A Comparative Study on Four RCPs Coastdown at 50 Hz Condition for APR1400

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1. Introduction

The COAST code has been verified extensively to predict the core flow reduction behavior as the Reactor Coolant Pump (RCP) coastdown after pump trip and the SPACE code is a system simulation code used for safety analyses including RCP model. However, no comparative study has been performed with computer code results and measured plant test data of the APR1400 plant four RCPs coastdown especially at 50 Hz condition. Because major pump design parameters such as the motor rotational speed and horsepower have been changed in 50 Hz RCP design for overseas exports, the four RCPs coastdown transient behavior may vary as compared to that for domestic plants with 60 Hz condition. Therefore, the purpose of this study is to evaluate the capability of predicting the RCP speed and core flow rate reduction in case of RCP coastdown at 50 Hz condition for APR1400 using the SPACE code by comparing with the COAST code results and plant test data.

2. Description of SPACE and COAST Code

2.1 SPACE Code

- Figure 1 shows the SPACE nodalization of APR1400. The RCP model reflects the pressure and dissipation energy produced by the pump into the momentum and energy equations, respectively. The interaction between the pump and fluid is calculated using the four quadrant curves, which are the parametric diagrams of pump head and torque on coordinates of speed versus flow rate.

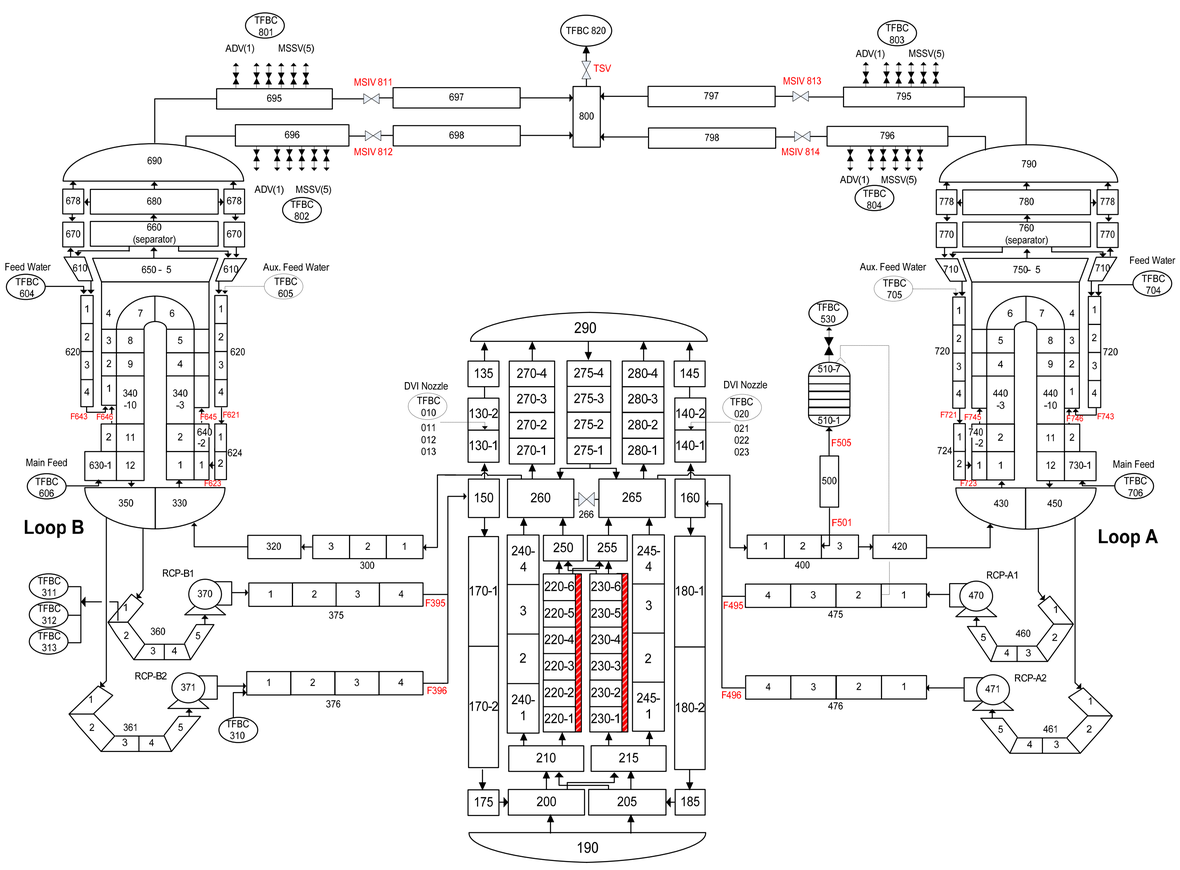

Figure 1. SPACE Nodalization of APR1400

2.2 COAST Code

- Figure 2 shows the COAST nodalization. The COAST code is used to calculate the RCP coastdown transient for any combination of active and inactive pumps and forward or reverse flow in Reactor Coolant System (RCS). Pump head for each active pump is determined by interpolation in pump head-flow characteristic curve inputs.

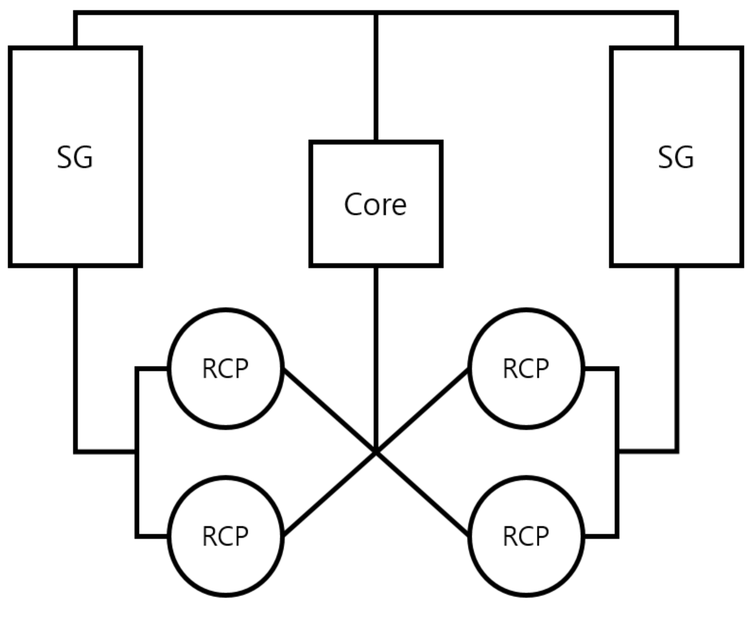

Figure 2. COAST Nodalization

3. Analysis Methods

3.1 RCP Inputs

- In the SPACE code, the pump speed reduction following the four RCPs trip is determined by the moment of inertia and the net torque which equals the motor torque minus the hydraulic torque and friction torque as shown in equation. Major factors determining pump speed and core flow reduction are pump inertia (including flywheel and impeller) and the hydraulic torque since motor torque is set to zero when the RCP trips and friction torque is only in the order of two percent of the hydraulic torque. And the motor and friction torques are neglected in the COAST code. Therefore, pump rated conditions (e.g. torque, head, flow rate, speed, density) used in SPACE and COAST inputs are the same as generated conditions of RCP homologous curve to accurately calculate the hydraulic torque during four RCPs coastdown.

$$I_p \frac{dw}{dt} = \tau_{net} = \tau_m - \tau_{hy} - \tau_{fr}$$

Where,

I_p : pump moment of inertia
w : pump rotational speed
τ_{net} : net torque
τ_m : motor torque
τ_{hy} : hydraulic torque
τ_{fr} : friction torque

3.2 Initial Conditions

- The post-core RCS flow measurement test was performed to verify that the coastdown curve used in safety analyses is conservative as compared to the measured coastdown curve. The plant test conditions at the Barakah unit 1 in UAE were applied as the initial conditions for analyses using SPACE and COAST codes.

4. Comparative Study Results

A total loss of forced circulation of the reactor coolant, which results in a degradation in heat removal from the reactor core and may cause fuel failure, can occur following a loss of electrical power to all RCPs.

The RCP speed and core flow rate reductions during four RCPs coastdown at 50 Hz condition for APR1400 are presented in Figure 3 and Figure 4, respectively. In Figure 3, the RCP speed coastdown plant test data are also compared with code simulation results. As these figures show, the SPACE code predicts the RCP speed and core flow rate reduction almost exactly same with COAST code results and plant test data.

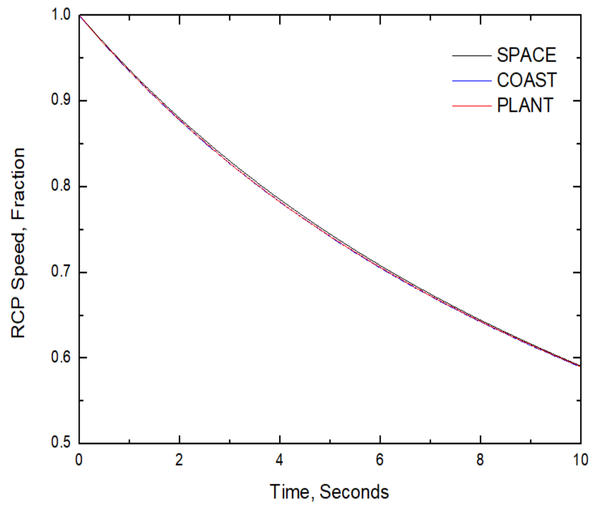

Figure 3. RCP Speed

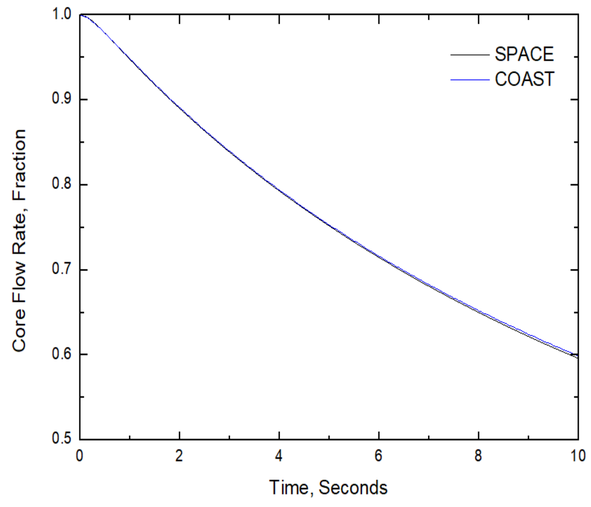

Figure 4. Core Flow Rate

5. Summary and Conclusion

A comparative study on four RCPs coastdown at 50 Hz condition for APR1400 shows that the SPACE code predicts the RCP speed and core flow rate reduction almost exactly same with COAST code results and plant test data. Therefore, it can be concluded that there is a possibility that the SPACE code replaces the COAST code in safety analyses.