CASE STUDY

Lawrence Livermore National Laboratory—Livermore, California

Power System Protection Crucial to Nuclear Weapons Test Simulations at Lawrence Livermore Facility

Lawrence Livermore National Laboratory (LLNL), a pre-eminent scientific resource for U.S. defense, science, and industry, is the institution that applies advanced interdisciplinary science and technologies to ensure that the nation's nuclear weapons remain safe, secure, and reliable. This is known as the Stockpile Stewardship Program, which entails authentication of the U.S. nuclear weapons stockpile (a responsibility of LLNL as part of the National Nuclear Security Commission) in support of the comprehensive nuclear test ban treaty.

Scientists and engineers at LLNL use supercomputers to certify weapon performance via simulation rather than actual testing. Because these simulations involve many trillions of computations that perform at ultra high speeds, a new mission was undertaken in the mid-1990s to upgrade these supercomputers to "monster" computer systems that perform at terascale levels (trillions of calculations per second). The mission resulted in LLNL's recently operational Terascale Simulation Facility (TSF).

Timing of the TSF project was influenced by resurgence in supercomputing science. But LLNL also desired to supplement simulation results with the knowledge of the few remaining scientists (soon to retire) who have hands-on experience in atmospheric and subterranean nuclear testing.

The TSF facility consists of two 24,000-square foot computer rooms enveloping tens of thousands of processors in hundreds of cabinets. The simulation system is capable of exceeding 100 tera-FLOPS (trillions of floating-point operations per second) peak performance, with aggregate memories of up to 50 terabytes and archive memory capable of handling petabytes (thousands of trillions) of data.

Figure 1—The TSF houses a total of 48,000 square feet of computer space with a projected load of 23 MW. The facility requires reliable electric power to ensure that the computations are not interrupted.

Figure 2—The computer room shown is 24,000 square feet of unencumbered space with a 48-inch raised floor. This room houses equipment capable of exceeding 100 tera-FLOPS at peak performance.

Assurance that such staggeringly high levels of computation would be completed without interruption requires not only reliable monitoring and protection of the electric power system, but also a scheme that enables TSF to transfer power sources should there be a problem with the primary source.

"The facility requirements far exceed those of conventional data centers," says Anna

Maria Bailey, P.E., Livermore computing program facility manager, who was the TSF design and construction manager of the facility. "The facility requires very high levels of power as well as cooling, unencumbered floor space, and a large communications infrastructure."

The TSF facility has a capacity of 25 MW to support the computers, and a robust mechanical system includes a large air handling system with cooling towers, fire protection, and alarm systems.

Bailey explains that among the operational priorities of the TSF are flexibility, scalability, and reliability. The latter would be greatly reliant on power system protection and the ability to switch power sources if necessary. Power protection and source transfer, as well as the communications technologies supporting them, would have to be advanced, simple to operate, and above all—reliable.

"This was one of the first projects I've been involved with where the electrical system was one of the first design considerations," Bailey says. "In many instances, the requirements for the electric power distribution are determined at the end, but it was critical for this project. We had to make certain that the availability of power was a priority."

Typical concerns were that an upstream glitch might cause a fault and that there would not be a safe way to shut down in the event that the cooling system was lost at the 24/7 facility. "We were very concerned that if we have a glitch, how do we safely shut down the chillers. The computers will usually ride through a glitch, but a chiller takes 20 minutes to restart, and the computational calculations are at risk. So then there is redundancy built into the mechanical system as well as the electrical," says Bailey. To further ensure the quality of computations, mechanical loads were separated from computer loads.

80,000-cfm Air Handling Unit

10-MW Cooling Tower

Chiller Unit Installation

Figure 3—Expansive HVAC system supports cooling requirements for the two 24,000-square foot computer rooms.

TSF's large mechanical infrastructure includes thirty 80,000-cfm air handlers, a 10-MW cooling tower, four 1,200-ton chillers, and one 675-ton chiller. The electrical infrastructure includes a 25-MW switching station, a 3-mile ductbank system, and elaborate fire alarm and communications systems.

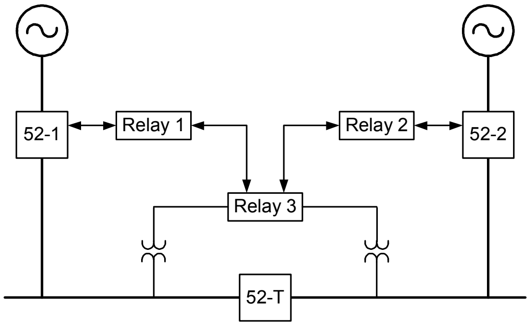

Figure 4—Automatic transfer scheme diagram for two 13.8-kV primary sources. Three SEL-351S Protection and Breaker Control Relays are used in this application. SELOGIC® control equations and MIRRORED BITS® communications provide the logic and coordination between relays to allow tie breaker operation with voltage synchronism-check supervision.

To further support the overall power system, Bailey wanted an automatic transfer scheme that would seamlessly switch sources between two 13.8-kV primary sources should there be a loss of power to an incoming feeder or any undervoltage condition.

"We didn't have the budget to provide uninterruptible power," Bailey says, "and with a total projected load of 23 MW, there would be no way for us to do that." The Schweitzer Engineering Laboratories, Inc. (SEL) solution met the budgetary and operational reliability requirements.

Figure 5—Microprocessor-based relays and other electrical devices are centrally located. Previously, electromechanical relays were used and required one relay per function. With microprocessor-based relays, only one relay is required for multiple functions.

TSF power system monitoring, protection, communications, and source transfer requirements, outlined in the specifications, led to the installation of multiple SEL-351S microprocessor-based relays for state-of-the-art protection and control technology that assures the mandated flexibility, scalability, and reliability.

Bailey says, "We had used a lot of individual SEL relays at various locations, and they had a good track record. But this was the first integrated project where all the relays are SEL. They offered the best combination of product and technology for what we wanted to accomplish. When it came to relay-to-relay digital communications [SEL MIRRORED BITS communications], we were impressed by the speed of operations."

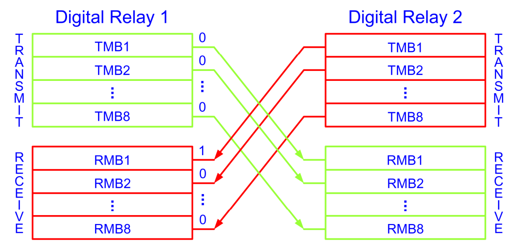

Figure 6—The diagram shows SEL MIRRORED BITS communications providing high-speed, secure, point-to-point real or virtual contact status bits. Automation applications include high-speed bus protection, sectionalizing, restoration and interlock schemes.

Figure 7—The SEL-351S includes a programmable four-shot auto-reclosing function with synchronism- and voltage-check logic to match a variety of reclosing practices.

The specification of SEL-351S multifunctional relays involved an array of advanced capabilities and features, such as the Sequential Events Recorder (SER) and oscillographic event reports, SEL interface with SEL-2030 Communications Processor, link to SCADA, engineering access, and programmable logic.

Automatic power source transfer is facilitated by SEL exclusive MIRRORED BITS communications between relays that are located on the main breakers and act to close the tie breaker with voltage and synchronism-check supervision.

Figure 8—The SEL-2030 Communicators Processor provides quick and economic integration of Intelligent Electronic Devices (IEDs) into SCADA, local human-machine interface (HMI), and overall substation integration applications.

"Schweitzer systems support is also important to us," Bailey says. The SEL Systems and Services Division in Pullman, Washington was contracted to implement the initial settings for the relays.

"I consider the educational support important to program management," adds Bailey. "Robin Jenkins, an SEL integration engineer who specializes in SCADA-type applications, came to the site and provided training on the communications processors." In addition to onsite training, several of the LLNL engineers and technicians attended SEL University courses for additional training.

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About Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a premier applied science laboratory that is part of the National Nuclear Security Administration (NNSA) within the Department of Energy (DOE). LLNL has been managed, since its inception in 1952, by the University of California for the U.S. government. LLNL has an annual budget of about $1.6 billion and a staff of over 8,000 employees. It is home to over 3,500 scientists, engineers, technicians, and professionals in many other disciplines that keep the laboratory running in a safe, secure, and efficient manner. For more information contact Anna Maria Bailey, P.E., Computations Directorate, Livermore Computing Program Facility Manager, Lawrence Livermore National Laboratory; phone (925) 423-1288; email: bailey31@llnl.gov; or visit the website at www.llnl.gov.

About SEL

Schweitzer Engineering Laboratories, Inc. (SEL) has been making electric power safer, more reliable, and more economical since 1984. This ISO 9001:2000-certified company serves the electric power industry worldwide through the design, manufacture, supply, and support of products and services for power system protection, control, and monitoring. For more information, contact SEL, 2350 NE Hopkins Court, Pullman, WA 99163-5603; phone: (509) 332-1890; fax: (509) 332-7990; email: info@selinc.com; website: www.selinc.com.

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