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THE INTERACTIVE GRAPHIC SIMULATOR (IGS): A HELPFUL TOOL FOR AN EFFICIENT TRAINING

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ABSTRACT:

The IGS is a natural response, in the training area, to the high technological advances in the computer disciplines for the graphic representations and advanced process models with a high level of reliability and friendliness.

Tecnatom has integrated a representation of advanced models in several workstations which permits, through its high resolution colour screens, the visualization of all the information available in control room with graphical representation of NPP's systems. Simultaneously with this, the IGS permits to operate any component in order to change its status, in the same way that operations upon the panels.

Through the flexibility of the software for graphic representations and the advanced models, Tecnatom has generated, based in the use of IGS, several training courses which have provided a tutorial worth, to understand complex phenomena, with a man-machine interface more friendly than the full scope simulator.

Therefore, the IGS appears as an important flexible tool which can adapt itself to the training of several collectives in a NPP, and it has a special importance for those which the ignorance of panels interferes with the training in a full scope simulator.

1. WHAT IS THE IGS?

The IGS is a system which provides a graphic display of the result of calculation of the models of a full scope simulator by means of high resolution colour monitors. Each plant system is represented by a diagram made up of graphic symbols denoting its components and by digital indicators showing the values of the process variables. These diagrams are enhanced by a colour coding indicating the status of the components and by the updating of the values displayed by the indicators.

The IGS also allows real time operation of the different components of the plant systems, interacting directly with the monitors instead of with the instrumentation that would exist on the corresponding control room (CR) panels.

Control of the components (valves, pumps, breakers, etc.) is accomplished by means of a keyboard or mouse device, and a graphic display of the associated control room instrument being generated on selection of the component to be operated.

The IGS is a modular simulator made up of several monitors connected to intelligent workstations. The configuration of the system may be varied from two to eight or more such monitors, in order to facilitate the assignment of tasks to the different individuals who are working simultaneously in the session. Each module is made up of two monitors, a keyboard and a mouse, and constitutes a workstation from which interactions may be maintained with the components of all the systems modelled and by means of which any type of plant information may be displayed.
Each of the four workstations supported is autonomous, inasmuch as the keyboard and mouse of each module may only interact with the monitors associated with that module, although all of them intervene in a single process and the different actions may be accomplished simultaneously.

2. SOFTWARE AND HARDWARE

2.1 Software

Implementation of the different IGS functions is based on advanced graphic user interface designed using sophisticated software programs. The use of a standardized operating system and software tools would allow to install the application software on a broad number of intelligent workstation. This software interacts directly and in real time with the simulation models, allowing "what-if?" studies to be performed and the information needed to be displayed simply and hierarchically.

The simulation models used are identical to those in the full scope control room simulator. They are predictive engineering models derived from the TRAC code and other maths models, and provide an extremely high degree of fidelity, even in the reproduction of complex phenomena such as breaks, ATWS, loss of electrical feed, etc.

2.2 Hardware

The IGS is supported, at Tecnatom, by a HP-747 (PA-RISC-7100 processor, clock frequency: 100 Mhz, 136 Specmarck’89, main memory 16 Mbytes SIMMECCRAM 2 disk units of 1.05 GB each, 115 MPIS/41 MFLOPS) and ENCORE RSX (Risk CPU, 252 MB main Memory, intelligent console, reflective memory SCSI Bus, physical parameters monitor) configuration allowing the above-mentioned models to be executed in real time. Likewise, the IGS is easily linkable to any real-time computer provided it has standard communication interfaces (Ethernet).

The operator-process interface takes place via SUN SPARC IPX intelligent workstations. The assembly made up of a station, two monitors, a keyboard and a mouse constitutes what is known as the trainee module.

Also available are peripherals such as laser printers and colour hardcopy for printouts of whatever information might be required on systems status, as well as trend and general plant status graphs.
3. USER INTERFACE BASES

As described before, the IGS is a powerful environment for the interactive display of dynamic data. Nuclear real-time processes comprehension is being benefited significantly due to the display of data in a graphical format. The primary objective of IGS is to provide an environment in which the data can be displayed and requested with a minimum of effort.

A detailed analysis of the most suited interaction techniques has been made. Furthermore criteria from man-machine interface standards have been considered to refine the user-interface design.

Data can be viewed through the several displays available in IGS. These formats include colour-key and pattern-key facilities on a schematic diagram, x-y plots, histograms, dials and dynamic symbols. Windowing facilities allow the user to concurrently display any combination of these formats, therefore, many variables can be displayed at one time on a single screen.

This type of user interface including graphic features and windows interface improve significantly communication between users and real-time models.

4. HOW THE IGS MAY BE USED

The IGS may be used in different ways depending on the teaching objectives mapped out and the plant personnel group in question.

a) The IGS may be used as a concept simulator. In this respect a teaching package has been developed for the study and analysis of the basic thermohydraulic and neutronic phenomena occurring in the reactor under normal and off-normal operations conditions. This type of course is particulary suited to those wishing to initiate study of nuclear reactor technology.

b) The IGS may also be used as a part-task simulator. A teaching package has been developed in this area for exhaustive study and analysis of the dynamic and logic behaviour of certain processes or systems. In this mode, the user is provided with extraordinarily detailed information and interactions relating to the process, with activated logic diagrams, the possibility of modifying component parameters, setpoints and characteristics and the capacity to generate equipment malfunctions, breaks, etc. under different initial and boundary conditions.

c) The IGS is also a full scope simulator. It covers all the systems included in the control room full scope simulator, offering the same possibilities for control of simulation, remote actions, activation of equipment failures, transients and accidents. Besides this, it provides greater power for analysis than the CR simulator due to its accessing the internal variables of the simulation models.
d) The IGS may also be used as an analytical tool for the complex thermohydraulic and neutronic phenomena contemplated in the EOP's, depending of the accuracy of its simulation models and the computational power of the full scope simulator computers. In Tecnatom due to the great capability of computation and the accuracy of its simulation models (engineering models running in real time), situations such as reverse flows, monitoring of two-phase levels, core uncover and the release of hydrogen and fission products, etc. are all observable in real time or at slow speed during emergency conditions.

5. CONFIGURATION OF IGS FOR TRAINING COURSES

For training courses, the IGS at Tecnatom, is configurated with three RISC technology workstations, six 19" colour monitro, an external 424 MB hard disk, a colour hardcopy and a Laser printer.

On this technical platform, users have access to the following functionality:

a) Instructor system functions.

Similar capabilities of the instructor system existing in a full scope simulator with control room replica are available:

- Selection of initial condition. Snapshot
- Freeze, run
- Real-time, fast time, slow-time. Backtrack. Replay
- Session log. Predefined exercises. Plots x-y; x-t
- Malfunctions, transient and/or accident insertion

Dedicated buttons allow users to manage simulation and control exercise. A wireless remote instructor system hand-held control (radio frequency) allows instructor to control session without using workstation.

b) Panel simulation

All the control room instruments are simulated to allow the manipulation of any component existing in the main control room. By clicking on components, displayed on screen, it appears their associated instrument (a dynamic graphical representation of current instrumentation of reference plant) allowing the user to change, with the help of a mouse device, the status of components.

As a matter of fact, user could interact on any existing plant devices using the remote manual function (to operate plant components not existing in control room) of the instructor system.
c) Safety Parameter Display System (SPDS)

In addition, users have also, in the same workstations, the SPDS displays with identical information and data validation criteria, existing in the reference plant (for the simulation world). Consequently, users have similar information the operators have, when they take decisions regarding EOP procedures and actions to be followed during accident situations.

d) Plant process computer (PPC)

Users might have also in the same technical platform the PPC's displays with identical information existing in the reference plant's PPC. It is available a lot of displays, lists, logs (Alarm list, Post-mortem log, NSS programmes, etc..) to facilitate transient analysis from users.

e) Systems visualization displays

Three levels of detail is used to present data and status components of any existing plant system. Data, status components, pipes, and instrumentation is showing the system performance in a familiar diagram to user.

Relationship arrows between systems, shown on diagrams, are also gates to navigate over all the systems existing in the plant.

In addition, any components have an attached "book" (block of information) to arrange, on the same display, a relation of the mechanical, electrical, operating and technical specification characteristics associated to each component.

f) Variables representation

The variables representation function is one of the most used function of IGS. The capability to select more than 10,000 variables is a powerful analysis utility for users to understand complex phenomena during some accidents. Most of these variables are normally hidden for a full-scope simulator user but for a IGS user the "heart" of models is at his "arm's length".

g) Images and sound

Some important components have images attached, usually a photography of this component taken at reference plant. These images could be selected by user to see the current physical aspect of components.

In addition, every system have a set of associated photography, showing the control room instrument layout.

These images are available to user through some "sheet" belonging to the "book" of components and systems of IGS. On the other hand, some sound messages, announcing plant special situations (reactor trip, turbine trip, low level in SG or
RPV, high/low pressure RPV, etc.) have been recorded and, even typical control room alarm sound may be set on/off by user during his session.

h) Others utilities

Miscellaneous applications are also available for experimented IGS users. For example an expert system (SASPOE) that is able to provide support in the application of the EOP (Emergency operating procedures) in a BWR NPP. SASPOE takes care of monitoring important plant parameters, activating the appropriate EOP, scheduling control actions and assisting the operator in the decision-making process concerning the emergency.

Debugger facilities and ATP (Acceptance Test Procedures) automatic execution system (SEAP) are also available for operating and software maintenance engineers.

At present there are in progress three programmes related with IGS, which will increase the scope of this training tool. Goals are to use the common technical platform of IGS to have all the training means, material and reference plant document stored in an optical support. In this sense we could distinguish three different type of information:

- Operating procedures (normal, abnormal and emergency procedures), Technical specification, training material (lesson plan, scheme, figures, related to academic and technological matter), etc. (hypertext software).

- Dynamic images and high sound capabilities (interactive video, multimedia in general) for specific training courses (multimedia technologies).

- Reference plant drawing (P&ID, CWD, etc.) (a survey of optical).

6. SOME TRAINING COURSES AND ACTIVITIES DEVELOPED USING IGS

- Fundamentals (Nuclear physics)

Using some x-y plots, historical diagrams, axial and radial o shape etc... we could observe influence of reactivity coefficients in the normal and abnormal operation of the plant; for example eliminating Doppler effect, user can compare core response, with or without Doppler effect, for a determined reactivity change.

- EOP’s training

Some EOP’s topical courses have been developed using EOP background documentation. These types of course have two levels of difficulty: one for operating licensed personnel and a second for other technical personnel (generally, staff, TSC members, etc...).
- Initial and continuing training for licensed personnel.

During the initial training of operating personnel, some practical sessions with IGS are scheduled to enhance knowledge about systems relationship and operating mode of some system and the plant overall. The manipulation of IGS is facilitated for novel trainees, even without any knowledge about CR, because they interact in the system at a component level in a scheme, on the screen, which is really a dynamic representation of the scheme they have just learn during the previous lecture session.

7. HOW IGS IS USED DURING TRAINING COURSES

An instructor is always controlling the session of a training course, introducing malfunctions (or a combination of them) and, occasionally, interrupting the session to emphasize some peculiar behaviour of reactor vessel and/or core. Through the selection, on screen, of some variables or special displays, instructor helps attendee to analyze the cause of some complex phenomena that could occur inadvertently for users.

Normally every workstation (WS) is managed by a single user or a team of two people. More attendee, for each WS, is allowed but only as observers. Depending on type of training courses, instructor may select, for each WS, some specific applications or systems to be manipulated by users (for example balance of plant systems for turbine operator, primary systems for reactor operator, all systems for the shift supervisor etc…). Each workstation may have all applications in service, although experiences have shown that it is convenient to have the simulation control functionality only in a unique workstation.

Every training course has its learning goals (terminal and enabling) identified and the instructor role is to ensure these objectives are fulfilled by users themselves or with his help.

8. WHO CAN USE THE IGS?

The IGS may be used for training the following staff personnel involved in nuclear power plant design and operation:

- Operations Personnel (licensed or otherwise) during initial training and subsequent retraining.
- Engineering Staff involved in support and design, for the study of system modifications.
- Maintenance Personnel, for insight into plant systems and the interrelations between them.
- Chemistry and Radiological Protection Personnel, during their basic technology training.
- Technical Support Personnel, during the development of procedures and transient analysis.
- Management Staff interested in the overall behaviour of the plant.
- Postgraduates interested in widening their studies of Nuclear Engineering.
- Members of the Technical Support Centre (TSC).

9. EMERGENCY OPERATING PROCEDURES TRAINING

The initial, overall training goals for the EOP training program are as follows:

- To enable the operators to understand the structure of the EOPs
- To enable the operators to understand the technical bases of the EOPs
- To enable the operators to have a working knowledge of the technical content of the EOPs
- To enable the operators to use the EOPs under operational conditions

It is well known that the training methods used for EOP training are mainly classroom instruction, control-room walk-through and simulator exercises. About simulator exercises, the training must be conducted using scenarios on a control room simulator. This is important to promote understanding of operators responsibilities and to enhance communication within the control room.

However it has been proved, through experiences, that IGS is a very good training environment for a better understanding of technical support for some EOP instructions. This is mainly due to the higher amount of information (and its representation) available to users during the accident evolution.

For instance, users can observe and analyze qualitatively and quantitatively the break flow evolution according to their corrective actions or differential pressure between primary side and containment. Or observe, residual heat, void fraction in all parts of RCS including reactor vessel; analyze and observe the effectiveness of heat transfer from the primary to the secondary side for each loop, reactivity balance during ATWS etc...

All these phenomena could be observed in a full scope simulator but only indirectly, because there are not meters in control room for such parameters. In other words, the attendee’s analytical process for each EOP scenario is highly effective in the IGS training tool.
Another good advantage of using IGS for EOP training is the availability of a big amount of historical data, in graphical forms, (in general curves) that can be overlay in any combination to observe, for example, the influence of one parameter to others or the operators actions.

Finally, scenario analysis is made by the team and trainees attention is focused to the understanding of phenomena and corrective actions rather than localization of instruments in a control room and/or monitoring parameters of their job's responsibilities. Access to the process is direct and very fast.

For continuous EOP training, benefits coming from the use of IGS are identical. However, additional advantages are given to plant staffs when they participate in the execution of refresher training because it is easier to follow, analytically, scenarios in the IGS for such type of personnel which are not familiar with their control room instrument layout.

10. IGS'S ADVANCED DISPLAYS

In addition to the features described above, recently it has been designed special advanced displays to "observe" results of the engineering code calculations, regarding thermohydraulics and neutronic performance, like it was through a glass vessel and/or a transparent core shroud.

These displays use the combination of the high power computer and the accurate and detailed calculus of the TRAC and neutronic codes. In other words, through a powerful graphical editor we see each vessel and core nodes status (pressure, temperature, void fraction, water level, power, liquid velocity, etc.). According to the value of variables to be represented, colour of nodes will change within a colour pattern. In addition, some variables like void fraction can be shown using dynamic bubbles with a size depending of the variables value.

Besides these nodes status representation a lot of interactivities features, using windowing techniques, like zoom, associated X-T, X-Y graphs, dynamic parameter value display, etc. is also implemented.

In summary, overall design is considered very helpful during complex accidents to "observe" and understand phenomena that can not be observed directly in a control room replica full scope simulator.

11. TECHNICAL CHARACTERISTICS

* Thermohydraulics
  . Two-phase model
  . Six equations (conservation of mass, energy and moment)
An additional equation (conservation of mass) for air
3-D nodalization of the reactor vessel. 80 nodes on the primary circuit

* Neutronics
  - 3-D nodalization of the reactor core
  - Radial representation of each fuel element
  - Four axial zones

* Containment
  - Representation of liquid, steam and non-condensable gases
  - Transport and treatment of hydrogen and fission products
  - Non-equilibrium thermodynamics

* Control of Simulation
  - Run, Freeze
  - Real time, fast and slow. Backtrack and replay

* Control of Drills
  - Initial conditions, snapshot
  - Malfunctions, remote actions, parameter modification
  - Predefined drills, database modification, flags
  - X-T and X-Y plots for 10,000 variables, 4-hour history, zoom effect, on-screen and colour printer outputs

* Operating Systems
  - MPX-ENCORE (Fortran)
  - HP-UX (Fortran/C)
  - SUN OS (C)

* Software Tools
  - Development: C/Fortran language
  - Graphics: Data View (DV Draw,DV Tools)
  - Communications: Ethernet TCP-IP

12. CONCLUSIONS

Having a IGS nodalized and adapted for owned NPP and adapted to the different job positions, means the following advantages:

✓ High fidelity degree (of loyalty) which makes possible its utilization by those NPP that do not have a full scope simulator.

✓ Increase in the training efficiency in the full scope simulator using previously or as complement the IGS. It is super thus the great difference between the technical study of a system or transient and the study practised of the same in the full scope simulator.

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✓ Possibility of accomplishing a training "to measure" adapted to the needs of each job position.

✓ Costs and optimization reduction of the training timing.

✓ Ideal for learning concepts and operation principles.

✓ Graphics X-T or X-Y of any variable of the simulation models, though it does not may have indication in control room with plotter colour "on line" printer.

✓ Different possibilities for the data analysis, graphic and comparison.

✓ Possibility of accomplishing an analysis of the transient either in parallel or later.

✓ Overcoming the limitation that supposes the great quantity and dispersion of the instrumentation located in panels with this system there is no need to know the control room.

✓ Simple and agreeable interaction with direct participation of the pupil in the something which training improves in away substantial the motivation and attitude of the same.

✓ Site in headquarters of Tecnatom or in the own NPP and possibility of utilization with instructor or in regime of self-study.

✓ Elimination of HW maintenance associated with control room.

All over it can be asserted that the IGS is a flexible and adaptable formation tool a great numbered of collectives of a NPP or of other industrial processes.