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APR1400 Pressurizer System Performance Criteria

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1. Introduction

The Maintenance Rule (MR) at Nuclear Power Plants (NPPs) is required to clear link between effective maintenance and safety as it relates to the number of transients and challenges to safety systems and the associated need for operability, availability, and reliability of safety equipment. Establishment of SSCs performance criteria (PC) for maintenance rule implementation is one of the most parts to satisfy MR. This paper present the establishment of performance criteria for APR1400 Pressurizer system and also include SSCs identification to scope of the MR and SSCs risk significance determination. Most of APCs are less than or equal to 4 hours, and dominant RPCs are 0 or 1 time. This PC will used for performance monitoring of APR1400 PZR system and for next steps of Equipment Reliability Process such as Corrective Action, Preventive Maintenance, and Long-Term Planning & Life Cycle Management. The applied methodology can use for any system in NPPs.

2. Methodology and Results

The Figure 1 illustrates the interaction of MR functions, SSCs, and PC. During PC development process for MR implementation, the MR functions and SSCs are grouped and linked in order to optimize the monitoring process. The establishment of specific performance criteria such as Reliability Performance Criteria (RPC), Availability Performance Criteria (APC), and Condition Monitoring Criteria (CMC) are to provide a basis for determining whether the function is under satisfactory performance (a)(2) or need goal setting (a)(1) of MR.

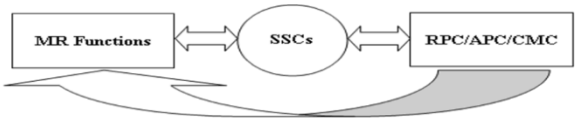

Figure 1. InteractionsofFunctions/SSCs and PC

2.1 Identification SSCs to Scope of the MR

The scoping determination process of the MR illustrates in Figure 2.

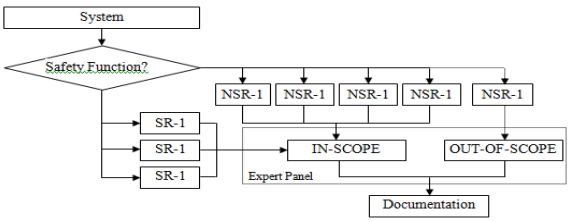

Figure 2. MR scoping determination process

2.1.1 Functions Analysis

The functions list of APR1400 Pressurizer system shows as in Table 1.

Table 1. Functions list of APR1400 Pressurizer system

FID	Function Description
P-01	To maintain RCS operating pressure and compensate for changes in reactor coolant volume during load changes
P-02	To provide overpressure protection for the reactor coolant pressure boundary
P-03	To permit Pressurizer spray during plant heat-up, or to allow cooling if the reactor coolant pumps are shutdown
P-04	To allows non-condensable gases to be vented to the RCGVS during post-accident operations when these gases may be collected in the PZR steam space
P-05	To provide gaseous samples for analysis in order to provide a basis for control of the RCS chemistry and radiochemistry during normal operation
P-06	To provide liquid samples for analysis in order to provide a basis for control of the RCS chemistry and radiochemistry during normal operation
P-07	To generate input signal for reactor protection when high or low Pressurizer pressure
P-08	To generate input signal for controlling Pressurizer pressure and level

2.1.2 SSCs Scope Analysis in MR

MR criteria scope includes safety-related and non-safety-related SSCs as describe following:

(1) Safety-related SSCs that are relied upon to remain functional during and following design basis events to ensure:

- **SR-1**: The integrity of the reactor coolant pressure boundary; or
- **SR-2**: The capability to shutdown the reactor and maintain it in a safe shutdown condition; or
- **SR-3**: The capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to 10 CFR Part 100 Guidelines.

(2) Non-safety-related SSCs:

- **NSR-1:** Non-safety-related SSCs that mitigate accidents or transients.
- **NSR-2:** Non-safety-related SSCs that are used in emergency operating procedures.
- **SSR**-3: Non-safety-related SSCs whose failure prevents safety-related SSCs from fulfilling their safety-related function.
- **NSR**-4: Non-safety-related SSCs whose failure causes a reactor scram or actuates safety systems.

The identification SSCs to Scope of the MR for APR1400 Pressurizer system show in Table 2.

Table 2. APR1400 PS SSCs In or Out scope of MR

FID	SR-1	SR-2	SR-3	NSR-1	NSR-2	NSR-3	NSR-4	Scope In/ Out
P-01	Y	Y	Y	N	N	N	N	In
P-02	Y	N	N	N	N	N	N	In
P-03	N	Y	N	N	N	N	N	In
P-04	Y	N	N	N	N	N	N	In
P-05	N	N	N	N	N	N	N	Out
P-06	N	N	N	N	N	N	N	Out
P-07	Y	N	N	N	N	N	N	In
P-08	Y	Y	Y	N	N	N	N	In

2.2 Determining Risk Significance

Risk significant criteria are established to determine which of the SSCs are risk significant. The Figure 3 illustrates the overall risk significance determination process. In this paper, PSA and Delphi method were used to determine the risk significance of PZR system.

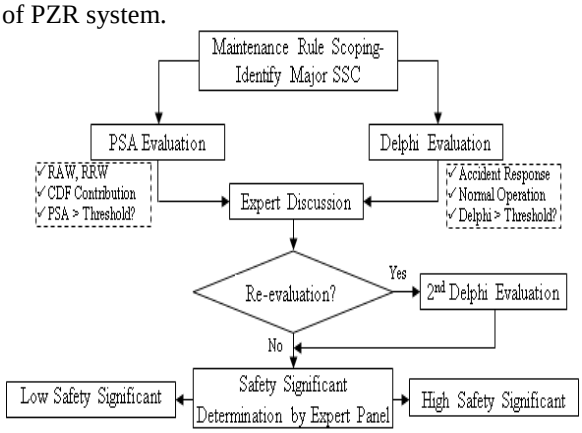

Figure 3. Safety significance determination process

2.2.1 Delphi Method

Table 3. Example of Delphi Risk Ranking Form

FID	MR Functional Description			Expert	
	Accident Response Functions	**x 3**	**WF**	**Scale**	**Result**
Q1	Required to shut down reactor and maintain it in safe shutdown condition.	7.3	**21.9**	1 - 10	
Q2	Required to maintain the reactor coolant pressure and fuel cladding boundaries.	7.1	**21.3**	”	
Q3	Required to remove atmospheric heat and radioactivity from containment and maintain containment integrity.	7.5	**22.5**	”	
Q4	Required to remove heat from the reactor.	9.5	**28.5**	”	
	Normal Operations				
Q5	Required to provide primary side heat removal.	**7.1**		”	
Q6	Required for power conversion.	**7.8**		”	
Q7	Required for primary, secondary, or containment pressure control.	**5.5**		”	
Q8	Required to provide cooling water, component or room cooling.	**6.7**		”	
Q9	Required to provide electric power (AC, DC power).	**7.7**		”	
Q10	Required to provide other motive or control power (instrument air).	**5.7**		”	
	Threshold				
-15% ≤ Threshold (404) ≤ +5%					
	Total Score				

2.2.2 Probabilistic Safety Analysis Method

PSA method used risk importance measures to determine the risk significance of SSCs. Importance measures that have been most commonly used for ranking PSA basic events are Risk Achievement Worth (RAW) and Risk Reduction Worth (RRW). The Figure 4 illustrates PSA risk significance determination process.

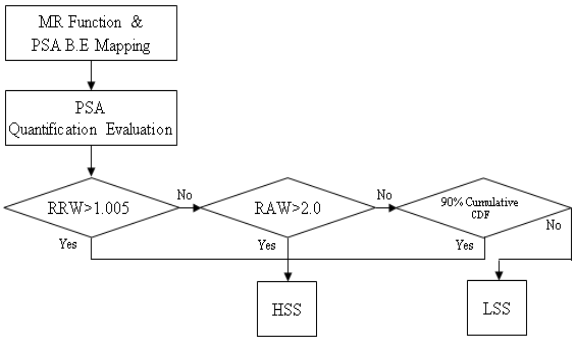

Figure 4. PSA for risk significance determination process

The final results for SSCs risk significance determination of the PZR system show in Table 4.

Table 4. Risk significance determination of APR1400 PS

FID	SSCs	PSA B.E Mapping	PSA Result	Delphi Result	Final Result
P-01	Heaters	PZR heaters	HSS	HSS	HSS
	PZR Spay	CV244	HSS	HSS	HSS
		MV242, MV243	HSS	HSS	HSS
		AV100F, AV100E	HSS	HSS	HSS
		V237, V241; V236, V240	HSS	HSS	HSS
P-02	POSRVs	PV200, PV201, PV202, PV203	HSS	HSS	HSS
P-03	Aux. Spray	SV203	HSS	HSS	HSS
		V431	HSS	HSS	HSS
P-04	RCGVS	SV410, SV411, SV412, SV413, SV419, SV420, SV418	HSS	HSS	HSS
		RV1430, RV1421	HSS	HSS	HSS
P-07	PT	PT-101A, PT-101B, PT-101C, PT-101D, PT-102A, PT-102B PT-102C, PT-102D	HSS	HSS	HSS
		PT199X, PT199Y	HSS	HSS	HSS
P-08	PT, TT, LT	TEW19A, TEW19B, TEW19C, TEW21A, TEW21B	HSS	HSS	HSS
		LT18, LT14(2), LT40A(2), LT40B(2)	HSS	HSS	HSS
		PT12(4), PT13(4), PT15(2), PT16(2), PT17(2), PT20(2)	HSS	HSS	HSS

2.3 Establishment of Performance Criteria

The PC selection establishment process shows as Figure 5.

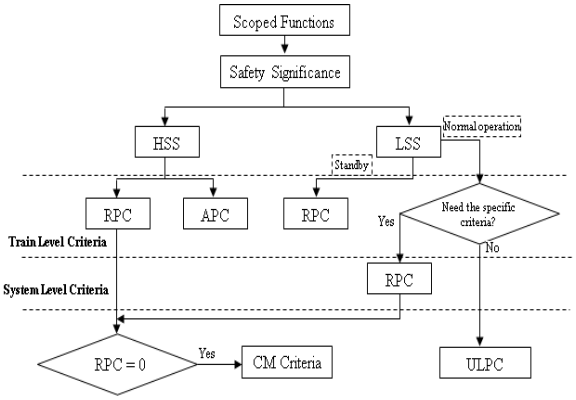

Figure 5. PC selection establishment process

2.3.1 RPC Calculation

RPC development process illustrates as Figure 6. In this paper, RPC were determined using EPRI methodology for the case of SSCs modeled in PSA and for the case in which PSA extended application is possible. Data sources for significance determination results using PSA reference to APR1400 DCD Tier2, APR1400 SSAR, and NUREG/CR-6928. The time period or mission time are considered every refueling cycle (18 months).

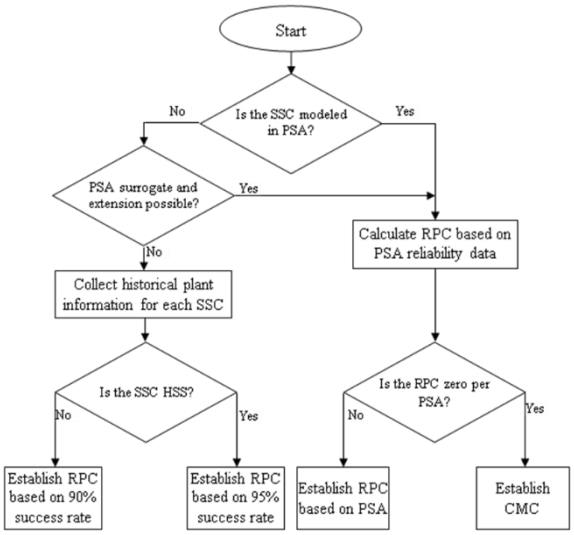

Figure 6. RPCdevelopmentprocess

2.3.2 APC Calculation

APC development process illustrates as Figure 7. APC is established for HSS SSCs. If functions of SSCs are modeled in the probabilistic safety assessment, APC will determine based on the PSA data. Another situation, APC will determine referring to Allowable Out-of-service Time (AOT) or maintenance hours if functions of SSCs are not modeled in the probabilistic safety assessment (eq. 1).

$$APC = RPC \times AOT \qquad (1)$$

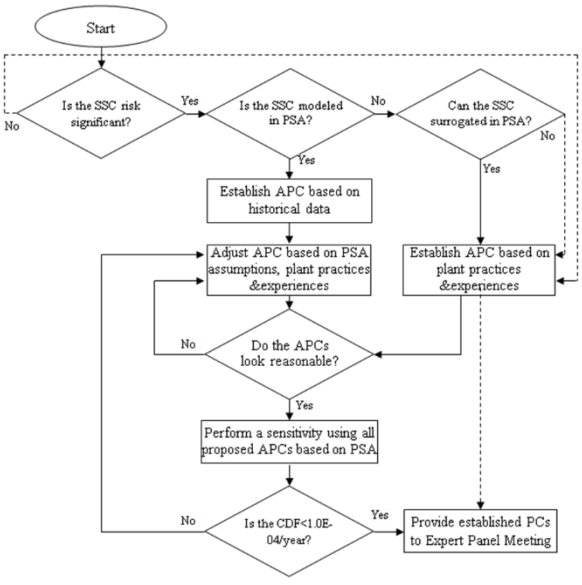

Figure 7. APC development process

2.4 Results

The performance criteria establishment results of APR1400 PZR system for MR implementation is show in Table 5.

Table 5. Performance criteria of APR1400 PZR System

FID	Key SSC	Failure Mode	RS	RPC *(number of failures)*	AOT	APC	CL	ML
P-01	PZR heaters	HXY	HSS	0	72 hr	0 hr	CMC	Train
	CV244	CVO	HSS	0	4 hr	0 hr	CMC	Train
		CVC	HSS	1		4 hr	Train	Train
	MV242, MV243	MVO	HSS	1	4hr	4 hr	Train	Train
		MVC	HSS	1		4 hr	Train	Train
		MVT	HSS	0		0 hr	CMC	Train
		MVFC	HSS	0		0 hr	CMC	Train
		MVSO	HSS	0		0 hr	CMC	Train
	AV100F, AV100E	AVO	HSS	0	4 hr	0 hr	CMC	Train
		AVG	HSS	0		0 hr	CMC	Train
	V237, V241; V236, V240	VVO	HSS	0	4 hr	0 hr	CMC	Train
		VVC	HSS	0		0 hr	CMC	Train
P-02	PV200, PV201, PV202, PV203	PVO	HSS	0	0.25 hr	0 hr	CMC	Train
		PVC	HSS	0		0 hr	CMC	Train
		PVSO	HSS	0		0 hr	CMC	Train
P-03	SV203	SVO	HSS	0	4 hr	0 hr	CMC	Train
		SVC	HSS	0		0 hr	CMC	Train
		SVFC	HSS	0		0 hr	CMC	Train
		SVSO	HSS	0		0 hr	CMC	Train
		SVT	HSS	0		0 hr	CMC	Train
	V431	CVO	HSS	0	4 hr	0 hr	CMC	Train
		CVC	HSS	0		0 hr	CMC	Train
P-04	SV410, SV411, SV412, SV413, SV419, SV420, SV418	SVO	HSS	0	72 hr	0 hr	CMC	Train
		SVC	HSS	0		0 hr	CMC	Train
		SVFC	HSS	0		0 hr	CMC	Train
		SVSO	HSS	0		0 hr	CMC	Train
		SVT	HSS	0		0 hr	CMC	Train
	RV1430	RVO	HSS	0	72 hr	0 hr	CMC	Train
		RVSO	HSS	0		0 hr	CMC	Train
P-07	PT-101A, PT-101B, PT-101C, PT-101D, PT-102A, PT-102B PT-102C, PT-102D PT199X, PT199Y	PTOP	HSS	0	72 hr	0 hr	CMC	Train
P-08	TEW19A, TEW19B, TEW19C, TEW21A, TEW21B	TTOP	HSS	0	72 hr	0 hr	CMC	Train
	LT18, LT14(2), LT40A(2), LT40B(2)	LTOP	HSS	0	72 hr	0 hr	CMC	Train
	PT12(4), PT13(4), PT15(2), PT16(2), PT17(2), PT20(2)	PTOP	HSS	0	72 hr	0 hr	CMC	Train

3. Conclusion

The APR1400 Pressurizer system performance criteria establishment for MR implementation is done with purpose to provide a basis for determining whether the function is under satisfactory performance (a)(2) or need goal setting (a)(1) of MR. The results is necessary to review by expert panel with reflection of plant experiences and practices. PC can be changed when PM base is changed and PSA results changed. The presented methodology can apply to other systems of NPPs.

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