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Development of An Integrated Test Facility (ITF) for the Advanced Man Machine Interface Evaluation

In-Seok.Oh*, Kyung-Ho.Cha, Hyun-Chul.Lee, Bong-Sick.Sim
Korea Atomic Energy Research Institute

ABSTRACT

An Integrated Test Facility(ITF) is a human factors experimental environment to evaluate an advanced man machine interface(MMI) design. The ITF includes a human machine simulator(HMS) comprised of a nuclear power plant function simulator, man-machine interface, experiment control station for the experiment control and design, human behavioural data measurement system, and data analysis and experiment evaluation supporting system(DAEXESS). The most important features of ITF is to secure the flexibility and expandibility of Man Machine Interface(MMI) design to change easily the environment of experiments to accomplish the experiment's objects

In this paper, we describe a development scope and characteristics of the ITF such as, hardware and software development scope and characteristics, system thermohydraulic modelling characteristics, and experiment station characteristics for the experiment variables design and control, to be used as an experiment enviroment for the evaluation of VDU-based control room.

1. INTRODUCTION

Recently, the Nuclear Industry has efforted to apply innovative techniques in design of man machine interface system(MMIS). In this efforts, hard-wired instrumentation and control systems have been replaced by modern digital technology and computer-driven VDU displays, disturbance analysis systems have been introduced to handle alarms and expert systems to perform fault diagnosis. However, the introduction of new technology have caused many problems in view point of human facrors, such as information navigation in workstations, staff organization, level of automarion, control and feedback, alarm processing, and information redundancy. Moreover, human factors evaluation in the each design stage of an MMIS is an important human factors licensing requirement. To solve the above mentioned human factors issues, it is necessary to establish the human factors evaluation methods and evaluation environments.

In this paper, we describe the characteristics of human factors evaluation environment ,that is ITF, for conducting human factors experiments leading to the design of the advanced MMIS for Neclear Power Plants(NPP).

2. CONFIGURATION OF ITF

The ITF has a capability to easily simulate the proposed advanced MMI design as real as possible and characteristics to have a flexibility and expandibility to easily accommodate the design options and incorporate new system, for example, newly developed computerized

operating procedure system, advanced alarm system, some other operator supporting system, etc for the comparative/absolute experimental study.

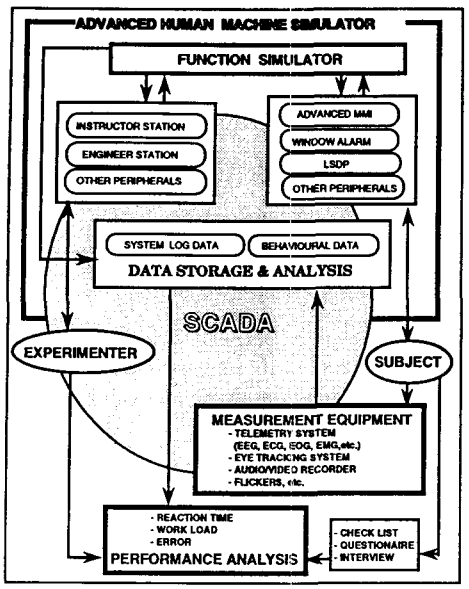

Fig.1 Functional Diagram of ITF

Also it has a capability to be suitable for experiment control, acquisition and analysis of operator performance and behavioural data. Figure. 1 represents the functional diagram of ITF. The function simulator, the supervisory control and data acquisition (SCADA) system, and MMI software will all execute on the main simulation computer.

During the experiments, the SCADA system collects data on the simulation computer. Data analysis and evaluation supporting function is performed off-line on the Indy workstation which also provides additional storage for achieved experimental data.

Performance measurement equipment is interfaced through the PC provided as part of the DAEXESS.

The overall configuration of the ITF basically consists of the following main elements

- The Function Simulator which includes PWR type neutronics, thermal-hydraulics model with various malfunctions. It also has a capability to absorb the changes in control mode between automatic and manual.
- The SCADA, which is the master controller for a experiment design and control, and includes supervisory control functions to handle of simulation execution. It also synchronizes all the data and measurement equipment with a system data of function simulator.
- The Main Test Room(MTR) which includes all kinds of interface to interact with subjects such as, large scale display panel(LSDP), touch color CRT, window alarm, flat panel, etc.
- The Supporting Test Room(STR) for pre- and post-experiment facilities.
- The experimental equipment which gathers the physiological and behavioural data.
- The data base and storage of experimental data

The function simulator and MTR are heavily used for data acquisition during experimental phase, but the analysis of the data can be done with close link between stored data base and analysis tools at the experimenter room. if necessary, the analyst can replay specific sequence or investicate details of scenario by the function simulator.

3. HARDWARE

The ITF is being developed based on generic advanced control room (ACR) concept. ITF consists of all the necessary MMI and experiment measurement equipment for the reserach of an important human factors issues in the ACR design.

Each test room of the ITF with all of the required MMI components for human factors experiment includ the following:

- MTR Operator Station

. Touch Screen 21" Color CRTs(6), Mouse/Trackball(6), Flat Panel(2), LSDP(1), Window
. Annunciator Alarm Tile(256),
- MTR Shift Supervisor Station
. Touch Screen 21" Color CRTs(2), Mouse/Trackball(2)
- Eye Tracking System
- Three dimension motion analyser
- STR #1 & #2
. Touch Screen 21" Color CRTs(4), Mouse/Trackball(4), Flat Panel(2)
- Experimenter Control Room
. Instructor Station(Touch Screen 21" Color CRTs(2), Keyboards(2), Mouse(2)
. Engineer Station(21" Color CRTs(2), Keyboards(2), Mouse(2)
. DAEXESSStation(INDY(1), 20" Color CRT(1), Keyboard(1), Mouse(1), PC(1)
. Telemetry System
. Audio/Video Control System, etc.

Thus, the ITF is broken down into the following categories and is summarized as follows:

- Simulation host computer system and its associated peripherals.
- MMIcomponents (Touch CRT, Flat panel, LSDP, Window Alarm, Mouse/Track Ball).
- Computer equipment that comprises the Instructor and Control Station.
- Computer equipment that comprises the Experiment design station.
- Computer equipment and peripherals for data storage and analysis.
- Experiment measurement equipment (operator physiological, behavioural, verbal data)
- Human Machine Simulator furnitures

Figure 2. represents layout of ITF. All of the operator workstations in MTR, STR are designed to provide flexibility and expandibility of the workstation will allow for east change of design parameters such as height, viewing angle, and position, also have a capability to allow for easy interface with outside systems such as display units, control variables, and conventional panels.

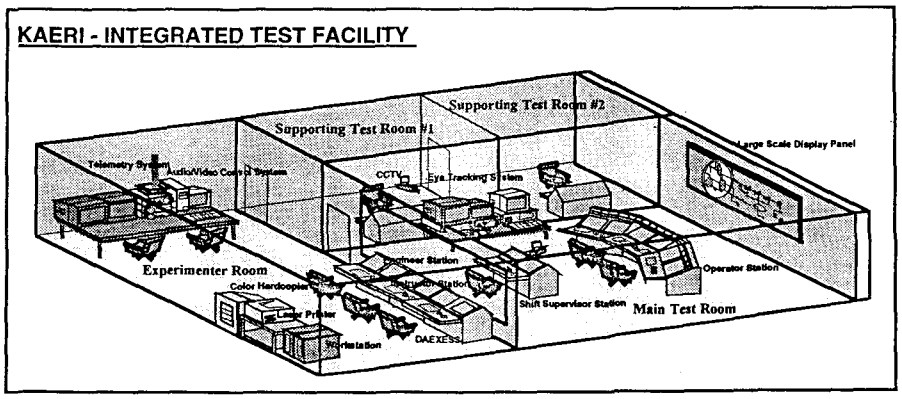

Figure 2. Layout of ITF

LSDP provides user friendly remote control of all setup and display parameters. In case a larger surface need of LSDP, it can be configured with additional LSDP units. These units can be configured to act as a single large viewing surface. Also the additional units can be achieved easily with simple software change. It is even possible to store image settings for each source for future future on a computer

Window Annunciator can be color coded by plant function with colored bezels and solid color

or sandwich type nameplate, and also the bezels are available in eight colors. Programming of alarm sequence, input /window/tile assignment, reflash function is through a standard terminal interface of a host computer.

Using Flat Panel, we can experiment with designs for what experiment wants to test by smply using the same display building software provided for creating VDU and LSDP displays.

Simulation Computer has a sufficient capability to provide real time simulation fot the MTR. Simultaneous to the running of real time simulation in the MTR, running of simulator models is performed in the STR.

4. SOFTWARE

- General

ITF software architecture, shown in figure 3, integrates the functional simulator with the SCADA system and software to provide a convenient environment for the design, execution and analysis of human factor experiments. The online software will interface with the SCADA system to display dynamic data from the functional simulator on user interface devices. In addition, the interface between the software and the SCADA system will allow control of the simulation models from the graphic interfaces. And, the SCADA capabilities of the ITF allow data to be collected from the simulator and other data sources to a common historical data format with time sychronization between the data sources. The base scope of the SCADA system includes a generic software interface to the data historian. Using this interface, experimenter may write specific data interfaces to integrate physiological measurement equipment, eye tracking system and motion analyzer. The historical data is available during the experiment to display trend graphs. After the experiment, some or all of the data files may be archived for subsequent analysis using the DAEXESS.

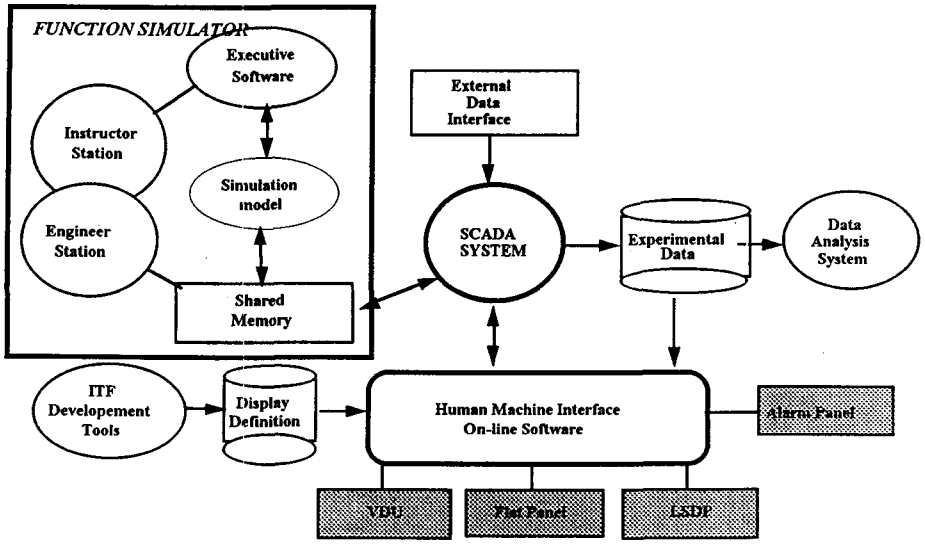

Figure 3 . Software Architecture

The ITF provides mimic graphic displays whereby graphical representations of Nuclear Power Plant (NPP) are provided with dynamic input and output responses. Remote functions are

provided which allow the operator to request functions to be performed that reside outside of the NPP control room. Combinations of the mimic displays and remote functions will allow the operator to test and evaluate many types of problems that could arise in NPP operation. Also, the ITF provides a powerful environment for developing advanced interfaces to process monitoring and control applications. The ITF software integrates a collection of tools with an object-oriented library of software functions and provides advanced capabilities for dynamic data presentation such as process diagrams, alarm lists, historical data trending, Rankine cycles, etc.

Using X-Windows, the HMS will provide a common mechanism for handling graphic displays on all display devices in the ITF including VDU, flat-panel, and LSDP displays. The HMS software allows the creation of powerful, modern user interfaces similar to MS-Windows style applications. In addition, the software also allows a fine degree of control to allow the creation of interfaces with more restrictive capabilities suitable for control room display systems and software allows applications in which windows are organized in tiled arrangements to avoid or minimize the use of overlapping windows. In general, the software offers the intuitive look and feel of modern windowing systems while supporting the special capabilities required for control room process monitoring and control applications.

The HMS software allows the following types of capabilities in configuring displays.

- Support for all standard widgets including labels, text areas, pushbuttons, toggle buttons, radio buttons, scrolling lists, selction boxes, drawing areas, etc.
- Capability to organize widgets into arbitrarily complex hierarchies allowing creation and reuse of large, complex sub-displays.
- Capability to size and place widgets including specifying how widgets respond to different window sizes and resolutions.
- Full control of font characteristics including typeface, size, an style.
- Full control of color including a color editor allowing color specification
- Capability to direct user events such as cursor movement, graphic selection, text entry, and so on to user-specified functions.
- Capability to preview displays as they are being created or modified.

The HMS software shall include related objects that allow us to create, edit and display trend groups showing collections of related points organized as one or more trend graphs and shall include a function for displaying tabular information .

- Supervisory Control and Experiment Design

For the ITF supervisory control, advanced instructor station(IS) is provided. The IS based on the industry-standard multi-tasking, multi-window and menu-driven OSF/Motif™ user interface is used. The IS has function to perform most operations directly from dynamic, interactive system diagrams and control-panel mimics. Alternately, simple keyboard commands is provide instant to access to all operations from any display. The IS supports all the standard features such as: initialization of initial condition, run, freeze, snapshot, reset, backtrack, replay, malfunctions, remote functions, overrides, monitored parameters, direct change of simulation variables, and so on. And, it provides three ways to activate the instructor functions in three ways, by dedicated function keys, by a mouse click on an icon, and by keying in the expert commands on an alphanumeric keyboard.

For experiment design and cotrol , the engineer station(ES) is provided. The ES is used for the process model development and validation, executive system software maintenance of simulation computer, instructor station maintenance, and engineer station software maintenance. So, it has the following functions to enable the experimenter to perform activities mentioned above

- Text editor to create/ modify the source code of an object program or model source program
- Object editor to create/modify an object and register it in the object library

- Graphic editor
- Automatic code generator
- Model test environment for the stand alone test and integration test of a process model, etc.

Also, the IS software (for the software maintenance) is also available on the ES. The HMS has the ability to modify the model being used at the ES without affecting testing in the MTR and have a capability to use(run) simultaneously different models at MTR and STR.

5. SCOPE OF SIMULATION

The models are designed based on nuclear power plant design data and are designed based on state-of-the-art real-time simulation technology. The scope of modelling covers all modes of operation, including from startup to 100% level power operation and from 100% level power operation to cold shutdown, necessary for safety operation and effective power production to meet the primary goal of nuclear power plants. The range of malfunctions contains the event scenarios including the initiating events necessary for control room MMI verification and validation.

6. CONCLUSIONS

The ITF is under development for the establishment of an environment for human factors experiment and evaluation as part of national medium-long term project titled in "The development of human factors experimental evaluation techniques". The basis for the thermal-hydraulic characteristics model is CE generic type PWR NPP and the entire MMI configuration is designed based on generic ACR concept. The ITF is to be designed so that (1) the acquisition and evaluation of operator performance data and test runs for human factors experiments can be accomplished easily, (2) changes to the MMI design can be implemented with ease, (3) the HMS possesses the flexibility and expandibility to easily integrate new system such as the operator support system into HMS. Afterwards, the ITF will serve as the basis for experimental research on a line of human factors issues.

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