A FUNCTIONAL MODEL FOR SIMULATOR BASED TRAINING IN THE PACIFIC BASIN

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ABSTRACT

According to expert estimate, the nuclear power installed capacity in the Pacific Basin region may reach 20 GWe by the year 2010. Facing a phenomenal growth in nuclear power development in the region, the development of high quality nuclear human resources for “nuclear power ready” developing countries in the Pacific Basin is an important issue at this time. This paper recommends a timely and cost-effective functional training model to the Pacific Basin countries. The model utilizes high quality simulation executed on low cost and readily available PCs to deliver *desktop simulator based training programs*, as an efficient and economical complement to full scope simulators, which may not be available for initial training until five years after the NPP project has started. The objective is to ensure the goals of self-reliance and the transfer of necessary NPP knowledge at the onset of the project, to build up a technological infrastructure in areas vital for subsequent technical support of the NPP in design, commissioning, and operator training: comprehension of control systems; familiarization of plant responses to accident conditions; man machine interface (MMI) functions and interactions; early guide to commissioning and operating procedures; presentation to safety reviewers, etc. An example of this model is demonstrated with the use of the (1) CANDU 9 (CANada Deuterium Uranium 900 MW Pressurized Heavy Water Reactor) desktop nuclear simulator and (2) CASSIM™ (CASsiopeia SIMulation development system).

1 INTRODUCTION

The rapid economic growth in Pacific Basin countries has resulted in a corresponding growth in electricity consumption. For instance, in Thailand, the electricity growth is expected to continue to increase by over 1000 MWe per year for at least the next twenty years. In China, the supply of electricity has consistently been 10% below demand. To overcome the barriers of limited energy resources, China has already entered the nuclear power development era, with an estimated 9,000 MWe of installed nuclear generation by the year 2000, which will be merely 3% of the total generation capacity in China at that time. Other Asian Pacific countries such as Thailand, Indonesia and Vietnam, are currently evaluating nuclear generation options because nuclear power is considered a viable option to ease the limited energy resources, the environmental concerns, as well as the energy transportation and distribution issues. According to expert estimate, the nuclear power installed capacity in the Pacific Basin region may reach 20 GWe by the year 2010. Facing a phenomenal growth in nuclear power development in the region, the development of high quality nuclear human resources for “nuclear power ready” developing countries in the Pacific Basin is an important issue at this time, because it usually takes a minimum of six years to develop competent nuclear personnel for NPPs. Of particular importance underlying this nuclear human resource development initiative is the development of an educational, technological and industrial infrastructure so as to maximize the efforts of a country towards self-reliance, and for the transfer of necessary technology in order to provide assured support for the safe, efficient operation and maintenance of NPPs over their lifetime.

2 STRATEGY FOR PACIFIC BASIN COUNTRIES IN NUCLEAR HUMAN RESOURCES DEVELOPMENT

In preparation for the nuclear power development era, Pacific Basin developing countries that have considered the nuclear generation options have been training and developing their nuclear human resources with help from international organizations such as the International Atomic Energy Agency (IAEA) and prospective reactor vendors. For instance in Thailand, a five year Human Resource Development (HRD) Linkage Project is being conducted under a cooperation agreement between Thailand institutions that include Chulalongkorn University, The Electricity Generating Authority of Thailand, and the Office of Atomic Energy for Peace, and Canadian Institutions which include Canadian International Development Agency (CIDA), Atomic Energy of Canada Limited (AECL) and several Canadian Universities [2]. The IAEA have also been conducting NPP personnel training and qualification seminars in China. Typically, the main task in these human resource development programs is to cultivate qualified persons with higher education qualifications such as Masters and Doctorate degrees, for the nuclear industries. They received basic theoretical training including such subjects as: nuclear reactor physics, reactor thermalhydraulics, reactor safety, reactor materials, instrumentation and controls, nuclear boilers, nuclear steam supply system (NSSS), steam power conversion system, radiation protection, quality assurance, etc.

Experience drawn from the Thailand HRD project indicates that the teaching of NPP design and operation can be greatly enhanced by the use of simulators that allow trainees to work with, and experience various NPP types and sizes, as well as to observe how the plant responds to parameter changes under normal, abnormal, upset and emergency scenarios. Feedback from these trainees indicates that the use of simulators to complement the traditional lectures and textbooks significantly improves the trainees' understanding of the theory and their skills in problem solving while gaining a deeper comprehension of NPP design, operation and safety.

Therefore, for the *"nuclear power aware"* countries, that is, countries that are seriously evaluating the nuclear option, properly implemented simulator based training is a very effective strategy suitable for initial familiarization and assessment of the various NPP's design, their operational characteristics and safety protection philosophy.

What must be done for "*nuclear power ready*" countries that are currently building a new nuclear power installation for which the experienced judgment of operational staff is more than seven years away? Some effective means of training must also be provided during the evolving NPP project life to ensure that adequate and efficient training is provided at the time when it is most needed.

The following paper section describes an effective functional model in which high quality simulation is executed on low cost and readily available PCs to provide immediate access to simulations by nuclear personnel for NPP familiarization, design evaluation, training, and early guide to commissioning/operating procedures. In fact this model fits very well with the recommendations made by the IAEA in the Nuclear Power Plant I and C Guidebook [4]. The suggested method for building up design and development infrastructure for developing countries acquiring a nuclear power program is the use of a Design and Development Performance Analysis Simulator as an essential design and operations' training tool.

3 A BETTER FUNCTIONAL MODEL FOR SIMULATOR BASED TRAINING—DESKTOP SIMULATOR IN SUPPORT OF DESIGN AND TRAINING

Full scope nuclear power plant training simulators have been an accepted tool for successfully training operators. However, despite the tremendous success of full scope nuclear power plant simulators in operator training, there are three important factors which warrant careful assessment of the training objectives versus the options provided (vis-à-vis the full scope simulators, and other economical alternatives/complement, *Desktop Simulators)*, before determining a training strategy which is totally dependent on full scope simulators. These are that full scope nuclear power plant training simulators are expensive; not easily accessible for NPP design purposes and less effective on knowledge acquisition training: "Know Why" and "Know Why Not" [3].

In view of the fore-going concerns for the use of full scope simulators, developing countries are facing a challenge in nuclear manpower training once the NPP contract commences. It can take a period of six to seven years from the signing of the nuclear power plant (NPP) contract to commercial operation. The associated full scope simulator may not be fully operational for operator training until the NPP is in service. In order to provide effective technical support to the NPP over its lifetime, the nuclear power plant engineers and scientists must know not only the design of their plants, but also have an in-depth knowledge of the equipment, instrumentation and controls, system design and of the design intent when the NPP is in commercial operation. Some of this knowledge can be acquired from the information analyses, design reports, etc. supplied by the NPP vendors. For the most part, this knowledge has to be built up from plant related experience and work practice. More importantly, once the plant goes into operation, there can be a gradual decoupling of the transfer of knowledge from the main supplier to the owner.

What should the NPP owners do at the onset of the project to train their engineers and scientists in order to meet the above challenge when the full scope training simulator may not be available for initial training until five years later? It is undisputed that simulator based training is a necessity, in support of classroom type instructions. However, as a complement to a full scope simulator, we recommend an effective functional training model utilizing the desktop simulators in support of design, commissioning and operation training.

4 DESKTOP SIMULATOR IN SUPPORT OF TRAINING

Equipped with similar training capabilities as a full scope training simulator but without the exact replica control room environment, the Desktop Simulator executes high fidelity mathematical plant models and "mimics" the traditional control room panel devices, CRT displays and process schematic diagrams as scaled down CRT monitoring and control displays. The traditional control board handswitches and panel devices are presented as on-screen control pop-ups, manipulated by mouse clicks and/or keyboard data entry. The primary training support functions for desktop simulators are to *complement* the full scope training simulator in the areas of "knowledge acquisition" training: "know why" and "know why not". Complex abnormal plant incidents can be demonstrated to the operators, nuclear engineers and safety reviewers. The user can evaluate possible logistics of incident mitigation, using the simulator, along with on-line hyper-link information, animation and visualization provided by desktop simulator support tools.

From experience, the desktop simulators have been designed to provide *basic*, *intermediate* and *advanced* level training tools to be used in addition to full-scope simulators. These tools have been found necessary by several utility training authorities in order to provide a complete training program. Therefore, the recommended training delivery strategy in utilizing the desktop simulator is to provide *just-in-time* training for basic, intermediate and advanced level knowledge. The just-in-time training concept advises that whoever needs training should get it; but suggests not spending an excessive amount of time and resources to develop high fidelity models up-front. It is better to start with a simplified low-fidelity but realistic model and progressively enhance the model over time to meet the various training needs, so that training payback is commensurate with development cost

The *basic* level of NPP related training is designated to interact with the PC based desktop simulator in order for the trainee to learn and master the basic technical theories and related equipment within the individual context and technical culture environment. This will involve *basic knowledge acquisition; physical phenomenon understanding and overview of basic operations*. Course materials include structured, self-paced learning modules employing interactive multi-media courseware for the following topics: Nuclear Power Plant Overview; Reactor Kinetics; Xenon transients; Heat Transport System Thermalhydraulics; Boiler Dynamics; Balance of Plant Systems; Plant Electrics, etc. These are self-paced, self-learned courses with no instructors. However, one innovation could be the Internet on-line tutorials, on-line questions and answers; on-line assignments and examination, etc.

The *intermediate* level of NPP training is designed to provide *hands-on feeling and orientation of NPP operations*, procedures understanding, instructions applications on unit operations which include unit startup; shutdown; trips and recovery. The program delivery includes three phases:

- Non-interactive Demonstration Phase - a programmed functional, dynamic sequence demonstration of operation, with interaction to allow pauses, data checks, time breaks etc.
- Interactive Coaching/Skills Practice Phase - trainees can practice written procedures, while coached by a computer via visual and audio messages.
- Skill Mastery Phase - when the trainees feel competent, they can disable the computer coaching and perform the operation themselves.

The intermediate level of training is also conducted as a self-paced, self-learned module interacting with the desktop simulator and supported by Internet tutorial, questions and answers, assignments and examinations.

The *advanced* level of NPP training is designed to provide refresher training in *specific situations' study as well as incidental and accidental training* which involves diagnosis and operation procedure application and physical understanding. For example, what should be done if primary heat transport system pressure is decreasing? An important part of this training level is to focus on abnormal incidence diagnostics; abnormal procedural training and teamwork building. The training delivery can involve a series of instructor-led teamwork practice sessions conducted on a Local Area Network (LAN) based multi-PC desktop simulators; environment. (Fig. 1).

5 DESKTOP SIMULATOR IN SUPPORT OF DESIGN—CANDU 9 EXAMPLE AND CASSIM™

Simulation in support of design has long been used in nuclear safety studies and reactor design involving reactor physics and thermalhydraulics. However, these simulations, though highly accurate, are usually very specialized, non-realtime, non-integrated, and have tedious input data requirements and usually have rudimentary outputs. The use of these programs requires special training in computers and numerical methods. As a result, such approaches are prone to long delivery schedules; high capitalization; reduced functionality and are less responsive to rapid design change cycles. Most importantly, they cannot easily be used by the other project process and control engineers in routine analysis and design checkout. Therefore, there is a niche for a simulation package, not intended to compete with the existing sophisticated analysis package, but rather to provide, for example, easily accessible, user-friendly tools for process engineers, control engineers and managers for quick evaluations of a hypothesis before specifying the most appropriate design parameters - for instance, where is the best location for a pressure transmitter take-off in a feedwater hydraulic network, which will be used to sense the "total loss of feedwater to the steam generators" and then used to trip the reactor -? As well, this tool allows early assessment of proposed MMI features and plant information presentation methods. The CANDU 9 desktop simulator, along with the use of CASSIM™ demonstrates an example of such application.

A low fidelity, comprehensive scope, dynamic model of a CANDU-PHWR (Canada Deuterium Uranium Pressurized Heavy Water) nuclear power plant was developed as a multi-purpose advanced desktop simulator using CASSIM™. This desktop simulator has played an integral part in the design and verification of the CANDU 900 MWe control centre mock-up located in the Atomic Energy of Canada

(AECL) design office, providing CANDU plant process dynamic data to the plant display system (PDS) and the distributed control system (DCS), as well as to the mock-up panel devices. As a design tool, the desktop simulator is intended to be used for control strategy development, human factors studies, analysis of overall plant control performance including the provisions of tuning estimates for major control loops. As a plant commissioning and operational strategy development tool, the simulation is intended to be used to evaluate routine and non-routine commissioning and operational procedures, examine “what-if” scenarios for operational strategy development, evaluate malfunction recovery procedures and verify human factors activities [1] (Fig. 2).

The CANDU 9 desktop simulator’s hardware architecture design is modular, based on a standard Intel Pentium processor PC running the Windows 95 or Windows NT operating system. The standard PC, open architecture, hardware and software configurations provide the flexibility of use and the ability to evolve, and to be “portable” to an evolutionary advanced hardware and software configuration, so that the modeling software will not be obsolete with the rapid changes of computer technologies.

The CANDU 9 desktop simulator is developed by using CASSIM™ which is a simulation development system developed by Cassiopeia Technologies Inc. (CTI), based on three common core technologies:

- **CASSBASE**: the database engine;
- **CASSENG**: the real-time simulation engine;
- **LABVIEW**: the MMI [1]

This simulation approach provides the *fast prototyping* ability to construct a dynamic model of all or part of a power plant by interconnecting individual pre-tested generic component models from an extensive library. The resulting system model can be used for:

(a) *Engineering Analysis*: to perform plant or subsystem design and analysis, control system design and analysis, operating procedure evaluation, or system operation or controls troubleshooting.

(b) *Operator Training Simulator*: for training of commissioning, operations’, maintenance personnel and power plant engineers.

(c) *Control System Checkout*: to design, evaluate, test, debug, and/or tune control system hardware/software, prior to final installation.

The CANDU 9 desktop simulator application has demonstrated that desktop simulation with CASSIM™ tools is a cost-effective technique with many advantages in support of NPP design:

- Short development time and competitive prices; very efficient and cost-effective development to adapt the simulator to user-specific needs.
- The large capacities of the new generation of Pentium computers and the Windows NT operating system allow high quality models to be included in such simulators, thus enhancing the capabilities of the simulator.
- Validation and verification of man machine interface (MMI), controls, instrumentation and control platform (e.g. DCS), control centre designs, etc.
- Flexible framework for diverse applications - integration with nuclear design and analysis “legacy” codes; or with decision support systems.
- Dynamic tool to assess a dynamic process or a critical event, without subjecting the commissioning or operating plant to such incidents.

- Can be used in evolving support of the plant design environment to improve the design accuracy, efficiency and effectiveness.
- Can be used in a commissioning environment to guide strategy, and to prepare high confidence "what-if?" predictions, or prepare/evaluate preliminary operating procedures.

Some of these advantages have also been experienced by nuclear engineers in Thailand. In an effort to better understand and demonstrate the design intent of CANDU 9 nuclear safety in the unlikely event of a loss of coolant accident (LOCA), CASSIM™ was used in a graduate research project at Chulalongkorn University of Thailand. A Master's degree student utilized CASSIM™ to develop a dynamic model for the emergency core cooling (ECC). system This model was used to evaluate the approximate peak fuel sheath and coolant temperature in the event of a LOCA, when ECC is initiated and undergoes the injection and recovery phases. Despite the fact such transient analysis was crude in comparison with the accurate safety analysis code, the student significantly deepened his understanding of the heat transfer phenomenon during LOCA and the importance of timely action by ECC in protecting fuel integrity (Fig. 3). As well, this work provides a significant training resource for future students in this faculty.

6 CONCLUSION

Desktop training simulators and CASSIM™ tools represent an efficient and economical complement to full scope simulators. Supported by enhanced multi-media visual and interactive user interface, PC based simulations become increasingly effective in knowledge-acquisition training. For developing countries embarking on a nuclear power program, the CASSIM™ tool and the desktop training simulator is recommended as an excellent vehicle for building up the technological infrastructure in areas vital for subsequent technical support of the nuclear power plant in design, commissioning, and operation training:

- Comprehension of control systems;
- Plant responses to accident conditions; evolving an improved MMI;
- Guide to commissioning and operating procedures; presentation to safety reviewers;
- Study the effect of any proposed changes prior to implementation, etc.

In summary, we have presented an effective functional model in which high quality simulation is executed on low cost and readily available PCs to provide immediate access to simulations by nuclear personnel for NPP familiarization, design evaluation, training, and early guide to commissioning/operating procedures. We recommend this model to the Pacific Basin countries that are either "nuclear power aware" or "nuclear power ready". In sharing our experience with interesting parties, we will co-operate with them to develop various levels of training programs within their individual context and technical culture environment and requirements using CTI's tools. In the process of working together, we will ensure the goals of self-reliance and the transfer of necessary NPP knowledge are met in order to fulfill their objectives of the nuclear human resource development initiatives.

7 REFERENCES

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KEY WORDS

CANDU; Nuclear Power Plant Simulator; Desktop Simulation; Real-time Dynamic Simulation Model Development System; Nuclear Human Resources Training and Development

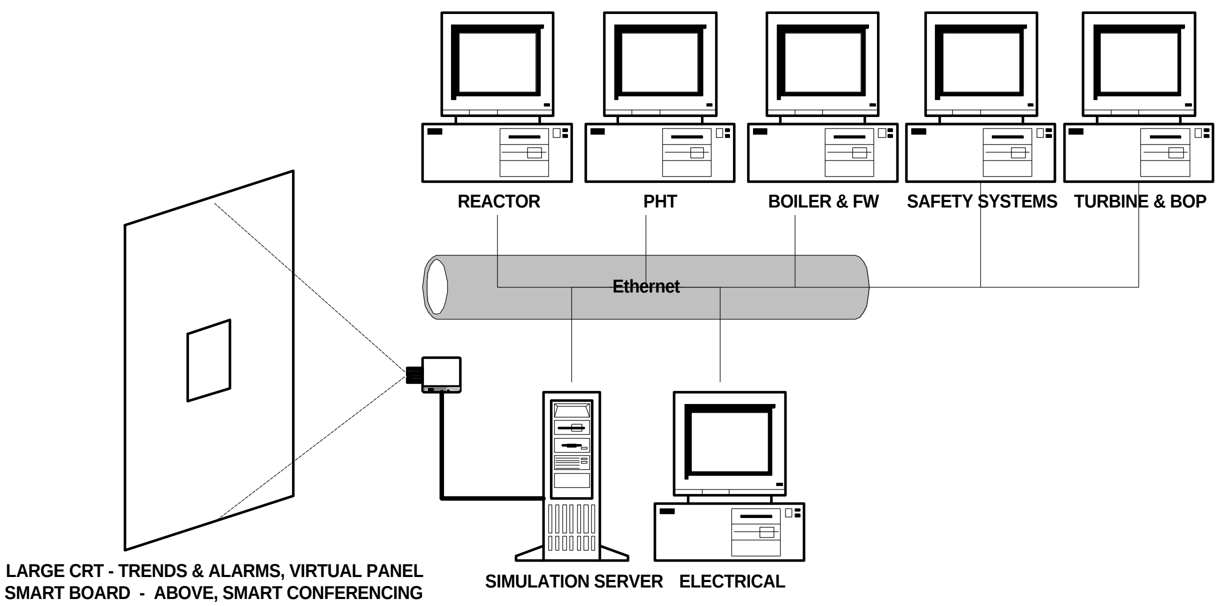

Figure 1 Local Area Network based Multi-PC based Desktop Simulators to provide Advanced Level training in Abnormal Incidence Diagnostics; Abnormal Procedural Training and Teamwork Building.

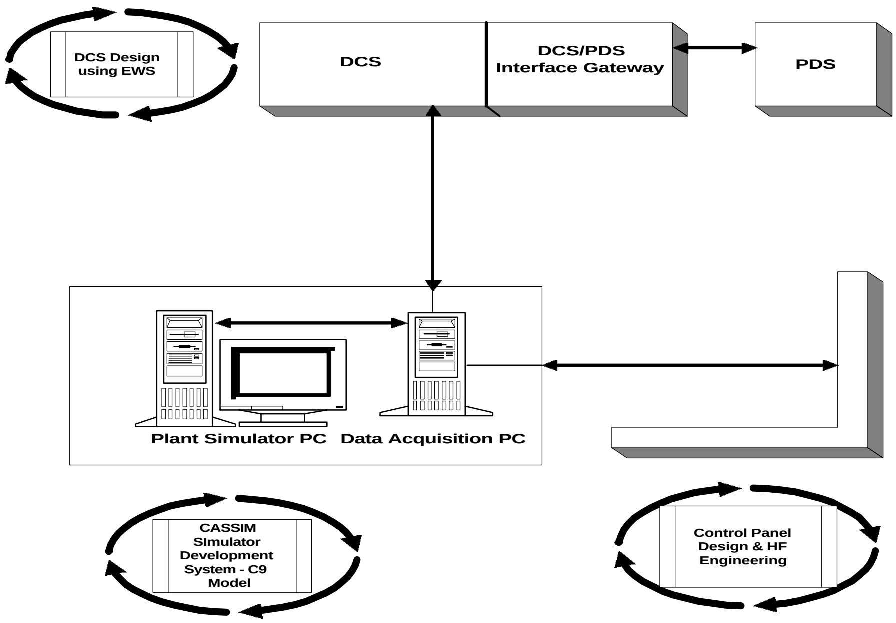

Figure 2 CANDU 9 Desktop Simulator in support of NPP Design concepts. The staged, progressive design process evolving the actual MMI-PDS, the actual control DCS platform and the Control Room Mock-up Panel is supported by the dynamic plant data generated by the simulator.

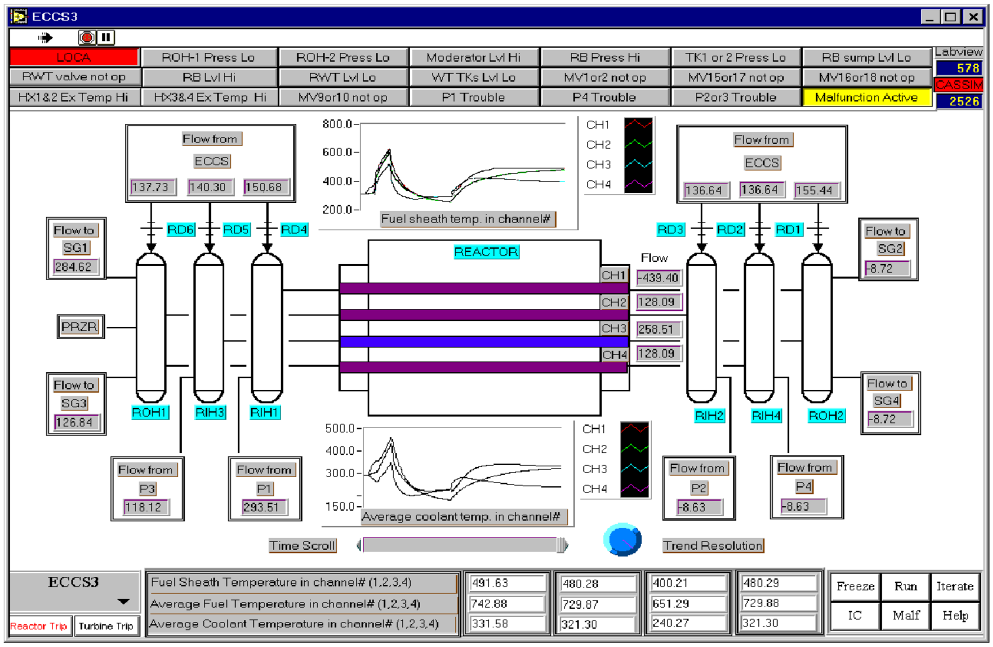

Figure 3 Typical CANDU 9 Emergency Core Cooling System Dynamic Model developed by Chulalongkorn University using CASSIM™ tools.