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Light Water Reactor Sustainability Program

Design Basis for Control System Implementation in a PWR to Enable 30-100% Thermal Power Extraction

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Design Basis for Control System Implementation in a PWR to Enable 30-100% Thermal Power Extraction

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EXECUTIVE SUMMARY

The Department of Energy's Light Water Reactor Sustainability (LWRS) Program at the Idaho National Laboratory (INL) has established a pathway to engage existing U.S. nuclear reactors in research to develop technologies and other solutions to enable nuclear power plants to support decarbonization of select industrial processes while accessing additional non-electric markets for potentially enhanced revenue. One thrust of this effort is to assess nuclear plant modifications that enable the use of large-scale thermal energy (steam) and electricity to support processes that can ultimately produce alternative energy products with substantially lower carbon emissions.

Previous work completed a plant system integration feasibility assessment to establish constraints and limitations for thermal energy extraction from the secondary system of a generic pressurized water reactor (PWR) without major secondary system redesign and modification and without significant impact to the primary function of the electric generator. That evaluation estimated the system operating conditions to assess the performance of the secondary systems, structures, and components when the plant is configured to divert a portion of the main steam from the turbine to the integrated energy system supply. The system was modeled and the system thermodynamic conditions estimated for thermal power dispatch (TPD) of 30%, 50%, and 70% of the rated system thermal power design.

In that design, steam was extracted from the high pressure (HP) steam header prior to the HP turbine such that a modification to the plant control system reactor coolant system (RCS) average reference temperature program will be necessary. This report provides the additional background and design basis of the RCS average reference temperature for that design effort. The control system considerations to be implemented in a digital implementation in the plant are identified, as well as the devices/components to be controlled and the impacts to existing control systems that need to be considered by end users. This review applies specifically to digital control systems and more specifically, Westinghouse 4-Loop PWRs. The assessment approach is generally applicable to other Nuclear Steam Supply System (NSSS) digital designs. All PWR plants will require a detailed plant-specific assessment to determine unit specific modification requirements.

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FIGURES

TABLES

ACRONYMS

BOP	balance of plant
DI	deionized
DOE	Department of Energy
ES	extraction steam
FWH	feedwater heater
FPOG	Flexible Power Operation and Generation
HP	high-pressure [steam]
HPT	high-pressure turbine
IES	integrated energy system
INL	Idaho National Laboratory
ISO	Independent System Operator (grid balancing authority)
LP	low-pressure [steam]
LPT	low-pressure turbine
LWR	light-water reactor
LWRS	Light Water Reactor Sustainability
MSR	moisture separator reheater
MTC	moderator temperature coefficient
MW	megawatt
NPP	nuclear power plant
NSSS	nuclear steam supply system
PEPSE	Performance Evaluation of Power System Efficiencies
SDA	standard design approval
SG	steam generator
SSC	systems, structures, and components
TPE	thermal power extraction
TPD	thermal power dispatch
RCS	reactor coolant system
PWR	Pressurized Water Reactor
TPD	Thermal Power Dispatch
USAR	Updated Safety Analysis Report

Design Basis for Control System Implementation in a PWR to Enable 30-100% Thermal Power Dispatch

1. INTRODUCTION

1.1 Background

Nuclear power has been proven vital as a key element to U.S. energy security. Nuclear power offers clean energy and remains a critical part of the energy transition process to meet climate goals to decarbonize the electric power and transportation sectors, while increasing energy independence.

Despite the benefits of nuclear power, the U.S. nuclear industry continues to face significant challenges. Market conditions have forced some reactors into early retirement and others have engaged in limited flexible operations to accommodate subsidized variable renewal generation, transmission constraints, and to avoid sustained periods of low to negative power pricing. Even where nuclear power provides substantial baseload generation, the value of operational flexibility is very high, allowing the grid operator the ability to provide the lowest cost power to the regional customer through a mix of baseload, intermediate and peaking generation assets. The ability of nuclear plants to curtail output to accommodate minimum operational output for intermediate assets is of high value, particularly in regional situations where net demand is marginally greater than nuclear output. Nuclear curtailment can also provide economic incentives where electric market participation avails the utility of very low-cost excess renewable generation.

The mission of the U.S. Department of Energy (DOE) is to advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs. In consideration of the economic impacts to the existing nuclear fleet and in recognition of the crucial role that existing nuclear plants play in providing clean generation and grid reliability, the DOE has established Office goals including enabling continued operation of the existing U.S. nuclear reactors. The DOE objectives are:

1. Develop technologies that reduce operating costs.
2. Expand to markets beyond electricity.
3. Provide scientific basis for continued operation of existing plants.

The DOE's Light Water Reactor Sustainability (LWRS) Program at Idaho National Laboratory (INL) has been funded by the DOE to advance the Office objectives. LWRS Program conducts research to develop technologies and other solutions to improve the United States (U.S.) domestic fleet of nuclear power plants in terms of economics, reliability, and safety. The program consists of several research and development sub-programs, or "pathways" including Flexible Plant Operation and Generation (FPOG). The FPOG pathway provides research and development to evaluate economic opportunities, technical methods, and licensing needs for light water reactors to directly supply thermal and electrical energy to co-located or adjacent industrial processes. This pathway adapts and uses analysis tools developed by the U.S. Department of Energy (DOE) to complete technical and economic assessments of large, realistic market opportunities for producing nonelectrical energy products. Carbon emissions from large-scale non-electric energy applications, such as hydrogen production, chemical synthesis, and petroleum refining can be substantially reduced by using heat and electricity sourced from clean nuclear power. The pathway has more recently engaged in technical programs for the engineering design, testing, and demonstration of integration of industrial processes with existing nuclear power plants. Design activities include feasibility assessments for nuclear plant modifications to divert thermal energy (steam) from the plant secondary system.

Recent global initiatives to reduce greenhouse gas emissions, most notably carbon dioxide emissions, have added an incentive to replace certain fuels and energy feedstocks with non-emitting sources, including nuclear energy. Direct steam utilization is one potential method of alternative revenue. Nuclear plant steam applications include hydrogen generation, desalination, district heating, thermal storage, and industrial processes. Steam utilization can help increase nuclear plant efficiencies and economics while providing a low-carbon solution for thermal power users.

For nuclear energy to be integrated in new ways, a variety of challenges must be overcome, including technological, regulatory, economic, and environmental. The biggest challenge is modification of the existing plants to provide large quantities of steam while maintaining full functionality of the plant design. Previous work has assessed the impacts of high levels of thermal power extraction (TPE)[a] on a generic nuclear plant design to determine feasible extraction limits for nuclear plant steam. A plant system integration feasibility assessment was also performed to establish constraints and limitations for thermal energy that can reasonably be extracted from the secondary system of a generic PWR. The evaluation considered the impacts on the secondary systems, structures, and components due to different levels of TPE up to 70% of the rated system thermal design. Plant-specific efforts will require analyses of specific control systems designs for digital plant applications, and all other design related aspects. As described in the next section, this report provides the plant digital control system design basis for a generic PWR that will engage in TPE, including an initial system modification requirements assessment to accommodate TPE from the High Pressure (HP) steam header.

1.2 Scope

This report provides the plant digital control system design basis for a generic PWR that will engage in TPE, including an initial system modification requirements assessment to accommodate TPE from the High Pressure (HP) steam header. The control system features to be implemented in a digital implementation in the plant are identified, as well as the devices/components to be controlled and the impacts to existing control systems that need to be considered by end users.

An initial assessment of the control system design basis and requirements associated with 30% to 70% TPE from a PWR power plant has been developed to inform future design activities [1]. As previously described, the TPE is assumed to be 30% to 70% of rated thermal power of the plant and is from the HP steam extracted from the plant's main steam header upstream of the HP turbine. Due to the steam being extracted prior to the HP turbine, a modification to the plant control system reactor coolant system (RCS) average reference temperature program is necessary. The background and design basis of the RCS average reference temperature is discussed in a later section of this report.

To isolate the nuclear plant from the thermal energy consuming process, the HP steam extracted from the nuclear plant's main steam header will be used to convert de-ionized water to steam in a reboiler. A discussion of the reboiler controls provided in [2] will also apply to the 30-70% TPD. The reboiler design would need to be scaled to account for the increased thermal extraction and the use of HP steam. This document does not cover the reboiler portion of the design. Control provisions for the reboiler have been previously addressed for smaller extraction systems [2].

The use of HP steam requires significant modifications to the existing NSSS and BOP control systems of the nuclear plant. Such modifications to an analog control system would require significant calibrations and operator manual actions thereby increasing operator burden, which is a significant design consideration. Additionally, coordination of controls with reactor power are required to ensure that reactor overpower conditions are minimized/eliminated. The coordination will consist of operator alarms and automatic control actions. As such, reuse of an existing analog control system is not feasible, and a digital control system implementation will be required. Consequently, this assessment does not apply to

[a] Thermal Power Extraction (TPE) generally applies to the system process of extracting steam from the plant secondary system whereas Thermal Power Dispatch (TPD) is the operation of the extraction system. These terms are considered interchangeable.

analog control systems. The assessment of digital control systems modifications will consider the impacts to existing control subsystems.

The purpose of the design basis is the following:

1. Identify the control system considerations to be implemented in a digital implementation in the plant;
2. Identify the devices/components to be controlled and the impacts to existing control systems that need to be considered by end users that pursue implementation;
3. Identify operational considerations for how operators shall enable the dispatch of steam.

2. Reactor Controls Considerations

2.1 Reactor Controls Requirements

Integration of a thermal power extraction system at large-scale will require modifications to the plant control systems to ensure that the plant remains within the design and licensing bases. Proposed design requirements for thermal power dispatch are summarized in **Error! Reference source not found.** [3]. Requirements can be broadly grouped into three categories: (1) shall not adversely affect the existing Updated Safety Analysis Report (USAR) Design Basis Accidents (DBA) analyses (2) must allow plant operators to maintain full control of steam flow within the plant; and (3) shall not cause the reactor power to exceed 100% of its rated power. These top requirements encompass additional sub-requirements that are discussed below, such as thermal power extraction must not excessively increase the operator cognitive load or burden because such impacts would adversely affect plant safety operations.

Table 2-1 Design requirement categories for thermal power extraction.

Item	Design requirement category
1	Thermal power extraction shall not adversely affect the existing Updated Safety Analysis Report (USAR) Design Basis Accidents (DBA) analyses (specifically, any effects on the step load decrease transient) (Requirement #1)
2	The nuclear plant operators must have full control of the steam flow in the thermal extraction system with prerogative to completely stop steam flow in that loop without possibility of interference from the thermal power customer (Requirement #2);
3	During operation of the thermal extraction system, the reactor power must not exceed 100% of its rated power due to changing the rate of steam extraction (Requirement #3);

Design decisions follow from the design requirements. The decisions that pertain to the design of the physical hardware are documented in [1]. Decisions that pertain to the control system are described in the following sections. Overarching decisions based on the design requirements in Table 2-1 are summarized as:

- Reactor controls will be modified in such a way that the reactor remains at 100% of rated thermal power or less while thermal power extraction is increased or decreased, preferably without the use of control rods or adjustments to boron concentration in the reactor coolant (supports Requirement #3);
- Steam pressure in the main steam header or steam flow rate in the extraction line are preferred as control variables. Steam pressure is a preferred control variable because it can be measured rapidly and accurately. Additional engineering analysis and testing, including hardware and human factor

engineering (HFE), will be employed in future work to determine the dominant control variable for specific applications;

- The control system will be designed to allow switching between 10% and 90% of thermal power extraction at least two times in each 24-hour period to accommodate potential change in steam demand from coupled thermal processes.

2.2 Reactor Controls Background

As noted in the design decisions in Section 2.1, the thermal power extraction system is intended to operate in such a way that the reactor remains at 100% rated thermal power or less while extraction power is increased or decreased, without the use of control rods or adjustments to boron concentration in the reactor coolant. To accomplish this goal, it is necessary to modify the controls governing the steam cycle in the secondary system. This section assumes a basic understanding of NPP operations; however, a few principles are reviewed here to define parameters and provide background. First, reactor power is approximately a linear function of the difference between the temperature of the reactor coolant entering the core (T_{cold}) and that exiting the core (T_{hot}) and has the form $P_{reactor} = m_{RCS} \times C_{p,RCS} \times (T_{hot} - T_{cold})$, where m_{RCS} and $C_{p,RCS}$ are the mass flow rate and average specific heat capacity of the reactor coolant at constant pressure. This relationship is shown in **Error! Reference source not found.**.

For the reactor power to remain constant during thermal power extraction, the energy flow to the turbine and feedwater heaters must decrease by an amount that is commensurate with the amount that is extracted from the main steam line. The secondary system controls must be modified to account for decreasing and increasing steam flow to the turbine. When an operator executes a load decrease at the turbine control panel, the governor valves partially close to restrict flow from the steam generator (S/G), which causes an increase in the steam header pressure in the S/G (P_{SG}). Importantly, steam in the S/G is saturated, so increasing P_{SG} causes an increase in the temperature of the reactor coolant exiting the S/G, which increases T_{cold}. Increasing T_{cold} decreases reactivity to decrease power generation in the core, which in turn decreases T_{hot}. This operation is consistent with the discussion above in which decreasing the difference $T_{hot} - T_{cold}$ corresponds to a decrease in $P_{reactor}$.

Three thermal power control strategies are typically considered to manage the relationships described above. Each reactor coolant temperature strategy has advantages and disadvantages as discussed in [4]. The first strategy is to hold the average of $T_{hot} - T_{cold}$ constant (denoted T_{avg}). With this approach, an increase in reactor power must correspond to an increase in T_{hot} and an equal decrease in T_{cold}. Because P_{SG} decreases with T_{cold}, this strategy necessarily forces P_{SG} to decrease substantially with increasing reactor power, which is undesirable for the secondary system because much more steam will be required as reactor power increases to account for decreasing steam enthalpy. This type of program reduces the need for reactivity control because the moderator temperature coefficient (MTC) of reactivity does not contribute to the total reactivity balance. However, this benefit does not sufficiently compensate for the large decrease in P_{SG} as the reactor power increases from zero to 100% of rated power.

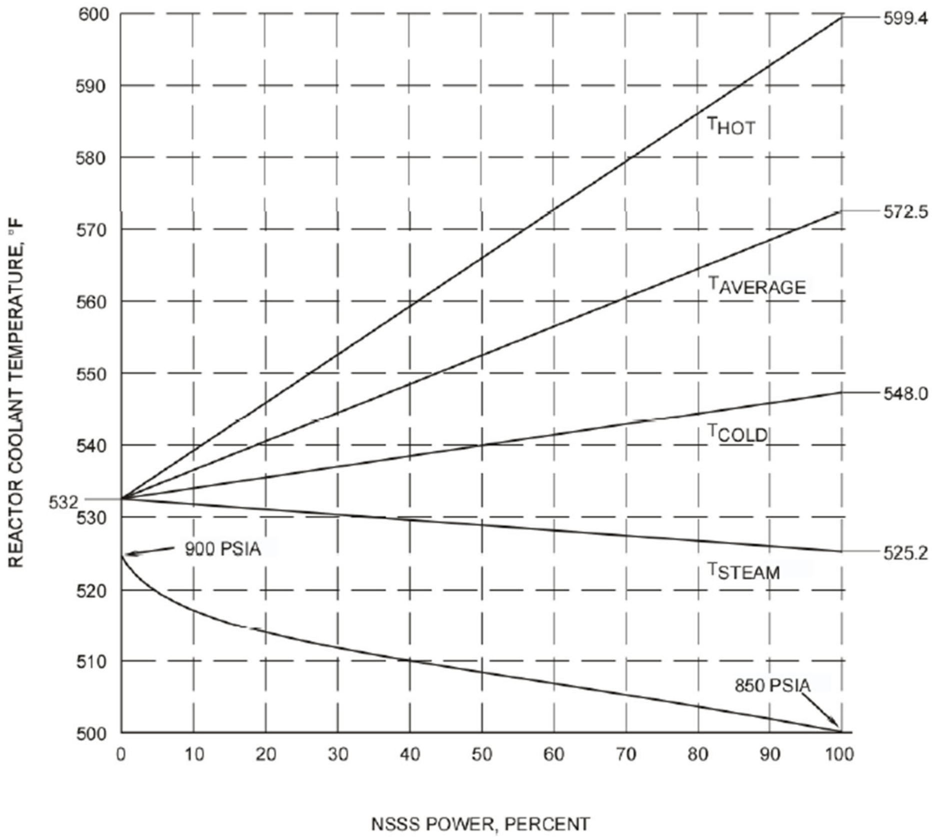

Figure 2.2-1. Graphical representation of sliding Tavg control mode for a PWR [4]

In the second control strategy, P_{SG} is maintained constant as reactor power changes, which also forces T_{cold} to remain fixed. In this strategy, increasing reactor power must be accommodated by only increasing T_{hot}. This strategy is not favored because T_{hot} can approach saturation values and affects the MTC of reactivity such that excessive control rod motion may be required. This mode also requires large, undesirable changes in the reactor coolant volume and consequently a large pressurizer to absorb reactor coolant expansion and contraction.

The final and preferred strategy, referred to as the sliding T_{avg} mode, is a compromise between the first two design approaches and allows T_{avg} to increase with increasing reactor power according to a control program. This mode produces acceptable steam conditions at full load for the turbine generator system while requiring less rod motion and a lower T_{hot} than a constant P_{SG} mode. The plant control system design basis transients and the USAR plant transient accident analysis conditions are based on a sliding T_{avg} operating mode. The USAR also includes the automatic rod control system, which is a redundant system that maintains a programmed average temperature in the reactor coolant by regulating the reactivity within the core. The control rod system can restore the average temperature to within ± 3.5 °F of the programmed temperature, including ± 2°F instrument error and a ±1.5 °F deadband, following design load changes; however, control rods are only deployed if operations based on the sliding T_{avg} mode are deemed insufficient to control reactivity in the core with the desired safety margin.

To meet the design requirements in Section 2.1, the sliding T_{avg} mode control program must be modified so that the effects on T_{avg} due to extracted (thermal power) are properly accounted for. The sliding T_{avg} control mode is implemented by creating a reference T_{avg} value called T_{ref}. The T_{ref} value is compared to the auctioneered T_{avg} value (the highest T_{avg} value of all S/G loops in the plant); if there is a mismatch between the values that is larger than a predetermined threshold value, the control rods receive a signal to move. The basic T_{ref} program and control mode of current PWRs is represented in **Error! Reference source not found.**2. An additional input parameter, the auctioneered high nuclear power is included in the control loop to help determine how fast the control rods need to move based on the extent of power mismatch between the turbine and the reactor [4]. The controls implementation plan for PWRs that will engage in thermal power extraction is based on measuring the flow of extracted steam or a surrogate pressure differential and uses that measurement to add a bias to the T_{ref} program that can account for the respective amounts of steam that is sent to the turbine and extracted for thermal power dispatch. This new parameter will be introduced into the T_{ref} control block shown in **Error! Reference source not found.**2 to replace turbine impulse pressure.

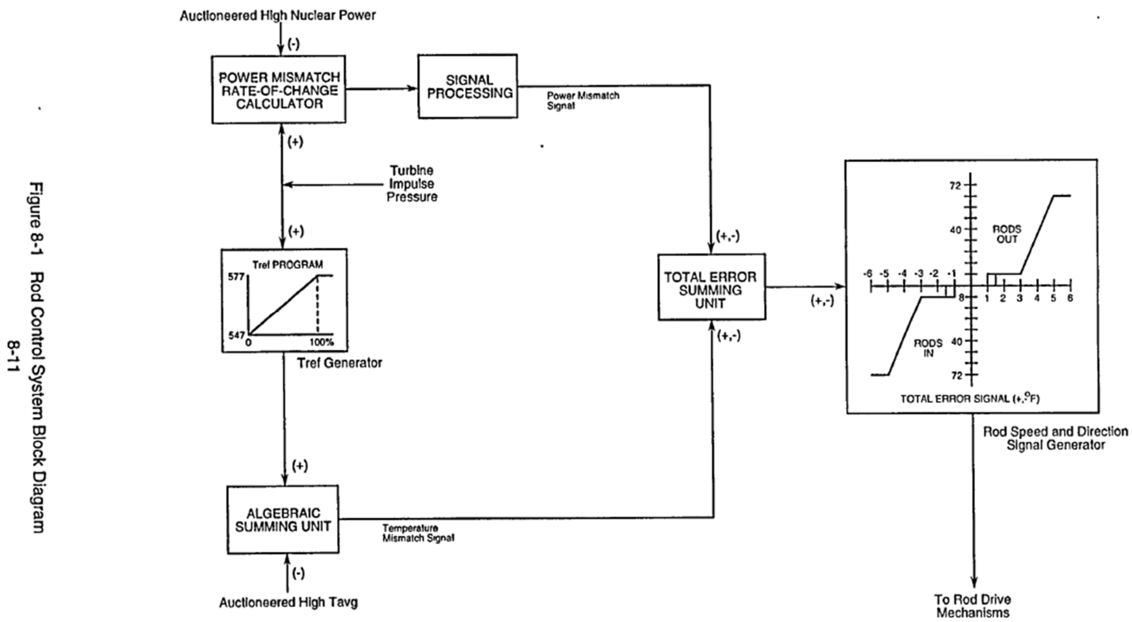

Figure 2-2. Rod control system block diagram [4]

The planned operation of this system is as follows. If the reactor is operating at full power, the operator first signals a reduction in turbine load so that steam can be made available for thermal power extraction without causing the reactor power to rise over 100%. The turbine-reduction signal causes the governor valves to slightly close to decrease mass flow to the turbine. The reduction in reactor power is verified and the control rods are monitored to make sure that they do not move. Steam flow is slowly initiated in the steam extraction system, which adds a bias to the T_{ref} program to compensate for decreased load on the turbine, which results in a full-power T_{ref} signal to maintain control-rod position. The turbine load is then reduced further, and the extraction steam valve is opened further following the same pattern to slowly decrease turbine power and increase extracted steam flow until the desired steady state condition is achieved without significantly perturbing reactor power. This process will require communication with the grid independent system operator (ISO) because the power output to the grid will decrease as the turbine load decreases. A similar process is followed to decrease the extracted steam flow and restore full flow to the turbines. It is anticipated that the process to increase or decrease the extracted thermal power will be automated to avoid excessive operator actions.

Initiating steam extractions is similar to engaging the steam dump system. The steam dump provides a path for generated steam to be sent directly to the condenser, which is needed during startup and shutdown of the reactor or following either a reactor trip or a turbine trip to allow for the plant to handle sudden load rejections while keeping the plant in a hot-standby condition. Following a load rejection, the steam dump system is used to compensate for limitations associated with control-rod motion. Typically, a load rejection of 10% or more will cause the steam dumps to open [5]. During a reactor or turbine trip, the plant enters hot standby by dumping steam to the condenser while maintaining T_{avg} and P_{stm} at their intended hot-zero power levels as shown in **Error! Reference source not found.**.

Because steam extraction is functionally similar to steam dump operation, employing a similar control strategy to manage the effects on reactivity will be simplest for operator interactions. A pressure-control valve in the extracted steam line will control the flow of extracted steam based on the turbine-load setpoint. Although the steam dump controller is in sliding T_{avg} control mode during full-power operations, the controller can theoretically be used in constant steam pressure mode to maintain full power while the turbine load decreases. This same methodology will be employed in the steam extraction system.

3. Design Basis

3.1 Operator Controls and Monitoring

a) The nuclear plant operator shall manually initiate the activation of the steam extraction to the reboiler (warmup and normal operation).

b) The nuclear plant operator shall have the capability to monitor and control the steam extraction and the associated reboiler field equipment (i.e., pumps and valves).

c) The nuclear plant operator shall be alerted to abnormal operating conditions within the steam extraction.

d) The nuclear plant operator controls shall be easily accessible to the operator and provide for automatic and manual operation.

e) The nuclear plant operator shall have the capability of initiating a rapid stop/closure of the steam extraction.

3.2 Permissive Interlocks

a) A permissive interlock shall be part of the controls to permit the opening of the steam admission valve for the steam extraction reboiler.

b) The interlock shall be a function of nuclear power such as nuclear instrumentation system power or the reactor coolant system delta temperature power.

c) The permissive interlock shall be maintained and if the plant conditions are no longer met the steam extraction valve shall rapidly close and isolate the TPD system.

d) A separate permissive interlock may exist for system warmup and standby operations.

3.3 Design Basis Transients

a) The controls associated with the TPD shall not negatively impact the NSSS design basis transients identified in the plant USAR:

b) ± 10% step change in load

c) 5%/min ramp loading and unloading

d) 50% step load decrease

3.4 Chapter 15 USAR Impacts

a) The USAR accident analysis and description shall remain valid regarding the inadvertent opening of a steam dump/bypass valve.

b) The USAR accident analysis description and analysis shall account for the addition of the TPD.

3.5 Existing Plant Control Logic Modifications

a) The nuclear plant's existing control systems shall require functional changes to accommodate TPD.

b) The reactor temperature control system temperature reference shall account for the turbine power and TPD power demands.

c) The steam dump control system temperature reference shall account for the turbine power and the TPD power demands.

d) The steam dump pneumatic arming signal (i.e., loss of load interlock) shall account for significant load variations due to a change in turbine power, TPD power, or a combination of power changes of the two steam loads.

e) The nuclear plant's existing control systems shall require interface and indication changes to the operator graphics to accommodate TPD.

f) The nuclear plant's control logic for alarms and alarm setpoints shall require functional changes to accommodate TPD.

4. Control System Considerations

4.1 Considerations for Control System Implementation

Careful consideration shall be given to the control system when implementing the TPD. Due to the complex modifications and the necessity to account for flexible operations covering the operating conditions for 1) only turbine steam load operation, 2) only the TPD steam load operation, or 3) a combination of the two steam loads on to the nuclear power plant, a digital control system implementation will be required. The control systems will need to coordinate the new TPD system with the other existing, upgraded NSSS and BOP controls:

- Steam Dump / Bypass Control
- Turbine Control

The following control systems will require functional and/or control system tuning changes:

- Steam Dump / Bypass Control
- Reactor Temperature Control
- Turbine Control
- Feedwater Control
- Feedwater Heater Control
- Pressurizer Level Control

4.2 Steam Dump / Bypass Control

- Controls shall be designed such that one or multiple valves (defined sequencing to open valves – similar to the existing steam dump controls) can be employed to extract the TPD steam.

- TPD shall have two isolation valves and associated logic (i.e., to ensure personal protection and ensure the TPD does not actuate/open due to a single failure).
- To provide finer control, multiple control valves can be used in the design such that the USAR accident analysis and description will remain valid regarding the inadvertent opening of a steam dump/bypass valve (possible to update analysis to account for larger valve(s) if necessary).
- Steam dump/bypass valve control shall be integrated and controlled with the TPD operation (i.e., coordinated with TPD startup, operation, and shutdown).
- Update T_{ref}/Power program based upon TPD. (T_{ref} = TPD Steam Load + Turbine Load + Steam Dump/Bypass Load.)
- To balance the load redistribution between the turbine and TPD, the system will transfer into steam pressure control mode during startup and shutdown to control steam pressure while TPD is opening/closing, and turbine control valves are closing/opening.
- Additional input to the steam dump control system shall become a permissive to allow TPD to actuate/continue (example; RCS ΔT for reactor power and possibly a simple secondary calorimetric which will not be used for absolute power but to monitor small power changes).

4.3 Reactor Temperature Control

Updated T_{ref}/Power program based upon TPD. (T_{ref} = TPD Steam Load + Turbine Load + Steam Dump/Bypass Load.)

Update/modify the rod insertion/withdrawal deadband for brief period when TPD is in startup or shutdown mode.

4.4 Turbine Control

f) Turbine control valve control/movement shall be integrated with the TPD operation (i.e., coordinated with TPD startup, operation, and shutdown).

g) Turbine control valve control shall be updated/modified to accept power changes and rate of change from TPD operation.

h) Turbine impulse and megawatt (MW) control loops shall remain as is and operational guidance shall be provided to operations if these loops are used.

4.5 Feedwater Control

Feedwater controls shall be tuned to account for the reduction in feedwater temperature as TPD is increased and turbine power is decreased. The reduction in feedwater temperature will increase the observed shrink/swell within the steam generator and the controls shall be tuned to account for this with no increase in operator burden associated with the SG water level control.

4.6 Feedwater Heater Control

Feedwater heater controls shall automatically account for the change in turbine power/ES due to the mode of the TPD system. This upgrade of the control logic shall allow for automatic control system tuning over the normal turbine power range (i.e., 15 – 100% power).

4.7 Pressurizer Level Control

Possible pressurizer level control setpoint adjustments may be needed if a reduced T_{avg} program is implemented.

5. CONCLUSIONS

An initial evaluation of the required control systems modifications, including changes to the RCS Average Reference Temperature program, has been completed. The design bases have been reviewed and control system modifications identified by system and detailed to inform future design modification development. This review applies specifically to digital control systems and more specifically, Westinghouse 4-Loop PWRs. The assessment approach is generally applicable to other NSSS designs. All PWR plants will require a detailed plant specific assessment and modification plan. The coordination of the operations will consist of operator alarms and automatic control actions. As such, application of this approach for an existing analog control system is not feasible, and digital control system implementation would be required. Consequently, this assessment does not apply to analog control systems.

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6. REFERENCES

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Appendix A
Digital Control Systems Functional Sketches

Incorporated from WNA-DS-05487-GEN, Revision 0

(3 Pages Total)

APPENDIX A
FUNCTIONAL SKETCHES

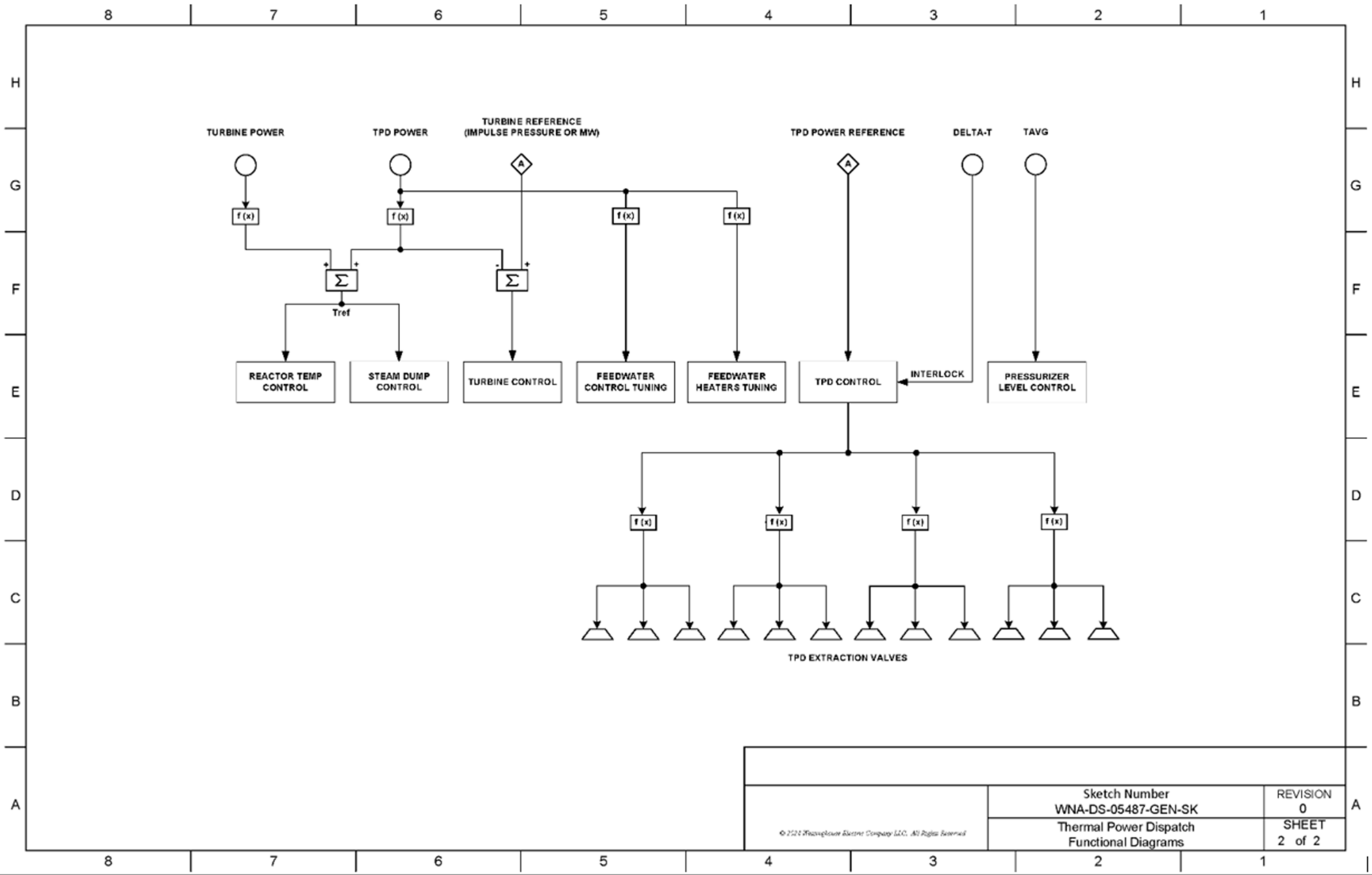
ENCLOSURE SYMBOLS

FUNCTION	ENCLOSURE SYMBOLS
MEASURING OR READOUT	○
FINAL CONTROLLING I/O	⏢

FUNCTION & SYMBOL	DEFINITION
SUMMING $\boxed{\Sigma}$	THE OUTPUT EQUALS THE ALGEBRAIC SUM OF THE INPUTS.
NONLINEAR OR UNSPECIFIED FUNCTION $\boxed{f(x)}$	THE OUTPUT EQUALS SOME FUNCTION OF THE INPUT.
ANALOG REFERENCE ◇A	THE OUTPUT IS AN ANALOG REFERENCE SET BY THE OPERATOR.

SH	DESCRIPTION	SUB
1	FUNCTIONAL SYMBOLS AND INDEX	REV. 0
2	THERMAL POWER DISPATCH	REV. 0

			Westinghouse Electric Company	
DEVELOPED	S. BRESKI	03/2024	Sketch Number WNA-DS-05487-GEN-SK	REVISION 0
REVIEWED	S. WHALEY	03/2024	Thermal Power Dispatch Functional Diagrams	SHEET 1 of 2
	N. OPPMAN	03/2024		
APPROVED	C. VERBOFSKY	03/2024		


TURBINE POWER
TPD POWER
TURBINE REFERENCE (IMPULSE PRESSURE OR MW)
TPD POWER REFERENCE
DELTA-T
TAVG
f (x)
Tref
REACTOR TEMP CONTROL
STEAM DUMP CONTROL
TURBINE CONTROL
FEEDWATER CONTROL TUNING
FEEDWATER HEATERS TUNING
TPD CONTROL
INTERLOCK
PRESSURIZER LEVEL CONTROL
TPD EXTRACTION VALVES
Sketch Number
WNA-DS-05487-GEN-SK
REVISION
0
Thermal Power Dispatch
Functional Diagrams
SHEET
2 of 2