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CPC and Methodology Changes for the CPC Improvement Program

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COMBUSTION ENGINEERING, INC.
Nuclear Power Systems
Windsor, Connecticut

LEGAL NOTICE

GLOSSARY

ANO	Arkansas Nuclear One
ANPP	Arizona Nuclear Power Project
AOO	Anticipated Operational Occurrence
AP&L	Arkansas Power and Light Company
ASGT	Asymmetric Steam Generator Transient
ASI	Axial Shape Index
BCEAW	Bank CEA Withdrawal
CEA	Control Element Assembly
CEAC	CEA Calculator
CEAD	CEA Drop
CEDMCS	Control Element Drive Mechanism Control System
CMI	CEA Motion Inhibit
COLSS	Core Operating Limit Supervisory System
CPC	Core Protection Calculator
CPCS	Core Protection Calculator System
CWP	CEA Withdrawal Prohibit
DBE	Design Basis Event
DNB	Departure from Nucleate Boiling
DNBR	DNB Ratio
EPRI	Electric Power Research Institute
LCO	Limiting Condition for Operation
LOF	Loss of Flow
LPD	Linear Power Density
LP&L	Louisiana Power and Light Company
MTC	Moderator Temperature Coefficient

PLCEA	Part Length CEA
ROPM	Required Overpower Margin
RTD	Resistance Temperature Detector
SAFDL	Specified Acceptable Fuel Design Limit
SCE	Southern California Edison
SONGS	San Onofre Nuclear Generating Station
[	]
VOPT	Variable Overpower Trip

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1.0 SUMMARY

The COLSS/CPC Oversight Committee, consisting of Arizona Nuclear Power Project (ANPP), Arkansas Power and Light Company (AP&L), Louisiana Power and Light Company (LP&L) and Southern California Edison (SCE), with Combustion Engineering as its technical consultant, has developed the CPC Improvement Program, a program of CPC modifications and methodology improvements scheduled to be implemented in 1986 and 1987. An initial presentation of concepts was presented to the NRC on November 8, 1984 and the schedule for implementation of the program was provided to the NRC on March 8, 1985. A detailed presentation of the portions of the program scheduled for implementation in early 1986 was provided in a meeting on April 18, 1985. Copies of the slides presented at that meeting have been provided to the NRC in Reference 1.

The CPC Improvement Program consists of three major areas:

- Part A - Optimization of CPC/CEAC Software for Reloads
- Part B - CEAC Desensitization to Spurious Signals
- Part C - Reload Data Block Constants

Parts A and B of the program will first be implemented in Cycle 3 of SCE's SONGS Unit 2 which is scheduled for start up in early 1986. Following this implementation, the same algorithms will be implemented in Cycle 5 of AP&L's ANO Unit 2 and Cycle 3 of SCE's SONGS

Unit 3 later in 1986. Functionally identical algorithms incorporating additional modifications for Part C of the program are planned for implementation in Cycle 2 of LP&L's Waterford Unit 3 and in Cycle 2 of ANPP's Palo Verde Units 1, 2, and 3 as these plants are refueled. Table 1-1 summarizes the implementation schedule.

This document provides a brief review of each functional change to the CPCS associated with Parts A and B of the CPC Improvement Program and the basis for those changes. Part C of the program will be addressed in a future submittal. In addition, a brief overview is provided of changes in analysis methodology associated with the functional changes. Detailed algorithm modifications, in the form of functional specifications, were provided in the CPC/CEAC Software Modification document (Reference 2). The modifications were described as changes relative to the CPC/CEAC algorithms currently in place at SONGS Unit 2 and ANO Unit 2 (References 3 & 4).

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Table 1-1

CPC Improvement Program Implementation Schedule

Utility	Plant	Cycle	Program Components*	Date
SCE	SONGS-2	3	A,B	Early 1986
AP&L	ANO-2	Mid-5	A,B	Early 1986
SCE	SONGS-3	3	A,B	Late 1986
LP&L	Waterford-3	2	A,B,C	Early 1987
ANPP	PVNGS-1	2	A,B,C	Early 1987
ANPP	PVNGS-2	2	A,B,C	Early 1988
ANPP	PVNGS-3	2	A,B,C	Early 1989

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*Part A - Optimization of software for reloads

Part B - CEAC desensitization to spurious signals

Part C - Reload Data Block Constants

2.0 CPCS AND METHODLOGY CHANGES

2.1 Variable Overpower Trip

A Variable Overpower Trip (VOPT) algorithm has been added to the UPDATE program to improve the CPC response to transients with rapid power increases such as low power CEA withdrawals and large excess load events. Previously, [ ] [ ] was required to correct for the maximum non-conservative power error that could occur during design basis transients. The addition of the VOPT algorithm will reduce the size of this adjustment.

The VOPT algorithm [ ]

[ ]

The new algorithm is functionally similar to the hardware VOPT system that is presently installed in the Palo Verde units except

The addition of the VOPT algorithm permits reanalysis of the CEA bank withdrawal and excess load events to credit the improved response of the CPCS to such transients.

2.1.1 Impact on Sequential CEA Bank Withdrawal Analysis

Protection against exceeding the DNBR SAFDL during a sequential CEA bank withdrawal (BCEAW) event at power was provided by the CPC Low DNBR trip. The CPC sensed the power rise and related changes in other parameters and determined if a Low DNBR trip was required.

The addition of the Variable Overpower Trip adds another level of plant protection for this event. The VOPT will initiate a reactor trip for events with rapidly increasing core power. Thus, the addition of the VOPT will affect those BCEAW events with large reactivity insertion rates. For such events, the VOPT will respond more rapidly than would the CPC Low DNBR trip. Due to the faster response of the VOPT, the dynamic response of the CPC DNBR algorithm was relaxed and [ ] was not required to assure a timely CPC trip for these rapid events. For example, during a typical BCEAW event from zero power the SONGS Unit 2 CPC will now initiate a trip via the VOPT algorithm when the power reaches approximately 30% of rated power. For the same event, a Low DNBR trip would not have been initiated until the power exceeded approximately 70% of rated power. This faster response to rapid BCEAW events simplifies the event analysis and improves the safety of the plant.

The CPC Low DNBR trip remains the primary protection for BCEAW events with lower reactivity insertion rates. However, for these slower events, [ ] implies a smaller impact on the plant operating flexibility and a reduced possibility of an unnecessary reactor trip. A re-evaluation of the spectrum of BCEAW events using current methodology but crediting the new trip will be performed to confirm that the events meet the SAFDLs on both DNBR and LHR as well as the criterion on peak system pressure.

2.1.2 Impact on Excess Load Event Analysis

The increased main steam flow event is the limiting excess load event and results in a power increase whenever the MTC is negative. Previous analyses credited either the CPC Low DNBR trip or the Linear High Power trip to demonstrate that the DNB and LPD SAFDLs were met for the event. Both of these trips can possibly be delayed by the rapid decrease in cold leg temperature: the DNBR trip due to beneficial impact of reduced temperature on calculated DNBR and the linear high power trip due to the increased shielding of the excore detectors by the colder (i.e., more dense) water. The VOPT algorithm will provide a reactor trip sooner than either the Low DNBR trip or the Linear High Power trip for some rapid power increasing excess load events.

A large excess load event causes the core inlet temperature to decrease rapidly which results in a significant core power rise for typical values of negative MTCs. The use of [ ] Using the current methodology, the response of the CPCS with the VOPT to the increased main steam flow events will be re-evaluated to confirm that the events meet the SAFDLs on DNBR and LHR.

2.2 Asymmetric Steam Generator Transient Algorithm

The UPDATE program in CPC includes an algorithm which provides automatic protection in the event of certain Asymmetric Steam Generator Transients (ASGT). In the previous version of this algorithm, a sufficiently large difference in cold leg temperatures caused [

]

Several modifications have been made to the ASGT algorithm to improve its response to asymmetric temperature transients. The use of [

]

The trip times obtained in the ASGT analysis based on the previous algorithm were adversely impacted by [

] This has the effect of reducing the sensitivity of the algorithm to short term perturbations of the temperature signals. In addition, the algorithm is less sensitive to changes in the RTD characteristics so that margin penalties are less likely.

As an additional benefit, the improved ASGT algorithm allows for the calculation of cycle independent [ ] This leaves only the trip setpoint, which is an addressable constant, that needs to be verified or recalculated on a cycle specific basis.

2.3 Incipient CEA Misoperation Detection

The CPCS provides protection against violation of a SAFDL due to CEA misoperations such as single CEA deviation, CEA subgroup deviation, out-of-sequence CEA group insertion, and excessive insertion of the PLCEAs. Modifications have been made to several of the CPC programs to initiate the CEA withdrawal prohibit (CWP) prior to exceeding the deadband for CPCS response to any of these misoperations.

The CPCS uses two CEA calculators (CEACs) to determine if any CEA has deviated from the remainder of its subgroup by an excessive amount. When either CEAC detects a small deviation, an alarm is initiated and, if the deviation exceeds an allowable deadband, each CEAC sends a penalty factor to each of the four CPCs to increase the radial power peaking. When operating margin is small, even a small penalty could result in a reactor trip.

The CEAC program has been modified to provide a flag bit to indicate wnen one or more CEAs have deviated from their subgroup by an amount greater than the alarm limit even if the deviation is not large enough to send a penalty factor. If this flag bit has been set by either CEAC, the UPDATE program will forward the flag to TRIPSEQ which will initiate a CEA Withdrawal Prohibit (CWP).

The POWER program determines if larger scale CEA misoperations have occurred. Penalty factors are applied to the radial power peaking whenever [ ] the core, the regulating CEAs are moved out-of-sequence, or there is a significant deviation between the subgroups within the same group. The penalty factor for these conditions may be large (e.g., an 8.0 multiplier) and may cause a CPC channel trip when applied in the calculation. The algorithm has been modified to set a flag when the plant is approaching one of the above situations but prior to application of a penalty factor. This flag is also sent to TRIPSEQ which will initiate a CEA Withdrawal Prohibit (CWP).

By warning the operator about the incipient application of a penalty factor and simultaneously preventing the CEA movement in the direction that would increase core power, the CWP provides time for the operator to take corrective action. This will sometimes prevent the plant from reaching a condition that might have required a trip and thus reduces the possibility that an unnecessary plant trip will occur.

[ ]

2.4 CEAC Desensitization to Spurious Signals

The previous UPDATE program selected the larger of the penalty factors transmitted by the two CEACs for immediate application to the core power used in the DNBR and LPD calculations. As a result,

[ ]

2.4.1 CEAC Fail Flag Interpretation

The penalty factor word that is transmitted by each CEAC includes a [ ]

The logic in UPDATE has been revised to [ ] Thus, the modification can not have any adverse effect on plant safety unless the CEAC failure should occur during a single CEA misoperation event while the other CEAC has been taken out of service for periodic testing or maintenance. [ ] However, the consequences of the event would only be slightly more adverse and will be considered in the safety analysis to confirm acceptable results.

2.4.2 CEAC Penalty Factor Delay

The algorithm in UPDATE which interprets CEAC deviation penalty factors has been modified [

]

[ ] for the initial implementation of this algorithm modification for SONGS Unit 2 Cycle 3.

2.5 [ ]

[ ]

2.6 Other Modifications

The remaining changes to the CPC algorithm have smaller impact on the performance of the system than do those already described. The changes include the incorporation into the algorithms of effects that had been previously obtained via selection of data base constants, removal of unused algorithms, the response to a new licensing position, the simplification of methods, and the provision of additional information to the plant operator.

2.6.1 Simplified Flow Calculation

The algorithm used to calculate coolant mass flow rate in the FLOW program has been simplified

[ ] The flow calculated by the revised algorithm does not differ significantly from that calculated by the current algorithm. The minor residual differences will be accommodated in the CPC uncertainty analysis. Simplifying the prior calculation, [ ] reduces the time required to calculate flow and thus reduces the loading on the CPC central processor unit.

2.6.2 Removal of Projected DNBR Algorithms

The previous FLOW program included a projection of the calculated DNBR for perceived changes in core mass flow. This projected DNBR was used to prevent violation of the DNBR SAFDL during the Loss of Flow (LOF) event. This event analysis now uses the CPC trip that occurs when the speed of one or more of the reactor coolant pumps drops below the new addressable trip setpoint on pump speed. The flow projected DNBR is no longer required and has thus been removed. The addressable pump speed trip setpoint will be determined from the LOF analysis for each plant. This change was first implemented (without the addressable constant) in the SONGS Unit 2 Cycle 2 analysis by modifications to data base constants.

Also, the previous UPDATE program included the calculation of a projected DNBR which accounted for dynamic pressure changes. Safety analyses have determined that such a projection is not required and data base constants have always nullified the calculation.

Therefore, this algorithm is being eliminated to reduce the calculational time and hence the loading on the CPC central processor unit.

Complementary modifications were made to the TRIPSEQ and FLOW programs to compare a single DNBR [ ] [ ] to the DNBR trip setpoint. In addition, the calculation of several parameters previously used in the flow projection algorithm has been removed from the POWER program.

2.6.3 Elimination of [ ]

The previous UPDATE program included [ ]

[ ]

2.6.4 Deviation Penalty Factor Simplification

The data base constants previously used in the CEAC program provided unique penalty factors for both DNBR and LPD for many combinations of deviation direction, deviated CEA, and general CEA configuration. A reduced set of penalty factor data will be used in the future to simplify the analysis that generates the CEAC data base. [ ] In either case, analysis required to support these deviation penalty factors for future cycles will be reduced. [ ] was first approved in mid Cycle 1 of SONGS Unit 2.

The previous UPDATE program included [ ]

2.6.5 ASI Dependent Parameters

2.6.6 Low Power ASI Display

At low power levels where excore signals are less reliable due to noise, 2.6.7 Elimination of the Augmentation Factor Array

The previous POWER program included adjustment of the 3-D power peaking factor for the effects of fuel densification via an axially dependent augmentation factor. A recently completed analysis performed by C-E for EPRI (Reference 5), demonstrated that the increased power peaking associated with the small interpellet gaps found in C-E's modern fuel rods (non-densifying fuel in pre-pressurized tubes) is insignificant and that the augmentation factors are no longer required. This analysis was presented to the NRC for Calvert Cliffs Units 1 & 2 (Reference 6) and was approved in Reference 7. Thus, the augmentation factors are no longer required in CPC and this calculation has been deleted from the POWER routine.

2.7. COLSS Modifications

The total Loss of Reactor Coolant Flow (LOF), the single full length CEA Drop (CEAD) and the Asymmetric Steam Generator Transient (ASGT) have typically been the most limiting transients with respect to determining DNBR margin related LCO's. As described in Reference 9, the thermal margin maintained by the LCO's has been monitored in COLSS [ ] and potential margin loss due to the need to use conservative conversion factors.

Recent analyses using HERMITE space-time methods (Reference 8) have reduced the margin requirements for LOF and ASGT on some plants. In contrast, the desire to avoid unnecessary plant trips [ ]

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[ ]

FIGURE 2.1
VOPT ALGORITHM RESPONSE

FIGURE 2.2
ASGT ALGORITHM SCHEMATIC

3.0 REFERENCES

1) "CPC Improvement Program - Detailed Presentation to NRC", CEN-302(S)-NP, April 1985

2) "CPC/CEAC Software Modifications for the CPC Improvement Program," CEN-308-NP Rev. 00-NP, August 1985

3) "Functional Design Requirements for a Core Protection Calculator," CEN-305-NP, July 1985

4) "Functional Design Requirement for a Control Element Assembly Calculator," CEN-304-NP, July 1985

5) "CEPAN Method of Analyzing Creep Collapse of Oval Cladding, Volume 5: Evaluation of Interpellet Gap Formation and Clad Collapse in Modern PWR Fuel Rods," EPRI NP-3966-CCM, Volume 5, Project 2061-6, Computer Code Manual, April 1985

6) "Calvert Cliffs Nuclear Power Plant Unit Nos. 1 & 2 Docket Nos. 50-317 & 50-318, Request for Amendment", Letter, A. E. Luduall, Jr. to J. R. Miller (Chief Operating Reactors Branch #3) 12/31/80

7) "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Amendment No. 104 to Facility Operating License No.

DPR-53, Baltimore Gas & Electric Company Calvert Cliffs Nuclear Power Plant Unit No. 1 Docket 50-317

8) "HERMITE - A Multi-dimensional Space Time Kinetics Code for PWR Transients", CENPD-188, March 1976

9) "Overview Description of the Core Operating Limit Supervisory System (COLSS)", CEN-312-NP, Rev. 0-NP, September, 1986

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