

# Response Time Analysis Technical Report

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- Introduction
- Table of Contents for TeR
- Response Time Requirements
- Signal Path
- Response Time Allocation
- Response Time Analysis
- Conformance to BTP 7-21

# Introduction

## Response Time Analysis TeR (APR1400-Z-J-N14003)

- NRC letter comments (Dec. 19, 2013)

TS

# Introduction

## Response Time Analysis TeR (Cont'd)

- **KHNP plan proposed at the 13th PARM (Feb. 11, 2014)**
  - TeR for response time allocation will be submitted.
  - TeR will include the following information;
    - The allocated response time of individual components.
    - The sum of allocated response time does not exceed the total response time requirement assumed in the safety analysis.

# Introduction

## Purpose of Response Time Analysis TeR

- **Demonstrate that the total allocated response time does not exceed the corresponding response time requirement.**
  - Define the safety system response time requirement for each trip function.
  - Determine the safety system signal path for each trip function.
  - Allocate individual response time to each component on the signal path.
  - Analyze safety system response time for each trip function.
- **Provide conformance of the safety I&C system to BTP 7-21**

# Introduction

## Scope of Response Time Analysis TeR

- **Response time analysis for the safety I&C system**
  - Reactor trip response times described in DCD Tier 2 Table 7.2-5.
  - ESF response times described in DCD Tier 2 Table 7.3-7.
- **Conformance of the safety I&C system to BTP 7-21**
  - Limiting response times
  - Digital computer timing requirements
  - Architecture
  - Design commitments
  - Performance verification
  - Use of cyclic real-time executive
  - Use of part-scale prototypes

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# Response Time Requirements

## Reactor Trip Functions

DCD Tier 2 Table 7.2-5 “Reactor Protective Instrumentation Response Time”

No.	Parameter	Response Time (second)
1	Low Pressurizer Pressure (LPP)	$\leq 1.15$
2	High Pressurizer Pressure (HPP)	$\leq 0.85$
3	Low Steam Generator Level (LSGL) (Example 1)	$\leq 1.25$
4	High Steam Generator Level (HSGL)	$\leq 1.15$
5	Low Steam Generator Pressure (LSGP)	$\leq 1.15$
6	High Containment Pressure (HCP)	$\leq 1.15$
7	Low Reactor Coolant Flow (LRCF)	$\leq 0.85$

# Response Time Requirements

## Reactor Trip Functions (Cont'd)

DCD Tier 2 Table 7.2-5 "Reactor Protective Instrumentation Response Time"

No.	Parameter		Response Time (second)
8	High Local Power Density (HLPD)	ENFMS Detector	$\leq 0.65$ (1)
		CEA Positions	$\leq 1.45$ (2)
		CEAC Penalty Factor (Example 2)	$\leq 0.85$ (2)
9	Low Departure from Nucleate Ratio (LDNBR)	ENFMS Detector	$\leq 0.65$ (1)
		CEA Positions	$\leq 1.45$ (2)
		Cold Leg Temperature	$\leq 8.65$ (3)
		Hot Leg Temperature	$\leq 8.65$ (3)
		Primary Coolant Pump Shaft Speed	$\leq 0.45$ (4)
		Reactor Coolant Pressure	$\leq 0.95$ (5)
		CEAC Penalty Factor	$\leq 0.85$ (2)

# Response Time Requirements

## Reactor Trip Functions (Cont'd)

### DCD Tier 2 Table 7.2-5 "Reactor Protective Instrumentation Response Time"

No.	Parameter	Response Time (second)
10	Variable Overpower Trip (VOPT)	≤0.55 <sup>(1)</sup>
11	High Logarithmic Power Level (HLOGP)	≤0.55 <sup>(1)</sup>

#### [Notes]

- (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. Acceptable CEA sensor response is demonstrated by compliance with Technical Specifications Subsection 3.3.1.

# Response Time Requirements

## Reactor Trip Functions (Cont'd)

### DCD Tier 2 Table 7.2-5 “Reactor Protective Instrumentation Response Time”

[Notes]

- (3) Response time is measured from the output of the resistance temperature detector (sensor). 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.

ENFMS : Ex-core Neutron Flux Monitoring System

CEA : Control Element Assembly

CEAC : Control Element Assembly Calculator

# Response Time Requirements

## Engineered Safety Features Actuation Functions

DCD Tier 2 Table 7.3-7 “ESF Response Time”

No.	Function	Initiating Signal	Response Time (second) <sup>(1)</sup>	
1	LPP	Safety Injection (Example 3)	≤40	
		Containment Isolation	CIAS actuated low volume purge valves	≤5
			Other CIAS actuated valves	≤83.5 <sup>(2)</sup> / 62.0 <sup>(3)</sup>
2	HCP	Safety Injection	≤40	
		Containment Isolation	CIAS actuated low volume purge valves	≤5
			Other CIAS actuated valves	≤83.5 <sup>(2)</sup> / 62.0 <sup>(3)</sup>
		Main Steam Isolation	MSIS actuated MSIVs	≤6.35
			MSIS actuated MFIVs	≤11.35
3	HHCP	Containment spray pump	≤50.4 <sup>(4),(6)</sup> / 28.5 <sup>(5),(6)</sup>	
		Containment isolation valves closed on CSAS	≤73.5 <sup>(2)</sup> / 52.0 <sup>(3)</sup>	



# Response Time Requirements

## Engineered Safety Features Actuation Functions (Cont'd)

DCD Tier 2 Table 7.3-7 "ESF Response Time"

No.	Function	Initiating Signal		Response Time (second) <sup>(1)</sup>
4	LSGP	Main Steam Isolation	MSIS actuated MSIVs	≤6.35
			MSIS actuated MFIVs	≤11.35
5	LSGL	Auxiliary feedwater pump (motor driven)		≤61.45 <sup>(4)</sup>
		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 <sup>(7),(8)</sup>
			Emergency makeup ACU fan	≤5.0 <sup>(7),(8),(9)</sup>

# Response Time Requirements

## Engineered Safety Features Actuation Functions (Cont'd)

DCD Tier 2 Table 7.3-7 "ESF Response Time"

No.	Function	Initiating Signal		Response Time (second) <sup>(1)</sup>
8	FHEVAS	Fuel handling area spent fuel pool area radiation – High	FHEVAS actuated isolation dampers	≤8.2 <sup>(7),(8),(9)</sup>
			Emergency makeup ACU fan	≤5.0 <sup>(7),(8)</sup>
			Normal ACU fan	Not applicable
9	CPIAS	Containment upper operating area / operating area radiation - High	CPIAS actuated isolation valves	≤9.9 <sup>(7),(8)</sup>
			High – Volume purge fan	Not applicable

[Notes]

(1) PPS cabinet delays are included.

# Response Time Requirements

## Engineered Safety Features Actuation Functions (Cont'd)

### DCD Tier 2 Table 7.3-7 "ESF Response Time"

[Notes]

- (2) A loss of offsite power. 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.

# Response Time Requirements

## Engineered Safety Features Actuation Functions (Cont'd)

### DCD Tier 2 Table 7.3-7 "ESF Response Time"

[Notes]

- (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 function.

# Response Time Requirements

## Engineered Safety Features Actuation Functions (Cont'd)

### DCD Tier 2 Table 7.3-7 "ESF Response Time"

[Notes]

CIAS	: Containment Isolation Actuation Signal
MSIS	: Main Steam Isolation Signal
MSIV	: Main Steam Isolation Valve
HHCP	: High-High Containment Pressure
CSAS	: Containment Spray Actuation Signal
CREVAS	: Control Room Emergency Ventilation Actuation Signal
ACU	: Air Cleaning Unit
FHEVAS	: Fuel Handling Area Emergency Ventilation Actuation Signal
CPIAS	: Containment Purge Isolation Actuation Signal

# Signal Path

## Reactor Trip Functions

No.	Parameter	Signal Path
1	LPP	Transmitter → APC-S → PPS → RTSS
2	HPP	
3	LSGL (Example 1)	
4	HSGL	
5	LSGP	
6	HCP	
7	LRCF	

# Signal Path

## Reactor Trip Functions (Cont'd)

No.	Parameter		Signal Path
8	HLPD	ENFMS Detector	Neutron Detector → ENFMS → CPCS → PPS → RTSS
		CEA Positions	RSPT → CPCS → PPS → RTSS
		CEAC Penalty Factor (Example 2)	

# Signal Path

## Reactor Trip Functions (Cont'd)

No.	Parameter		Signal Path
9	LDNBR	ENFMS Detector	Neutron Detector → ENFMS → CPCS → PPS → RTSS
		CEA Positions	RSPT → CPCS → PPS → RTSS
		Cold Leg Temperature	Temperature Sensor → CPCS → PPS → RTSS
		Hot Leg Temperature	
		Primary Coolant Pump Shaft Speed	RCPSSSS → CPCS → PPS → RTSS
		Reactor Coolant Pressure	Transmitter → APC-S → PPS → RTSS
		CEAC Penalty Factor	RSPT → CPCS → PPS → RTSS



# Signal Path

## Reactor Trip Functions (Cont'd)

No.	Parameter	Signal Path
10	VOPT	Neutron Detector → ENFMS → PPS → RTSS
11	HLOGP	

### [Notes]

- APC-S : Auxiliary Process Cabinet – Safety
- CPCS : Core Protection Calculator System
- ENFMS : Ex-core Neutron Flux Monitoring System
- PPS : Plant Protection System
- RTSS : Reactor Trip Switchgear System
- RSPT : Reed Switch Position Transmitter
- RCPSSSS : Reactor Coolant Pressure Shaft Speed Sensing System

# Signal Path

## Engineered Safety Features Actuation Functions

No.	Function	Initiating Signal		Signal Path
1	LPP	Safety Injection (Example 3)		Transmitter → APC-S → PPS → ESF-CCS → Pump/Valve
		Containment Isolation	CIAS actuated low volume purge valves	
			Other CIAS actuated valves	
2	HCP	Safety Injection		
		Containment Isolation	CIAS actuated low volume purge valves	
			Other CIAS actuated valves	
		Main Steam Isolation	MSIS actuated MSIVs	
	MSIS actuated MFIVs			

# Signal Path

## Engineered Safety Features Actuation Functions (Cont'd)

No.	Function	Initiating Signal		Signal Path
3	HHCP	Containment spray pump		Transmitter → APC-S → PPS → ESF-CCS → Pump/Valve
		Containment isolation valves closed on CSAS		
4	LSGP	Main Steam Isolation	MSIS actuated MSIVs	
			MSIS actuated MFIVs	
5	LSGL	Auxiliary feedwater pump (motor driven)		
		Auxiliary feedwater pump (turbine driven)		
6	HSGL	Main Steam Isolation	MSIS actuated MSIVs	
			MSIS actuated MFIVs	

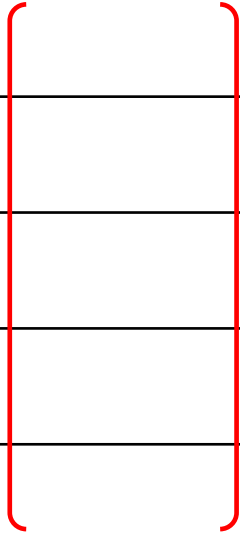
# Signal Path

## Engineered Safety Features Actuation Functions (Cont'd)

No.	Function	Initiating Signal		Signal Path
7	CREVAS	Control room air intake radiation - High	CREVAS actuated isolation dampers	Transmitter → RMS → ESF-CCS → Damper/Fan/Valve
			Emergency makeup ACU fan	
8	FHEVAS	Fuel handling area spent fuel pool area radiation – High	FHEVAS actuated isolation dampers	
			Emergency makeup ACU fan	
			Normal ACU fan	
9	CPIAS	Containment upper operating area / operating area radiation - High	CPIAS actuated isolation valves	
			High – Volume purge fan	

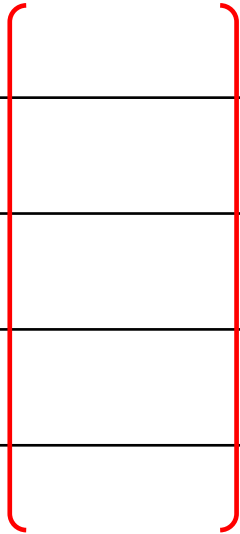
# Response Time Allocation

## Example 1: LSGL Reactor Trip Function

No.	Equipment	Allocated Response Time (second)
1	Transmitter	
2	APC-S	
3	PPS	
4	RTSS	
<b>Total</b>		
<b>Requirement</b>		<b>1.250</b>

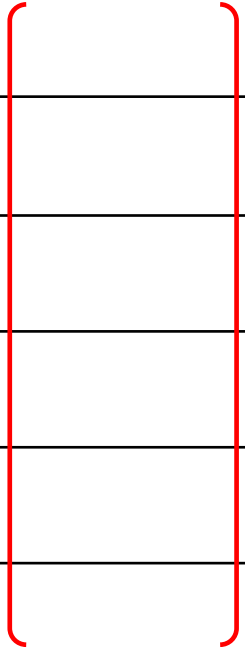
# Response Time Allocation

## Example 2: CEAC Penalty Factor for HLPD

No.	Equipment	Allocated Response Time (second)
1	RSPT	
2	CPCS	
3	PPS	
4	RTSS	
<b>Total</b>		
<b>Requirement</b>		<b>0.850</b>

# Response Time Allocation

## Example 3: LPP ESF Actuation Function (SI)

No.	Equipment	Allocated Response Time (second)
1	Transmitter	
2	APC-S	
3	PPS	
4	ESF-CCS	
5	SI Pump	
<b>Total</b>		
<b>Requirement</b>		<b>40.000</b>

# Response Time Analysis

## Example 1: LSGL Reactor Trip Function

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# Response Time Analysis

## Example 1: LSGL Reactor Trip Function (Cont'd)

# Response Time Analysis

## Example 1: LSGL Reactor Trip Function (Cont'd)

- PPS Response Time Analysis

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# Response Time Analysis

## Example 1: LSGL Reactor Trip Function (Cont'd)

- PPS Response Time Analysis (Cont'd)

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# Response Time Analysis

## Example 2: CEAC Penalty Factor for HLPD

15<sup>th</sup> Pre-application Review Meeting

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# Response Time Analysis

## Example 2: CEAC Penalty Factor for HLPD (Cont'd)

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# Response Time Analysis

## Example 2: CEAC Penalty Factor for HLPD (Cont'd)

- CPCS Response Time Analysis

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# Response Time Analysis

## Example 2: CEAC Penalty Factor for HLPD (Cont'd)

- CPCS Response Time Analysis (Cont'd)

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# Response Time Analysis

## Example 2: CEAC Penalty Factor for HLPD (Cont'd)

- CPCS Response Time Analysis (Cont'd)

TS



# Response Time Analysis

## Example 2: CEAC Penalty Factor for HLPD (Cont'd)

- PPS Response Time Analysis

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# Response Time Analysis

## Example 2: CEAC Penalty Factor for HLPD (Cont'd)

- PPS Response Time Analysis (Cont'd)

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# Response Time Analysis

## Example 3: LPP ESF Actuation Function (SI)

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# Response Time Analysis

## Example 3: LPP ESF Actuation Function (SI) (Cont'd)

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# Response Time Analysis

## Example 3: LPP ESF Actuation Function (SI) (Cont'd)

- PPS Response Time Analysis

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# Response Time Analysis

## Example 3: LPP ESF Actuation Function (SI) (Cont'd)

- PPS Response Time Analysis (Cont'd)

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# Response Time Analysis

## Example 3: LPP ESF Actuation Function (SI) (Cont'd)

- ESF-CCS Response Time Analysis

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# Response Time Analysis

## Example 3: LPP ESF Actuation Function (SI) (Cont'd)

- ESF-CCS Response Time Analysis (Cont'd)

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# Response Time Analysis

## Example 3: LPP ESF Actuation Function (SI) (Cont'd)

- ESF-CCS Response Time Analysis (Cont'd)

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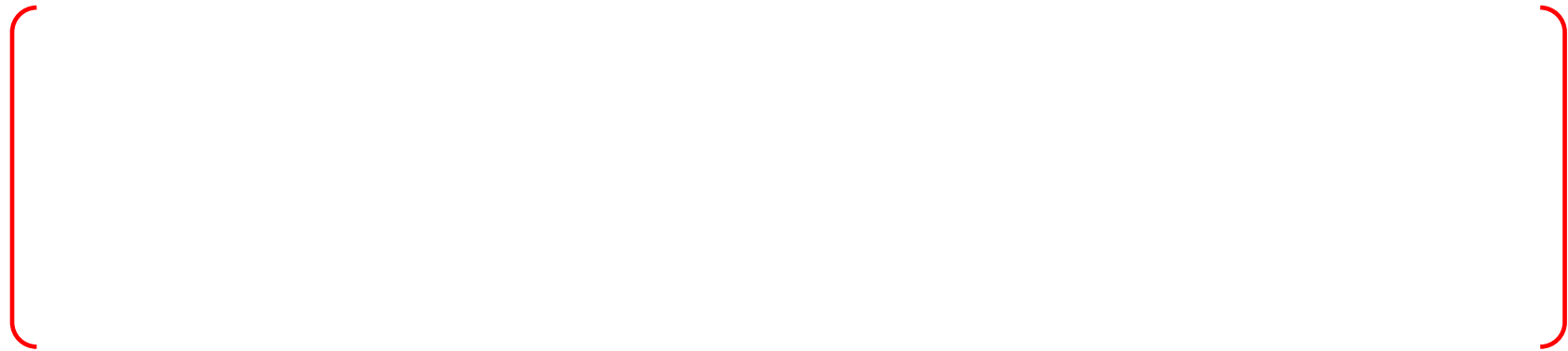


# Response Time Analysis

## Example 3: LPP ESF Actuation Function (SI) (Cont'd)

- ESF-CCS Response Time Analysis (Cont'd)

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# Conformance to BTP 7-21

## Example: Limiting Response Times

- **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.*

# Conformance to BTP 7-21

## Example: Limiting Response Times (Cont'd)

- Conformance

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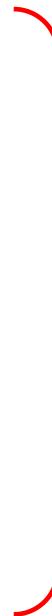


# Conformance to BTP 7-21

## Example: Limiting Response Times (Cont'd)

- Conformance (Cont'd)

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# Plan for Further Meeting

## Path Forward

- **Plan for the PARM in August**
  - Present draft TeR (if needed)
- **Plan for the Pre-application Audit in October**
  - Present final TeR
  - Confirm NRC acceptability

# Summary

## Summary of TeR

- **Response time analysis**
  - All reactor trip and ESF actuation functions of the safety I&C system will be incorporated into the TeR.
- **Conformance to BTP 7-21**
  - The conformances for all 7 acceptance criteria of BTP 7-21 will be described in the TeR.