# TECHNICAL REQUIREMENTS FOR SIMULATOR-BASED TESTING OF CANDIDATES FOR AUTHORIZATION

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*ABSTRACT*

*The introduction of simulator-based testing of candidates by the AECB, as part of the authorization of nuclear operators and shift superintendents, is planned for the spring of 1993.*

*The following are the four main technical requirements that a training simulator must meet in order to support the testing of candidates for authorization:*

- *reliable operation,*
- *the ability to perform the full range of exercises under a combination of normal and malfunction conditions,*
- *a high degree of fidelity in replicating the appearance and response of the reference generating unit,*
- *facilities to record all the information necessary to evaluate the candidate's actions within the context of the simulator's response.*

*The paper outlines the steps being taken at Ontario Hydro to ensure that the training simulators will meet all of these technical requirements.*

## 1.0 INTRODUCTION

Ontario Hydro had decided in the early 1970s to acquire its first training simulator, for units 1-4 of Pickering NGS. Subsequently a full-scope replica training simulator was installed for each of the other four multi-unit nuclear generating stations. The in-service dates of the generating station units and of the replica simulator are given below:

| Station Name | Station In-service | Simulator In-service |
|---|---|---|
| Pickering NGS-A | Jul/71-Jun/73 | Nov/76 |
| Bruce NGS-A | Sep/77-Jan/79 | Apr/83 |
| Pickering NGS-B | May/83-Aug85 | Jul/84 |
| Bruce NGS-B | Sep/84-May/87 | Aug/86 |
| Darlington NGS-A | Oct/90-Mar/93* | Apr/89 |

*planned

Ontario Hydro provides extensive training to personnel who are authorized by the Atomic Energy Control Board (AECB) to operate the nuclear power plants. AECB authorized staff consist of Authorized Nuclear Operators (ANO), Shift Operating Supervisors (SOS), and Shift Superintendents (SS). A significant component of the training program is the use of full-scope control room replica simulators as training aids and assessment tools.

Figure 1 shows the main components of a typical CANDU training simulator. It consists of a replica of the control room panels of one unit of the corresponding generating station. All instruments on the panels are connected to a digital computer system via the Main Control Panel Interface. The Simulation Computer System (SCS) computes the response of the nuclear plant to all operator actions, under normal as well as abnormal and emergency conditions. The realism of the simulator is such that an experienced operator does not notice any significant differences between the response of the simulator and that of the reference plant.

The control room layout includes the operator's desk and peripheral equipment, in addition to the control panels. The specific details of the layout vary between the various stations, in terms of the number of panels, their shape and orientation, the operator console's complexity, the number of instruments, the number and resolution of the CRT displays. Each generating unit at a nuclear station is controlled by two digital computers, called DCC'X' and DCC'Y'. These computers are duplicated in their entirety on the simulator (with the exception of Pickering-A, where they are emulated in software). Since the simulator DCC hardware and software is the same as the plant DCC's they control and monitor the simulated plant in much the same way as they control and monitor the actual plant. The simulator DCC's run the same software which runs at the reference plant with some modifications to provide simulator specific functions such as freeze, initialization and malfunction insertion.

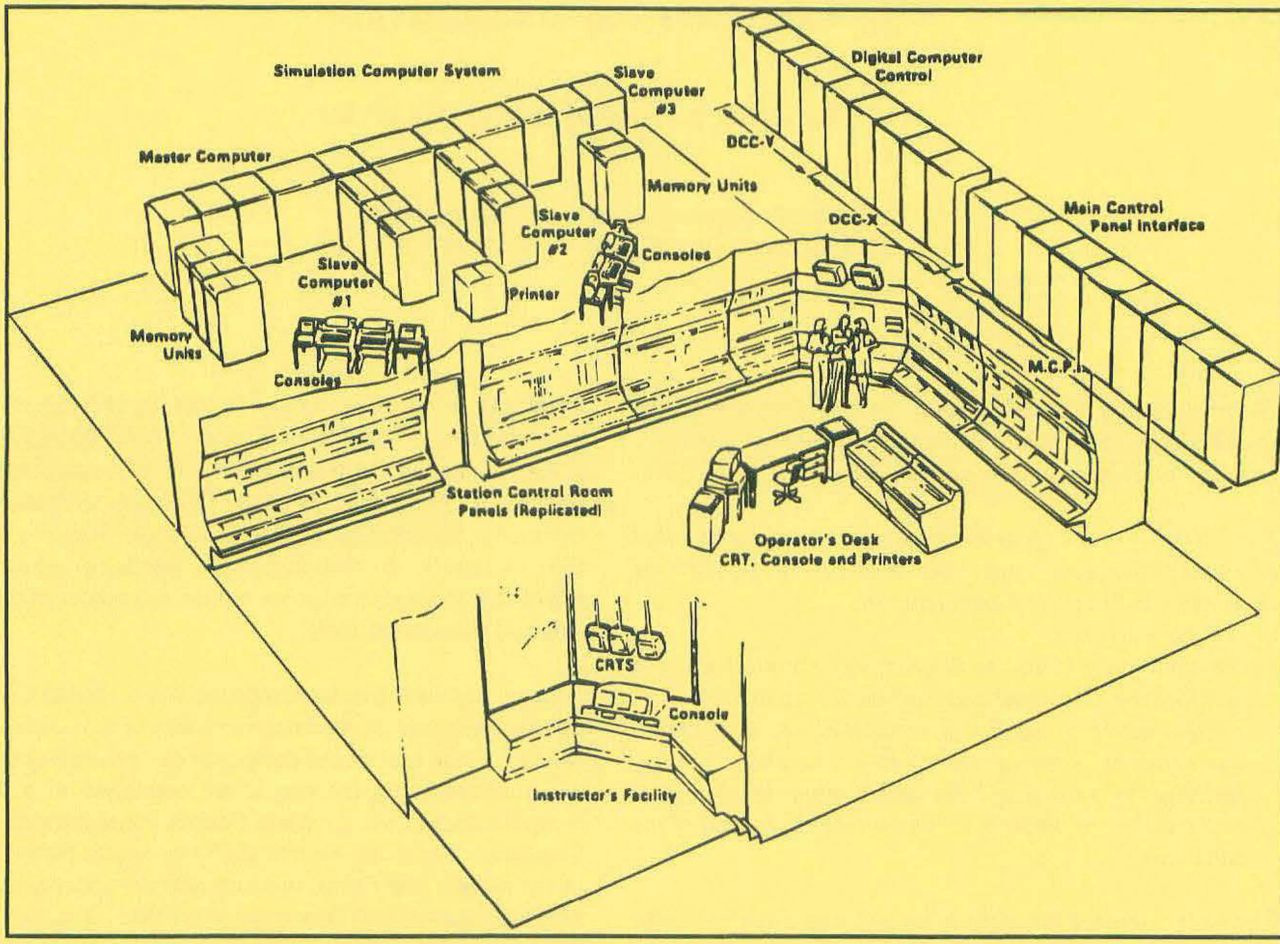


Figure 1. Perspective View of a CANDU Training Simulator.

There are various plant monitoring computers, other than the DCC's, which are also duplicated at the simulators. These include: Shutdown System and Sequence of Events Monitoring computers on the Darlington simulator, Safety System Monitoring computers on the Bruce simulators and Regional Overpower Monitoring computer on the Pickering B simulator. Like the DCC's the simulator plant monitoring computers are hardware and software duplicates of the station computers, with the exception of the Darlington ones mentioned above.

An essential component of the simulator is the Instructor Facility (I/F) which the trainers use to operate and monitor the simulator. There is a mobile I/F and a Fixed I/F. The mobile I/F is a single CRT and keypad mounted on a cart and situated in the control room. The mobile I/F can be moved to suit the instructor for a particular lesson. The Fixed I/F is located at the back of the simulator and separated by windows to allow observation of the simulator control room. The fixed I/F has multiple CRT's and expanded controls.

## 2.0 ONTARIO HYDRO'S SIMULATOR TRAINING PROGRAM

Training simulators have been recognized in the nuclear industry as essential to the training and retraining of staff who conduct and supervise the operation of nuclear generating units. Because of the high reliability of these units there are insufficient events to practice such normal operations as unit start-up and shutdown, or even significant power level changes. Because of both operational and safety considerations, the introduction of malfunction conditions for training purposes at the power plants is out of the question. Hence the need for simulators to provide the means to learn and practice the complex procedures that are involved in the safe and reliable operation of a nuclear generating unit.

Training on the simulators is principally provided for staff who are in the program to become Authorized Nuclear Operators, Shift Operating Supervisors, and Shift Superintendents. Individuals who are already in these positions receive periodic refresher training on the simulators. There are different training programs for the two groups, as described in the next two sections.

## 2.1 Initial Authorization Training

Initial authorization training is a comprehensive program delivered in several phases over a period of approximately three years. The instructional format is a combination of classroom lectures, independent study, simulator demonstrations, on the job experience, and simulator practice. Specific milestones must be achieved to continue progression through the program. At regular intervals the candidates are assessed to measure their knowledge and operating competence via written assignments, written examinations and simulator performance tests. A candidate must also successfully complete five separate written examinations (audits) administered by the AECB.

The following are the main phases of the initial authorization Training program:

- science fundamentals and generic nuclear plant systems training;
- AECB Conventional General Audit;
- AECB Nuclear General Audit;
- "on-the-job" experience;
- specific nuclear generating station systems training;
- overall unit operation training;
- simulator competency test;
- AECB Conventional Specific Audit;
- AECB Nuclear Specific Audit;
- radiation protection principles training;
- AECB Radiation Protection Audit;
- final authorization review (co-piloting).

The first formal phase of the program involves classroom instruction and testing in science fundamentals, nuclear plant systems and equipment, reactor kinetics, thermodynamics, electricity, etc. The simulator does not normally play a role in this phase, except for the occasional demonstration to reinforce principles taught in the classroom. Understanding of the information presented is monitored by a comprehensive series of written tests and candidates must demonstrate a specified level of achievement before progressing in the program. Successful completion of the generic training phase leads to preparation for and sitting of the Conventional and Nuclear General AECB examinations.

After completion of the generic training, candidates are assigned to a plant operating crew for a period of time to gain on-the-job experience. During this period they participate in the day to day operation of the plant and specific training assignments are completed to increase knowledge of plant systems, components and operating procedures. Formal training in supervisory skills is also completed during this phase.

The next phase of the program is specific station systems training. Each plant system is studied in detail focusing on the particular system's control schemes, control room indications, operating controls and procedures. The training includes classroom lectures by system experts from the station's technical department, complemented by simulator demonstrations of indications, controls and system responses and practice of system specific procedures. Again each candidate's knowledge and understanding is measured regularly by assignments and written testing. A comprehensive written examination of plant systems knowledge must be successfully completed before progression to the next phase.

Overall unit operation training integrates all of the preceding theoretical and plant systems knowledge, and develops operating skills. Simulator practice is the main component of this training, complemented by classroom instructions. The focus is on developing all the necessary skills for safe and efficient operation of the entire nuclear generating unit under both normal and abnormal situations. The training follows a logical sequence that first addresses normal situations and routine operations, then transient or upset situations that have a productivity or economic impact, and finally abnormal incidents which impact on reactor or plant safety. Soft skills such as problem diagnosis, communication and teamwork are also taught and practiced during this phase. A progressive series of simulator based tests are used to measure skill and knowledge development throughout this phase.

On completion of the overall unit operation phase, training candidates are assessed in a formal simulator competency test. In the realistic control room environment of the simulator, candidates must demonstrate proficiency in controlling plant evolutions as well as diagnosis and mitigation of a wide variety of component failures and system perturbations. A satisfactory test result indicates that the individual's knowledge and skills meet the Ontario Hydro standard for Authorized Nuclear Operators or Shift Superintendents. The prescribed standards must be met at every stage of the training program before progression to the next stage is permitted.

The final phase of the plant specific training is preparation for and sitting of the AECB Conventional and Nuclear Specific audits.

Following the plant specific phase, candidates receive classroom training in radiation protection theory and principles. This stage also culminates in every candidate sitting for the Radiation Protection AECB audit.

After successful completion of all previous phases of the authorization training program, a candidate proceeds to the final authorization review phase. This involves a probationary period during which all of the actual job functions are performed in a co-piloting role, under the close scrutiny and supervision of authorized staff. Final authorization is granted after successful completion of this review.

### 2.2 Refresher or Continuing Training

All authorized staff must keep their knowledge and skills up-to-date, and demonstrate their competence at a level that assures continued safe and reliable operation of the nuclear generating units. This is the governing principle of Ontario Hydro's continuing training program. This program provides training and practice to maintain and where necessary restore performance levels of authorized staff. Competence is measured via on-the-job performance assessment and simulator testing.

The refresher training program is composed of the following modules:

- Classroom Refresher Training;
- Simulator Refresher Training;
- Operating Crew Drills;
- Operational Overview Training;
- Simulator Assessment.

Classroom and Simulator Refresher Training sessions are event based. Scenarios which have severe consequences, are difficult to diagnose and/or require complex operating responses, are routinely practiced during refresher training sessions. Classroom refresher encompasses operating policies, procedures and related enabling knowledge. A typical classroom session would examine a particular scenario, including a review of every step in the procedure, the rationale behind procedure actions, any related Operating Policies and Principles, as well as the strategy for handling the event and possible consequences.

Simulator Refresher Training provides practice in diagnosing and handling various scenarios in a realistic control room environment. Operating crews perform their normal roles while dealing with simulated plant incidents to maintain and improve their operating, teamwork and communication skills. Events are usually repeated several times to ensure familiarity, and performance feedback is provided by the instructors. Secondary failures are included in these scenarios to add realism and maintain interest.

Training and practice in operating crew drills is provided for a variety of crew response situations. These drills are conducted, in the nuclear stations, on a routine basis and involve all crew members participating in their normal roles in handling emergency situations, such as a station radiation emergency.

Operational Overview Training is designed to bring authorized personnel up to date with respect to recent or upcoming developments in the nuclear industry or changes to plant systems and procedures. Included are reviews of selected Significant Event Reports and case studies for the specific station, for other CANDU stations and for the nuclear industry. Station technical staff provide updates on planned or implemented plant equipment and procedural changes.

Simulator Assessment is a formal evaluation of an authorized individual's ability to deal with simulated plant transients as part of his/her normal duties. The objectives of the assessment program are to:

- confirm the competency of the authorized staff to handle unit transients in a safe manner;

- provide performance feedback, relative to station expectations, in order to allow recognition and correction of performance shortfalls;

- highlight any weaknesses in the training program.

All authorized individuals are tested three times per year and their performance is rated against specified criteria that measure competence in several areas, including diagnosis, monitoring of unit status, operating skills, communication, use of resources, knowledge and overall approach to handling the events. Continued authorization is contingent on satisfactory performance in these tests. Simulator tests are conducted under strict guidelines to ensure that the tests are fair and the results valid. The testing process will be described in greater detail later in this paper.

## 3.0 ONTARIO HYDRO'S EXPERIENCE WITH SIMULATOR-BASED TESTING

Ontario Hydro's operating and training departments have been conducting simulator-based tests for many years as part of the Authorization Training programs. The same type of tests have recently become a compulsory part of the Continuing Training program. There have also been a number of specific cases, when as a supplement to the written examinations, the AECB required a candidate to demonstrate competence in a simulator test. These occasions have provided extensive experience in using full-scope training simulators as a competency assessment tool.

### 3.1 The Role of Testing in the Training Program

Currently Ontario Hydro conducts three main types of simulator tests:

(a) formative or progress evaluation to measure accomplishment of learning objectives and to provide guidance on areas of strength and weakness as skills are developed;

(b) summative or cumulative evaluations on completion of training program phases, representing an overall assessment of performance against the prescribed standards for the course;

(c) periodic re-evaluations to measure continuing proficiency at a standard consistent with expectations for authorized staff.

A tenet of effective training requires regular performance evaluations during and at the completion of a training program. Accordingly Ontario Hydro administers simulator tests types (a) and (b) during the Initial Authorization Training program while type (c) is administered as part of the Continuing Training program.

The basic simulator test format used in the two programs is very similar, the main difference being on the focus of the assessment. The emphasis is on individual performance during initial authorization testing, as distinct from team performance during continuing training simulator tests. For each test, candidate performance is rated against specified criteria to measure competence in several areas including:

- problem diagnosis;
- monitoring;
- operating skills;
- knowledge;
- procedure adherence;
- communication;
- team skills;
- use of resources;
- overall approach.

All simulator tests are conducted in an environment that duplicates that of the station's control room, with an emphasis on each candidate responding to problems in his or her normal operating role. The physical environment in the simulator also matches, as closely as possible, the actual station control room, including duplication of such items as furniture, operator desks, telephone systems, available documentation and operating aids. The realism is further enhanced by extensive role playing during simulator testing sessions, by having training centre and station staff perform the roles of other workers who are normally involved in unit operations to provide assistance and remote operations, including communications via telephone and two-way radios.

To ensure that simulator-based evaluations are fair and accurate, the performance standards are clearly communicated to the participants and practice sessions are conducted using the same format and environment as used for testing. Prior to use, test scenarios are carefully planned and rehearsed to ensure that the simulator's response is accurate and reliable, and that all aspects of the test are within the guidelines. Test scenarios which could lead to simulator responses that are considered to be incorrect or misleading, are not used. Despite such careful planning, there are occasions when tests have to be aborted due to a simulator fault or an operator error which results in moving the event outside the expected test boundaries. Decision to abort is made on the spot by the simulator test evaluators.

### 3.2 Evaluation of Individual Performance

Accurate evaluation of performance in a full scope simulator test presents significant difficulties. Nuclear plant evolutions and transients often require complex problem solving and mitigating responses in a very short time frame. Operating staff can frequently choose different courses of action to achieve similar results while maintaining the nuclear unit within a safe operating envelope.

Simulator performance evaluators must have detailed knowledge of the respective plant, its operating controls and procedures. Ontario Hydro uses only current or previously authorized staff to perform simulator assessments. Assessors are trained in observation and evaluation techniques as well as post-exercise critique and feedback facilitation. Sufficient numbers of assessors are provided for each test to ensure correct and comprehensive evaluation of every participant. During a test performance is observed and recorded in detail by the various assessors. Assessment guides or check sheets which list the expected responses to the particular scenario may be used as an aid to reduce the required writing during a test.

Following the test the assessors compile their observations, discuss the performance and decide on a grading. Several aids are available to the assessors to help with post-exercise evaluation such as the Trainee Action Monitor (TAM) which records chronologically all control panel operations. Other information is available from the plant control computers in the form of historical graphical trend data, recorded alarms, etc. Video and audio taping of test situations has also occasionally been employed but has proved to be of limited value to assessors due to poor quality equipment and high background noise levels in the simulator control room. Plans are currently under way to install better quality equipment, since the recording of tests has been found to be helpful in analyzing the exercise.

Grading of performance in simulator tests is also a complex task. Experience has shown that accurate quantitative measurements are not possible using subjective assessment techniques. Experiments have been performed with quantitative measures but results have not been conclusive and frequently opposed the evaluation of experienced simulator assessors for the given test. At the present time only two grades are used in Ontario Hydro's simulator tests: satisfactory or unsatisfactory.

During the post-test discussions deviations from expected responses are summarized and the "consequences" of the actions or non-actions are evaluated. Consequences are rated on a scale based on the severity of their impact on Public Safety, Worker Safety, Environmental Safety, Reliability or Cost. Deviations from normal expectations with high severity consequences result in an unsatisfactory grading. An unsatisfactory simulator test result is followed by root cause analysis to examine factors such as:

- individual performance;
- expectations;
- plant procedures;
- system design;
- test environment.

The results of this analysis are used to identify possible remedial training required, procedure corrections, system design changes or test revisions.

Performance feedback is an important part of the testing process. After the grading is complete, the participants and the assessment team meet to conduct a test feedback and critique session, where assessors highlight specific strengths and/or weaknesses, and identify areas requiring follow-up action. These feedback sessions are normally viewed very positively by the participants as an opportunity to understand and improve performance.

## 4.0 EXPECTED NEW REQUIREMENTS FOR SIMULATOR-BASED TESTING OF AUTHORIZATION CANDIDATES

It has long been recognized, by both the utilities and the AECB, that full scope simulators provide a more realistic means of assessing the control room specific operating and supervisory skills of nuclear operators and shift superintendents than the currently used written audits. The AECB has informed all the utilities that operate CANDU reactor units, that simulator-based examinations will be implemented beginning in the Spring of 1993. An inter-utility/regulatory working group has been established to study and recommend requirements for simulator-based examinations, specifically in the areas of assessment methodology and minimum simulator characteristics. With respect to the required simulator characteristics, the terms of reference of this working group are to:

- establish minimum requirements for simulation capability and fidelity of simulation;
- establish requirements for simulator reliability and data collection devices;
- identify the shortcomings of each simulator with respect to the minimum requirements established.

This group is not expected to complete its recommendations until the Fall of 1992. Preliminary indications are that Ontario Hydro's simulators will meet the requirements to commence a limited scope of simulator-based testing in 1993, but various amounts of upgrades will be necessary to meet the expected full set of requirements.

### 4.1 Simulator Reliability

Historically, Ontario Hydro's simulators have been very reliable, routinely exceeding the 97% availability target (Availability = actual training time / scheduled training time). However, we realize that improvements are required in the methods used to measure reliability to improve the accuracy and scope of our statistics. One of the initiatives we have recently implemented, on a trial basis, is the recording of the possible effects of simulator failures occurring in the course of simulator testing situations. This data should give us a much more accurate indication of the frequency of failures which may invalidate a simulator examination.

### 4.2 Training and Testing Capability

With respect to simulator-based testing, capability means that the simulator must be able to perform, realistically, the full range of scenarios and a wide variety and combination of secondary malfunctions which have been identified as critical to testing the prescribed knowledge and skill of the nuclear control room operator and shift supervisor candidates.

For each simulator a system is in place that measures its training capability. These measurements are based on an assessment of outstanding deficiencies and station changes versus the training exercises required to be performed as part of the various training programs. For each outstanding deficiency or station change the affected training exercises and the impact of the deficiency on them are identified. This provides a record of the training exercises that cannot be done, the ones that require some instructor intervention and the ones that are completely acceptable for training use. The number of training exercises that cannot be done is very close to zero on our simulators, however there is room for improvement in the category of exercises which require some intervention to complete successfully. A concerted maintenance effort is presently being directed towards resolving deficiencies which fall into this category.

The second expected area of capability improvement is the addition of new and more varied malfunctions. This has been an area of continuing simulator improvement for the past few years driven by the current Ontario Hydro simulator testing programs. New malfunctions are required to increase the variety available for testing situations to challenge the operating staff and reduce predictability of simulator scenarios. AECB representatives have clearly stated, with respect to simulator test scenarios:

"A special effort should be made to include credible scenarios that are not an exact replica of cases covered during training. Although basic test scenarios usually represent situations that are covered by abnormal or emergency operating procedures, variations are introduced in a way to present the candidate with situations that are not addressed directly in the operating procedures."

### 4.3 Data Collection

Many devices for data collection are presently in place on Ontario Hydro's simulators and are used routinely during simulator performance testing. The need for some improvements in this area have been recognized and will be implemented. Improved video/audio recording systems are to be installed on all simulators to supplement or replace currently installed monitoring and recording devices. Efforts are also being made to synchronize and time stamp all data collection and recording systems to simplify post-test evaluations.

It is clear that the AECB will require comprehensive automatic data logging capabilities. This is important for recording trainee actions and the relationship of these actions to the evolution of plant conditions, in order to assess each candidate's performance. The facilities available to achieve this objective are listed below:

- Trainee Action Monitor (TAM);
- Graphical Trend Recording
- DCC Annunciation Printouts and Hard Copies
- Audio/Video Recordings.

### 4.4 Fidelity Requirements

The fidelity of a simulator is defined as a measure of the extent to which the simulator replicates both the reference plant measured and predicted responses and the physical appearance of the control panels and control room environment.

The AECB has not explicitly stated fidelity requirements for simulators. However a joint committee which is a working subgroup of the Standing Inter-utility/Regulatory Working Group, consisting of the AECB, Ontario Hydro, Hydro Quebec and New Brunswick Power are currently addressing this issue.

It is clear that the AECB will require the simulators to perform a wide range of plant and system malfunction scenarios which may cover the full range of plant conditions. It is also apparent that the fidelity of the simulation must be sufficiently high to ensure that the candidate being evaluated is not distracted or misled by any shortfalls in simulator fidelity.

Ontario Hydro's simulator training program recognizes three types of fidelity:

1. Physical Fidelity or Panel Replication.
2. Operational Fidelity.
3. Dynamic Response Fidelity.

The following sections explain these measures, and indicate the current status of Ontario Hydro's simulators in all three areas.

#### 4.4.1 Physical Fidelity or Panel Replication

Physical Fidelity or Panel Replication is a measure of how closely the simulator control panels, control room furniture and environment match the corresponding reference unit hardware. This is the easiest fidelity requirement to satisfy, and all Ontario Hydro nuclear training simulators rate close to 100% on this measure.

Changes to the main control panels occur as a result of design changes at the reference station. These design changes are described in Engineering Change Notices (ECNs). ECNs which result in control room panel changes are copied at the simulator.

As a check on this process an annual audit of the main control panels is performed. This is accomplished by taking high resolution photographs of the reference plant control panels and manually comparing these with the simulator control panels. Any discrepancies are noted, investigated and resolved.

In addition, operations or training staff identify any discrepancies they notice. Most of these are minor and usually involve wording, size or colour of labels, or alarm windows.

#### 4.4.2 Operational Fidelity

Operational Fidelity measures the ability of the simulator to perform all the relevant operating procedures as per the Station Operating Manuals, with no discernible differences between the responses of the simulator and the reference unit. In order to achieve a high degree of Operational

Fidelity the simulations must be full scope, i.e. all station systems and equipment relevant to the training program are simulated in detail. For example, the control logic for all simulated systems is generally modeled to the individual fuse, relay and contact level, replicating the control drawings. In addition, control and monitoring computers are usually duplicates of the station computers and run essentially the same software as the station.

The operational fidelity of the simulators is continuously assessed by the simulator instructors and trainees. During training sessions the instructors compose a wide variety of lesson plans which cause the simulator to be exercised through its full range of capabilities. During these scenarios both the refresher trainees and the instructors are monitoring simulator performance. All these individuals are experts in plant systems and overall plant operations. Consequently, simulator performance/fidelity is continuously scrutinized. All significant performance deficiencies are recorded on deficiency reports (D/R's) and are scheduled to be corrected.

At the present time the operational fidelity of Ontario Hydro simulators is close to 100% in terms of being able to do all the exercises in the training program. However, about 20% of the exercises are affected by outstanding ECNs, D/Rs or computer updates. The evaluation of fidelity for testing purposes awaits the publication of the pertinent guidelines.

#### 4.4.3 Dynamic Response Fidelity

This is the most stringent form of fidelity, involving a quantitative assessment of the deviations between simulator parameters and recorded plant data or approved design/safety code calculations. The limits of acceptable deviations need to be specified in terms of both magnitude and time, and have different tolerances depending on the importance of the parameter to safe plant operations. The specified parameters are compared for a set of approved operating events, and the extent to which they fall within the prescribed envelope measured. Ontario Hydro has so far made limited use of such measures.

When establishing the need for dynamic fidelity testing it is essential to recognize that the purpose of a training simulator is to replicate station response to the extent needed to develop and verify the authorized staff's ability to operate the unit as per the operating procedures. Provided the simulator's response is consistent with the observed and/or expected generating unit response within the operating envelope and tolerance of the operating procedure, and within the accuracy of the plant instrumentation, the simulator should provide a valid basis for testing the candidates' unit operating knowledge and skills.

The testing of dynamic fidelity beyond the above accuracy will produce increasingly diminishing returns for the very large effort needed, and probably at the expense of improving Operational Fidelity, which has far greater relevance to authorized staff training and testing.

### 4.5 Fidelity Assurance

Irrespective of the fidelity level that a simulator has, it is essential that the level be known. Once the training events to be used for testing and the desired fidelity standards have been identified, each simulator will have to be evaluated in terms of the standards, the deviations recorded, and the tests planned so that the known deficiencies do not detract from the tests. The aim of fidelity assurance is to know the level of fidelity and assure that it is being met. Subsequently, as the identified deficiencies are resolved, mechanisms must be put in place to assure the people conducting the training and testing that fidelity improvements in one area do not result in a decrease of fidelity in another area.

Fidelity assurance will need to address the extent to which the simulator is up-to-date with the station and the nature and consequences of all performance deficiencies.

#### 4.5.1 Simulator "Up-To-Dateness"

The simulator "up-to-dateness" refers to the degree to which changes to the reference plant are incorporated on the simulator. When building a simulator it is necessary to freeze the design with respect to the reference plant at a particular point in time. That time can be over a year before the simulator is even delivered to site. Although the simulator design is frozen the station continues to change as described above. Consequently the simulator is out of date before it is ever used for training, and so far no Ontario Hydro training simulator has reached a state of being completely up-to-date with respect to all station changes.

In order to measure and improve this aspect of simulator fidelity, it is essential to have a method of tracking and assessing changes to the reference plant and making provisions to have the changes relevant to training incorporated on the simulator.

The bulk of changes which occur at the generating stations are design changes to various systems and equipment. Each design change is described by an Engineering Change Notice (ECN).

All ECNs which affect the reference plant are reviewed by the simulator training delivery staff and the simulator configuration control staff. Each ECN is assessed for its impact on the training program and is assigned a priority. The ECN information, training program impact and priority are entered in an ECN database. This database becomes a vital part of the configuration management system for each simulator. The database essentially describes a complete set of past and pending ECNs based changes which affect the simulator and the impact of these ECNs on specific simulator exercises. Based on the assessed priority and impact of a particular ECN the task of correcting the discrepancy is assigned to a member of the simulator technical staff and a target date for completion is set. The ECN database permits the configuration management staff and the training staff to track simulator ECNs and ensure that the maintenance effort is being directed effectively.

An important factor which complicates keeping the simulator up-to-date is that various units at the reference plant have the same ECN installed to varying degrees of completion. Sometimes there is a training requirement for the simulator to be upgraded before the reference unit, or even before any unit has received the particular ECN. This is generally so training can be provided in advance of the change occurring at the station. Consequently, the simulators may reflect a hybrid unit which has a set of ECNs which exists on a combination of station units.

The DCC's and monitoring computers are maintained up-to-date by tracking software revisions on the station computers. Station DCC Patch Sheets, which describe changes to DCC software are sent on a regular basis to the simulator. Occasionally station software updates, or patches, are sent on disk or paper tape. The changes are then made on the simulator computers as time permits.

This system is not as well developed as the ECN tracking system and occasionally patches are not received at the simulator. It is sometimes necessary to get a complete dump of station software and install it on the simulator. It is then necessary to re-install all the simulator specific patches which allow the simulator DCC's to perform simulator functions. This is a relatively complicated process and is done on an as-required basis.

### 4.5.2 Configuration Control

The Configuration Control task referred to previously is an essential component of Fidelity Assurance. The system is designed to keep an up-to-date record of all components of the simulator that impact on its performance, and to provide assurance that each change to the hardware or software achieves the desired improvement and does not cause performance decrements.

The simulation software is particularly susceptible to changes that are not fully tested and documented. While resolving the original problem, the change may introduce one or more new, apparently unrelated problems. In order to minimize such occurrences, whenever the simulation software is changed the new models are fully tested by the person responsible for configuration control as well as by the simulator instructors before the changes are incorporated as part of the simulator configuration.

### 4.5.3 Dynamic Tests

The simulator maintenance work program has principally been focused on installing the station ECNs and resolving the deficiencies that have been identified by the training department as having the greatest impact on training. There are sufficiently large numbers of these performance deficiencies on every simulator to keep the existing technical staff fully occupied, hence there has been neither the incentive nor the opportunity to conduct formal dynamic tests, other than the ones needed to assure configuration control. Techniques for conducting dynamic fidelity assurance are under investigation, but the high priority day-to-day work has so far not permitted a significant amount of resources to be dedicated to this subject.

It is apparent that in order to conduct formal Dynamic Fidelity Assurance, a suite of operating events needs to be developed which exercise the simulator over the entire range of normal and abnormal operations required for training and testing. The data collected from these events would be compared with reference data from the station. Acceptance criteria for success in a test must be developed. The results of the tests will have to be documented and reported.

In principle, the comparison between the station data (measured or computed) is quite straightforward; one measures the same parameters in the plant and the simulator under identical conditions and compares the results. The difficulties are encountered in producing reference data for the full range of exercises, knowing all the conditions during each event, and quantifying the differences for the huge amounts of data that are potentially available, and producing meaningful measures for the deviations found.

The effort involved in collecting suitable data is complicated by the following factors:

- Data sets are not always available for the scenarios of interest;

- Plant conditions are not necessarily the same as the simulators with respect to equipment status and operating points for various systems;

- Panel operations taken by operators and equipment status during a plant transient are not accurately recorded;

- ECNs may be in a different state of implementation at the plant than at the simulator.

There are many thousands of data points available for sampling on the reference unit and on the simulator. Some will not be relevant, others will only have marginal impact on the development of the simulated exercise. The subset of data which is relevant to a scenario will vary depending on the event.

Comparison of data is currently a manual process which is difficult, inaccurate and time consuming. It typically consists of visual comparison of plots and alarm message printouts. The simulator is also evolving as updates and improvements are made. Consequently, the evaluation of simulator fidelity needs to be a continuous process, and is likely to require a significant level of dedicated resources.

## 5.0 ONTARIO HYDRO'S PLANS TO MEET SIMULATOR-BASED TESTING REQUIREMENTS

Ontario Hydro has dedicated a significant level of resources to the maintenance, updating and upgrading of its training simulators in order to meet the needs of the authorization and refresher training programs. This effort is planned to be continued, even without the introduction of simulator-based testing of authorization candidates, or the mandated use of simulators in refresher testing. Once the detailed regulatory requirements are known, these will be taken into full consideration when deciding the priorities for resolving the known simulator deficiencies.

It is expected that there will not be a significant difference between the improvements required to meet AECB testing criteria and the ones already identified by the training departments. For example, the upgrading of the reactor models of all simulators, to produce a more realistic response to Xenon induced spatial flux oscillations, has already commenced as a result of operating events at Bruce NGS-B and Pickering NGS-A. To accommodate this and other modelling upgrades, as well as several major station equipment changes, Ontario Hydro has recently started a major capital program to replace the simulation computer system of the Pickering-A Simulator. The Darlington Simulator will also need to have at least one major addition: simulation of the Unit 1 electric power system to enable the testing of exercises involving loss of Unit 2 electric power. The other three simulators will also need a variety of modelling upgrades, as well as upgrades to, or replacement of, the simulation computer systems that are becoming obsolete.

As described in this paper, testing of candidates has been carried out for many years as an integral part of the training program. It is expected that the experience gained in using the simulators in these tests will be taken into account, and will lead to requirements that are not significantly different from the ones currently used.

## 6.0 CONCLUSIONS

Ontario Hydro welcomes the proposed change to simulator-based tests from the written examinations as the key component of the AECB's audit of the Authorization Training Program. All reasonable efforts will be made to have the simulators upgraded to meet the requirements being developed by the inter-utility/AECB team that is defining the simulator performance of requirements.

It is of concern to the simulator technical staff that the requirements are not expected to be published until the Fall of 1992, while the first set of simulator-based examinations could take place as early as the Spring of 1993. The intervening time of six months is insufficient to analyze the extent to which each of five simulators deviate from the requirements, to prioritize, plan, correct, test and accept the resolution of the identified problems, as well as to allow time for all candidates to practice the events with the new features. At best a few minor problems can be corrected in the above time-frame. Approximately one year will be needed to prepare a detailed action plan to correct all agreed deficiencies, and to resolve the high priority problems that do not involve major hardware and/or software changes.

The authors' expectation is that satisfying the testing requirements will be an evolving process over several years. Some of the desired features will take one or more years to implement, and the requirements are very likely to change as more experience is gained with testing process.

High simulator reliability is expected to be a particularly difficult requirement to satisfy, given the age of some of the equipment in the simulators. While the simulator specific equipment can be upgraded to improve reliability, station specific equipment, such as the panel instruments, control and monitoring computers, must correspond to the ones used at the station. Failure rates of such equipment are often higher on the simulator than at the station due to much more frequent on/off cycles, and this type of failure will need to be tolerated during testing, provided the failure does not significantly detract from the intended evolution of the exercise.

Since simulator-based testing is preferred by all parties over the written examinations, it is expected that the requirements for improvements and the work needed to implement the necessary changes will be kept in perspective, so that simulator training, testing and maintenance can all make their contributions to continued safe and reliable CANDU operations.