Transactions of the Korean Nuclear Society Autumn Meeting
Pyeongchang, Korea, October 30-31, 2014

A Reliability Study for RPS in Jordan Research & Training Reactor(JRTR)

Auther's Name:
Ayman EL-Bordany, Won Young Yun

KAIST Korea Advanced Institute of Science and Technology

KINS Korea Institute of Nuclear Safety

Contents:

1. Overview of JRTR RPS
2. Research Scope
   - 2.1 Description of the Basic assumption
   - 2.2 Fault tree Analysis Model
   - 2.3 Common Cause Failure (CCF) Model
3. Results
4. Conclusions

1.Ovierview of JRTR RPS

- **The JRTR RPS provides:**

I. The protective action to shutdown the reactor.

II. Engineered Safety Features (ESF) actuation function to mitigate the consequences of accidents.

- JRTR RPS is designed to fail-safe, by means to shut down the reactor when it is de-energized due to the loss of electrical power supply .

- JRTR RPS completes the reactor trip by insert :
  - Four Control Absorber Rods (CARs)
  - Two hydraulic actuated Second Shutdown Rods (SSRs)

Into the core whenever the trip parameters exceed the trip set-points.

1.Ovierview of JRTR RPS

- **The RPS Consists of 3 redundant channels and each channel consists of :**

I. Sensors
II. Bistable Processor (BP)
III. Coincidence Circuit (CC)
IV. Initiation Circuit (IC)
V. Actuation Circuit (AC)
VI. Interface and Test Processor (ITP)
VII. Maintenance and Test Panel (MTP)

- And each channel have it's own measurements(independent measurements), with electrical isolation and physical separation.
- There are two control rooms, one of them is a supplementary control room (SCR).

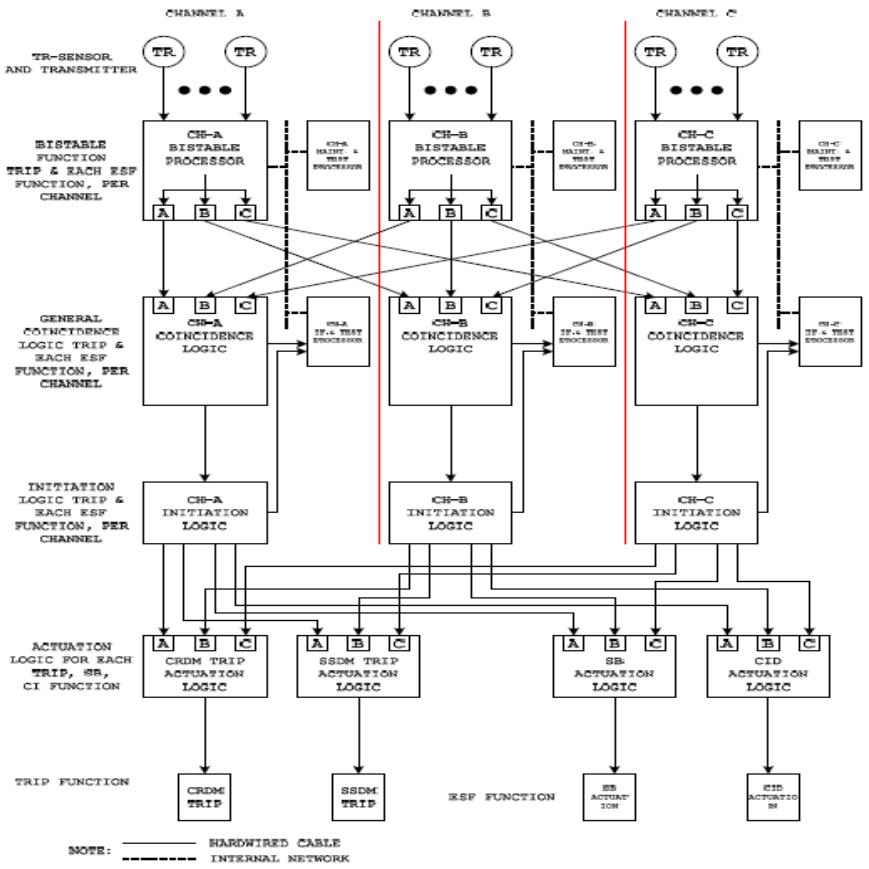


Figure 1 RPS basic block diagram

2. Research Scope

- Calculate unavailability of the JRTR RPS using AIMS code.
- Comparing the unavailability output results with and without manual trip.
- In this study, we consider only the failure of the CRDM actuation circuit because the SBV and CID have the same circuits and it will give the same output results.

- By constructing Fault Tree Analysis (FTA) model
  - The failure events represents in the random failure of
    i. Hardware components
    ii. Operator errors
    iii. Common cause failure (CCF)
  - The unavailability of the system can be calculated by summing all of the cut-set events in the FTA.
  - The failure data must be available from the manufacturer or the assumption data can be considered.

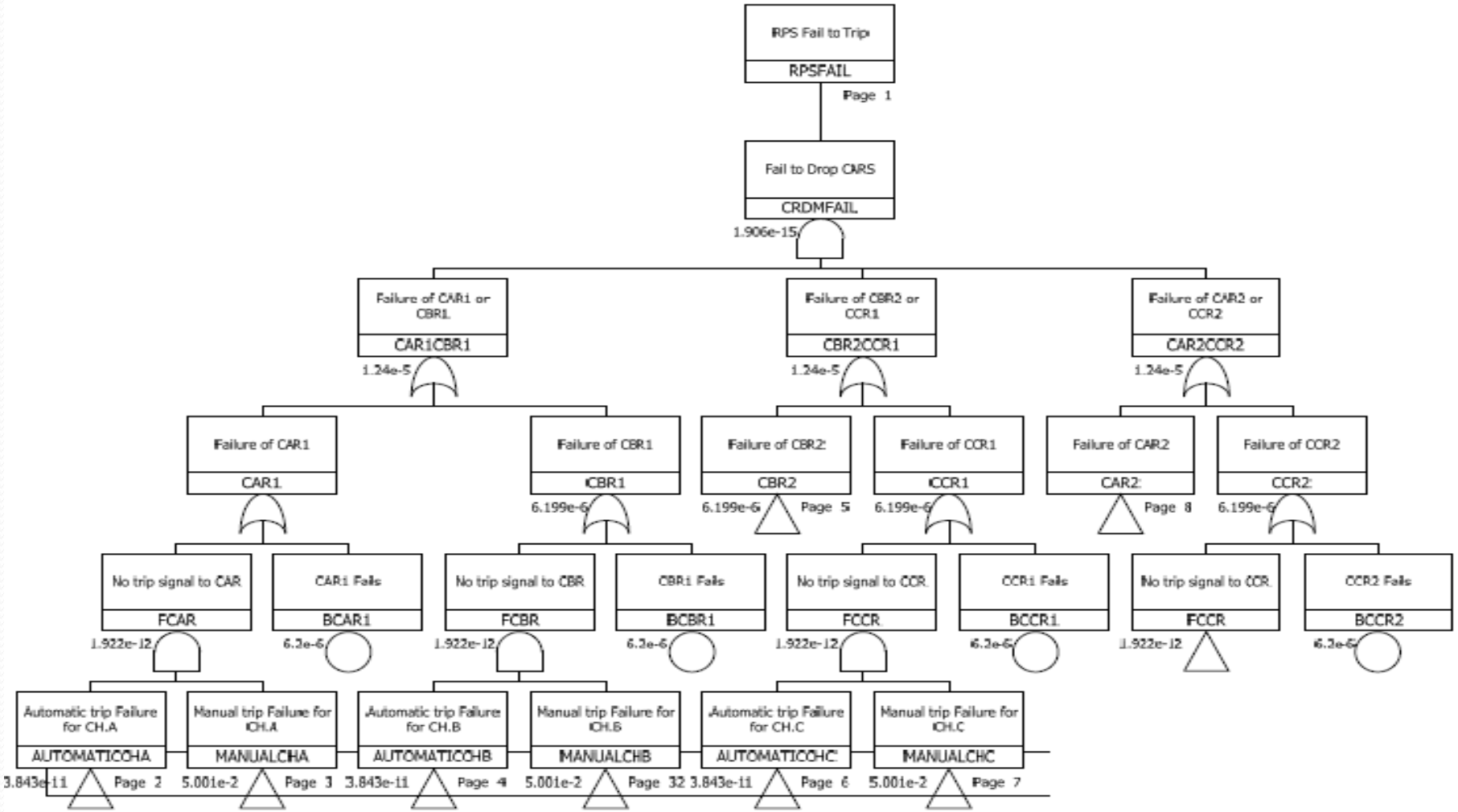
2.1 Description of the Basic assumption

- In this study, the assumption data was chosen to calculate the unavailability.
- The assumed failure rate (data) was taken from Hanul nuclear power plants (NPP) units 5&6, and also from NUREG/CR-5500, Vol.10.
- Table below shows the chosen failure data from Hanul NPP unit 5&6 and NUREG/CR-5500, Vol.10.

Module	Failure rates 1	Failure rate 2
Processor module	1.17E-03	5 E-04
Analog input module	7.2E-04	7.6 E-03
Digital output module	2.95 E-04	2.7 E-03
Relay Failure	6.2 E-06	1.2 E-04
Logic Relay Failure	--	2.6 E-04
Operator Failure	5 E-02	1 E-02
Switch Failure	1.5 E-05	1.3 E-04
Sensors failure	4.5 E-03	1.1 E-04

- Failure rates 1: Chosen failure data from Hanul NPP unit 5&6.
- Failure rate 2: Chosen failure data from NUREG/CR-5500, Vol.10.

2.2 Fault Tree Analysis (FTA) Model



2.3 Common Cause Failure (CCF) Model

- AIMS code generates the common cause failure probability of the RPS using Alpha Factor model including independent event.

- Table shows the estimated CCF probabilities of the JRTR RPS obtained from AIMS code.

Description	Prob.
Independent Event	**3.8E-03**
CCF (2/3)	**4.26E-05**
CCF (3/3)	**4.04E-05**
CCF (2/2)	**8.52 E-05**

3.Results

- The safety assessment of the RPS is determined by summing up the individual probabilities of the basic events in the FTA model.
- Table shows the unavailability results of the RPS:

Items	Unavil.1	Unavil.1 without manual scram	Unavil.2	Unavil.2 without manual scram
FT without CCF	4.569e-6	9.122e-5	3.252e-6	3.252e-4
FT with CCF	2.310e-4	6.004e-4	2.116e-4	9.470e-4

- Unavil.1: Unavailability output after using data from Hanul NPP unit 5&6.
- Unavil.2: Unavailability output after using data from NUREG/CR-5500, Vol.10.

•For the selected trip parameters such as pressure transmitter, differential pressure transmitter, level transmitter, and neutron flux detector, the safety assessment result of the RPS is shown in Table .

Trip Parameter	Failure Rate	Output 1	Output 2
pressure transmitter	7.99E-05/h	3.343E-06	2.116E-04
differential pressure transmitter	7.99E-05/h		
level transmitter	7.99E-05/h		
neutron flux detector	1.53E-05/h		

Output 1: Output result of the FTA using NUREG/CR-5500, Vol.10 with changing the sensor data only using the reference data from a reliability study. Output 2: By using CCF.

4.Conclusions

- The cut-sets are the various combinations of component failures or operator errors that result in the defined top event of the model.
- Calculated results of the JRTR RPS are summarized in terms of the probability that RPS would fail to trip the reactor on demand.
- It was found that the unavailability of the JRTR RPS reduced when the automatic and manual failure are combined together in one FT.
- And also, it was found that the data selected from the NUREG/CR-5500, Vol.10 is much better than the selected data from Hanul NPP unit 5&6. When the CCF added to the system, it will have a great effect on the system and the unavailability of the RPS will increase as shown in the Table.

Items	Unavail.1 reduced by approximately%	Unavail.2 reduced by approximately%
FT without CCF	95% when manual trip added	99% when manual trip added
FT with CCF	61.5%	77.65%

Future Work

- Using another code to compare the results with AIMS code.
- Calculate the sensitivity of JRTR RPS


Thank you