Statistic Approach to Static Conductor Thermal Rating

Miaolei Shao, Ward. T. Jewell
Department of Electrical and Computer Engineering, College of Engineering

Abstract — This paper proposes applying the statistic analysis method for determination of static conductor thermal rating. The spectrum of the maximum current of conductor over a year is first calculated using Typical Meteorological Year (TMY2) data set as weather data and IEEE Standard 738-1993 as computation engine. The statistic analysis is then performed to calculate the cumulative distribution function (CDF) of the maximum current. Finally, the static conductor thermal rating can be determined based on the risk level which utilities are willing to take. The statistic analysis method helps system planners to determine the static conductor thermal rating by quantifying the risk of a conductor's actual allowable maximum current higher than the static rating. This proposed method is applied to determine the static conductor thermal rating of different zones within Rocky Mountain and Desert Southwest area.

Introduction

Given the ambient weather conditions along an overhead transmission line and the designed maximum allowable conductor temperature, the maximum allowable current of a transmission line can be calculated using heat balance method [1], [2]. Since weather conditions vary with time, the maximum allowable conductor current of a transmission line also changes with time. However, transmission planners need to determine the static rating of transmission lines in order to study the capability and adequacy of the transmission network.

Traditionally, the static rating is usually determined based on conservative weather condition assumptions. It has been recognized that such methodology is conservative and therefore results in under-utilization of conductors [3]. This issue can be of particular importance in a competitive energy market environment since utilities try to fully utilize existing equipments to maximize transmission capacities.

This paper proposes a statistic analysis method to determine static conductor thermal ratings. The proposed approach first uses the typical annual weather conditions to calculate the spectrum of the maximum current of a conductor over a year. Then the statistic analysis is performed to calculate the CDF of the maximum current. According to the risk tolerance, one can determine the static rating of a transmission line. The proposed method is tested using the Typical Meteorological Year (TMY2) data set in the Rocky Mountain and Desert Southwest area.

This paper first presents the weather data used in this study, including the TMY2 data set, the definition of 5 zones and the corresponding weather stations in those zones in Section II. Then, Section III introduces IEEE Standard 738-1993 as the method to calculate the maximum current. Section IV presents the statistic analysis method and the results of static conductor thermal rating.

Weather Data

Typical Meteorological Year (TMY2) Data Set

The weather data used in this study is Typical Meteorological Year (TMY2) data set derived from National Solar Radiation Data Base (NSRDB) [4]. TMY2 is a data set of hourly values of solar radiation and meteorological elements for a 1-year period. It consists of months elected from individual years and concatenated to form a complete year. The purpose of developing the weather database is to produce a full set of 8760 hourly weather observations containing real weather sequences for a particular weather station.

Weather Zones and Weather Stations

The Rocky Mountain and Desert Southwest area contains diverse geographic and climatic characteristics. This study classifies the area into 5 zones based on common geographic and climatic characteristics.

Modification of Wind Speed Data

Wind speed varies with time and location along overhead transmission lines. This study modified the wind speed data to a minimum of 4 feet per second in daytime (6:00 am to 8:00 pm) and to a minimum of 2 feet per second in nighttime (8:00 pm to 6:00 am).

Study methodology

IEEE Standard 738-1993

Conductor thermal ratings are typically calculated based on the heat balance method: the heat loss due to convection and radiation is equal to heat gain due to Ohmic losses and solar heating. This study uses the IEEE method (IEEE Standard 738-1993) to calculate the conductor thermal rating. The maximum allowable current can be obtained using Equation (1).

$$I = \sqrt{\frac{(Q_c + Q_r - Q_s)}{R}} \qquad (1)$$

Where Q_s is the solar heat gain, Q_c is the heat loss due to convection, Q_r is the heat loss due to radiation, and R is the conductor resistance.

Parameter Determination

Wind Angle of Incidence

The conductor thermal rating is sensitive to wind angle of incidence. This study used 45º as the wind angle of incidence to calculate the conductor thermal rating.

Coefficient of Emissivity and Absorption

The coefficient of emissivity (ε) and coefficient of absorption (α) must be estimated respectively when determining the static conductor thermal rating. This study used 0.7 and 0.9 for coefficient of emissivity (ε) and coefficient of absorption (α) respectively.

Statistic Analysis and Study Results

Using the methodology addressed in Section III, the spectrum of the maximum current of conductor over a year can be obtained in each zone. Then the statistic analysis is performed to calculate the CDF of the maximum current. Once the risk level is determined by system planners, the conductor rating can be determined.

This study use 795 MCM ACSR (Drake) as test conductor and three maximum allowable conductor temperatures 50ºC, 75ºC and 100ºC to determine the static conductor thermal rating.

Table I summarizes the static conductor thermal ratings of Drake conductor determined based on statistic analysis. These results are based on 1% risk level. The ratings are calculated using both the unmodified wind data and the modified wind data.

TABLE I. STATIC CONDUCTOR THERMAL RATINGS IN 5 ZONES (AMPS)

	Unmodified Wind Data			Modified Wind Data		
	50ºC	**75ºC**	**100ºC**	**50ºC**	**75ºC**	**100ºC**
Zone 1	587	841	1025	703	1025	1216
Zone 2	606	882	1060	666	1034	1234
Zone 3	503	783	978	678	1016	1208
Zone 4	601	880	1058	662	1029	1221
Zone 5	493	811	1004	561	978	1182

In addition, this study examined different risk levels (from 1% to 10% in 1% incremental) for determining the conductor thermal rating. Fig. 1 shows the results of the static conductor thermal ratings of 5 zones based on different risk levels. It clearly shows that the static conductor thermal rating increases as risk tolerance increases.

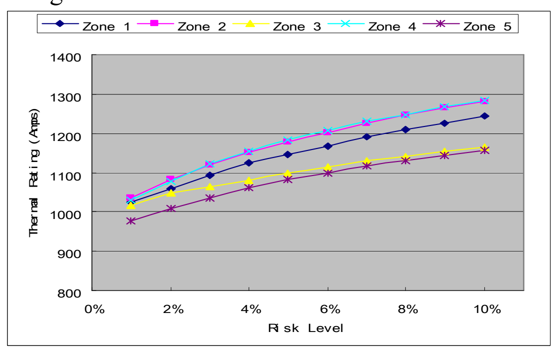

Fig. 1. Thermal Ratings at different Risk Level (Amps)

Conclusion

This paper has presented a statistic analysis method for determination of static conductor thermal rating. The proposed method can help system planners to quantify the risk of a conductor's allowable maximum current lower than the determined static rating. System planners can determine the static conductor thermal rating based on the risk tolerance level which they are willing to assume. Study results indicate that the proposed approach can improve the utilization of transmission lines.

References

[1] *IEEE Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors*, IEEE Standard 738-1993, May 1993.

[2] CIGRE WG22.12,"The thermal behavior of overhead conductors", *ELECTRA*, No. 144, pp.107-125, Oct. 1992.

[3] J Reding, "A method for determining probability based allowable current ratings for BPA's transmission lines," *IEEE Trans. Power Delivery*, vol. 9, pp. 153-161, Apr. 1994.

[4] W. Marion, K. Urban, User's Manual for TMY2s, National Renewable Energy Laboratory. (June 1995). Available at http://rredc.nrel.gov/solar/old_data/nsrdb/tmy2/