CHAPTER TWO

Threads in the distance: Power, Transmission and Demand

During the mid-20th century, America again went west—but with a new purpose. Striking gold or eking out a living on a 160-acre homestead never occurred to this generation of trailblazers in search of new jobs, room in the suburbs and the promise of room to grow. According to the 1950 census, 48.1 million people lived west of the Mississippi River.[1] As that number grew with each passing census, both natural and man-made resources—notably water and power—bore the weight of increasing demand. Clusters of consumptive sprawl, first born in Southern California, drove this craving for electricity. Population quickly boomed in places as diverse as Sioux Falls, S.D., and Phoenix, Ariz., intensifying the region's hunger for power. By the century's close, 63.1 million people called the West home.[2]

As the West's population grew, the energy needs of metropolitan areas like Las Vegas, Nev., shown in 1965, also grew. (Photo by the Bureau of Reclamation)

From 1978 to the present, Western Area Power Administration supplied more customers with power, despite no significant increases in available Federal resources. In Western's first full year of operation, it served 457 customers. A quarter-century later, that number jumped to 688—a 37-percent increase. In the 20th century's final quarter, Western contributed to the construction and maintenance of the existing transmission system in many ways, including realizing the long-held engineering dream to "tie" the nation's power grids together. These interconnections enabled the safe transfer of power between the east and west. On the Pacific coast, the agency was also instrumental in bringing the hydropower resources of the Pacific Northwest to millions in California through the California-Oregon Transmission Project. In the Missouri, Colorado, Sacramento and San Joaquin river basins, Western built numerous transmission lines and substations to ensure reliable power delivery throughout the West.[3]

Despite Western's contributions to bolster the regional transmission system, in winter 2001, the nation watched the specter of rolling blackouts unfold in California. The battle to deliver affordable power reawakened the public's interest in the electricity industry, but the basic elements of the subject of electricity remain a mystery to the masses.

The Mystery of Electricity

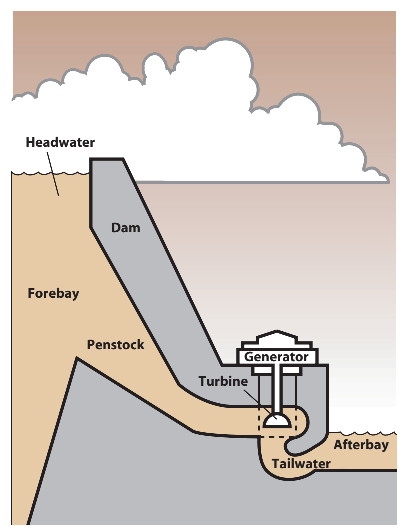
To understand the immensity of Western's transmission operations, it is necessary to go into the smallest detail. Western markets and delivers cost-based hydroelectric power and related services. Agencies such as the Bureau of Reclamation and the U.S. Army Corps of Engineers generate the power and preference customers distribute it to end-use customers. Western's primary responsibility is to market power, operate the power system reliably and competently transmit that electrical energy.[4]

Water is the source of nearly 11 percent of the nation's energy resources. (Photo by the Bureau of Reclamation)

The production, movement and delivery of kilowatthours to customers requires a large investment in facilities and equipment. During the 20th century, the Federal government, rural electric cooperatives, public power utilities and private companies built integrated substations, powerplants and dispatch centers as the components of regional power supply systems. Since crews strung the first line, the nation's transmission system has been in a never-ending race to keep up with customer demand and withstand the ever-changing moods of nature. Melting snow and falling water serve as the starting point for hydropower generation in the West. Western inherited from Reclamation a primarily hydropower generation system and since the agency's beginnings, Western's fortunes rise or fall on a surplus or shortfall of moisture.

Hydropower: It's the Water and a Lot More

The West's most precious resource—water—is the precarious foundation supporting the lives and livelihoods of its inhabitants. In 2000, more than 2,300 hydroelectric dams across the United States provided nearly 11 percent of the country's total energy supply. Hydropower comes in third among sources of electric energy production, behind fossil fuel with 73 percent of the market and nuclear at 14 percent. Energy drawn from the sun, wind and biomass (agricultural or municipal waste materials) accounts for less than 1 percent. Hydropower's future growth is limited due to few opportunities for upgrades and environmental concerns. In addition, the most cost-effective hydropower sites are already developed. However, those plants in service are the most efficient now in use. Ninety percent of the "fuel" flowing into a hydroelectric generating plant converts into electricity compared to only 35 percent at coal- or gas-burning plants.[5]



Hydropower is generated from water behind the dam, which flows through a pipe called a penstock and then turns a turbine that drives a generator.

As far back as 2,000 years ago, the Romans knew the power of flowing water to drive machinery, but the first steps toward the modern hydropower plant took the better part of those two millennia. In 1831, inventor Michael Faraday discovered the principles of electromagnetic induction after he passed a wire coil through a magnetic field, creating an electrical current. Faraday's discovery led to the invention of the electric generator and transformer. Exactly a half-century later, 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.

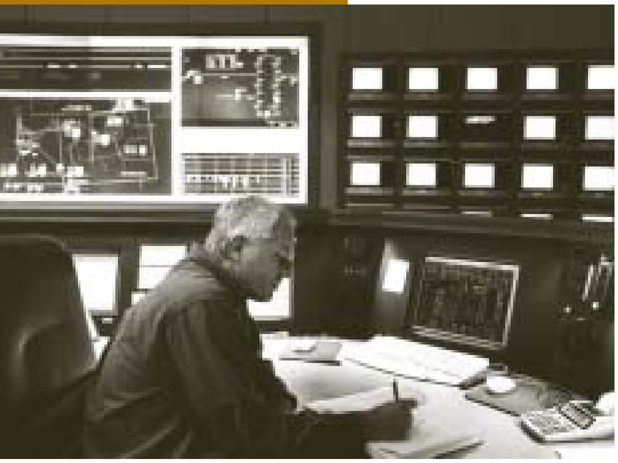
Water into Energy

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



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)

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.

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

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]

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

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 the next step. "They allowed us to solve problems in a two- or three-state area in a few hours," he explained. By the close of Rose's career with Western, engineers could determine and calculate solutions to transmission problems anywhere in 15 states in a matter of minutes.[16]

Farmers in the early years of rural electrification use a road map to plan power line routes.

In the days before increased Federal regulations and greater environmental awareness, Reclamation held free rein in placing and building transmission lines. Reclamation and Western veteran Lloyd Greiner remembered: "In those days the Bureau of Reclamation simply said point to point, they drew a line and that's where they built a line. That was their survey and that was their planning. They went across Indian reservations. There was no input from environmentalists and no EIS (the Federally mandated environmental impact statement.)"[17]

Construction of major irrigation projects inspired Reclamation's power division to develop—and redevelop—plans to build high- and extra high-voltage lines across the West. In the early 1950s and late 1960s, power division management and staff proposed two different schemes to build a major transmission system between Minneapolis and the West Coast. These proposals would have developed 50,000 MW of generation and required at least 15,765-kV transmission lines. According to Reclamation and Western veterans Harvey Hunkins and Tom Weaver, the scale of such a program would have equaled a half-dozen Grand Coulee Dam projects.[18]

By the early 1970s, Federal funding toward transmission and power decreased, and those ambitions never got off the drafting table. According to Al Peschong, Western's construction and inspection division director from 1978 to 1994, the cupboard was bare for new transmission projects during Western's first full year of operations in 1978: "There were programs we had inherited from Reclamation. A very small power program. As I recall that first year, it was about $12 million worth for construction."[19]

Besides living off Reclamation's power budget for the first year, Clark Rose recalled the territorial confusion over the transfer of the transmission system from Reclamation to Western:

> *Reclamation wanted to keep in some areas, and did keep, the powerplant and the switchyard and the interconnection. So, WAPA's dispatch had to work with Reclamation's powerplant operators to control the system facility at Yellowtail and at plants in California. Other lines of demarcation were at the generator terminal, so the step-up transformer switchyards were all WAPA's. In other places, it was the high-voltage terminal and transformer. Trying to write a Memorandum of Understanding between WAPA and Reclamation defining these points of demarcation was difficult. There were a lot of heated discussions between WAPA and Reclamation regional people.*[20]

Western Begins Building

Money soon changed everything, as Western's Administrator Bob McPhail returned each year from appropriations hearings in Washington with more funding for construction. Rose remembered how larger budgets equaled more ambitious projects:

The first year we were in business as Western, we inherited a budget of roughly $10 to 11 million, I recall. The second year of operation we had a construction budget of $25 to $30 million. The third year we went to $47 million. The fourth year we got up to somewhere between $80 and $100 million. After we got close to the $100 million level, we got down to building the COTP (California-Oregon Transmission Project).[21]

Reclamation retained ownership of the Yellowtail powerplant and switchyard after Western's formation. (Photo courtesy of Harvey Hunkins)

The bulk of the budget for Fiscal Year 1978 went toward completing projects first designed by Reclamation. Two notable efforts were completing the 177-mile Watertown, S.D., to Sioux City, Iowa, 345-kV line and the 186-mile Hayden-Ault 345-kV line in eastern Colorado.

After the split of the two agencies in 1977, Reclamation left Western a transmission foundation in need of repair. For the newly formed Division of Construction and Inspection, rehabilitating the existing system was a priority. Maintaining substations and replacing relays and circuit breakers originally built and installed by Reclamation in the early 1950s required money comparable to that needed for new construction. One of the first studies conducted by the head of that division, Al Peschong, revealed the amount of money needed to replace old transmission lines and wood poles across the system: "Just to replace 300 miles of line each year cost $40 million to $50 million a year. Imagine 13,000 to 15,000 miles of line, and you're redoing 300 miles a year. The magnitude of the whole thing surprised a lot of people."[22]

Of Western's nearly 17,000 miles of circuit lines, almost half—8,200 miles—is on wood poles. The agency keeps maintenance records on more than 120,000 individual wood poles.[23] Peschong explained the magnitude of those costs forced Western to pick its spots when performing maintenance: "The lifetime of a wood pole is 40 to 45 years. In substations, transformer and breaker life spans depend on how well they are taken care of and how heavily they're used; but what's normally accepted (for those pieces of equipment) is anywhere from 20 to 45 years. By fall 2000, some of that equipment has been out there for 50 to 60 years."[24]

A 1990 study found that Western's system needed replacements at a rate of 300-plus miles a year. Try as they could, Western's line crews could only modernize or replace 120-plus miles a year. By Fiscal Year 1999, Western budgeted $2 million for various wood pole testing, treating and replacement activities in both divisions of Pick-Sloan and the Colorado River Storage Project. Because it cost less to restore than replace, Western anticipated "continuing these annual programs indefinitely."[25]

Western did not venture far from corporate headquarters for its first wood-pole replacement project. The Sterling-Holyoke 115-kV transmission line in northeastern Colorado was the first construction project totally designed, planned and built under Western's wood-pole replacement program. Originally completed in 1948 by Reclamation, the line experienced excessive transmission losses and voltage drops with peak loads even under normal conditions. Studies conducted by Western in the late 1970s found that high loads on the 69-kV line led to the transmission problems. During August 1979 alone, lightning strikes caused 47 interruptions in service.

It was not the load, but the significance that made Sterling-Holyoke important. In 1982, soon after completion, McPhail reflected that Western was thinking big, but had to start small to get established: "We had plans in the mill now for very large construction programs. But for a start, back in 1978, the 60-mile section of line from Sterling to Holyoke was a very ambitious project for a very new staff and a newly formed agency."[26]

Ungerman concurred to a point: "It was a penny-ante line. However, McPhail was very sensitive to that. He took a personal interest, not because we needed it from an engineering prospective, but from a political prospective."[27]

Sterling-Holyoke was the first of several projects during the 1980s. Other early projects included a transmission line from Casper to Thermopolis, built with the assistance of Tri-State Generation and Transmission Association of Westminster, Colo. Before the line was built, that stretch of south-central Wyoming was the black hole of blackouts. "There used to be two to three blackouts a year in this area when WAPA was first formed," Ungerman explained. "This area was identified by the North American Electric Reliability Council as the one major region in the United States that was unable to meet accepted reliability criteria. Any little thing that would happen would upset the apple cart. The system was so overloaded, there was no margin for abnormality."[28] Western worked jointly with Tri-State to replace portions of existing 69-kV lines and add a 115-kV bay and a second 230/115-kV transformer. The construction package included completing a new maintenance facility for the line crew at the Thermopolis Substation.[29]

In 1993, three years after the Bears Ears-Bonanza line was completed, line crews from across Western worked together to replace insulators along the 101-mile line. Linemen like Sam Naill and Scott Westover worked from 6 a.m. until early evening six days a week to complete the massive job. (Photo by Dennis Schurman)

During the 1980s, when many projects ran concurrently across the West and Western established partnerships with its customers through construction activities. One example of several organizations coming together for the common good occurred in a transmission trouble spot between western Colorado and eastern Utah.

Bears Ears-Bonanza

In July 1985, work began on the 102-mile, 345-kV transmission line from the substation outside of Craig, Colo., to the Bonanza Generating Station near Vernal, Utah. Working with a handful of other organizations, Western built the Bears Ears-Bonanza project to improve service to customers in western Colorado and eastern Utah.

Previously, the region faced the uncertainty of cascading outages when other major transmission lines in Colorado and Wyoming went out of service. In addition, customer demands often exceeded the power generated by the existing Bonanza station. Before the upgrade, Western's only remedy was to authorize localized operating restrictions.

Upgrades included installing new 138-kV transmission lines and building 96 miles of 345-kV, single-circuit, lattice-steel line and six miles of 345-kV and 138-kV double-circuit lattice-steel line. These additions doubled the system's capability to transmit power.[30]

The project faced a gauntlet of construction, engineering, land and environmental concerns on the road to completion. The lines crossed a paleontological site, two coal leases and land held by the state of Colorado. Western served as project manager for construction of the line and Bears Ears Substation. A host of participating utilities joined Western to complete Bears Ears-Bonanza, including the Utah Associated Municipal Power Systems, Deseret Generation and Transmission Association, Platte River Power Authority and Tri-State G&T. Western financed $25.6 million of the $38 million total project cost. Bears Ears-Bonanza was energized in February 1990—an estimated $1 million under the original budget and two months ahead of schedule.[31]

During the 1980s, as work on Bears Ears-Bonanza and other Western projects began, developed and concluded, Western's engineers directed their attention toward solving a problem that stumped a generation of engineers—how to bring the nation's power grids together.

Tying Two Elephants Together

A trick of geography left Reclamation, then Western, operating on both sides of an electrical separation between the nation's two main power grids. The unregulated evolution of the national power grids brought on this dilemma, as the eastern and western power systems developed separately over the years. In the 1950s, initial attempts by the Federal government and private utilities to "tie" the systems together failed due to disturbances in one power grid affecting operations in the other. Three decades later, it fell to Western to lead the Federal charge to find the ties, construct the interconnections and unite the grids.[32]

The June 1985 edition of *Closed Circuit* described the frustration of a disharmonious transmission nation this way:

> *Imagine languishing through a brownout on a hot and humid June day in eastern Nebraska because there's not enough electricity to meet demand. It would be even more uncomfortable if you knew that, over in Colorado, there was a surplus of hydroelectric power because of an abundance of melting snow high in the Rockies.*
>
> *Put yourself in the shoes of the general manager of a West Coast utility. His company is supplying expensive electricity generated by oil-fired plants, when coal-fired generating plants have the ability to produce more power than they can sell.*[33]

There was another reason for bridging the separation. With a tie, energy produced by the Colorado River Storage Project could serve customers in the Missouri River Basin. Tom Weaver served both Reclamation and Western in a number of executive positions during his Federal career. Weaver explained that bringing the nation's power supply together reminded him of an analogy: "Somebody told the story it was kind of like tying two elephants together with rubber bands. They can only go so far in opposite directions before the rubber bands snap."

Weaver recalled earlier attempts by Reclamation to unify the power system. Unfortunately, none of those solutions were permanent: "We had done something back in the early '50s where we had tied Yellowtail (Powerplant) and had some fancy, brilliant schemes to close the East-West ties. But, there were problems with them. If something would happen on one side or the other, you wound up tripping the ties," he lamented. "The people who lived right along the ties were not happy campers, because their voltages were going up and down."[34]

After spending years as an employee of two Federal agencies looking for a solution, Peter Ungerman delivered the final understatement on the situation in 1984, "Electrically—these two systems ain't talkin' to each other now."[35]

Western's engineers decided that the answer was not in extended extra voltage lines, but converting AC power to DC, then back to AC. A converter station would house an AC-DC-AC tie that would convert alternating current from one system to direct current and back to alternating current before it entered the second system. The converter would allow the transfer of energy across the existing east-west electrical separation and provide mutual assistance during emergencies. Proponents believed it would balance power resources with demand, enhance economic energy exchanges and reduce environmental impacts. The technology had already proven itself after Basin Electric Power Cooperative of Bismarck, N.D., built the first sustaining AC-DC-AC tie at Stegall, Neb., in 1977. However, Basin designed the tie to meet its own firm power requirements in balancing loads and resources. Western looked to the bottom line to see if it would duplicate Basin's achievement at Stegall. The agency's analysis concluded that a series of converter stations along the east-west separation would cost $430 million—a bargain compared to a $1.5 billion extra-high voltage AC system.[36]

The Miles City Converter Station is used to transfer power between the eastern and western grids.

Spurred on by a 1980 NERC report projecting the nation's future loads and available resources, in 1981 Western studied potential sites and sizes for additional back-to-back ties. The report examined eight locations along the east-west separation from Fort Peck, Mont., to Lamar, Colo. Western's engineers found that the most promising location for a tie was Miles City, Mont. Western had three 230-kV lines and a 230/115-kV transformer at the recently completed Miles City Substation. A converter station at Miles City would also enhance transmission capability and offer a direct path for surplus energy from coal-fired generators in the Upper Midwest to loads on the West Coast.[37]

In 1982, General Electric began construction under contract to Western and Basin Electric Power Cooperative. Western financed a 60-percent share and Basin paid the remaining 40 percent of the $30 million price tag. The station's initial transfer capacity was 200 MW from east to west and 150 MW from west to east. Western operates and maintains the converter station, which was completed in 1985.[38]

The Miles City Converter Station was an immediate success, and Western sought a repeat performance somewhere else along the separation. A study by the Mid-Continent Area Power Pool's Reliability Council found that additional ties would transmit excess generation to the northwestern and southwestern United States. Western sought to place another converter station to benefit utilities in Wyoming, Nebraska and Colorado. Before the converter station, displacement arrangements among area utilities offered the only assurance of serving all the loads.

In early 1985, Western selected Siemens Automation and Energy of Erlangen, Germany, as primary construction contractor for the new station at Sidney, Neb. Construction proceeded smoothly, as 17 different utilities in the eastern and western grids participated in planning the station, nine different Nebraska contractors provided services and 13 other organizations, including state and local government groups, helped build the station. Coming in significantly under budget in March 1988, the Sidney station went on line at 100 MW.

Congresswoman Virginia Smith helps Western's Bill Clagett break ground for the converter station that will eventually bear her name.

In 1990, a ceremony honored Congresswoman Virginia Smith for her efforts in getting funding for the converter station. The Republican congresswoman represented Nebraska's Third District from 1974 to 1986 and always stood as a defender of agriculture and rural electrification. At the dedication of the Virginia Smith Converter Station, the congresswoman said the facility was just as important to "linking together this vast nation" as the railroads meeting at Promontory Point, Utah, in 1869, or the interstate highway system a century later.[39]

Linking the nation's grid also won Western's engineers kudos among their peers. The design of both facilities served as the subject of papers presented before the Institute of Electric and Electronic Engineers and CIGRE (International Conference on Large High-Voltage Electric Systems), based in France. In 2000, the Washington D.C.-based National Academy of Engineering listed electrifying North America as the No. 1 "Greatest Engineering Achievement of the 20th Century." The Academy specifically cited Western's role in linking the two grids as a harbinger of "further advantages in economy and reliability" as demand increases in the 21st century.[40]

Will it Go Round in Circles? The Dilemma of Loopflow

Loopflow is a whimsical term for a serious power headache. Power physically follows the path of least resistance. Problems occur because this may or may not be the same as the contract path. Loopflow stems from the difference between scheduled power (the amount intended to flow) and the actual power (the amount actually flowing) on a transmission line or system.

Loopflow as a phenomenon is not unique to the western United States, but the Western Systems Coordinating Council (renamed Western Electricity Coordinating Council in 2002) was the first organization to tackle the problem. Over the years, geographic features and population distribution formed the power transmission system in the West into the shape of a doughnut, or a multi-state loop. Loopflow can cause additional power loss and affect a generator's capability to transfer power due to system stability limits.[41]

Western reduced the problem of loopflow by installing phase-shifting transformers. A PST can raise or lower the apparent impedance (a measure of the total opposition to the current flow in an AC circuit) on a transmission line and, under certain conditions, reverse the flow of power. Electrical engineers first used PST technology on low-voltage distribution systems in the 1930s. However, there were only 10 in operation in the WSCC system as recently as the mid-1980s. Western's use of PSTs on high-voltage lines was unprecedented. Western built its first PST at Glen Canyon Powerplant in Arizona in 1978 as part of an operating agreement between Western and Arizona Public Service Company to alleviate loopflow problems in the Four Corners area. The PST at Glen Canyon weighs 624.7 tons, is 46 feet long, 40 feet wide and 24 feet tall. Western operates phase-shifting transformers at Shiprock and Waterflow, N.M.; Hardin, Mont.; Glen Canyon, Ariz., and the Liberty Substation near Phoenix.[42]

In late 1986, Western awarded Westinghouse a $13.4 million contract to install PSTs on two transmission lines beginning in southwest Colorado and ending in northwest New Mexico. The PST stood as tall as a two-story house and required a specially built 126-wheel truck to move it over terrain where no railroad existed. The project relieved loopflow on the interconnected transmission systems operated by other WSCC members. Western's System Engineering Division Director, Steve Fausett, said the WSCC favored installing PSTs on those two lines because they linked Western's facilities in the Billings, Loveland and Salt Lake City area to Boulder City.[43]

In 1991, a joint project between the Electric Power Research Institute and Western examined retrofitting phase-shifting transformers with thyristor controls, which allow system operators to adjust the line to meet changing conditions by varying impedance. This eliminated the potential of cascading outages caused when one line trips and the remaining lines overload.[44]

Dave Balkenbush of Western's Montrose District Office explains the advanced series capacitor at Kayenta, Ariz., during the Kayenta dedication ceremony on Sept. 30, 1992.

This technology was tested when Western dedicated the Kayenta Advanced Series Compensation station in northern Arizona on Sept. 30, 1992. A joint development of Western and Siemens, the ASC cost $12 million. It allowed Western's power system dispatchers to closely control power flow and voltages on the transmission system, improve system stability and increase the power-carrying capacity of the existing Shiprock-Glen Canyon 230-kV line from 300 megawatts to 400 megawatts.[45]

Kayenta's ASC project allowed power to flow through the transmission lines quickly, continuously and directly. Tony Montoya, then an engineer at Western's Headquarters in Golden, Colo., explained the ASC technology in terms the average homeowner could understand: "Advanced series compensation is like the difference between having a light switch on or off, compared to a dimmer switch that you can continuously control whenever you want. It has the added advantage that you can automatically control the level of power flow on the line so that the dispatchers don't have to constantly adjust the power flow."[46]

By the early 1990s, Western had completed two-thirds of a transmission hat trick by tying the nation's transmission grids together and taming loopflow. The remaining hurdle was a complicated job that many Western employees remember as their toughest assignment.

The Pacific Northwest-Pacific Southwest Intertie

Some commentators refer to the lights along the Los Angeles skyline after dark as a "string of diamonds." Aesthetics aside, the cost of maintaining this nightly light show has often threatened to put a chokehold on the state's power supply and prosperity. Western found a role in this long-running drama as a protagonist that kept one of the world's largest economies going.

Western's most complex transmission achievement, the California-Oregon Transmission Project, was rooted in a time when orange groves outnumbered people in Southern California, and the Pacific Northwest had yet to develop its hydropower potential.

The COTP began as a matter of haves and have-nots—Canada and the American Pacific Northwest held the natural resources and power generation, and California wanted more power to 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]

There was no time for all involved to rest on their laurels. Demand for electricity in California grew during the 1970s, and this hunger quickly overwhelmed capacity. The situation forced California's public power suppliers to study potential upgrades to the Intertie and the possible addition of new facilities. It was at this point that Western entered the scene.[50]

California-Oregon Transmission Project

Crews begin work on the Maxwell Series Compensation Station as part of COTP.

If Reclamation boasts about Hoover Dam and the Corps of Engineers points to the Pick-Sloan program, then Western's technical point of pride during its first 25 years is the California-Oregon Transmission Project.

The southern third of the third AC line—COTP—is a high-capacity transmission line energized at 500 kilovolts and stretching 346 miles from Captain Jack Substation near Malin, Ore., through Northern California to PG&E's Tesla Substation, east of San Francisco. The line can carry power in either direction, depending on electric costs, need and supplies of the two areas at any given time. The 1,600 megawatts of electricity COTP transmits meets the needs of a million people, or a city the size of Sacramento. The Transmission Agency of Northern California—a group of 15 public power utilities and water districts—oversaw the construction of this line as project manager.[51]

Western's primary construction role in COTP required upgrading an existing 170-mile-long, 230-kV Central Valley Project line to 500-kV from Redding south to the Sacramento River. In exchange for upgrading the line, Western retained 100 MW of capacity to serve Department of Energy's national laboratories near San Francisco. Led by Project Manager James Feider, Western also installed transformers, line reactors, power circuit breakers, series capacitors, shunt capacitors and 500-kV relays; built Olinda Substation and the Maxwell Series Compensation Station and expanded its existing substation at Tracy, Calif.[52]

Western's involvement with COTP did not begin in Northern California, but almost 3,000 miles to the east. Ron Greenhalgh, Western's liaison officer at DOE Headquarters in the Forrestal Building in Washington, D.C., remembers passage of the COTP project legislation as something of a "fluke." Working with Congressman Vic Fazio of California, Greenhalgh was able to insert into an appropriations bill language authorizing the Secretary of Energy to "construct or participate in the construction of such additional facilities as he deemed necessary to allow mutually beneficial power sales between the Pacific Northwest and California."

Senator Mark Hatfield (R-OR) also lent his considerable authority to advance the project. Hatfield was one of many champions for Bonneville in Congress. According to Greenhalgh, "He (Hatfield) liked the idea of somebody besides the privates owning the Intertie." On July 16, 1984, President Ronald Reagan signed Public Law 98-360, giving the go-ahead for construction.[53]

Studies of potential engineering, economic and environmental impacts followed. The project passed a major hurdle in 1988 after a combined Federal Environmental Impact Statement/State Environmental Impact Study was completed. Next were additional design and technical studies. Then Western began the important work of acquiring rights-of-way from public and private landholders.

Western's Lands Division Director, Bobby Bond, recalled COTP as "the most stressful, difficult project" he faced during his 14 years at Western. In explaining the delicate negotiations required in crafting a deal to build transmission lines on private and public lands, he reflected that a Lands man must be careful in his use of the "velvet hammer" of Federal condemnation to expedite the project. Before the project started, Western identified three potential areas of concern over rights-of-way:

- the Sacramento River Delta, where siting the line over a new home development had incoming residents concerned about the health effects of electric fields;
- where the line crossed private timber property; and
- near Willows, Calif., where a landowner filed an environmental suit over the location of the Olinda Substation.

Crews prepare the Olinda Substation (later renamed for Congressman Vic Fazio) for the arrival of the first transformer.

Bond believed that the best thing to do for all parties was to "cultivate relationships." Bond said this attitude is reflected in the limited number of condemnations in Contra Costa County, Calif., where Western faced a great deal of initial opposition to building the line.[54]

Dave Coleman, Sacramento Area manager from 1980 to 1993, was one of Western's point men in completing COTP. Coleman said the COTP made Western "a high-profile operation in California and leveled the playing field with PG&E and Southern California Edison." Coleman saw COTP as Western's opportunity to earn some respect from its private competitors and win "a place at the table."[55]

The year 1990 was a high water mark for project construction for Western. That year, the agency's engineers finished designing and building 56 projects, including 535 miles of upgraded transmission lines and 30 substations. However, it was the first shovels of dirt in a California field that most who worked for Western will remember.[56]

On Oct. 15, 1990, in a field outside Redding, Calif., 150 people witnessed a groundbreaking ceremony marking the start of COTP construction. Over the next two-and-a-half years, 500 construction workers excavated land, poured concrete for hundreds of tower footings, erected 10-story-high steel structures and strung tens of millions of pounds of conductor line along the 340-mile route. Transporting and setting the transformers and other heavy equipment into place was a major undertaking. Measuring 25x12x15 feet and weighing 325,000 pounds each, the transformers were some of the largest ever built by heavy electrical manufacturer ASEA Brown Boveri. Six of the transformers—three at the 60-acre Olinda Substation and three at Tracy, California—are used to step down the voltage from 500-kV to 230-kV.[57]

Accidents plagued construction despite Western's excellent safety record that consistently ranks above the industry standard. The first mishap occurred on June 19, 1991, when a falling transmission tower injured three contract construction workers. On March 20, 1992, the project's first fatality occurred near Rio Vista, Calif. A contract employee and three other crewmembers were performing operations on a tower structure when a sling supporting the power conductors broke, delivering a fatal blow to one worker's head. Another accident occurred on Aug. 12, 1992, when a helicopter crashed while pulling in an overhead ground wire on the Olinda-Maxwell section of the COTP, killing the pilot.[58]

Almost four years of rapid construction ended on March 17, 1993, when the COTP delivered power between Bonneville's Captain Jack Substation in Oregon and Western's Tracy Substation in central California. Nearly two months later on May 10, Administrator Clagett officially changed the name of the Olinda facility to the Vic Fazio Substation in honor of the congressman who supported the crucial appropriation through Congress eight years earlier.


Tracy Substation was expanded to accommodate COTP transmission requirements.

Al Peschong, Western's construction division director, spoke for many in Western who remembered COTP as their most challenging assignment: "(It was) a huge volume of work involving hundreds and hundreds of construction people. It was very complicated, and lots of things had to come together right. I had worked around quite a few projects where we had commissioned major 345-kV facilities—Fort Thompson, Grand Island, Watertown, Sioux City—and there were always glitches that you had to work out. I forecast that when we did the 500 out there, it would take a month to six weeks to get everything worked out. So when it first fired up in less than a week to full capacity, it blew my mind that it was that well put together."[59]

The Mead Lines

Not all the action during the early 1990s was in central California. Western was also involved in building two new lines through the heart of the Arizona desert. Western's Desert Southwest Office in Phoenix oversees the marketing, repayment and operation and maintenance of the southern portion of the Pacific Northwest-Southwest Intertie. This southern portion consists of a 345-kV line stretching for 238 miles from Mead Substation in Nevada to Liberty Substation in Arizona, and a 19-mile, 230-kV line from Westwing to Pinnacle Peak Substation.[60]

An additional 260-mile, 500-kV AC Mead-Phoenix line and the 202-mile 500-kV AC Mead-Adelanto line developed from a long-range plan by Western, Salt River Project, Los Angeles Department of Water and Power and several other municipal utilities. The Mead-Phoenix 500-kV AC transmission line runs between Marketplace Substation and Adelanto Switching Station in southern California. First conceived as DC projects, Western redefined the lines to AC to provide needed transmission access and eliminate a surplus energy bottleneck. Since 1996, these projects link the Phoenix area with Southern California to create regional marketing opportunities for electricity and better use of Western's power resources through interregional power transfers and seasonal exchanges.[61]

By 1993, Western began a shift away from new construction toward replacing aging equipment and facilities and maintaining the existing transmission system. In the FY 1993 budget, Western had about $100 million for construction. By the end of the decade, that number had dropped to a little more than $20 million.[62]

Western line crews work through snow, heat and rain to ensure the reliability of Western's transmission system.

The theme of these major projects during Western's first 25 years was interconnection. With them came industry interconnections that enhance Western's reputation in the power industry, improve reliability, develop new technologies and promote training and safety.

Born in a Blackout

In 1980, Mike Groves, then Western's Operations and Maintenance division director, emphasized the importance of interconnections: "Interconnections provide for the exchange of power between the various utilities. If one utility has extra generation, then it can supply the extra demand of another utility or vice versa. Sharing resources to maintain operational continuity is the basis for power pooling. Pooling optimizes system use and helps hold down costs."[63]

It is worth noting that interconnections go beyond lines and power pools. Western's transmission system operates as an integral part of an overall interconnected power grid. The agency is a member of several industry groups that strive to maintain a reliable bulk power system across the North American continent. The most influential of these groups resulted from the most infamous moment in North American power history.

North American Electric Reliability Council

Nine months after the infamous November 1965 Northeast blackout, hospitals from Quebec to New York City reported a spate of new births. However, one other offspring arrived three years later. In 1968, a new organization came into the world pledging to prevent a repeat of that outage—the North American Electric Reliability Council. NERC works to assure reliability of bulk electric systems through the voluntary participation of all aspects of the electricity industry. This covered organizations on both sides of the public-private divide—from investor-owned utilities to the power marketing administrations. More than three decades later, 10 regional councils that make up NERC still work to prevent power outages and improve reliability for both consumers and businesses across the continent.

Maintaining the interconnected power grid required close compliance with NERC operating criteria. Day-to-day system reliability is monitored through NERC's regional reliability councils. Western's service area falls within two of these geographic territories: the Mid-Continent Area Power Pool and the Western Electricity Coordinating Council. The largest in size of the 10 regional reliability councils, WECC's members provide electrical power to 65 million people in 14 Western states, two Canadian provinces and part of one Mexican state. Most of Western's geography is within WECC's area. The Upper Great Plains Region also has facilities within MAPP's territory. Western staff serve on a number of technical and oversight committees for WECC, MAPP and NERC itself.

"The technical expertise shared by the many utility members of EPRI and the EPRI staff helps our engineers do their jobs at Western."

EPRI

Western is also a member of the industry-funded research and development organization. EPRI, formerly the Electric Power Research Institute, was formed in 1972. Western joined EPRI in March 1986 as a way to leverage customer funding for applied research. Since then, through EPRI, Western has joined other utilities in many practical research and development projects. Together, EPRI and its utility partners work toward designing high-capacity transmission equipment, improving energy conservation efforts and making the best use of renewable resources. Western's former Engineering Development and Coordination Division Director Larry Bressler said in 1991, "EPRI is the major electric utility research body. Western is proud to be a member. The technical expertise shared by the many utility members of EPRI and the EPRI staff helps our engineers do their jobs at Western."[64]

Transmission College: Western's Electric Power Training Center

Although it happened half a continent away and 12 years before its birth, in many ways Western owes its existence to the great blackout of 1965. The actions of a single, nameless operator turned a minor disturbance into a multi-state blackout. Vowing never to let that happen in the West, Reclamation developed plans for a transmission training center for dispatchers and other power operations people. After four years of planning and construction by Reclamation, the $400,000 training facility went on-line in April 1971. Western inherited the EPTC in 1977. From 1971 to 1986, Reclamation housed the Electric Power Training Center on the grounds of the Denver Federal Center in Lakewood, Colo. Since 1986, after a monumental move of 54,000 pounds of equipment, 3,000 components and 300 cables, the EPTC has been located in Building 19 of the Denver West Office Complex, in Golden, Colo.[65] EPTC students try out actual situations faced by dispatchers. They get hands-on experience using a simulator that includes a miniature system replicating a two-unit, 200-MW hydroelectric powerplant and associated switchyard, substations and transmission lines. The mini power system also features full-size relays to provide a realistic operating situation.

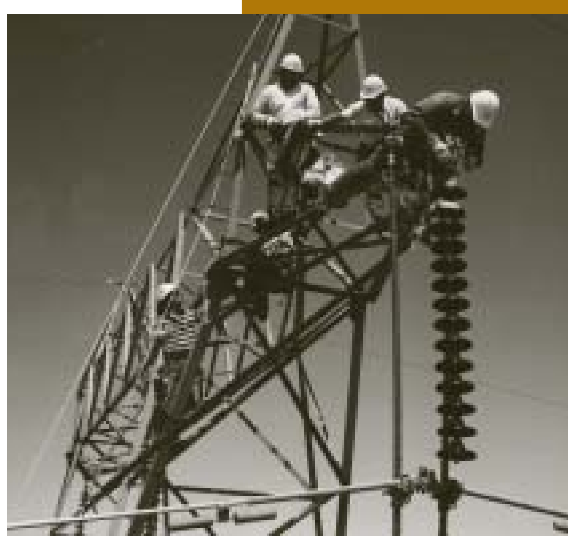
The Electric Power Training Center provides world-class training for utilities and agencies across the country.

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]

The End of the Line

During the 1990s, customer demand and deregulation put the power system and the people who run it on alert. In 1996, FERC issued Orders No. 888 and 889 requiring jurisdictional utilities to provide open access to their transmission systems for wholesale transactions. While not required to, Western has complied with these orders voluntarily as an open access advocate. An early side effect of deregulation was utilities lowering their costs to remain competitive. This came for some at the price of postponing or canceling transmission improvements and maintenance.[68]

Transmission development in the West is at a crossroads as a new century begins. New powerplants are being built, but transmission construction is lagging. Western's deployment of the Kayenta ASC project and expansion on existing DC systems helped to ensure reliability. Innovations will come, but the safe delivery of transmission remains rooted in a tradition of reliability. Lloyd Greiner explained why some choose to make service and technology work together to benefit the customer: "In my early days, I got out and was able to put new facilities into service and do troubleshooting. Several times, I was called out when a substation was in the dark and people were out hollering, and I was able to find the problem and restore power. That always made you feel pretty good."[69] ▼