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Finding Hidden Capacity In Transmission Lines

Dynamic line rating can harness unused transmission line capacity while avoiding clearance violations.

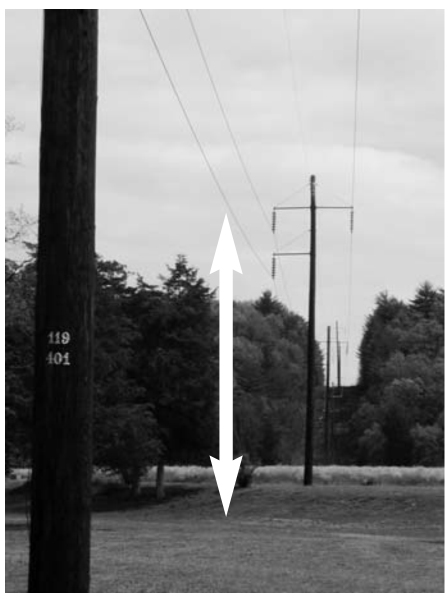
BY DAN LAWRY & BERNIE FITZGERALD

To be economically viable, wind generation must be located in areas with favorable wind conditions – in other words, you have to put the wind farm where the wind is. Quite often, existing transmission lines in the desired location of a wind farm may not appear to have sufficient power transfer capacity to support the wind farm. Therefore, the wind generation is not built.

This article will introduce the critical topic of transmission line capacity and offer suggestions for increasing the capacity of existing lines. The power transfer capacity of a transmission line may be limited by thermal, stability or voltage criteria. This article will focus on the most common of these – the thermal limitation.

Conductors, clearance and sag

In the U.S., the National Electric Safety Code (NESC) defines the clearance requirements between overhead conductors and objects underneath. Sufficient clearance is required to prevent the conductor from either physically contacting or flashing over to an object beneath the line. The minimum clearance depends primarily on the line's voltage and the type of vehicle expected to clear the line. For example, the clearance for wires over roads must be about 25 feet for 115 kV lines and another foot for 230 kV lines.



Transmission line clearance must be maintained.
Photo courtesy of The Shaw Group.

Conductor clearance is dependent on the temperature of the aluminum conductor because as the conductor grows hotter, it elongates and sags closer to the ground. If you know the temperature of a conductor hanging between two towers, you can calculate its sag. Therefore, a maximum operating conductor temperature is specified for every line, and the line is built high enough so that it will not sag beneath the clearance limit as long as the conductor temperature does not exceed this temperature limit.

Typically, maximum operating temperatures are between 75 degrees C and 125 degrees C, although they may be lower for older lines and can be higher for new high-temperature conductors.

An aluminum conductor has some electrical resistance, so it becomes hotter as more current moves through it. Therefore, when one is operating a transmission system, the important question is, "What is the maximum current that I can transfer through a line and still keep the conductor temperature below its limit – and therefore keep the conductor above the minimum clearance?" This maximum current – sometimes specified as its maximum power in megavolt amperes (MVA) – is called the "thermal rating" of the line.

Rating calculations

The question of a line's maximum current is complicated to answer because the temperature of the conductor depends on many factors, including:

- current through the conductor,
- conductor characteristics, such

as diameter, material and surface "darkness,"

- location – latitude, elevation and line direction affect sun input – and
- weather – e.g., wind speed and direction, air temperature, and sunlight.

Therefore, standard methods for calculating conductor ratings have been established. In the U.S., the IEEE-738 method from the Institute of Electrical and Electronics Engineers is used often. A similar method, CIGRE WG22, is common outside the U.S.

These methods describe how to calculate the temperature of a conductor given the conductor characteristics, weather conditions and current through the conductor. Our company has made available a thermal rating calculator for ease of calculating conductor temperature at shawgrp.com/EDS/techinfo.aspx.

To illustrate, consider the rating of a line of Drake conductor. Drake is a common overhead conductor, approximately one inch in diameter and made of 26 aluminum strands wrapped around seven steel strands. Power conductors usually are aluminum, measure between three quarters of an inch and an inch and a half in diameter, and often have a steel core to increase strength. Consider the following potentially worst-case rating – high air temperature, low wind, full sun – scenario:

- the air temperature is 40 degrees C (104 degrees F),
- the wind speed is 2 feet per second (1.4 miles per hour) perpendicular to conductor,
- the conductor emissivity, which relates to how well conductor cools by radiation, is 0.5,
- the conductor absorptivity, which relates to how well conductor absorbs solar power, is 0.5.,
- the conductor elevation is sea level, which affects solar intensity and convection due to air density,
- the solar conditions are clear sky at noon on July 4, which affects solar intensity,

Drake conductor
Photo courtesy of The Shaw Group.

- the latitude is 35 degrees N, which affects solar intensity, and
- the rating temperature is 90 degrees C, which is the maximum temperature the conductor can be without sagging too low.

Under these conditions, the 90-degree rating is calculated to be 903 amps. Consequently, if the weather conditions were as specified, the conductor could transfer up to 903 amps without growing hotter than 90 degrees C – the maximum temperature that the conductor can be without exceeding the sag clearance.

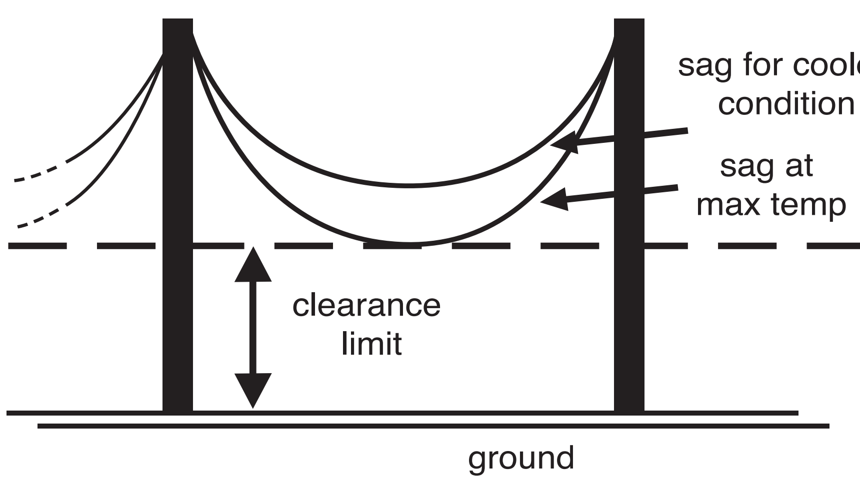
If the air is cooler than 40 degrees C or the wind speed is faster than 2 feet per second – cooling the conductor – the rating would increase. For example, if the air temperature is 30 degrees C (86 degrees F), the rating would be 999 amps, a 10% increase. Similarly, if the wind speed is 5 feet per second (3.4 miles per hour), the rating would be 1,250 amps, a 35% increase over the original case. If the wind is 15 feet per second (10 miles per hour), the rating would be 1,715 amps, representing a 90% increase.

Sun also has a significant effect on rating. Consider the first case at 903 amps. If the sun is not shining, the rating would increase 9%. Furthermore, the air temperature probably would be less than 104 degrees F, increasing the rating even more. These examples, which can be repeated with the online thermal rating calculator, demonstrate that the thermal rating of a line is influenced considerably by weather conditions.

Assumed weather conditions

Presently, transmission owners rarely measure the actual weather conditions and calculate the true rating of their lines. If ratings are dependent on weather but actual weather conditions are not measured, the question remains, "What weather conditions should be assumed when calculating the rating of a line?" Since clearances must not be violated for safety reasons, conservative weather assumptions of high air temperature, low wind speed and full sun must be used.

In North America, transmission owners typically use one set of weather assumptions for the summer and a second set for the non-summer



Clearance limit for transmission lines

months in order to calculate a summer rating and winter rating for a line. For example, common weather assumptions for the summer are full sun at noon, 40 degrees C (104 degrees F) air temperature and 2 feet per second (1.4 miles per hour) wind speed perpendicular to the conductor. While these weather assumptions are conservative, they are not a true worst-case scenario (e.g., the wind speed could drop below 2 feet per second).

Using assumed weather conditions greatly underutilizes the line, since the actual line rating can be much higher than the worst-case assumed rating. This difference can be seen in the Actual Ratings graph, which shows the actual ratings of a certain line in the northern U.S. during a month in the summer. The actual ratings exceeded the assumed 127 MVA rating more than 96% of the time, with the actual rating often more than 50% greater than the assumed rating. Furthermore, since true worst-case assumptions were not used, the assumed rating of the line was higher than the actual rating of the line almost 5% of the time, so clearance violations could have occurred. The shape of this plot is typical for most lines.

Dynamic line rating can be used to harness this unused or hidden line capacity while simultaneously eliminating the possibility of clearance violations. Dynamic line rating is the process of measuring actual conductor cooling conditions, determining the actual line rating and supplying this rating to the system operator in real time. If the actual rating of the line is reported in real time, it is possible to increase the average capacity 15% to 30% over the assumed capacity. In addition, dynamic line rating will eliminate the potential hazard that occurs when the actual rating is less than the assumed rating. Several dynamic line rating methods are available, including methods that measure weather conditions, net cooling effect on a conductor replica, and conductor sag, tension or temperature.

Increasing line rating

The following are suggestions for wind power project developers who want to install wind generation but have found that the low rating of a nearby transmission line prevents development.

■ Check the most recent NESC clearance requirements. Over time, the NESC has reduced clearance requirements, so if the line is old, it is possible to allow additional sag – and therefore additional power transfer – simply by adjusting to the present requirements.

■ Examine as-built drawings of the line to see if the line was designed with a clearance buffer. Often towers were constructed a few feet taller than the original design in order to give additional clearance. Removing or reducing the buffer makes it possible to increase the rating of the line.

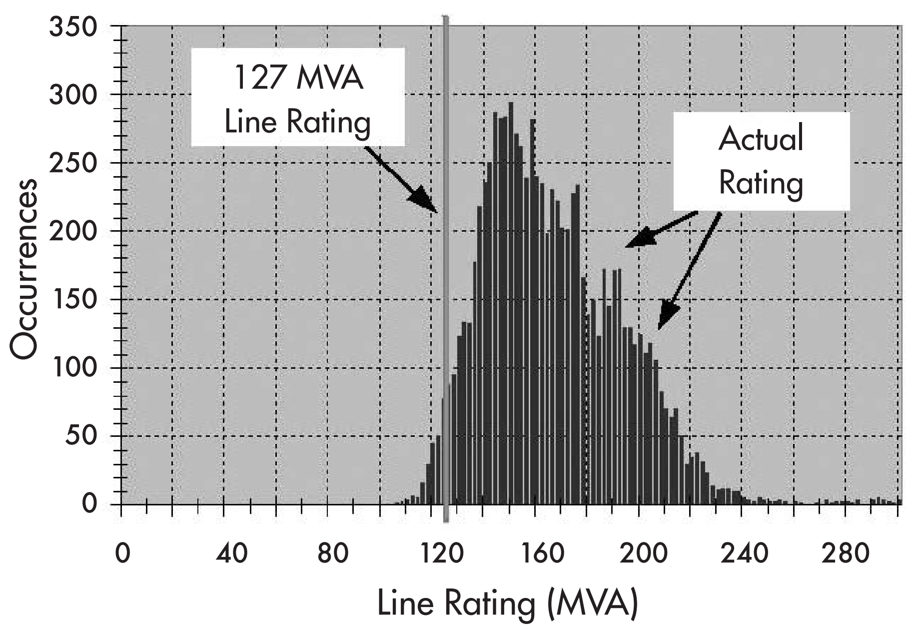
■ Verify that the line's rating was calculated appropriately. See if the assumptions are reasonable. A study of the weather conditions in the line's area would be valuable. If the line in question is close to the proposed wind generation, it may be possible to increase the assumed wind speed.

■ Re-survey the line to see if the maximum allowable conductor temperature can be increased, while observing the NESC clearance requirement. If the maximum temperature can be increased, so can the rating.

■ There are a number of nuts-and-bolts methods to increase the capacity of a line, such as raising towers, installing a new, larger conductor or a conductor of a different type, or increasing the conductor's tension (i.e., pulling it up tighter). These methods can be effective, but typically they are expensive and require line outages.

■ Examine the as-built drawings of the line to determine if one particular section is limiting the whole line. That particular section can be modified (e.g., raised, monitored or tightened). In addition, if a particular trouble section does not have a road under it, but the whole line was assumed to have roads, the rating of the entire line could be increased by simply re-calculating the rating of the trouble section.

■ Install a dynamic line rating system. This can be done quickly and even as a short-term measure. Dynamic rating determines the line's true capacity, instead of assuming the low-line capacity with worst-case weather. The actual ratings are sup-



Actual Ratings During A Summer Month

plied to the system operator in real time. By using actual, rather than assumed, weather conditions, dynamic rating can increase capacity and reliability simultaneously. NWP

Dan Lawry has worked for Shaw Energy Delivery Services and Power Technologies Inc. since 1993 in the area of thermal uprating of overhead lines and other outdoor power equipment. Lawry has been involved with developing Shaw's ThermalRate System, a non-contact system for determining the thermal rating of overhead transmission lines in real time. Lawry can be reached by telephone at (518) 395-5032 or by e-mail at dan.lawry@shawgrp.com.

Bernie Fitzgerald has a BSEE from Rensselaer Polytechnic Institute and an MSEE from Union College. He has worked for Shaw Energy Delivery Services since 2005 and has more than 20 years of experience designing instrumentation and control systems for electric power system applications. He is responsible for much of the hardware and software in Shaw's ThermalRate System. Fitzgerald can be reached by telephone at (518) 395-5181 or by e-mail at bernie.fitzgerald@shawgrp.com.