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Campus Distribution Makes the Grade

The University of California, Santa Barbara updates a legacy distribution system with automation and a state-of-the-art network.

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THE NEED FOR A RELIABLE, ROBUST ELECTRICAL SYSTEM TO MEET THE VAST REQUIREMENTS OF A MAJOR UNIVERSITY IS PARAMOUNT. The University of California, Santa Barbara (UCSB; Santa Barbara, California, U.S.) is in the midst of a major capital building program designed to keep the campus infrastructure up to world-class standard. UCSB is in the forefront of advanced research and development programs, is home to one of only two of the California Nano Sciences Institutes and has many notable faculty members, including five Nobel Prize recipients.

TAKING A NEW DIRECTION

The UCSB campus is served by two electrical distribution systems, the first a 16-kV system owned and operated by Southern California Edison (SCE; Rosemead, California) and the second a 4.16-kV legacy system owned and operated by the university. The origins of the legacy system can be traced back to 1952, when the campus was moved onto what was the Marine Air Base at Goleta Point. The age and condition of the existing systems, as well as limitations with the current design, led UCSB to develop a plan to replace the existing electrical distribution system with a campus owned and operated system that is modular in design and takes advantage of emerging automation technology for a high level of reliability.

UCSB started a partnership with P2S Engineering Inc. (Long Beach, California) to assist in the design and implementation of the new system. Talks with SCE began in 2001 and a Campus Distribution Master Plan was developed. The decision was made to standardize a 12.47-kV system; incoming SCE delivery would remain at 66 kV. UCSB would install its own 66/12.47-kV double-ended substation and replace all of the campus underground cable system with new 15-kV cables, all owned and maintained by the university. Detailed planning and work procedures were required between UCSB and SCE to permit entrance into structures operated by SCE, but destined to become UCSB property.

The 12.47-kV side of the new University of California, Santa Barbara-owned 20-MVA 66/12.47-kV substation.

Campus photograph by Tony Mastres.

New switchgear building with new indoor vacuum circuit breaker and metal-clad switchgear.

All building primary transformers needed to be replaced to accept the incoming 12.47-kV service. Building vaults with SCE equipment required special consideration because of jurisdictional and ownership issues. In many cases, temporary generators were needed to provide building power during the removal of the old service equipment and the installation of the new equipment.

In addition to the fundamental distribution design of transformers, switchgear and cable, the master plan included the use of a high-reliability distribution system (HRDS) from S&C Electric (Chicago, Illinois, U.S.). This system uses S&C Vista 15-kV class, SF_6-gas-insulated fault interrupters, which are located throughout the campus and distribute power to individual building service transformers. Rather than offering simple switching and standard building feeder protection, the HRDS switches automatically sense cable failures within campus loops and isolate faulted-cable sections with virtually no impact on building loads. The status of each HRDS switch throughout the campus and the main incoming service switchgear are monitored from a central facility management location via a supervisory control and data acquisition (SCADA) system. S&C's Power Systems Services division designed and tested the protection system and provided start-up services.

EXISTING DISTRIBUTION SYSTEM

SCE has a dedicated 66-kV transmission line routed to the campus, which supplies electrical power to a 66/16-kV substation. From this substation, SCE routes two 16-kV circuits throughout the campus to provide power to various buildings and the campus's 4.16-kV distribution system. There are more than 110 manholes on campus, 9 miles (14 km) of underground duct bank, and approximately 100 building and facility primary transformers.

The distribution system has suffered numerous unplanned outages in past years, the result of aged cable and components. The lack of system-design redundancy and the unavailability of replacement components have exasperated the length of outages.

PHASE-BY-PHASE PROGRESS

The project was divided into three construction phases. To date, the first two phases have been completed and the remaining phase started in May 2007. The project will be completed by July 2008.

During Phases 1 and 2, a new 20-MVA, 66/12.47-kV transformer was installed in the same substation yard as the SCE 16-kV service transformer and breaker rack. The campus and SCE made special arrangements to ensure controlled separation between their respective equipment. An outdoor rack on the 12.47-kV side of the transformer holds the utility-provided current transformers (CTs) and potential transformers (PTs) used for revenue metering. Three sets of 15-kV 500-kcmil cables run in underground conduit to the university's new switchgear building. This building contains a 48-ft by 24-ft (14.6-m by 7.3-m) underground cable vault and the indoor 15-kV vacuum circuit breakers and associated metal-clad switchgear. Campus feeder-cable circuits drop from the feeder breakers into the underground vault and are distributed through an extensive conduit and manhole system. The switchgear uses a main-tie-main configuration with 10 feeder-breaker positions and provisions for two additional sections for future co-generation system connection.

Three 12.47-kV underground-distribution (looped) circuits (Research North, Research South and Central Academic) were installed along with a dedicated fiber-optic loop for each circuit. To facilitate the routing of these new circuits, 14 new manholes, 14,000 ft (4270 m) of new duct banks, 84,000 ft (25,600 m) of conduit, 75,000 circuit ft (22,900 m) of 500 MCM EPR cable, and 28,000 circuit ft (8500 m) of 2/0 underground service cables were installed. Also installed were 67 unit substations (27 outdoor padmounted and 40 indoor dry-type) and 27 padmounted S&C Vista SF_6 switches.

Of the existing underground infrastructure, 75% is used for the new system. Therefore, SCE and the university scheduled campus power outages during the removal of the abandoned circuits and the installation of new 12.47-kV circuits. In many cases, generator sets were installed to maintain building power, with special consideration given to science buildings, where power continuity is essential for ongoing experiments and research functions.

The final phase of the project will install a second 20-MVA, 66/12.47-kV substation transformer. Also, the fourth campus 12.47-kV loop (Housing Auxiliary) will be installed, along with the addition of 15 S&C Vista padmounted SF_6 switches and 38 building-unit substations. Final removal of SCE facilities, the university-owned 4.16-kV substation and all associated feeders also will be completed under this phase. The real estate occupied by the existing 4.16-kV substation is already planned for a new university building.

DISTRIBUTION AUTOMATION

The UCSB system uses a closed-loop, primary-voltage distribution-automation system with padmounted switch-


Electrical service area for advanced engineering/research building.

gear and relays communicating through a multiplexed fiber-optic network.

The system uses relays and fault-interrupting switchgear to eliminate feeder-cable outages. The primary network is protected by S&C Vista automatic switchgear units, which consist of two 600-A feeders and multiple 200-A branch-line ways, each with vacuum fault interrupters. These interrupters are in a sealed stainless-steel tank insulated with SF_6 gas.

Each switchgear way also has an integrated three-position disconnect and grounding switch in series with the vacuum interrupter. A large viewing window is provided at each switch way to physically verify a visible open gap and grounding of the cables for maintenance operations. Each 600-A feeder way is trip-controlled by a dedicated SEL 351 relay (Schweitzer Engineering Laboratories; Pullman, Washington, U.S.). The relays are placed in low-voltage cabinets, mounted on one end of each switchgear. Battery backup for up to four hours is provided within each low-voltage cabinet for the relays and fiber-optic transceiver. The 200-A branch-line ways are protected by Vista Overcurrent Controls.

The switchgear relays on the main feeders provide both permissive over-reaching transfer trip (POTT) and directional comparison blocking (DCB) protection to the feeder circuits. This combination provides speed isolation and protection redundancy. Before the segment is isolated, the POTT requires the directional overcurrent relays on each end of a cable segment to agree there is a fault between them.

The DCB is the backup scheme and also is active at all times. The DCB is slower than the POTT and is the only scheme functional during open-loop conditions of the circuit. The DCB relays also will want to trip when they see a forward fault and will do so unless they receive a block signal from their partner relays at the other end of the cable. Both POTT and DCB schemes use the fiber-optic multiplexer system to communicate between relays.

The overcurrent control that protects the branch-line circuits from each switchgear is a self-contained relay that acts as a nondirectional resettable fuse. It is powered from CTs within the switchgear tank and mounted within the switchgear enclosure on the side of the vacuum fault interrupter's SF_6 tank. Each overcurrent relay controls two branch-line fault interrupter ways.

Backup protection in the form of nondirectional overcurrent elements programmed in the substation feeder relays is further provided. These backup elements are coordinated with primary communications protection, branch-line protection and source transformer fuses to allow clearing of faults, even in the event of a complete communications system outage.

SCADA SYSTEM

The relays also serve the function of a remote terminal unit by sending valuable information to facilities monitoring personnel through the SCADA system. Status, control and alarms are provided for each 600-A way of the switchgear units. Alarms for battery condition, loss of ac control power, loss of communications or high bit-error rate, relay malfunction, status of local/remote switch, status of low SF_6-gas-pressure indicator and status of branch-line fault interrupters are monitored. The relays also provide analog information, including amps, volts, watts and VARs scanned on approximately 4-second intervals. Remote monitoring of system data is provided to a Facilities Management Center. In addition, information for up to 16 events stored in each relay is available by on-site downloads. This information includes fault location, targets, amps and oscilloscope data.

Status, alarms and analog data are brought back to a substation interface computer in the 12.47-kV switchgear building. Interface software (Substation Explorer from Subnet Solutions) provides a graphical user interface at the substation for alarm annunciation, monitoring of power flow and interface to the Facilities Management Center SCADA system. Graphical views include an overall system one-line diagram and detailed views down to individual switchgear to quickly determine status of any component throughout the distribution system. An automatic dial-out e-mail pager feature of the interface software alerts system-operating personnel to critical alarms assuring prompt response to any evolving system condition.

The fiber-optic communication system (H&L Instruments Model 570) moves the information between switchgear locations with a delay of less than 2 msec (one-eight cycle). Reliable high-speed communication is critical to supporting the 0.1 sec (six cycles) or less total clearing time provided by the primary network protection system. The same fiber-optic system also carries SCADA information back to the substation interface computer.

To further promote reliability, the fiber system uses a redundant ring topology. This system allows for the immediate rerouting of information to the alternate direction around the loop in the event of a fiber break, dig-in or failed multiplexer. The fiber system can reconfigure from loop to radial operation in 4 msec (one-quarter cycle) with no loss of data — so quickly that the relays may not even detect the fiber break. This assures the integrity of this critical portion of the distribution system.

RELIABILITY AND SELF-RELIANCY

Upon completion of Phase 3, UCSB will be totally self-reliant on its own campus-wide electrical-distribution system. With this ownership and the new multi-loop distribution-system configuration, system reliability and operational flexibility will be greatly improved. A loop-feeder fault will be quickly isolated by the HRDS design and no effect on building power is expected. A failure on a branch-line building circuit will isolate that building only and will have no impact on other buildings. Preventive maintenance is enhanced by the multipoint HRDS condition alarms, which are monitored and recorded for all major system devices in the HMI interface, located in the main switchgear building. Alarm messages are remotely transmitted to facilities personnel by Ethernet connection and dial-up pagers.

Also, portions of the loop feeders can be opened for cable maintenance or the addition of a new selector switch without affecting building services. All conductors are fire-taped in manholes to prevent collateral cable damage caused by catastrophic failure on a separate circuit. At the front end, the two 20-MVA substation transformers provide redundancy, as one can carry the total university load using its fan rating.

To increase system reliability in the event of a main switchgear bus fault, strategic feeder-to-feeder ties are installed to provide backup for this condition. To operate the system in this configuration, university personnel must operate the substation and field switches manually.

With the common-distribution 12.47-kV voltage rating, all switchgear, cables and building primary components are consistent, lessening confusion of multiple system voltages for maintenance personnel. In addition, the spare-parts inventory is reduced for items such as fuses, cables and switchgear components.

The UCSB campus electrical distribution system now operates with a microprocessor silent sentinel watching over its operation. With its state-of-the-art controls and flexible configuration, the distribution will provide reliable electrical service for UCSB students, professors and staff for decades. TDW

Davidson Library Vista switchgear and 2500-kVA padmount transformer.

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