Appendix B5:
A Systems View of the Modern Grid

IMPROVED INTERFACES AND DECISION SUPPORT

Conducted by the National Energy Technology Laboratory
for the U.S. Department of Energy
Office of Electricity Delivery and Energy Reliability
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Reliability

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EXECUTIVE SUMMARY

We urgently need a fully modern power grid if we are to meet our country's growing requirement for power that is reliable, secure, efficient, economic, safe, and environmentally responsible.

To achieve a modern grid, a wide range of technologies must be developed and implemented. These technologies can generally be grouped into five key technology areas as shown in Figure 1.

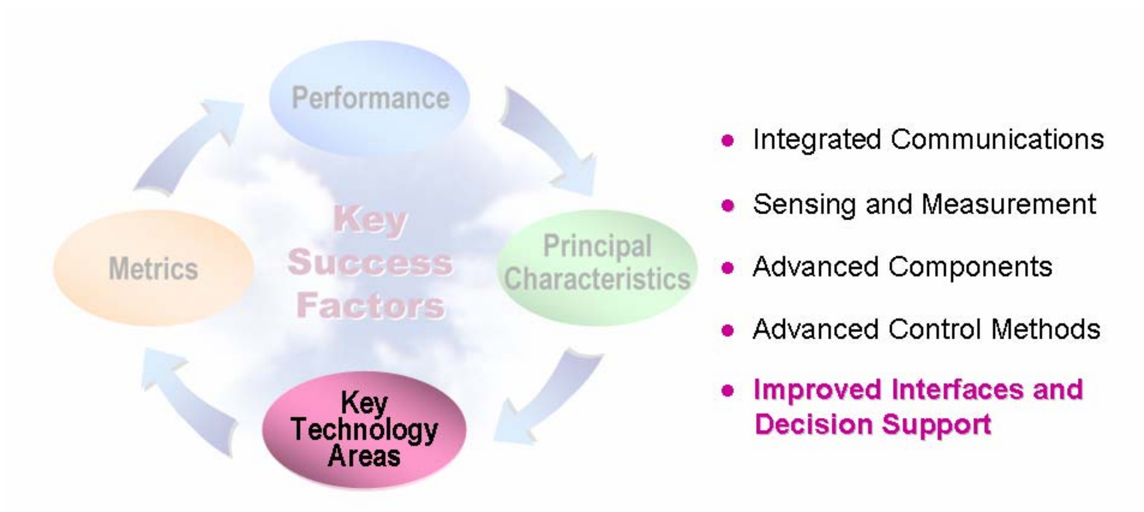


Figure 1: A Systems View of the Modern Grid provides a direct approach to a total system solution.

Improved interfaces and decision support (IIDS), the focus of this paper, are essential technologies that must be implemented if grid operators and managers are to have the tools and training they will need to operate a modern grid.

IIDS technologies will convert complex power-system data into information that can be understood by human operators at a glance. Animation, color contouring, virtual reality, and other data-display techniques will prevent "data overload" and help operators identify, analyze, and act on emerging problems.

In many situations, the time available for operators to make decisions has now shortened from hours to minutes, sometimes even seconds. Thus, the modern grid will require the wide, seamless, real-time use of applications, tools, and training that equip grid operators and managers to make decisions very quickly.

Here are some areas where IIDS technologies will make a significant difference in the modern grid:

- **Visualization** – IIDS will take vast amounts of data (gathered by other advanced key technologies) and reduce it into the format, timeframe, and technical categories most crucial to system operators. Visualization techniques will present this information in a quickly-grasped visual format to support operator actions and decisions.
- **Decision Support** – IIDS technologies will identify existing, emerging, and predicted problems and provide what-if analyses for decision support. For situations requiring system operator action, multiple options and the probabilities of success and risk for each will be presented.
- **System Operator Training** – Dynamic simulators utilizing IIDS tools and industry-wide certification programs will significantly improve the skill sets and performance of today's system operators.
- **Customer Decision Making** – Demand Response (DR) systems will provide information to customers in easily understood formats that allow them to make decisions about how and when to purchase, store, or produce electric power.
- **Operational Enhancements** – As IIDS technologies are integrated with existing asset management processes, managers and users will be able to improve the efficiency and effectiveness of grid operation, maintenance, and planning.

The IIDS technologies in use today fall short of accomplishing these tasks. Improvements are needed at the human – machine interface to assist operators in comprehending the growing volume of data collected, its availability on a near real-time basis, and the complexity and speed of the advanced control methods that analyze and process this wealth of information (see "Appendix B4: Advanced Control Methods").

In this paper, we will look at the following important topics:

- Current state of IIDS technologies
- Future state of IIDS
- Benefits of implementation
- Barriers to deployment

Although it can be read on its own, this paper supports and supplements "A Systems View of the Modern Grid," an overview prepared by the Modern Grid Initiative team.

Current State

On August 14, 2003, North America experienced the largest power blackout in its history.

Affecting an estimated 10 million people in Canada and 40 million people in the United States, this outage shut down more than 100 power plants and caused financial losses estimated at 6 billion dollars.

The internal control room procedures, protocols, and technologies of the day did not adequately prepare system operators to identify and react in time to prevent the August 14 emergency. In fact, throughout the afternoon of August 14, there were many clues that one of the control areas had lost its critical monitoring functionality and that its transmission system's reliability was becoming progressively more compromised. Clearly, the technologies and training in place at that time did not provide the visualization or decision support needed to manage that scenario.

The August 14, 2003, blackout task force, in analyzing causes of the blackout, emphasized the need for Improved Interfaces and Decision Support (IIDS) technologies. This necessity for better visualization capabilities and decision support tools over a wide geographic area has been a recurrent theme in blackout investigations. However, not enough progress has been made to date: Our power grid remains at risk for incidents of this nature until key technologies of the modern grid are in place.

In the first place, data are not available in the quantity and quality needed for operation of a modern grid. Advancement in grid management and operations is handicapped by these limitations in available data and tools for converting it into timely information.

IIDS technologies need data to function and vast amounts of it to be effective. However, data of the desired type and quality are not yet widely available from as broad an area as needed. In many cases today, the data acquired by multiple isolated systems stay isolated. To increase the effectiveness of this information, it must be shared with and utilized by other subsystems.

One more area needed by the modern grid is visualization for system operator use. Recently, research has been conducted to determine how various techniques, such as color contouring, animation, and virtual reality environments as well as other data-aggregation techniques, can prevent data overload and help operators identify problems, analyze them, and quickly take corrective action. Some of these techniques are already being used for operations, and others have been used for several years by such power system simulators as POWERWORLD™, which uses a power-system simulation engine to present the information calculated by its complex power-system analysis tools.

Another visualization tool has been released by the North American Electric Reliability Council (NERC): the Area Control Error (ACE)-Frequency Real Time Monitoring System. Visualization provided with this tool improves the reliability coordinator's monitoring of ACE and frequency at the interconnection level over a wide area. Additionally, it provides early and automatic notification and alarming for abnormal frequencies, improves the analysis of interconnection ACE-frequency relationships, and reduces from months to minutes the time it takes to search for the root causes of abnormal frequency.

Significant progress is being made by independent system operators (ISOs), who use IIDS technologies to manage the great volume of reliability- and market-information they receive; however, this is only occurring at the transmission level. The use of IIDS applications at the ISOs could be a model for the entire transmission system including those systems not currently operated by ISO's and for addressing the needs of the distribution system.

Overall, the current state of development of IIDS leaves much to be desired. This is of special concern because, as the other key technology areas are developed and implemented, critical IIDS technologies must be in place to enable the human operators to fully utilize the wealth of information and tools that will be available to them.

FUTURE STATE

As we move toward the modern grid, significant additional advances in IIDS technologies will become available to prevent the kind of data overload that would hinder system operators from understanding true grid conditions.

Supporting these technologies will be supercomputers capable of accepting the extensive flow of near real-time data, processing these data through a variety of analytic programs, and presenting recommended actions to the operator in a timely fashion.

Software systems will take more autonomous control actions both at the centralized and decentralized levels when advanced control methods operate synergistically with IIDS technologies. By allowing advanced controls to take on more of the analyses and control responsibilities, the human operators will be free to focus on grid conditions at a higher level. System operators will analyze system-wide parameters and review the automatic actions of new advanced controls, taking action themselves only when needed to override these controls or to handle issues outside the controls' permission sets.

Modern grid technologies will provide the data needed to assess current system status and conditions and predict the probability of future problems. It is the availability and presentation of this quantity of data by IIDS technologies that will allow operators to significantly improve grid performance.

Future operators will have more control options. They will have flexible alternating current transmission system (FACTS) devices on key transmission lines, high temperature superconducting synchronous condensers, adaptive relay settings, distributed energy resources (DER), and demand response (DR) dispatch. They will use IIDS technologies to guide them on how best to utilize these new assets.

Additionally, the diagnosis of power quality (PQ) issues requires that relevant data and sophisticated analyses be available to determine the cause and location of PQ disturbances (whether on the transmission system, distribution system, or on the consumer's side of the meter).

The ability of the modern grid to collect and analyze the necessary real-time data and, through advanced visualization techniques, present the cause of the condition to the operator will greatly reduce the time it takes to resolve PQ issues.

IIDS technologies will also assist in improving the economics of electricity markets. As consumers become engaged in market operations, they too will need access to more information. IIDS technologies will supply the visualization and analysis tools that will interface with consumer-based agents and portals.

Generation, transmission, and distribution operators, as well as consumers down to the residential level will be able to better understand the state of the grid and current conditions of the energy market, allowing them to more effectively participate in it. This widespread participation will improve the economics of the modern grid by creating more efficient markets.

Integration with other enterprise-wide technologies will lead to substantial improvements in information sharing among users. For example, IIDS technologies will utilize a standard information architecture that enables such areas as outage management, weather forecasting, transmission congestion, work management, condition-based maintenance, DR, dispatch of decentralized energy sources, and geographic information systems (GIS) to effectively and efficiently share information.

As IIDS technologies are integrated with existing asset management processes and technologies, system operators and users will be enabled to improve the efficiency and effectiveness of grid operation, maintenance, and planning. Substantial improvements will be seen in the following areas:

- **Spatial analyses** will give a better understanding of the location of human and material assets, leading to improved emergency response.
- **Identification of stressed equipment** will allow action to be taken to reduce stress and prevent equipment outage loss.
- **Assessments of asset conditions** will optimize the utilization of assets and reduce out-of-service times.
- **Understanding the actual loading conditions of equipment** will lead to more accurate predictions of when and where capacity additions will be needed.
- **The application of artificial intelligence** will facilitate the transfer of knowledge from an aging workforce to a new generation of power system workers.

As managers, operators, and users become equipped with advanced IIDS technologies, still more improvements in efficiency will be realized.

We will now look in more detail at three areas where the technology of human interface with power system tools will be further developed and implemented in the modern grid of the future.

VISUALIZATION, DECISION SUPPORT, AND OPERATOR TRAINING

Visualization

The vast amount of information collected and utilized by the modern grid will be one of its greatest assets. These data alone, however, are of little value to the operator in their as-received condition. To be effective, appropriate rule-based algorithms must reduce and simplify the data into the format, time frame, and technical categories most important to the power system operator. This is the role of advanced visualization tools.

System operators will judge the reasonableness of the results generated by the technologies, and they must rapidly intervene when they detect a technology malfunction. IIDS technologies will rely heavily on visualization to provide the essential link between human and machine. These human interface technologies engage the operators and allow them to ensure that modern grid parameters remain within prescribed limits.

Although advances in data visualization have been made, they are yet to be put to power system use on a widespread basis. In fact, because visualization tools remain largely unavailable, it is more and more difficult for operators and others to gain an intuitive understanding of the actual real-time operations and control of the grid. For instance, the August 14, 2003, blackout gave the system operators only 19 seconds to analyze the data and take corrective action. Yet conditions leading up to that event could have been better understood through the use of advanced analysis and visualization tools combined with enhanced training. These tools could have provided the support needed for operators to take sufficient and timely corrective action

Tomorrow's grid will have the needed advanced controls and IIDS technologies to prevent such events. With the modern grid of the future, system information will be presented to the operator using proven human-factors engineering techniques that will incorporate the latest two- and three-dimensional visualization tools and performance dashboards in conjunction with advanced control room designs.

Recent advances in computer hardware and software technology have made it possible to move beyond the simple tabular displays and one-line diagrams in common use today. The ability to draw relatively complex displays at frame rates close to, or even at, full-motion video speeds opens new possibilities for dynamic online displays. For example, animation can produce visually appealing displays of real and reactive flows and line loadings to point out overloads.

The following are examples of several technologies that will aid in the presentation of useful information to the operator:

- **Artificial Intelligence- (AI) driven data reduction** – AI will be utilized in conjunction with advanced control methods to minimize data volume without losing the information needed by the operator and to create the format most effective for human comprehension.
- **Color contouring and animation** – The use of color contouring and animation will be further researched and applied as part of IIDS technologies to increase not only operator speed of recognition but also speed of diagnosis.
- **Rapid refresh** – Advancements in communication and processor speeds will enable rapid refresh and display of real-time conditions so operators can quickly understand rapidly moving trends.
- **Voice recognition** – Advances in this area will increase the speed and effectiveness of the human-machine interface.
- **Virtual reality environments** – Virtual reality techniques will be applied to grid control centers to closely integrate the "thinking" of the operator and the IIDS technologies.

Of these, it is the contour displays that will illustrate spatial data such as bus voltage magnitudes and angles, line flows, or even derived values such as line power transfer distribution. Contours provide a natural encoding mechanism for displaying large amounts of spatial data. The advantage of the contour is that it allows the user to rapidly process large amounts of information and quickly spot developing trends. Thus, through the combined use of contours and animation, the operator will be able to quickly assess how the system state has been changing over a specified period.

Some examples of these visualization techniques are shown in Figures 2, 3, and 4, which follow:

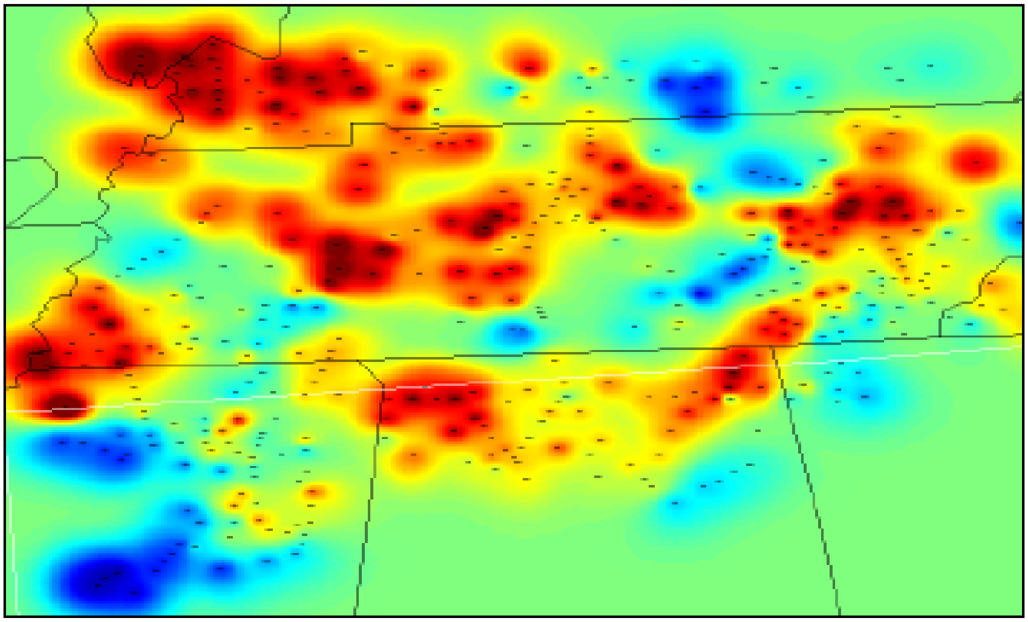


Figure 2: Bus voltage contours. Image courtesy of Tom Overbye University of Illinois at Urbana-Champaign.

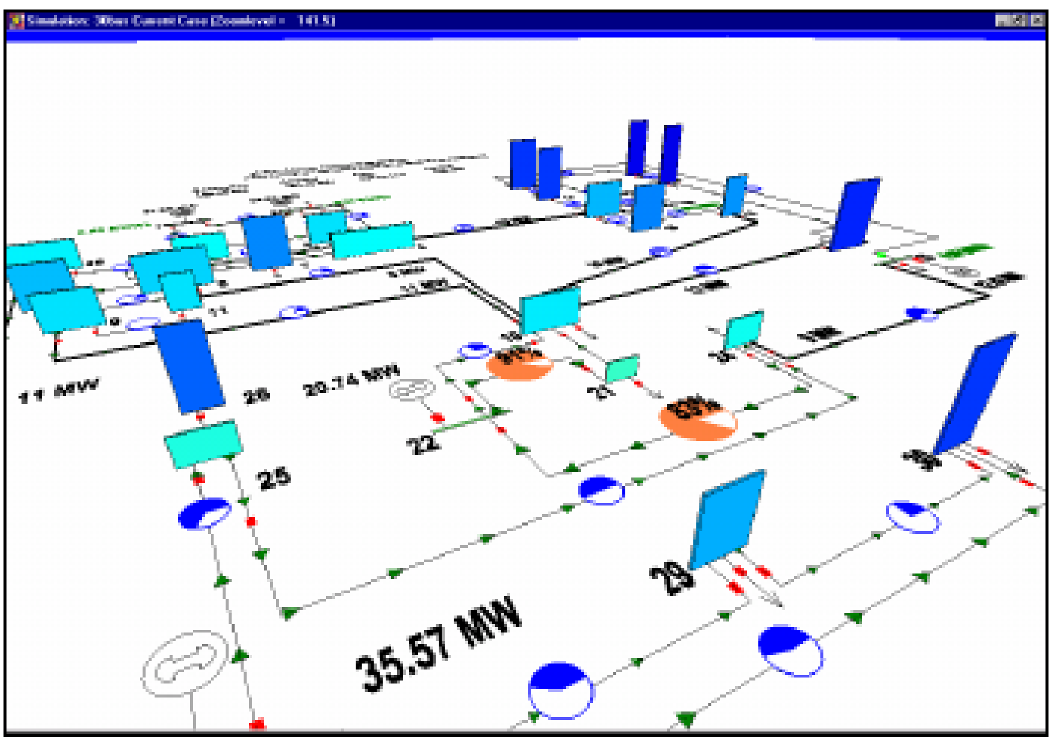


Figure 3: 3-D Visualization. Image courtesy of Tom Overbye University of Illinois at Urbana-Champaign.

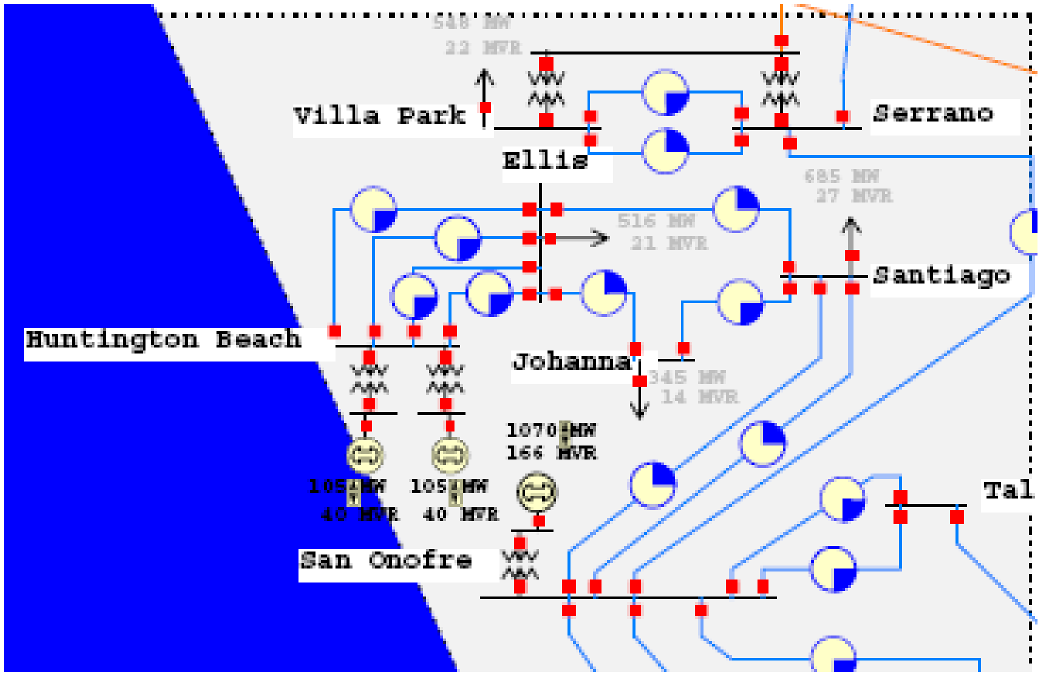


Figure 4: POWERWORLD™ display. Image courtesy of Tom Overbye University of Illinois at Urbana-Champaign.

Before data can be put into visual form, however, data optimization – the reducing, combining, and categorizing of data to eliminate unnecessary clutter – must be performed so that the visualization processes can present the data to an operator using the most effective visual interface.

Online optimization software is currently being demonstrated that transforms complex calculations into an easily visualized graphic format. In the future, software of this kind is expected to be widely accepted and implemented. Figure 5, below, depicts the results of such an online transmission-system optimization program.

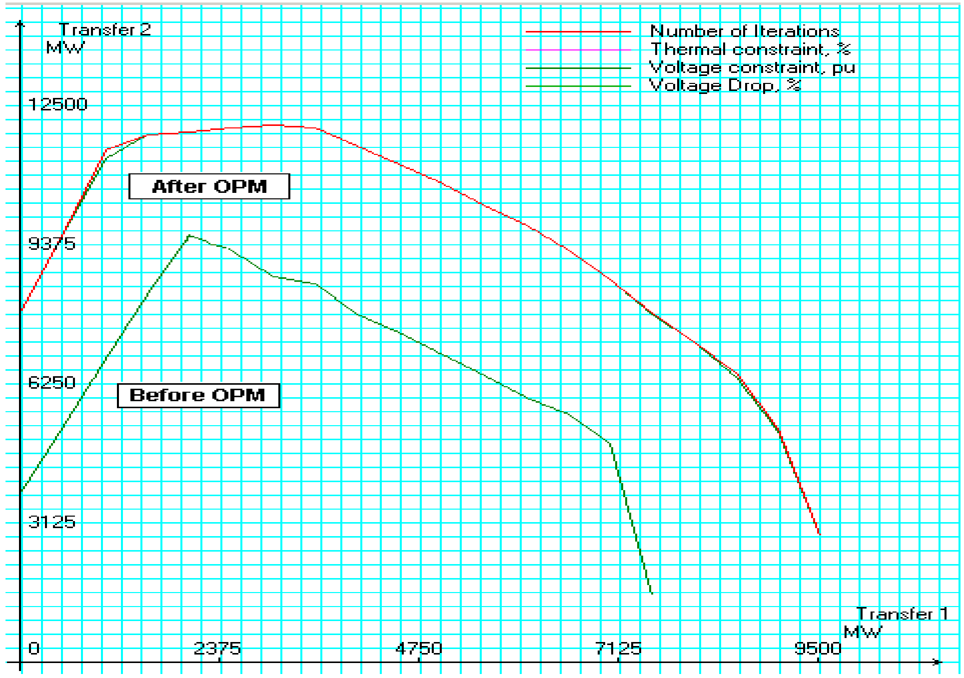


Figure 5: Visualization of online transmission system optimization. Image courtesy of V&R Energy Systems Research, Inc.

Without optimization, the secure region of operation is limited by voltage constraints, but after optimization, the secure region of operation increases until lines become limited by voltage stability.

Using visualization technologies, the system operator may optimize the transmission system by applying control measures such as these:

- MW dispatch
- MVAR dispatch
- Capacitor and reactor switching
- Operation of FACTS devices
- Transformer tap changes
- Line switching
- Adjustment of phase shifter settings
- Load curtailment
- Defined operating procedures
- Switching not-affected lines

In the near future, many new applications will be available that will improve visualization and thus increase the human operator's understanding and speed of comprehension. Here are some examples:

- **Advanced pattern recognition** – Used for intruder detection, forgery detection, biometrics, next-generation computer interfaces, and automatic paraphrasing, translation and language understanding.

- **Advanced speech recognition** – Speech recognition systems are composed of three major functions: Words are captured and translated into a digital signal; speech-recognition algorithm then compares those signals to words and phrases from a pre-set dictionary; and finally, the software offers the most likely match for the spoken phrase. The goal of the speech-to-speech translation (S2S) research is to enable real-time, interpersonal communication via natural spoken language for people who do not share a common language.
- **Haptic interfaces** – Will enable users to generate inputs through hand movements and provide users with tactile and force feedback consistent with what the user is seeing. These interfaces permit users to sense and manipulate 3D virtual objects with respect to features such as shape, weight, surface textures, and temperature. Haptic devices such as haptic gloves, joysticks, and tactile arrays have advanced rapidly and can generate a wide range of force and tactile feedback.
- **Holographic video** – Enables users to observe high-resolution spatial images that can be viewed from any angle as the user moves around the display.
- **Geographic information systems (GIS)** – will create and manage spatial data and associated attributes. The power of spatial information and location has been underutilized as a vital resource for improving economic productivity, decision-making, and delivery of services. Open interface specifications for GIS will enable users to freely exchange and apply spatial information, applications, and services across networks, platforms, and products. Advancements are expected in the integration of GIS technologies with virtual reality simulation and modeling.
- **Dashboard presentations** – Simplified displays of specific parameters, similar to the dashboard in today's modern vehicles, will assist users to rapidly detect the status of key variables.

In addition, human-factor engineering principles and techniques currently used in air traffic control and other industries, as well as those available from military applications, will be incorporated into the advanced control centers of the modern grid. IIDS technologies will also utilize the sophisticated analytical capabilities of the modern grid's advanced control methods to generate visualizations.

Visualization methodologies will differ somewhat, depending on the time scale of the data displayed. However, when possible, they will be standardized to simplify operator training. This will enable the system operator to rapidly identify and analyze issues and take corrective action within seconds.

Decision Support

The autonomous controls performed by advanced control methods will do much to stabilize the grid, but system operators will still be

responsible for monitoring these controls and making decisions that are beyond the scope of ACM.

Advanced control methods will only perform autonomous control actions when those actions are within their prescribed "permission sets" (i.e., a set of circumstances or conditions where technologies are given permission to act without first "checking" with operators). When other control actions are required of the operator, these will be presented to the operator in a way that maximizes the probability of success. IIDS technologies will recognize and address the relatively limited capability of the operator to make rapid decisions as compared to the speed of advanced control methods.

One of the principal causes of the extensive August 14, 2003, blackout was a lack of situational awareness, which was in turn the result of inadequate reliability tools and backup capabilities. Failures by control computers and alarm systems contributed directly to this lack of situational awareness. Incomplete tool sets and the failure to supply state estimators with correct system data also contributed.

In the future, however, there will be many tools to alert operators to existing, emerging, and predicted problems: AI, operator decision tools (such as alerting, what-if, and course-of-action tools), semi-autonomous agent software, visualization and systems tools, performance dashboards, advanced control-room design, and real-time dynamic simulators for training are some of these tools. In addition, for each issue and opportunity requiring operator action, multiple options for resolution and the probabilities of success and risk for each will be presented to assist in the decision-making process.

Some wide-area tools to aid situational awareness, such as real-time phasor measurement systems, have been tested in some regions but are not yet in general use. Improvements in this area will require significant new investments involving existing or emerging technologies.

Over the past few years, research has been done to incorporate a risk-based approach into the decision-making process. This approach recognizes that credible contingencies have different probabilities of occurrence. By understanding the consequences of each contingency and its probability of occurrence, decision support systems can quantify the relative risk and severity. These relative risks can be integrated into a composite risk factor and presented to the operator to assist with decision-making. This is more effective than the current approach to making security assessments and operating decisions. The current approach is to review past and current states of the system and to take actions based on the single most severe credible contingency.

Risk as a computable quantity will be used to integrate security with economics in formal decision-making algorithms. By applying probabilistic risk assessment (PRA) techniques into decision support technologies, grid operations can be made more secure and more economic.

In addition to risk-based decision support technologies, other forms of decision support are being developed. For example, intelligent user interfaces, utilizing techniques from the field of autonomous agents, provide a new complementary-style of human-computer interaction in which the computer becomes an intelligent, active, and personalized collaborator.

Some other examples of decision-support technologies are as follows:

- Practical real-time applications for wide-area system monitoring, using phasor measurements and other synchronized measuring devices, including post-disturbance applications.
- Enhanced techniques for the modeling and simulation of contingencies, blackouts, and other grid-related disturbances
- Improved visibility of the grid's status beyond an operator's own area of control – will aid the operator in making adjustments in operations and thereby mitigate potential negative impacts elsewhere on the grid.
- Extensive use of what-if technologies, including PRA techniques, to enable system operators to forecast the future state of the grid, identify potential issues, and take preemptive action to prevent future negative consequences.
- As part of the IntelliGrid program, EPRI has undertaken the Transmission Fast Simulation and Modeling (TFSM) project to develop a technical vision that models and simulates system behavior based on real-time data. TFSM will anticipate changing conditions and provide timely response during system disturbances, including prevention, containment, and support for recovery. A key concept incorporated in TFSM is the recognition of the different time frames associated with the various aspects of the modern grid that need to be controlled. TFSM is expected to also address the decision-support and human-interface needs of the modern grid.

System Operator Training

Since system operators will supply both the intelligence and intuition necessary to ensure the modern grid's successful operation, training programs and simulators in the future will be adjusted to incorporate the new features of the modern grid.

Visualization and decision support technologies, once developed, will need to be incorporated into the training and certification programs that support the operation of the modern grid.

IIDS technologies, together with system operator training, will be continuously evaluated and improved through control-room design reviews, human-factor reviews, and human-performance analysis, as well as through corrective actions based on critiques of the operators' responses to system events.

Operators will need a deep understanding of power system theory and will need to be trained in relevant power system engineering disciplines. Operator training will advance substantially beyond that provided today. Processes, procedures, and technologies used by NASA, the U.S. military, and nuclear power plants will be applied where appropriate to improve training programs.

The August 14 blackout task force investigation team found that some reliability coordinators and control area operators had not received adequate training in recognizing and responding to system emergencies. Most notable was the lack of realistic simulations and drills to train and verify the capabilities of operating personnel. Such simulations are essential to prepare operators and other staff to respond adequately to emergencies. This training deficiency contributed to the lack of situational awareness on August 14.

In the future, the development and use of real-time dynamic simulators and industry-wide certification programs will significantly improve the skill sets and human performance of system operators. Simulator training will be conducted using both normal and emergency scenarios and will be complemented by power-system engineering course work to ensure operators have a thorough understanding of the theories behind dynamic system performance.

Power-system simulators, specific to each operating area and region, will also be used. Training will include not only routine operations but also emergency operations and restoration. To the extent practical, the simulators will mirror the actual control room and will be tested to ensure their scenarios are realistic when compared to actual events.

Certification programs will be in place to verify that the simulators perform correctly and to certify that operators have completed specific training requirements prior to assuming duty.

Several new applications are available, or will be in the near future, to improve the training of system operators. Some examples include the following:

- PNNL's Integrated Energy Operations Center (IEOC) is a new user-based facility dedicated to energy and hydro-power research, operations training, and back-up resources for energy utilities and industry groups.
- Advanced simulators will give operators a real-time or historic view of the power system and its various parameters quickly, accurately, and in a format that increases situational awareness. These new technologies are extremely visual and efficiently perform power-flow analysis on systems containing up to 100,000 busses.

Significant progress must be made in the area of training and the operator's use of advanced decision support technologies. As the complexity of the transmission and distribution (T&D) systems and their connected generation sources grows, as the operating margins shrink, and as loads requiring higher power quality and improved reliability increase, additional stresses will be placed on the human operator that only first-rate, systematic training will be able to relieve.

BENEFITS OF IMPLEMENTATION

Overall, with improved interfaces and decision support technologies in place, the grid will experience more reliable operation and fewer incidences of outage from natural events and human error.

With IIDS, complex and extensive system information will be rendered into formats quickly understood by trained system operators so that they can accomplish the following:

- Understand the overall status of the grid at a glance and thus lend support to the self-healing aspect of the grid
- Maintain grid security and integrity by quickly detecting and mitigating threats against it
- Monitor and control a large number of new, decentralized energy sources (such as DER, DR, and advanced storage)
- Deal quickly with emerging PQ issues
- Identify stressed equipment so that relief can be provided or equipment replaced before a breakdown can cause a costly outage
- Identify the location of system assets, human resources, portable equipment, and physical landmarks such as roads, bridges, and city streets, thus enabling system operators to significantly improve worker and public safety and to create a safer environment for completing restoration work
- Better understand the environmental impact of grid resources and thus balance that impact with economics in the dispatch of centralized generation and DER.
- Improve overall operation and maintenance of the entire power delivery system

In addition, IIDS technologies will assist other stakeholders in the following ways:

- Provide an effective interface to allow consumers to actively participate in the energy market and grid operations, thereby incorporating load as an active factor in grid operations
- Assist in the communication of grid information to stakeholders, thereby providing the needed level of transparency of operations and market information
- Support the integration of key technology areas with other enterprise-wide processes and technologies to improve their overall understanding of grid conditions

BARRIERS TO DEPLOYMENT

One obvious barrier is the extent of work that remains to be done to gain consensus among all stakeholders on the national vision for the modern grid.

The vision needs to be communicated, examined, refined and accepted by all stakeholders, including federal, state, and local regulators. It will provide the fundamental framework around which the necessary supportive regulatory and other environments will emerge.

Another barrier to overcome is the lack of sufficient power system data. IIDS technologies cannot be effective regionally and nationally at either the transmission or distribution levels until sufficient quantities of data are made available by advancements in the technology areas listed below:

- Integrated Communications (Appendix B1)
- Sensing and Measurement (Appendix B2)
- Advanced Control Methods (Appendix B4)

More research is needed to improve grid reliability, with particular attention to improving the capabilities and tools for system monitoring, management, and operations.

Although some progress has been made, there still remains a wide gap between today's IIDS technologies and what is required to meet the vision for the modern grid. For example, many of the recommendations from the August 14, 2003, blackout task force have yet to be implemented, including improvements needed in IIDS technologies that will give system operators the capability to detect and prevent cascading outages.

Here are some additional barriers that need to be addressed:

- **Development is needed in applications** that integrate advanced visualization technologies with geospatial tools to improve speed of comprehension and real-time decision-making.
- **Advances in computing power** are needed to support the processing of complex, near real-time applications and in presenting it to the operators.
- **Development of low cost sensors and an integrated communications infrastructure** are needed to acquire the type of data needed by the modern grid.

- **Consumer-based agents and portals** need to be equipped with decision support algorithms and visualization technologies that empower consumers to participate in the energy markets.

In addition to the needed technologies, effective and successful system operator training programs – which depend on a corporate commitment to training – need to be in place. Adequate funding is needed to maintain the power system models and provide for instructors. Also, operating procedures, documentation, and training must be reviewed and updated each time a new technology is introduced that will impact control room operations.

SUMMARY

Improved Interfaces and Decision Support is one of five key technology areas that need to be developed and implemented to reach the goal of achieving a modern power grid that is reliable, secure, economic, efficient, environmentally friendly, and safe.

IIDS technologies are essential if system operators are to have the tools and training necessary to most effectively operate and maintain the modern grid. IIDS will equip managers, operators, and even consumers with the needed applications and tools.

IIDS technologies are also needed to present the vast and wide-ranging volume of data collected by the modern grid in a quickly comprehensible format. Often this information will have to be presented in ways that can be very quickly assimilated and understood, such as when operators have only minutes or even seconds to make decisions.

Today, however, sufficient information is not available to grid operators and managers to enable them to provide consistently reliable, economic, clean, and safe power throughout the grid.

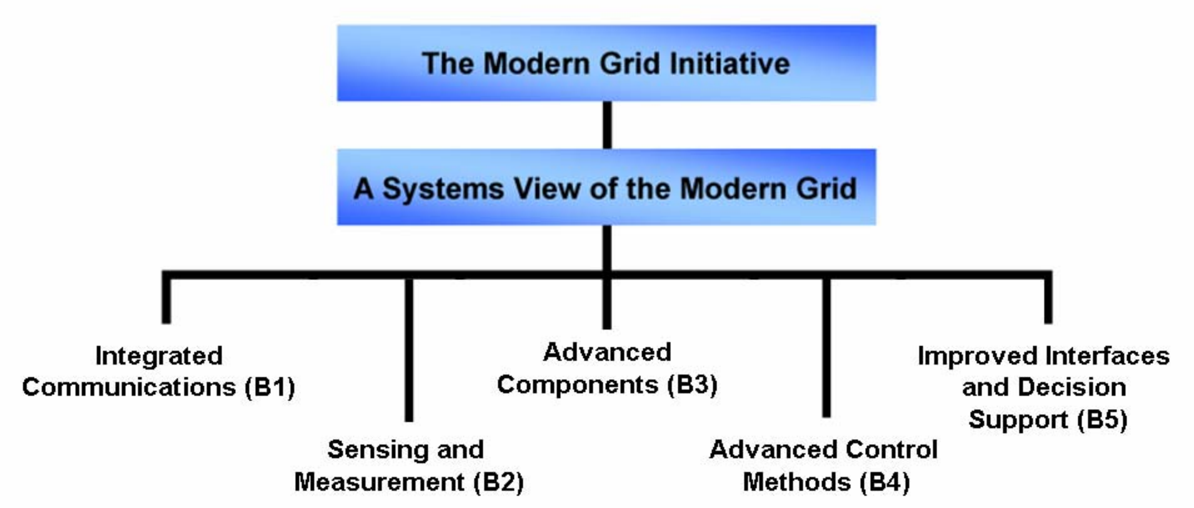
Development is needed in several areas before IIDS technologies can be fully implemented in the grid:

- **Visualization** – to enable system operators to grasp system changes quickly and thus respond very quickly to emerging changes and problems
- **Decision support** – to present system operators and other stakeholders with the best decision options for actions that fall outside of the system's autonomous controls
- **Training and certification of system operators** – to adequately prepare operators to utilize all tools available to assist in maintaining grid integrity

For more information

This document is part of a collection of documents prepared by the Modern Grid Initiative (MGI) team. For a high-level overview of the modern grid, see "A Systems View of the Modern Grid." For additional background on the motivating factors for the modern grid, see "The Modern Grid Initiative."

MGI has also prepared five papers that support and supplement these overviews by detailing more specifics on each of the key technology areas of the modern grid. This paper has described the fifth key technology area, "Improved Interfaces and Decision Support."



These documents are available for free download from the Modern Grid Web site.

The Modern Grid Initiative

Website: www.netl.doe.gov/moderngrid

Email: moderngrid@netl.doe.gov

(304) 599-4273 x101

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ACRONYM LIST

ACE	Area Control Error
AI	Artificial Intelligence
DER	Distributed Energy Resources
DR	Demand Response
EPRI	Electric Power Research Institute
GIS	Geographic information system
IEOC	Integrated Energy Operations Center
IIDS	Improved interfaces and decision support
ISO	Independent System Operator
MW	Megawatt
NERC	North American Electric Reliability Council
PNNL	Pacific Northwest National Laboratory
PQ	Power Quality
PRA	Probabilistic risk assessment
S2S	Speech-to-speech
T&D	Transmission and Distribution
TFSM	Transmission Fast Simulation and Modeling