Reliability Centered Maintenance (RCM) Methodology and Application to the Shutdown Cooling System for APR1400

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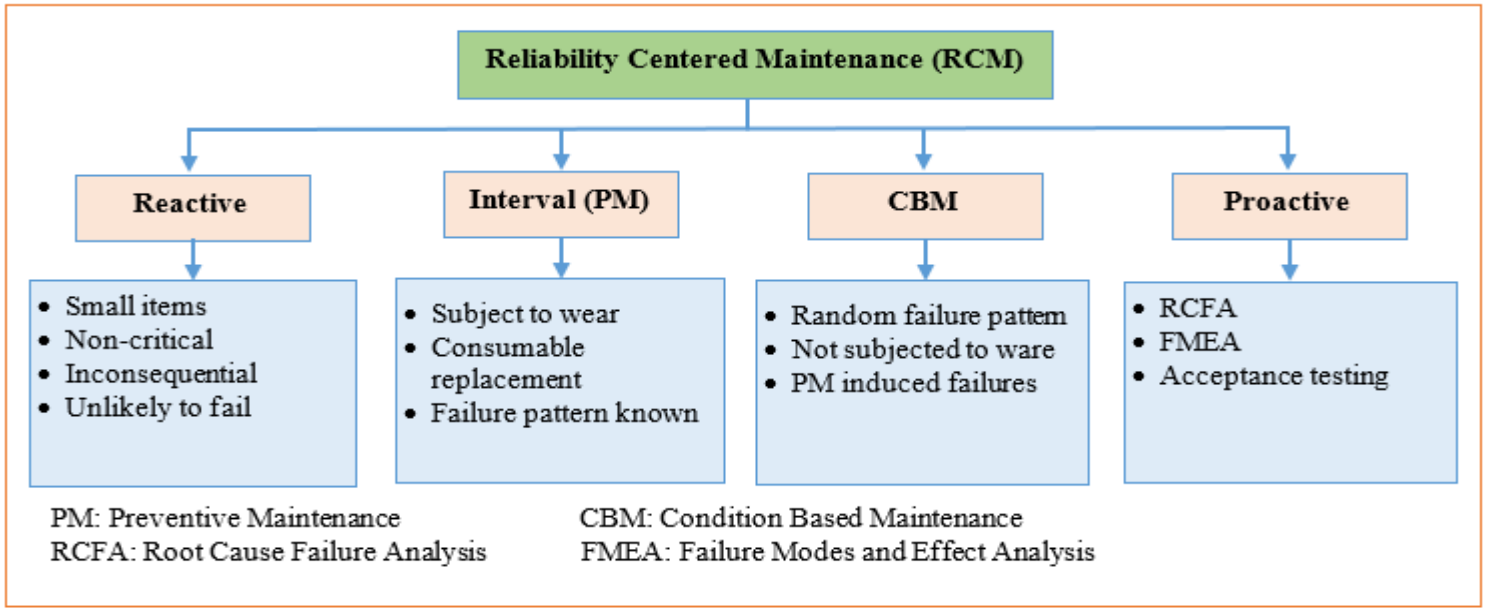
Introduction

- Shutdown Cooling System (SCS) is a safety-related system that is used to cooldawn the reactor coolant to a refuelling temperature and to maintain the proper reactor coolant temperature during refuelling.
- In this study RCM analysis is performed based on evaluation of Failure Modes Effects and Criticality Analysis (FME&CA) on the component, system and plant. The Logic Tree Analysis (LTA) is used to determine the optimum maintenance tasks.

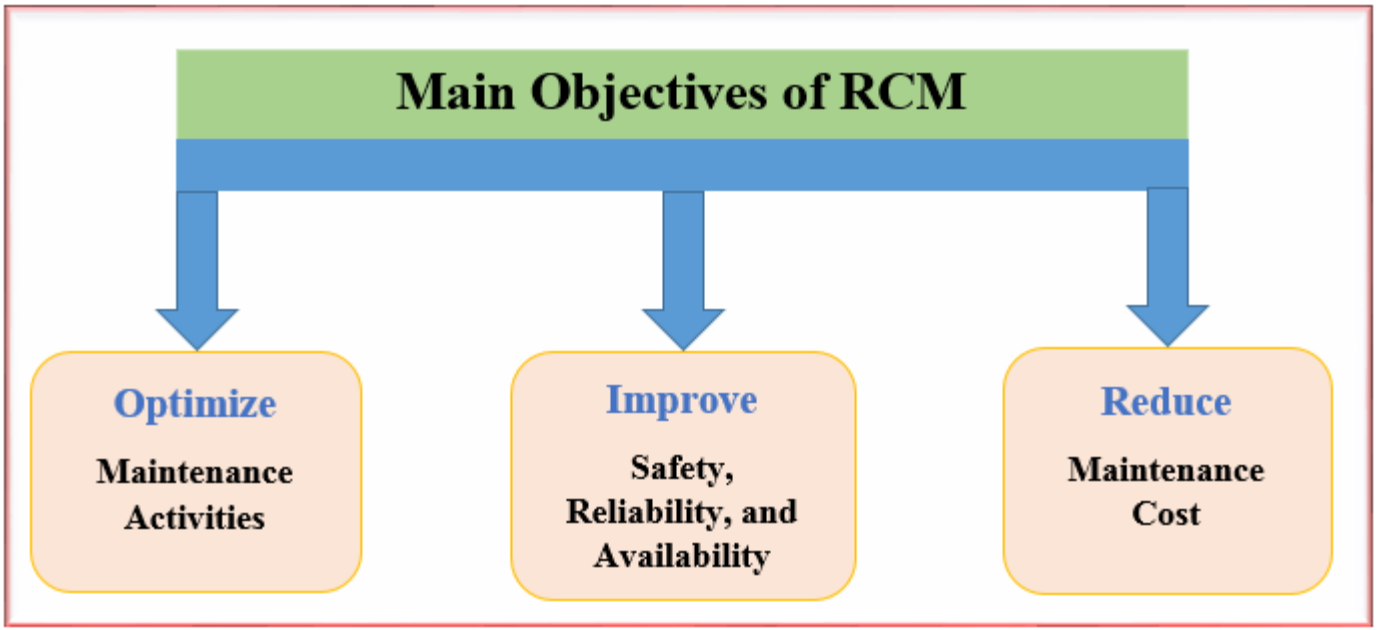
Methodology (1/2)

- RCM:
  - It is a systematic evaluation approach for developing or optimizing a maintenance programme, utilizes LTA to identify the maintenance requirements of equipment according to the safety and operational consequences of each failure and the degradation mechanism.
  - RCM employs (PM), (PdM), (CBM), (RTF) and Proactive Maintenance techniques



Methodology (2/2)

- Objective of RCM:

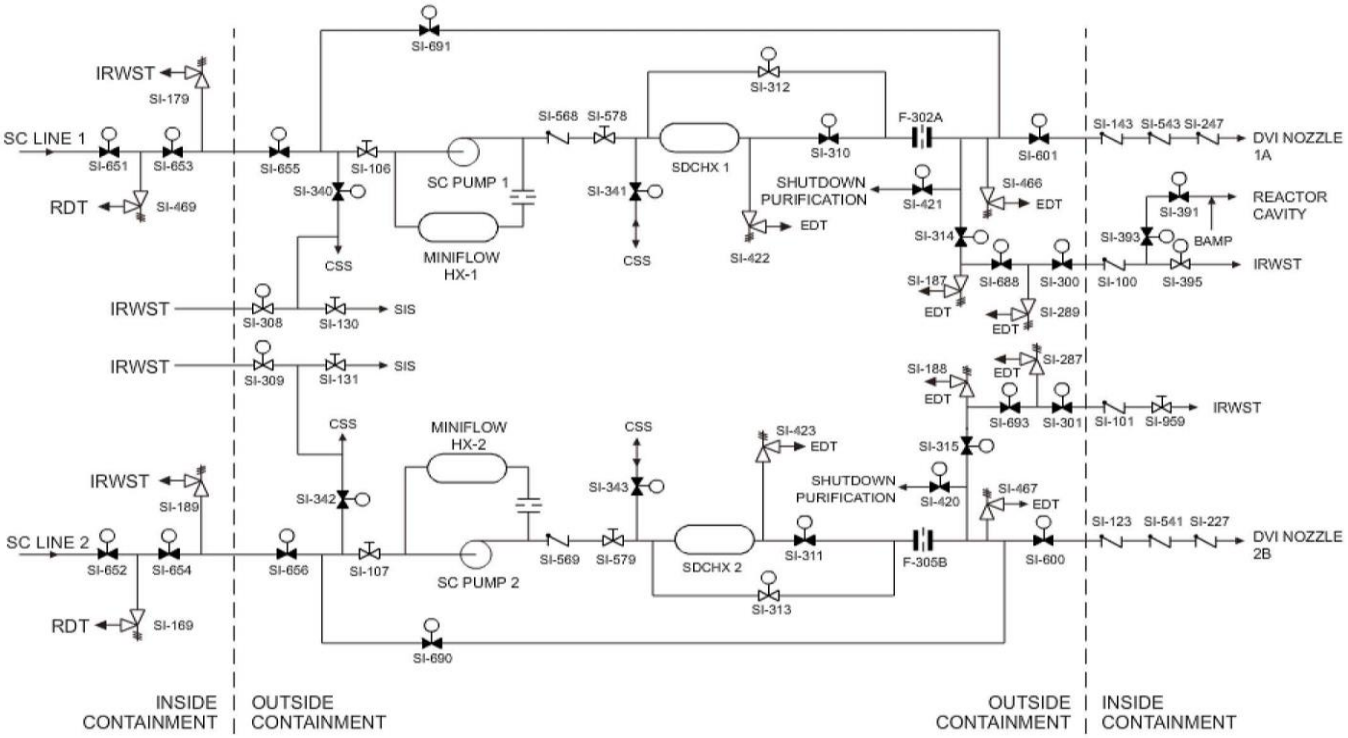


Reasons for selecting the SCS

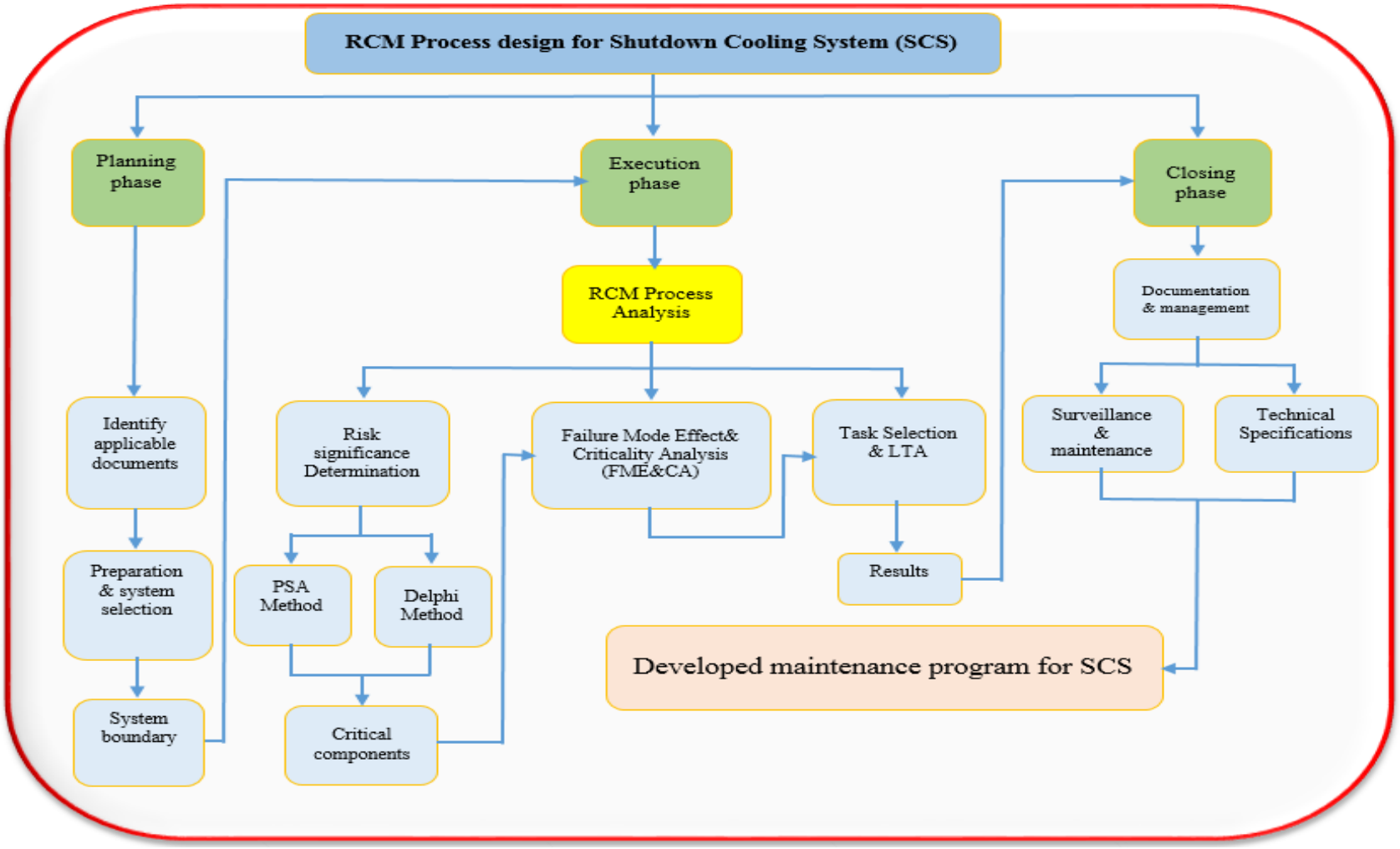
- SCS is safety related system, we have to maintain its availability and reliability.
- SCS has standby modes as well as operational modes, and this makes it to have many troubles and maintenance staff may forget to apply the maintenance rule.
- SCS Used for Cool the RCS down following design basis accidents (SBLOCA, MSLB, MFLB or SGTR).

System description

- Shutdown Cooling System Schematic Diagram for APR1400



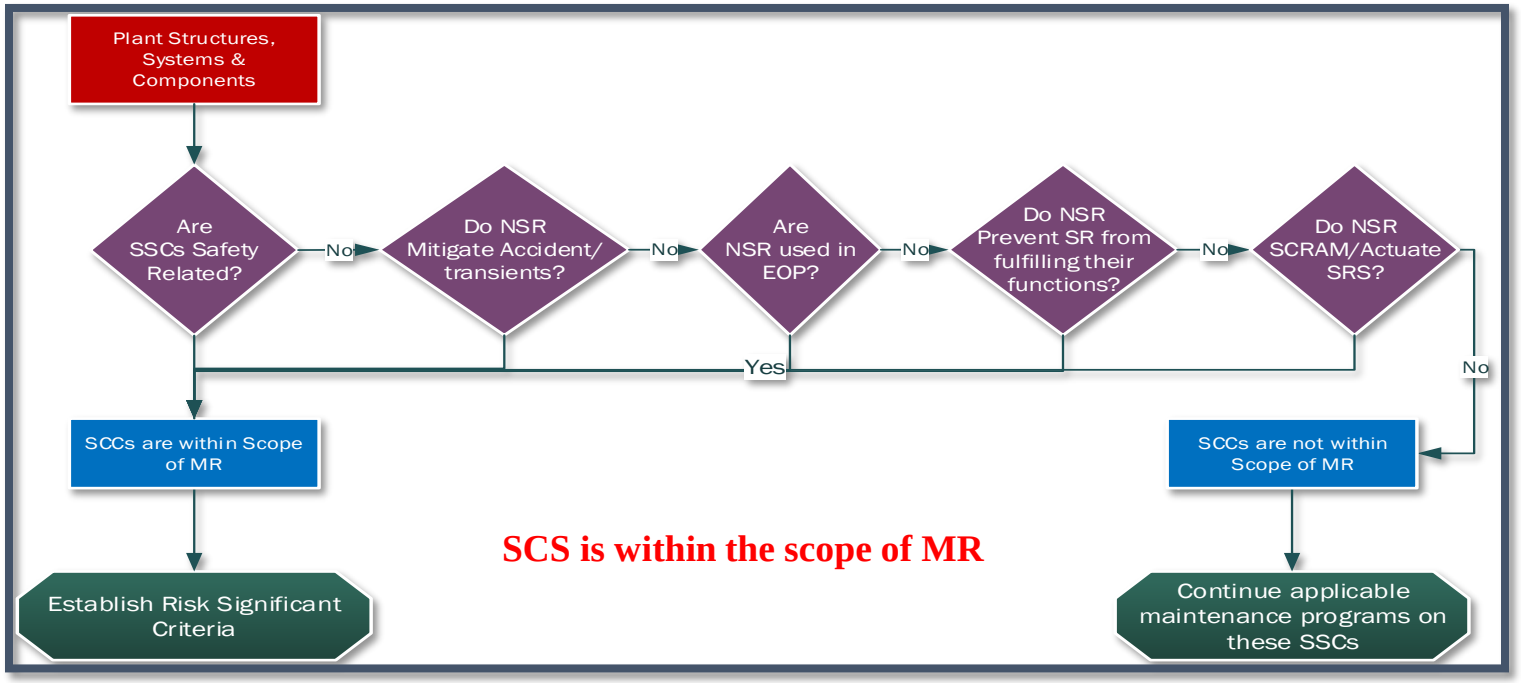
Implementation of RCM Process for SCS (1/10)



Implementation of RCM process for SCS (2/10)

1- System Selection Process

- The scoping process identified the SCS as a system that falls within the scope of maintenance rule.



Implementation of RCM process for SCS (3/10)

- System Functions

ID	Functional Description
SC-01	Cool the RCS down from hot shutdown temperature to the refueling temperature and maintain it for extended periods of time.
SC-02	Cooldown the RCS following design basis accidents (SBLOCA, MSLB, MFLB or SGTR)
SC-03	Provide water for initial External Reactor Vessel Cooling (ERVC) under hypothetical core melting severe accident.
SC-04	Provide cooling of IRWST during post-accident feed-and-bleed operation utilizing SIS and POSRVs.
SC-05	Transfer the RCS fluid to the CVCS for purification during SCS operation.
SC-06	Transfer borated water between the IRWST and refueling pool.

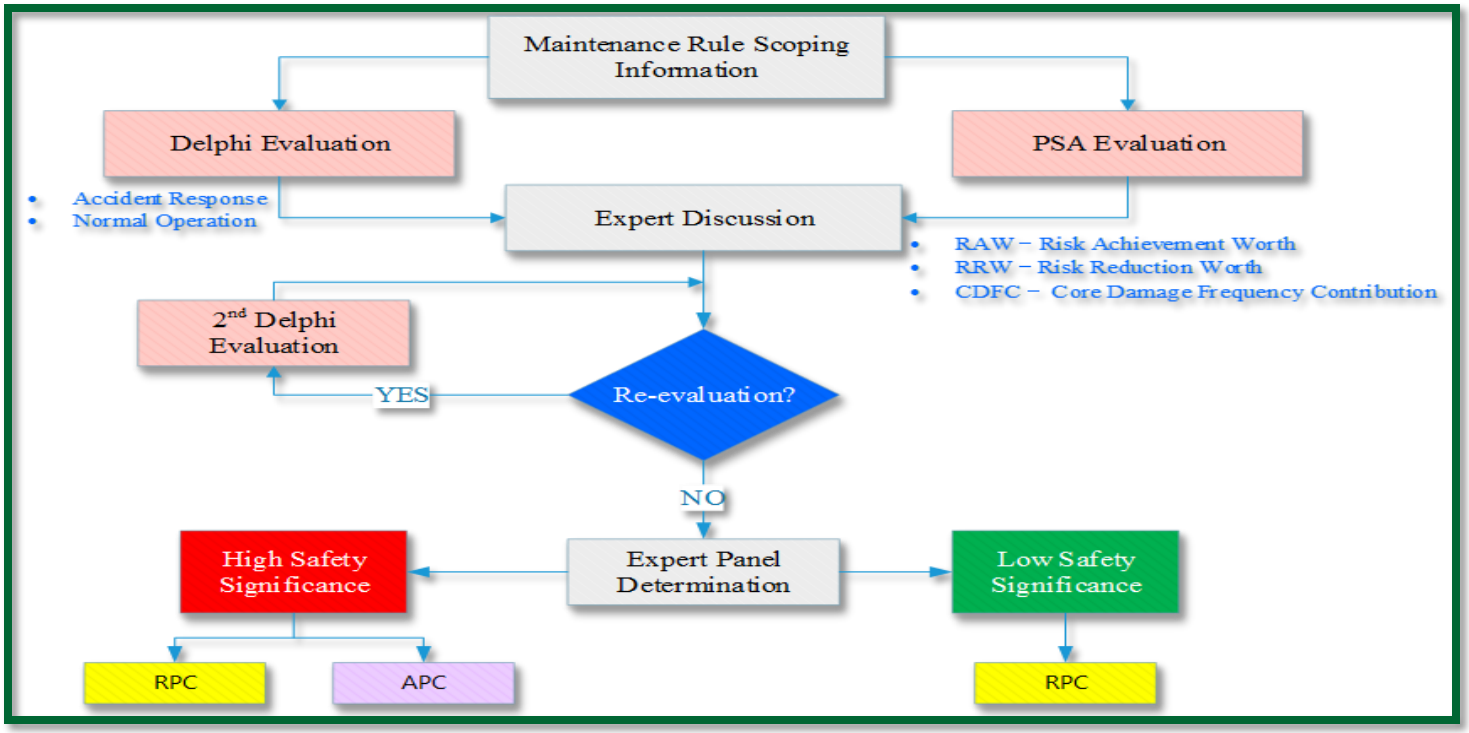
SC-1,SC-2,SC-3 ,SC-4 (Safety Function)

SC-5,SC-6 (Non-Safety Function)

Implementation of RCM process for SCS (4/10)

2-Risk Significance Determination

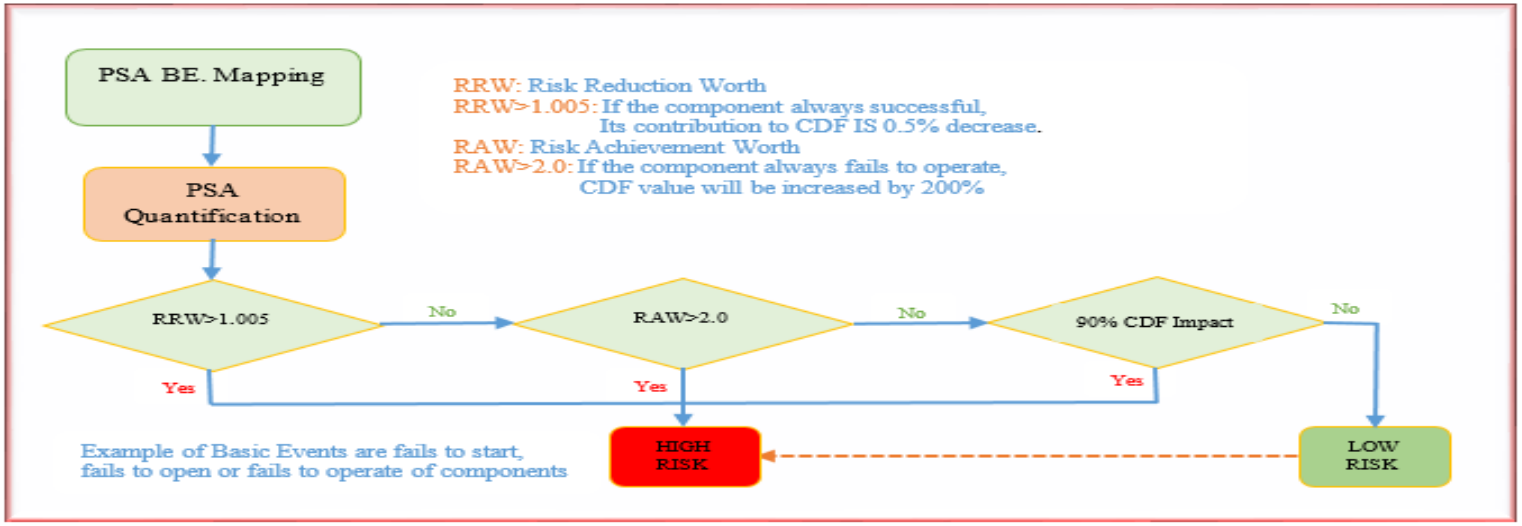
There are two method that are used to determine the safety significance. These include Delphi method and Probabilistic Safety Analysis method (PSA).



Implementation of RCM process for SCS (5/10)

a) PSA method

SAREX software developed by KEPCO E&C is used to model the SCS. SAREX is used to determine the safety significance of each component and identify the critical component by using the following flowchart.



PSA data from SAREX

HSS

Implementation of RCM process for SCS (6/10)

b) DELPHI method

- This method depend on the engineering judgment for the expert panel

PSA Results	DELPHI Results
Vertical Centrifugal Pump	Vertical Centrifugal Pump
Motor Operated Valves	Motor Operated Valves
Heat Exchanger	Check valves
Check valves	Heat Exchanger

Implementation of RCM process for SCS (7/10)

3- RCM analysis for critical components

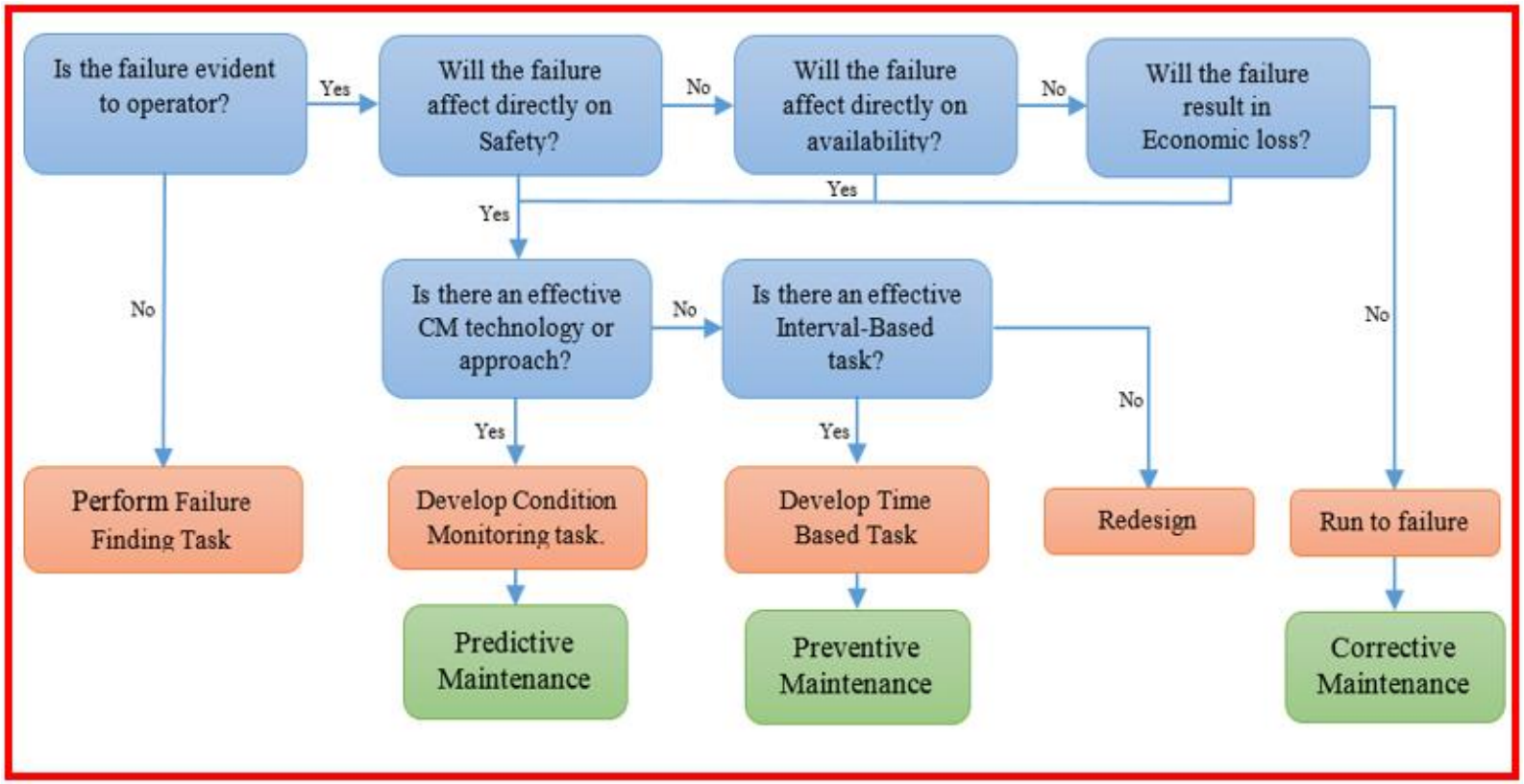
- Failure Mode Effect and Criticality Analysis (FME& CA)

  - Vertical Centrifugal Pump (SCP)
  - Motor Operated Valves (MOV)
  - Check Valves (CV)
  - Heat Exchanger(SDCHX)

FME&CA

Implementation of RCM process for SCS (8/10)

4 - Tasks selection by LTA



Implementation of RCM process for SCS (9/10)

❑ Summary of tasks selection

Component Type	Number of CBM	Number of TBM	Number of Redesign	Failure Finding
SCP	31	10	1	3
	68.9 %	22.2 %	2.2 %	6.7 %
MOV	11	7	1	1
	55 %	35 %	5 %	5 %
CV	14	4	0	0
	77.8 %	22.2 %	0	0
SDCHX	8	3	0	0
	72.7 %	27.3 %	0	0
Total Tasks	64	24	2	4
	68.1 %	25.5 %	2.1 %	4.3 %

Implementation of RCM process for SCS (10/10)

5 - Tasks comparison

After applying RCM process which are condition based maintenance we have to compare between the new selected tasks according to LTA decision making and the old tasks. The purposed option will be:

- The new tasks exactly match the existing PM tasks. — Retain
- The new tasks differ from the existing PM tasks. — Modify
- The existing tasks may be replaced or deleted. — Delete
- The new PM tasks should be added to prevent or mitigate identified failures for the components whose existing tasks do not provide this appropriately. — Add

Results and discussions

- According to PSA data and DELPHI method SCP, MOV, CV and SDCHX, are the critical components in the SCS .
- The FME&CA carried out in this study investigated the possible failure modes for the major components in the system.
- Results showed that 68.1% of potential failures can be detected and prevented by CBM, 25.5% of failure can be detected and prevented by TBM, 2.1% needs to redesign, 4.3% for failure finding and no run to fail for any failure modes.

Conclusion

- The RCM methodology is useful for improving the equipment reliability by strengthening the management of equipment condition, and leads to a significant decrease in the number of periodical maintenance, extended maintenance cycle, longer useful life of equipment, and decrease in overall maintenance cost.
- Shifting from TBM to CBM strategy, will ensure close monitoring of system and component performance without compromising nuclear safety or availability. It is recommended to reduce the number of periodic maintenance activities. Future studies will be done on the cost benefit analysis for RCM application to the SCS .

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Thank you for your attention