There are many different types of electrical power lines serving North Dakota residents. Each line has a specific job. Some carry electricity long distances from the power plant to a substation. The voltage of these transmission lines may be as high as 500,000 volts AC (alternating current) or 400,000 volts DC (direct current).

From the substation to the consumer a distribution line takes over. These lines are usually 7,200 volts or 14,400 volts. At the point of use the voltage is again reduced, typically to 120 to 240 volts for service to the farmstead or home.
Commercial electrical generation facilities produce electricity at voltages below 25,000 volts. A typical large unit operating in western North Dakota generates 24,000 volts. This voltage is then stepped up with transformers to transmission levels. The voltage of the transmission lines may be as low as 41,600 volts to as high as 500,000 volts. The choice of voltage will depend upon the amount of energy transmitted (watts), the distance to be covered and the cost of materials for the line.

As an example of how voltage affects the line, let's take a look at the relationship between energy (watts), volts, amperage and energy lost in transmission. To transmit a million watts (1,000 kw) (enough electricity to light 10,000 light bulbs of 100 watts each) requires a million volts at one amperge or one volt and a million amperes or any combination between. Watts equal volts times amperes. If the voltage is very high the conductors must be well insulated either with special insulating materials such as porcelain or large air spaces. In an overhead line this means tall towers, long insulators and wires far apart. High voltage means that there is a lot of pressure on the electricity. If it takes less pressure for the electricity to travel through the air or insulation than it does to go through the wire, the electricity will leave the wire and follow the path of least resistance.

When high amperages (large current flow) are used a very large diameter conductor is needed to keep power lost along the line low. Twice as much power can be transmitted for a given loss by doubling the voltage as can be transmitted by doubling the amperage.

The design engineer is then faced with the problem of balancing cost of conductor against the cost of poles and insulators.

**TRANSMISSION LINES**

Figures 2, 3, 4, 5 and 6 show some of the typical support structures for transmission lines. The operating voltage may be less than the amount shown in the photos but it will seldom exceed the voltage shown for that type of structure. Transmission lines are usually direct current or three phase alternating current. The use of three phase permits more power to be carried than a single phase line of the same size will handle.

For voltages above 50,000 volts the minimum ground clearance to the current carrying wires shall be 17 feet for areas accessible to pedestrians only and 22 feet for cultivated land and up to 30 feet over the tracks of a railroad. For each 1,000 volts above 50,000 the ground clearance increases 0.4 inches. A 230,000 volt line would then need to be at least 28 feet above farm land at the low point in the sag.

As conditions change so does the amount of clearance. For example, if the air temperature is warm (above 80°F.) and a line is heavily loaded (lots of electricity being transmitted) the ground clearance will be less than it is on a cold day with a lightly loaded line. If the line is covered with ice the ground clearance will obviously be less than normal. So, the amount of clearance over field equipment will vary from day to day and season to season. Just because a piece of equipment would barely go under a line one day doesn’t mean it will do so on another day.

Transmission lines are not normally placed underground due to the cost. It costs approximately 10 times as much to place a line underground as it does to place it overhead. In addition to trenching costs, undergrounding requires insulated wires and some method of cooling the wires. Releasing this heat in the ground dries the soil and retards plant growth. With overhead construction, the air provides the insulation and cooling functions.

**DIRECT CURRENT LINES**

The DC lines shown in Figure 2 is a 250,000 volt line. The towers vary in height from 56 to 155 feet. The footings are approximately 5 feet in diameter. The wires typically carry 1,000 amperes which keeps the conductor warm enough that ice is not expected to form on it. Each wire is approximately 2 inches in diameter.

![Figure 2. A 250,000 volt direct current line has two current carrying conductors supported by strings of insulators. Normally the minimum ground clearance will be 29 feet.](image)

The 400,000 volt DC line shown in Figure 3 is designed for a minimum ground clearance of 35 feet. In irrigated areas a clearance of 50 feet is provided. The average tower is 130 feet high and is 35 feet wide at the base. The wire is about 1.5 inches in diameter.

![Figure 3. A 400,000 volt direct current line. There are two pairs of conductors. At the top of the tower are two static wires designed to reduce the hazard of lightning strikes.](image)

Direct current lines require less right-of-way and wire than AC lines. Since only two wires are needed, smaller structures can be used then for a similar capacity AC line. Induced voltage in surrounding objects is practically nil. This reduces the cost of construction, but the conversion facilities at each end offset any savings unless the lines are longer than about 400 miles.
DISTRIBUTION LINES

Figures 7 and 8 show two types of distribution lines. These are usually 7,200 volts or 14,400 volts. They are used for relatively short distances and may be either single phase or three phase. Three phase lines may be either three or four wires. A three wire system is often called a delta system while the four wire system is called a Y system. The major difference occurs in the connections that are made to the distribution transformers from which the standard 120/240 volt single phase power is obtained to operate most appliances.

Figure 7. A 7,200 volt, 3-phase distribution line. Three phase lines may have 3 or 4 conductors. If only 3 conductors are used, all carry current. A four wire system will have a ground wire, usually the lowest wire on the pole.

Figure 8. A 7,200 volt single phase distribution line. The top wire will carry 7,200 volts while the lower wire should have zero volts (ground voltage).
The single phase, 7,200 volt distribution line is the most common in North Dakota. These lines are usually installed to provide from 15 to 20 feet clearance to the conductor wire (the top wire). The lower wire is designed so that the voltage is at ground (zero volts) potential at all times. There are a number of factors which might cause the lower wire to be at a voltage different from the ground. The most likely is damage to ground wires and ground rods, extremely dry soil, contact with the high voltage conductor or mechanical damage (a broken wire). Always treat overhead power lines as though all wires are high voltage.

With AC systems, at one instant the voltage in one wire is 120 volts above ground and the other is at 120 volts less than ground for a total of 240 volts. 1/120 of a second later the voltage is reversed so that the wire that was at +120 volts is now at -120 volts. The ground wire should remain at 0 volts throughout the cycle.

Two wiring systems are commonly used between the transformer and the meter. One is the use of three separate insulated conductors and the other is triplex (two insulated conductors and one bare wire wrapped together). Always treat these wires as uninsulated since the insulation deteriorates with age and may have bare spots exposed.

UNDERGROUND WIRING

In North Dakota, the distribution lines and local low voltage lines may be placed underground. There are a number of advantages to undergrounding including less damage from the weather, especially sleet storms. Wires may be placed underground to reduce potential conflicts with machinery or buildings. North Dakota law provides that no building may be placed so that any part of it is within 10 feet of an overhead electrical line. Placing the line underground takes care of such a problem.

LOCAL LINES

The final change in voltage occurs at the point of use, the farmstead or house. Just before the meter, the voltage is stepped down at the transformer to the usable voltage for the job (120 or 240 volts). Some special uses such as irrigation systems may use 240/480 volt systems.

With the normal single phase system, there are three wires. Two of the wires are considered energized or hot wires and the third is the ground wire.

Figure 9. Overhead wires can run in all directions from the meter pole and transformer. Three wire clusters carry 120 and 240 volts depending upon the connections while two wire systems are almost always 120 volts.

Figure 10. A farmstead with underground wiring.

Some of the disadvantages of placing lines underground include forgetting where they are and later digging into them, damage from rodents such as gophers, corrosion of shield wires, insulation deterioration and higher costs.

Whether you get your electrical power from a local cooperative, a municipal system, or an investor owned utility, electric lines are essential. Always remember that other people have power lines on their property so you may enjoy the convenience of electricity. We should do everything possible to reduce the need for major additional power lines by using our electrical energy wisely and efficiently.