Nuclear Engineering and Design 249 (2012) 41–48

Contents lists available at SciVerse ScienceDirect

Nuclear Engineering and Design

journal homepage: www.elsevier.com/locate/nucengdes

ABWR power tests simulation by using a dual RELAP5 nuclear power plant simulation platform

Chung-Yu Yang [a,*], L.C. Dai [a], Thomas K.S. Liang [a], B.S. Pei [a], C.K. Shih [a], L.C. Wang [b], S.C. Chiang [b]

[a] Institute of Nuclear Engineering and Science, National Tsing Hua University, 101 Sec. 2, Kuang-Fu Road, Hsinchu 30013, Taiwan
[b] Department of Nuclear Safety, Taiwan Power Company, 242 Sec. 3, Roosevelt Road, Taipei 10016, Taiwan

ARTICLE INFO

Article history:
Received 7 January 2011
Received in revised form 5 August 2011
Accepted 5 August 2011

ABSTRACT

Lungmen nuclear power plant is the first advanced boiling water reactor (ABWR) plant in Taiwan. According to the most up-to-date schedule, Lungmen Plant will begin its power tests in later 2011. The tests contain (1) loss of feedwater heater test, (2) one feedwater pump trip test, (3) one reactor internal pump trip test, (4) three reactor internal pumps trip test, (5) loss of offsite power and turbine/generator trip test, (6) turbine trip test, (7) load rejection test, (8) fast load winddown test, and (9) reactor full isolation test. The acceptable values of the plant major parameters in all test criteria of each plant power test have been provided by the plant vendor's analysis results. Thus, the verification of the correctness of the vendor results is important. A dual RELAP5 advanced Lungmen Plant specific simulation platform (ALPS) has been used to simulate the plant power tests. ALPS is developed based on two independent RELAP5 modules: one for the reactor system modeling and the other one for the balance of plant system modeling. All plant systems simulation models are synchronized on a PC-based commercial simulation platform, namely 3KeyMaster. The plant major control systems and the emergency core cooling system are simulated in great detail with the built-in modeling tools of 3KeyMaster. ALPS calculation results have been compared with the plant vendor's preliminary power tests analysis results. The comparison results have been delivered to the plant vendee for references. In this article some typical power tests simulation and comparison results are presented for (1) one feedwater pump trip test, (2) one reactor internal pump trip test, (3) load rejection test, and (4) reactor full isolation test.
© 2011 Elsevier B.V. All rights reserved.

1. Introduction

Lungmen nuclear power plant is the first advanced boiling water reactor (ABWR) plant in Taiwan. Lungmen Plant has two identical units with 3926 MW rated thermal power each. Under the long-term sponsorship of Taiwan Power Company, a whole plant RELAP5 model and a plant specific simulation platform are developed for Lungmen Plant to support the plant licensing analysis, the plant operating issue resolution, and the coming plant power tests onsite simulation.

Due to one of the improvements in ABWR that the recirculation loops in traditional BWR are replaced by the reactor internal pumps design, the blowdown data of the feedwater line break event becomes important to the containment pressure and temperature analysis in ABWR. In 2003, the development of a whole plant RELAP5 model, including the reactor and balance of plant systems modeling was started. For this purpose, system code RELAP5-3D/K, which satisfies all the requirements in 10 CFR 50 Appendix K (U.S. NRC regulations for the emergency core cooling system evaluation models in the loss of coolant accident analysis), has been used to provide the blowdown mass and energy of the feedwater line break event. This event is for the containment pressure and temperature licensing analysis in the final safety analysis report (FSAR) of Lungmen Plant (Thomas et al., 2006, 2010).

Regarding the plant vendor's notice in 2006 that the turbine driven feedwater pump (TDRFP) in Lungmen Plant had an over-designed performance, the pump might run in its critical speed region during the reactor power ascension. If the pump operates in the critical speed region for a longer time, the pump may be damaged due to the system vibration. To analyze the speed of this feedwater pump during the reactor power ascension, the RELAP5 model for the whole plant has been modified to perform the pump speed simulation. The calculation results have verified that the pump speed reached the minimum value of the critical speed region at a reactor power of 25% rated and departed the critical speed region when the reactor power increased to a value of 35% rated (Thomas et al., 2009).

According to the most up-to-date schedule, Lungmen Plant will begin its power tests in later 2011. The acceptable values of the plant major parameters in all test criteria of each plant power test

* Corresponding author. Tel.: +886 3 5715131x34303; fax: +886 3 5165721.
E-mail address: edwardcyyang@hotmail.com (C.-Y. Yang).

0029-5493/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.nucengdes.2011.08.044

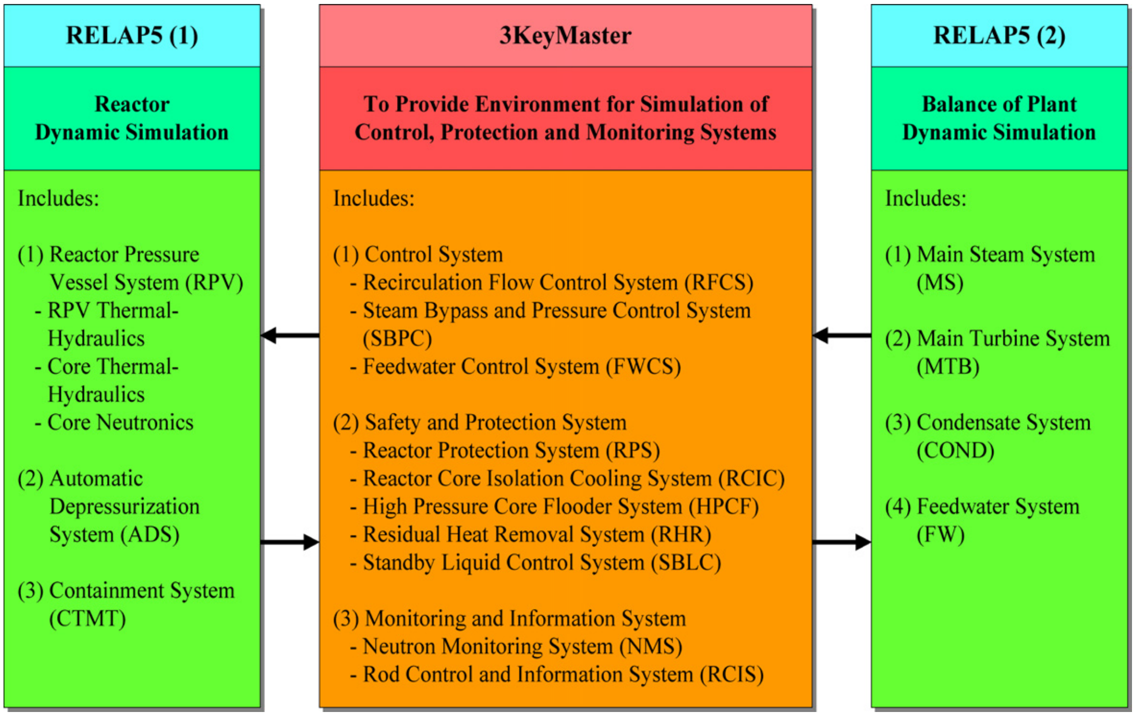

Fig. 1. ALPS framework and modeling scope.

have been provided by the plant vendor's analysis results. To do the verification of these vendor's results, the development of a dual RELAP5 advanced Lungmen Plant specific simulation platform (ALPS) was started (Yang et al., 2009) in 2008. The ALPS can be applied to perform the onsite simulation supporting for the coming Lungmen Plant power tests. ALPS calculation results have been compared with the plant vendor's preliminary power tests analysis results (General Electric Company, 2007). The comparison results have been delivered to Taiwan Power Company for references. In this article some typical power tests simulation and comparison results are presented for (1) one feedwater pump trip test, (2) one reactor internal pump trip test, (3) load rejection test, and (4) reactor full isolation test.

2. Platform characteristics and models verification

The parallel calculation and system simulation technologies have been adopted in presented engineering simulator ALPS. ALPS is developed based on two independent RELAP5 modules and all plant systems simulation models are synchronized on a commercial simulation platform, namely 3KeyMaster (Western Services Corporation, 2008). The component models and the integrated plant model in ALPS have been verified.

2.1. Platform framework

A PC-based commercial simulation platform 3KeyMaster has been modified to communicate with two independent RELAP5 modules. One of these two modules is for the reactor system modeling (RPV model) and the other one is for the balance of plant system modeling (BOP model). The RELAP5 model for the whole plant has been divided into two independent RPV and BOP models for ALPS. These two models have been updated and modified to reflect the current Lungmen Plant design. RPV model is used mainly to perform the reactor thermal-hydraulic and the core neutronic calculations. BOP model is used to execute the thermal-hydraulic simulation of the balance of plant system. The plant major control systems and the emergency core cooling system are simulated in great detail with the built-in modeling tools of 3KeyMaster. ALPS framework and modeling scope are shown in Fig. 1.

The dual RELAP5 modules platform provides the flexibility for user to control the simulation scope of the plant systems. User can run one or both of RELAP5 models based on the event scenario and the system importance. For instance, RPV and BOP models can be initially activated together to simulate the loss of offsite power event. After the occurrence of feedwater pump trip and the closure of main steam line isolation valve, the running of BOP model can be terminated, since it is of less importance for the further calculation. In this way the calculation can be more efficient. In addition, the two independent RELAP5 models do not share the component numbers owing to the code limitation. Thus more component numbers can be used for each model to simulate the model in more detail. The boundary locations and the interface data exchange frequency for both models have to be defined carefully to avoid the instability and distortion of the calculations.

2.2. Modules synchronization

In order to keep the calculation precision of ALPS, the modules synchronization is always controlled by the most time-consuming one, generally referring to one of two RELAP5 modules. Both RELAP5 modules are allowed to reduce their own time step to satisfy the calculation convergence criteria. As shown in Fig. 2, RELAP5 and 3KeyMaster modules are synchronized in every small unit time slot, for example 0.02 s. All modules are activated at the beginning of the unit time slot and march to the end with proper time steps determined by the calculation convergence criteria of the module itself. In each unit time slot, all marching completed modules wait for the synchronization signal generated by the slowest one. During the time advancement, the most time-consuming module may dynamically change. Right after receiving the synchronization signal from the slowest one, the interfacial information is exchanged between the modules and then all modules march together into next unit time slot.

Download English Version:

https://daneshyari.com/en/article/297160

Download Persian Version:

https://daneshyari.com/article/297160

Daneshyari.com