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the Centre which are designed for specific stations and which are attended by each shift of engineers on a two year cycle.

The principal purpose of the revision courses is to augment the engineer's knowledge of fault studies, safety principles, etc. The appropriate simulators are used to enable the engineer to operate interactively with faults that hopefully may occur infrequently during the normal base-load operation of the nuclear station. Regular site training is also provided in the procedures necessary to cope with a nuclear emergency. A series of emergency exercises is organized throughout the year, usually with sufficient frequency to enable each shift team to gain adequate experience of the emergency procedures.

Simulation

The special nature of nuclear plant operation, with its emphasis on safe operation and the base-load characteristics resulting from low unit cost, make any form of interactive on-job training difficult to achieve. It is essential, however, for the engineer to experience the kinetics of the reactor plant particularly under fault conditions during both his initial and subsequent revision training. This important aspect of nuclear training is assisted by simulation. The techniques of simulating nuclear plant characteristics have developed rapidly over the past five years under the stimulus of large national nuclear power programmes and the availability of more sophisticated (and expensive!) computers.

Nuclear plant simulation in the CEGB is provided at the Nuclear Training Centre to give two distinct levels of training. To enable the engineer to understand the fundamental kinetics of gas-cooled reactors, an analogue computer simulator was constructed. This has a generic design of control desk and demonstrates, with a limited degree of interaction by the student, the kinetics of a single fuel channel having the basic characteristics of a Magnox Design. This machine has given almost continual and reliable use over a period of about ten years and is an invaluable training tool for the introductory courses and for demonstrating the fundamentals of reactor kinetics to the Magnox operational course student.

The second phase of simulator construction is currently nearing completion at the Centre. This involves the provision of exact replicas of each of the AGR station control desks (Hinkley B, Dungeness B, and Hartlepool/Heysham; the latter being almost identical stations have a combined desk) thus providing "full scope" simulation facilities for each of the stations. This advanced type of simulator will provide training in operating procedures under normal and fault conditions.

However, the fundamental principle behind the CEGB nuclear training philosophy is that the engineer should have an in-depth appreciation of the plant kinetics and a fundamental knowledge of why certain operating procedures are necessary in contrast to the "mechanistic" approach to plant operation. For this reason the design of the AGR simulators extends beyond exact replication of the control room desk. The training staff have developed advanced methods of data presentation which will present the engineer with more information than is available in the control room to enable him to have a clear understanding of the effects of operating procedures on, for instance, gas and metal temperatures within the once-through boilers.

The provision of comprehensive simulators is an essential feature of nuclear training. It should be emphasized, however, that the simulator alone cannot provide the full in-depth training which is necessary for engineers to operate a plant safely. A fundamental knowledge of all aspects of the plant design and characteristics can only be achieved by the use of a wide variety of modern teaching aids including lectures by experienced design and operating engineers, supplemented by both basic and full-scope simulation.

The nuclear plant simulators of the CEGB have been designed specifically to form an important part of an overall integrated training package. The prime objective of this package is to achieve safe and economic station operation by engineers with an in-depth and intelligent knowledge of the plant kinetics and characteristics under all operating conditions.

The pattern of nuclear training in the Board is continually under review with the objective of meeting the requirements of both the current and future nuclear power programmes, particularly following the Three Mile Island incident in the United States. As the single generating utility in England and Wales, the CEGB is in a favourable position to ensure that its nuclear training policies are integrated throughout the industry. Included among the topics which are currently being reviewed are the relationship between "on-job" and formal training, the assessment of operating engineers, competence, the role and location of simulators with varying degrees of sophistication and the effect of the introduction of pressurized water reactors into a currently gas-cooled reactor technology.

Making the best use of modern simulators

By Robert D. McInnis and Ronald M. Maslo*

Nuclear power plant simulators are valuable not only for operator training but in obtaining better plant performance and an understanding of design and engineering. Important developments are taking place particularly in standardization, in the aids available to the instructor and in the programming of plant malfunctions.

A noted acceleration of interest in power plant training simulators (PPTS) has taken place since the Three Mile Island incident. And, despite conjecture over who, or what, caused the problems at the Pennsylvania nuclear plant, all parties agree that greater emphasis should be placed on more comprehensive training for nuclear power plant operators.

A number of utilities – under pressure, but not yet required to use control room simulators for training operating personnel – are expressing more than just a passing interest in simulation devices, and not strictly for training purposes either.

Among the reasons for the increased interest is the fact that today's simulators more than justify capital expenditures on training programmes. This advanced equipment is also providing owners with reduced generating plant downtime, higher operating efficiencies, added safety measures (for personnel and equipment) and a better understanding of plant design and engineering reasoning. As a further benefit, users are reporting that simulators are among "the best public and community relations tools we have".

Until recently, the majority of simulators were designed only to duplicate the control rooms of plants already operating or under construction. The basic requirement was to train new operators to run existing nuclear plants, as well as to be ready to operate the new facilities as soon as they became opera-

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tional. These replica simulators present operators and trainees with the chance to receive extensive "hands on" experience for startups, power manoeuvering and shut downs. Additionally, they have been widely used for operator licensing examinations, requalification training and refresher courses.

Basic to most of the PPTS system is the fact that they can be programmed to subject an operator to many or more, abnormal and emergency situations than he would be exposed to during his lifetime.

Basic principles

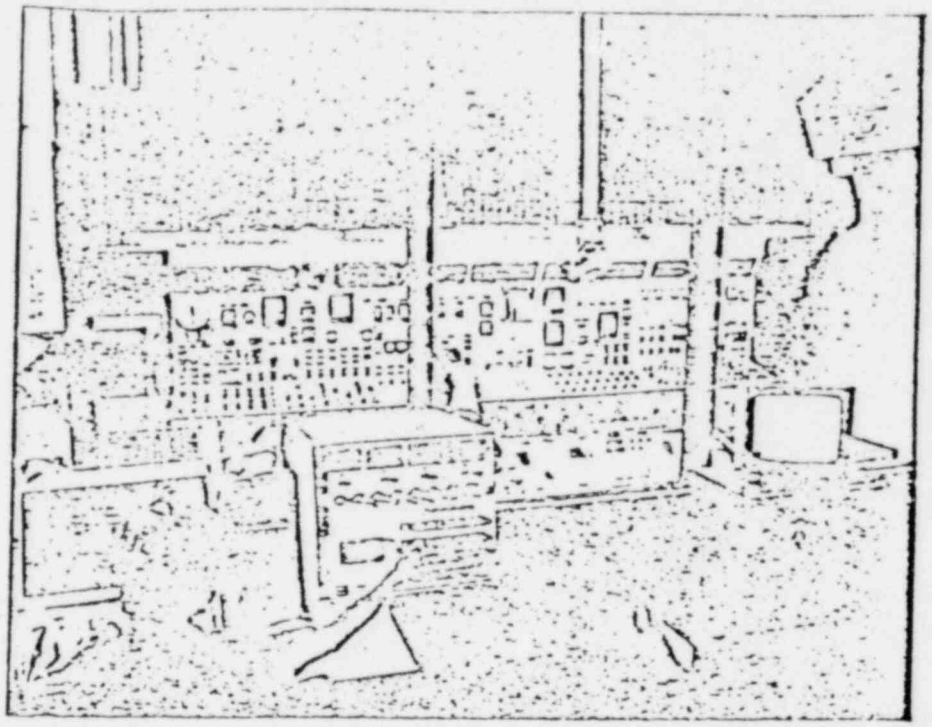
Demands from several types of power and power-oriented organizations for a generic, rather than a replica simulator system, have more recently led to the development, by Electronic Associates, Inc., of a smaller, less complex, Basic Principles Training Simulator (BPTS). The two models, one simulating a PWR plant and the other a BWR plant, are designed to train power personnel in the general principles of conventional nuclear power plants.

The BPTS, which only costs about one-tenth the price of a full-scale replica simulator, is also limited in the number of malfunctions that can be programmed in. And, unlike a replica, which must look, feel and react like a real control room, the BPTS is designed to illustrate general concepts. For example, it can be used to provide preliminary operator training at low cost, so that an instructor can identify the most promising operator candidates to advance to a full-scale simulator. Other uses include: teaching plant theory to personnel other than operators; and teaching nuclear engineering and science students the basic dynamic interactions in a power plant.

Of extreme importance to smaller power companies is the fact that a BPTS can be used in a "pool" arrangement. All operator trainees can be taught the basics of nuclear plant operations on the generic simulator before moving on to the specialized equipment that has been designed to their own company's specifications.

Design

Because each utility has built some degree of individualism into its nuclear plants, no two training simulators are exactly alike. A trend, however, that seems to be shaping up and leading to what may become a standardization of simulator and control room design, calls for simulation modelling in strict accordance with scientific principles. Should the trend continue, all simulators will be capable of providing a greater degree of accuracy in simulating plant operations.



From this training simulator console overviewing the "plant" control panels the instructor monitors all system operations, including introduction of single or multiple malfunctions. Pushbuttons actuate "freeze", "replay", "backtrack" and many other system operations.

At EAI's research and development facility, in West Long Branch, NJ., engineers are also programming a number of new details into the memory systems of nuclear power plant training simulators.

For one, they have taken a page from the Three Mile Island experience and provided their equipment with even wider capabilities to imitate multiple malfunctions. What's more, these "canned" programs can be activated from the instructor's console *or* the trainee's station. Thus, if an operator trainee makes a judgment error, he automatically creates a simulated malfunction. Previously, only the instructor could initiate emergency situations.

The increased programming capabilities also permit the operator trainees, or the instructor, to create a series of situations in which one malfunction leads to others. Because of this factor, built into the nuclear plant simulator for Virginia Electric Power Company, it was possible to create a simulated Three Mile Island type mishap, within hours of the real thing occurring. Portions of the intensive investigations of the incident were performed on the VEPCO equipment. This EAI-installed simulator was the only one in the United States, that was capable of imitating the Three Mile Island situation at such short notice.

Although the US National Regulatory Commission only requires training simulators to recreate less than 100 possible malfunctions, modern nuclear plant simulator units are programmed to present upwards of 600 different situations. And because of the many unknowns that could surface in a nuclear plant, at least 25 per cent of the system memory is kept available for future malfunction programs. Such programming can easily and quickly be accomplished by an instrctor, via a digital keyboard, entering the information into the system through the engineering-oriented Fortran language.

With so many new complexities being designed into nuclear-powered electricity generating plants, and more due as the result of proposed stricter regulations, it is now practical to design training simulators to allow the operator to perform his major function of safe and efficient plant operations. Today's power plant training simulator is finely tuned to simulate all components of modern nuclear plants.

Instructor aids

Effective use of a replica simulator demands that innovative techniques be available to the instructor for conducting training exercises. These techniques are controlled from the instructor's console, which overlooks the simulated power plant control panels. From his console, the instructor can initiate any exercise by activating any of up to 100 initial conditions. These could consist of cold shutdown, hot standby, 100, 90 or 50 per cent power. All conditions are expandable

and can be readily modified to provide a degree of training flexibility not possible in an actual plant.

Among the instructor's aids is a Run/freeze control to suspend simulated plant action whenever desired. This permits the instructor and trainees to review and analyze reactions and operations of plant components. In a real plant, they can only use hindsight. other instructor aids include:

Snapshot a feature that lets the instructor take status pictures almost instantly. System parameters and variables are stored in disc files and can be used to generate new initial conditions. These can be analyzed and displayed upon desire.

Recall allows the instructor to bring initial conditions back as many times as they are needed. When he re-activates the simulator, the sequence will start with the newly-loaded initial condition.

Backtrack is used to recall a portion of an exercise to allow a trainee to repeat his actions as many times as required for him to gain a complete understanding?

Replay permits initiation and "hands off" review of a previous exercise. When completed, the operation starts from where it left off. When combined with "backtrack", it offers an analysis capability and repitition impossible to get in a real plant.

Cry wolf/over-ride features are used for similar situations. "over-ride" gives the instructor control of panel instrumentation via digital inputs, outputs and analog signals. "Cry wolf" provides control over the annunciators. Both controls permit the instructor to set panel inputs while the system is operating. It may over-ride a warning that is expected by the student, or introduce erroneous information to the panel instrumentation. Thus a student is forced to build up a system understanding instead of learning to rely on rote reaction or conditioned reflex.

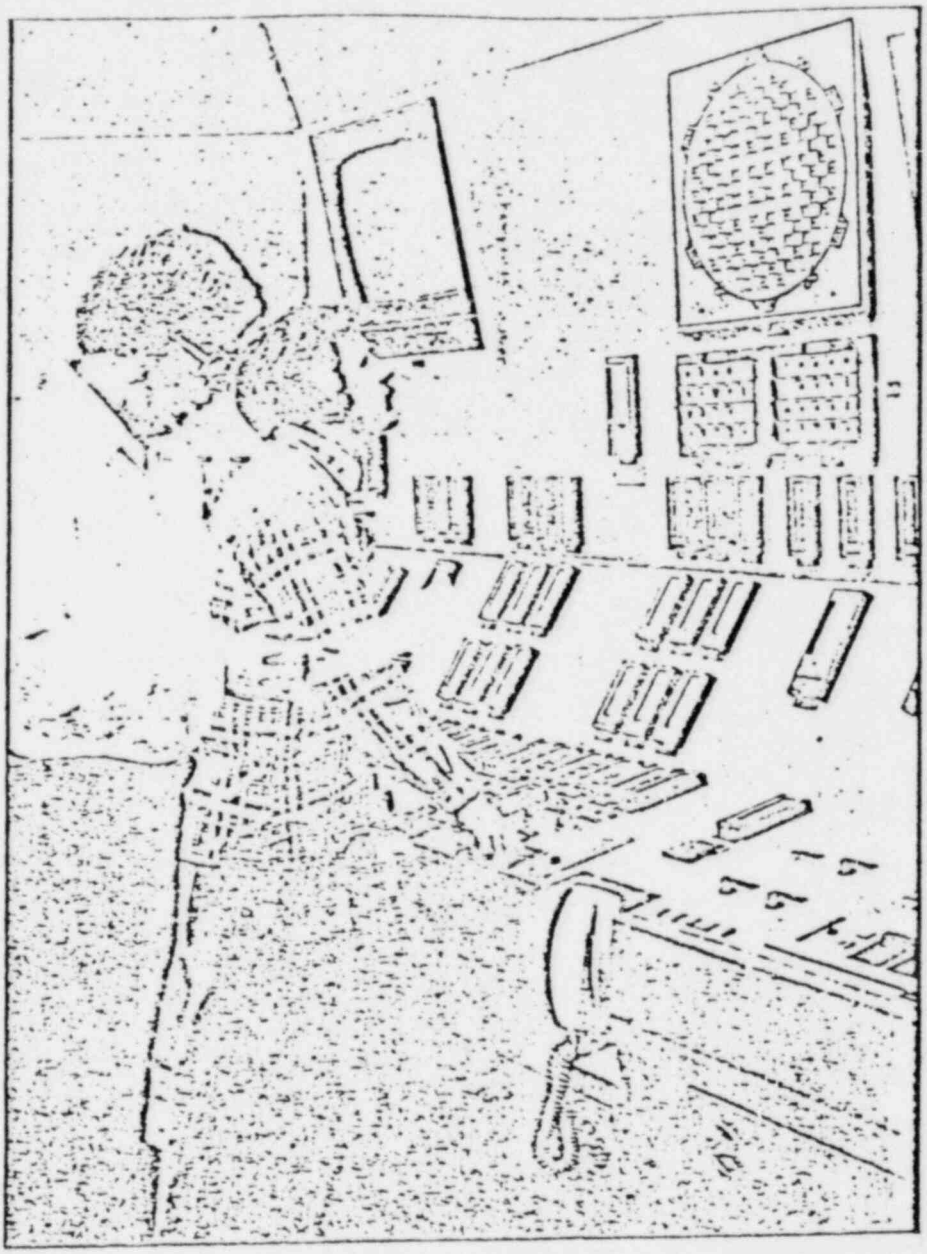
Training performance actually records, on magnetic tape, key performance data throughout any exercise. This permits the instructor to watch his students, interact with and control them during various runs. At the end of any lesson, he can then evaluate the students' performance, individually or as a group.

Computer aided exercises help the instructor pre-program complete exercises. The computer aided exercises are stored on discs for recall whenever desired. These drills could include, "set initial conditions", "select for monitoring", "set malfunctions at various points", "run through prescribed operational procedures".

Programmed malfunctions are initiated and displayed at the instructor's console. A time-lapse feature permits him to start one, or more, malfunctions whenever he pleases. He can select from a variety of malfunctions (with levels of degradation and time skews) to offer trainees experience in dealing with abnormal situations;

Micellaneous controls include startup and shutdown master system controls.

Diagnostics allow the operator/instructor quickly to check all the panel lights, switches and potentiometers prior to the start of an exercise.



During "freeze" or "replay" operations, simulator trainees have the luxury of reviewing a situation without penalty. The telephone connects with the instructor's console in this system being constructed for Arizona Public Service Company, USA, by Electronic Associates.

When to order

Designing and constructing an operator training simulator can take three or more years, the most time-consuming portion being alloted to the preparation of proper software. Thus if a company with a new power plant in the planning stages, is considering the purchase of a simulator, they would be well-advised to order one for installation about one year before the scheduled startup of the plant. Effective operator training and a checkout of startup procedures, can be assured before the real plant becomes operational.

For nuclear power plants that are already operating, anytime is the right time to place an order. For example, Duke Power Company, which had plants on line before the NRC even required operator licensing, will have another new simulator delivered in 1981. The company plans to use the equipment for purposes other than just training its operators.