PCTRAN/APR1400 – A PC-based Simulator for APR1400

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1. Introduction

Following completion of PCTRAN/KSNP1000 [1], a PC-based simulation software for APR1400 was successfully developed. Advanced Power Reactor 1400 (APR1400) is Korean-designed evolutionary nuclear power plant up-scaled from the 1000 MW electric Optimized Power Reactor (OPR1000) to 1400 MW electric (4000 MW thermal) with numerous upgraded design features. The advanced features, their modeling and performance during design basis and severe accidents, and verification analyses against published references are presented in this paper.

2. APR1400 Design Features

Other than size and output, the major upgrades relative to OPR1000 are:

- Reduced hot leg temperature (324℃) and increased pressurizer volume for larger thermal margin for enhanced transient response.
- Pilot Operated Safety Relief valves (POSRV) on the pressurizer; more stable operation.
- Four trains Safety Injection System (SIS) with Direct Vessel Injection (DVI to eliminate cold leg spill.
- Fluidic device in SIS tank to regulate injection rate during LOCA.
- In-containment refueling water storage tank (IRWST) along with Safety Depressurization and Vent System (SDVS) actuation for a RCS depressurization. It performs water collection, supply and heat sink during normal and accident conditions, so eliminating sump recirculation following a LOCA.
- Hydrogen Management System (HMS) with Passive Auto-catalytic Recombiners (PARs) and glow plug igniters limit the average hydrogen concentration.
- In-Vessel corium Retention through External Reactor Vessel Cooling (IVR-ERVC).
- Cavity Flooding System (CFS) for enhancement of corium cooling reliability.

They are incorporated into the PCTRAN/APR model as seen in the NSSS and containment mimics (Fig. 1 and 2). The prototype is working and has been benchmarked against a few published studies by KAERI.

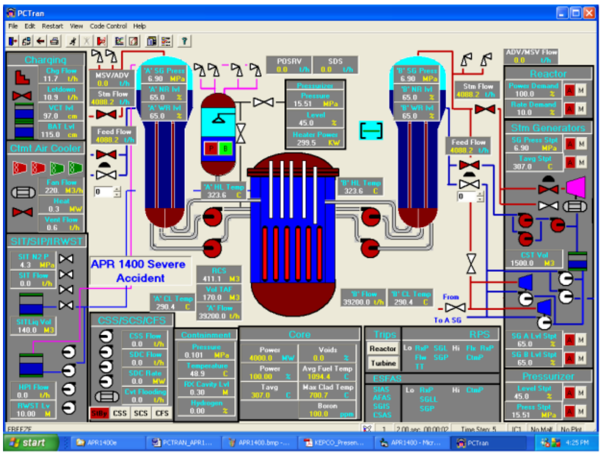

Fig. 1 PCTRAN/APR1400 NSSS mimic

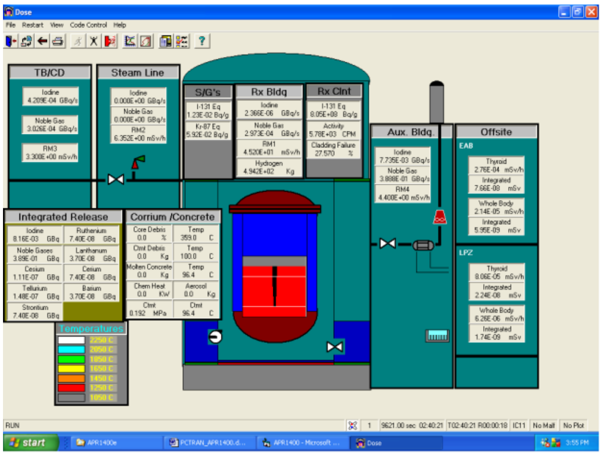

Fig. 2 PCTRAN/ Containment mimic

These include a large break LOCA case to verify the effect of Fluidic Device of SI tank [2] and a station blackout (SBO) without auxiliary feedwater (AFW) to check timings of core damage [3].

3. Direct Vessel Injection (DVI) Emergency Core Cooling System

Rather than injecting into the cold legs as traditional PWR's, there are four independent ECCS trains injecting into the reactor vessel. In each Safety Injection Tank (SIT) there is fluidic device that increases the flow resistance when the driving head is reduced after initial refill phase following a large break loss-of-coolant-accident (LBLOCA). This saves coolant spill from the break and extends operation of SIT to the later reflood phase.

In Reference 2 Fig. 8 the flow from one SIT following a double-ended cold leg LOCA is reproduced below:

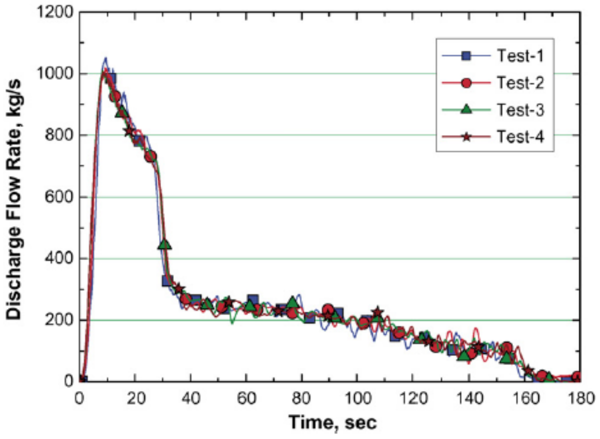

Fig. 8. Discharge flow rate of the ECC water from the SIT.

In PCTRAN benchmark Fig. 3 the green curve is 2-SIT flow. It shows the flow reached about a peak about 6,500 t/hr and then fell to about 1,500 t/hr when the SIT dropped below the standpipe. It terminated in about 260 seconds. The flow rates per SIT closely resemble the test results in [2].

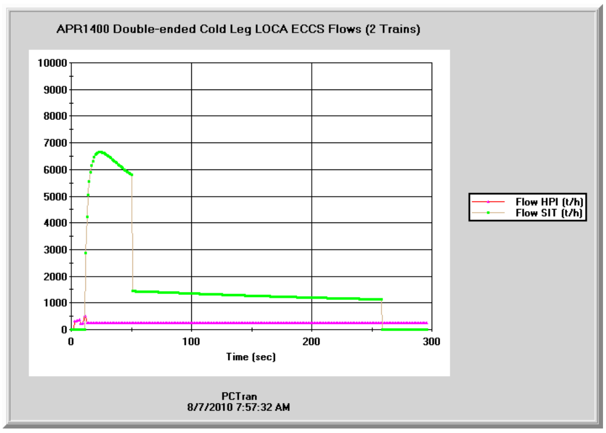

Fig. 3 PCTRAN APR ECCS flows after DELOCA

4. Station Blackout without AFW

The second case is a SBO without AFW in [4]. The RC primary pressure following SBO without AFW is shown in Fig. 4. After the steam generator dryout in about one hour, the pressure rose to lift the POSRV until complete vessel boil off within 3 hours. The vessel bottom then failed in approximately 4 hours.

The sequence of events listed below is comparison between the two analyses. Timing of the major events such as SG dry-out, core uncovery, core plate failure and vessel bottom penetration are quite comparable.

Table 1 Station Blackout Without AFW Event Sequence Comparison

Event Sequence	KAERI Study (seconds)	PCTRAN (seconds)
TMLB SG dryout	3,682	3,790
Pressurizer PSORV open	4,750	4,360
Cover uncovery start	5,797	6,100
Complete core uncovery	7,837	8.200
UO2 melting start	8.543	8,750
Core support plate fail	12,832	14,100
Lower head penetration fail	12,840	15,740

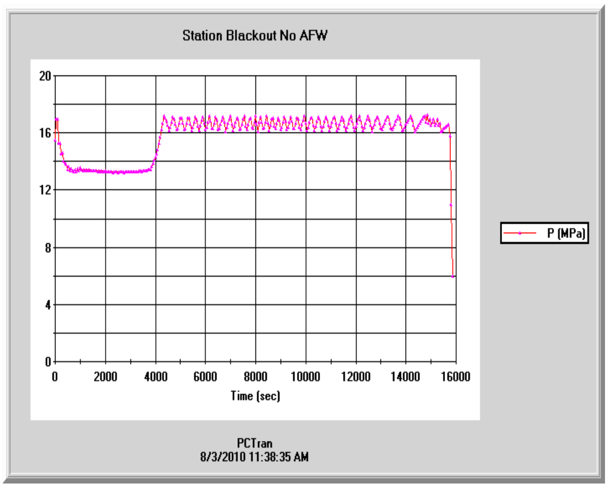

Fig. 4 PCTRAN SBO without AFW RC pressure

5. Conclusions

The PC-based simulation code has been successfully developed for both OPR and APR. Partnered between Micro-Simulation Technology and FNC Technology, the tool should be useful for education and training, severe accident management and emergency exercise.

REFERENCES

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