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ADVANCED CONTROL TEST OPERATION (ACTO) FACILITY

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ABSTRACT

The Advanced Control Test Operation (ACTO) project, sponsored by the U. S. Department of Energy (DOE), is being developed to enable the latest modern technology, automation, and advanced control methods to be incorporated into nuclear power plants. The facility is proposed as a national multi-user center for advanced control development and testing to be completed in 1991. The facility will support a wide variety of reactor concepts, and will be used by researchers from Oak Ridge National Laboratory (ORNL), plus scientists and engineers from industry, other national laboratories, universities, and utilities. ACTO will also include telecommunication facilities for remote users.

INTRODUCTION

The major objective of the ACTO project is to maximize the benefits that the nuclear industry derives from advanced control technology, particularly in the areas of plant availability and safety. By using control systems that are more intelligent, reliable, and fault-tolerant, there can be significant reductions in the number and duration of nuclear plant outages, reductions in the likelihood of "incidents" becoming "accidents", and improvements in operating performance. Operator errors presently account for about 3% of the forced outage time in U. S. power reactors, and were responsible for conditions that led to major accidents at Three Mile Island and Chernobyl. It is maintained that by use of advanced equipment and computer software techniques, operational errors (both operator and equipment problems) can be reduced to improve plant availability by at least 3%, and overall safety can be enhanced significantly. Reactors in the U. S. have a relatively poor record of on-line availability, and every 1% improvement in average plant availability would be approximately equivalent to the operation of another (new) large plant; hence the economic incentives for improvement are substantial.

Figure 1 shows a conceptual layout of the ACTO facility. Shown symbolically are the large (number cruncher) computers, which will incorporate the reactor dynamics simulators, the symbolic computers for artificial intelligence (AI) and expert system development, the database computers for storage of archives of data, a test control room for setting up and testing prototype controls and interfaces with operators, a series of advanced design workstations for control system development, and the communications networks for both the local and remote signal transmissions. Figure 2 shows an architect's sketch of the ACTO facility to be located at ORNL.

ACTO FACILITY JUSTIFICATION AND SCOPE

The ACTO concept is based on the premise that advanced control systems featuring innovative hardware and software system designs can provide a high degree of automation and result in considerable benefits to the reactor industry. It is clear, however, that such advanced systems will not be incorporated into any reactor designs without extensive prior demonstration, testing, qualification, and verification. A major driving force behind the ACTO project is the thesis that effective support for promoting and developing these advanced controls could best (and most efficiently) be provided by a centralized general purpose simulation and test facility.

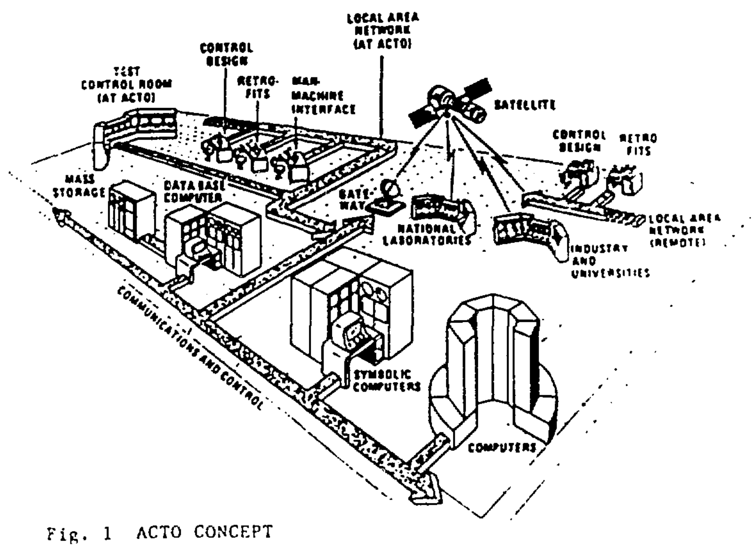

Fig. 1 ACTO CONCEPT

*Operated by Martin Marietta Energy Systems, Inc., for the U. S. Department of Energy, under Contract No. DE-AC05-84OR21400.

DISCLAIMER

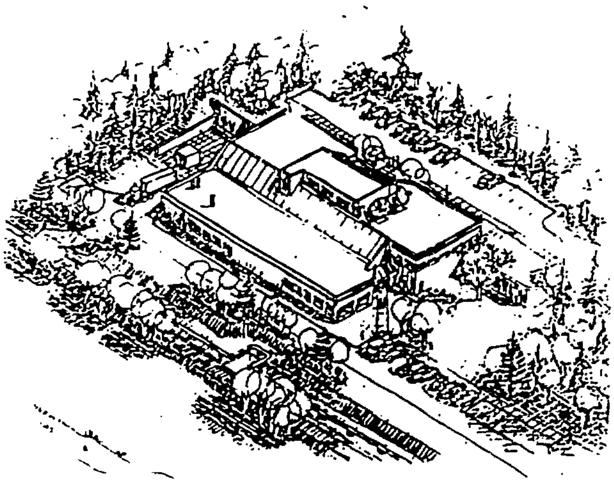

Fig. 2 ARCHITECT'S SKETCH OF ACTO

The concept requires the development of advanced methodologies and software for integrating plant simulations with the design and testing capabilities for control systems. This is to be accomplished via an integrated system (software) architecture capable of supporting multiple users (on-site and off) for current and advanced light-water cooled reactor (LWR), liquid-metal cooled reactor (LMR), and high-temperature gas-cooled reactor (HTGR) designs, as well as for military and space-based nuclear power system designs. The payoff to DOE (and the nuclear industry) would come from a one-time development of general purpose tools that would make the process of designing, testing, and qualifying complex automated systems much more efficient for each of many reactor projects.

Any single commercial reactor development program or public utility could develop methods to incorporate advanced designs. However, there is no guarantee of Nuclear Regulatory Commission (NRC) approval, the one reactor/one control system design approach is expensive, and this activity is long term. A center for advanced control systems for nuclear reactors would be able to efficiently provide development services through extensive hardware and software resources. This service can be shown to be less expensive (with the hardware and software shared by many reactor programs), use standardized methods, and be expedient for control system designers. To be effective, a large amount of hardware is needed and innovative software development is necessary to design, test and qualify the control system designs.

The ability to solve existing problems and retrofit advanced control systems into commercial light water reactors will lead to safer and more economical plants, and is an ACTO Facility goal. Current NRC regulations preclude installing any control system that is not tested and qualified. ACTO will provide this capability.

At the center of ACTO will be an extensive set of both generic and plant-specific dynamic simulations, along with the requisite data bases, that can be used to support control system development, interfacing, and testing. The new emerging technologies to be applied here are those of advanced computer architectures, very high level languages (to generate software automatically), area networking, fault-tolerant control, and artificial intelligence and expert systems. Implementation of these technologies requires an environment supportive of an integrated approach to the entire life cycle of a control system design. ACTO will consist of the personnel, hardware, and software required to support this process from the initial conception to final testing before installation at the individual plant sites, and with communications packages supportive of both local and remote users.

The ACTO project began in FY 1986 with support from the ORNL Director's R&D Fund. Later, additional funding was obtained from the DOE Advanced Reactors (LMR) Program. The initial projects addressed by ACTO are directly applicable to the advanced LMR designs.

The technical issues addressed in FY 1986 included:

1. Determining an overall strategy for applying automation to reactors,
2. Outlining software development and management plans for the ACTO facility's development environment software (which supports users in their simulation and controller design and testing efforts) as well as for the plant simulation and controls software,
3. Beginning evaluation, acquisition, and testing of existing software packages (both commercial and government sponsored) for eventual use in ACTO,
4. Evaluating hardware (such as parallel processors and workstations) for ACTO use,
5. Initiating demonstration projects, and
6. Completing a Preconceptual Design Report.

ACTO SOFTWARE IMPLEMENTATION

This section gives a brief description of the concepts and software features needed to achieve the ACTO objectives, along with the developments in control system design that must be incorporated into the software. These developments include the Control System Design Life Cycle, the Control Engine, and Artificial Intelligence.

The Control System Design Life Cycle

The ACTO software is designed around the control system design life cycle, as shown in Fig. 3. The design life cycle provides a context for ACTO developers to tailor a software tool to a specific step in the process by defining the inputs, outputs, and processing required for each step. It also defines interfaces to the rest of the design procedure. These definitions - input, output, processing and interfaces - are the essential inputs to begin developing the ACTO software tools.

As shown in Fig. 3, the backward facing arrows indicate the retracing of steps expected and provided by the ACTO software. The ability to readily correct errors is one of the major incentives to develop ACTO. Any experience with a good word processor or spreadsheet program demonstrates that, although some productivity is gained through the initial text or problem entry, the greatest productivity gains occur when editing or revisions are required. The same is expected of ACTO. Design changes and functional specification changes will be able to propagate through the remainder of the design process in a well controlled manner.

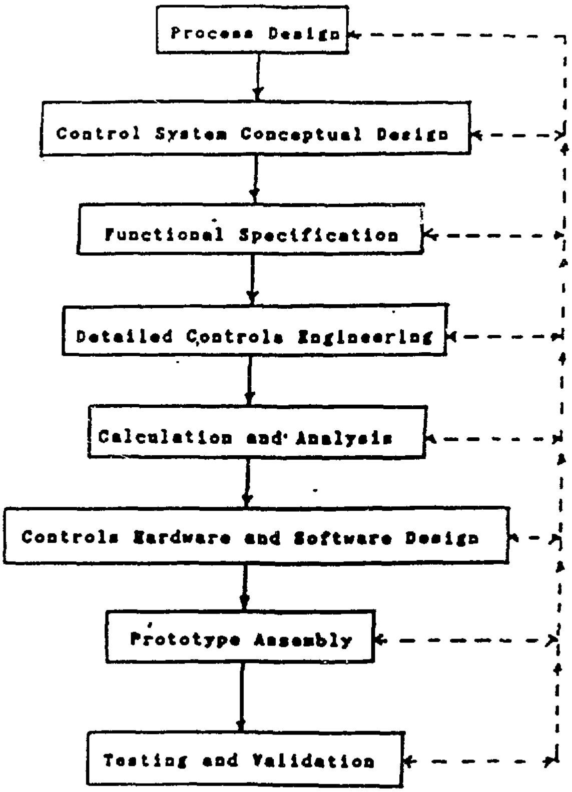

Fig. 3 THE CONTROL DESIGN LIFE CYCLE

The "Control Engine"

The "control engine" concept is an idea developed and promoted by the General Electric Co. As applied to reactor control problems, the control engine is a useful means for integrating all the essential elements of a comprehensive automated control system. It also presents a logical scheme for dividing up (and later integrating) the tasks and the technology (and technologists) involved in the overall design problems.

The major elements of the control engine are shown in Fig. 4. The conventional part of the control system is represented by the "automatic control systems" block. While the control system would be all digital (vs. the conventional mostly-analog systems), many of the control algorithms would be similar to those imbedded in the analog hardware. A significant difference would be in the ability of the automated digital control system to automatically account for changes in control modes (such as startup, low power, and full power ranges), integrate the control of multiple reactor modules tied to a common steam system, and make allowances for various subsystems to be out of service. On-line diagnostic systems that automatically account for failures of sensors and instrumentation subsystems, known as "smart sensors", would also be included. These take advantage of the redundancy (sometimes physical, sometimes analytical) that exists in the instrumentation.

The "data processors and archives" block represents an automated scheme for recording, retrieving, and analyzing information that would bear on maintenance scheduling, predicting subsystem and system faults (based on operating experiences), and any other data storage chores required by system designers, QA database managers, or regulators. The design objectives of this system deal with the efficient storing of very large data bases that must have ready access and versatile display and analysis features.

The "plant state analysis" block incorporates on-line real-time (and faster than real time) plant simulators that are used to provide advanced operational and diagnostic decision aids to the operators. The real-time simulation would provide information about the expected plant status, based on operational history and current data, assuming that there are no system malfunctions or instrumentation errors. This computed state of the plant is compared (continuously) with the measured state, and differences are computed, flagged (if significant), analyzed for possible causes, and the digested information presented to the operator. The faster-than-real-time simulators would be used to predict the outcomes of alternative strategies to overcome operational difficulties. For example, in an emergency shutdown situation, where several alternative shutdown cooling mechanisms could be used, the simulator (which is tied in to the plant instrumentation system) could help the operators predict the outcomes of several emergency strategies, depending on the resources such as cooling water inventories or pumping capabilities available. Other

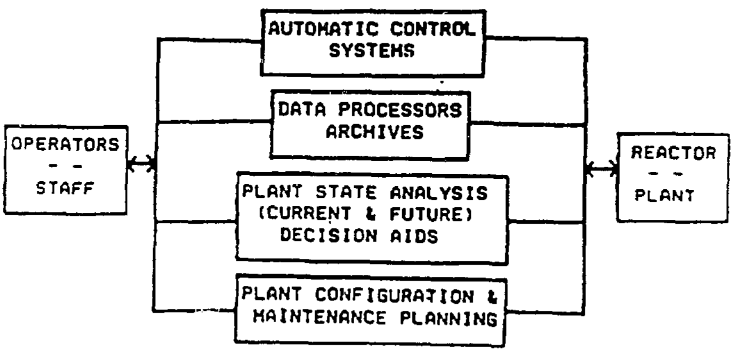

Fig. 4 ELEMENTS OF ADVANCED "CONTROL ENGINE"

operator aid and diagnostic packages would be included here, including such things as alarm filtering, automatic procedures generation, and expert advisor (AI) systems.

The "plant configuration and maintenance planning" block refers to a sophisticated scheme to perform predictive (rather than simply scheduled) preventive maintenance, and includes the generation of current database information on all significant plant components whose failure could affect continued operation or plant safety. The maintenance management scheme would also inform the plant maintenance supervisor of the current equipment status and of the safety or operational implications of taking any piece of equipment out of service for maintenance.

Artificial Intelligence in the Controls Design Process

Artificial intelligence methods can be used to aid the design engineer working on the ACTO system as well as in the control system itself. On the ACTO system, artificial intelligence techniques will perform sophisticated tracking of the user's problems and progress. The following list of features are examples of aids which could be incorporated in the User Interface Program at ACTO.

- User assistance to aid and guide novice users
- Expert teacher to tailor tutorial programs to the experience and needs of the user
- Command "spy" to recognize context or user objectives using pattern recognition based on the most recent series of user commands
- Natural language interpreter to recognize approximations to commands and instructions
- Intelligent database management to aid in searching for information or categorizing information to be stored
- Interactive high-level planner to specify controls design with an autonomous low-level planner using controls analysis programs to create the design details

ACTO SOFTWARE SYSTEM ARCHITECTURE

The ACTO development plan calls for the incorporation of existing commercial and government sponsored software into the overall framework. The use of existing software makes the ACTO feasible both in terms of the development time and project cost. Commercial software tools are already available to assist in planning the design, creating engineering drawings, simulating and analyzing the controls, storing and retrieving information, and managing the project. At this stage, however, the tools are simply are not assembled into an integrated work environment. The integration task involves development of the linkage or "glue" software which joins the separate codes into a cohesive package in which the design process flows naturally from one step to the next. The ACTO goals for productivity and accuracy in the development of controls software and hardware are achieved through integrating all of the software used in the controls design process.

The User Interface Program controls coordination and communications between the application programs that are integrated within the ACTO framework. The functions of the User Interface Program are to:

- Provide communications to the ACTO network of resources,
- Provide menu selections and commands to guide the user through control design tasks,
- Provide "expert system" assistance and tutorials within the context of the task the user is performing,
- Provide data pipelines from one application to another,
- Provide project management information such as project activities and system usage, project schedule and status on key milestones, and a history of project revisions by date and revision identifier.

The User Interface Program will run on local personal computers or workstations. The local computer serves as the primary point of contact for most users. The local computer will be connected to the network of ACTO computers through communications links. The local personal computer is able to perform a great percentage of the total user workload. Operations such as large model simulation and controls analysis, which require a mainframe computer, will automatically access the appropriate computing hardware via the local computer network, or via the satellite network for remote users. This architecture frees the communications link and the central computers from unnecessary traffic and improves the total system response.

The communications can be fully automated within the User Interface Program. The controls designers do not need to learn how or where tasks are performed or how to guide the computer through its maze of operating system commands. They only need to be proficient in selecting the function to be performed. The User Interface Program will respond by issuing the requisite commands automatically.

CONCLUSIONS

The development of ACTO involves dealing with many difficult software and hardware planning issues. In order for the facility to become (and remain) useful in the face of the extraordinarily rapid changes in technologies, the tools developed and acquired need to be flexible and universal. Obsolescence considerations are primary, especially considering that the life span of a power reactor is typically an order of magnitude greater than the (useful) life spans of computer hardware and software.

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