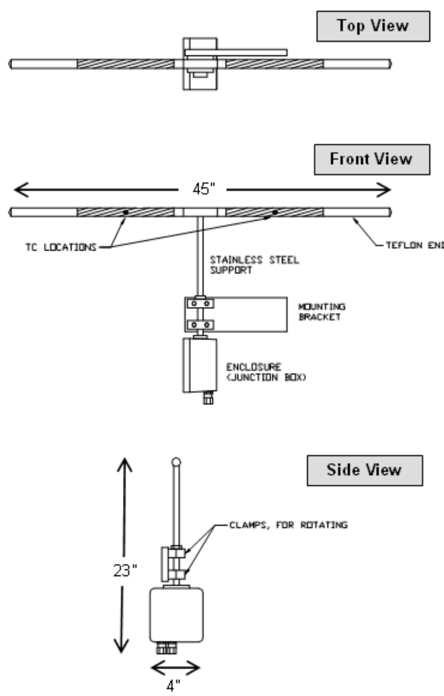
TECHNICAL INFORMATION

ThermalRate™ System Patent #6,441,603

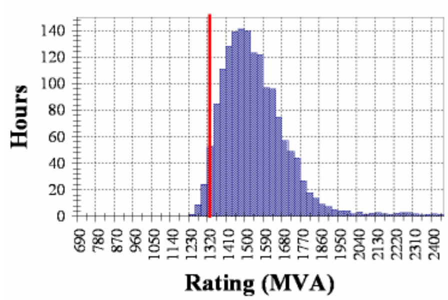
Sensor Dimensions



What is a Thermal Rating?

The thermal rating of an overhead line is the maximum current that the line can transfer without overheating. The line rating is a function of the weather conditions seen along the line, including wind speed, wind direction, air temperature, and sun. Other secondary influences (which are not considered in IEEE-738) might also affect the rating. These include the various forms of precipitation, turbulent air flow, and indirect solar radiation.

The following figure shows that over time a line has a distribution of ratings. This figure shows a summer of actual rating data. Low ratings correspond to times of low wind speed, full sun, and/or high ambient temperature.



High ratings correspond to times of high wind speed crosswise to the conductor, low ambient temperature, precipitation, and/or no sun.

The thermal rating of most lines is based on the conductor sag. As electrical current increases through an overhead conductor, the conductor temperature increases and therefore the conductor expands and sags.

Each line has a minimum clearance to ground, which must never be isolated for safety reasons. The thermal rating is the maximum current which results in the conductor just sagging down to the minimum clearance. Any additional current would result in a safety problem because of the amount of sag.

Most utilities have adopted a semi-worst-case weather approach to establish a "static rating" for each line. Common weather assumptions are simultaneous 40Â°C (104Â°F) air temperature, full sun, and 2 ft/s (1.4 mph) wind speed crosswise to the conductor. The static rating for the line shown in the figure is approximately 1330 MVA. In reality, the actual line rating rarely falls to the static rating. Therefore, using the static rating approach can waste much of the line's transfer capacity.

There are a number of methods to increase the capacity of a line.
Physical approaches such as raising structures, reconductoring, or retensioning might be feasible. They are often expensive or even impossible,due to the required line outage. Monitoring approaches try to harness the capacity that already exists by permitting safe operations above the static rating of the line.

What is IEEE-738?

IEEE-738 is a widely used and accepted method of calculating the ampacity (thermal rating) of transmission conductors under specified weather conditions. Conductor parameters and major weather conditions are input into the method. Major weather conditions affecting rating include air temperature, wind speed/direction, and solar input, although there are some other minor effects. Both steady-state and short-duration ratings can be calculated.

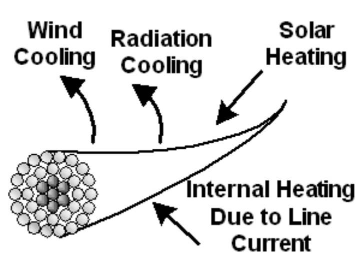
IEEE-738 is based on both experimental data and theoretical equations. The full name of the standard is, "IEEE Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors". The standard may be purchased from IEEE (Institute of Electrical and Electronics Engineers, Inc.) at www.ieee.org.

How to Calculate a Thermal Rating

An equation to calculate conductor rating is developed by first recognizing that the total input heat (per unit length) to a conductor must equal the total output heat in the steady state. The conductor is heated by ohmic losses (I^2R) and solar input, and it is cooled by convection and radiation.
The following equation and figure shows this main "heat balance":
$Q_{solar} + I^2R = Q_{convection} + Q_{radiation}$

where

- Q_{solar} is the heat input due to solar radiation, W/ft
- I^2R is the heat input due to line current, W/ft (R is a function of conductor temperature)
- $Q_{convection}$ is the heat output due to convection (a function of wind, air temp, conductor temp), W/ft
- $Q_{radiation}$ is the heat output due to radiation (a function of air temp and conductor temp), W/ft



Heating and Cooling of an Overhead Conductor

Now, the equation can be reworked to solve for current as a function of the weather conditions. The Qconvection, Qradiation, Qsolar, and R terms are all functions of weather conditions and of conductor temperature. If the weather conditions are measured and the conductor temperature is set to the maximum allowable conductor temperature,the calculated current is the rating current as shown in the following equation.

$$I_{rating} = \sqrt{\frac{Q_{convection}+Q_{radiation}-Q_{solar}}{R}}$$

How ThermalRate™ Calculates Ratings

First, the temperatures of both the heated and unheated conductor replicas and the wattage into the heated replica are measured. A heat balance equation is applied to the heated rod and then solved for the convective cooling term. Then, using the IEEE-738 equations, the effective wind velocity is calculated. This effective wind velocity is a wind speed and wind direction pair that results in the correct conductor cooling (makes the heat balance work). Precipitation is also included in the effective wind. Then, this same effective wind is used in an application of the heat balance equation to calculate the rating for the actual conductor.

The TRM does not need to have exactly the same emissivity or diameter as the line itself. The differences just need to be known. The effect of differences is to alter the replica temperatures, and if there are known differences, this value can be compensated in software.

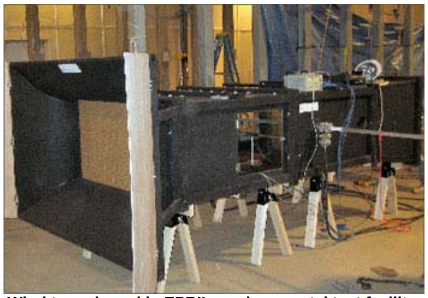
TRM Controller at base of pole.
The Controller contains the microprocessor, radio, and other electronics to receive data from the TRM Sensor.

Laboratory Testing Performed by EPRI

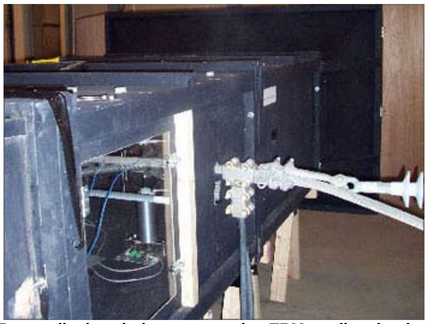
In November 2005, the Electric Power Research Institute (EPRI)performed laboratory testing of the TRM over a number of different operating conditions. The operation of the TRM was tested by comparing its rating to the rating calculated by IEEE-738 and to the temperature of an actual conductor loaded with the calculated rating current.

To download the Test Report Executive Summary, click here. For the full report, contact Dan Lawry at Pike, dlawry@pike.com

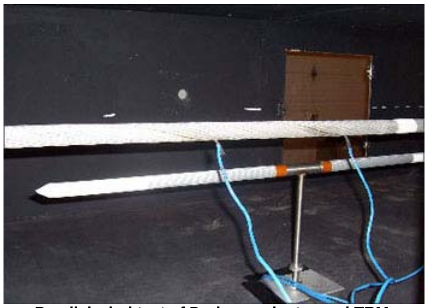
The following are some pictures from the testing:



Wind tunnel used in EPRI's environmental test facility.



Perpendicular wind test comparing TRM predicted rating to Drake conductor at full rating current.



Parallel wind test of Drake conductor and TRM.
Blue wires are thermouples measuring the conductor's temperature.

Conductor exiting the wind tunnel in a parallel wind test.

TRM determining thermal rating during mist and rain testing.

TRM operating in 10 kV/m electric field.

Frequently Asked Questions (FAQs)

FAQ1: Does the ThermalRate™ Monitor know that a line's thermal rating increases during precipitation?

Answer:Yes, all precipitation is considered by the Sensor. Measuring the effects on rating of rain, fog, humidity, and snow are intrinsic to the Sensor design.

FAQ2: Does the ThermalRate™ Monitor measure solar input and adjust the rating accordingly?

Answer: Yes, it measures total solar input, including both direct solar input from the sun and any indirect solar input reflected from clouds or ground. The magnitude of the solar input is reflected in the rating.

FAQ3: Does the ThermalRate™ Monitor require a minimum circuit load to determine a valid line rating?

Answer: No. Unlike the tension or sag monitors, ThermalRate™ gives equally accurate results at high- and low-line loading. Tension, sag, and line temperature monitors require a fairly substantial load, at least 35% of the static rating, to determine the line rating. Without this minimum load, these monitors can tell you the present sag or tension, but it is impossible for them to calculate a rating. Often normal line loads can be low, and the line is rated based on a contingency loading. ThermalRate™ allows operators to see the line rating BEFORE the contingency. It is often too late to receive rating information after the contingency happens.

FAQ4: Does the ThermalRate™ Monitor consider vertical wind velocity?

Answer: Yes. Sometimes wind can have a small vertical component, due to heat rising off the ground or due to turbulent wind. Since the monitor is a replica of the actual conductor, the monitor design naturally responds to this vertical wind velocity.

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