

# REGULATORY COMPLIANCE AND THE DYNAMIC DATA LIFE CYCLE

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## BACKGROUND ON MODELLING/TESTING

Development of mathematical models, and their use in digital simulation studies is by no means new to the industry. The use of these models to predict the behaviour of individual generators and entire sections of the interconnected North American grid has been ongoing for decades. The Northeastern blackout of November 9, 1965 accelerated the efforts of many utilities, particularly those located in the Northeastern US and Southern Ontario.

The 1990's were a period of renewed interest and emphasis on the modelling of generators and their associated control equipment. The heightened interest was driven by several factors including deregulation of the electric utility industry throughout North America and the blackouts in the summer of 1996 on the West Coast. These events captured the attention of the US Department of Energy, North American Electric Reliability Council, and state regulators and led to the development of plans for mandatory reliability compliance. The Western Systems Coordinating Council (WSCC) Board of Trustees adopted a reliability compact in November 1996. In March 1997 they established a policy group and three task forces to develop a Reliability Management System (RMS) and a proposed implementation plan.

There is a consensus that the data compiled for many of the units on the North American power system is incomplete or does not accurately reflect current equipment status. Whether upcoming testing/modelling activities will produce a significant and sustained improvement, will hinge upon the approach used by the participating utilities. Some utilities are treating the process as a necessary evil. They are participating solely to avoid possible penalties or lose face with their peers. Other utilities see this as an opportunity to define a systematic approach to their maintenance and documentation and establish performance standards for their equipment.

This paper outlines a life-cycle model for testing and documentation that can help your utility improve its overall operation. With this approach, regulatory reporting requirements are met as a byproduct of the process, rather than being the main focus. Compliance is achieved at a reasonable cost with minimal disruption to normal operation.

## THE COMPLIANCE LIFE CYCLE

Even utilities that have been involved in performing wide-scale simulations based on detailed dynamic data have done so based on a series of "snapshots" of their systems. The data collected represented the status of the system at a particular instant in time. The validity of this snapshot was always questionable because there was no change control process in place to ensure that settings and configurations were maintained. Operators could change the operating status of the unit (e.g. transferring from AVR to Manual control of excitation) or maintenance staff could change control settings without fully appreciating the effect on a generator's interaction with the power system. In extreme cases, wholesale equipment changes were made without communication of the changes to the personnel responsible for maintaining the data and performing system studies.

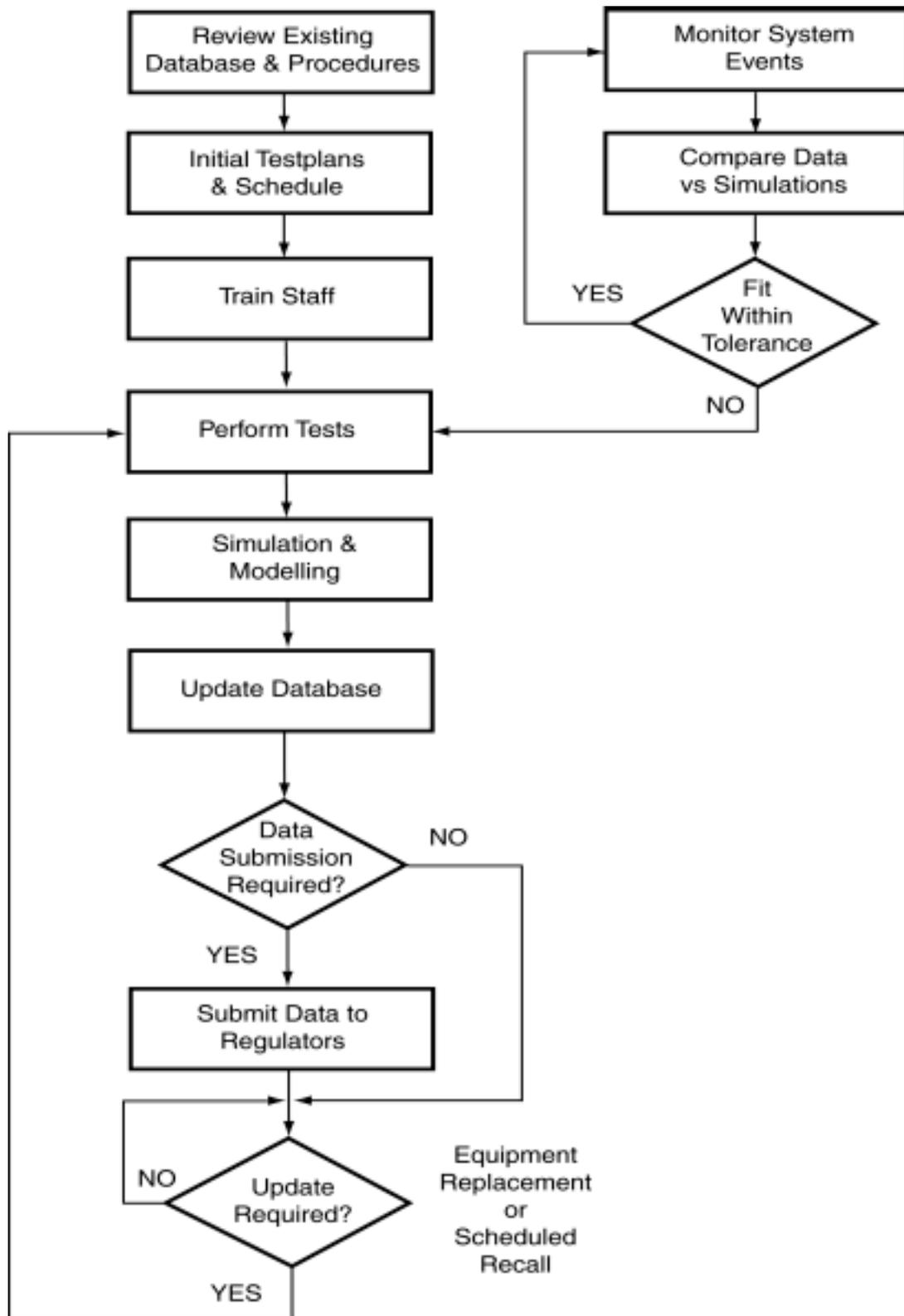
The emphasis of this paper is to promote an approach whereby a living database of equipment status and performance information is created. The database is constantly in a state of transition reacting to changes in the system as they happen. In this model, testing is triggered by events such as equipment changes or maintenance cycles rather than arbitrary time periods. Engineering judgement and cooperation between all levels of an organization is used to reduce unnecessary testing or duplication of effort. Improved communications and staff training are the cornerstones of this process.

Figure 1 is a simplified flow chart that summarizes the process. Prior to embarking on any data collection or testing, you need to create a roadmap that will guide all of the subsequent work. Your organization should tailor this process to take advantage of its strengths while capitalizing on available expertise that can help accelerate its progress in other areas. The following sub-sections describe each of the stages in detail.

For utilities with limited experience in testing or dynamic simulation, this process will seem daunting at first glance. For others it is simply an extension of existing initiatives. In either case, moving towards the process described in this paper will yield benefits.

This paper concludes with an overview of the benefits and risks associated with compliance testing.

FIGURE 1: DYNAMIC DATA COLLECTION AND COMPLIANCE CYCLE



## Review of Existing Data and Procedures

Prior to embarking on this work program it is important that you review the existing state of preparedness of your organization. It is difficult for the organizer of any compliance program to be in regular contact with all of the technical staff involved in simulation, data collection or testing. As a result, valuable information may be overlooked. By identifying all of the stakeholders at the beginning of the process you can avoid the risk of “re-inventing the wheel”.

At this stage you should try and answer the following questions:

- What kinds of tests are performed when generators are first commissioned?
- Do you have centralized testing expertise, do you rely on expertise in each plant or do you rely on manufacturers and consultants?
- Do you have documented change control processes? In other words, if generator equipment or settings are changed, are the changes reviewed and approved in a consistent manner?
- What internal documentation is available and who are the custodians?
- Who uses the data?
- What kinds of simulation studies are performed and what tools are available?

In obtaining answers to these questions you should be able to identify your utility’s strengths and weaknesses. You will also be generating the list of stakeholders that will be involved in the process. This is critical to your eventual success, because this process is multi-disciplinary, requiring cooperation between many different levels within the organization.

## The Dynamic Database

If a database is already in use within your organization, this will obviously be your starting point. Even for utilities that regularly perform simulation studies, these databases are often incomplete. The most common areas where existing databases are deficient are:

- Information on steady-state capabilities (i.e. active and reactive output capabilities) is not integrated with data on generator controls and equipment status.
- Data sources and dates are not identified. It is critical that the database include pointers to the source of the data (e.g. test reports, manufacturer’s data, equipment status reports, operational data, disturbance records)

- Data is reported using non-standard definitions, models or terminology.

If a database is not currently in use within your utility, it is a good idea to “shop around” before deciding to create one from scratch. Many large utilities have already created databases incorporating information-sharing requirements within their Region or Council. Purchasing a commercially available database or joining forces with other organizations may make economical sense.

At the project definition phase select the simulation tools that will be used during the modelling process. By creating models in a form that can be directly entered into your commercial simulation package, the need to translate models from one format to another, a common source of errors, is eliminated.

Another important step at the project definition phase is the selection of the standards and guidelines to be used during the modelling phase. For excitation systems, definitions are provided through the IEEE Excitation System Subcommittee. References [1-3] provide definitions and standard models for representation of most commercial excitation system configurations. The situation is not as clear-cut for selecting standard models of governors, however References [4-6] provide a good sampling of the common structures available in most commercial programs. The use of custom “user-defined” models should be discouraged wherever possible, since they are more difficult to maintain and exchange with other groups.

Once the structure of the database has been defined, a well-designed survey is often a good tool for collecting data. Conversely a badly organized survey can actually do more harm than good. For example, asking station personnel for mathematical models of generator control equipment rarely produces any meaningful results and reduces confidence in the process. Carefully identify what information you should ask for from each stakeholder and provide them with tools (e.g. definitions of terms) and reasonable deadlines. The survey format should allow for electronic data entry and match the database format to reduce transcription errors.

Once this initial pass is complete, you will be in a position to accurately assess your actual test requirements.

## Development of Testplan and Schedule

The results of a system-wide survey can be used to prioritize the test schedule. Large stations with little or no available data are obvious candidates for early testing.

The survey should also allow station staff to identify maintenance or equipment replacement schedules. Nobody benefits from tests performed on obsolete equipment scheduled for replacement. There can be a significant economic benefit to harmonizing compliance testing with plant outage schedules. In some cases, the costs of adding these tests to an existing workplan will be almost negligible.

Depending on the available resources at a given plant site, it may be possible to obtain some of the required results using the station’s operating and maintenance staff by integrating the tests into the normal dispatching of the units. For example, reactive capability tests can be performed at a variety of different active power levels during a normal run-up or following an outage. The existing station transducers can be used to provide the measurements as long as they have been calibrated against known references prior to the test. The advantage of using your operating staff to perform these tests includes:

- Familiarizes staff with the actual capabilities of the unit in a controlled fashion
- Minimizes disruption to normal unit operating schedule
- Allows tests to be performed during appropriate system conditions. For example under-excited capability tests can be run during light-load conditions (e.g. at night) when system voltages are normally high, allowing the unit(s) to absorb reactive power without reducing voltages below acceptable levels

Tests that require expertise not normally available within your plants may require coordination and supervision by your organization’s specialist or an

outside consultant. Give plant maintenance staff enough preparation time and training to participate in the tests so that they can increase their involvement during subsequent cycles.

Include controlled copies of the testplan for each location in your database, and treat them as a resource for future testing and troubleshooting. Update and correct the plan based on test experience and whenever required based on changes to plant equipment or settings.

**Staff Training**

A critical stage of this process, and one that is frequently overlooked is training of staff. Regardless of whether the tests are performed by in-house specialists or outside consultants, this provides an excellent opportunity for training of Operations and Maintenance personnel. Our experience has shown that even experienced station staff can benefit from sessions dealing with the design and operation of generator controls, power system operation and synchronous generator reactive capability. This training can take the form of classroom sessions, practical training during testing, Computer-Based Training (CBT) or combinations of these three. A combination of these three approaches is usually used due to the advantages and disadvantages listed in Table 1.

Combining these three different training techniques can provide all of the advantages and reduce or eliminate the disadvantages.

**Table 1: Training**

<b>Type of Training</b>	<b>Advantages</b>	<b>Disadvantages</b>
classroom	<ul style="list-style-type: none"> <li>• opportunity for in-depth training</li> <li>• allows for detailed questions/answers</li> <li>• allows interaction with other staff with different expertise and experience</li> </ul>	<ul style="list-style-type: none"> <li>• limited practical learning opportunity</li> <li>• training is only as good as the instructor</li> </ul>
test sessions	<ul style="list-style-type: none"> <li>• best practical experience opportunity</li> <li>• information is directly applicable to operation</li> </ul>	<ul style="list-style-type: none"> <li>• limited opportunities for questions</li> <li>• limits number of staff that can participate</li> <li>• scheduling can be difficult or impractical</li> </ul>
computer-based	<ul style="list-style-type: none"> <li>• allows all staff to participate, regardless of shift schedule</li> <li>• self-paced</li> <li>• low-cost refresher training</li> </ul>	<ul style="list-style-type: none"> <li>• trainee’s computer skills may limit their ability to participate</li> <li>• no direct feedback and limited opportunity to get answers to questions</li> </ul>

**Table 2: Test Participant Duties**

<b>Participant</b>	<b>Duties</b>
Test Coordinator	<ul style="list-style-type: none"> <li>• coordinate activities of all other participants</li> <li>• overall authority to make decisions on tests</li> <li>• point of contact for system operations</li> <li>• safety coordinator</li> </ul>
Senior Operator	<ul style="list-style-type: none"> <li>• control dispatch and operating status of unit</li> <li>• monitor station auxiliaries and inform Test Coordinator of potential problems/conflicts</li> <li>• communicate test plan and status to System Control Center or Regional Operating Authority</li> </ul>
Technical Consultant	<ul style="list-style-type: none"> <li>• provide technical guidance on all aspects of tests</li> <li>• provide specialized test equipment and supervise installation</li> <li>• collect data for use in reporting/simulations</li> </ul>
Maintenance Staff	<ul style="list-style-type: none"> <li>• calibrate station instrumentation required for tests</li> <li>• arrange for temporary interconnection points for test equipment and transducers</li> <li>• make connections to station equipment</li> <li>• assist Operators in monitoring station equipment during tests</li> </ul>

**Execution of Tests**

After all of the preparation and advance discussions, the actual tests can be somewhat anti-climactic. In terms of duration, this part of the process may take the least amount of time. It is important that everyone involved in the tests has a role, and understands the role of the other participants. Typical participant duties are listed in Table 2.

Start tests with a brief meeting to review the expected outcomes, possible problems and remedial actions. A meeting after completion of all of the tests can also be invaluable in identifying portions of the test procedure that require changes or problems with equipment requiring follow-up. This will help avoid a common complaint of station staff, that they are left out-of-the-loop after tests are completed.

**Modelling and Simulations**

One frequently encountered problem is that staff involved in station maintenance and testing, and those involved in the simulation of the data and modelling of the equipment have difficulty communicating. Even if you plan to use an external consultant to take the lead in the analysis of the data and modelling, allow your simulation staff the opportunity to gain valuable practical experience. Allow them to attend training sessions and tests, participate in the simulation of the results and submission of the data, and review test reports.

The real benefit of their involvement will be realized through their ability to identify incorrect data or erroneous simulation results in their future studies. The contacts that they make with station staff will open up much needed lines of communication.

**Updating of Dynamic Data and Initial Submission**

As we have emphasized throughout this paper, the submission of dynamic data and compliance information to the appropriate regulatory body should not be considered as the end of the process. Rather it is simply a byproduct of the life cycle process. For utilities with established testing and modelling programs the previously described steps will already be part of their business process. For these groups the focus will be on tailoring the available data to meet regulatory reporting requirements.

To minimize overall costs, arrange the data collection process so that the required forms or electronic submissions do not require any translation or re-entry of data. Eliminating data re-entry will reduce needless re-verification by technical staff. Organize the database so that non-expert staff can readily extract information at any time rather than requiring preparation at each submission deadline.

**Equipment Performance and Dynamic Data Maintenance Responsibilities**

Much of the debate surrounding the implementation of the new standards has surrounded the selection of the re-verification interval. A fixed interval (e.g. five years) leads to the data being treated as a snapshot of the system state at these points in time. The validity of the data at any other point in time is always in question since most staff will move on to other tasks and deadlines.

A more logical process involves treating the “database” as a living entity constantly in a state of change based on the status and settings of equipment on the system.

In order to implement this approach a certain infrastructure is required. Some of the key elements are listed below:

- Database Accessibility – Make the data accessible to as many staff as possible, in a form that it is clear to a wide audience. Relating the physical equipment settings (e.g. AVR potentiometers) to the corresponding model parameters in a transparent fashion will allow station staff to understand the implications of their actions when they need to make changes. Identify and label critical settings or components.
- Change Control Process – Implement a simple process to allow station staff to inform stakeholders of changes, seek approvals, and trigger the required changes to models.
- Assignment of Responsibilities – Delegate the responsibility for maintaining the integrity of the data to stakeholders throughout the business. At the stations, assign maintenance staff the responsibility to automatically identify equipment problems that could potentially affect overall performance and data validity. Staff at the system operating level, should analyze power system events for evidence of suspicious behaviour. Staff responsible for scheduling equipment outages and modification/replacement of equipment should ensure that the required tests and updates are triggered.

With this type of infrastructure in place it should be possible to move away from scheduled test intervals toward event-driven testing and re-verification. You can respond to requests for compliance data at any time by simply accessing the database. This process enables the use of engineering judgement in assessing the need for regular testing. For example, settings are less likely to change on newer digital equipment than on systems that use older analog-electronic or mechanical components to implement control functions.

### **Monitoring of System Operation and Updating**

A key element of the process required to move from routine testing intervals to event-driven testing is developing a power system monitoring infrastructure. Some utilities past attempts at developing this type of infrastructure were not entirely successful due to the high costs of recording equipment and wiring, and the lack of business drivers. Also, the analysis often focussed on reproducing wide-scale disturbances spanning many utilities. The cost of developing this infrastructure has been greatly reduced in recent years by the installation of digital control and monitoring equipment and networking capability within stations.

Many pieces of station equipment (e.g. exciters, governors, relays, operator interfaces) now have the capability of capturing digital data records of system events. Following system events, you should collect

data from these sources and compare against the simulated response for each unit/station obtained using the current database information. If the results match within a reasonable tolerance document this in the database, eliminating the requirement for scheduled staged testing. If you cannot resolve differences between simulated and measured data then tests can be scheduled to correct the database or problems within the equipment.

### **Building Compliance Into the Business**

The long-term costs of implementing this process can be greatly reduced if it is built in to other business activities.

For example, review equipment purchasing specifications, modifying them to take into account compliance testing and data monitoring requirements. A governor or exciter with a built-in step-test facility and data recording feature can be tested in a fraction of the time required for a unit without these options. Make sure that digital controls include communications and human interface software to allow data to be readily accessed following system events. Another example of compliance-friendly elements of digital controls, is password-restricted access that protects the integrity of key settings.

Integrate compliance measurements into maintenance routines so that costly outages for testing are not required. Simple tests applied during return-to-service of equipment will ensure that performance has not been changed

### **BENEFITS AND RISKS**

A conventional cost-benefit analysis is of very little use in determining the appropriate level of effort. Critics of compliance requirements point to the fact that widespread system disturbances are infrequent. While this is true, North American industry and households are highly dependent on electricity and even short duration interruptions can result in very high costs and public backlash. The possibility of increased government regulation of the electricity industry was sufficient to convince most WSCC members to participate in the development of their compliance process.

Avoiding government intervention or economic penalties imposed by regulators is not the only reason to enter into this process, although corporate risk management policies may guide some utilities in this direction. A positive view of the situation is that the following collateral benefits will provide adequate justification.

- Identification of latent defects. Controls such as excitation limiters are rarely called upon to operate, but failures can lead to unnecessary trips,

damage to equipment or cascading of disturbances to other parts of the power system.

- Improvement in system capability. As confidence in system models improves, margins on operating security limits can be reduced potentially leading to increased opportunities for exports, and improved usage of transmission facilities.
- Improved staff training. Staff involved with testing and vigilant for changes to equipment performance can identify small problems before they become significant. If training is integrated into the process, improved job satisfaction is often an additional benefit.

Concerns over risks to the generating equipment and power system are legitimate and must be addressed at every stage of the process. Employee safety and protection of equipment are of paramount importance and must never be compromised in an effort to collect or validate data. There is no question that when power system equipment is operated outside of its typical range, problems may be uncovered due to latent defects or improper coordination between controls and protective equipment. Uncovering these defects under controlled circumstances will almost always result in fewer problems than during abnormal system operating conditions and widespread disturbances. Examples of steps that you can take to minimize risk include:

- Test/review all protective relay settings prior to testing controls and limiters. Equipment damage is highly unlikely if protective relays are functioning properly. A review of the settings by the test engineers will ensure that they are aware of any unusual operating limitations at the plant.
- Never remove protective relays or limiter functions from service to permit operation over a wider range during tests. If settings are not appropriate or do not allow the unit to satisfy compliance requirements, changes need to be processed through proper channels following a thorough review.
- Ensure that all staff are aware of the expected outcome of each test, and understand the steps that should be taken if the test fails.
- Use engineering judgement to extrapolate available results to avoid unnecessary tests. For example, if reactive output limits cannot be demonstrated due to system voltage limitations, calculations can be used to accurately extrapolate available data to obtain the required limits.

Through the use of common sense and by learning for other utility's past experience in this area, tests can be performed with minimum risk, and a maximum probability that the required data will be obtained.

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