NERC

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Reliability Readiness Evaluation Report

Balancing Authority/Transmission Operator

Sacramento Municipal Utility District

Sacramento, California

to ensure the reliability of the bulk power system

September 24–27, 2007

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Introduction and Evaluation Process

The North American Electric Reliability Corporation (NERC) Reliability Readiness Evaluation and Improvement Program is one of the commitments of NERC and the industry to strengthen the reliability of the North American bulk power system. The program conducts independent evaluations of balancing authorities, transmission operators, reliability coordinators, and other key entities that support the reliable operation of the bulk power system to assess their preparedness to meet their assigned reliability responsibilities. The evaluations identify strengths and areas for improvement in an effort to promote excellence in operations among these organizations.

Since its inception in 2004, NERC and the industry have been working collaboratively to enhance the program. The evaluation process is based on fundamental aspects of reliability: culture, operations, maintenance, planning, and training. The document *NERC Readiness Evaluation Procedure* describes and defines the process used for reliability readiness evaluations. This document and other documents related to the program are available at http://www.nerc.com/~rap/.

The reliability readiness evaluation teams, each led by a NERC staff member and a regional co-leader, include industry volunteers with considerable expertise selected to provide representation from other interconnections, other regions, and neighboring operating entities. The teams also typically include representatives from the Federal Energy Regulatory Commission (FERC) staff.

The public version of the reliability readiness evaluation report contains the majority of the evaluation team's findings. Any discussion of findings pertaining to critical infrastructure will be contained in Appendix 1, a confidential appendix to the report that is sent privately to the evaluated entity and is not included in the public version of the report.

An evaluation team met on-site with Sacramento Municipal Utility District (SMUD) representatives on September 24–27, 2007. This report reflects the views and recommendations of the evaluation team regarding the readiness of the SMUD to meet its responsibilities as a balancing authority and transmission operator.

Evaluation Team

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Organization Profile

Sacramento Municipal Utility District (SMUD) is the nation's sixth-largest community-owned electric utility in terms of customers served. The SMUD transmission operator area includes the 900-square-mile service area of Sacramento County and a portion of Placer County in California. SMUD generates, transmits, and distributes electricity to approximately 580,000 customers over 477 circuit miles of electric transmission, operated at 115 kV and above, and 9,736 circuit miles of electric distribution.

SMUD is registered with NERC as a balancing authority and a transmission operator. Within the SMUD balancing authority area are SMUD and a sub-balancing area of the Western Area Power Administration — Sierra Nevada Region (WASN). The WASN sub-balancing area includes the cities of Redding, Roseville, and Shasta Lake, California; the Modesto Irrigation District; and the generation of the United States Bureau of Reclamation. The WASN sub-balancing area operates under an interconnection operating agreement with SMUD as the balancing authority.

The peak load for the SMUD balancing area (including WASN, the Modesto Irrigation District, the City of Redding, and the City of Roseville) was 4,906 MW in July of 2006, and the peak load for the SMUD transmission footprint was 3,299 MW during the same month. SMUD's energy sales in 2006 were approximately 15,345 GWh, supplied primarily from owned cogeneration (31%), owned hydroelectric (19%), and purchased power (50%), including purchases from generation owned by joint power agencies controlled by SMUD.

SMUD has 27 tie lines, operated at 115 kV and above, with neighboring reliability authorities, including WASN, the Bonneville Power Administration, Pacific Gas and Electric Company, and the Turlock Irrigation District.

SMUD has contractual arrangements with the California Independent System Operator, the Western Systems Power Pool, and the Northern California Power Pool to facilitate the purchasing and selling of power on a short-term basis. SMUD is a member of the Western Electricity Coordinating Council (WECC), a NERC Regional Entity. At this time, SMUD's reliability coordinator is the California-Mexico Reliability Coordinator, a reliability coordination center of WECC for the California and Baja Mexico area. SMUD is a member of the Northwest Power Pool and is currently pursuing participation in the Northwest Power Pool Reserve Sharing Group.

Executive Summary

The evaluation team found no significant operational problems and concluded that SMUD has adequate facilities, processes, plans, procedures, tools, and trained personnel to perform the balancing authority and transmission operator functions necessary to maintain the reliable operation of the bulk power system.

SMUD's corporate culture and senior management provide strong support for maintaining and improving system reliability. Communication both up and down the organization regarding system operations is open and effective. The system operations' culture has promoted positive attitudes by all personnel involved in or providing support for the group. The management of system operations, system operators, and support personnel are all highly experienced, well trained, and competent in performing their assigned tasks.

The evaluation team made several positive observations related to SMUD's system operations. The team notes the robust set of tools provided for the system operators and the close working relationship between the operators and operational planning. In addition, the team notes the dedicated support for the energy management system and the high level of availability achieved. The team also recognizes the development of a state-of-the-art backup control center that can easily be established as an active alternate control center.

The evaluation team, jointly with SMUD, identified key recommendations related to enhancing the wide-area visibility of the system operators with additional information related to the status of neighboring systems and implementing a formal shift-change procedure to ensure the complete transfer of information between system operators.

Overall, the evaluation team identified 17 positive observations. In addition, the team offers five recommendations that, if implemented, will enhance SMUD's readiness to operate reliably and maintain the reliability of the bulk power system.

Positive Observations

The evaluation team noted the following positive observations during the reliability readiness evaluation process:

1. SMUD has telemetry and alarms for power system stabilizers and automatic voltage regulator status that provides timely and accurate information for the operators (Section 2.1).

2. SMUD has a robust set of operator tools, including but not limited to the following (Sections 2.1, 2.3. & 2.4):

    a. customizable trending displays
    b. dynamic nomogram displays
    c. manual load tripping display and program
    d. undervoltage monitoring and load shedding program
    e. contingency reserve monitoring displays
    f. reactive reserve display

3. SMUD has a well-organized document control process for both operating procedures and operating agreement contracts that follows a standard template with revision history, approval signatures, and dates (Section 2.2.3).

4. The electronic document system allows easy access for operators and other SMUD personnel (Section 2.2.3).

5. SMUD has a competent staff of operators with extensive operating experience (Section 8).

6. Energy management system (EMS) availability was 99.9983% for 2006, with only one EMS outage event of 9 minutes 10 seconds (Section 3.2.1).

7. SMUD has a well-designed process for EMS software upgrades — the EMS support team and operations engineering team work closely to test software upgrades off-line before implementing them on the production system and work with the training group to provide appropriate instruction to operators for the upgrades (Section 3.2.2).

8. Operational planning works closely with operations, providing around-the-clock support, performing studies remotely from home, and developing and updating operator tools and nomogram displays (Section 4).

9. SMUD ensures that operators are trained prior to new or changed procedures being implemented and for changes to any of the systems supporting the operators (Section 2.2.3).

10. Communications both up and down the organization appear to be open and effective (Section 1.2.5).

11. Reliability projects receive support and funding from senior management and SMUD's Board — examples include the training simulator, backup control center, and EMS upgrade (Section 1.1).

12. SMUD operations personnel display positive attitudes about their jobs and their operational environment (Section 1.2.2).

13. SMUD has a redundant, fully functional, state-of-the-art backup control center. See further discussion in Appendix 1.

14. Operators can start up the backup control center independent of any other personnel. See further discussion in Appendix 1.

15. SMUD has a dedicated EMS support team that ensures the needed operational support is provided on a priority basis (Section 3.1).

16. The emergency backup system provides a third backup for area control error calculation and automatic generation control functionality (Section 3.1).

17. SMUD has a multiplicity of communication systems ensuring reliable communications. See further discussion in Appendix 1.

Recommendations

The evaluation team offers the following recommendations:

1. Develop and implement a formal documented shift-change procedure to ensure uniform and complete transfer of information between power system operators (Section 2.2.3).*

2. Develop and implement a tracking process that ensures power system operators have read new and revised operating procedures (Section 2.2.3).*

3. Expedite the implementation of and secure support resources for the state estimator, contingency analysis, and operator training simulator projects to provide power system operators with additional tools to ensure reliability (Section 2.3).

4. Review and increase, as appropriate, visibility into neighboring systems to provide power system operators with increased real-time information from neighboring entities (Section 2.1).*

5. Investigate involving local law enforcement in the procedure for emergency evacuations to the backup control center to ensure a smooth and timely transition and implement findings. See further discussion in Appendix 1.

*Jointly identified by the company and lead evaluator as a key recommendation

Discussion

The reliability readiness evaluation team examined the following key areas during the evaluation. The detailed discussion that follows provides the foundation for the recommendations and positive observations the team identified. The report uses the generic term "system operator" to refer to all on-shift operating personnel responsible for executing the functions necessary to operate reliably and maintain the reliable operation of the bulk power system. This term will be used in this report unless additional specificity is required, such as the *balancing* system operator, or *transmission* system operator.

1. Culture

1.1 General

The corporate organization provides the necessary leadership and management for system operations to sustain high levels of safe, reliable operation.

SMUD's Board of Directors has developed a major policy guide for SMUD's operations. As part of a strategic planning process, the Board sought input from customers, outside experts, and community representatives. As a result of this process, new mission and vision statements were developed, along with a set of core values, to guide SMUD in its planning and operations. The core values are deemed to be essential to the success of SMUD in serving its customers.

One of the core values established by the Board is system reliability. The performance measure established states that SMUD "will assure all customer energy requirements are met. This will be accomplished through the use of its generation resources and purchase power portfolio 100% of the time; and use of its transmission assets to assure an overall availability of at least 99%."

A staff implementation plan has been developed to define the metrics, plans, programs, and activities SMUD will use to support the core values and meet the goals established by the Board. SMUD has made an effort to break the goals down into levels applicable to the upper management, general management, and operations and has developed a wage management system that is tied 50% to corporate-level goals and 50% to operations-level goals.

As a result of the commitment to the corporate goals, funding for projects to improve system reliability — such as a training simulator, a new state-of-the-art backup control center, and EMS upgrades — has received consistent support from management at all levels. The evaluation team notes, as a positive observation, that this support for reliability projects has been received when needed.

1.2 Organizational Effectiveness

1.2.1 Foundation for System Reliability

The organization's values and behaviors—modeled by its leaders and practiced by its members—serve to make system reliability a top priority.

The status of SMUD's system operations is communicated, discussed, and shared among senior management in a variety of ways to keep a focus on overall system reliability. Weekly System Operations and Reliability status reports providing an overview of events and concerns regarding reliability-related matters are sent to all executives. Long-range and seasonal plans and assessments of system reliability are provided to senior management on a regular cycle. The Reliability Compliance Steering Committee meets every two weeks to discuss reliability compliance. Project prioritization in the budget ensures reliability needs receive discussion and a high priority. In addition, reliability-related issues that are not addressed in these forums have a permanent agenda slot at weekly executive-level meetings.

Another indication of management's support for system reliability is the involvement of system operations employees in activities to support the industry and improve reliability. This includes working with regional and national reliability organizations in the support of bulk power system reliability. SMUD participates in committees, working groups, and task forces associated with the California Independent System Operator, the Western Electric Coordinating Council, and the Northwest Power Pool on a regional level and NERC, the American Public Power Association, Large Public Power Council, and North American Energy Standards Board on a national level.

1.2.2 Leadership and Management

Managers, by leadership, commitment, and example, establish and reinforce high standards of performance and align the organization to achieve safe, reliable system operation.

SMUD coordinates the review of any proposed changes in operations or facilities that could impact system operations. Issues are explored through a coordinated group within the Energy Supply Division, composed of System Operations and Reliability staff from Power Operations Engineering, Power System Operations, System Protection and Control, Operations Management Systems, Power System Assessments, Energy Trading, Legal and Regulatory, and Contracts. This ensures system operations has the input and control required to resolve any issues with changes that could impact system reliability.

SMUD has corporate policies that encourage maintaining a professional atmosphere within system operations and other functions. Corporate rules prohibit non-professional communications. Managers are required to treat all employees professionally and provide clear expectations. The enforcement of these policies fosters a respect for individuals, their organizational unit, and the work they do. The evaluation team finds, as a positive observation, that SMUD's operations personnel display positive attitudes about their jobs and their operating environment.

1.2.3 Corporate Oversight and Monitoring

Line management is used to strengthen reliability and improve performance. System reliability is kept under constant scrutiny through techniques such as self-assessments, performance indicators, and periodic management meetings.

SMUD's Performance Incentive Program (PIP) provides incentive salary increases or lump-sum payments based on reaching performance goals established each year. If goals are not met, incentive payments are reduced. Within the system operations organization, the goals include improving operating tools and facilities, achieving system reliability statistical measurements,

and meeting compliance standards. This program encourages all employees to work as a team to achieve the incentive goals and provides management with an assessment of how well the organization is performing.

SMUD's corporate management maintains an overview of system operations through reports and regular meetings but does not get involved in the details unless support is needed. Corporate management operates as a buffer between the community and system operations to allow operations to perform its function without interference.

SMUD's system operations does not have an identified risk analysis process; but when making critical decisions regarding system reliability issues, system operators have operating procedures detailing the actions to be taken to ensure reliable operation. For system reliability issues made outside of real-time operations, supervisors provide recommendations on options to management indicating the safest and most reliable alternative.

1.2.4 Human Resources

Personnel resource needs are anticipated and individuals are systematically recruited, developed, and assigned positions in the system operations organization.

In the past, SMUD has been successful in hiring system operators and staff with operations experience similar to what is required for SMUD's system operations. This allowed SMUD to quickly fill operating positions without extensive additional training. SMUD realizes that hiring of employees to fill system operations positions has become more difficult in the last few years. Utilities are competing against each other and higher paying firms, while the number of students with the needed operational skills is decreasing. To prepare for replacing personnel in critical positions, SMUD is taking the approach of "growing its own staff" by providing training and developmental assignments.

SMUD does not have a formal succession plan, but uses continuous training in system operations and in career development and management courses to train and retain employees. The courses are made available to all SMUD personnel. When combined with on-the-job experience, this training is intended to prepare employees to apply for desired positions.

The evaluation team finds that SMUD has a competent staff of operators with extensive operating experience and notes this as a positive observation.

SMUD has recently established a training group, appointed a supervisor of training, and funded two training positions that report to the supervisor. Candidates are being reviewed on a high priority basis to fill those training positions on a permanent basis. Staff personnel are being used on a short-term basis to fill the positions.

1.2.5 Corporate Communications

System operations communications inform and engage both corporate and system operations employees so they can contribute to the strategic priorities of the organization.

As previously discussed, there are several routinely scheduled meetings in which corporate-level management is informed about system reliability issues, and the corporate performance plan

ensures that system reliability has the attention of management at all levels. Management typically uses surveys, email notices, and performance goal discussions to convey changes to processes, procedures, or policies, and to get feedback from employees. Senior management has an open-door policy and tries to meet with each employee individually at least once a year. Supervisors play an important role in reviewing all changes with their employees and providing a forum for discussions. The evaluation team finds, as a positive observation, that communication up and down the organization's chain of command is open and effective.

2. Fundamentals of Operations

2.1 General

Operations personnel monitor and control the system in a manner that ensures safe, reliable operation.

SMUD's primary control center is staffed by three system operators and a senior system operator on each shift. Each operator can select from a set of electronic displays to support a variety of functions. The electronic displays, driven by SMUD's EMS, provide visibility of all major transmission and generation facilities in the SMUD and Turlock Irrigation District balancing authority areas. The operators have limited visibility of the adjoining California Independent System Operator (CAISO) footprint and the Bonneville Power Administration (BPA) balancing authority area. Transmission system displays show voltages, real and reactive line flows, and the status of automatic tap changers. For tie lines, the total transfer capability is also shown. Generation displays show unit availability, real and reactive outputs, and capabilities. SMUD remote terminal units (RTUs) are scanned every 2 seconds for breaker status and tie-line flows. All other data are scanned every 10 seconds. Data from other reliability areas is brought into the EMS through an inter-control center communications protocol (ICCP) data link.

Alarms are displayed for all status changes, exceeded limits, and communication failures. The system operators have the ability to filter alarms to each operator's desk so that the balancing, transmission operation, and interchange scheduling desks only receive alarms pertaining to that desk. The forecasted load, prepared by SMUD's marketing group, is available on the operator displays along with weather data. Television screens mounted in the control room are also used to monitor weather forecasts.

Area control error (ACE) calculations are presented on a display in front of the balancing desk. The display shows the ACE for the SMUD balancing area, as well as the ACE for the SMUD's service area and the ACE for the WASN service area. The displays also show frequency, system load, total generation, and actual and scheduled net interchange for the two areas and the total SMUD balancing area.

SMUD's measurements of system frequency for the calculation of ACE are provided by two "TrueTime" frequency transducers. The frequency signals from the transducers provide a redundant pair for the calculation of ACE. Two additional frequency sources are available from CAISO and WAPA. Both of these frequency signals are supplied to SMUD's EMS through ICCP data links. All four frequency measurements available through the EMS are available for the calculation of ACE with automatic failover. The SMUD system operators also have a display used to monitor frequency across the system. Additional frequency measurements are

available through the EMS for 16 identified locations throughout the SMUD balancing area to provide sufficient coverage to detect islanding across the SMUD footprint.

SMUD has a plant information (PI) historical data trending program available through the EMS that provides the system operators considerable flexibility in selecting data trends to display. This provides support in detecting metering errors, selecting load forecast models, and observing changes occurring on the system. SMUD's system operators also have a display that shows tie line measurements available from multiple sources. Typically, four sources are available for each tie. If the difference between the selected source and the other available sources deviate beyond a specified dead-band, an alarm is issue to the system operator. At the beginning and end of each hour, pulse accumulator readings for every tie line are automatically compared to the integrated analog value for that time period and alarmed if excessive difference is found.

SMUD's system operators have routine daily interaction with neighboring reliability authorities and SMUD's reliability coordinator for both day-ahead planning and real-time operational issues. The senior system operator is the primary contact with the reliability coordinator. Planned outages for the day are sent to the reliability coordinator, and the reliability coordinator provides the senior operator the outlook across the system for the day. The senior system operator briefs the other operators on shift. If changes occur on the system during the day and transmission path ratings have not been agreed to, the senior operator, the reliability coordinator, and any other parties affected hold a conference call to determine each party's needs and if analysis is required. The system operators all have the WECCNet message system available to communicate with the reliability coordinator and SMUD's neighboring reliability authorities.

SMUD's senior system operator on shift monitors reactive reserves for SMUD's footprint. SMUD has a requirement to maintain a minimum of 250 Mvar of reactive reserves at all times. An alarm is initiated when the reactive reserves fall below the minimum requirement. Under-load tap changers and capacitor banks are capable of being operated both manually and automatically to maintain reactive capability. Automatic voltage regulators and power system stabilizers are installed on the SMUD generating units covered by WECC procedures. The status of these devices is telemetered to the EMS and displayed for system operators. When any device is removed from service, an alarm is generated notifying the system operators. The status of these devices is also telemetered to SMUD's reliability coordinator.

The evaluation team makes several positive observations about the capabilities provided for the system operators to observe and control SMUD's bulk power system. The telemetering and alarming of the status of automatic voltage regulators and power system stabilizers provide timely and accurate information to support system reliability. The displays provided by the plant information (PI) data trending application provide the system operators flexibility in monitoring the system and another source for detecting metering errors. The display of real and reactive actual values, capabilities, and remaining reserves provide the system operators a convenient method for monitoring reserves.

The system operators have good visibility throughout SMUD's system but may benefit from additional capabilities to view information on the California-Oregon Intertie and the 500 kV breakers and capacitor banks. The evaluation team recommends that SMUD review and

increase, as appropriate, the visibility of neighboring systems to give the operators increased information on system conditions at SMUD's boundaries.

2.2 Operational Focus

2.2.1 Operational Safety

System operation activities are conducted in a manner that maintains high levels of safety and reliability for all system conditions.

SMUD has two special protection and remedial action schemes and several overload protection schemes within its footprint. The company also participates on transmission circuits that are impacted by a remedial action scheme operated by Pacific Gas and Electric Company. None of the special protection systems and remedial action schemes are owned or operated by SMUD, but its system operators monitor the status of the special protection schemes.

2.2.2 Operational Decision-Making

Operational decisions are reached using a systematic and thorough approach that supports safe, reliable, and efficient system operations.

SMUD's system operators are trained to make critical operational reliability decisions, with safety and system reliability issues receiving priority. SMUD's operating procedures specifically describe the roles and responsibilities of the system operators as well as other company personnel.

Power system operations studies are performed annually on a seasonal basis, as well as a daily basis when necessary, with the results documented in operating procedures and transmission outage application clearance tickets. System operator tools aid the operators in monitoring key operating parameters of critical facilities that could lead to a system operating limit or interconnection reliability operating limit condition. Operating procedures provide references to constraints to mitigation of system operating limits on the critical facilities and identify the facilities that can impact or change the system operating limits. Additional operating tools are developed when necessary to illustrate the operating criteria and aid the operators in monitoring the associated system conditions.

SMUD requires transmission switching orders to be presented to system operations at least 45 days in advance. Any system operator can write a switching order, but at least two others check it before it is approved for execution. Switching requests for the current and next day are shared and discussed with the reliability coordinator.

SMUD plans and operates its generation to reliably meet peak demand under heat-storm conditions (1 in 10 year temperatures). Currently, SMUD uses an informal staff review to identify and mitigate potential risks that could cause shortfalls in resources for meeting planning and operating criteria.

2.2.3 Operational Alignment

Organizational structure supports safe and reliable system operation.

SMUD has a complete set of agreements covering arrangements with its interconnected neighboring systems, its reliability coordinator, and its reliability organization (WECC). SMUD also has a complete set of agreements covering its delegated and assumed reliability functions with WASN and CAISO. In addition, SMUD has a well-organized set of operating procedures. NERC certificates for SMUD system operators are posted in the control center along with the system operators' letter of authority, signed by upper management, allowing operators to take the actions necessary to provide system reliability, including shedding load, without supervisory approval. SMUD has a principal power contract specialist designated to maintain its agreements.

SMUD has a formal documented document control procedure. The procedure provides a development guide and a template that describes the creation (standard layout of procedures, guidelines on writing style, detailed steps for creating new procedures), storage (adding the procedures to the electronic file system), and distribution (sending out notifications, printing hard copies) of documents. SMUD maintains three sets of hard-copy procedures, one each for the primary control center, backup control center, and Power Operations Engineering. SMUD's Power Operations Engineering group is responsible for developing operating policies and procedures. The power operations engineers ensure that any required training material is identified and developed with the Power System Operator Training unit, prior to changes in procedures taking effect, and the training staff ensures the training is delivered in a timely fashion.

SMUD system operators have access to a complete, current hard copy of all operating policies and procedures, and an electronic file system provides access to the policies and procedures on operator displays. The electronic system includes an announcements page to highlight new documents. For contracts, it includes the date created or modified, person who entered it in the system, date executed, and parties involved in the procedure. For operating procedures, it includes date created or modified and person responsible for each procedure. Authors enter procedures in the appropriate electronic file after approval and send out an email notification (with a receipt request) to the system operators and support personnel. The hard copies are updated simultaneously. All operating procedures are reviewed at a minimum once a year.

The evaluation team makes the following positive observations regarding SMUD's document control process:

- SMUD has a well-organized document control process for both operating procedures and operating agreement contracts that follows a standard template with revision history, approval signatures, and dates.
- The electronic document file system allows rapid and easy access for the system operators and other SMUD personnel.
- Operator training is an integral part of the procedure change-process, ensuring that the operators are trained prior to new or changed procedures being implemented and for changes to any of the systems supporting the operators.

SMUD does not currently have a system to verify that operators have read new procedures or revisions. SMUD is working on a system that would require acknowledgement of email notifications and possibly quiz operators on changes in procedures. The evaluation team

recommends that SMUD develop and implement a tracking process that ensures power system operators have read new and revised operating procedures.

SMUD does not have a documented shift-change procedure. The system operators review a shift turnover report and discuss system conditions and ongoing outages, clearances, holds, etc., with the outgoing operators before they leave, but the review is not a formalized process. The evaluation team recommends that SMUD develop a formal, documented shift-change procedure to ensure uniform and complete transfer of information between the system operators.

2.3 Managing System Configuration

Power system configuration is carefully designed, analyzed, maintained, and controlled throughout the life of the infrastructure, ensuring that system and equipment margins are understood, considered in decision-making, and managed consistent with design and system requirements.

SMUD's system operators do not have state estimation or real-time contingency analysis programs. A state estimation program is under development by the Power Operations Engineering and EMS groups. The system operators currently rely on a well-devised set of nomograms to analyze system contingencies. The nomograms are provided by SMUD's power operations engineers from base cases developed seasonally, as discussed in Section 4. Using the transmission outage database, a conservative base case is developed to update the transmission configuration and historical trending data for generator outputs for similar days. N-1 and N-2 contingencies are evaluated on the conservative base case, and nomograms are generated along with mitigation actions for the operators. The results are recorded in the transmission outage application (for the system operators' reference) and communicated to the reliability coordinator. The nomograms automatically update for the studied contingencies, and the power operations engineers are available to provide support in analyzing any unusual events. The system operators are provided a hard copy of the nomograms for reference if EMS displays are unavailable.

The evaluation team notes the dynamic nomograms capability discussed above as a positive observation. The team recognizes that SMUD is currently working on the implementation of state estimation and real-time contingency evaluation applications and has to overcome issues related to stability analysis and treatment of special protective systems and remedial action schemes. The team recommends that SMUD expedite the implementation of these applications and an operator training simulator, and secure the associated support resources needed to support these applications to provide the system operators the additional analysis tools and simulator training needed to improve system reliability.

SMUD has a reactive reserve monitoring tool, based on off-line studies performed each summer by the Sacramento Valley Study Group, to develop operating nomograms and import limits, along with voltage limits and reserve requirements, for maintaining voltage stability for the area. The tool provides the system operators the reactive reserve available based on real-time data, identifies the acceptable post-contingency voltages, and determines the percentage of load that should be shed for cases where reactive reserve cannot correct voltages within limits. The operators can take action manually based on the steps determined by the tool.

SMUD utilizes an Open Access Technology International, Inc. tagging system for its tagging functions. The system operators have a tool that helps identify interchange schedule disagreements. A color-coded display indicates whether the net interchange agrees with the transaction tags for an hour. If the two do not agree, the operator can call up a display of the existing tags. Each tag that has been properly agreed to during pre-scheduling will be indicated. If a tag appears that was not there during pre-scheduling checkout, the operator has to determine why the tags do not agree with the net scheduled interchange for the hour.

2.4 Emergency Preparedness

The organization is prepared to manage and mitigate the impact of system emergencies in order to preserve the reliability of the system and to protect the interests of the public.

SMUD operates an underfrequency load shedding program in accordance with the *WECC Coordinated Off-Nominal Frequency Load Shedding and Restoration Requirement Plan*. This plan requires SMUD to automatically shed up to 31.1% of its load in five steps as frequency drops from 59.5 Hz to 57.9 Hz. In addition, the generators connected to the grid that protect for off-nominal frequency operation have relaying protection that accommodates underfrequency and overfrequency operation, with trip settings and time delays coordinated with the automatic load shedding plan. The system operators also have manual load shedding capabilities. The operators select the quantity of load to be shed from an electronic display, and a manual load shedding application chooses the feeders to trip, from a predetermined list, to achieve the required load reduction. Undervoltage load shedding is used to shed load automatically during extreme system undervoltage conditions. This application is designed to automatically trip 12 kV feeders when armed by the system operators and two or more of the monitored 230 kV lines are lost or when the majority of the voltage at the monitored buses is below 212 kV for 10 seconds. Another relay-based undervoltage load shedding scheme trips 69 kV busses if voltage on a local 230 kV bus is too low. SMUD also has a small amount of contractually interruptible load that can be shed if a decision is made by 10:00 a.m. on the day the load reduction is needed. The load reduction is achieved by direct contact with the customers.

The evaluation team recognizes, as a positive observation, that SMUD has developed a robust set of tools for the system operators, including the manual and undervoltage load shedding applications.

SMUD's *Capacity/Energy Shortage Contingency Plan* documents the procedures to reduce SMUD's system loads when available resources are below acceptable limits or when other situations require load reductions to ensure the system is operated reliably. Either SMUD's system operators or SMUD's reliability coordinator can initiate the procedures. The plan has three defined energy emergency levels, and if initiated by SMUD a request is made to SMUD's reliability coordinator to declare an alert through the WECC Telenet.

3. Fundamentals of Maintenance

3.1 General

Maintenance is conducted by skilled personnel to achieve safe, reliable control center equipment and system performance.

SMUD has three production EMSs. SMUD's primary control center houses the primary EMS and an emergency backup EMS (EBS). SMUD's backup control center houses the backup EMS (BCC EMS). The three systems are interconnected by redundant routers on two separate fiber communications paths with automatic failover at the primary and backup control centers. While in standby mode, the BCC EMS receives data from the primary EMS. When the backup control center is activated, the BCC EMS receives data directly from the remote terminal units (RTUs) and the ICCP network. The EBS is in the same computer room and shares network connections with the primary EMS. In a case of failure of the primary EMS, the EBS is the immediate backup used for system operations, as long as the communications network to the primary control center is in operation. The EBS has all tie-line data, generation data, and ACE calculation capability. The primary EMS and the BCC EMS are fully redundant.

SMUD's EMS support staff consists of a supervisor and 12 engineer/programmer positions and provides around-the-clock support for the EMS facilities. During normal working hours, the EMS support personnel are located at the primary control center and in close contact with system operations. Telecommunications support personnel are also on-call around-the-clock, and additional personnel are called in to assist with troubleshooting and repairs. The evaluation team notes the dedicated EMS support staff, the fully redundant BCC EMS, and the EBS as a third backup for maintaining area control error as positive observations.

3.2 Equipment Reliability

3.2.1 Equipment Performance

The organization achieves high levels of equipment reliability. Equipment problems that impact reliability are resolved in a thorough and timely manner.

The primary EMS monitors RTU communication errors, and server and workstation status. RTU communication errors are available on EMS displays in the control room, and a daily report is generated for support personnel. A rate-of-change monitor is used to detect excessive deviation of data values between two successive EMS scans and generates an alarm when a limit is exceeded. Data points can be enabled or disabled on the monitor. All tie lines have multiple sources for data, and EMS alarms are generated when the data from the different sources is different by a preset amount. The system operators can view all the available sources on tie-line data on a display. Each hour, integrated values for tie-line power flows are compared to pulse accumulator values and alarms are generated if the difference is excessive. SMUD's shift-change process includes the review of any overridden data vales, and the system operators review the trending displays to detect data problems that have not been reported. Trouble reports, which are sent to support staff by system operators, are logged and tracked until completed.

Telephone, microwave, fiber-optic networks, and company radio systems are monitored using various commercial monitoring systems, and alarms are generated for failures. Satellite phones are tested weekly with each interconnected reliability authority. Any problems noted are communicated to the telecommunications support staff for repair.

SMUD's EMS availability was 99.9983% for 2006, with only one EMS outage event lasting 9 minutes 10 seconds: a replacement of an uninterruptible power supply. This achievement is recognized as a positive observation by the evaluation team.

3.2.2 Work Management

Work activities, including corrective, elective, and preventive maintenance, surveillance testing, and modifications, are managed effectively to support safe, reliable operation during both outage and routine periods.

SMUD has a well-designed process for EMS software upgrades. The EMS support staff works closely with the power operations engineers to test software upgrades offline before implementing the changes on the primary EMS. If training is required for the changes, the support staff work with the trainers to ensure any required training material is developed and delivered in a timely manner. The evaluation team notes the software upgrade process as a positive observation.

4. Fundamentals of Operational Planning

Operational planning provides the technical information and support necessary for safe, reliable system operation.

The General Electric Positive Sequence Load Flow (PSLF) is the primary application used by SMUD for system analyses. The Sacramento Valley Study Group (SVSG) develops base cases for the members' use through a collaborative process. SVSG includes SMUD, the Western Area Power Administration-Sierra Nevada Region, Pacific Gas and Electric Company, the California Independent System Operator, City of Roseville, City of Lodi, California Department of Water Resources, Northern California Power Agency, the US Bureau of Reclamation, Modesto Irrigation District, and Turlock Irrigation District. The base cases are developed by updating facility additions, transmission and generation outages, load forecasts, historical generation patterns, reactive device status, etc. Generation dispatch scenarios are developed using historical data.

The WECC base cases are used by SMUD's power operations engineers, in conjunction with the PSLF, to develop transmission system limits and nomograms that provide the system operators guidance on whether limits are exceeded for n-1 and n-2 contingencies. Operating procedures are updated as necessary to provide the system operators transmission system limiting factors and remedial actions. SMUD uses WECC planning standards for thermal, voltage, and stability criteria. For the voltage stability, SMUD uses the methodology defined in the WECC reports *Voltage Stability Criteria, Undervoltage Load Shedding Strategy, and Reactive Power Reserve Monitoring Methodology, Summary of WECC Voltage Stability Assessment Methodology* and *Study Guidelines to Determine SOLs for Seasonal, Next-Day, and Current-Day Operations.*

SMUD participates with several regional groups in annual and seasonal studies of the transmission system. The SVSG performs studies for the Sacramento Valley Area, coordinates the seasonal interconnected transmission system operations, and develops operating procedures for establishing imports during the summer peak. The Westley Transmission Study Group performs studies to determine the maximum import and export for the Modesto Irrigation

District and Turlock Irrigation District and to determine any interaction with California Independent System Operator transmission paths. The WECC Operational Studies Subcommittee coordinates seasonal study plans on subregional and WECC system-wide bases, identifies critical operating conditions and appropriate measures to ensure reliable operation, and prior to each season conducts seasonal operating studies to determine operating transfer capability limits. The studies are documented in a report available to system operations employees. SVSG provides a summer report; while the Westley Group provides summer and winter reports, and the WECC subcommittee provides spring, summer, and winter reports.

Power operations engineers are on call around-the-clock to assist the system operators in evaluating unusual system situations. The power operations engineers review the operators' log and tools daily to review significant events and check in with operators at least twice a day to ensure the operators have analysis support.

5. Fundamentals of Training

5.1 General

Training in both specific job-related skills and broader technical fundamentals is used to provide highly skilled, knowledgeable personnel for safe, reliable operations, and to achieve performance improvement.

SMUD's initial training program for new operators includes a new employee orientation session and a set of basic training tasks. A task list is provided to keep the trainee on track. The objective of the initial training program is to give new operators a basic orientation to the SMUD's system and to ensure they have the fundamental skills and knowledge required. Trainees must achieve NERC certification to be allowed to operate on a control room desk. Training is provided to assist them in becoming NERC certified. As trainees progress through the list of tasks, training is provided to familiarize the new operators with the operator tools in the control room, including communications systems and the EMS workstation, displays, and applications. The task list includes tasks specific to each operator desk (balancing, interchange scheduling and transmission operations). As trainees become familiar with the electric system and the control room, they are given the opportunity to reinforce their learning by performing desk tasks under the supervision of a qualified operator. The trainee will learn the tasks of one desk before advancing to the next. The trainees also complete training modules to increase knowledge on fundamental topics applicable to each desk, familiarize themselves with SMUD's operating procedures and processes, tour SMUD facilities, meet with subject matter experts to discuss abnormal and emergency situation, and attend WECC training sessions.

The primary objectives of SMUD's ongoing training are to maintain operators' certifications and train operators on new procedures. Individual development plans are developed by SMUD's trainers for each operator. Ongoing training usually consists of NERC required training, SMUD developed courses on new procedures and systems, and annual training on blackstart and backup control center procedures. Outside courses are used to supplement training.

SMUD is a NERC continuing education provider and has a goal to have all the training courses in the NERC individual learning activities structure. SMUD's training approach is to use a variety of course delivery methods for classroom, operator training simulator, and on-the-job

training. SMUD uses a training database to rank courses and archive individual learning activities, course evaluations, and individual development plans. The database also tracks total continuing education hours, NERC standards hours, simulation hours, emergency operation hours, and regional requirements hours.

SMUD has appointed a project manager for operator training curriculum development. SMUD's vision for the training program is to "grow our own" operators and expand the training program to include other operating entities in SMUD's balancing authority area, i.e., the City of Redding; the City of Roseville; the Modesto Irrigation District; the US Bureau of Reclamation; and the Western Area Power Administration, Sierra-Nevada Region.

SMUD uses a course evaluation form to obtain feedback on its training program. An evaluation form is provided to each trainee to complete for each course. Completed forms are reviewed and entered into a database. The evaluation data are summarized for supervisors and course developers to determine necessary improvements.

SMUD's system operations operate on a five-week rotation, with one week designated as training or relief week. If the operators are not filling in for other operators, the week is reserved for training. Currently, approximately 65% of training is done during overtime.

5.2 Organizational Effectiveness

5.2.1 Human Performance

Personnel select and apply appropriate human error prevention techniques commensurate with the importance of assigned tasks to minimize the frequency and consequences of events.

SMUD requires at least two system operators to check all switching orders to minimize human errors or undesirable impacts to operations. During urgent situations, Power Operations Engineering works closely with the senior system operator to make sure decisions are correct. Power Operations Engineering also develops tools as needed to assist system operators in making decisions.

SMUD has sent employees to the California Electricity Training Advisory Committee training for the past few years to be trained in the psychology of shift work, situational awareness, and decision making. SMUD plans to incorporate this into the simulator training being developed.

Along with the supervisor, power system operations, SMUD's Power Operations Engineering group evaluates incidents that occur in SMUD's balancing area. Generator responses, operating reserve deployment, California-Oregon Intertie transfer capability mitigations, switching incidents, system disturbances, and frequency excursions are evaluated; and self-assessments are performed.

Self-assessments of operating reserves deployment, power-plant tripping, and mitigation of tie line transfer constraints, and system protection actions have resulted in improvements to operating procedures and communications with neighboring reliability authorities.

APPENDIX 1: Critical Infrastructure

The following discussion will be presented under private letter to the evaluated entity only and will not be included within the public version of the report.

APPENDIX 2: Entity Participants

The following will be presented under private letter to the evaluated entity only and will not be included within the public version of the report.

APPENDIX 3: Documents Reviewed

The following will be presented under private letter to the evaluated entity only and will not be included within the public version of the report.