

Power Delivery System Integration and Automation at Overton Power District No. 5 Overton, Nevada

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POWER DELIVERY SYSTEM INTEGRATION AND AUTOMATION AT OVERTON POWER DISTRICT NO. 5 OVERTON, NEVADA

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ABSTRACT

Overton Power District No. 5 (OPD5), located in Nevada, is a winter- and summer-peaking utility that saw its customer base climb from 3,100 customers in 1990 to 8,700 customers in 2000. OPD5, which operates three transmission-class and eight distribution-class substations, has a 230 kV tie line and two 69 kV tie lines.

OPD5 wanted to make investments in their system to help ensure that their billing rates remained attractive and the quality of delivered electric service met or exceeded customer expectations. Fiscally responsible operation and management of the system was another important goal.

These goals presented several challenges. OPD5 did not have a Supervisory Control And Data Acquisition system (SCADA) or Energy Management System (EMS). Several substations had some dial-up capabilities, but remote operation of circuit breakers was cumbersome. Switching, in substations without dial-up capabilities, required that personnel be dispatched to the substation. Lack of both communication and remote operation created delays in restoring service after transmission breaker lockouts, lockouts that also affected other power systems. Other challenges included: high overtime work expenses during line maintenance procedures; slow response times between computers in separate business offices; repeated lockups in office printers; engineering functions without access to Internet resources; and limited local phone service.

OPD5 management began the search for a system integration project that would provide communications infrastructure, communications terminal hardware, substation connectivity between varied intelligent electronic devices (IEDs), and a strategic plan for human machine interfaces (HMIs). Criteria used for the evaluation included: proprietary versus nonproprietary communications protocol, demonstrated capability to integrate existing IEDs, and cost.

The SCADA/EMS developed for this project includes a Virtual Private Network (VPN) to provide the operations teams secure access to system data from key locations. The locations for viewing the data include general offices, substations, and the homes of on-call technical staff. On a contractual basis, the system integrator has secure administrative access to the SCADA/EMS, which enables the integrator to respond to OPD5 requests for technical support and further system development.

INTRODUCTION

Overton Power District Number 5 (OPD5) is a utility located approximately 65 miles northeast of Las Vegas, Nevada. The OPD5 service territory, crossed by Interstate Highway 15, covers approximately 2,025 square miles, with most of the population spread among the communities of Mesquite, Overton, and Logandale, Nevada. Geographically, the OPD5 service area embraces two valleys, the Moapa and the Virgin.

Mesquite, in the Virgin Valley, is a prosperous border town, with hotel-casinos, golf courses, and other commercial, residential, and light industrial loads. Mesquite is located on the Nevada side of the border with Arizona, just 30 miles from St. George, Utah. Approximately 60 percent of the OPD5 load is located in and around Mesquite.

Overton and Logandale, in the Moapa Valley, are 35 miles southwest of Mesquite. These towns are primarily bedroom communities that attract both retired residents during the winter months and full time residents who commute to the Las Vegas area. Access to Lake Mead is a tourist and recreation attraction. OPD5 is headquartered in Overton, but also maintains a business and service/maintenance facility in Mesquite. Electric customers in the Mesquite area can pay their power bills at the OPD5 customer service counter in Mesquite, and be credited by printed receipt prepared by the company billing computer in Overton.

Thirty customers account for half of the OPD5 system load. Load growth in past years was as high as 20 percent, but has recently settled to about seven percent, mainly for increased housing developments, and the gaming businesses in Mesquite.

Table 1 OPD5 Customer Growth

Type of Customer	December 1990	December 2000
Residential	2,571	7,466
Irrigation	47	56
General Services	519	1,099
Total Customers	3,137	8,621

Power is purchased through long-term agreements with the Colorado River Commission of Nevada and with Nevada Power. OPD5 is electrically close to the Reid Gardner coal-fired thermal generating station and Hoover Dam hydropower. Transmission voltages that tie OPD5 with Nevada Power are 230 kV. Other neighboring utilities that are downstream from the OPD5 transmission system include Lincoln County Power District Number One (LCPD) and Dixie-Escalante REA (DE-REA).

The OPD5 power system is a radial transmission and distribution network. The transmission system consists of Tortoise, Sandhills, and Painted Hills substations. Power enters the system at the Tortoise transmission substation via the 230 kV tie with Nevada Power’s Reid-Gardner plant. The voltage is then stepped down to 138 kV and 69 kV in the Tortoise substation. The 138 kV power is transmitted to Sandhills and Painted Hills transmission substations where it is stepped down to 69 kV for transmission to the outlying distribution substations. Power for LCPD comes from the Tortoise transmission substation and power for DE-REA from the Painted Hills transmission substation. If the Reid-Gardner line fails, limited power (15–20 MW) can be brought in via the Winterwood backup line from Las Vegas. If the 138 kV transmission lines between Tortoise and Sandhills or between Sandhills and Painted Hills should fail, OPD5 can loop power to the affected distribution substations via 69 kV lines.

OPD5 operates eight distribution-class substations: three in Mesquite, one in Overton, one in Logandale, one in Glendale, one in Bunkerville and one in Moapa. Incoming power to the distribution substations is at 69 kV. Distribution voltage levels are 12.47 kV.

BACKGROUND

The primary operating goals of OPD5 management are to manage the system in a fiscally responsible and successful way, and to keep the lights on. They are very aware of ongoing deregulation activities in the industry and concerned about the implications of such on Public Utility Districts. Because electric customers may eventually be able to choose among power providers, management at OPD5 is investing in their system to help ensure that their billing rates remain attractive and the quality of delivered electric service meets and exceeds customer expectations.

OPD5 did not have the technology to meet their goals. They lacked a Supervisory Control And Data Acquisition (SCADA) system. Several substations did have dial-up capabilities for the purpose of reading metering quantities on a feeder and station bus level. All switching was done locally via manual means. Operations staff were faced with ongoing challenges to restore service in a timely fashion following transmission breaker lockouts during lightning storms. A lockout on the Tortoise-Nevada Power 230 kV line meant loss of power for LCPD, DE-REA, and OPD5. Another operating challenge arose during line reconstruction of the Tortoise-Lincoln County line. Every day that crews were working on these lines, the breakers were tagged and reclosing was blocked. Because the contracted maintenance crew often stayed on the project until well after normal working hours, OPD5 operations staff had to work overtime, drive to the Tortoise substation, and remove breaker tags to enable reclosing during nighttime hours. This was a substantial financial burden for OPD5.

OPD5 initiated a search for a solution to their lack of a SCADA system. Numerous vendors and consultants were contacted, and offered solutions were closely examined. The scope of the needed work was identified to include communications infrastructure, communications terminal hardware, substation connectivity between a variety of Intelligent Electronic Devices (IEDs), and type and location of Human Machine Interfaces (HMIs).

In October 1999, OPD5 requested proposals from eight system-integration firms. Management then evaluated six respondents on criteria that included: proprietary versus nonproprietary communications protocol, demonstrated ability to integrate existing IEDs, and cost. All six presented solutions that were within the predetermined OPD5 cost target, and therefore received equal scrutiny. At the conclusion of the evaluation process, OPD5 management selected an integrator based on technical and commercial criteria.

TECHNICAL APPROACH

The agreed upon scope of work included: communications network topology design, substation IED connectivity design, relay settings, communications processor settings, HMI screens development, and on-site testing and commissioning of the integrated network. Initial meetings between OPD5 and the integrator/contractor quickly identified the need for developing a detailed communications networking plan. A third party network consultant was brought into the team.

The project team consisted of the OPD5 Manager, Network Administrator, and Operations Supervisor, the SCADA/EMS integrator, the network consultant, and the two phone service providers for the Moapa Valley and Virgin Valley. As the communications network plan developed, objectives expanded to include engineering access to Internet resources, greater compatibility between shared network printers, and increased network access speed for business office use between the Mesquite Service Center and the Overton head office.

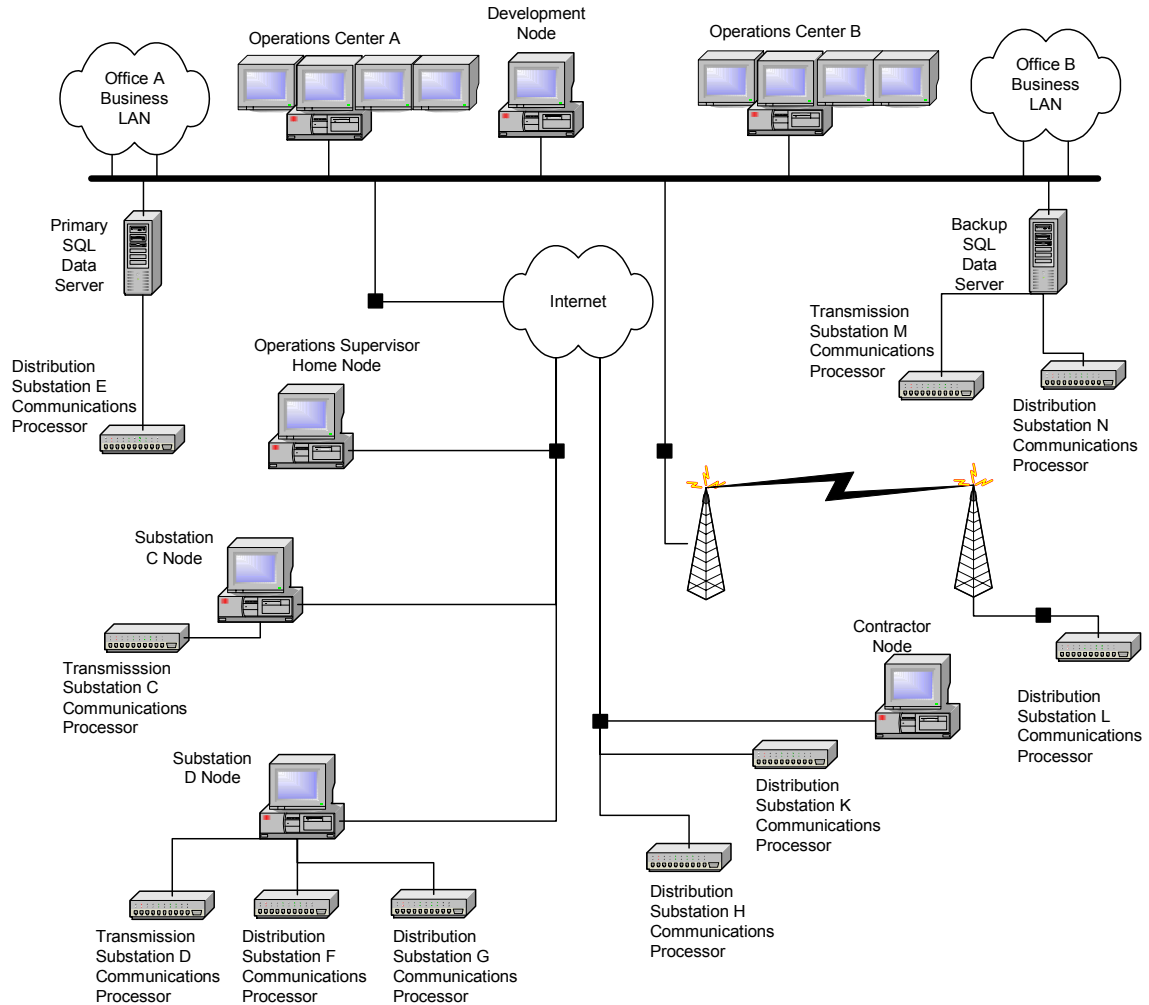


Figure 1 Network Communications Diagram

The system communication consists of a variety of communication types, partly because of the differing capabilities of two separate phone service providers in the region. This issue continues to evolve as the providers' capabilities improve.

Communications between the Overton office and the service center in Mesquite are via Overton's own T1 line. OPD5 relies on the Moapa Valley Telephone Company to deliver high-speed Asynchronous Digital Subscriber Line (ADSL) connectivity between the Overton office, the Internet, Sandhills substation, Tortoise substation, Logandale substation, and a system operator's house. Overton substation is connected to the Overton office via single mode fiber-optic cable. The Glendale substation is connected to the Tortoise substation via single mode fiber-optic cable and the Moapa substation is connected to the Tortoise substation via multimode fiber-optic cable. In Mesquite, wireless Ethernet is used between Bunkerville substation and the Mesquite Office. Direct multimode fiber connects the Painted Hills transmission and distribution substations to the Mesquite office. The Mesquite substation will be connected to the Mesquite office via single mode fiber-optic cable as soon as permits to route cable across Interstate Highway 15 are received. When this fiber is installed, the Pulsipher substation, currently connected via a dial-up modem, will also be on a direct fiber connection to the Mesquite office.

ADSL link performance was measured at 512 kbps with secure, Digital Encryption Standard (DES) encrypted signaling. Prior to the installation of the SCADA system, round trip

communications performance between the Mesquite service center and the Overton home office data processing equipment was measured at 15+ seconds for acknowledgement and printing of payment receipts. The current system interconnectivity now provides 3-second round trip response times, which greatly facilitates customer service transaction activities.

Network security is provided with ADSL router/modems and secure firewalls procured from a major hardware vendor. The hardware firewall is used in the Overton office to secure the office network and provide terminations for the Virtual Private Network (VPN) tunnels to the DSL connected substations. The secure router/modems are used in Sandhills, Logandale, and the system operators' home PCs to terminate the VPN tunnels and secure the substation from the outside world. Another hardware firewall is used to terminate the VPN tunnel and secure the Tortoise substation from the outside world, and a companion firewall is used to terminate the VPN in the system integrator's home office. This connection is provided so that the system integrator can provide troubleshooting help and easily assist OPD5 in future additions to the system.

The VPN Tunnel is built using pre-shared keys on each firewall or router. Once the tunnel is built, all communication is via DES encryption. Firewall/router security provides workstation access to all substations across the protected communications network. This security also provides translation of public addresses to private addresses. Only connections opened by the private control machines are allowed access back through the firewall/routers. When data transmittal is finished, each firewall/router closes the door. Oman [1,2] identifies and discusses technologies and procedures for safeguarding IEDs and networked SCADA systems against electronic intrusions. OPD5 has employed technologies for access restrictions, authentication, encryption, and network security to reduce the vulnerability of their integrated protection, metering, and SCADA solution against cyber attacks.

The VPN developed for the Overton Power District SCADA system provides secure access for the operations team from several key locations, including the general office, substations, and the homes of on-call technical staff. On a contractual basis, the system integrator also has secure, administrative access to the VPN. This enables the contractor to respond to OPD5 requests for technical support, which can include setting relays and communications processors, retrieving and analyzing oscillographic event and sequence-of-event reports, and de-bugging IED data streams. This form of on-demand technical support makes good use of factory/integrator experts, and is extremely cost-effective for the end-user.

Operations personnel are provided ADSL service to their personal residences. High-speed connectivity to the system operators' home PCs provides timely response to system events. For a utility the size of OPD5, this home access was more viable than staffing 24-hour system operations centers.

IEDs in the substations communicate via serial connections to communications processors. The communications processors applied in transmission and distribution class substations are set to concentrate required IED data and provide specific control functions. They are physically located in station control buildings or mounted in outdoor enclosures. A point-to-point "star" topology is applied to achieve fast, efficient, and robust transmission of measurement data and control actions. Cost-effective MODBUS[®] RTU protocol is used between the communications processor and the HMI computer. A second separate transparent link is applied between the communications processor and the HMI computer to provide engineering access to connected IEDs. This link allows engineers to communicate directly with the IEDs through the communications processor. Once the connection is established, the communications processor becomes "transparent" and passes data to and from the IEDs. The current plan is to add Ethernet cards to

substation communications processors for local and remote engineering access to IEDs from throughout the enterprise.

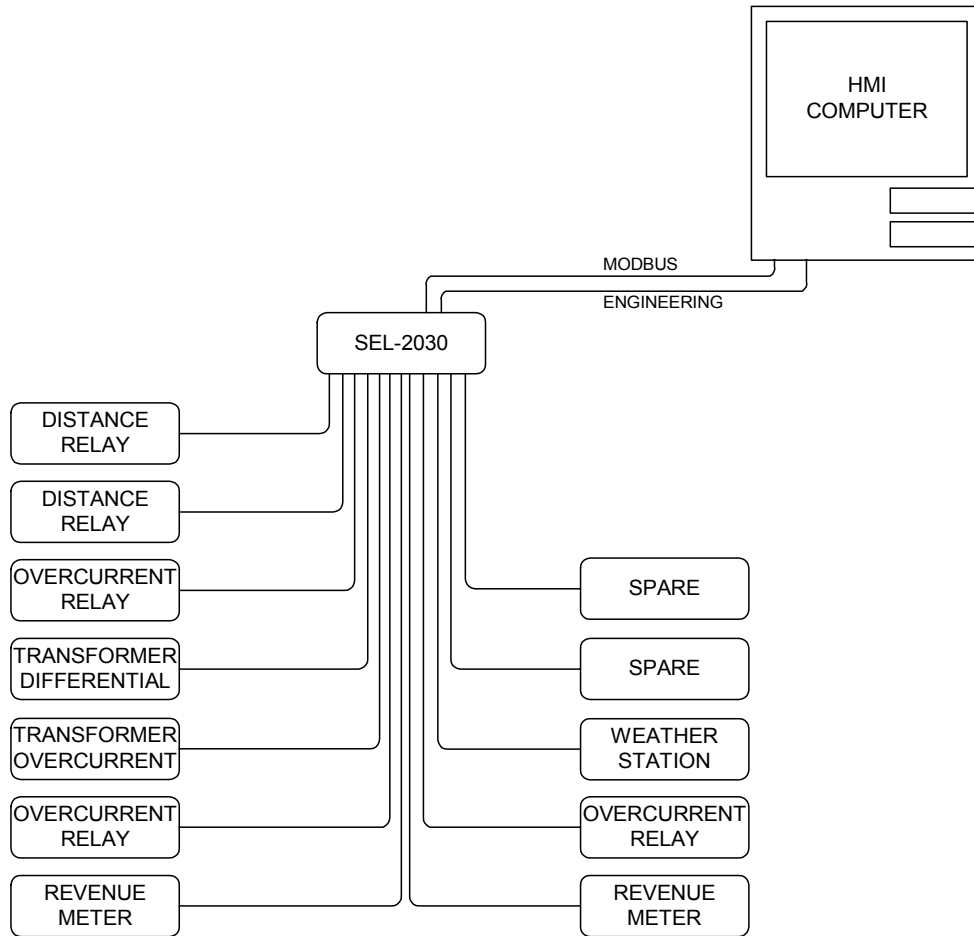


Figure 2 Typical Single-Tier Substation Communications Diagram

Distribution substations are typically two-transformer, four-feeder designs. Reclosers protect the distribution lines and three single-phase voltage regulators control the substation distribution bus voltage. All protective relays, regulator controls, and meters are remotely mounted inside the substation control building.

Communications designs for virtually any number of IEDs are easily created using communications processors. Single-tier substation designs refer to stations with 12 or fewer IEDs connected to a single communications processor. Larger stations with more IEDs are accommodated by connecting all IEDs to communications processors and then connecting the communications processors to each other in a tiered fashion. This tiered connection allows data to pass from the IED to one communications processor, then up to another communications processor, then on to the HMI and other destinations.

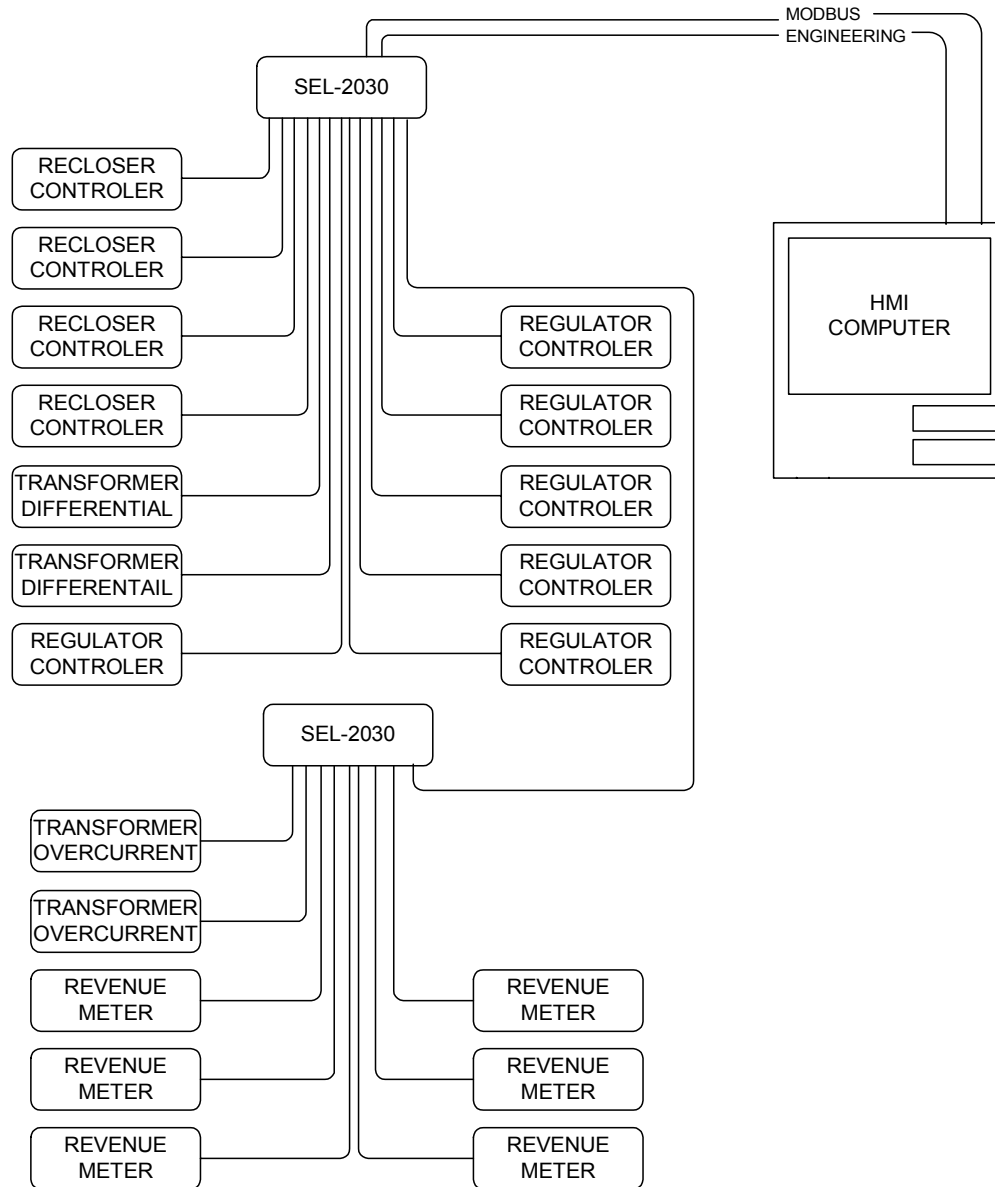


Figure 3 Typical Two-Tier Substation Communications Diagram

Wonderware[®] Manufacturing Management Information System FactorySuite[™] 2000 was chosen to provide HMIs, and data management. The Wonderware software used in the project included InTouch[®] HMI, IndustrialSQL Server[™] database, and ActiveFactory[™] client. Updates to Wonderware applications are automatically deployed using Wonderware's Network Application Development tools. This approach helps ensure timely and efficient upgrades to the HMI drivers and data management tools. One "View Node" application fits all present and future HMI installations. This simplifies the process for maintaining and adding functionality to the HMI system.

HMIs are provided in the Overton Operations office, Mesquite Operations office, Tortoise substation, Sandhills substation, and operations personnel' homes. These HMIs allow users to view substation data as well as control substation equipment. The rights allowed by the system security limit this view and control capability.

In the two operations centers a single PC drives four monitors. The system is capable of displaying information from a single substation or from multiple substations. A single HMI monitor is used at the control operators' homes and at one substation that has a permanent PC installation. Portable notebook computers are used by control operators at all other substations via local area network connections.



Figure 4 Four-Monitor Control Station

The default screen for the operators' homes is the system overview. In a substation the local substation single line is the default screen. When an operator is properly logged on, other substations can be viewed and controlled from any HMI location.

The HMI includes a screen view of recorded event histories. Substation IEDs log operational events, which are then automatically retrieved and stored by the SCADA system. Operators have near-instant access to key information regarding relay trips and operator-initiated switching actions. Online documentation for switching procedures and operations troubleshooting guides complements automatic retrieval of event history information. This documentation helps ensure that operators have easy access to approved work instructions and the corporate knowledge base for more efficient system operations.

To ease the transition from no SCADA to full SCADA, the operator interfaces seen on HMI screens were designed to be as similar to the actual device installed in the substation as possible.

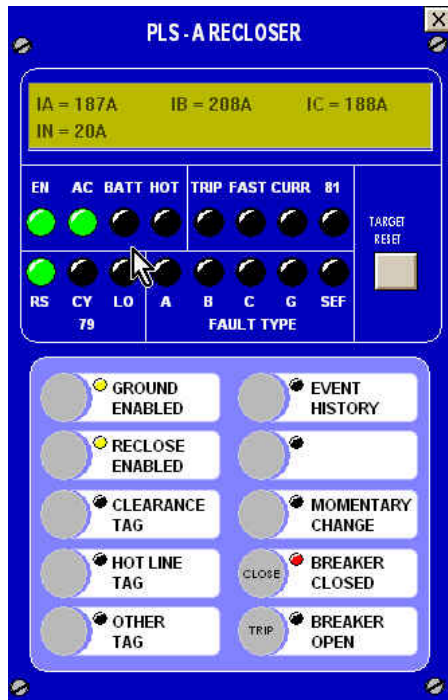


Figure 5 Recloser Control Screen

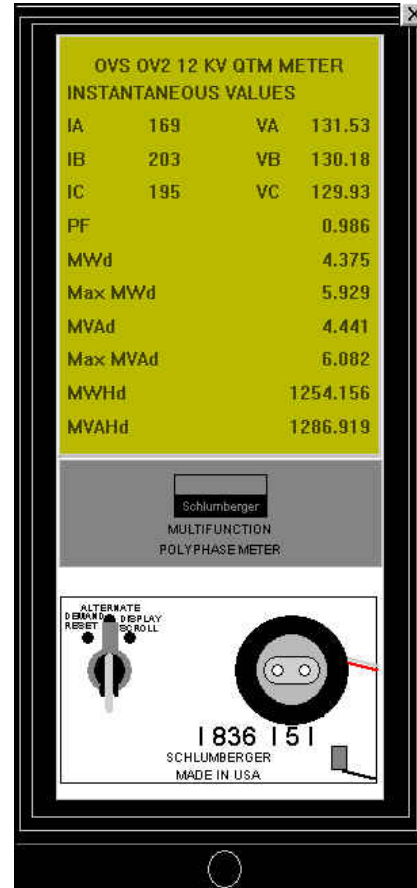


Figure 6 Meter Screen

Note that Figure 5 includes operator control functions for “Hot Line Tag” and “Other Tag.” All control operator tags are logged to an SQL database. This process helps ensure that accurate historical logs are maintained for the date, time, and operator comments associated with each tag application and removal. Main and backup server applications provide high availability of SCADA and historical records.

Historical and Report Data

The IndustrialSQL database provides storage for historical data, as well as a central location for general data storage. Every morning at 5:00 AM, the new system automatically queries the database and generates a daily usage/peak demand report. This report is automatically published to the OPD5 intranet for use by the Engineering and Operations departments to determine daily usage and forecast future power purchases.

Prior to implementing this system, operations personnel would dial-up the three intertie meters each morning, download the data, then copy and paste it into a spreadsheet. Management would then copy the spreadsheet, plus weather report data, for weekly distribution to other departments. The new report is in the same format, but is generated daily without any operator intervention. It is also stored on a central server that Management, Operations, Engineering, and Construction can access. Anyone with access can now view the report at any time.

Another report, on substation loads, required at least a day to compile from the daily reports and additional fieldwork. This report details total load for the substation, per-transformer loads, and

individual circuit load information. Now operators need only query the database for the report, which is updated monthly from stored data in the SQL database.

The SQL data is also used in OPD5 Operations intranet web page. Operations can now share more information, more quickly, with less work. Since the information can be viewed from any location on the network, other departments can now watch and/or monitor switching procedures, outages, or substation loads.

RESULTS

Prior to implementing the new SCADA/EMS system, only a few substations had dial-up access for remote control of circuit breakers. The remote control process was difficult and was understood by only one person. The new system provides remote access to all substations from various communications network access locations. Easy-to-teach and understand point-and-click graphical user interfaces deliver remote breaker control capabilities for all authorized operations staff.

The HMI screens provide remote capabilities to enable/disable protective functions, set/clear hot line tags, set/clear clearance tags, enable /disable reclose, and enable/disable ground relaying. Remote override control of automatic voltage regulator tap controllers is now used to improve customer service and decrease operating costs.

Direct labor costs for maintenance and operations are reduced for each event that used to require a crew to enter a substation. Many of these control tasks are now performed remotely from access points on the OPD5 network. These access points include the Overton and Mesquite business offices, each substation, and the on-call operators' homes. Comparing the previous process for disabling and enabling breaker reclosing shows an example of this savings. Previously a minimum of one hour was required to develop a switching procedure and dispatch a crew to a substation to disable the breaker reclosing. Afterwards, another hour of crew time was required to restore the reclosing function. Now, the same operational procedure requires about two minutes to write-up the necessary paperwork and then remotely disable the substation breaker reclose function.

Remote control of distribution bus voltage regulators has resulted in several benefits. Operators can remotely change the regulator tap position during times of system peak demand, and instantly see a reduction in the system load. This saves energy costs when system demand approaches peak values.

Improved customer service was also achieved during times of heavy demands for water. The local water utility was experiencing some difficulty in operating their pump motors and called on OPD5 for assistance. In one case, OPD5 determined that boosting their voltage regulators up a tap would improve the water pump motor operational capabilities, without incurring negative impacts on other connected customer loads. In another instance, an electrical operating problem experienced by the water utility was traced to a system problem in the end-user's low voltage wiring. In both of these examples, OPD5 operators were able to quickly respond to customers' needs without leaving the control center.

Changes in status and alarms are reported by the remote IEDs when they occur. The system also polls the IEDs for metering data every ten seconds. This data is stored in the system server database and displayed on the system HMIs. Near real-time display of substation bus voltages, feeder loads, and intertie power exchanges provides system operators a critical view of important system data. Recently, operator detection of inconsistent meter readings revealed inadvertent switching of a transmission system intertie breaker by a neighboring utility. A normally open

system tiebreaker was closed for a short period of time, less than the fifteen-minute storage period of the custody transfer meter. Because the intertie revenue meters record demand over fifteen-minute intervals, the closure would probably have gone unnoticed if these meters were the sole means for detecting abnormal switching. However, the ten-second polling rate of remote IEDs provided a clear indication of inappropriate switching that had the net effect of transmitting load currents through the OPD5 network from and to the neighboring utility. Had this switching not been detected, OPD5 would have received billing for energy consumption that was in fact not due to OPD5 loads.

All live data and archived data are available on the corporate intranet. Ten-second update rates of data presented on the web pages is typical. The intuitive web pages that are used to deliver system data use point-and-click menu navigation and the user's choice of browsers, and require minimal training. A variety of recorded data is graphically trended, including transmission tie energy exchanges, distribution feeder loading, and weather station parameters. Access to the live and archived data is provided to a wide variety of OPD5 staff, including corporate managers, engineers, technicians, and system operators. With online data available, there is no longer a need for personnel to spend time creating custom or repetitive reports.

The new system also greatly improves the efficiency of engineering tasks that depend on analysis of recorded data. The data servers operating with an SQL database make recorded data retrieval activities fast and easy. In addition, the design and deployment of the SCADA/EMS system by the Operations Department made a significant change in the roles, responsibilities, and knowledge base of this group. The Operations Department is now responsible for the corporate communications system, including the maintenance and growth of the local area networks.

Monthly substation inspections that used to take a week to complete are now finished in a single day.

Using the communications backbone of the SCADA/EMS system throughout the OPD5 enterprise also improved customer service procedures. The time to print customer payment receipts in the Mesquite business office was reduced from fifteen seconds to less than three seconds, still using the business system servers located in Overton, some 35 miles away.

A difficult to measure, yet important, aspect of the new system is the increased credibility of OPD5 managers and operators as viewed by all neighboring utilities. Accurate and timely data is a powerful asset. OPD5 now has instant access to live and recorded system data, which is used to resolve all sorts of questions that normally arise among interconnected utility companies, as well as issues that arise between utility energy providers and connected end-users. OPD5 may be a small utility compared to the industry average, but it now has world-class capabilities for remote system control and data acquisition.

ONGOING ENHANCEMENTS

Because all OPD5 operators have laptop computers the current plan is to remove the PCs from the very dusty substation environments. Instead, OPD5 will install Ethernet switches in the substations that the operators will use to connect their laptops to the OPD5 network and SCADA system. Once the Ethernet switches are installed, OPD5 plans to implement Ethernet Cards in their communications processors. These Ethernet cards will provide OPD5 with remote settings management and remote retrieval of oscillographic event reports. The integrator will also be able to provide remote event analysis and remote relay and communications processor settings assistance.

LCPD, which shares the Tortoise transmission substation with OPD5, is starting to install a SCADA system that will be connected to the OPD5 system. The current plan is to include three substations that are under construction and six LCPD substations now in use.

OPD5 also plans on increasing their use of SQL data. OPD5 management, purchasing, engineering, and operations continue to find additional uses for the archived data. They are looking into providing more information to internal and external customers via web pages and automatic reports.

CONCLUSIONS

The SCADA/EMS has improved awareness of the OPD5 power system capabilities. Instead of calling a single meter in one substation for a glimpse at that substation, OPD5 operators can now see all the system loads on the HMI screens in one of the control rooms.

Additional improvements made possible by the OPD5 SCADA/EMS include:

- Verification of large customer metering accuracy.
- Load and usage information to aid decisions on where to construct new substations.
- Three to five percent reduction in peak loads through better control of distribution voltage regulation.
- Power purchasing and contract negotiation based on data from the power system.
- Increased accuracy in forecasting usage.

Because of increased performance in the OPD5 power system, the SCADA/EMS will pay for itself in less than two years.

The SCADA/EMS is being used for all aspects of power system control. Hot Line permits are issued by the operator of the day and installed from one of the central control HMIs or one of the local HMIs. This solves a problem that occurred several times in the past when a crew installed a tag on a line and did not remove it at the completion of the project. Then, these tags would have remained installed until operations made their monthly substation inspection. Now, the tags can be easily removed the same day.

In summary, the installed SCADA/EMS system has met and exceeded the expectations of OPD5 management. The system is highly adaptable for the addition of new substations and new functionality for engineering and business purposes. The adaptiveness is made possible by readily available software applications tools and by flexible communications architecture that uses off-the-shelf equipment. The continuous improvements brought about by the new SCADA/EMS system help to ensure that OPD5 will remain a technically and financially secure power provider for many years to come.

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BIOGRAPHIES

Kevin Streett majored in Construction Management at Boise State University. Prior to joining Overton Power District No. 5 in 1986, he worked as a construction foreman and supervisor in the U.S. and overseas, building substations, transmission lines, and distribution systems. He is presently Operations Supervisor at OPD5, responsible for substation construction and maintenance, metering, and operations.

Kevin Leech received his BSEE from the University of Wyoming in 1994. He worked for CME Engineers as a Design Engineer. In 1998, he joined SEL as a System Integration Engineer. He is now an Integration Application Engineer. His experience includes process automation and control, substation automation and integration, human machine interfaces, radio telemetry, SCADA, PLCs, programming and start up of PLC and HMI systems, control panel design, and lighting system design. He is a member of IEEE.

Gregory B. Rauch is the Utility Solutions Manager for Schweitzer Engineering Laboratories in Pullman, Washington, USA. He holds BSEE and MEEE degrees from Brigham Young University. During his industry career he has worked in many capacities, including relay application engineer, EPRI project manager, and consulting engineer. He is a senior member of the IEEE, and a registered professional engineer in the state of California.