

**Keeping The Lights On**



**F O R T H E N O R T H W E S T**

**B O N N E V I L L E**  
POWER ADMINISTRATION



# FROM THE DAM TO YOUR DOORSTEP

## Terms & Fun Facts\*

**Transmission** - The bulk transport of electricity.

**Generator** - A machine that converts mechanical energy, such as a spinning turbine, into electrical energy. Before 1892, generators were called "dynamos."

**Substation** - A facility with equipment to switch, transform or control electric power.

If placed end-to-end, the circuit miles in the Northwest federal grid would stretch halfway around the globe, from California to Kenya.

Length of time it would take an electric current to travel the federal grid end-to-end: 8/100ths of a second

\* Source: Encyclopedia Britannica, World Book Encyclopedia, the engineers, craftsmen and journeymen of the Bonneville Power Administration



### Thomas Edison-

In 1878, invented the electric light bulb and founded in the Edison Electric Light Company to "generate, transmit and distribute electric power." In 1882, formed Pearl Street Station, the first invested-owner electric utility in the U.S. He used DC.



## What it takes to keep the lights on in the Pacific Northwest

Lightning streaks across the sky. A child walks across a carpet on a dry day then gets a shock when touching a doorknob. The size of the event is different, but the force that drives both is the same: electricity.

Electricity has captured people's imaginations since the ancient Greeks, but it was only about 125 years ago that Thomas Edison finally captured in a bottle the force behind lightning. He called it an electric light.

Within a year Edison had his first commercial order. Strangely enough, it was from Portland, Ore., 3,000 miles away from his Menlo Park, N.J. laboratory. Oregon Railroad and Navigation wanted to illuminate a new ship.

Electricity came in small doses to the Northwest for the next decade: A hotel in Portland. A silver smelter in Hailey, Idaho. A mill in Tacoma, Wash. Street lights near the Spokane River from the Northwest's first hydro-electric dam. But "long distance" transmission didn't come to the U.S. until 1889 when - again a Northwest first - the Willamette Falls Electric Company sent power from its dam at Oregon City to Portland streetlights 14 miles away.

Electricity was the high technology of the day. But few electric companies could afford the cost of building generators and transmission systems. Bottom line: The more customers per mile, the lower the cost. Cities such as Portland, Seattle and Spokane and some towns had electricity but rural areas did not.

### A STRING OF EVENTS LED TO THE FEDERAL SYSTEM OF DAMS AND TRANSMISSION FACILITIES WE HAVE TODAY

1932	In a presidential campaign speech, Franklin Roosevelt said, "The next great hydro electric development to be undertaken by the federal government must be that on the Columbia River." Within a year, work began on the Bonneville and Grand Coulee dams.
1937	Congress created the Bonneville Power Administration to market and transmit electric power from the new federal dams.
June 3-9, 1938	The agency built its first 3.4 miles of transmission. Most of it was built by hand and horsepower.
June 9, 1938	Bonneville Dam's first generator sent power on that line to the city of Cascade Locks.
March 1939	BPA broke ground on its first high-voltage line. The 230,000-volt line ran 37.4 miles from Bonneville Dam to Vancouver, Wash., then to Portland General Electric's St. Johns substation in Portland, Ore. Later that year BPA built its first major line, 234 miles from Bonneville Dam to Grand Coulee to deliver Grand Coulee's first 108,000 kilowatts.

By 1945, BPA had built nearly 3,000 miles of high-voltage line and had put up the core of an interconnected transmission system called the "grid": a loop connecting Portland, Seattle and Spokane with arms radiating to Montana, Idaho, Canada and California.

As the demand for electric power grew in the Northwest, larger and more costly hydropower dams were conceived. To fund them the public looked to the federal government. Ironically, it was the Great Depression and the need to create jobs for the unemployed that gave the final push for the Columbia River hydropower — and transmission — that electrified the Northwest.

Today's federal grid moves nearly 26 billion watts of electricity throughout the Northwest — enough power to serve 8 million people and the businesses where they work — through more than 15,000 miles of high-voltage line and 400 substations. Four high-voltage lines — called the "southern intertie" — connect the Northwest and Southwest so the two regions can swap power and make the most of each other's generators.

The light switch flipped this morning could have brought power from as far away as Alberta or Albuquerque. How is it possible that power can come, without fail from hundreds, even thousands of miles away?

What follows here is a story of one project. Roosevelt-Guthrie is its name. It is fictitious. But it is typical of what it takes to serve the Northwest's growing demand for electricity — and our constant need to make sure someone is working to “keep the lights on.”

## Tracking the Future

Intel in Hillsboro, Ore., and Microsoft in Redmond, Wash., decide to expand their business parks. City leaders in Portland and Seattle react by rezoning land to add suburbs, shops and homes to handle an expected influx of new office workers.

On the eastern Oregon desert near Hermiston, Ore., developers announce plans to build two new power plants. In Spokane, fish managers hold a press conference to declare that endangered salmon will need more flows in the Columbia and Snake rivers. In Vancouver, B.C., Powerex decides it soon will have excess power to sell to the U.S. On the evening news, meteorologists forecast a winter cold snap and a cooling trend for the Northwest over the next few years.

These events may seem far apart and disconnected. Yet they have one thing in common. Not a person can be hired, not a family can move in until they have electricity. Not a megawatt can be moved, for fish or for power, until there is room — or capacity — on the transmission system — the interstate highway for electricity.

These issues fall to the utility planners and analysts. They know that the supply of electricity and the use of it have to be in equilibrium every second of the day without fail. Electrons and the laws of physics wouldn't have it any other way.

Planners foresee trends and spot troubles long before there is an emergency. They constantly study the grid to look for weakness or constraints. They look at how changes impact the grid whether from new growth or the winter cold snap. They come up with a list of solutions.

Can energy conservation offset the new demand for electricity? Will the high-tech firms use back-up generators or some alternate source of energy? Can BPA beef up equipment at existing substations? What about adding more controls to monitor the system and make sure it is staying within the safety zone? The planners consult with other utilities, regulators, community leaders and elected officials.

Turns out the solution is to do all of these, and one item more. The planners propose a new 500,000-volt power line, the Roosevelt-Guthrie project. That's the only way to bring megawatts from the Hermiston power plants to market. The project has a side benefit.

The southern intertie is overbooked at times of the year. Yet dam operators need it. In spring they spill water to pass young salmon through the dams. If river flows get too high, they tone down the spill by generating power and sending some of the megawatts south on the intertie. The bottleneck on the intertie will only get worse when Powerex tries to sell its excess south as well. Roosevelt-Guthrie will relieve that constraint.

Before they work up a proposal, the planners contact a project manager who pulls together a team of engineers and utility specialists. Together they estimate a budget and the time, effort, public review, materials, people and skills needed to take the job from beginning to end.

Then they argue the project's priority against a list of projects proposed by other teams. Roosevelt-Guthrie wins its case. Its cost is within the rates BPA is charging for use of the grid. It is put on the schedule for construction three years out. The real work has just begun.

## FROM THE DAM TO YOUR DOORSTEP

### Terms & Fun Facts\*

**Megawatt (MW)** - 1,000,000 watts. The amount of power that plant can produce at any given moment of time. A city the size of Seattle can consume 1,100 MW at any given moment in time.

**Capacity** - Amount of electricity a conductor can carry at any given moment in time. A transmission line's operating capacity, that is, its rating, typically is higher than what it has available at any given time due to weather, outages or unusual flows on the grid.

**Generation** - The act of producing electricity from some form of energy, such as hydro, coal-fired steam turbines or photovoltaic solar panels.

Length of time it would take an electric current to travel from Los Angeles to Seattle: 5/100ths of a second

Length of time it takes to detect and control a problem on the federal grid: About 50/1000ths of a second

\* Source: Encyclopedia Britannica, World Book Encyclopedia, the engineers, craftsmen and journeymen of the Bonneville Power Administration



Surveying the first Bonneville-Grand Coulee high-voltage line, 1939.

# FROM THE DAM TO YOUR DOORSTEP

## Terms & Fun Facts\*

**Conductor** - Material, such as an aluminum transmission line, suitable for carrying an electric current.

**Transformer** - An electrical device that changes the voltage of alternating current. It can step up - transform voltage from low to high - or step down the voltage.

**Circuit breaker** - A device designed to open automatically and very quickly in order to protect other electrical equipment during a fault or overload. Operators also open breakers manually in order to "isolate" a piece of equipment before working on it. You have circuit breakers in your house on a much smaller scale.

Height of the Seattle Space Needle:  
520 feet

\* Source: Encyclopedia Britannica, World Book Encyclopedia, the engineers, craftsmen and journeymen of the Bonneville Power Administration

## André Marie Ampere-

His work created the basic instrument for measuring the magnitude of electric currents.

**Ampere** - the measure of the rate of flow of an electric current.

Marv Landauer -

Planner Marv Landauer gets excited when thinking out loud through the intricacies of designing a 500,000-volt line from Schulz to Hanford substations in Washington. Although it won't be completed until 2005, the new line could go a long way to correcting the constrained transmission capacity from northern Washington to the Oregon border.

If done right, the new line could help solve other problems as well. That's what Landauer and others who design solutions to transmission system problems look for. They strive to achieve multiple purposes for every project they work on.

"Certainly, the line will bring more generation in from the north - places like Grand Coulee Dam and Canada - and that's related to the southern intertie," Landauer says. But, that's not the end of the benefits. "The line is also related to salmon recovery. Getting more power into the mid - and lower - Columbia River means dams can spill more water to pass fish and keep the intertie capability up."



## Turning an idea into action

Avalanche, winds and floods. The design engineers on the project team look at every civil and electrical engineering challenge Roosevelt-Guthrie will have to face in altitude, weather and terrain from the footings to the top of the towers. Environmental specialists review all the project's possible impacts to the land, water and scenic views. They look for sensitive plants and animals and research whether there are cultural heritage sites in the area. Together, they come up with a list of six alternative ways to build Roosevelt-Guthrie.

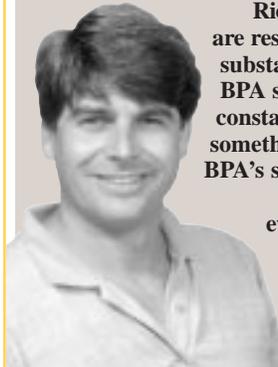
A team of real estate experts checks out the corridors proposed for the line and compiles a list of all who live near the routes. Then a public involvement team meets with the project's neighbors. The project manager also briefs community leaders and elected officials. After several meetings and several months, everyone decides the best thing to do is to upgrade an existing 230,000-volt line to 500,000 volts.

Towers will have to be changed; new conductors strung. There will be upgrades to transformers and circuit breakers at substations at both ends of the line. But BPA won't have to buy new land because the existing corridor is wide enough for the higher voltage. That also means BPA won't have to cut into a hillside and risk dumping dirt into a nearby stream. BPA agrees to compensate farmers if crops are damaged during the upgrade. For the most part, the neighbors are happy about the choice.

Richard Becker -

Keeping the power flowing throughout the transmission grid requires more than the lines and towers that dot the landscape. The system must be constantly monitored to make sure it's functioning properly and power is being delivered.

Richard Becker works in the system protection control group. They are responsible for maintaining meters and protection devices within substation control houses. The meters measure the amount of power BPA sells to customers in order to bill them correctly. Protective relays constantly monitor the condition of the system and send an alert when something's amiss. This large network connects every substation in BPA's system.



Becker likes the variety of work but admits it may not be for everyone. He says a person has to be willing to change their plans at a moment's notice if something goes awry with the system. "You also have to be the type of person who wants the job done right the first time. We can't have loose ends out there that jeopardize the system."

Facility engineers complete the specifications for the towers, conductor, insulators and concrete. Substation engineers specify the breakers and transformers. Another group selects the computer controls and protection schemes to make sure the upgraded line will survive faults and overloads. Yet another group chooses the telecommunications equipment — in this case a fiber optic cable — so computers and staff miles away can control the line and the substations, instantaneously detect problems and make sure these facilities work in unison with the rest of the grid.

After two years, the project is ready. Engineers are done. The line has been surveyed. Specifications are completed. Materials have been ordered through the procurement staff. Manufacturers have them scheduled. Come summer, Roosevelt-Guthrie will be ready for construction.



Leon Kempner -

The secret's out. BPA projects are supported not only by superior electrical engineering, but also through the notable contributions of civil, mechanical, hydraulic, environmental, geological and other types of engineers.

In fact, one of BPA's most honored and recognized engineers, and the force behind numerous national and international industry standards is . . . a civil engineer.

The areas influenced and experienced by Leon Kempner during his BPA career include everything from the transmission industry's premier steel tower designs, to design software, to regional seismic mitigation standards that keep the Northwest from losing electrical equipment during an earthquake.

Kempner, like other exemplary engineers for whom anything less than full commitment just doesn't cut it, has been most inspired by the design failures, excited by "the ability to investigate it, to study it, to correct it." But expect to put in long hours, way beyond the anything resembling an 8-to-5. "This group is more than willing to put in big hours to see big rewards."

## Getting grounded

It's June and raining hard when the construction crew prepares the sites for the new towers' footings. They pray for a dry day so field carpenters can build the forms and a contractor can pour the concrete on schedule.

At Roosevelt and Guthrie, other crews are preparing sites for the new equipment. Roosevelt will need a larger control house. With the engineers' drawings in hand, sheet metal workers, carpenters and painters produce the control house shell. Other workers prepare the control house racks that will hold the communications, relay and metering equipment.

A new transformer for Guthrie has arrived at a nearby port. The size of a single-car garage but as delicate as your grandmother's Wedgwood china, it takes a special crane to gently lift it from a barge to a low, wide railcar. Along the route, a laboratory engineer checks a seismic chart to make sure nothing breaks loose. The transformer arrives in good shape. At Guthrie, a dozen burly riggers gently, slowly coax it onto the concrete pad, then strap it down.

By now the control house and its equipment are ready. Riggers transport the pieces to Roosevelt. The construction crew works with local specialists to situate the control house, install the racks and wire the equipment to the new transformer and circuit breakers.

Over on the right of way, material handlers are trucking in the tower steel. The Pasco line crew gets the honor of setting it into the sky. A helicopter leans up the base. The crew bolts it into the footings. Then strapped in harness, four men climb what looks like an oversized Erector set while the helicopter carefully eases the new top in place. The holes on each leg match perfectly. A dozen bolts later, the crew is ready for the next tower.

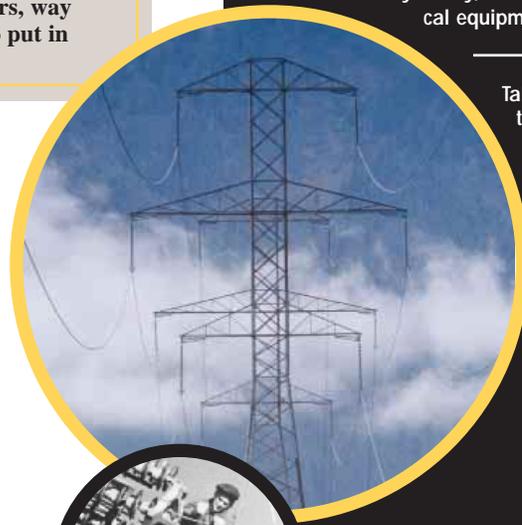
## FROM THE DAM TO YOUR DOORSTEP

### Terms & Fun Facts\*

**Insulator** - Something that does not conduct electricity well, such as porcelain. Utilities use porcelain insulators to support transmission and power lines, keep them separate from each other and from the towers that hold them.

**Fault** - What happens when the electrons complete the circuit through an undesirable path, such as when a tree falls into a transmission line.

**Riggers** - Journeymen skilled at moving very heavy, but delicate, electrical equipment.



Tallest tower on the federal transmission system: 537 feet

\* Source: Encyclopedia Britannica, World Book Encyclopedia, the engineers, craftsmen and journeymen of the Bonneville Power Administration



Dead ending the conductor on a river crossing tower for the Bonneville-Vancouver line, 1939.

# What's Watt

## The Basics of Electricity

3

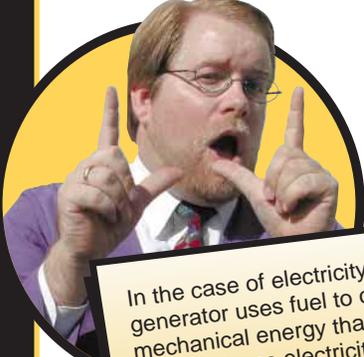


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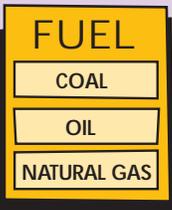
Electricity is just another form of energy. Energy is anything that does work. Your body's energy comes from the food you eat. Food is your fuel.

The electricity moves from the generator to a switchyard at the power plant. There it is transformed to a higher voltage and sent on its way via a transmission line. Transmission lines generally are rated at 69,000 to 500,000 volts (compared to the 120 or 240 volts in your home).



In the case of electricity, a generator uses fuel to create mechanical energy that in turn produces electricity. For much of the nation, the fuel is coal, oil or natural gas. Fuel is burned to heat water to make steam.

2



GENERATOR

4

The transmission line joins a generator to a power plant. The transmission line connects the power plant to the homes and businesses who use the power. The power is made up of power from the power plant.

For some Americans, the heat comes from a nuclear power plant, where the nuclear reaction heats water to make steam.



NUCLEAR POWER PLANT

GENERATOR

5

Near town, the electricity enters the distribution system. The electricity is sent to a lower voltage for the distribution system. The distribution system is made up of neighborhood lines typically 34,500 volts. The voltage is lower than that of the electricity distributed to the homes. There is a transformer at the end of the power line looking for the transformer.

In the Northwest, about 70 percent of the fuel is falling water. The power of a river is held behind a dam. The power plant's steam or the dam's falling water hits turbine blades and the turbine turns. The turbine is connected by a drive shaft to a generator - a magnet inside a coil of wire. As the magnet spins, it moves a magnetic field across the turns of wire in the coil, creating an electric current. The more the coils of wire, the larger the generator and the more powerful the electric current.



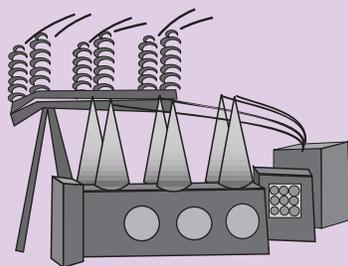
DAM

GENERATOR

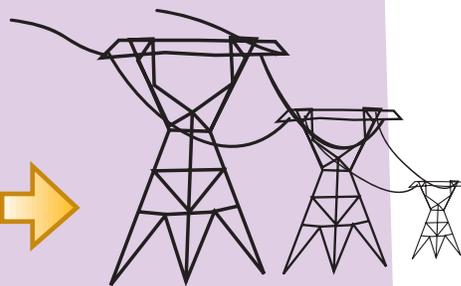
ELECTRICITY



ELECTRICITY



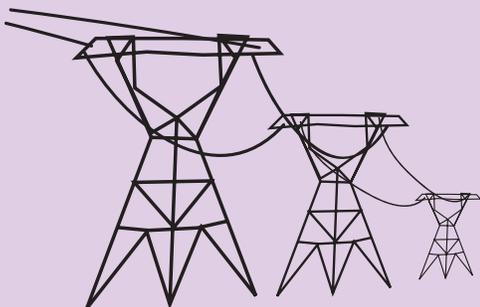
SWITCHYARD



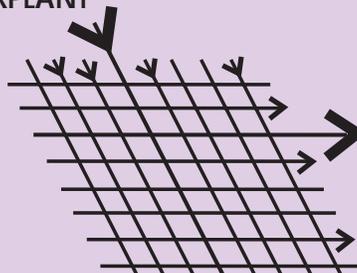
TRANSMISSION LINES

Transmission line quickly  
grid - a network of  
lines from various  
plants. The grid not only  
several power plants, it  
to several customers  
the power. This allows a  
ous flow and shifting of  
from one area to another to  
ure there is adequate  
or customers at all times.

POWERPLANT



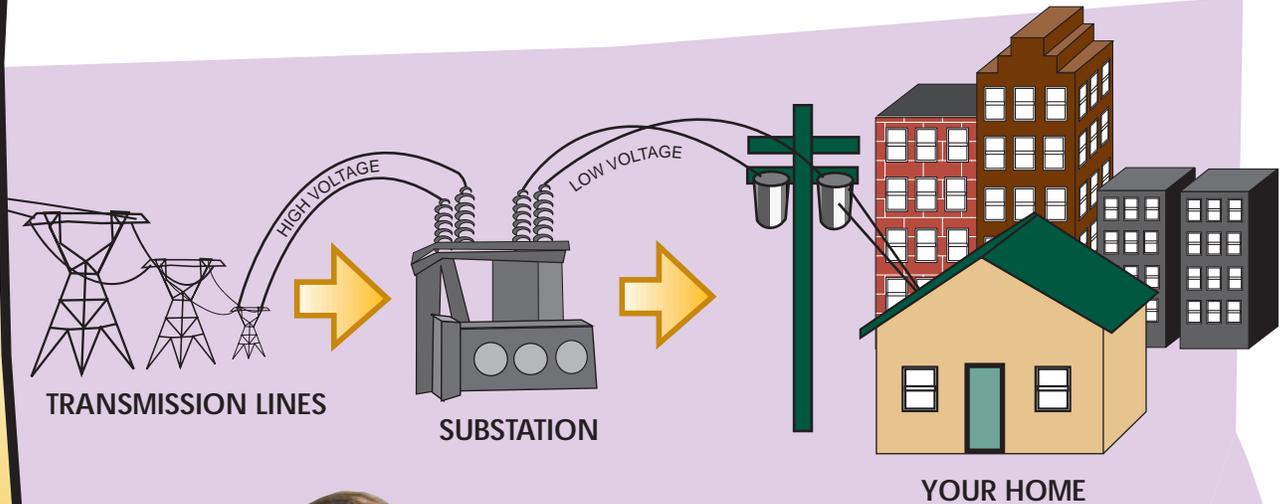
TRANSMISSION LINES



POWER GRID

CUSTOMER

ns, the transmission  
s a substation where  
ricity is transformed  
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e use. Look outside, if  
a metal can at the top  
ower pole, you are  
at a distribution  
mer.



6



Managing electricity is much the same as managing traffic between major cities. Cars enter a freeway until they approach the chosen location. Then they take an off ramp to a main street and eventually to a side street to the final destination.



## FROM THE DAM TO YOUR DOORSTEP



### Terms & Fun Facts\*

**Circuit** - A closed path through which electricity follows. Electrons have to "complete a circuit," that is, they have to flow from the power plant to your appliances, and then back to the power plant.

**Control house** - Facility that houses switches, relays and communications equipment to operate and protect high voltage equipment in the substation yard and associated transmission lines.

**Current** - The flow of electricity. Alternating current (AC) - Electrons reverse at regularly recurring intervals with alternately positive and negative values. Alternating current is used in your home.

The current needed to light a 10-watt bulb is more than enough to kill you.

\* Source: Encyclopedia Britannica, World Book Encyclopedia, the engineers, craftsmen and journeymen of the Bonneville Power Administration

### Ben Franklin -

In 1752 he flew a kite during a storm. When the kite and string became electrically charged, he was convinced lightning was a huge electric spark. Fortunately, lightning did not strike Franklin's kite. If it had, he probably would have been killed.

## Getting grounded (continued)

As one line crew moves on to erect the next tower, a second crew uses the helicopter to pull the end of a new reel of conductor to the top of the finished tower. Two men suspended 150 feet in the air at the top of the tower clamp the conductor to a string of insulators. A small explosion seals the fitting.

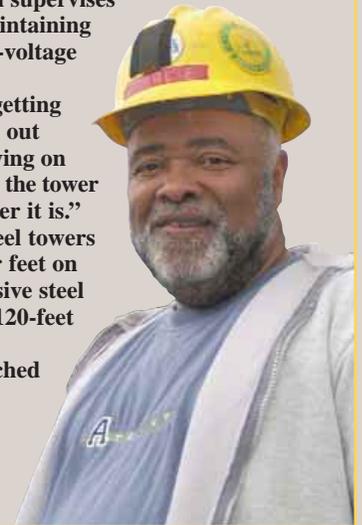
### Charlie Pursiful -

As a lineman foreman, Charlie Pursiful supervises a 10-person crew, and is responsible for maintaining and repairing more than 900 miles of high-voltage transmission lines.

"There's nothing like the challenge of getting the lights back on," Pursiful says. "You're out in a big storm and this large conductor's lying on the ground and its up to us to get it back on the tower and energized. The tougher it gets, the better it is."

Linemen are often required to climb steel towers ranging from 80 to 500-foot tall, placing their feet on small step bolts located on one side of the massive steel frame. Wooden poles that can range from 40 to 120-foot tall are no easier. Then the lineman uses a safety belt strapped around the pole and digs in sharp hooks attached to his heavy boots as he makes his way to the top. In both cases, they're often required to carry heavy loads while they climb.

"The job is not dangerous if you do it like we teach you. But I can't tell you it's not scary."



Within a month, the line is complete, the substations expanded, the new equipment in place. Then comes the tricky part.

To connect the upgrade to the system, that section of the grid needs to be temporarily taken out of service. That's not easy when millions of people depend on the power of the line. Utilities and power marketers stand to forego thousands of dollars for lost sales.

Knowing this, an outage team of engineers, planners, dispatchers, schedulers, operators and customer service managers meet with marketers and utilities to pick a date when use of the section is low and reliability on the rest of the grid is high - and when there would be the least danger to the crew. The outage date is posted on the Internet 45 days before it happens so all can plan ahead.



Building the tower along Shell Rock Mountain for the Bonneville-The Dalles Line, 1941.

The date arrives. The construction crews complete their last connections. Then come the test and energization engineers. They run the new equipment through its paces, often working 24-hour days with little rest. Design engineers are on hand if something goes wrong. Construction crews are on notice for emergency re-work. At last, tests show the upgrade is sound. It can withstand faults. It can run at expected standards. It is synchronized with the rest of the grid. Roosevelt-Guthrie goes into service.

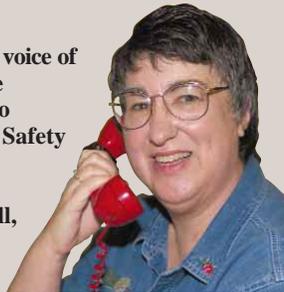
## Keeping the kilowatts coming

Roosevelt-Guthrie is now a normal part of the grid. At two control centers it's on the computer screens and on map boards, each the size of two billboards. One control center is in Vancouver, the other in Spokane. Each backs up the other. Each has three independent sources of electricity as a precaution against power outages. The centers monitor and control, not only Roosevelt-Guthrie, but also the rest of the grid, the communications and control systems and about 400 substations. They also monitor generators in the region to maintain balance between generation and load, and to control voltage on the grid.

Jeanne Cozad -

**Dispatchers like BPA's Jeanne Cozad are the steady hand and voice of experience behind the complicated maneuvers needed to run the transmission grid. "We are the overseers of the power system to make it safe for people to work on. We approve how it's done. Safety is first; then, keep the power flowing."**

**Before her are a vast array of computer screens and print readouts, providing her with a deluge of technical data. But still, "The operators are our eyes and ears at the substation. Good communication with them is crucial."**



Like traffic cops, the control centers' dispatchers monitor and control movement of millions of kilowatts of electricity through the grid. From their computer consoles, dispatchers can call up data on how any part of the system is working. Color-coded displays show the status of any power line or other piece of equipment, including the new transformers and circuit breakers and Roosevelt and Guthrie.

In a separate area at one of the control centers, operations engineers run digital simulations of the grid. Through their computers, they add outages, suddenly take out generators and boost demand for electricity just to see how the grid will react. Their job is to set limits on capacity, to make sure the alarms and controls all work properly and that the grid never operates beyond standards of reliability.

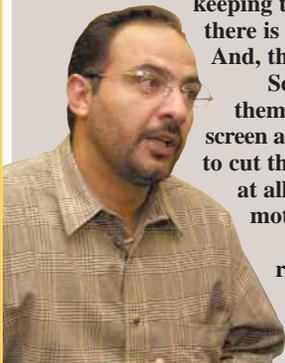
In yet another room, schedulers book use of the grid. Roosevelt-Guthrie was scheduled the second it was ready for service. Today, the staff handles about 2,000 schedules for about 350 customers. Customers range from small rural cooperatives to large utilities to marketers and independent power producers to industries that buy power directly from BPA. Ten years ago, before deregulation hit the electric utility industry, the number of schedules was negligible and customers numbered less than 100.

Salah Kitali -

**Real-time schedulers like Salah Kitali keep the transmission system in balance by making sure scheduled sales don't exceed the system's capacity. Their importance to keeping the lights on is unmistakable: if the system is out of balance — if there is more load than capacity — then some schedules must be cut. And, they must do all this as it happens.**

**Several computer screens that surround each scheduler allow them to monitor transactions and transmission line activity. A touch screen automatically dials up any marketer they need to talk to, whether to cut their schedule or to sleuth out a discrepancy. If a schedule differs at all with real-time use, then that is an alarm that sets Kitali in motion to find out why and to get the marketer to correct it.**

**"If we lose a line, the dispatchers tell us how much we need to reduce from schedules on the system," Kitali said. "We then have to call the appropriate customers and tell them they need to cut their schedules by certain amounts or go to zero."**



Most transactions take place through OASIS — an open-access, same time information system on the Internet. It's updated often to give users the latest on outages, available capacity and changes on the grid. After checking OASIS, users book space on the grid through schedulers.

## FROM THE DAM TO YOUR DOORSTEP

### Terms & Fun Facts\*

**Direct current (DC)** - Electrons flow in one direction, and usually at an almost constant magnitude, as in a battery. Direct current is used in your automobile.

**Electricity** - The flow of electrons in a conducting material.

**Electrons** - A subatomic particle with a negative charge.

**Frequency** - The number of AC cycles per second, that is, the number of times the current goes from plus to minus to plus again. Sixty is standard in the U.S.

**Ground** - During a fault, electricity will follow the path of least resistance to the earth, or an object that substitutes for the earth. You have separate ground wires in your house so in case of a fault the electricity flows to the earth and not you.

Amount of voltage in a typical house in the United States: 120 and 240 volts

Amount of voltage in a typical lightning bolt: 100 million volts

\* Source: Encyclopedia Britannica, World Book Encyclopedia, the engineers, craftsmen and journeymen of the Bonneville Power Administration

# FROM THE DAM TO YOUR DOORSTEP

## Terms & Fun Facts\*

**Kilowatt-hour (kWh)** - Measurement of electricity you see on your electric bill. Measurements are metric so a kilowatt is a thousand watts. A kilowatt-hour is the amount of energy used if you use 1,000 watts for one hour. Use 10 100-watt light bulbs for one hour and you've used 1 kilowatt-hour of electricity.

**Load** - The amount of electric energy delivered or required at any specific point on an electrical system.

**Megawatt-hour (MWh)** - The amount of energy delivered over a period of time; in this case, a megawatt for one hour. A 1,000 MW plant can produce 1,000 MWh if it is run full force for an hour. It can produce 24,000 MWh if it is run full force for a day.

Number of days the United States could run on the electrical energy supplied by a single thunderstorm: 4.

Amount of time a typical hurricane could supply all the electric energy needed by the United States: 3-4 years.

\* Source: Encyclopedia Britannica, World Book Encyclopedia, the engineers, craftsmen and journeymen of the Bonneville Power Administration



### George Westinghouse

In 1886, formed the Westinghouse Electric Company and used AC. AC proved more popular than DC because it was easier to transform and, at lower voltages, it was easier to transmit long distances. Edison fought back by claiming ac was dangerous. He was so convincing that New York used AC to power the nation's first electric chair. Of course, AC and DC equally are dangerous. AC is now the standard.

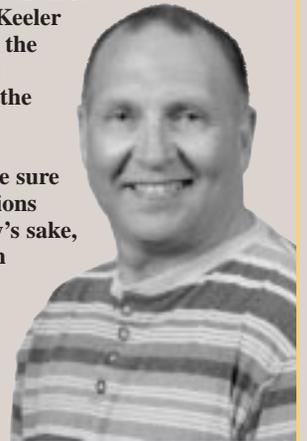


### Malcolm Mackey -

Substation operators are the first to respond to trouble and emergencies. Malcolm Mackey, an operator at Keeler substation in Hillsboro, Ore., said he's been called out in the middle of the night after an earthquake that put on the ground much of the substation equipment that should have been up in the air. Another time was due to a fire on a transformer that sent workers to the hospital.

Substation operators have a life-and-death job. They make sure line crews, craftsmen or electricians can work safely at substations and on the transmission lines between substations. If for safety's sake, doing the work means a line has to be taken out of service, then Mackey and his colleagues work to limit an outage's impact on the transmission system and on consumers.

"This job is a matter of timing and of knowing how the transmission system works," Mackey said. "There is no tolerance for error. Someone could lose power or, worse, someone could get hurt."



## Keeping the lights on

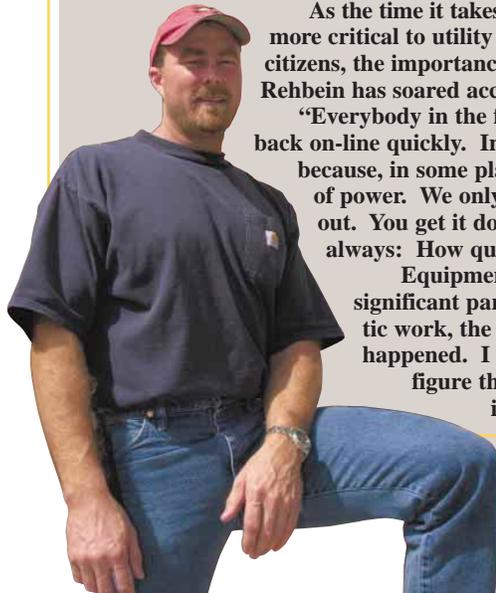
A tree falls into a line during a winter storm. Circuit breakers automatically trip open the line to isolate the problem. Alarms in the dispatch center sound. Computers pinpoint the fault. Dispatchers test the faulted equipment for damages, then call out substation operators at both Roosevelt and Guthrie to clear the line for the Pasco line crew. Thanks to Roosevelt-Guthrie, the power was rerouted so the crew can work safely and consumers didn't even notice there was a problem.

Aircraft patrols scan Roosevelt-Guthrie three to four times a year with infrared equipment to check for hot spots on the transmission lines. Linemen follow up with their own hands-on inspections of the towers, insulators, fiber optic cable and conductors. Natural resource specialists check vegetation and cut dangerous trees.

Substation electricians and maintenance experts regularly diagnose the new transformers and circuit breakers for preventive maintenance. All stand ready to respond to emergencies, any day of the week, any time of the day or night during any kind of weather.

Meanwhile, it's time for your favorite television program. The thermostat is set at a comfortable temperature. The microwave pops a bag of popcorn. In another room, a machine washes your clothes. All you have to do is to make sure the electric cord is plugged into the outlet. And, like a miracle, electricity is there to do the rest.

### Garett Rehbein -



As the time it takes to restore equipment after an outage becomes more critical to utility revenues and the health and safety of Northwest citizens, the importance of the skills BPA electricians such as Garett Rehbein has soared accordingly.

"Everybody in the field realizes how important it is to get things back on-line quickly. In Spokane we did a lot of midnight outages because, in some places when the station fails, a whole town is out of power. We only have so long of a window. The work is planned out. You get it done in that time. That's on people's minds always: How quickly we have to get it back in."

Equipment failures stand out in his mind as the most significant part of his work. "That's when you do the diagnostic work, the research, the troubleshooting, to figure out what happened. I go out every day thinking 'I'm going to try and figure this out today.' In that way, my job stays really interesting."

NOW YOU  
KNOW WHAT  
IT TAKES  
TO KEEP  
THE LIGHTS  
ON IN THE  
NORTHWEST



**For more information**

Contact the BPA Public Information Center at 1-800-622-4520 and ask for:

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- Dittmer Control Center:** Bringing power to our lives (DOE/BP-3266)
- Power Center:** BPA's Celilo Converter Station and the Eugene Starr Complex (DOE/BP-2264)
- Keeping the way clear for better service:** The danger tree program (DOE/BP-2816)
- Stay Alive:** (DOE/BP-3181)
- High-Powered Energy:** BPA story (DOE/BP-876)
- Find Your Future:** Careers at BPA (DOE/BP-3208)
- Or visit our Web site at:** <http://www.transmission.bpa.gov/> and click "About TBL"

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