Response Time Analysis of Safety I&C System

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ABSTRACT

This technical report provides the response time analysis of safety instrumentation and control (I&C) system which is intended to be used for Nuclear Regulatory Commission (NRC) Design Certification application of the APR1400.

The safety function of safety I&C system regarding response time analysis is divided into reactor trip (RT) function and engineered safety features (ESF) actuation function. The response time of RT function is defined as the time interval from when the monitored parameter exceeds the trip setpoint value at the input to the sensor until electrical power is interrupted to the control element assembly (CEA) drive mechanism. The response time of ESF actuation function is defined as the time interval from when the monitored parameter exceeds the trip setpoint value at the input to the sensor until the final component such as pump, valve, damper or fan actuates. This report demonstrates that the total response time allocated to the individual components of the safety I&C system such as sensor, signal processing module, digital computer, actuation device does not exceed the corresponding RT or ESF response time requirement assumed in the safety analysis.

This document also demonstrates in Appendix A that the APR1400 safety I&C system conforms to NUREG-0800 Branch Technical Position (BTP) 7-21.

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ACRONYMS AND ABBREVIATIONS

ACU	air cleaning unit
AFAS	auxiliary feedwater actuation signal
AIM	analog input module
APC-S	auxiliary process cabinet – safety
BP	bistable processor
BTP	branch technical position
CEA	control element assembly
CEAC	control element assembly calculator
CEDM	control element drive mechanism
CIAS	containment isolation actuation signal
CPCS	core protection calculator system
CPIAS	containment purge isolation actuation signal
CPU	central processing unit
CREVAS	control room emergency ventilation actuation signal
CSAS	containment spray actuation signal
CTRLM	control module
DCD	design control document
DOM	digital output module
EDG	emergency diesel generator
ENFMS	ex-core neutron flux monitoring system
ESF	engineered safety features
ESF-CCS	engineered safety feature – component control system
FHEVAS	fuel handling area emergency ventilation actuation signal
HCP	high containment pressure
HHCP	high-high containment pressure
HLPD	high local power density
HLPL	high logarithmic power level
HPP	high pressurizer pressure
HSGL	high steam generator level
HVOPT	high variable overpower trip
I&C	instrumentation and control
IR	interposing relay
ITAAC	Inspections, tests, analyses, and acceptance criteria
LCL	local coincidence logic
LDNBR	low departure from nucleate boiling ratio
LPP	low pressurizer pressure
LRCF	low reactor coolant flow
LSGL	low steam generator level
LSGP	low steam generator pressure
MFIV	main feedwater isolation valve
MSIS	main steam isolation signal
MSIV	main steam isolation valve

NRC	U.S. Nuclear Regulatory Commission
PLC	programmable logic control
PPS	plant protection system
PROM	programmable read only memory
RCPSSSS	reactor coolant pump shaft speed sensing system
RSPT	reed switch position transmitter
RT	reactor trip
RTD	resistance temperature detector
RTSS	reactor trip switchgear system
SDL	serial data link
SIAS	safety injection actuation signal
SRP	standard review plan
TD	time delay

1 INTRODUCTION

1.1 Purpose

The purpose of this technical report is to demonstrate that the sum of individual response time allocated to each component on the critical path of safety I&C system functions does not exceed the response time assumed in the APR1400 safety analysis.

This technical report also demonstrates that the safety I&C system for APR1400 conforms to NUREG-0800 branch technical position (BTP) 7-21.

1.2 Scope

This technical report provides the response time analysis of APR1400 safety I&C system, which includes the response times of the reactor trip (RT) system and the engineered safety features (ESF) actuation system.

The response time analysis of safety I&C system consists of defining the response time requirement for each safety I&C system function, determining the safety system signal path for each trip function, allocating individual response time to each component on the signal path, and analyzing safety system response time for each trip function.

This document also provides conformance of the safety I&C system of APR1400 to the seven acceptance criteria of NUREG-0800 BTP 7-21.

2 CODES AND STANDARD

This section describes the applicable or reference codes, regulations and standard used for the basis of response time analysis for APR1400 safety I&C system. The general design criteria (GDC) is described to identify the overall requirements for the response time, while these criteria are also addressed in the APR1400 design control document (DCD) (Reference 1) and the Safety I&C System TeR (Reference 2) as the compliance commitment for the response time.

2.1. “GDC 10, Reactor Design”, 10CFR50 Appendix A.

2.2. “GDC 13, Instrumentation and Control”, 10CFR50 Appendix A.

2.3. “GDC 20, Protection System Functions”, 10CFR50 Appendix A.

2.4. “GDC 29, Protection Against Anticipated Operational Occurrences”, 10CFR50 Appendix A.

2.5. “Guidance on Digital Computer Real-Time Performance”, NUREG-0800 BTP 7-21, Revision 5.

2.6. “Setpoints for Nuclear Safety-Related Instrumentation”, ANSI/ISA-67.04, Part I, 1994.

3 SAFETY I&C SYSTEM DESCRIPTION

3.1 Safety Functions

The safety functions of safety I&C system regarding response time analysis consist of RT functions and ESF actuation functions. The safety I&C system is designed in accordance with Sections 2.1 through 2.6. All trip parameters of RT functions and ESF actuation functions are as follows:

(1) RT functions

- Low Pressurizer Pressure (LPP)
- High Pressurizer Pressure (HPP)
- Low Steam Generator Level (LSGL)
- High Steam Generator Level (HSGL)
- Low Steam Generator Pressure (LSGP)
- High Containment Pressure (HCP)
- Low Reactor Coolant Flow (LRCF)
- High Local Power Density (HLPD)
- Low Departure from Nucleate Boiling Ratio (LDNBR)
- High Variable Overpower Trip (HVOPT)
- High Logarithmic Power Level (HLPL)

(2) ESF actuation functions

- Low Pressurizer Pressure
  - Safety Injection
  - Containment Isolation

- High Containment Pressure
  - Safety injection
  - Containment isolation
  - Main steam isolation

- High-High Containment Pressure (HHCP)
  - Containment spray pump
  - Containment isolation valves closed on containment spray actuation signal (CSAS)

- Low Steam Generator Pressure
  - Main steam isolation

- Low Steam Generator Level
  - Auxiliary feedwater pump (motor driven)
  - Auxiliary feedwater pump (turbine driven)

- High Steam Generator Level
  - Main steam isolation

- Control Room Emergency Ventilation Actuation Signal (CREVAS)
  - CREVAS actuated isolation dampers
  - Emergency makeup air cleaning unit (ACU) fan

- Fuel Handling Area Emergency Ventilation Actuation Signal (FHEVAS)
  - FHEVAS actuated isolation dampers
  - emergency makeup ACU fan

- Containment Purge Isolation Actuation Signal (CPIAS)
  - CPIAS actuated isolation dampers

3.2 Assumptions

3.2.1 If a total allocated response time is the same as its response time requirement, it is assumed that sufficient margin between an individual component response time and its allocated response time is maintained.

3.2.2 Response time requirements for RT function do not include Control Element Drive Mechanism (CEDM) release time and rod drop time that are assumed in the safety analysis.

3.2.3 Response time allocations for transmitters, auxiliary process cabinet – safety (APC-S), plant protection system (PPS), core protection calculator system (CPCS), engineered safety feature – component control system (ESF-CCS), reactor trip switchgear system (RTSS), radiation monitoring system (RMS), damper, fan, pump and valve are based on actual response time from Shin-Kori Nuclear Power Plant Units 3 and 4. These will be confirmed for as-built APR1400 components through APR1400 design certification inspections, tests, analyses, and acceptance criteria (ITAAC).

3.2.4 In order to ensure 75% maximum central processing unit (CPU) load, configuration restrictions and tests required by Reference 5 will be incorporated into the CPCS design. The PPS and ESF-CCS will be designed not to exceed 70% of CPU full load.

4 RESPONSE TIME REQUIREMENTS

The response time requirements for safety I&C system trip parameters are described in Tables 4.1 and 4.2 below and based on Tables 7.2-5 and 7.3-7 of the DCD (Reference 1). The safety analysis establishes an analytical limit in terms of a measured or calculated variable and a specific time after that value is reached to begin protective action. According to section 2.6 of this TeR, satisfying these two constraints will ensure that the safety limit will not be exceeded during anticipated operational occurrences and postulated accidents. The response times assumed in the safety analysis are established as the response time requirements for RT function and ESF actuation function.

4.1 Response Time Requirements for RT Functions

Table 4.1-1 Response Times for RT Functions

No.	Function		Response Time(s)
1	LPP		≤1.15
2	HPP		≤0.85
3	LSGL		≤1.25
4	HSGL		≤1.15
5	LSGP		≤1.15
6	HCP		≤1.15
7	LRCF		≤0.7
8	HLPD	Ex-core neutron flux monitoring system (ENFMS) Detectors	0.65[1)]
		CEA positions	≤1.45[2)]
		CEA calculator (CEAC) penalty factor	≤0.85[2)]
9	LDNBR	ENFMS detectors	≤0.65[1)]
		CEA positions	≤1.45[2)]
		Cold leg temperature	≤8.65[3)]
		Hot leg temperature	≤8.65[3)]
		Primary coolant pump shaft speed	≤0.45[4)]
		Reactor coolant pressure from pressurizer	≤0.95[5)]
		CEAC penalty factor	≤0.85[2)]
10	HVOPT		≤0.55[1)]
11	HLPL		≤0.55[1)]

1) Neutron detectors are exempt from response time testing. The response time of neutron flux signal portion of the channel is measured from the detector output or from the input of first electronic component in channel.

2) Response time is measured from the output of the sensor.

3) Response time is measured from the output of the resistance temperature detector (RTD). RTD response time is measured at least once per 18 months. The measured response time of the slowest RTD is less than or equal to 8.0 seconds.

4) The pulse transmitters measuring pump speed are exempt from response time testing. The response time is measured from the pulse shaper input.

5) Response time is measured from the output of the pressure transmitter. The transmitter response time is less than or equal to 0.3 second.

4.2 Response Time Requirements for ESF Actuation Functions

Table 4.2-1 Response Times for ESF Actuation Functions

No.	Function	Initiating Signal		Response Time(s)[(1)]
1	LPP	Safety Injection		≤40
		Containment Isolation	Containment isolation actuation signal (CIAS) actuated low volume purge valves	≤5
			Other CIAS actuated valves	≤83.5[2)] / 62.0[3)]
2	HCP	Safety Injection		≤40
		Containment Isolation	CIAS actuated low volume purge valves	≤5
			Other CIAS actuated valves	≤83.5[2)] / 62.0[3)]
		Main Steam Isolation	Main steam isolation signal (MSIS) actuated main steam isolation valves (MSIVs)	≤6.35
			MSIS actuated main feedwater isolation valves (MFIVs)	≤11.35
3	HHCP	Containment spray pump		≤50.4[4),6)] /28.5[5),6)]
		Containment isolation valves closed on CSAS		≤73.5[2)] / 52.0[3)]
4	LSGP	Main Steam Isolation	MSIS actuated MSIVs	≤6.35
			MSIS actuated MFIVs	≤11.35
5	LSGL	Auxiliary feedwater pump (motor driven)		≤61.45[4)]
		Auxiliary feedwater pump (turbine driven)		≤61.45
6	HSGL	Main Steam Isolation	MSIS actuated MSIVs	≤6.35
			MSIS actuated MFIVs	≤11.35
7	CREVAS	Control room air intake radiation - High	CREVAS actuated isolation dampers	≤8.4[7),8)]
			Emergency makeup ACU fan	≤5.0[7),8),9)]
8	FHEVAS	Spent fuel pool area radiation - High	FHEVAS actuated isolation dampers	≤8.4[7),8),9)]
			Emergency makeup ACU fan	≤5.0[7),8)]
9	CPIAS	Containment upper operating area / operating area radiation - High	CPIAS actuated isolation valves	≤9.9[7),8)]

Notes

1) PPS cabinet delays are included.

2) A loss of offsite power. Emergency diesel generator (EDG) starting delay is included. Response time includes movement of valves and attainment of pump or blower discharge pressure.

3) Offsite power is available. EDG starting delay is not included. Response time includes movement of valves and attainment of pump or blower discharge pressure.

4) Same as No. 2. In addition, delays of load-sequencing are included.

5) Same as No. 3. In addition, delays of load-sequencing are included.

6) Spray line fill time is not included.

7) EDG starting delay is not included.

8) The response time of the radiation detectors is not included. The response time of the radiation signal portion of the channel is measured from the detector output or from the input of the first electronic component in channel to closure of dampers / valves or start fans.

9) Fan motor run-up time is not included since the building volume is too large to make a substantial change to pressure compared to the isolation functions.

5 SIGNAL PATHS

This section describes the signal path of the safety I&C system. The safety I&C system configuration required to determine signal paths of RT system and ESF actuation system is delineated in Sections 7.1, 7.2, and 7.3 of DCD (Reference 1) and Section 4 of the safety I&C system TeR (Reference 2). The APC–S is to perform the distribution of a transmitter's output signal. If the output signal has another destination in addition to the PPS, the APC-S is located between the transmitter and the PPS to split and distribute the signal.

5.1 Response time of the RT system

The signal path for each trip parameter of RT functions is provided in Table 5.1-1.

Table 5.1-1 Signal Path for RT Functions

<table>
<tr><th>No.</th><th colspan="2">Parameter</th><th>Signal Path</th></tr>
<tr><td>1</td><td colspan="2">LPP</td><td rowspan="3">Transmitter → APC-S → PPS → RTSS</td></tr>
<tr><td>2</td><td colspan="2">HPP</td></tr>
<tr><td>3</td><td colspan="2">LSGL</td></tr>
<tr><td>4</td><td colspan="2">HSGL</td><td>Transmitter → PPS → RTSS</td></tr>
<tr><td>5</td><td colspan="2">LSGP</td><td>Transmitter → APC-S → PPS → RTSS</td></tr>
<tr><td>6</td><td colspan="2">HCP</td><td rowspan="2">Transmitter → PPS → RTSS</td></tr>
<tr><td>7</td><td colspan="2">LRCF</td></tr>
<tr><td rowspan="3">8</td><td rowspan="3">HLPD</td><td>ENFMS Detectors</td><td>Neutron Detectors → ENFMS → CPCS → PPS → RTSS</td></tr>
<tr><td>CEA Positions</td><td rowspan="2">Reed Switch Position Transmitter (RSPT) → CPCS → PPS → RTSS</td></tr>
<tr><td>CEAC Penalty Factor</td></tr>
<tr><td rowspan="7">9</td><td rowspan="7">LDNBR</td><td>ENFMS Detectors</td><td>Neutron Detectors → ENFMS → CPCS → PPS → RTSS</td></tr>
<tr><td>Cold Leg Temperature</td><td rowspan="2">Temperature Sensor → CPCS → PPS → RTSS</td></tr>
<tr><td>Hot Leg Temperature</td></tr>
<tr><td>Primary Coolant Pump Shaft Speed</td><td>Reactor coolant pump shaft speed sensing system (RCPSSSS) → CPCS → PPS → RTSS</td></tr>
<tr><td>Reactor Coolant Pressure</td><td>Transmitter → APC-S →CPCS→ PPS → RTSS</td></tr>
<tr><td>CEA Positions</td><td rowspan="2">RSPT → CPCS → PPS → RTSS</td></tr>
<tr><td>CEAC Penalty Factor</td></tr>
<tr><td>10</td><td colspan="2">HVOPT</td><td rowspan="2">Neutron Detectors → ENFMS → PPS → RTSS</td></tr>
<tr><td>11</td><td colspan="2">HLPL</td></tr>
</table>

5.2 Response time of the ESF actuation system

The signal path for each trip parameter of ESF actuation system is provided in Table 5.2-1.

Table 5.2-1 Signal Path for ESF Actuation Functions

No.	Function	Initiating Signal		Signal Path
1	LPP	Safety Injection		Transmitter → APC-S → PPS → ESF-CCS → Pump/Valve
		Containment Isolation	CIAS actuated low volume purge valves	
			Other CIAS actuated Valves	
2	HCP	Safety Injection		Transmitter → PPS → ESF-CCS → Pump/Valve
		Containment Isolation	CIAS actuated low volume purge valves	
			Other CIAS actuated valves	
		Main Steam Isolation	MSIS actuated MSIVs	
			MSIS actuated MFIVs	
3	HHCP	Containment spray pump		
		Containment isolation valves closed on CSAS		
4	LSGP	Main Steam Isolation	MSIS actuated MSIVs	Transmitter → APC-S → PPS → ESF-CCS → Pump/Valve
			MSIS actuated MFIVs	
5	LSGL	Auxiliary feedwater pump (motor driven)		
		Auxiliary feedwater pump (turbine driven)		
6	HSGL	Main Steam Isolation	MSIS actuated MSIVs	Transmitter → PPS → ESF-CCS → Pump/Valve
			MSIS actuated MFIVs	
7	CREVAS	Control room air intake radiation – High	CREVAS actuated isolation dampers	RMS → ESF-CCS → Damper/Fan/Valve
			Emergency makeup ACU fan	
8	FHEVAS	Spent fuel pool area radiation - High	FHEVAS actuated isolation dampers	
			Emergency makeup ACU fan	
9	CPIAS	Containment upper operating area / operating area radiation - High	CPIAS actuated isolation valves	

6 RESPONSE TIME ALLOCATION

This section describes the allocation of individual response time to each component on the critical signal path of the safety I&C system.

6.1 LPP for Reactor Trip

Table 6.1-1 Response Time Allocation for LPP

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	APC-S	
3	PPS	
4	RTSS	
Total		
Requirement		1.150

6.2 HPP for Reactor Trip

Table 6.2-1 Response Time Allocation for HPP

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	APC-S	
3	PPS	
4	RTSS	
Total		
Requirement		0.850

6.3 LSGL for Reactor Trip

Table 6.3-1 Response Time Allocation for LSGL

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	APC-S	
3	PPS	
4	RTSS	
Total		
Requirement		1.250

6.4 HSGL for Reactor Trip

Table 6.4-1 Response Time Allocation for HSGL

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	PPS	
3	RTSS	
Total		
Requirement		1.150

6.5 LSGP for Reactor Trip

Table 6.5-1 Response Time Allocation for LSGP

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	APC-S	
3	PPS	
4	RTSS	
Total		
Requirement		1.150

6.6 HCP for Reactor Trip

Table 6.6-1 Response Time Allocation for HCP

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	PPS	
3	RTSS	
Total		
Requirement		1.150

6.7 LRCF for Reactor Trip

Table 6.7-1 Response Time Allocation for LRCF

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	PPS	
3	RTSS	
Total		
Requirement		0.7

6.8 HVOPT for Reactor Trip

Table 6.8-1 Response Time Allocation for HVOPT

No.	Equipment	Allocated Response Time (s)
1	Neutron Detector	TS
2	ENFMS	
3	PPS	
4	RTSS	
Total		
Requirement		0.550

6.9 HLPL for Reactor Trip

Table 6.9-1 Response Time Allocation for HLPL

No.	Equipment	Allocated Response Time (s)
1	Neutron Detector	TS
2	ENFMS	
3	PPS	
4	RTSS	
Total		
Requirement		0.550

6.10 HLPD FOR REACTOR TRIP

6.10.1 ENFMS Detectors

Table 6.10-1 Response Time Allocation for ENFMS Detector (HLPD)

No.	Equipment	Allocated Response Time (s)
1	Neutron Detector	TS
2	ENFMS	
3	CPCS	
4	PPS	
5	RTSS	
Total		
Requirement		0.650

*The allocated response time of ENFMS is included in that of CPCS.

6.10.2 CEA Positions

Table 6.10-2 Response Time Allocation for CEA Positions (HLPD)

No.	Equipment	Allocated Response Time (s)
1	RSPT	[ ]TS
2	CPCS	
3	PPS	
4	RTSS	
Total		
Requirement		1.450

6.10.3 CEAC Penalty Factor

Table 6.10-3 Response Time Allocation for CEAC Penalty Factor (HLPD)

No.	Equipment	Allocated Response Time (s)
1	RSPT	[ ]TS
2	CPCS	
3	PPS	
4	RTSS	
Total		
Requirement		0.850

6.11 LDNBR for Reactor Trip

6.11.1 ENFMS Detectors

Table 6.11-1 Response Time Allocation for ENFMS Detector (LDNBR)

No.	Equipment	Allocated Response Time (s)
1	Neutron Detector	[ ]TS
2	ENFMS	
3	CPCS	
4	PPS	
5	RTSS	
Total		
Requirement		0.650

*The allocated response time of ENFMS is included in that of CPCS.

6.11.2 CEA Positions

Table 6.11-2 Response Time Allocation for CEA Positions (LDNBR)

No.	Equipment	Allocated Response Time (s)
1	RSPT	TS
2	CPCS	
3	PPS	
4	RTSS	
Total		
Requirement		1.450

6.11.3 Cold Leg Temperature

Table 6.11-3 Response Time Allocation for Cold Leg Temperature (LDNBR)

No.	Equipment	Allocated Response Time (s)
1	Temperature Sensor	TS
2	CPCS	
3	PPS	
4	RTSS	
Total		
Requirement		8.650

6.11.4 Hot Leg Temperature

Table 6.11-4 Response Time Allocation for Hot Leg Temperature (LDNBR)

No.	Equipment	Allocated Response Time (s)
1	Temperature Sensor	TS
2	CPCS	
3	PPS	
4	RTSS	
Total		
Requirement		8.650

6.11.5 Primary Coolant Pump Shaft Speed

Table 6.11-5 Response Time Allocation for Primary Coolant Pump Shaft Speed (LDNBR)

No.	Equipment	Allocated Response Time (s)
1	RCPSSSS	TS
2	CPCS	
3	PPS	

4	RTSS		TS
Total			
Requirement		0.450	

6.11.6 Reactor Coolant Pressure from Pressurizer

Table 6.11-6 Response Time Allocation for Reactor Coolant Pressure (LDNBR)

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	APC-S	
3	CPCS	
4	PPS	
5	RTSS	
Total		
Requirement		0.950

6.11.7 CEAC Penalty Factor

Table 6.11-7 Response Time Allocation for CEAC Penalty Factor (LDNBR)

No.	Equipment	Allocated Response Time (s)
1	RSPT	TS
2	CPCS	
3	PPS	
4	RTSS	
Total		
Requirement		0.850

6.12 LPP for ESF Actuation

6.12.1 Safety Injection

Table 6.12-1 Response Time Allocation for LPP for ESF actuation – Safety Injection Actuation Signal (SIAS)

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	APC-S	
3	PPS	
4	ESF-CCS	
5	SI Pump	
Total		
Requirement		40.000

6.12.2 Containment Isolation

Table 6.12-2 Response Time Allocation for LPP for ESF actuation – CIAS actuated low volume purge valves

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	APC-S	
3	PPS	
4	ESF-CCS	
5	Valve	
Total		
Requirement		5.000

Table 6.12-3 Response Time Allocation for LPP for ESF actuation – Other CIAS actuated valves

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	APC-S	
3	PPS	
4	ESF-CCS	
5	Valve	
Total		
Requirement		83.500 / 62.000

6.13 HCP for ESF Actuation

6.13.1 Safety Injection

Table 6.13-1 Response Time Allocation for HCP for ESF actuation - SIAS

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	PPS	
3	ESF-CCS	
4	SI Pump	
Total		
Requirement		40.000

6.13.2 Containment Isolation

Table 6.13-2 Response Time Allocation for HCP for ESF actuation – CIAS actuated low volume purge valves

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	PPS	
3	ESF-CCS	
4	Valve	
Total		
Requirement		5.000

Table 6.13-3 Response Time Allocation for HCP for ESF actuation – CIAS actuated low volume purge valves

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	PPS	
3	ESF-CCS	
4	Valve	
Total		
Requirement		83.500 / 62.000

6.13.3 Main Steam Isolation

Table 6.13-4 Response Time Allocation for HCP for ESF actuation – MSIS actuated MSIVs

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	PPS	
3	ESF-CCS	
4	Valve	
Total		
Requirement		6.350

Table 6.13-5 Response Time Allocation for HCP for ESF actuation – MSIS actuated MFIVs

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	PPS	
3	ESF-CCS	
4	Valve	
Total		

Requirement		11.350

6.14 HHCP for ESF Actuation

6.14.1 Containment Spray Pump

Table 6.14-1 Response Time Allocation for HHCP for ESF actuation – Containment Spray Pump

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	PPS	
3	ESF-CCS	
4	Pump	
Total		
Requirement		50.400 / 28.500

6.14.2 Containment Isolation Valves Closed on CSAS

Table 6.14-2 Response Time Allocation for HHCP for ESF actuation – Containment Isolation Valves Closed on CSAS

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	PPS	
3	ESF-CCS	
4	Valve	
Total		
Requirement		73.500 / 52.000

6.15 LSGP FOR ESF ACTUATION

6.15.1 Main Steam Isolation

Table 6.15-1 Response Time Allocation for LSGP for ESF actuation – MSIS actuated MSIVs

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	APC-S	
3	PPS	
4	ESF-CCS	
5	Valve	

Total			TS
Requirement		6.350	

Table 6.15-2 Response Time Allocation for LSGP for ESF actuation – MSIS actuated MFIVs

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	APC-S	
3	PPS	
4	ESF-CCS	
5	Valve	
Total		
Requirement		11.350

6.16 LSGL FOR ESF ACTUATION

6.16.1 Auxiliary Feedwater Pump (motor driven)

Table 6.16-1 Response Time Allocation for LSGL for ESF actuation – Auxiliary Feedwater Pump (motor driven)

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	APC-S	
3	PPS	
4	ESF-CCS	
5	Pump	
Total		
Requirement		61.450

6.16.2 Auxiliary Feedwater Pump (turbine driven)

Table 6.16-2 Response Time Allocation for LSGL for ESF actuation – Auxiliary Feedwater Pump (turbine driven)

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	APC-S	
3	PPS	
4	ESF-CCS	
5	Pump	
Total		
Requirement		61.450

6.17 HSGL for ESF Actuation

6.17.1 Main Steam Isolation

Table 6.17-1 Response Time Allocation for HSGL for ESF actuation – MSIS actuated MSIVs

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	PPS	
3	ESF-CCS	
4	Valve	
Total		
Requirement		6.350

Table 6.17-2 Response Time Allocation for HSGL for ESF actuation – MSIS actuated MFIVs

No.	Equipment	Allocated Response Time (s)
1	Transmitter	TS
2	PPS	
3	ESF-CCS	
4	Valve	
Total		
Requirement		11.350

6.18 CREVAS

6.18.1 Control Room Air Intake Radiation –High

Table 6.18-1 Response Time Allocation for CREVAS for ESF actuation – CREVAS actuated isolation dampers

Propagation No.	Equipment	Allocated Response Time (s)
1	RMS	TS
2	ESF-CCS	
3	Damper	
Total		
Requirement		8.400

Table 6.18-2 Response Time Allocation for CREVAS for ESF actuation – Emergency makeup ACU fan

Propagation No.	Equipment	Allocated Response Time (s)
1	RMS	TS
2	ESF-CCS	
3	Fan	
Total		

Requirement		5.000

6.19 FHEVAS

6.19.1 Spent Fuel Pool Area Radiation – High

Table 6.19-1 Response Time Allocation for FHEVAS for ESF actuation – FHEVAS actuated isolation dampers

Propagation No.	Equipment	Allocated Response Time (s)
1	RMS	[ ] TS
2	ESF-CCS	
3	Damper	
Total		
Requirement		8.400

Table 6.19-2 Response Time Allocation for FHEVAS for ESF actuation – Emergency makeup ACU fan

Propagation No.	Equipment	Allocated Response Time (s)
1	RMS	[ ] TS
2	ESF-CCS	
3	Fan	
Total		
Requirement		5.000

6.20 CPIAS

6.20.1 Containment Upper Operating Area / Operating Area Radiation – High

Table 6.20-1 Response Time Allocation for CPIAS for ESF actuation – CPIAS actuated isolation valves

Propagation No.	Equipment	Allocated Response Time (s)
1	RMS	[ ] TS
2	ESF-CCS	
3	Valves	
Total		
Requirement		9.900

7 RESPONSE TIME ANALYSIS

This section provides the results of the safety I&C system response time analysis for each trip function. The allocated response times are verified by the vendor specifications or the worst case response time analysis.

7.1 LPP for Reactor Trip

TS

Figure 7.1-1 LPP Reactor Trip Function

Notes

TS

7.1.1. PPS

TS

Figure 7.1-2 Response Time Analysis for PPS

Notes

TS

7.2 HPP for Reactor Trip

TS

Figure 7.2-1 HPP Reactor Trip Function

Notes

TS

7.2.1. PPS

TS

Figure 7.2-2 Response Time Analysis for PPS

Notes

TS

7.3 LSGL for Reactor Trip

TS

Figure 7.3-1 LSGL Reactor Trip Function

Notes

TS

7.3.1. PPS

TS

Figure 7.3-2 Response Time Analysis for PPS

Notes

TS

(1) + (2) + (3) + (4) + (5) + (6) + (7) = 642 ms

TS

7.4 HSGL for Reactor Trip

TS

Figure 7.4-1 HSGL Reactor Trip Function

Notes

TS

7.4.1. PPS

TS

Figure 7.4-2 Response Time Analysis for PPS

Notes

TS

TS

7.5 LSGP FOR REACTOR TRIP

TS

Figure 7.5-1 LSGP Reactor Trip Function

Notes

TS

7.5.1. PPS

TS

Figure 7.5-2 Response Time Analysis for PPS

Notes

TS

7.6 HCP for Reactor Trip

TS

Figure 7.6-1 HCP Reactor Trip Function

Notes

TS

7.6.1. PPS

TS

Figure 7.6-2 Response Time Analysis for PPS

Notes

TS

7.7 LRCF for Reactor Trip

TS

Figure 7.7-1 LRCF Reactor Trip Function

Notes

TS

7.7.1. PPS

TS

Figure 7.7-2 Response Time Analysis for PPS

Notes

TS

TS

7.8 HVOPT for Reactor Trip

TS

Figure 7.8-1 HVOPT Reactor Trip Function

Notes

TS

7.8.1. PPS

TS

Figure 7.8-2 Response Time Analysis for PPS

Notes

TS

7.9 HLPL for Reactor Trip

TS

Figure 7.9-1 HLPL Reactor Trip Function

Notes

TS

7.9.1. PPS

TS

Figure 7.9-2 Response Time Analysis for PPS

Notes

TS

7.10 HLPD FOR REACTOR TRIP

7.10.1 ENFMS Detector

TS

Figure 7.10-1 Response Time Analysis for ENFMS Detector

Notes

TS

7.10.1.1 CPCS

TS

Figure 7.10-2 Response Time Analysis for CPCS

Notes

TS

TS

7.10.1.2 PPS

TS

Figure 7.10-3 Response Time Analysis for PPS

Notes

TS

7.10.2 CEA Positions

TS

Figure 7.10-4 Response Time Analysis for CEA Positions

Notes

TS

7.10.2.1. CPCS

TS

Figure 7.10-5 Response Time Analysis for CPCS

Notes

TS

7.10.2.2 PPS

TS

Figure 7.10-6 Response Time Analysis for PPS

Notes

TS

TS

7.10.3 CEAC Penalty Factor

TS

Figure 7.10-7 Response Time Analysis for CEAC Penalty Factor

Notes

TS

7.10.3.1 CPCS

TS

Figure 7.10-8 Response Time Analysis for CPCS

Notes

TS

7.10.3.2. PPS

TS

Figure 7.10-9 Response Time Analysis for PPS

Notes

TS

7.11 LDNBR FOR REACTOR TRIP

7.11.1 ENFMS Detectors

TS

Figure 7.11-1 Response Time Analysis for ENFMS Detector

Notes

TS

7.11.1.1. CPCS

TS

Figure 7.11-2 Response Time Analysis for CPCS

Notes

TS

TS

7.11.1.2 PPS

TS

Figure 7.11-3 Response Time Analysis for PPS

Notes

TS

7.11.2 CEA Positions

Non-Proprietary

TS

Figure 7.11-4 Response Time Analysis for CEA Positions

Notes

TS

7.11.2.1 CPCS

TS

Figure 7.11-5 Response Time Analysis for CPCS

Notes

TS

TS

7.11.2.2 PPS

TS

Figure 7.11-6 Response Time Analysis for PPS

Notes

TS

TS

7.11.3 Cold Leg Temperature

TS

Figure 7.11-7 Response Time Analysis for Cold Leg Temperature

Notes

TS

7.11.3.1 CPCS

TS

Figure 7.11-8 Response Time Analysis for CPCS

Notes

TS

TS

7.11.3.2 PPS

TS

Figure 7.11-9 Response Time Analysis for PPS

Notes

TS

7.11.4 Hot Leg Temperature

TS

Figure 7.11-10 Response Time Analysis for Hot Leg Temperature

Notes

TS

7.11.4.1 CPCS

TS

Figure 7.11-11 Response Time Analysis for CPCS

Notes

TS

TS

7.11.4.2 PPS

TS

Figure 7.11-12 Response Time Analysis for PPS

Notes

TS

7.11.5 Primary Coolant Pump Shaft Speed

TS

Figure 7.11-13 Response Time Analysis for Primary Coolant Pump Shaft Speed

Notes

TS

7.11.5.1. CPCS

TS

Figure 7.11-14 Response Time Analysis for CPCS

Notes

TS

TS

7.11.5.2 PPS

TS

Figure 7.11-15 Response Time Analysis for PPS

Notes

TS

7.11.6 Reactor Coolant Pressure from Pressurizer

TS

Figure 7.11-16 Response Time Analysis for Reactor Coolant Pressure

Notes

TS

7.11.6.1 CPCS

TS

Figure 7.11-17 Response Time Analysis for CPCS

Notes

TS

TS

7.11.6.2 PPS

TS

Figure 7.11-18 Response Time Analysis for PPS

Notes

TS

7.11.7 CEAC Penalty Factor

TS

Figure 7.11-19 Response Time Analysis for CEAC Penalty Factor

Notes

TS

7.11.7.1 CPCS

TS

Figure 7.11-20 Response Time Analysis for CPCS

Notes

TS

7.11.7.2. PPS

TS

Figure 7.11-21 Response Time Analysis for PPS

Notes

TS

7.12 LPP FOR ESF ACTUATION

7.12.1 Safety Injection

TS

Figure 7.12-1 Response Time Analysis for Safety Injection

Notes

TS

7.12.1.1 PPS

TS

Figure 7.12-2 Response Time Analysis for PPS

Notes

TS

TS

7.12.1.2 ESF-CCS

TS

Figure 7.12-3 Response Time Analysis for ESF-CCS

Notes

TS

[ ]TS

7.12.2 Containment Isolation

7.12.2.1. CIAS actuated low volume purge valves

[ ]TS

Figure 7.12-4 Response Time Analysis for CIAS actuated low volume purge valves

Notes

[ ]TS

7.12.2.1.1. PPS

[ ]TS

Figure 7.12-5 Response Time Analysis for PPS

Notes

TS

7.12.2.1.2. ESF-CCS

TS

Figure 7.12-6 Response Time Analysis for ESF-CCS

Notes

TS

7.12.2.2. Other CIAS actuated Valves

TS

Figure 7.12-7 Response Time Analysis for Other CIAS actuated Valves

Notes

TS

7.12.2.2.1 PPS

TS

Figure 7.12-8 Response Time Analysis for PPS

Notes

TS

TS

7.12.2.2.2 ESF-CCS

TS

Figure 7.12-9 Response Time Analysis for ESF-CCS when loss of offsite power

Notes

TS

TS

Figure 7.12-10 Response Time Analysis for ESF-CCS when offsite power is available

Notes

TS

7.13 HCP for ESF Actuation

7.13.1 Safety Injection

TS

Figure 7.13-1 Response Time Analysis for Safety Injection

Notes

TS

7.13.1.1 PPS

TS

Figure 7.13-2 Response Time Analysis for PPS

Notes

TS

7.13.1.2 ESF-CCS

TS

Figure 7.13-3 Response Time Analysis for ESF-CCS

Notes

TS

7.13.2 Containment Isolation

7.13.2.1 CIAS actuated low volume purge valves

TS

Figure 7.13-4 Response Time Analysis for CIAS actuated low volume purge valves

Notes

TS

7.13.2.1.1 PPS

TS

Figure 7.13-5 Response Time Analysis for PPS

Notes

TS

TS

7.13.2.1.2 ESF-CCS

TS

Figure 7.13-6 Response Time Analysis for ESF-CCS

Notes

TS

7.13.2.2 Other CIAS actuated valves

TS

Figure 7.13-7 Response Time Analysis for Other CIAS actuated valves

Notes

TS

7.13.2.2.1 PPS

TS

Figure 7.13-8 Response Time Analysis for PPS

Notes

TS

[ ]TS

7.13.2.2.2 ESF-CCS

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[ ]

Figure 7.13-9 Response Time Analysis for ESF-CCS when loss of offsite power

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Figure 7.13-10 Response Time Analysis for ESF-CCS when offsite power is available

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7.13.3 Main Steam Isolation

7.13.3.1 MSIS actuated MSIVs

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Figure 7.13-11 Response Time Analysis for MSIS actuated MSIVs

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7.13.3.1.1 PPS

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Figure 7.13-12 Response Time Analysis for PPS

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7.13.3.1.2 ESF-CCS

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Figure 7.13-13 Response Time Analysis for ESF-CCS

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7.13.3.2 MSIS actuated MFIVs

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Figure 7.13-14 Response Time Analysis for MSIS actuated MFIVs

Notes

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7.13.3.2.1 PPS

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Figure 7.13-15 Response Time Analysis for PPS

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7.13.3.2.2 ESF-CCS

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Figure 7.13-16 Response Time Analysis for ESF-CCS

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7.14 HHCP for ESF Actuation

7.14.1 Containment spray pump

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Figure 7.14-1 Response Time Analysis for Containment Spray Pump

Notes

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7.14.1.1. PPS

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Figure 7.14-2 Response Time Analysis for PPS

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7.14.1.2 ESF-CCS

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Figure 7.14-3 Response Time Analysis for ESF-CCS when loss of offsite power

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Figure 7.14-4 Response Time Analysis for ESF-CCS when offsite power is available

Notes

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7.14.2 Containment isolation valves closed on CSAS

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Figure 7.14-5 Response Time Analysis for Containment isolation valves closed on CSAS

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7.14.2.1. PPS

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Figure 7.14-6 Response Time Analysis for PPS

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7.14.2.2 ESF-CCS

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Figure 7.14-7 Response Time Analysis for ESF-CCS when loss of offsite power

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Figure 7.14-8 Response Time Analysis for ESF-CCS when offsite power is available

Notes

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7.15 LSGP for ESF Actuation

7.15.1 Main Steam Isolation

7.15.1.1 MSIS actuated MSIVs

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Figure 7.15-1 Response Time Analysis for MSIS actuated MSIVs

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7.15.1.1.1 PPS

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Figure 7.15-2 Response Time Analysis for PPS

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7.15.1.1.2. ESF-CCS

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Figure 7.15-3 Response Time Analysis for ESF-CCS

Notes

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7.15.1.2 MSIS actuated MFIVs

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Figure 7.15-4 Response Time Analysis for MSIS actuated MFIVs

Notes

1. Transmitter response time of 0.2 s will be confirmed by vendor specification.
2. APC-S response time of 0.05 s will be confirmed by vendor specification.
3. The PPS and ESF-CCS worst case response times are analyzed in following subsections.
4. Valve response time of 4.5 s will be confirmed by vendor specification.

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7.15.1.2.1 PPS

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Figure 7.15-5 Response Time Analysis for PPS

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7.15.1.2.2. ESF-CCS

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Figure 7.15-6 Response Time Analysis for ESF-CCS

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7.16 LSGL FOR ESF-ACTUATION

7.16.1 Auxiliary Feedwater Pump (motor driven)

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Figure 7.16-1 Response Time Analysis for Auxiliary Feedwater Pump (motor driven)

Notes

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7.16.1.1. PPS

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Figure 7.16-2 Response Time Analysis for PPS

Notes

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TS

7.16.1.2 ESF-CCS

TS

Figure 7.16-3 Response Time Analysis for ESF-CCS when loss of offsite power

Notes

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7.16.2 Auxiliary Feedwater Pump (turbine driven)

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Figure 7.16-4 Response Time Analysis for Auxiliary Feedwater Pump (turbine driven)

Notes

TS

7.16.2.1 PPS

TS

Figure 7.16-5 Response Time Analysis for PPS

Notes

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TS

7.16.2.2 Auxiliary feedwater pump (turbine driven)

TS

Figure 7.16-6 Response Time Analysis for ESF-CCS

Notes

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7.17 HSGL FOR ESF-ACTUATION

7.17.1 Main Steam Isolation

7.17.1.1 MSIS actuated MSIVs

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Figure 7.17-1 Response Time Analysis for MSIS actuated MSIVs

Notes

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7.17.1.1.1 PPS

TS

Figure 7.17-2 Response Time Analysis for PPS

Notes

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7.17.1.1.2 ESF-CCS

TS

Figure 7.17-3 Response Time Analysis for ESF-CCS

Notes

TS

7.17.1.2 MSIS actuated MFIVs

TS

Figure 7.17-4 Response Time Analysis for MSIS actuated MFIVs

Notes

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7.17.1.2.1 PPS

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Figure 7.17-5 Response Time Analysis for PPS

Notes

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7.17.1.2.2 ESF-CCS

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Figure 7.17-6 Response Time Analysis for ESF-CCS

Notes

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7.18 CREVAS

7.18.1 Control room air intake radiation – High

7.18.1.1 CREVAS actuated isolation dampers

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Figure 7.18-1 Response Time Analysis for CREVAS actuated isolation dampers

Notes

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7.18.1.1.1 RMS

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Figure 7.18-2 Response Time Analysis for RMS

Note

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7.18.1.1.2 ESF-CCS

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Figure 7.18-3 Response Time Analysis for ESF-CCS

Notes

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7.18.1.2 Emergency makeup ACU fan

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Figure 7.18-4 Response Time Analysis for Emergency makeup ACU fan

Notes

TS

7.18.1.2.1 RMS

TS

Figure 7.18-5 Response Time Analysis for RMS

Note

TS

7.18.1.2.2 ESF-CCS

TS

Figure 7.18-6 Response Time Analysis for ESF-CCS

Notes

TS

7.19 FHEVAS

7.19.1 Spent fuel pool area radiation – High

7.19.1.1 FHEVAS actuated isolation dampers

TS

Figure 7.19-1 Response Time Analysis for FHEVAS actuated isolation dampers

Notes

TS

7.19.1.1.1 RMS

TS

Figure 7.19-2 Response Time Analysis for RMS

Note

TS

7.19.1.1.2 ESF-CCS

TS

Figure 7.19-3 Response Time Analysis for ESF-CCS

Notes

TS

7.19.1.2 Emergency makeup ACU fan

TS

Figure 7.19-4 Response Time Analysis for Emergency ACU fan

Notes

TS

7.19.1.2.1 RMS

TS

Figure 7.19-5 Response Time Analysis for RMS

Note

TS

7.19.1.2.2 ESF-CCS

TS

Figure 7.19-6 Response Time Analysis for ESF-CCS

Notes

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7.20 CPIAS

7.20.1 Containment upper operating area / operating area radiation – High

7.20.1.1 CPIAS actuated isolation valves

TS

Figure 7.20-1 Response Time Analysis for CPIAS actuated isolation valves

Notes

TS

7.20.1.1.1 RMS

TS

Figure 7.20-2 Response Time Analysis for RMS

Note

TS

7.20.1.1.2 ESF-CCS

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Figure 7.20-3 Response Time Analysis for ESF-CCS

Notes

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8 REFERENCES

[1] DCD for the APR1400.

[2] APR1400-Z-J-NR-14001-P, “Safety I&C System”, Rev. 0, November 2014.

[3] APR1400-Z-J-NR-14005-P, “Setpoint Methodology for Plant Protection System”, Rev. 1, February 2017.

[4] WCAP-16097-P-A, “Common Qualified Platform Topical Report”, Rev. 3, February 2013.

[5] APR1400-A-J-NR-14004-P(WCAP-17922-P), “Common Q Platform Supplemental Information in Support of the APR1400 Design Certification”, Rev.0, November 2014.

[6] BTP 7-21, “Guidance on Digital Computer Real-Time Performance”, Rev. 5, March 2007.

[7] BTP 7-14, “Guidance on Software Reviews for Digital Computer-based Instrumentation and Control Systems”, Rev. 5, March 2007.

9 DEFINITIONS

RT Response Time	Time interval from when the monitored parameter exceeds the trip setpoint value at the input to the sensor until electrical power is interrupted to the CEA drive mechanism through the actuation of the RTSS.
ESF Actuation Response Time	Time interval from when the monitored parameter exceeds the trip setpoint value at the input to the sensor until the final actuator for the final plant component, such as the motor starter for a pump, valve, damper or fan, repositions to energize or de-energize that plant component.

APPENDIX A
CONFORMANCE TO BTP 7-21

A.1. LIMITING RESPONSE TIMES

A.1.1 Acceptance Criteria

Limiting response times should be shown to be consistent with safety requirements (e.g., suppress power oscillations, prevent fuel design limits from being exceeded, prevent a non-coolable core geometry). Setpoint analyses and limiting response times should also be shown to be consistent. The reviewer should verify that limiting response times are acceptable to the organizations responsible for reactor systems, electrical systems, and plant systems before accepting the limiting response times as a basis for timing requirements.

A.1.2 Conformance

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A.2. DIGITAL COMPUTER TIMING REQUIREMENTS

A.2.1 Acceptance Criteria

Digital computer timing should be shown to be consistent with the limiting response times and characteristics of the computer hardware, software, and data communications systems. Computer system timing requirements that should be addressed in software requirements specifications are described in standard review plan (SRP) BTP 7-14(Reference 7).

A.2.2 Conformance

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A.3. ARCHITECTURE

A.3.1 Acceptance Criteria

The level of detail in the architectural description should be sufficient that the Staff can determine the number of message delays and computational delays interposed between the sensor and the actuator. An allocation of time delays to elements of the system and software architecture should be available. In initial design phases (e.g., at the point of design certification application), an estimated allocation of time delays to elements of the proposed architecture should be available. Subsequent detailed design and implementation should develop refined timing allocations down to unit levels in the software architecture.

A design should be feasible with currently known methods and representative equipment. Design timing feasibility may be demonstrated by allocating a timing budget to components of the system architecture so that the entire system meets its timing requirements. See NUREG/CR-6083, Sections 2.2, 2.3.1, and 2.3.2, and NUREG/CR-6082. The timing budget should include internal and external communication delays, with adequate margins.

Any non-deterministic delays should be noted and a basis provided that such delays are not part of any safety functions, nor can the delays impede any protective action.

Software architectural timing requirements should be addressed in a software architectural description as described in SRP BTP 7-14. Databases, disk drives, printers, or other equipment or architectural elements subject to halting or failure should not be able to impede protective system action.

A.3.2 Conformance

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A.4. DESIGN COMMITMENTS

A.4.1 Acceptance Criteria

Design basis documents should describe system timing goals.

Timing requirements should be satisfied by design commitments.

A design should consider data rates, data bandwidths, and data precision requirements for normal and off-normal operation, including the impact of environmental extremes. There should be sufficient excess capacity margins to accommodate likely future increases in demands or software or hardware changes to equipment.

Design basis documents should identify design practices that the applicant/licensee will use to avoid timing problems. Risky design practices such as non-deterministic data communications, non-deterministic computation, use of interrupts, multitasking, dynamic scheduling, and event-driven design should be avoided. When such practices are allowed, the applicant/licensee should describe methods for control of the associated risk. NUREG/CR-6082 and NUREG/CR-6083 describe risky design practices in more detail.

A.4.2 Conformance

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A.5. PERFORMANCE VERIFICATION

A.5.1 Acceptance Criteria

The means proposed, or used, for verifying a system's timing should be consistent with the design. Testing and/or analytic justification should show that the system meets limiting response times for a reasonable, randomly selected subset of system loads, conditions, and design basis events. The subset should include some limiting load conditions and be chosen by persons independent of the persons who designed the system.

Both analytical and test techniques of timing analysis have drawbacks. It is difficult to demonstrate completeness of timing tests. Completeness is easier to demonstrate for analyses, but analyses predict extreme times that are not actually possible. Therefore, analysis and testing are often combined in a complementary manner to confirm that a system can meet the limiting response times.

Measurement methods should be appropriate to the resolution and detail required.

Timing measurements should meet projections or the anomalies should be satisfactorily explained (NUREG/CR-6083, Sections 2.1, 2.3.3, and 2.3.4).

A.5.2 Conformance

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A.6. USE OF CYCLIC REAL-TIME EXECUTIVE

A.6.1 Acceptance Criteria

In systems that include a cyclic real-time executive (operating system), a typical cycle includes application modules, diagnostic modules, and other support modules. A watch-dog timer is normally set at the beginning of each cycle and reset at the end. If the cycle is not completed before the watch-dog timer period is complete, an error is generated.

A basis should be provided that describes the cycle and demonstrates that the watch-dog timer is correctly implemented, the time required for the application modules does not exceed the allotted time given in the architecture timing budget, and diagnostic and other support modules will not cause the allotted time to be exceeded.

Examples of solutions acceptable to the Staff may be found in the Safety Evaluation Reports for the Palo Verde Nuclear Generating Station, Units 1, 2, and 3, "Issuance of Amendments on the Core Protection Calculator System Upgrade," dated October 24, 2003, and the Siemens Power Corporation, Topical Report EMF-2110(NP), "Teleperm XS: A Digital Reactor Protection System," dated May 5, 2000.

A.6.2 Conformance

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A.7. USE OF PART-SCALE PROTOTYPES

A.7.1 Acceptance Criteria

In systems that have not been implemented and tested on a full scale, expected system delays on scale-up should be calculated and shown to be less than limiting system response times (NUREG/CR-6083, Sections 2.1.3 and 2.1.4).

A basis should be provided that describes the effects of adding sensors, divisions, communication links, controllers, computer nodes, or actuation devices required to scale the test system to full scale.

Test data should confirm scaling as well as performance projections. Exceptions are considered anomalies or abnormal events.

Prototypes designed to demonstrate scaling should include all significant architectural elements plus enough additional elements to show the scaling effects to be measured.

A.7.2 Conformance

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