2.3.1 OTSGs are on low level limit

              4.4.3.2.3.2 FW demands are in hand

          4.4.3.2.4 Tavg increases ☞ increase FW demand

          4.4.3.2.5 Tavg decreases ☞ decrease FW demand

          4.4.3.2.6 Heat transfer areas increases/decreases with FW flow, therefore Tavg can be controlled.

  4.4.4 Reactor to Feedwater Crosslimits

      4.4.4.1 Functions to maintain heat generation and heat removal equal. (**Objective 2**)

      4.4.4.2 Circuitry

          4.4.4.2.1 Sensed in RX Demand

          4.4.4.2.2 Rx demand > Rx power ☞ overcooling (FW demand and Rx demand are the same)

          4.4.4.2.3 Rx demand > Rx power ☞ + error

          4.4.4.2.4 5% is subtracted from error signal to avoid unnecessary cross limits.

          4.4.4.2.5 + error inverted ( -K)

4.4.4.2.6　– error subtracted from FW demand ☞ reduces FW flow

4.4.4.2.7　Rx demand < Rx power ☞ overheating

4.4.4.2.8　Rx demand < Rx power ☞ - error

4.4.4.2.9　5 % is added to error signal to avoid unnecessary cross limits

4.4.4.2.10　–error inverted (-K)

4.4.4.2.11　+ error added to FW demand ☞ increase FW flow.

4.4.5　Loop Feedwater Demands

4.4.5.1 Loop A FW Demand = FW demand x (gain of variable gain unit – normally 1/2)

4.4.5.2 Loop B FW Demand = FW demand – Loop A FW demand

4.4.6　Asymmetric RCS Flow Control

4.4.6.1 Purpose – ensures that heat removal is equal to heat deposition in each OTSG.

4.4.6.2 Circuitry

4.4.6.2.1　RCS loop flows

4.4.6.2.2　Δ amplifier

4.4.6.2.3　Σ

4.4.6.2.4　Input into Loop A FW demand variable gain unit

4.4.7　Loss of RCP Example

4.4.7.1 RCP in RCS Loop A trips

4.4.7.2 Runback signal to 75% at 50% per minute

4.4.7.3 Δ Amplifier in RCS flow circuitry changes gain of variable gain amplifier from ½ to 1/3.

4.4.7.4 Loop A FW demand = FW demand time gain = (75%) (1/3) = 25%

4.4.7.5 Loop B FW demand = FW demand – Loop A FW demand = 75% - 25% = 50%.

4.4.8　Delta Tc control

4.4.8.1 Purpose – to ensure a zero Δ Tc which prevents radial tilts (Incomplete mixing at the bottom of the Rx vessel)

4.4.8.2 Also functions as a bias for the RCS flow signal

4.4.8.3 Circuitry

4.4.8.3.1　Narrow range Tc RTD input

4.4.8.3.2　Δ amplifier

4.4.8.3.3　Delta Tc = Loop A Tc – Loop B Tc

4.4.8.3.4　Error summed with flow error

4.4.8.3.5　Error signal changes gain of variable gain amplifier in Loop A FW demand circuitry.

4.4.8.3.6　Any change in Loop A FW gain also affects Loop B

4.4.8.3.7　Calibrating integral for small steady state errors – blocked when load is changing > 2%/minute

4.4.9  Btu Circuitry
    4.4.9.1 Originally functioned to change FW flow to maintain superheated OTSG steam. Now only an alarm function.
    4.4.9.2 Purpose – to alert the operator that the OTSG is approaching saturated limits.
        4.4.9.2.1  No moisture separating equipment in OTSG
        4.4.9.2.2  Moisture in steam could damage HP turbine
    4.4.9.3 OTSG Heat Input Circuitry
        4.4.9.3.1  Selected hot leg temperature
        4.4.9.3.2  RCS flow
    4.4.9.4 OTSG Heat Removal Circuitry
        4.4.9.4.1  OTSG pressure
        4.4.9.4.2  FW temperature
    4.4.9.5 Btu limit = ((Th limit + Feedwater Temp limit + OTSG Pressure limit – 200)(RCS flow limit))

4.5  FW Reactor Trip Circuitry
    4.5.1  Purpose – to rapidly reduce FW flow to prevent overcooling following a reactor trip.
    4.5.2  Relay T10 selects level error when a reactor trip occurs. Since level is usually greater than 24 inches, a negative signal will close the valves reducing FW flow

4.6  Low Level Limits
    4.6.1  Functions to ensure a minimum OTSG level for decay heat removal.
    4.6.2  Circuitry
        4.6.2.1 SU range level input
        4.6.2.2 Two setpoints – relays T12 and T13
            4.6.2.2.1  Normal – 24 inch input
            4.6.2.2.2  Loss of all RCPs – 72 inch setpoint for natural circulation
            4.6.2.2.3  Δ amplifier
            4.6.2.2.4  Error signal to high select
        4.6.2.3 High Select unit
            4.6.2.3.1  Selects higher of FW demand or level error
            4.6.2.3.2  <15%, level error is higher
            4.6.2.3.3  > 15%, demand signal is higher
            4.6.2.3.4  Auto change over from level to FWd as power is escalated above 15%.

4.7    FW Valve Control
     4.7.1    Three valves
          4.7.1.1 SU feedwater regulating valve - 0% to 15% flow
          4.7.1.2 FW Regulating Block valve - used to prevent leakage through the FW regulating valve from interfering with flow control at low power levels.
          4.7.1.3 FW Regulating valve – 15% to 100% flow
     4.7.2    At 80% SU regulating valve position, the MF block valve opens
     4.7.3    Both valves fully open at 100%

4.8    Main Feed Pump speed control
     4.8.1    FW valve $\Delta$P low selected
     4.8.2    50 psid setpoint
     4.8.3    Flow error used as an anticipatory signal for speed demand.

4.9    Reactor Demand Subassembly
     4.9.1    Functions to control Reactor power and Tavg
     4.9.2    Tavg Error Correction
          4.9.2.1 Selected Tavg from NNI system
          4.9.2.2 Setpoint (normally 601°)
          4.9.2.3 $\Delta$ amplifier
          4.9.2.4 Tavg > setpoint ☞ Rx demand is decreased
          4.9.2.5 Tavg > setpoint ☞ Rx demand is increased
     4.9.3    FW Cross limits
          4.9.3.1 Function to ensure heat generation is equal to heat removal
          4.9.3.2 Circuitry
               4.9.3.2.1    Total FW flow
               4.9.3.2.2    FW demand
               4.9.3.2.3    $\Delta$ amplifier
          4.9.3.3 Negative errors > 5% are used to **REDUCE** reactor demand.  FW cross limits cannot increase reactor power.
     4.9.4    Tavg Calibrating Integral
          4.9.4.1 Corrects steady state Tavg errors
          4.9.4.2 Output to summer and variable gain – same as MW error calibrating integral
          4.9.4.3 Blocked if demand is changing > 2% / minute
     4.9.5    Demand limits Circuitry
          4.9.5.1 High Limit – 103% - allows for the correction of low Tavg errors at the high end of the control band.
          4.9.5.2 Low Limit – 10% - allows for the correction of high Tavg errors at the low end of the control band.
     4.9.6    Hand/Automatic Station – manual ☞ Track

4.9.7 Neutron Error

    4.9.7.1 Error = Reactor demand – Reactor power

    4.9.7.2 Error > | 1% | is required to move rods (Figure 9-7)

        4.9.7.2.1 + 1% ☞ outward rod motion – stops when error is < 0.25%

        4.9.7.2.2 – 1% ☞ inward rod motion – stops when error is > -0.25%

4.9.8 Reactor Demand Interlocks (Figure 9-8)

    4.9.8.1 Asymmetric Rod – 60% - stops outward rod motion

    4.9.8.2 Feed and Bleed interlocks – used in MU&P system

    4.9.8.3 RCP Start Interlock – 22%

## 5.0 ICS Operations

### 5.1 General

5.1.1 Full automatic control of the ICS means that all hand/automatic stations are in automatic with the exception of the ULD.

5.1.2 The manual signals track the automatic signals, therefore, there is a bumpless transfer when a station is transferred from automatic to manual.

5.1.3 Each station has a meter and a two position selector switch. One position is called POSITION and the other is called DEVIATION.

    5.1.3.1 For most H/A stations, POSITION is the station input, while DEVIATION is the station output.

    5.1.3.2 Transfer to automatic is accomplished by centering the needle by use of the manual push buttons while in the DEVIATION position.

    5.1.3.3 Exceptions

        5.1.3.3.1 ULD – Position = demanded MWs, Deviation = Rate circuit output

        5.1.3.3.2 Reactor demand – Position = Rx demand, Deviation = Tavg error

    5.1.3.4 Reactor Demand Special Feature

        5.1.3.4.1 If the reactor demand and the diamond station are both in manual, then neutron error is forced to zero.

        5.1.3.4.2 This feature allows the reactor demand to be transferred to auto without rod motion occuring.

### 5.2 Normal Power Increases

5.2.1 Initial Conditions

    5.2.1.1 Plant is at 30%

    5.2.1.2 New load demand of 80% and a rate of 5% per minute are input into the ULD.

5.2.2 ULD Actions

5.2.2.1 The operator must input the new load and rate values.

5.2.2.2 At > 2% / minute, the following calibrating integrals are blocked:

5.2.2.2.1 MW error

5.2.2.2.2 Delta Tc error

5.2.2.2.3 Tavg error

5.2.2.3 Any necessary frequency error modifications are combined with ULD output.

5.2.3 Integrated Master Actions

5.2.3.1 – MW error is generated in difference amplifier

5.2.3.2 Header pressure setpoint is lowered.

5.2.3.3 Actual pressure > setpoint

5.2.3.4 Governor valves open to lower header pressure.

5.2.3.5 Actual header pressure drops ☞ kicker signal adds to MW demand that is sent to FW and Rx.

5.2.4 FW Subassembly Actions

5.2.4.1 No modifications are needed from:

5.2.4.1.1 Feedwater temperature

5.2.4.1.2 Tavg

5.2.4.1.3 Cross limits

5.2.4.2 Increased FW flow demand compared with actual FW flow, and a + error signal is generated.

5.2.4.3 + flow error ☞ FW regulating valves open.

5.2.4.4 FW regulating valves open ☞ $\Delta P$ across valves decreases

5.2.4.5 $\Delta P$ error combined with flow demand anticipatory signal increases MFP speed.

5.2.5 Reactor Demand Subassembly Actions

5.2.5.1 Assume no FW cross limits

5.2.5.2 Any Tavg error will be combined with increasing reactor demand signal

5.2.5.3 Assume no demand limits exist

5.2.5.4 When neutron error signal exceeds 1%, rod motion starts.

5.2.5.5 Rod motion stops when neutron error signal is < 0.25%

5.3 Normal Power Decrease

5.3.1 Initial Conditions

5.3.1.1 Plant is at 80%

5.3.1.2 New load demand of 30% and a rate of 5% per minute is placed into the ULD.

5.3.2 ULD Actions

    5.3.2.1 The operator must input the new load and rate values

    5.3.2.2 > 2%/minute, the following calibrating integrals are blocked:

        5.3.2.2.1   MW error

        5.3.2.2.2   Delta Tc error

        5.3.2.2.3   Tavg error

    5.3.2.3 Any necessary frequency error is combined with the ULD output.

5.3.3 Integrated Master Actions

    5.3.3.1 +MW error generated in $\Delta$ amplifier

    5.3.3.2 Header pressure setpoint is increased

    5.3.3.3 Actual header pressure < setpoint

    5.3.3.4 Governor valves close to increase header pressure ☞ load decreases

    5.3.3.5 Actual header ☞ kicker signal subtracts from FW and Rx demand signal.

5.3.4 Feedwater Demand Subassembly Actions

    5.3.4.1 No modifications from:

        5.3.4.1.1   FW temperature

        5.3.4.1.2   Tavg

        5.3.4.1.3   Cross limits

    5.3.4.2 Decreased flow demand compared with actual flow generates a – flow error signal

    5.3.4.3 – flow error ☞ FW regulating valves close

    5.3.4.4 Valves close ☞ $\Delta$P increases

    5.3.4.5 Increased $\Delta$P + anticipatory signal from FW flow demand ☞ decrease in MFP speed.

5.3.5 Reactor Demand Subassembly Actions

    5.3.5.1 No FW cross limits

    5.3.5.2 Tavg error combined with reactor demand signal

    5.3.5.3 Assume no high or low demand limits

    5.3.5.4 When neutron error exceeds –1%, rod motion starts

    5.3.5.5 When neutron error drops to –0.25%, rod motion stops.

5.4 Runback Example – Loss of One RCP in Loop B

    5.4.1 Initial Conditions

        5.4.1.1 Unit load at 90%

        5.4.1.2 Group 7 rods are 90% withdrawn – remind students of the shape of the integral rod worth curve.

    5.4.2 ULD actions

        5.4.2.1 Loss of RCP generates a runback signal

        5.4.2.2 –100% signal is transferred to $\Sigma$ amplifier, and a rate of 50% /minute is transferred to the Rate circuit

        5.4.2.3 ULD output starts to decrease toward zero at 50% / minute.

        5.4.2.4 The feedback signal to the Unit Master (dotted line) will cause the Unit Master signal to track the output of the rate unit.

    5.4.3 Integrated Master Actions

        5.4.3.1 The rapidly decreasing MWd modifies the header pressure setpoint

        5.4.3.2 The increased header pressure setpoint is compared with actual header pressure

        5.4.3.3 Actual pressure < setpoint ☞ close governor valves

        5.4.3.4 FW and Rx demand are also reduced by "kicker" signal

        5.4.3.5 If the rapid reduction in turbine load causes a large increase in header pressure, the bypass or dump valves may open. (center bias values)

    5.4.4 Reactor Demand Subassembly Actions

        5.4.4.1 Reduced demand signal from the Integrated Master + Tavg error will cause inward rod motion.

        5.4.4.2 Because group 7 is almost fully withdrawn, reactor power cannot decrease as fast as demand ☞ Reactor cross limits to feedwater.

    5.4.5 Feedwater Subassembly Actions

        5.4.5.1 The FW demand subassembly receives a reduced signal from the Integrated Master, but feedwater demand is not really reduced at 50%/minute. The actions of cross limits from the reactor demand subassembly retard the rate of decrease of feedwater demand.

        5.4.5.2 RCS flow error will change the variable gain in the Loop A FW demand from ½ to 2/3 to ration feedwater flow to each SG. The FW demand for B OTSG will be 1/3.

        5.4.5.3 Any differences in FW flow will result in a delta TC error which will affect the flow to both SGs

    5.4.6 Final Conditions

        5.4.6.1 Unit is at 75%

        5.4.6.2 Delta Tc = 0

        5.4.6.3 The level in A OTSG is at the 100% value while the level in the B OTSG is about 50% of the level in A OTSG.

5.5     Other Runbacks
        5.5.1   The actions in the subassemblies is essentially the same as
                described above, however, rationing of FW flow will not occur.
                The following statements provide additional runback information.
        5.5.2   Dropped Rod
                5.5.2.1 Setpoint – any rod that deviates from its group average by
                        more than 9 inches.
                5.5.2.2 Runback to 60% at 30%/minute
                5.5.2.3 Withdrawal prohibit generated because reactor power is
                        greater than 60% and an asymmetric fault exists.
        5.5.3   Loss of MFP
                5.5.3.1 Runback to 60% at 50%/minute
                5.5.3.2 Feedwater cross limits to reactor will probably be
                        generated.
                5.5.3.3 Remind students that FW cross limits can only reduce
                        reactor power.
5.6     Load Rejection
        5.6.1   Initial Conditions
                5.6.1.1 Unit at 100%
                5.6.1.2 Group 7 at 90%
                5.6.1.3 Load rejection initiated by opening of out put breakers.
        5.6.2   ULD Actions
                5.6.2.1 Output breakers open ☞ TRACK
                5.6.2.2 When in TRACK, generated MW becomes the MWd signal
                5.6.2.3 Rate of load decrease is 20%/minute
        5.6.3   Integrated Master Actions
                5.6.3.1 OPC (Overspeed Protection Controller) closes the turbine
                        governor valves to prevent turbine overspeed.
                5.6.3.2 A large header pressure error reverts turbine control to
                        manual.
                5.6.3.3 Large header pressure error ☞ Independent relief actions
                        for bypass and dump valves
                5.6.3.4 Left hand bias values will be selected when ULD < 15%
                        and header pressure error is < 10 psig
        5.6.4   Feedwater Demand Subassembly
                5.6.4.1 FW demand reduced at 20% per minute
                5.6.4.2 Reduction continues until level error is greater than the
                        flow error signal ☞ Low Level limits
        5.6.5   Reactor Demand Subassembly
                5.6.5.1 Because group 7 is almost fully withdrawn, reactor power
                        cannot decrease as fast as demand ☞ cross limits to FW
                5.6.5.2 Reduction in demand continues until the low limit of 15%
                        in Integrated Master is reached
                5.6.5.3 Reactor demand may be reduced to 10% if Tavg is > 601°F
                        at 15% power.

5.6.6 Final Conditions

    5.6.6.1 Reactor power = 15%

    5.6.6.2 Tavg = 601°F

    5.6.6.3 Header pressure = 1035 psi being maintained by the turbine bypass valves

    5.6.6.4 OTSGs are on low level limits

    5.6.6.5 Turbine is at 1800 rpm – ready for loading

## 5.7 Reactor Trip

5.7.1 Initial Conditions

    5.7.1.1 Unit at 100% - full ICS control

    5.7.1.2 Reactor trip manually initiated

5.7.2 ULD actions

    5.7.2.1 Reactor trip ☞ TRACK

    5.7.2.2 0 MWd at a rate of 20% per minute

5.7.3 Integrated Master Actions

    5.7.3.1 Reactor trip ☞ Turbine trip

    5.7.3.2 Turbine trip ☞ EHC to manual

    5.7.3.3 Reactor trip bias values selected ☞ header pressure = 1200

5.7.4 Reactor Demand Subassembly

    5.7.4.1 Receives tracking reduction in demand, but as Tavg decreases, Tavg error signal will reduce the rate of demand signal decrease. All of this doesn't matter because all the rods are on the bottom.

    5.7.4.2 Diamond reverts to manual on a reactor trip

5.7.5 Feedwater Demand Subassembly Actions

    5.7.5.1 T10 and T11 select level error signal.

    5.7.5.2 Large level error closes FW regulating and bypass valves

    5.7.5.3 When level drops to 24 inches, the SU regulating valves open to maintain low level limits.

5.7.6 Final Conditions

    5.7.6.1 Header pressure = 1200

    5.7.6.2 Tavg = 567°

    5.7.6.3 OTSGs are on low level limit

    5.7.6.4 Turbine is coasting down

    5.7.6.5 Turbine bypass valves are removing decay heat

    5.7.6.6 Student question – what would happen if reactor trip signal was cleared?

## 5.8 Turbine EHC in manual

5.8.1 Initial Conditions

    5.8.1.1 Unit is at 50%

    5.8.1.2 Operator Auto is selected on the EHC

    5.8.1.3 Load reduction to 40% is initiated

5.8.2 ULD Actions

    5.8.2.1 EHC in manual ☞ TRACK

    5.8.2.2 T1 relay supplies actual generated MW as MWd signal

5.8.3   Integrated Master Actions

    5.8.3.1 EHC in manual → no ICS control of turbine

    5.8.3.2 "On line" bias values protect against large header pressure increases.

5.8.4   Feedwater Subassembly

    5.8.4.1 As the demand signal from the ULD decreases, FWd decreases.

    5.8.4.2 FWd decreases → valves close, MFP speed decreases due to $\Delta P$ signal and anticipatory demand signal.

5.8.5   Reactor Demand Actions

    5.8.5.1 Reduced demand → reduced reactor demand

    5.8.5.2 When neutron error exceeds 1% → inward rod motion

5.8.6   Final Conditions – unit stable at 40%

5.9   SG/Rx Master in Hand

5.9.1   Initial Conditions

    5.9.1.1 Unit at 75%

    5.9.1.2 SG/RX master output is increased to 80%

5.9.2   ULD actions

    5.9.2.1 T1 supplies MW generated as MWd signal

    5.9.2.2 Rate = 20%/minute

5.9.3   Integrated Master Actions

    5.9.3.1 T2 prevents modification of header pressure signal

    5.9.3.2 No corrections to demand signal will be seen because the SG/Rx master is in hand

5.9.4   Feedwater and Reactor Demand Subassemblies

    5.9.4.1 The FWd and Rx demand will follow the increase in SG/Rx output – no rate limits apply

    5.9.4.2 Power and feedwater flow increase

5.9.5   Final Conditions – unit is stable at 80% power

5.10   Both FW Demand to Hand

5.10.1   Initial Conditions

    5.10.1.1   Unit is at 50%

    5.10.1.2   Both FW demand to manual → TRACK

    5.10.1.3   Increased output FWstations → more FW flow

    5.10.1.4   More FW flow → greater heat transfer

    5.10.1.5   Greater heat transfer → increase in header pressure

5.10.2   ULD Actions

    5.10.2.1   Track → MW generated is the demand signal

    5.10.2.2   Rate is 20% per minute

5.10.3   Integrated Master Actions

    5.10.3.1   In TRACK, T2 prevents modification of header pressure setpoint

    5.10.3.2   As header pressure increases, governor valves open

5.10.4   Reactor Demand Subassembly

    5.10.4.1   As MWg increases, Rx demand increases

    5.10.4.2   Outward rod motion

5.10.5 Final Conditions – load is stable and equals new value of FW demand.

5.11 RX Demand To Hand

  5.11.1 Initial Conditions

    5.11.1.1 Unit at 100%

    5.11.1.2 Reactor demand to hand and output dropped to 90%

  5.11.2 Rx Demand Actions

    5.11.2.1 When neutron error drops below –1%, rod motion starts

    5.11.2.2 Insertion of rods lowers power.

    5.11.2.3 Reduction in power ☞ less energy available to OTSGs ☞ header pressure decrease

  5.11.3 Integrated Master

    5.11.3.1 T2 blocks the modification of header pressure setpoint

    5.11.3.2 As header pressure decreases, governor valves close

  5.11.4 ULD Actions

    5.11.4.1 TRACK ☞ MW generated becomes demand.

    5.11.4.2 TRACK ☞ 20/minute rate

  5.11.5 FW Subassembly Actions

    5.11.5.1 FWd decreases as MWg decrease

6.0 ICS Differences

6.1 Integrated Master Differences

  6.1.1 177 FA Units typically have a total dump/bypass capacity of 15%

  6.1.2 Bias values are different

  6.1.3 High Select selects the higher of :

    6.1.3.1 Header pressure error

    6.1.3.2 OTSG pressure error when compared to a fixed setpoint of 1025 psig

  6.1.4 If condenser is available, error signal to turbine bypass valves

  6.1.5 If condenser is not available, T2 sends signal to atmospheric dumps.

6.2 FW Demand Differences

  6.2.1 Low Select unit selects lower of:

    6.2.1.1 FWd or Level Error Demand

    6.2.1.2 Level Error = "high" limit to prevent covering of aspirating ports ☞ loss of FW preheating

  6.2.2 Rapid Feedwater Reduction – prevents overcooling during a reactor trip.

6.3　Feedwater Flow Control

　　6.3.1　Three Valves

　　　　6.3.1.1 SU Regulating Valve – 0 to 15% power

　　　　6.3.1.2 Low Load Regulating and Block valve

　　　　　　6.3.1.2.1　Block valve opens at 80% SU valve position

　　　　　　6.3.1.2.2　Low Load controls flow from 15% to 50%

　　　　　　6.3.1.2.3　At 50% Main Feedwater Block opens, and the MFW cross connect closes

　　　　　　6.3.1.2.4　FW flow controlled by MFP speed from 50% to 100%

　　6.3.2　Applicable to ANO1 and CR3