Electric Transmission Lines

PUBLIC SERVICE COMMISSION OF WISCONSIN

Electricity from the Power Plant To the Consumer

The Nature of Electricity

Electricity must be used as it is generated. Unlike other commodities, there is very little ability to store electricity. Because of the instantaneous nature of the electric system, constant adjustments must be made to assure that the generation of power matches the consumption of power. The electric system we've grown to depend on is very complex and dynamic, constantly adjusting to meet changing needs.

The amount of power on any electric line at any given moment depends on generation production and dispatch, customer use, the status of other transmission lines and their associated equipment, and even the weather. The transmission system must accommodate changing electricity supply and demand conditions, unexpected outages, planned shutdowns of generators or transmission equipment for maintenance, weather extremes, fuel shortages, and other challenges.

The Transmission Grid

The electrical transmission system is more complex and dynamic than other utility systems, such as water or natural gas. Electricity flows from power plants, through transformers and transmission lines, to substations, distribution lines, and then finally to the electricity consumer. Figure 1 depicts a very simplified diagram of the electric system. In reality, the electric system is highly interconnected.

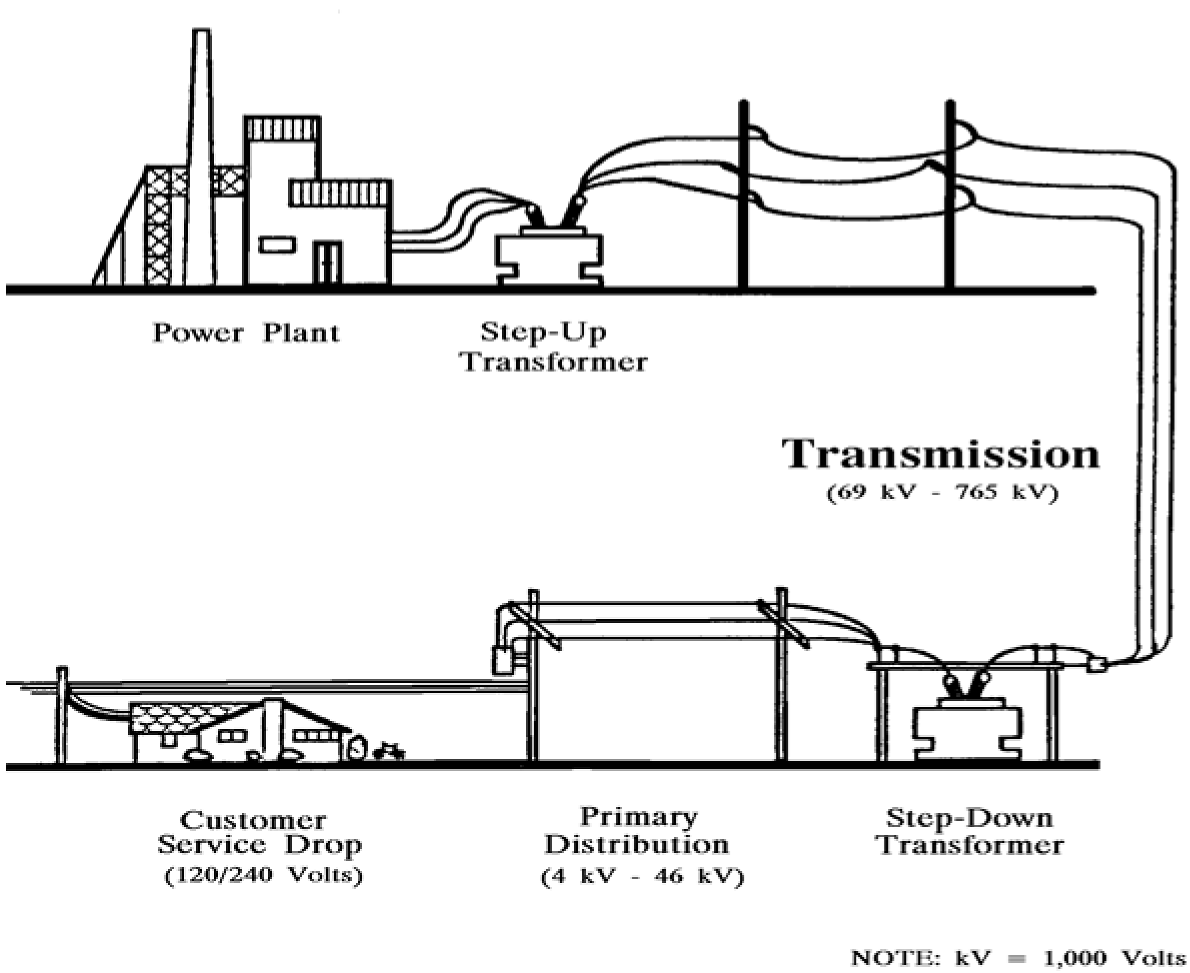
The interconnectedness of the system means that the transmission grid functions as one entity. Power entering the system flows along all available paths, regardless of boundaries of service areas, counties, states, or even countries.

The current transmission grid includes not only transmission lines that run from power plants to centers where electricity is used, but also from transmission line to transmission line, providing a redundant system that helps assure the smooth flow of power. If a transmission line is taken out of service in one part of the power grid, the power reroutes itself through other power lines to continue delivering power to the customer.

In essence, the electricity from many power plants is "pooled" in the transmission system and each distribution system draws from this pool. This networked system helps to achieve a high reliability and availability for power delivery since any one power plant only constitutes a fraction of the power being delivered by the power grid to meet the instantaneous demand requirements.

This pooling of power also means that power is provided from a diversity of sources, including coal, nuclear, natural gas, oil, or other renewable energy sources such as hydropower, biomass, wind, or solar power.

Figure 1 Simplified Electric System



Transmission Outages

A transmission line outage acts like a dam, forcing the electricity around the blockage onto other lines. If adjacent transmission lines cannot handle the extra power flow, safety devices may switch them off to prevent damage. Severe overloads can lead to cascading outages and system-wide failure, *i.e.*, a blackout. This is one of the disadvantages of the interconnectedness of the transmission grid. Multiple failures in one location can quickly affect the entire system, producing a large scale blackout. This does not happen very often. For reliable power transmission, a region requires backup transmission lines with adequate capacity. Due to the 2003 blackout in the Northeast, the Federal Energy Regulatory Commission (FERC) passed mandatory reliability rules in 2005 which resulted in a series of new mandates including requirements for redundancy, reliability, and rigorous ROW maintenance.

Components of the Transmission System

Power plants generate three-phase alternating current (AC). This means that a transmission line is constructed with three wires, one for each phase.

On a transmission structure, the three large wires are called conductors and carry the electric power. They are usually about one or two inches in diameter. There is also a smaller wire at the top of the structure, called a shield wire. The shield wire is designed to protect the power line from lightning and may also contain fiber optic communication cables. Electric lines with two sets of three conductors are referred to as double-circuited structures. Sometimes a distribution line is strung under a transmission line.

The electric grid consists of two separate infrastructures: the higher voltage transmission system and the lower voltage distribution system. Transmission lines in Wisconsin range from 69 to 345 kilovolts (kV) and are used to minimize electrical losses over hundreds of miles. Lines with higher voltages, such as 500 kV or 765 kV lines have to-date not been constructed in Wisconsin but are in use in other Midwestern states. The lower voltage distribution system draws electricity from the transmission lines and distributes it to individual customers. Distribution lines range from 4 to 35 kV. The voltage that connects to your house is even lower, at 120 or 240 volts. One thousand volts equals one kilovolt.

The interface between different voltage transmission lines and the distribution system is the electrical substation. Substations use transformers to "step down" voltages from the higher transmission voltages to the lower distribution system voltages. Transformers located along distribution lines further step down the line voltages for household use.

Transmission Line Design

The electric lines that generate the most public interest are often high-voltage transmission lines. These are the largest and most visible electric lines. Most large cities require several transmission lines for reliable electric service. Figure 2 shows an example of two 345-kV double-circuited transmission structures sharing the same right-of-way (ROW).

Transmission lines are larger than the more common distribution lines that exist along rural roads and city streets. Transmission line poles or structures are commonly between 60 and 140 feet tall. Distribution line structures are approximately 40 to 60 feet tall.

There are several different kinds of transmission structures. Transmission structures can be constructed of metal or wood. They can be single-poled or multi-poled. They can be single-circuited, carrying one set of transmission lines or double-circuited with two sets of lines. Figure 3 shows a close up of a commonly built double-circuited, single-pole transmission structure. Figure 4 shows diagrams of different types of transmission structures.

Figure 2 Two High Voltage Double-Circuit Transmission Structures

Figure 3 A Single-Pole, Double-Circuit Transmission Structure

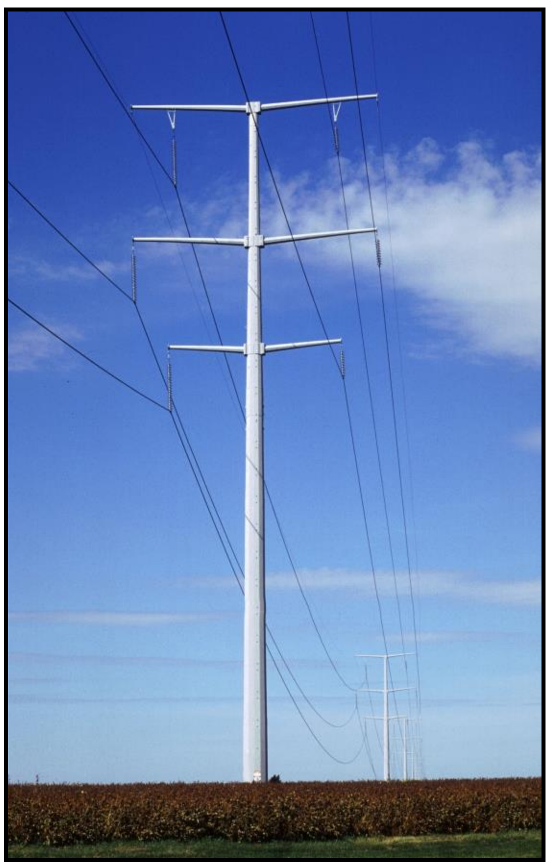
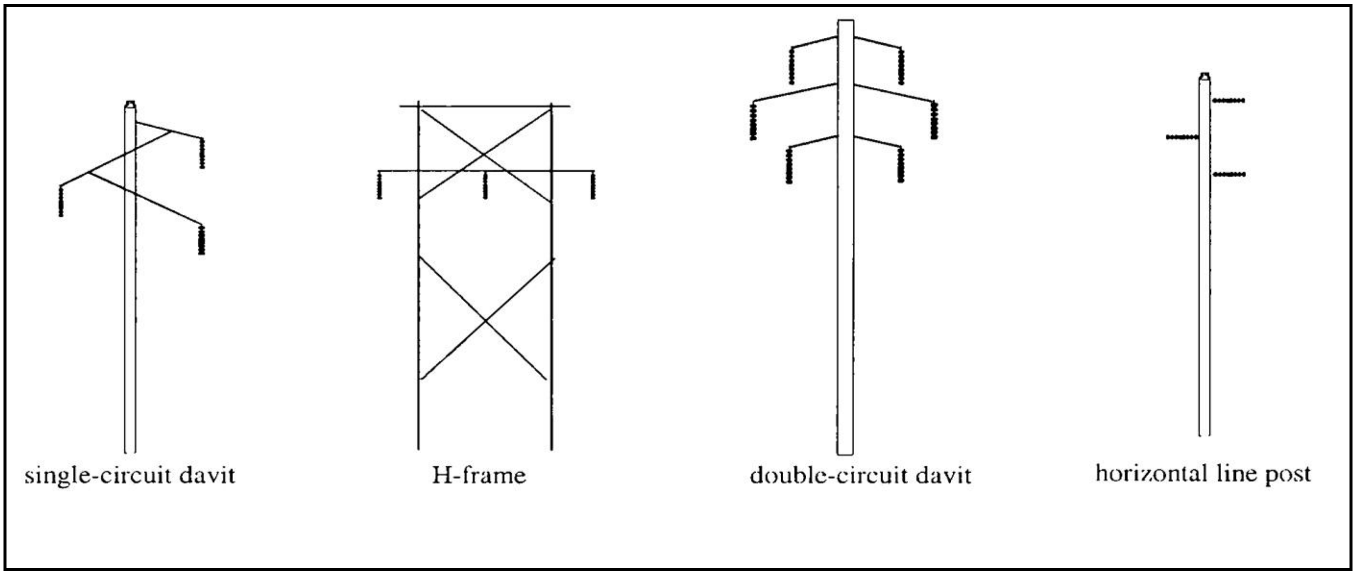
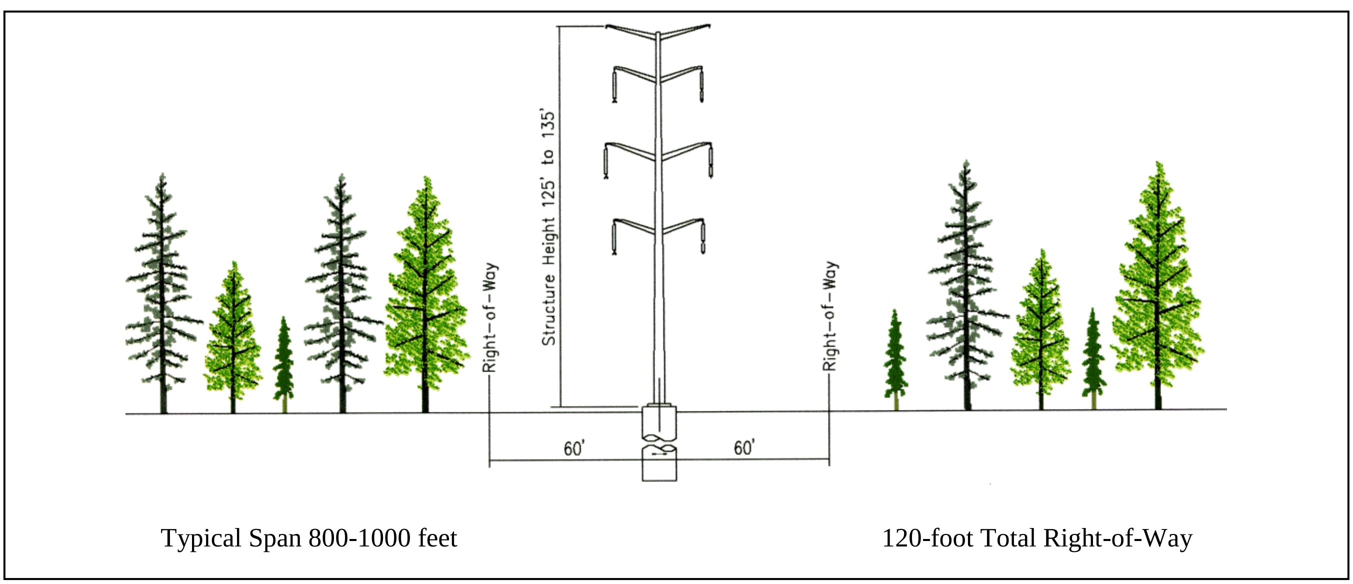


Figure 4 Different Transmission Structures



Different transmission structures have different material and construction costs, and require different right-of-way widths, distances between structures (span length), and pole heights. Construction requirements and costs also vary with the different sized voltages. In the past, many transmission lines were constructed on H-frame wood structures and metal lattice structures. New lines are most often constructed with single pole structures because of right-of-way width limitations and environmental considerations. Current right-of-way widths vary between 80 to 150 feet. A typical right-of-way is diagrammed in Figure 5.

Figure 5 Typical Right-of-Way Diagram



Pole height and load capacity limitations determine the distance between poles (span length) either on the basis of ground clearance or ability to support heavy wind and ice loads. In areas where single-pole structures are preferred, weak or wet soils may require concrete foundations for support. Where a transmission line must cross a street or slightly change direction, larger angle structures (Figures 6 and 7) or guy wires may be required. Poles with guy wires impact a much larger area. Angle structures are usually more than double the diameter of other steel poles. They are made of steel, usually five to six feet in diameter, and have a large concrete base. The base may be buried ten or more feet below the ground surface. The diameter of the pole and the depth the base is buried depends on the condition of the soils and the voltage of the line.

Figure 6 A Transmission Line Diagonally Crossing a Street between Two Angle Structures

Figure 7 Close-up of the Base of an Angle Structure

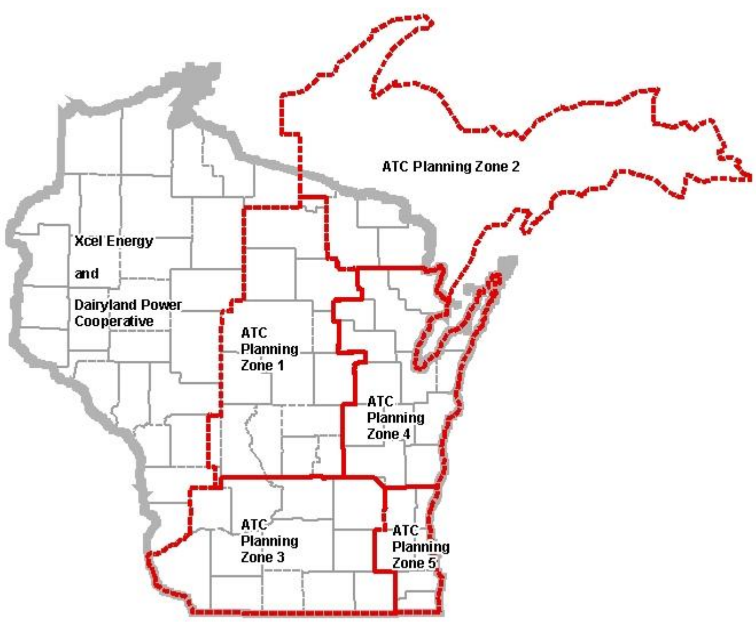
The Wisconsin Transmission System

There are approximately 12,000 miles of transmission lines in Wisconsin. High-voltage transmission lines deliver large amounts of power on a regional basis. The higher the voltage, the more power the line can carry on the same size conductor. The Wisconsin transmission system has a general electric flow from northwest to southeast through the state. The western part of Wisconsin is connected by high-voltage lines (161 and 345 kV) primarily from Minnesota. The southeastern part of Wisconsin is connected to northern Illinois by 345 kV high-voltage lines. The Wisconsin transmission system can become congested under normal power flow conditions. In addition, there are many transmission lines in Wisconsin that are more than 60 years old, requiring upgrades or replacement. Since 2005, there have been mandatory federal reliability standards for transmission system planning and operation which requires upgrades to maintain the same performance level in the Midwest power market. The introduction of renewable power sources such as wind-power electric generation in Wisconsin and other Midwest states have required new high-voltage transmission lines for the delivery of reliable and economical energy.

Restructuring the Electric Industry and Wisconsin Transmission

Up until 1999, individual Wisconsin utilities were vertically integrated. In other words, the utilities owned all the electrical facilities from power plants, substations, and transmission lines to the lines that carried the electricity to individual residences. After 1999, the electric industry in the eastern portion of the state was restructured in accordance with the Federal Energy Regulatory Commission (FERC) orders. Ownership of the transmission lines were transferred to the American Transmission Company LLC (ATC). ATC commenced operation, in January 2001. ATC owns transmission facilities in the Upper Peninsula of Michigan, as well as Wisconsin. Transmission lines in the western part of the state are owned by Xcel Energy Services, Inc. (Xcel or Northern States Power-Wisconsin) and Dairyland Power Cooperative (DPC). Figure 8 shows the approximate territories of the three companies that own and operate transmission facilities in Wisconsin. Both Xcel and DPC own transmission and generation facilities in Wisconsin and in other states.

Figure 8 Transmission Companies of Wisconsin



Wisconsin Transmission Needs

There are several drivers for new transmission construction.

- Growth in a local area's electricity use may require new distribution substations and new lines to connect them to the existing transmission system, or increased capacity on existing transmission lines. During the past decade, Wisconsin's growth in electrical demand has ranged between 0 and 2 percent. However currently, there is little to no growth in electrical demand.
- The existing transmission system must be upgraded or reinforced with new lines to prevent equipment overloads and low voltages.
- New power plants need new transmission lines to connect them to the existing transmission system. Also when older power plants retire, some new lines may be needed to provide local transmission network support.
- New transmission lines needed to alleviate congestion and maintain system reliability.
- New regional transmission lines needed to move cleaner, electric energy from renewable energy resources such as wind farms located in Wisconsin, Iowa, and Minnesota to load sources.
- New transmission to allow more economic power flow.

The Public Service Commission of Wisconsin (PSCW) regulates the siting and construction of new transmission lines within Wisconsin. Transmission line projects approved by the PSCW are required by statute (Wis. Stat. §§ 196.49(3) and 196.491(3)(d)) to have costs that are in proportion with their benefits. They must satisfy the reasonable needs of the public for adequate electric energy supply and must not be overbuilt or be designed in excess of probable future electric needs.

Regulation of the Electric Industry

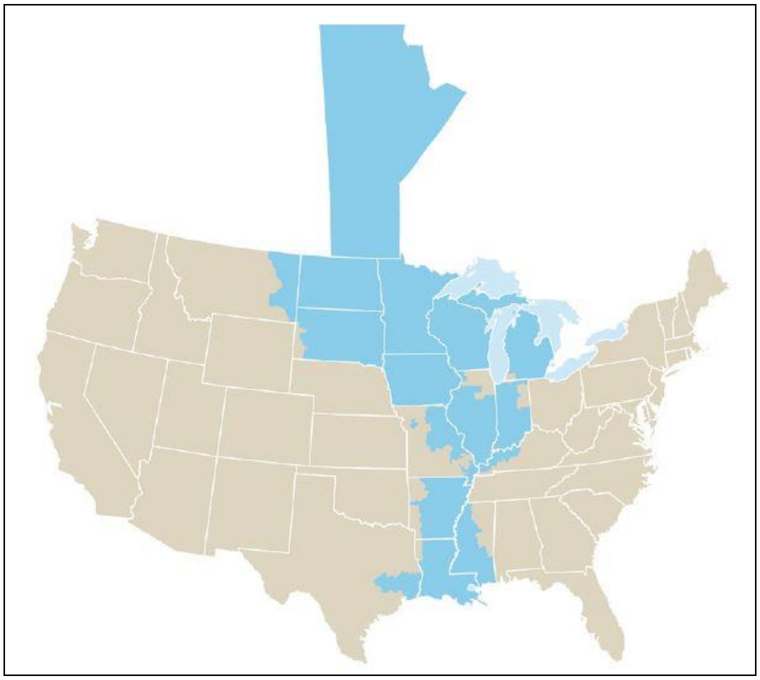
The Federal Energy Regulatory Commission (FERC) is an independent agency that regulates the interstate transmission of natural gas, oil, and electricity. Its mission is to assist consumers in obtaining reliable, efficient and sustainable energy services at a reasonable cost through appropriate regulatory and market means. One of FERC's tasks is to regulate the transmission and wholesale sales of electricity in interstate commerce.

Under FERC oversight, the North American Electric Reliability Corporation (NERC) is responsible to develop and enforce standards for the planning and operation of the electric transmission system. It is a reliability organization which oversees the programs carried out by eight Regional Entities and seeks to ensure consistency and fairness. Wisconsin is part of two regional entities, Reliability*First* Corporation (RFC) and the Midwest Reliability Organization (MRO).

During the years 1996 to 2000, FERC ordered utilities to offer other energy providers fair and open access to their transmission lines. FERC created independent system operators to oversee the nation's power grid. These system operators typically cover territories that can be multi-state. Wisconsin is part of the independent system operator known as MISO (Midcontinent Independent System Operator).

MISO is specifically structured to comply with FERC's concept of an independent organization that ensures the smooth regional flow of electricity in a competitive wholesale marketplace. MISO also administers the use of the transmission system in its service area. It directs the physical operation of the system through the individual transmission owners and local generation operators. One of its primary functions is transmission planning process which is an ongoing comprehensive expansion plan for both the reliability and economic needs of 11 states and one Canadian province. In 2013, the MISO Reliability Coordination Area increased to include portions of four additional southern states (see Figure 9)

Figure 9 MISO Reliability Coordination Area



Source: MISO Corporate Information, June 2013

Individual transmission projects are usually proposed by transmission owners and must go through the transmission planning process at MISO. The MISO planning process analyzes these transmission projects and possible alternatives. The planning effort is a collaboration of MISO's planning staff and its many stakeholders, including utilities, independent power producers, rate payer advocates, and the regulatory sector. The planning process is conducted at many different levels, including special task forces, work groups, sub-committees, and, finally, the Planning Advisory Committee.

Transmission Cost Allocation

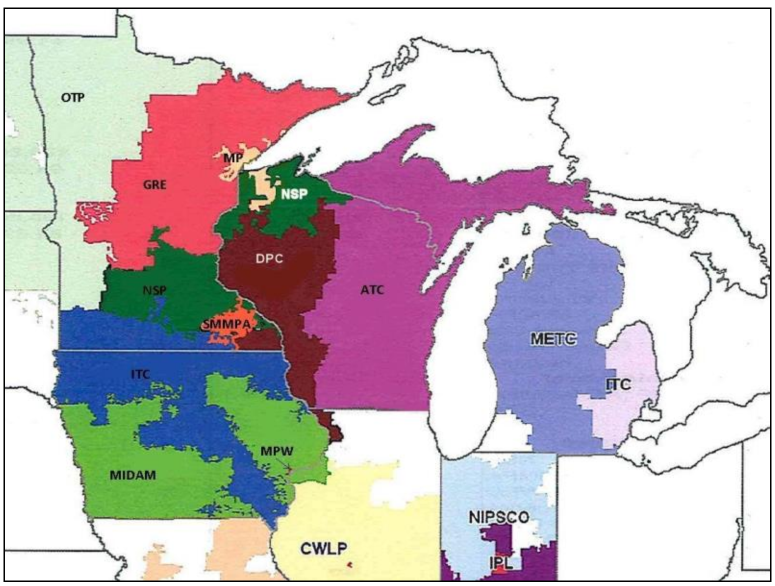
As transmission planning is becoming increasingly regional and inter-regional, there has been improved coordination between MISO and all the neighboring system operators to improve cross-border planning and cost allocation.

Prior to a utility or transmission owner submitting an application to the PSCW, MISO reviews the general purpose of a proposed transmission project. This review is documented in the MISO Transmission Expansion Plans (MTEPs) made public on the MISO web site at https://www.midwestiso.org, under planning. The MISO Board does not approve the construction of a project, but rather through the MTEP process determines if the project will work with the existing electric system, and under the federal tariff, whether the project costs should be shared beyond the local area. Actual project construction, siting and need determinations remains a state public utility commission function, which in Wisconsin is regulated by the PSCW.

The determination of which consumers pay the cost of a transmission project depends on the proposed function of the project. Transmission projects can serve one of four main purposes: reliability, economic, generation interconnection, or multi-purpose.

Transmission projects proposed to satisfy issues of reliability are built to prevent equipment overloads as a line's condition ages over time and to ensure compliance with reliability standards. The cost of building and maintaining a reliability project is paid by the customers in a local transmission owner's pricing zone in which the line is built. Within Wisconsin, there are four transmission pricing zones as shown in Figure 10.

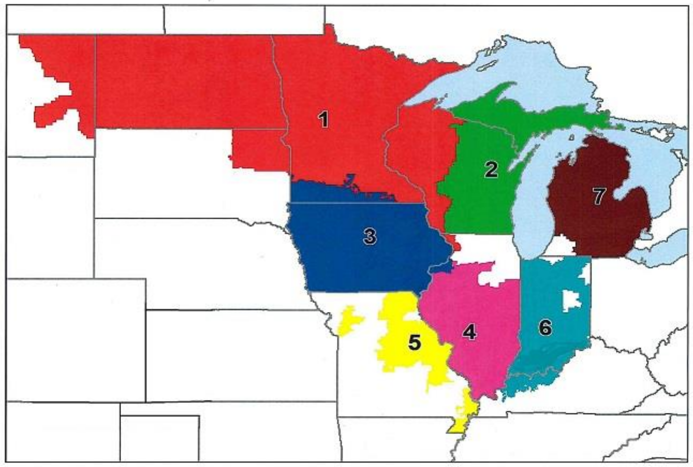
Figure 10: Transmission Pricing Zones



Source: MISO presentation

The other two major types of new transmission construction are called Market Efficiency Projects (MEP) and Multi Value projects (MVP). MEPs are built to address economic congestion. Congestion occurs when there is insufficient transmission capability to move the cheapest priced energy to where there is demand. MEPs must cost at least 5 million dollars, be 345 kV or greater, and provide multiple types of economic value across multiple pricing zones. For projects in Wisconsin, 80 percent of the cost of MEP-qualified projects will be paid for by customers in the Local Resource Zones based on the benefits of the project to each zone (see Figure 11) and the remaining 20 percent is paid by the customers in the MISO grid footprint. Wisconsin is divided into two Local Resource Zones.

Figure 11: Local Resource Zones



Source: MISO presentation

MVP projects address energy policy laws such as renewable portfolio standards, and/or provide widespread benefits across the MISO footprint. These projects must meet one or more of three goals:

- Reliably and economically enable regional public policy needs
- Provide multiple types of regional economic value
- Provide a combination of regional reliability and economic value

All of the costs associated with MVP transmission projects are paid for by the customers in the MISO footprint. The MVP category was first used in 2011. These larger projects for which the cost is substantially higher than for smaller reliability projects is thus borne by a larger customer base and reduces the potential cost to any individual rate-payer.

The chart below summarizes the major types of transmission projects, their drivers or factors that initiate the need for the project, and the designated cost allocation.

Table 1: Sample Transmission Cost Allocations for Wisconsin

Allocation Category	**Drivers**	**Allocation of Costs**
Baseline Reliability	NERC Reliability Criteria	Paid for by customers in the pricing zone where the line is built.
Generation Interconnection	Interconnection Request	Primarily paid for by requester. If the proposed line is 345 kV or above, 10 percent of the cost is allocated to the rest of the customers in the MISO grid footprint.
Market Efficiency	Reduce market congestion when benefits are at least 1.25 times the cost.	80 percent of the cost is allocated to customers in the Local Resource Zones proportional to benefits and 20 percent is allocated to customers in MISO grid footprint.
Multi-Value	Address energy policy laws and/or provide widespread benefits.	100 percent of the cost is allocated to all customers in the MISO grid footprint.

PSCW and Inter-Regional Planning

The Organization of MISO States (OMS) is engaged in planning efforts in MISO. OMS is a non-profit, self-governing organization of representatives from each state with regulatory jurisdiction over entities participating in MISO. Wisconsin is a member of the OMS. The purpose of OMS is to coordinate regulatory oversight among the states, including providing recommendations to MISO, the MISO Board of Directors, the Federal Energy Regulatory Commission (FERC), other relevant government entities, and state commissions as appropriate.

The OMS provides an opportunity for formalized input at various stages in the MTEP process. The OMS is dependent on state staff, including staff from the PSCW, to monitor and actively engage in MISO transmission planning activities, as well as other MISO/FERC issues. Through these processes the OMS Commissioners are kept informed of any issues related to the transmission planning process. The PSCW closely monitors and is involved with individual transmission proposals and other issues that could impact Wisconsin energy delivery and pricing.

Community Planning

In prior decades, electric transmission lines were constructed from Point A to Point B, in the most direct manner possible with limited concern for communities, crops, natural resources, or private property issues. As these older lines require improvements, they may be rerouted to share corridors with roads and to avoid, where practicable, community and natural resource impacts. At the same time, continued growth in energy usage will require new electric substations and transmission lines to be sited and constructed. New and upgraded electric facilities may impact many communities and many property owners.

To meet future growth, communities often draft plans for sewers, roads, and development districts, but few cities, towns, or counties include transmission lines in their plans. Transmission lines are costly to build and difficult to site. Cities, towns, and counties can help reduce land use conflicts by:

- Dedicating a strip of land along existing transmission corridors for potential future right-of-way expansions,
- Identifying future potential transmission corridors and substation sites in new developments, and
- Defining set-backs or lot sizes for properties adjacent to transmission lines so that buildings don't constrain future use of the right-of-ways.

Being an active participant in the decision-making process will improve the ability of communities to manage future growth and protect their resources.

The Role of the PSCW

The PSCW regulates Wisconsin's utilities. A three-member board (the Commission) is appointed by the governor to make decisions for the agency based on analyses by a technical staff with a wide range of specialties.

The PSCW staff analyzes transmission line applications to determine whether the transmission lines are needed, whether the applicant's cost estimates are reasonable, and to determine their potential social and natural resource impacts. The size and complexity of the proposed project determines the PSCW review process. The PSCW considers alternative sources of supply and alternative locations or routes, as well as the need, engineering, economics, safety, reliability, potential for individual hardships, and environmental factors when reviewing a transmission project.

An applicant must receive a Certificate of Pubic Convenience and Necessity (CPCN) from the Commission for transmission line projects that are either:

- 345 kV or greater; or,
- Less than 345 kV but greater than or equal to 100 kV, over one mile in length, and needing some new ROW.

The CPCN review process includes a public hearing in the affected project area.

Projects less than 100 kV and/or less than one mile long must receive from the Commission a Certificate of Authority (CA) if the project's cost is above a certain percent of the utility's annual revenue. The CA review process does not automatically include a public hearing. For those cases in which hearings are held, members of the public are encouraged to testify to their views and concerns about the project. Public comments are also solicited for new lower voltage transmission projects that do not require a public hearing.

The Commission is responsible for making the final decisions about proposed transmission lines. The Commission decides whether the line will be built, how it is to be designed, and where it will be located. If there is a hearing, the Commission reviews all hearing testimony from PSCW staff, the applicant, WDNR staff, full parties, and members of the public. The three Commissioners meet regularly in "open meetings" to decide cases before them. The public can observe any open meeting. At these open meetings, the Commission approves, denies, or modifies the proposed project. The Commission has the authority to order environmental protections or mitigation measures as a condition of construction.

The Public Service Commission of Wisconsin is an independent state agency that oversees more than 1,100 Wisconsin public utilities that provide natural gas, electricity, heat, steam, water and telecommunication services.

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