in 1881, a plant in Goldaming, England, produced the first hydroelectric power. The technology traveled quickly, and the first hydroplant in the United States began operating in Appleton, Wis., in 1882.[6]

In the West, most hydro facilities that generate power are storage plants. At a storage plant, a dammed river creates a reservoir to hold the power of the water in reserve. The dam creates a "head" (the height from the powerplant turbine to the water surface behind the dam). The amount of head, coupled with the volume of water flowing through the turbines, determines how much power a hydropower plant produces.[7]

Nature can only tell half the story of electricity. Technology picks up the narrative at the dam's turbines.

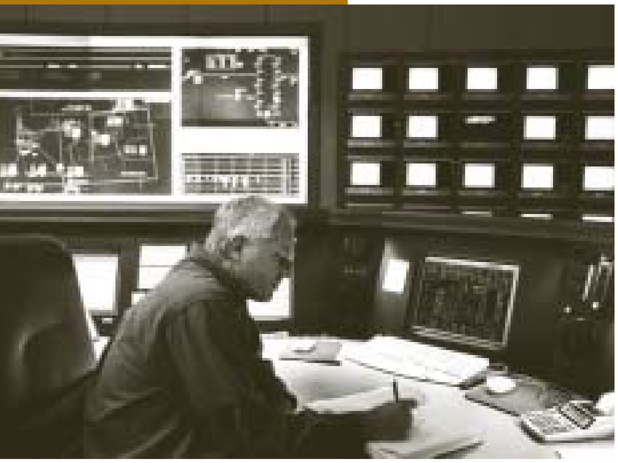
Water into Energy

At the close of the 19th century, the public followed the wonders created by scientists and inventors with the same interest reserved for today's football players and film stars. Physically sensitive to light and sound, but emotionally drawn to bright lights and notoriety, Nikola Tesla successfully developed and promoted an alternating current transmission system while working for the Westinghouse Company. Today's power grids use alternating current. AC is rapid movement of current in a system like the flow of a river going downstream, then upstream and back downstream at many times per second. Tesla's development and marketing of AC faced strong opposition from America's dean of inventors, Thomas Edison. Edison was the chief proponent of a system where current flowed from a battery in only one direction, a method known as direct current. DC may have come before AC in general use, but DC never became the standard because its current could only travel short distances before the power would drop off markedly.[8]

Prophetically, Tesla built the first practical AC transmission system in the United States in southwestern Colorado—now part of Western's service area. Tesla's system transmitted power nearly 20 miles from a small hydroplant to a mine. His experiments proved the superiority of AC, the method used by most electric utility systems in the United States. AC offers simpler design, and, with the aid of transformers, it is more economical to increase and decrease voltage at various points in the system. The act of increasing or decreasing voltage at a generating plant is known as "stepping up" or "stepping down" voltage.[9]

Switchyards connect the transmission grid with generating plants. (Photo by the Bureau of Reclamation)

A network of transmission lines, switchyards, substations and distribution lines comprise the nation's electrical grid. Western's transmission system includes 260 substations and more than 16,000 miles of high-voltage transmission lines, making it the third largest transmission-line owner in the United States. Western transmits 10,500 megawatts of generation from 56 powerplants.[10] To reach its customers, Western also buys or assists its customers in buying transmission service for Federally generated power from neighboring utilities. To avoid overloading high-voltage power lines, Western's power system operators monitor load and match generation in four separate control areas. Western's power marketers not only buy and sell energy; they also acquire capacity on transmission lines that have room to carry more electricity.



During Western's first quarter century, video monitors (above) have replaced schematic drawings (below), giving dispatchers a better visual representation of the transmission system. (Bottom photo courtesy of Thomas Weaver)

Switchyards are junction points where transmission lines connect with each other and with generating plants. Contained in a fenced area, a switchyard houses large circuit breakers and switches that open and close various transmission circuits. Breakers and switches route the flow of electricity from generating plants to delivery points throughout the transmission network. A switchyard at a generating plant usually includes one or more large step-up transformers that increase generator voltage to a higher level on the transmission system. The line carries the current to geographically dispersed delivery points called substations. Step-down transformers in substations reduce the voltage from the high levels needed for economical long distance transmission to lower levels appropriate for delivery to customer loads.[11]

On the transmission system, relays, circuit breakers and other equipment act as control devices. Relays react quickly to problems on transmission lines and work with circuit breaker relays to protect the power grid from faults—sudden increases or decreases in voltage are caused by manmade or natural events, such as lightning strikes and downed lines. Those fluctuations can damage other parts of the system if they are not isolated. System operators in the dispatch center must find alternate routes away from the faults to keep delivering power.

Power system dispatchers play the key role of keeping the transmission system in balance. Frank Carpenter, an operations specialist for Western's Headquarters Division of Operations and Maintenance in the early 1980s, described dispatching as a mental balancing act: "Dispatchers are special kinds of people. They have to maintain a good logical thought process under a vast number of emergency situations. Their decisions affect the lives and functions of everyone in the United States. "Dispatchers also have to adapt to nature's moods and balance that against man's need for electricity. "No two emergency situations are exactly the same," Carpenter said. "A variety of factors affect crisis situations, such as geography, weather conditions, number of customers, the demand for power and the river's flow."[12]

The skills of those directly involved with maintaining the power system in the field—the dispatcher and the lineman—evolved from years of experimentation and innovation. The period that saw the greatest modifications to the West's transmission system grew out of the social and political stresses brought by the Great Depression and the Second World War.

Transmission Before Western

Transmission lines are the electron highways that carry electricity from the generating facility to the utility.

Electricity has always meant promise. President Franklin D. Roosevelt's New-Deal hydropower triumphs in the Tennessee River Valley and Pacific Northwest brought the conveniences of the 20th century to millions of Americans for the first time. Giving people a taste of that promise led to an appetite for hope. A 1934 article in the Washington Star newspaper looked to the American skyline 30 years in the future. It predicted one day electricity would belong to every citizen: "Gigantic spider webs of trestles towering starkly in the rose-tints of a dying sun, proudly bearing their burden; long lines of bronze dwindling to tiny threads in the distance, climbing mountain, sliding into valley and traversing prairie, desert land."[13]

Many of those visions became a reality in the West due to a Federal agency primarily responsible for irrigation. From the late 1940s to the mid-1970s, Reclamation established the modern Federal power presence in the West. Reclamation staffers designed and built lines and facilities, conducted studies to improve the transmission network and adopted technologies that upgraded transmission capabilities. Located in Denver, Reclamation's Power Systems Technical Section developed the first fringe control concepts and equipment for speed governors and solid-state power swing relays used by utilities allied with the Western Systems Coordinating Council for automatic system separation. They also conducted early studies of DC transmission circuit breakers. While few outside the engineering community could appreciate these advancements, the contributions made by electrical engineers working for Reclamation propelled the entire world of power transmission.[14]

Western's first Loveland Area Office Manager, Peter Ungerman, cited Ferb Schleif as one of Reclamation's unsung engineers whose work improved the industry's overall reliability:

> *The Bureau's claim to fame as far as individuals go was a guy by the name of Ferb Schleif. Ferb Schleif should be on page one of the history of the power business in the West. For example, at Grand Coulee (Dam in Washington State), they were having trouble getting a pump on because they were getting too much power—boom, it was there, and boom, the pump couldn't handle it. So Ferb Schleif built a 25-cycle operation that would bring the pumps on to half-speed and then slowly bring them on to full speed. Well, that was translated into PSS stuff—power system stabilizers. Now there's a PSS on every governor and generator in the United States. And that was all Ferb Schleif's invention, working for the Bureau of Reclamation. The Bureau of Reclamation made more big significant contributions to electrical engineering as a profession than probably anybody. People don't understand—they don't give the Bureau credit.*[15]

Clark Rose, a 40-year Federal veteran and Western's initial engineering development and coordination division director, began his career as an electrical engineer with Reclamation. He marked the changes in his career by Reclamation's use of new technologies: "In the late 1940s, it sometimes took two or three engineers two or three weeks with a slide rule and desk calculator to analyze transmission problems in a particular geographic area," Rose said. By the late 1950s, an analog computer could "analyze the same problems in two to three days." Digital computers were

meet an ever-increasing demand. In 1919, Professor Carl Edward Magnusson of the University of Washington proposed building a 230-kV line from the Canadian border to Los Angeles, interconnecting the systems of Washington, Oregon and California along the way. In 1935 and 1938, the Pacific Northwest Regional Planning Commission and Bonneville Power Administration proposed building a high-voltage transmission line, known as the Pacific Northwest-Pacific Southwest Intertie, as part of an overall regional interconnection system.

By the time of the California-Oregon Transmission Project, construction techniques had advanced from hand-powered pole raising (above) to helicopter-aided construction techniques (below).

A handful of preliminary studies by Federal and state governments followed during the late 1940s and the early 1950s, but it took a commercial giant to make things happen. In 1958, the nation's largest privately owned utility, Pacific Gas and Electric Company, underwent a conversion in philosophy through economics. Surplus hydropower drawn from dams in Oregon and Washington was cheaper than oil-fired generation, so as the 1960s dawned, occasional rivals PG&E, Bonneville and Reclamation voiced their support for the Intertie.[47]

On Aug. 31, 1964, Congress authorized the project under section 8 of the Pacific Northwest Power Marketing Act. Originally, engineers designed the Intertie as a combined AC and DC system connecting the Pacific Northwest with the Desert Southwest. As authorized, the overall project was a cooperative construction effort between Federal and non-Federal groups. Bonneville handled construction within its service area, while the local utilities built the lines and facilities in their respective territories.

Principal owners and users of the Intertie were a boarding house of strange bedfellows. They included Reclamation (later Western), Bonneville, California Department of Water Resources, Los Angeles Department of Water and Power, Pacific Power and Light Company, Portland General Electric Company, PG&E, Sacramento Municipal Utility District, Southern California Edison and San Diego Gas and Electric Company.[48]

The Intertie was to consist of four high-voltage transmission lines: two 500-kV lines, one 345-kV AC line and an 800-kV DC line. The 500-kV AC lines would provide a transmission path from John Day Dam in Oregon through northern California to Los Angeles. The 345-kV AC line would connect Hoover Dam with Phoenix. The 800-kV DC line was designed to run directly from Celilo Dam near The Dalles in northern Oregon through Nevada to Los Angeles. The three Intertie lines connecting the northwest to California were all in service within six years after authorization.[49]

The Electric Power Training Center provides world-class training for utilities and agencies across the country.

Beginning in 1999, Western's EPTC staff began the work of transforming the school into a self-supporting organization. EPTC Manager Dennis Schurman explained that Western seeks to make the EPTC a public operation that will pay for itself. Schurman's goal is to maintain the EPTC as a world-class training facility. Students from investor-owned utilities, other Federal and state agencies as well as public power utilities come to the EPTC to learn about the delicate and demanding art of being a dispatcher, along with other crafts within the energy industry.[66]

The EPTC continues its role as a vital training facility. During a July 16, 2002, visit to Western's CSO, Undersecretary of Energy Robert Card toured the facility. He commented, "I would have hated to come all this way and miss this. The EPTC is an important, educational gift to the nation."

Safety in the Air

Increased demands on power meant expanding existing transmission networks and building additional power-generating facilities. By the 1950s, extra-high voltages of 345-kV, 500-kV and 765-kV were increasingly common. Live-line, bare-hand maintenance technique is the most effective way of maintaining the continuity of the electrical system. Since 1979, Western has regularly offered training courses to linemen to transmit the live-line, bare-hand knowledge throughout the industry. A fiberglass pole known as a "hot stick" allows linemen to work safely around energized high voltage.

Western blazed a trail for liveline barehand training, like this class in May 1992 on the Stegall-Wayside 230-kV transmission line near Stegall, Neb.

In addition to live-line, bare-hand training, Western employees have pioneered a lot of climbing safety regulations in the power industry. Al Peschong noted: "Several of the fatalities and injuries we've had were fall-type accidents. We got involved with OSHA (Occupational Safety and Health Administration) and formed several internal teams to tackle real safety problems involved with transmission tower and pole climbing. Working with OSHA, we were the leaders in the United States on fall protection and probably the most active organization OSHA was associated with on that one issue."[67]