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data integration/exchange

part 1: existing technical and business opportunities

THE DEREGULATION OF THE electric utility industry combined with development of advanced technology has raised many questions as how to make the power system operation more cost effective while preserving a high level of reliability and security. The utilities are developing different strategies for achieving this goal, enabling them to stay competitive. Many other new businesses are being formed to take advantage of the new opportunities in the marketplace. This article provides an overview of the possible new technical and business opportunities and benefits in developing advanced strategies for data integration and information exchange.

The Requirements for Staying Competitive

While the restructuring of the utility industry introduces many unknowns about the future electricity market design and organization of the power grids in the United States, a few rather obvious requirements for any business entity to stay competitive in the utility industry can be easily recognized as follows.

- ✔ Ability to manage the assets as efficiently as possible. Many in the business have recognized this requirement, but efficient solutions are still being sought. The goal is to associate asset management decisions with the risk taken when operating the system and to optimize the risk while maintaining the lowest maintenance cost.
- ✔ Capability to maintain an uninterrupted quality service under any anticipated contingency. Maintaining quality service becomes now a focal point for creating a competitive edge in the new customer-focused environment.
- ✔ Flexibility in developing new business strategies for profitable market participation. The electricity markets are evolving and a major requirement of a competitive business entity is to have full and timely access to the required information, enabling it to adjust its strategies for market participation quickly and effectively.

While many other considerations and related requirements may be defined, a successful business strategy has to be able to address the above-mentioned requirements comprehensively. This study was aimed at "discovering" new approaches to achieving this goal. The focus of the investigation was on the role of data integration and information exchange in developing new technical and business opportunities in the deregulated market place. We will revisit the system security issues and illustrate possible enhancements that can be derived from the new data and information infrastructure.

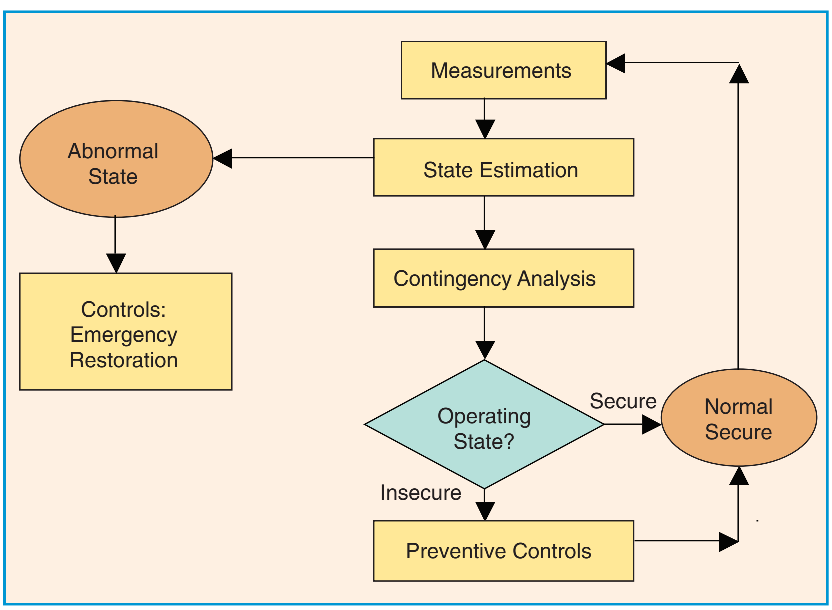

figure 1. Layout of current power system operation and security analysis paradigm.

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New Paradigm for Power System Operational Security

Establishment of modern control centers equipped with supervisory control and data acquisition (SCADA) infrastructure and an energy management system (EMS) allowed system operators to monitor the power system state and take preventive actions when necessary based on anticipated contingencies. The concept of steady-state security has been at the center of power system operation for the past several decades. This approach to system operation is very effective as long as all possible contingencies can be anticipated and the required preventive controls can be implemented in a timely fashion. Uncertainties in power system operation and cascading failures may, however, lead to situations where existing security measures cannot cope. In such a case, the system will be driven into an emergency state and the control actions are typically local, initiated by the protection system at the substations. Figure 1 illustrates the static security analysis and the emergency/restorative controls. Note that, under emergency conditions, the conventional state estimator will not be functional temporarily until a new postdisturbance steady state is reached.

An alternative paradigm for maintaining system security is shown in Figure 2, where a fast tracking tool is used to predict the short-term trajectory of the system state and attempts to navigate the state back into the secure normal operating region via system-wide coordinated real-time controls. While this is easier said than done, one of the prerequisites for its success is faster and more detailed monitoring of both the dynamic system state and system topology. An integrated data and information exchange system to be implemented using advanced IT solutions will provide this capability at various levels of detail depending upon the application requirement.

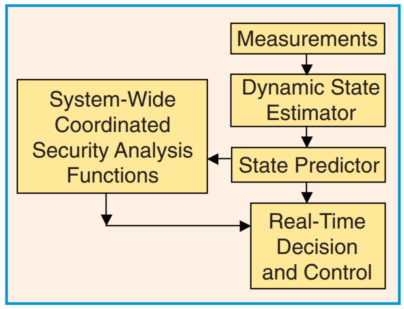

figure 2. Layout of new power system operation and security analysis paradigm.

How to translate this broad view of the benefits of exploring a different use of data and information becomes clearer when the existing infrastructures for data collection and information processing are analyzed in more detail. As a result, new uses of data and information may be defined producing new value for the users.

In order to put the above discussion into better perspective, two new applications, namely a comprehensive fault and disturbance analysis and a novel two-stage state estimation, will be presented as illustrative examples of how additional benefits can be obtained through assigning new business value to information and data.

The Value in an Automated Fault and Disturbance Analysis

The traditional fault and disturbance analysis is a postmortem function primarily performed by protection engineers and aimed at monitoring the performance of protective relays and related fault-clearing equipment at the instances of faults and other disturbances. The value of data and information in this case can be uniquely associated with the needs of protection engineers. This approach leads to deciding on a specific level of investments in the data collection and information processing equipment as well as establishing a specific criteria for evaluating the expected returns. When exercising this judgment in the deregulated (competitive) environment, the outcomes are rather well known: the preference is to abandon any specialized recording equipment, such as digital fault recorders or sequence of event recorders, and place an emphasis almost exclusively on the use of digital protective relays. Two motivating factors are almost always used to justify such a decision: since the digital relays provide a wealth of information such as operator measurements, digital fault recording function, fault locating function, and sequence of events function, it is clear that they provide the greatest return on investment. In making such decision, some subtle facts associated with the value of data and information obtained from the other equipment are commonly ignored or devalued.

- ✔ It is widely known that the digital fault recording function in a digital relay has a more narrow frequency bandwidth in recording analog waveforms than the one provided by a digital fault recorder (DFR), which may produce less capabilities when analyzing the behavior of analog waveforms during disturbances.
- ✔ The fact that DFRs record data across the entire substation in a synchronized way, which is hard to obtain with digital relays today, makes the temporal and phase-angle-related analysis across the substation easier by using data from DFRs than from digital relays
- ✔ It is well known that the replacement of the entire protective relaying infrastructure with digital relays is still at least 5–10 years away in most of the utilities. The location of digital relays is still rather sparse, impairing the ability of relays to accurately determine fault location on the lines not covered by digital relays, while the use of DFR data can help with this process.
- ✔ While DFRs are recording the inputs to the relay, hence enabling the comparison of relay operation knowing what the relay has "seen," using data from digital relays alone leaves one with an option to only speculate what the actual inputs were at the time of relay operation.

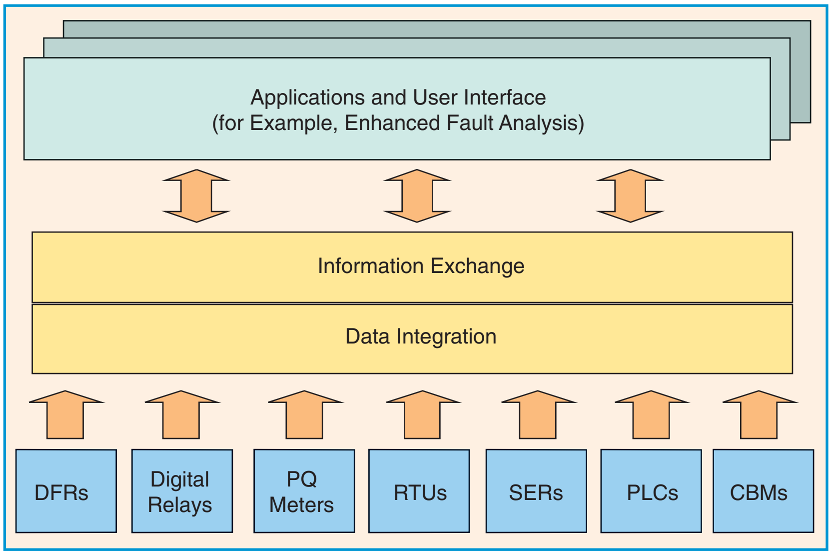

figure 3. The equipment setup for comprehensive fault and disturbance analysis.

We will now try to illustrate how the value of data and information associated with using a combination of equipment can be enhanced if a new approach to data integration and information exchange is implemented. The key to the new approach is automating the process of data integration and information extraction as well as serving multiple users by utilizing the same data but customizing the information to the needs of the specific user.

To illustrate the point, a comprehensive approach to automated fault and disturbance analysis is shown in Figure 3.

It may be noted that selected IEDs in Figure 3 provide detailed information about the following situations.

- ✔ Power quality disturbances. The main source of the data is power quality (PQ) meters, but combining the information about relay operations can explain some important power quality disturbances such as voltage sags induced by relaying operation. An example of such an implementation is referenced in the "For Further Reading" section.
- ✔ Fault type and location. Utilization of several types of equipment can contribute to better analysis of faults. Besides using digital protective relays (DPRs), using data from DFRs, remote terminal units (RTUs), sequence of event recorders (SERs), programmable logic controllers (PLCs), and circuit breaker monitors (CBMs) enables implementation of a system-wide technique for determining fault location in the case when only sparse measurements are available. The "For Further Reading" section references such an approach.
- ✔ Operation of protective relays. The main source of information is DPRs, but the information from other intelligent electronic devices (IEDs) is invaluable in determining what were the inputs to the relay (using DFRs), what were the consequences of relay operation (using CBMs), and what was the overall system impact of relay operation (using RTUs).
- ✔ Operation of circuit breakers. Many different aspects of circuit breaker operation can be captured by different IEDs shown in Figure 3. CBMs can allow close monitoring of the control circuitry (trip initiate, close initiate, A&B contacts, X&Y contacts, etc.), DPRs can monitor circuit breaker duty (I^2t), DFRs can monitor the sequence and timing of protective relay and CB operation as well as the corresponding interruption of currents, PLCs can provide details of autoreclosing operation and breaker failure actions, etc.

The information has to be extracted from the data recorded by separate IED types and integrated for this purpose. The collection of data, its integration, and processing need to be done automatically to have a full benefit. Once the data is processed, the obtained information needs to be packaged in appropriate reports aimed at serving several different groups in the utility. The value of data and information is now quite different from the original (traditional) uses. The new value is in serving multiple users and enabling them to obtain new benefits as follows.

- ✔ The managers responsible for reliability and efficiency of the power system operation. This group can get a very comprehensive view of the cause, performance, and consequence of equipment operation. It is important to recognize that only the data acquired by multiple IEDs are allowing this information to be extracted. Without the proposed data integration and information exchange the benefit of making more informed decision would not be readily available.
- ✔ Protection engineers responsible for performance of protection relays and related fault-clearing equipment. Besides the traditional benefits, the relay engineers get more comprehensive understanding of the relay inputs, relay operation, and its consequences, including the performance of fault-clearing equipment. Obtaining this information in real-time with an extensive capability for automatically keeping the historical records enables protection engineers to track down and fix the problems more efficiently, resulting in improved reliability of power system operation.

- ✔ Maintenance crews responsible for performance of the circuit breaker operation. There is a totally new use of mentioned data where the maintenance crews can now get far more comprehensive understanding of CB behavior using the condition-based data from multiple IEDs. All of this is available automatically and almost instantly after the breaker operates, allowing for development of a more cost-effective "just-in-time" maintenance strategy.
- ✔ Customer service representatives responsible for quality of power supply and fulfillment of power delivery contracts. This new business opportunity can be fully explored with additional data allowing the customer services to be expanded and improved. Including a range of performance assessment functions related to the quality of power delivery and performance of equipment

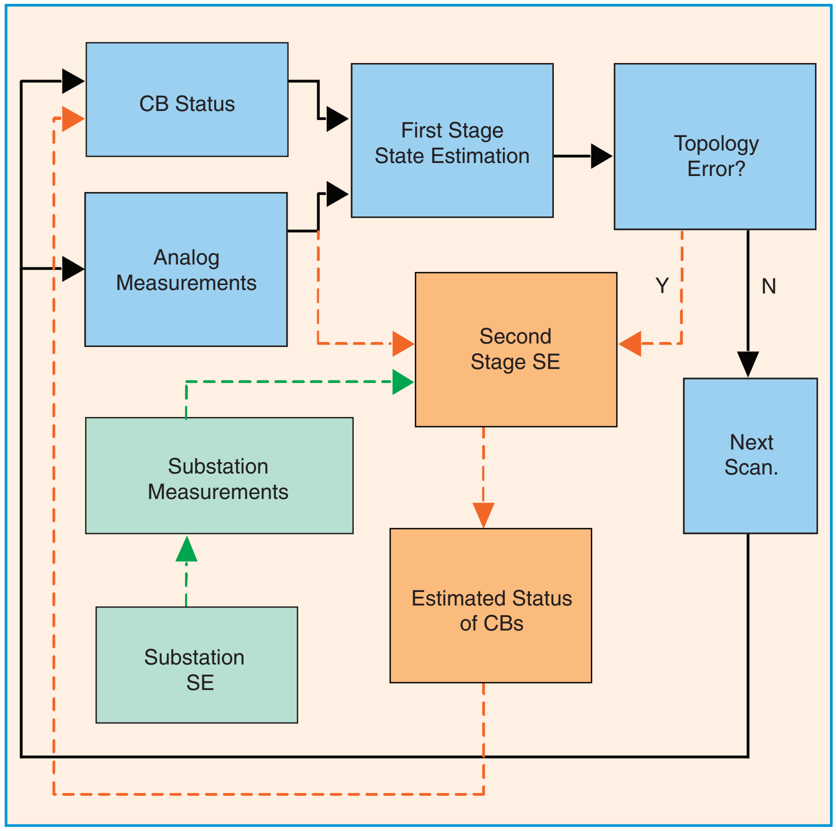

figure 4. Two-stage state estimator software flowchart.

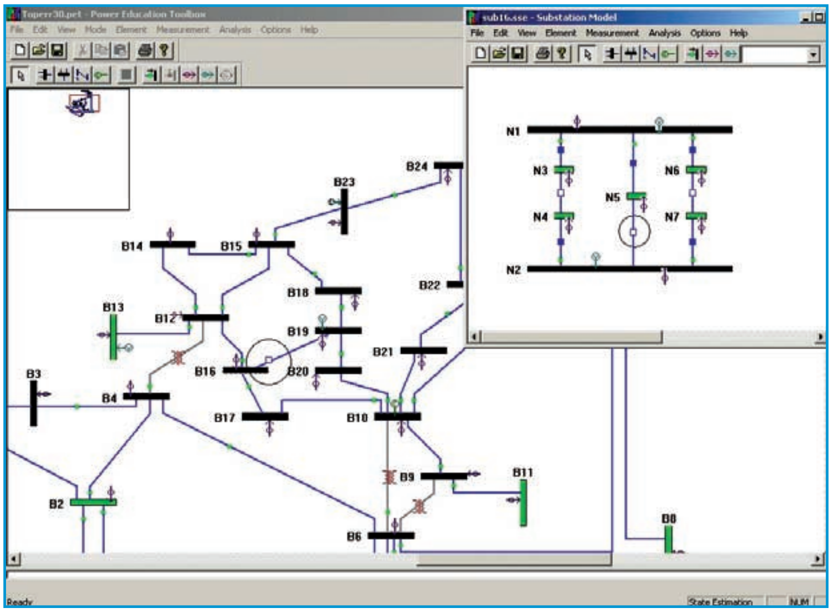

figure 5. Two-stage state estimator user interface.

operation opens new business opportunities in the customer service and support area.

- ✔ Dispatchers responsible for locating the faults and restoring the system operation. This group of users has traditionally used the RTU data and SCADA functions to extract information relevant to alarm processing and determining the fault location. The use of additional IED data can alleviate the need for traditional alarm processing and significantly improve the fault location capability enabling dispatchers to restore the system much quicker.

As a conclusion, the new value of data and information puts the issue of investments in the equipment and related benefits in a totally new perpective. It is now very important to decide how the integration of data and information exchange may benefit multiple users. The investment judgments can now be made based on the business value of new automated solution for comprehensive assessment of faults and disturbances benefiting multiple groups of utility personnel.

The Value in a Two-Stage State Estimation

Traditionally, state estimators make use of analog measurements of the line power flows, bus injections, and voltages in order to determine the system state. The information about the network model is obtained from the topology processor, which provides the one-line diagram of the system based on the monitored status of circuit breakers at each substation. If a change in the status of any of the breakers is inadvertently not reported to the control center, then the network topology processor will build the wrong network model. This model is shared by all the application functions at the control center, including those that are responsible for maintaining system security. Hence, any improvements in maintaining the correct real-time network model will directly reflect on the security of the system.

Consider the state estimator that is run at a control center and receives measurements every few seconds scanned by the remote terminal units (or IEDs) from substations. Since the data collected and processed at a substation for various purposes including protective relaying, limit monitoring, revenue metering, power quality monitoring, etc., are overwhelmingly voluminous, only a subset of it is actually telemetered to the control center for purposes of state estimation. In the case of topology errors, the amount of measurements and information ordinarily received by the state estimator may not be sufficient to identify where the error actually is. So, those substations suspected of having topology errors can be polled for more detailed data. This provides a means of tapping on to the advantages of having an integrated data and information system already set up at the substations.

Figure 4 shows the data and information flowchart for such a state estimator. The estimator runs as a conventional state estimator unless a substation is suspected for having a topology error. In case a substation is suspected for topology errors, it will be polled and detailed information and data are requested. A second stage estimation will then be carried out using the detailed data and information for the suspect substation. The correct estimates for all the substation circuit breakers can thus be obtained.

A prototype program that simulates this setup is implemented and tested. Figure 5 shows a snapshot taken during the execution of this program. The network diagram for a 30-bus system and the detailed view of a single suspect substation model is shown. State estimator is executed using the detailed data and information received from substation 16, while maintaining the compact bus-level models for the remaining substations. Incorrect status of individual switches or circuit breakers inside the suspect substation can thus be determined.

Additional benefits of data integration and information exchange for the state estimators exist for the following functions.

- ✔ Improved calibration of measurements. Aging instruments will deteriorate gradually, introducing drifts and biases in the measured values. This necessitates periodic calibration of the meters. Instead of physically calibrating the instruments, an error compensation procedure can be developed in order to correct the meter readings remotely. This procedure requires continuous and detailed data and information from the corresponding substation.

- ✔ Tuning of measurement weights. Measurements are weighted based on their accuracies, which are typically assumed based on manufacturer's data. Detailed monitoring of significant quantities at the substation will facilitate the tracking of changes in the accuracies of meters and incorporate this information into the assignment of measurement weights. This will also enhance the bad data-processing function in the state estimator.
- ✔ Ability to implement dynamic state estimation. Dynamic state estimation, which requires faster and more detailed data and information processing, will benefit from the availability of such capability. Scan rate estimation may be possible with a properly implemented advanced substation data and information exchange system.

Up Next

The second part of this article, to appear in the May/June 2004 issue, will investigate future trends and expected improvements and new opportunities that can be achieved by them.

For Further Reading

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Biographies

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