APR1400 PRESSURIZER SYSTEM PERFORMANCE CRITERIA

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Abstract: U.S.NRC Regulation 10CFR50.65 "Requirement for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants" was published and became effective as from 1996 and known commonly as the Maintenance Rule. This rule requires all of utilities in U.S. must be satisfy to get license for nuclear power plants operation and to provide reasonable assurance that SSCs are capable of performing their intended functions. Utilities in other countries are also applying this rule because it is required to clear link between effective maintenance and safety as it relates to the number of transients and challenges to safety systems and associated need for operability, availability, and reliability of safety equipment. This paper presents on APR1400 PZR System Performance Criteria that is one of the importance parts of the project on "Maintenance Rule Applicaion to APR1400 Pressurizer System". The research on APR1400 Pressurizer System PC applied methods, guidelines by NRC and other organizations such as NEI, INPO, EPRI, and Owners Groups. The main contents to establish APR1400 Pressurizer System PC cover on identification SSCs to scope of the MR (function analysis of APR1400 PZR system, SSCs scope analysis in MR); determining safety significance (using Delphi method and probability safety analysis for identification HSS or LSS of SSCs); performance criteria establishment (RPC and APC calculation). The research results can consider for reference to apply for APR1400 Pressurizer system.

Keywords: *APC, EPRI, INPO, MR, NEI, NRC, PC, PZR, RPC, SSCs, APR1400, Availability, Reliability*

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 systems, structures and components (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. PSA method and Delphi method were used to determine the safety significance for SSCs of APR1400 Pressurizer system. The Delphi method is a powerful approach that can be used to collect data and ideas from experts or lead to group decisions. PSA method was done using SAREX software (KEPCO E&C produce), input data used was the component failure basic events and their probabilities. The failure probabilities were obtained from APR1400 DCD Tier 2 Chapter 19, APR1400 SSAR Chapter 19, NUREG/CR-6928, and NUREG/CR-4639. Most of Availability Performance Criteria (APCs) are less than or equal to 4 hours, and dominant Reliability Performance Criteria (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.

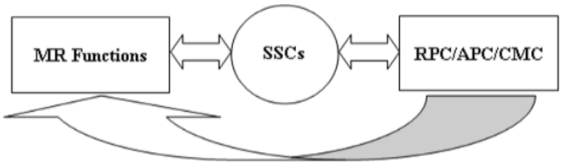

Figure 1. InteractionsofFunctions/SSCs and PC

2.1 Identification SSCs to Scope of the MR

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

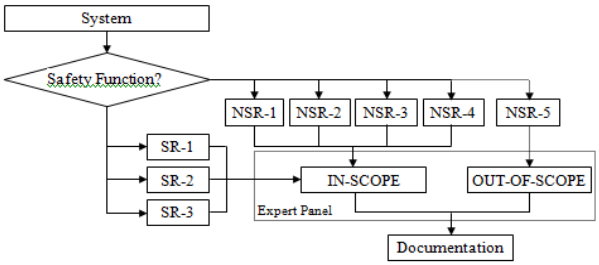

Figure 2. MR scoping determination process

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.

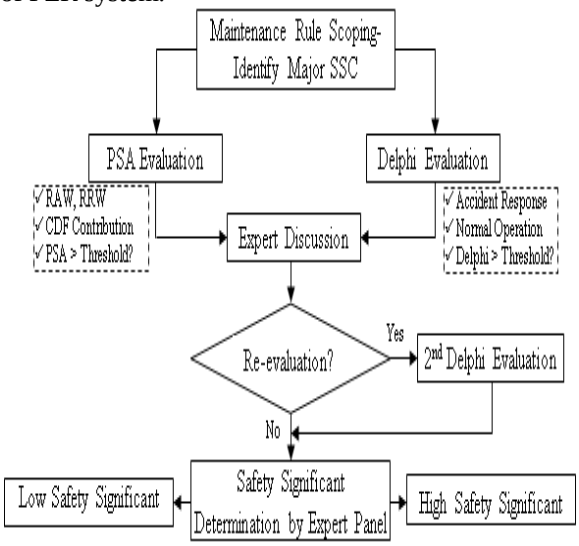

Figure 3. Safety significance determination process

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.

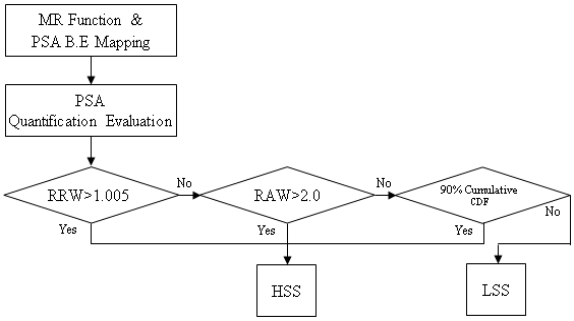

Figure 4. PSA for risk significance determination process

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.

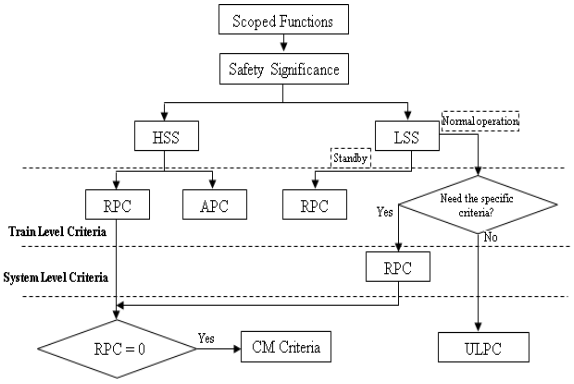

Figure 5. PC selection establishment process

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).

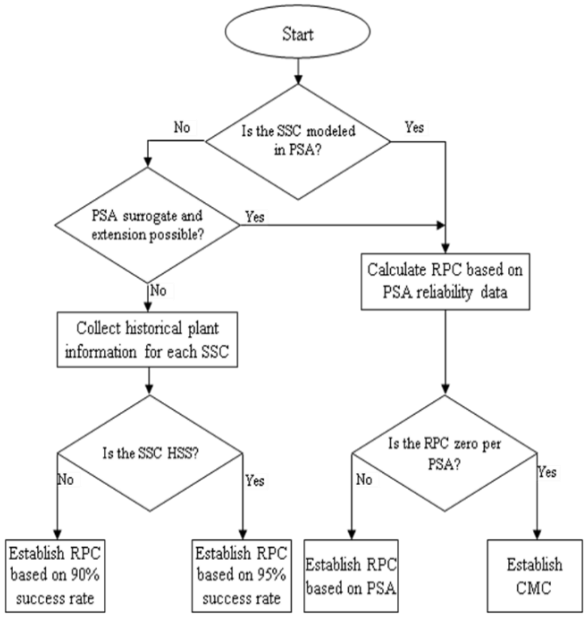

Figure 6. RPC development process

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).

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

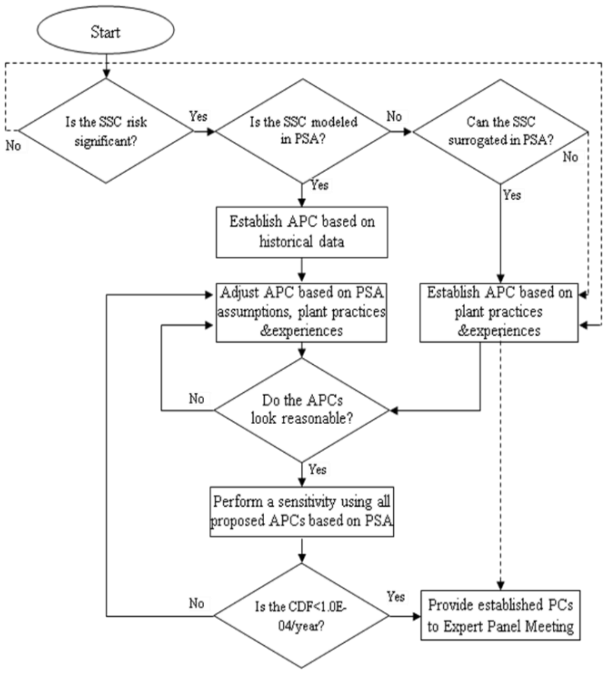

Figure 7. APC development process

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	Train	Train
	CV244	CVO	HSS	0	4 hr	0 hr	Train	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	Train	Train
		MVFC	HSS	0		0 hr	Train	Train
		MVSO	HSS	0		0 hr	Train	Train
	AV100F, AV100E	AVO	HSS	0	4 hr	0 hr	Train	Train
		AVG	HSS	0		0 hr	Train	Train
	V237, V241; V236, V240	VVO	HSS	0	4 hr	0 hr	Train	Train
		VVC	HSS	0		0 hr	Train	Train
P-02	PV200, PV201, PV202, PV203	PVO	HSS	0	0.25 hr	0 hr	Train	Train
		PVC	HSS	0		0 hr	Train	Train
		PVSO	HSS	0		0 hr	Train	Train
P-03	SV203	SVO	HSS	0	4 hr	0 hr	Train	Train
		SVC	HSS	0		0 hr	Train	Train
		SVFC	HSS	0		0 hr	Train	Train
		SVSO	HSS	0		0 hr	Train	Train
		SVT	HSS	0		0 hr	Train	Train
	V431	CVO	HSS	0	4 hr	0 hr	Train	Train
		CVC	HSS	0		0 hr	Train	Train
P-04	SV410, SV411, SV412, SV413, SV419, SV420, SV418	SVO	HSS	0	72 hr	0 hr	Train	Train
		SVC	HSS	0		0 hr	Train	Train
		SVFC	HSS	0		0 hr	Train	Train
		SVSO	HSS	0		0 hr	Train	Train
		SVT	HSS	0		0 hr	Train	Train
	RV1430	RVO	HSS	0	72 hr	0 hr	Train	Train
		RVSO	HSS	0		0 hr	Train	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	Chan.	Chan.
P-08	TEW19A, TEW19B, TEW19C, TEW21A, TEW21B	TTOP	HSS	0	72 hr	0 hr	Chan.	Chan.
	LT18, LT14(2), LT40A(2), LT40B(2)	LTOP	HSS	0	72 hr	0 hr	Chan.	Chan.
	PT12(4), PT13(4), PT15(2), PT16(2), PT17(2), PT20(2)	PTOP	HSS	0	72 hr	0 hr	Chan.	Chan.

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.

ACKNOWLEDGEMENTS

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ACRONYMS

AOT	Out-of-Service Time
APC	Availability Performance Criteria
CDF	Core Damage Frequency
CFR	Code of Federal Regulations
CMC	Condition Monitoring Criteria
DCD	Design Control Document
EPRI	Electric Power Research Institute
FID	Function ID
HSS	High Safety Significance
INPO	Institute of Nuclear Power Operation
KHNP	Korea Hydro & Nuclear Power
KINGS	KEPCO International Nuclear Graduate School
LSS	Low Safety Significance
MR	Maintenance Rule
NEI/NUMARC	Nuclear Energy Institute
NPPs	Nuclear Power Plants
NRC	Nuclear Regulatory Commission
NSR	Non Safety Related
PC	Performance Criteria
PSA	Probabilistic Safety Assessment
POSRV	Pilot Operated Safety Relief Valve
PZR	Pressurizer
RAW	Risk Achievement Worth
RCS	Reactor Cooling System
RPC	Reliability Performance Criteria
RRW	Risk Reduction Worth
SR	Safety Related
SSAR	Standard Safety Analysis Report
SSCs	Systems, Structures and Components
WF	Weight Factor

Component	**Failure Mode**	**Identifier**
PZR Heaters	Fail to operate	HXY
Check Valve	Fail to open	CVO
	Fail to close	CVC
Motor Operated Valve (MV)	Fail to open	MVO
	Fail to close	MVC
	Fail to remain open	MVT
	Fail to control	MVFC
	Spurious operation	MVSO
Self-Actuated Valve (AV)	Fail to open	AVO
	Fail to re-close	AVG
Manual Valve (VV)	Fail to open	VVO
	Fail to close	VVC
	Fail to remain open	VVT
Pilot Operated Safety Relief Valve (PV)	Fail to open	PVO
	Fail to close	PVC
	Spurious operation	PVSO
Safety Relief Valve (RV)	Fail to close	RVC
	Fail to open	RVO
	Spurious operation	RVSO
Solenoid Operated Valve (SV)	Fail to open	SVO
	Fail to close	SVC
	Fail to control	SVFC
	Spurious operation	SVSO
	Fail to remain open	SVT
HI PZR PR. Transmitter	Fail to operate	PTOP
LO PZR PR. Transmitter	Fail to operate	PTOP
Temperature transmitter	Fail to operate	TTOP
Level transmitter	Fail to operate	LTOP
Pressure transmitter	Fail to operate	PTOP

TIÊU CHÍ THỰC THI HỆ THỐNG BÌNH ĐIỀU ÁP LÒ PHẢN ỨNG APR1400

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Tóm tắt: Quy định 10CFR50,65 của Ủy ban điều tiết hạt nhân Hoa Kỳ "Yêu cầu giám sát hiệu quả việc bảo dưỡng tại các nhà máy điện hạt nhân" đã được xuất bản và có hiệu lực từ năm 1996 và thường được gọi là Luật bảo dưỡng. Luật bảo dưỡng cho các nhà máy điện hạt nhân ở Hoa Kỳ được yêu cầu thực hiện để có giấy phép hoạt động và để đảm bảo hợp lý cho các cấu trúc, thành phần và hệ thống có khả năng thực hiện các chức năng được mong đợi của chúng. Các nhà máy điện hạt nhân ở các quốc gia khác cũng đang áp dụng luật này vì nó liên quan đến số các sự kiện tức thời và những thách thức tới các hệ thống an toàn liên quan đến hoạt động, khả năng vận hành, và độ tin cậy của thiết bị. Bài báo trình bày về các tiêu chí thực thi hệ thống điều áp bình áp lực lò phản ứng APR1400, một trong những nội dung quan trọng trong đề tài "Áp dụng luật bảo dưỡng cho hệ thống bình điều áp lò phản ứng APR1400". Nghiên cứu tiêu chí thực thi hệ thống bình điều áp lò phản ứng APR1400 đã áp dụng các phương pháp, chỉ dẫn của NRC và các tổ chứa khác như NEI, INPO, EPRI và nhóm chủ sở hữu các nhà máy điện có cùng nhà chế tạo hoặc cung cấp thiết bị hạt nhân. Những nội dung chính để thiết lập tiêu chí thực thi hệ thống bình điều áp lò phản ứng APR1400 bao gồm nhận diện các thành phần, cấu trúc và hệ thống thuộc phạm vi luật bảo dưỡng (phân tích chức năng của hệ thống, phân tích phạm vi các thành phần, cấu trúc và hệ thống); xác định tầm quan trọng của an toàn (sử dụng phương pháp Delphi và phân tích an toàn xác suất để xác định tầm quan trọng an toàn cao hay thấp cho các thành phần, cấu trúc và hệ thống); thiết lập tiêu chí thực thi (tính toán tiêu chí thực thi độ tin cậy, tiêu chí thực thi khả năng). Các kết quả nghiên cứu có thể xem xét cho tham khảo để áp dụng vào hệ thống bình điều áp lò phản ứng APR1400.

Từ khóa: *APC, EPRI, INPO, MR, NEI, NRC, PC, PZR, RPC,SSCs, APR1400, khả năng, độ tin cậy.*