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PETASCALE SIMULATION BASED INVESTIGATION ON STRUCTURAL INTEGRITY OF NUCLEAR POWER PLANT ATTACKED BY STRONG EARTHQUAKE

Shinobu Yoshimura[1],

Tomonori Yamada[2], Tomoshi Miyamura[3], Hiroshi Kawai[4] and Kohei Murotani[1]

[1] Department of Systems Innovation, School of Engineering, The University of Tokyo
7-3-1 Hongo, Bunkyo, Tokyo 113-8656, Japan, yoshi@sys.t.u-tokyo.ac.jp
http://save.sys.t.u-tokyo.ac.jp/ http://adventure.sys.t.u-tokyo.ac.jp/
[2] RACE, The University of Tokyo, Japan
[3] Department of Computer Science, Nihon University, Japan
[4] Department of Mechanical Systems Engineering, Tokyo University of Science in Suwa, Japan

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Nowadays latest supercomputers offer the computing power of petascale, and exascale systems are expected to be available by the end of this decade [1]. Practical finite element simulations on such supercomputers have been attracting much attention. However, petascale supercomputers with tens of thousands of computing nodes, each of which has many cores, require the following three kinds of special consideration in algorithms and implementations : a) Speedup within Core : Increase peak performance of calculation within core, b) Parallelism in inter-node : Increase parallel efficiency in multicore calculation considering memory band width, c) Parallelism in intra-node : Increase parallel efficiency in intra-node calculation considering intra-node communication speed.

Consequently not only the time consuming hot spots of the algorithms but also the entire algorithms must be well tuned and parallelized [2-4]. Quite a few finite element softwares can run on such petascale supercomputers effectively.

Since 1997, we have been developing the advanced parallel finite element analysis software known as ADVENTURE system [5-9]. The ADVENTURE system is very unique open source finite element software that enables very precise analyses of practical structures and machines using over 100 million to one billion DOFs mesh. Those analyses can be very efficiently and easily performed on not only ordinary PC clusters, but also latest supercomputers such as the Earth simulator, Blue Gene/L and the K-computer. The basic parallel solution algorithms employed are the hierchical domain decomposition method (HDDM) with balancing domain decomposition (BDD) as preconditioner. As one of typical and important application areas of petascale simulation, we have been targetting seismic safety of large scale and complex critical falicities such as nuclear power plants (NPPs).

In worldwide, over 430 NPPs are under operation to provide electricity. At the same time, a huge number of earthquakes occur everywhere in the world. Establishing methodologies of reliable and accurate seismic proof design plays a key role in maintaining safety and stability of the NPPs regardless of operation or not. Recent strong earthquakes attacking some

Japanese NPPs such as Niigataken-Chuetsu-Oki (NCO) earthquake of 6.8 Mw on July 16, 2007 and The Great East Japan Earthquake / Tsunami (GEJE/T) of 9.0 Mw on March 11, 2011 recalled its practical importance seriously.

On March 11, 2011, 11 units among 14 units of 4 NPP facilities located along the east coast of Tohoku area were under operation. The 11 units were safely shutdown with automatic scram systems. Among 6 units of TEPCO's Fukushima Dai-ichi NPP Facilities, Nos.1-4 units failed in containing radioactive materials inside due to long term Station Blackout (SBO). Actual causes of the accidents and actual damaging processes of the NPPs' structures, systems and comonents (SSCs) due to either or both seismic loading and Tsunami waves of huge height far exceeding a design limit need to be precisely investigated. There is also an urgent and crucial demand in accurately evaluating seismic proof capabilities of each new or existing NPP subjected to strong earthquake far exceeding its design limit, and in taking appropriate actions a priori to prevent further accidents.

In this presentation, first we overview the latest R&D of the implemented solution algorithms, pre and post tools for performing petascale simulations. Then we describe precise investigation on how the Unit 1 of TEPCO's Fukushima Dai-ichi NPP facilities responded to the GEJE. For this purpose, we precisely modeled its pressure vessel, containment vessel, suppression chamber, vent piping, several supports and reactor building with two billion DOFs finite element mesh. Its dynamic response during 140 sec was solved by using ADVENTURE_Solid Ver.2 on the K-computer of 10 Petaflops peak performance. As a part of post processes, structural integrity assessment including stress and low cycle fatigue evaluation are performed over the whole analysis model in a systematic manner in addition to parallel walkthough visualization of the simulation results.

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