PCTRAN/KSNP1000 – A PC-based Simulator for KSNP1000

Li-Chi Cliff Po[a*] and Juyoul Kim[b]
[a]*Micro-Simulation Technology, 10 Navajo Court, Montville, NJ 07045, USA,*
[b]*FNC Technology Co., Ltd. Bldg.#135, Seoul National University, Gwanak-gu, Seoul, 151-742, Korea*
**Corresponding author: info@microsimtech.com*

1. Introduction

PCTRAN is PC-based nuclear simulation software developed by Micro-Simulation Technology of USA. Since its first DOS version release in 1985 [1], it has evolved to Microsoft Windows XP environment. Numerous PWR, BWR and new Generation 3 plant models have been completed. Recently teaming up with FNC Inc. of Korea, a KSNP1000 model was developed. It has been successfully verified against Ulchin3,4 FSAR and KAERI's RELAP5 studies [2]. In addition to training, its degraded core and dose release capability can be used in severe accident management and emergency exercise.

2. PCTRAN Model

2.1 Theory and Mathematical Models

A reduced-node approach (compared to the large system code and full-scope simulator that have much more nodes) was used to model the coolant system. For PWR a non-equilibrium pressurizer model handles its normal controls by the spray, heater and relief valves. It also allows sudden changes and extreme conditions such as "water solid" in the pressurizer and two-phase in the reactor core. The steam generators are modeled as homogeneous equilibrium two-phase volumes. Heat transfer from the primary to the secondary is treated rigorously during both forced and natural circulation.

The simulation includes a point kinetics model for reactor power calculation and thermal-hydraulic balance equation solution for the coolant systems. By including containment simulation in addition to the original NSSS model, PCTRAN is a complete nuclear plant simulator. During a severe accident with the core exposed to steam for extended period of time, the cladding may become overheated and hydrogen will be generated. Without proper mitigation the fuel and even the vessel bottom may be melted that further heats up the containment atmosphere. Transient progress is handled by Euler integration over every time step increment. Key plant parameters are then displayed graphically in a mimic with live animation.

2.2 KSNP Plant Model

For many years MST has worked on C-E designed Fort Calhun, Calvert Cliffs and Ste Lucie plants in the US. Based on CE System 80+ design, KSNP1000 is similar with further improvements. The KSNP model's Nuclear Steam Supply System (NSSS) contains:

- Reactor vessel and control assemblies
- Two hot legs and four cold legs connecting to 2 steam generators
- One Reactor Coolant Pump in each cold leg
- One pressurizer connecting to one of the hot legs
- Three-stage positive displacement charging pumps
- Two High Pressure Safety Injection (HPSI) pumps
- Four Safety Injection Tanks
- Two Containment Spray Pumps
- Four Containment Air Coolers
- Two Low Pressure Safety Injection (LPSI) pumps operating either for normal shutdown cooling or safety injection during major loss of coolant event
- Remote-controllable Atmospheric Dump Valves in both steam lines
- Main feedwater pumps and condensate pumps for normal feed to the steam generators
- Main steam safety valves in both steam lines for over-pressure protection
- Motor-driven and Turbine driven auxiliary feedwater pumps

The figure below shows the NSSS mimic.

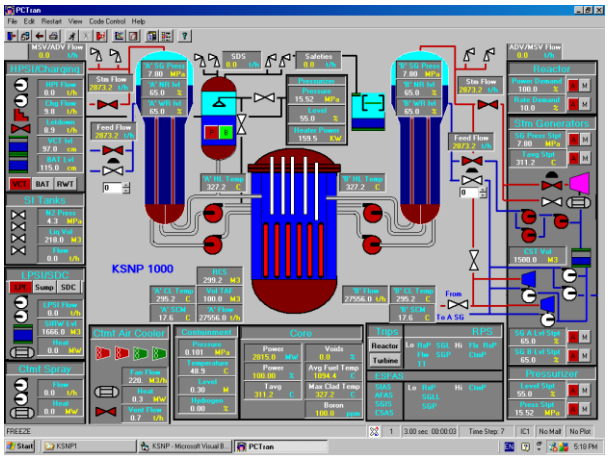

Fig. 1 PCTRAN/KSNP NSSS mimic

2.3 Simulator Software Configuration

PCTRAN is programmed in Microsoft Visual Studio Visual Basic 6.0 application. Data input/output are in MS Access database format. Operation of PCTRAN adheres strictly to the Windows XP specifications. It is compatible to later Vista and System 7 environment. Simulation speed is either real-time or up to 16 times faster for long runs. Transient variables can be plotted online during a run or achieved afterwards. All operator actions and automatic events are recorded into a text log file. The graphs and data can be saved into Office software such as Word, Excel, Access or PowerPoint for documentation or presentation.

3. Transient Runs Verification

A number of accident analysis cases in Ulchin3,4 FSAR [2] have been benchmarked. These include:

- Control assembly withdrawal
- Loss of flow
- Opening of SG atmospheric dump valve
- Steam generator tube rupture

It was further benchmarked against KAERI's SCADP/RELAP and MARS studies [2]. The three cases of total loss of feedwater event: one with and one without Safety Depressurization System actuation, and the third station blackout are compared in Figures 2 and 3. They are in good agreement.

4. Conclusions

PCTRAN has been used by numerous government agencies and utility companies in Japan, Europe, Taiwan, Mexico and USA. The UN agency IAEA has used it in its annual *Advanced Reactor Simulation Workshop* since 1996. In cooperation with FNC Ltd. of Korea, the PCTRAN KSNP1000 model should be useful to both the government regulatory and safety agency and operating plants. Another model for the 1400 MW plants is under development. With expanding opportunity overseas, the tool has potential to contribute to the Korean nuclear export industry significantly.

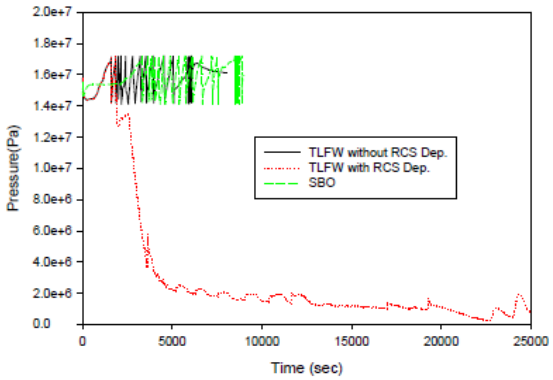

Fig. 2 Pressurizer pressure results from SCDAP/RELAP5/MOD3.3.

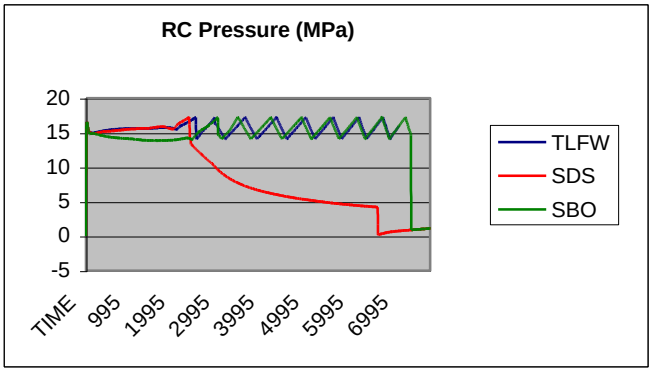

Fig. 3 PCTRAN benchmark of Total Loss of Feedwater events.

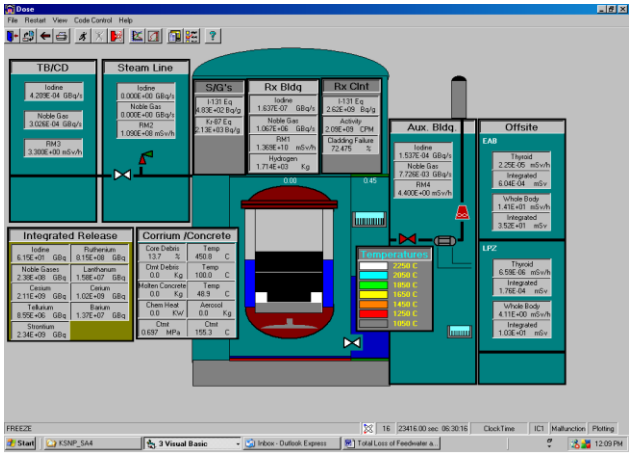

Fig. 4 Severe Accident Containment and Dose Release Source Terms mimic.

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[1] L. C. Po, "Analysis of the Rancho Seco Overcooling Event Using PCTRAN, " *Nuclear Science & Engineering*, 98, 154-161 (1988).

[2] R. J. Park, S. B. Kim and S. D. Kim, "Analysis of In-vessel Late phase Melting Progression using SCADP/RELAP5 mode 3.3", Proceedings ICAPP 2004, paper 4020.