CEN - 281 (S) - NP

CPC/CEAC SOFTWARE MODIFICATIONS

FOR

SAN ONOFRE NUCLEAR GENERATING STATION UNITS No. 2 AND 3

JULY, 1984

POWER SYSTEMS
COMBUSTION ENGINEERING, INC

LEGAL NOTICE

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1.0 INTRODUCTION

1.1 REPORT SCOPE

The Core Protection Calculator (CPC) System developed by Combustion Engineering is a digital mini-computer system which calculates the minimum Departure from Nucleate Boiling Ratio (DNBR) and the peak Local Power Density (LPD) on-line and generates a reactor trip if either the minimum DNBR or the peak LPD approaches the appropriate Specified Acceptable Fuel Design Limit. The CPC System has been reviewed by NRC and approved for operation in Arkansas Nuclear One (ANO) Unit 2, Waterford-3, San Onofre Nuclear Generating Station (SONGS) Units 2 and 3 and Palo Verde Nuclear Generation Station (PVNGS) Units 1, 2 and 3. The CPC/CEAC software for SONGS Unit 2 and 3 is being modified for operation in Cycle 2. This modification is being made using the PVNGS Cycle 1 CPC/CEAC software (Reference 1.3-3) as a basis since it is the latest NRC approved software. The modification for SONGS Units 2 and 3 Cycle 2 includes algorithm changes derived from the implementation of the PVNGS Cycle 1 software as well as other algorithm changes. These changes were made to the CPC System in accordance with the NRC-approved CPC software change procedure (References 1.3-1 and 1.3-2).

This report describes the changes to the SONGS software for Cycle 2. Changes derived from the implementation of the PVNGS Cycle 1 software are described briefly since they have been approved and implemented previously (Reference 1.3-3) while other changes are described in detail.

1.2 REPORT SUMMARY

The modifications to the CPC/CEAC software which will be applicable to Cycle 2 of SONGS Units 2 and 3 are:

1) Modification of the temperature shadowing factor algorithm.

2) Modification of the CPC core power bias algorithm.

3) Improvement to the UPDATE algorithm.

4) Modification of the heat flux distribution extrapolation in STATIC.

5) Addition of [ ] new addressable constants.

6) Modification of the four linear heat distributions in STATIC program to account for differences between the hot channel and hot pin relative powers.

7) Upgrade of the non-uniform heating correction factors (FK) in the UPDATE program.

The general format used in describing each software modification contained in this report is a statement of the change, the reason for the change, and a detailed description of the change including algorithm descriptions in symbolic algebra. This is the same format used in Reference 1.3-3.

1.3 REFERENCES FOR SECTION 1.0

1. CEN-39(A)-NP, Revision 02, The CPC Protection Algorithm Software Change Procedure, December 21, 1978.

2. CEN-39(A)-NP, Supplement 1-NP, Revision 01, January 5, 1979.

3. Dockets STN-50-470F, Enclosure 1-NP to LD-82-039, CPC/CEAC Software Modifications for System 80, March, 1982.

2.0 SOFTWARE MODIFICATIONS

2.1 CHANGES DERIVED FROM IMPLEMENTATION OF PVNGS CYCLE 1 SOFTWARE

The changes in CPC software for SONGS Units 2 and 3 Cycle 2 that have been derived from implementation of the PVNGS Cycle 1 software are described in the following summaries. These changes were submitted previously to the NRC (Reference 2.5-1).

1. The non-uniform heating correction factor (F_K) in the UPDATE program was adjusted by the addition of [ ] constants based on the [ ] in quality margin.

2. The calculation of the four linear heat rate (LHR) distributions in the STATIC program was modified to account for the difference between the hot channel and hot pin relative powers.

3. The positive range limit on the CEAC penalty factor multipliers, [ ], was shifted from [ ] to [ ].

4. Algorithms were added to the CPC and CEAC (Control Element Assembly Calculator) for detecting the actuation of a Reactor Power Cutback (RPC) event, for using off-line calculated RPC penalty factors, and for allowing the CPC calculation to more closely model core conditions without generating an inadvertent trip in the event of a RPC. Since SONGS Units 2 and 3 do not have a RPC system, the effect of these algorithms will be nullified through the appropriate data base constants.

5. Addressable constants have been added to the CPC and CEAC to define the duration that the RPC flags can remain set. (For SONGS these addressable constants will be set to [ ]).

6. An algorithm was added to the FLOW Program to account for forward flow through a reactor coolant (RC) pump at or near zero revolution per minute (RPM). Since SONGS Units 2 and 3 do not have a very rapid occurrence of negative head across an RC pump with a locked rotor, the effect of this algorithm will be nullified through the appropriate data base constants.

2.2 ADDITIONAL CORE PROTECTION CALCULATOR (CPC) ALGORITHM CHANGES

2.2.1 Modification of the Temperature Shadowing Factor Algorithm

Change:

Implement for cycle 2 a [ ] the Temperature Shadowing Factor (TSF) on moderator temperature using a [ ] inlet moderator temperature. The slope of the correction for temperatures [ ] [ ] will be chosen to bound all expected TSF data, including uncertainties. A [ ] will be used for temperatures [ ]. The excore detector calibration procedures will be modified to be consistent with this determination of the TSF and its use in adjusting the neutron flux power.

Reason:

The temperature shadowing factor (TSF) is used to correct the CPC neutron flux power for decalibration effects resulting from changes in inlet coolant density. A moderator temperature-dependent multiplier is applied to the neutron flux power calculation to correct excore detector response. In the current algorithm, the TSF is a [ ] of the change in moderator temperature the slope of which is measured at start-up. The uncertainty in the measurement of the TSF is currently accommodated in the CPC Departure from Nucleate Boiling (DNB) and Linear Heat Rate (LHR) overall uncertainty terms [ ].

This change will allow the TSF uncertainty to be included directly in the factor itself. This insures a conservative correction for temperature at moderator temperatures above or below the inlet moderator temperature at which the neutron flux power was calibrated (calibration temperature) while removing unnecessary penalties for uncertainty at the calibration temperature (which is anticipated to be near nominal conditions).

Description:

[ ]

[ ]

2.2.2 Modification of the CPC Core Power Bias Algorithm

Change:

Implement [ ] to adjust the thermal power and neutron flux power level in the CPCs.

Reason:

[ ]

Description (See Figure 1):

[ ]

FIGURE 1

[ ]

where: [ ]

Where

2.2.3 Improvement to UPDATE Algorithm

Change:

The penalty on DNBR in UPDATE will be modelled more realistically. When the

Reason:

The UPDATE algorithm of CPC provides rapid and conservative recalculation of DNBR based upon the detailed DNBR calculation contained in the STATIC algorithm and updated state parameters. During the CPC overall DNB uncertainty analysis, off-line comparisons of UPDATE and STATIC-predicted DNBRs based on

period are used to quantify the conservatism. Presently, the UPDATE algorithm of CPC applies a penalty to the updated DNBR at all times. This change provides greater margin to pre-trip alarms during steady state operation and is justified by the high accuracy of the UPDATE algorithm for small changes in conditions. The safety margin of the CPC's during transients is preserved by the larger conservative penalty factors which are applied when the UPDATE DNBR changes significantly from the STATIC value.

Description:

[ ]

where [ ]

[ ]

2.2.4 Modification of Heat Flux Distribution Extrapolation in STATIC

Change:

Modify the heat flux distribution extrapolation in STATIC [ ] [ ] nodal heat flux distribution values.

Reason:

For certain CEA configurations, radial peaking factor assignments, and/or radial peaking factor multipliers, it is possible to [ ]

Description:

This change is applied in the section of the STATIC program where [ ].

A check is performed for [ ]. If any are detected, [ ].

[ ]

Where:

$\phi_c(i)$ = [ ] node hot pin normalized heat flux distribution

2.3 CPC ADDRESSABLE CONSTANT CHANGES

1. Change·

Addressable constant [ ] replaces [ ].

Reason:

Consistent with TSF algorithm change described in section 2.2.1.

Description:

[ ]

2. Change

Addressable constant [ ] has been added to the CPC in relation to the core power level.

Reason:

To implement new algorithm using [ ] and [ ] bias terms described in section 2.2.2.

Description:

[ ]

2.4 TYPICAL DATA BASE CONSTANTS CHANGES FOR SONGS UNIT 2

2.4.1 Data Base Constants for the Temperature Shadowing Factor Algorithm Constants.

[ ]

2.4.2 Data Base Constants for Power Dependent Biases

[ ]

[ ]

2.4.3 Data Base Constants for DNBR Penalty in UPDATE

[ ]

2.4.4 Change in UPDATE DNBR Uncertainty and Threshold Constants

[ ]

2.4.5 Data Base Constants for RPC Algorithm

[ ]

2.5 REFERENCES FOR SECTION 2.0

1. Dockets STN-50-470F, Enclosure 1-NP to LD-82-039, CPC/CEAC Software Modifications for System 80, March, 1982.

2. CEN-147(S)-NP, Functional Design Specification for a Core Protection Calculator, January 1981.

3. CEN-148(S)-NP, Functional Design Specification for a Control Element Assembly Calculator, January 1981.

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