Applying Statistical Methods to Optimise Transmission Line Ratings

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Abstract

With the growing demand for power, it is Western Power's responsibility that the transmission lines can maintain the higher load demand predicted in the future. Western Power uses conservative standards to determine the maximum ratings of these transmission lines. According to these standards, Western Power would need to up-rate many lines to meet the demand for power and would incur large cost to the corporation. However, many lines are often under-utilised and Western Power may defer their up-rating.

1.0 Introduction

The purpose of this project is to determine if transmission lines would be able to meet with the load demand predicted in the future and whether Western Power may defer up-rating such transmission lines. By analysing the weather effects on transmission lines, Western Power may optimise transmission line ratings.

1.1 Relationship between the maximum load and the weather

Power rating is limited and constrained by the temperature of the conductor. At high temperatures, there is more heat in the conductor causing the material to expand and thus sag more. The more the line sags; it increases the chance of line failure, line stress and may decrease the lifetime of the conductor. The main limiting factor is that the line may not sag below a certain height, as it may be dangerous to the public. For example, it would be disastrous if a truck driver drove through a sagging transmission line.
The conductor temperature is dependent on the heating and cooling effects of the weather. The thermal equilibrium equation is

$$\text{Heat in} = \text{Heat out}$$

There are several factors in which the line can gain heat or lose heat.

Heat Gain

1) Solar Radiation- occurs when sunlight makes contact with the line heating it up.
2) Ambient Temperature- will continuously heat up the line and as a consequence the conductor temperature of the line will never go below ambient temperature.
3) Power Loss- determined by the power loss equation I^2R. With resistance practically held constant, power loss is mainly affected by the amount of current in the line.

Heat Loss

1) Wind Speed- causing force convection (when wind speed is high) or natural convection (when wind speed is low) removing heat away from the line

2) Ambient Temperature- When the conductor temperature is above ambient temperature; the line loses heat by emitting radiation.
3) Wind Direction- the amount of heat removed from the line by the wind may have little to great effect depending on the direction the wind is blowing in respect to the line. If the wind is blowing parallel to the line, this will cause little convection whereas if the wind is blowing perpendicular to the line, this will cause high convection.

2.0 The Data

EDM's (Colorado, USA) Sagometer, installed in mid December 2006 was chosen by Western Power to measure the conductor sag. The Sagometer is a camera system that is attached to the pole of a transmission line. A target is placed on the conductor and in every 10-minute interval the Sagometer will take a photo of the target and determine the sag of the conductor by counting the pixel displacement of the target.

On the transmission line pole is a small weather station and a datalogger. The weather station measures and records the weather data every 10 minutes and the datalogger will store these readings, ready to be downloaded.

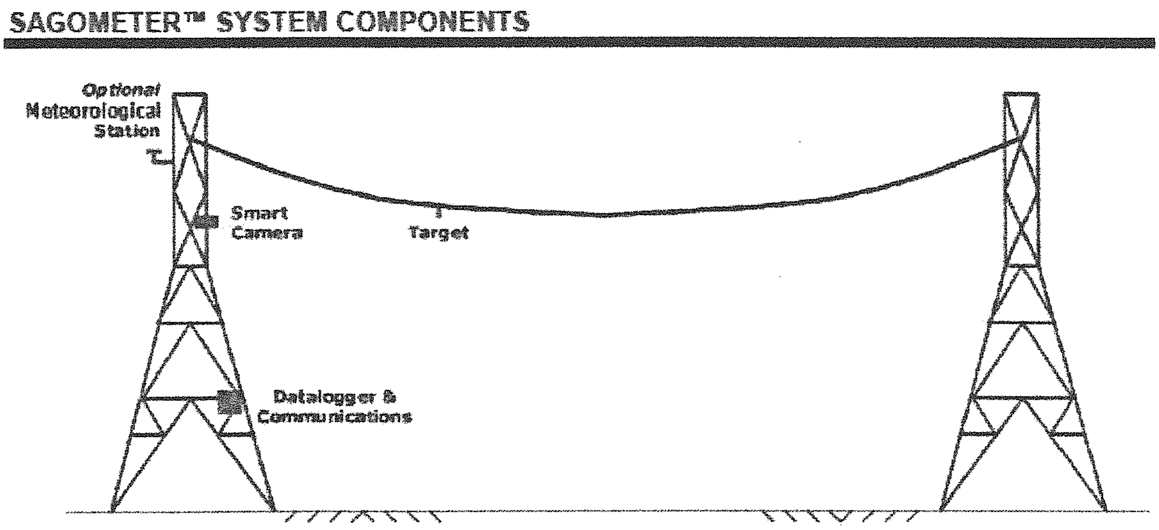

Figure 1: Sagometer Diagram

The sagometer measures the following parameters:

- Date/Time
- Clearance Height (m)
- Ambient Temperature (degrees C)
- Radiation (W/m^2)
- Rain (mm)
- Wind Speed (m/s^2)
- Wind Direction (degrees)

Western Power's database gives:

- Load (A)

3.0 Analysis of Data

There were two main equations used to calculate conductor temperature of the line.

- IEEE (The Institute of Electrical and Electronic Engineers) Std 738
- TNSP (Transmission Networks Service Providers) Operational Line Ratings

3.1 Relationship between Sag and Ambient Temperature

Following shows the graphical result of sag and ambient temperature during January 2007:

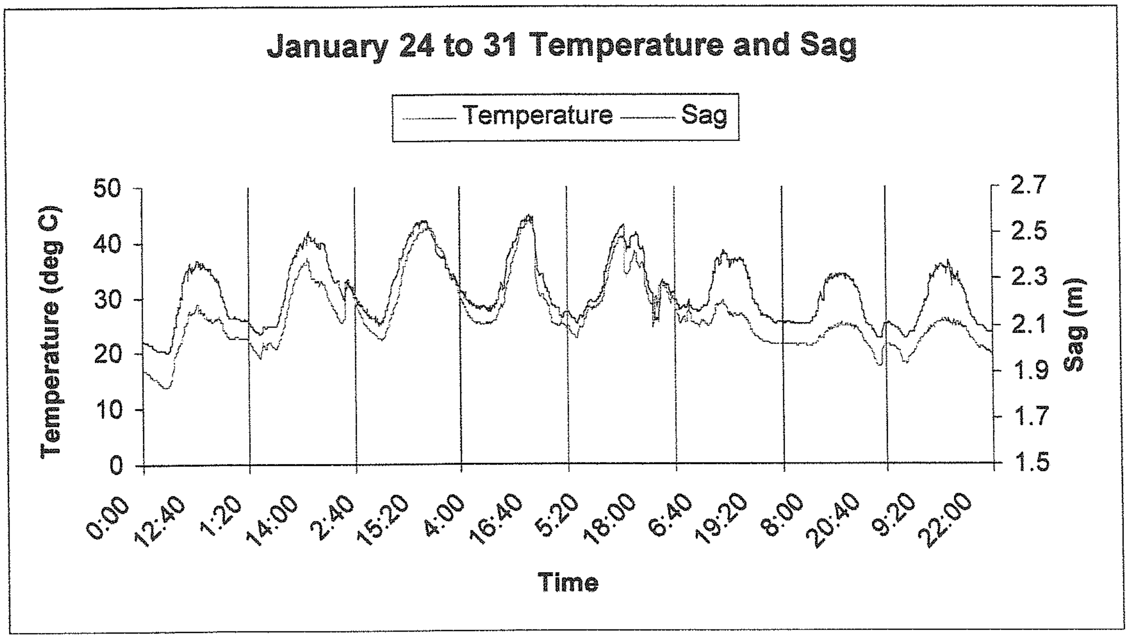

Figure 2: Temperature and Sag plot

In this graph, it shows that the sag of the conductor closely resembles and matches the ambient temperature. This is very odd, especially during a really hot summer day where the load demand is suspected to be very high. The sag would be quite random and in fact more dependent on the load than temperature. This relationship between sag and temperature is also very similar for the rest of the year.

There were several theories that were purposed to explain this relationship.

1) There is very little load in the line to effect the sag
2) The weather is very ideal that all excess heat in the line was greatly removed by the weather

3.2 Relationship between Wind Speed and Load

Following shows the graphical result of wind and load during January 2007:

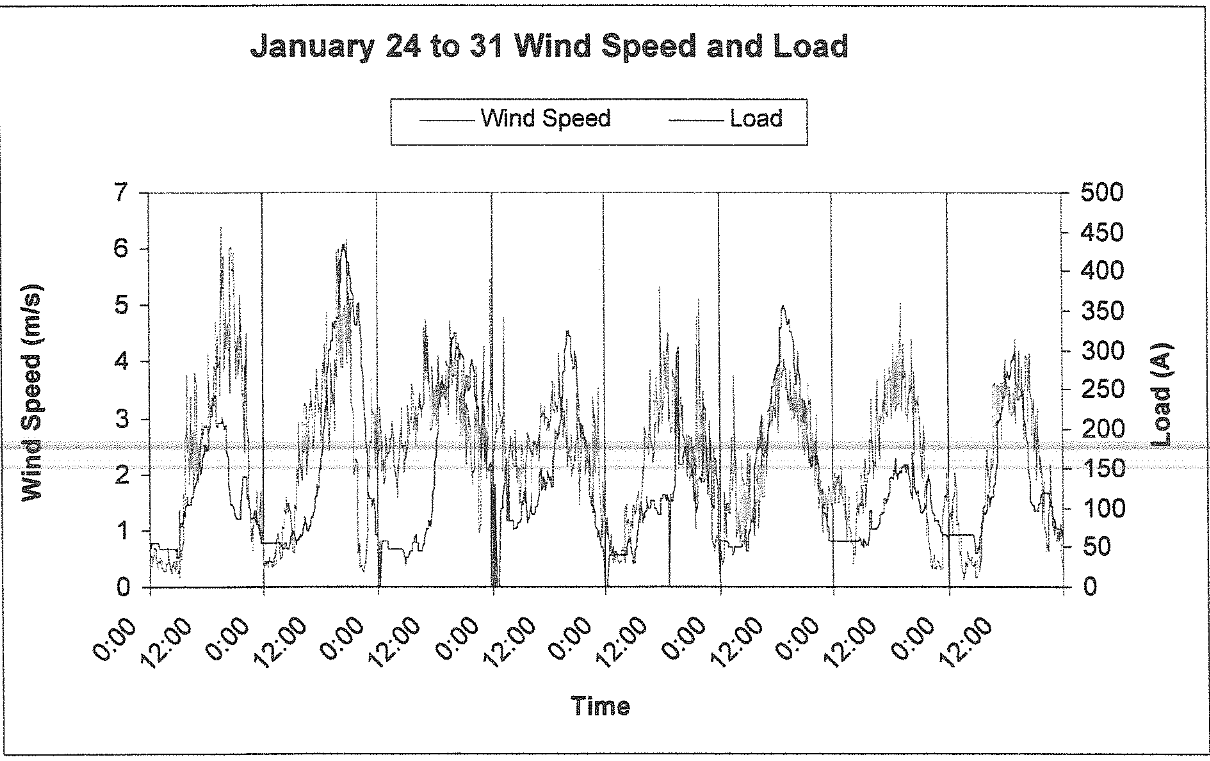

Figure 3: Wind Speed and Load plot

In this graph it shows that the wind speed is very substantial, especially during the times of high load. The load itself is quite low (with the max allowable rating being 900A) and is not pushing the line. The reason for the low load is due to many substations having at least two ways to deliver or receive power. The purpose for this contingency planning is the ability to provide power via an alternate transmission line in case one line fails. However if one line fails, the other lines must be able to maintain the excess load that would be normally transmitted by the failed line. This shows that many lines are under-utilized or conservatively rated for most of the time.

However the relationship between load demand and wind speed is very promising. It appears that when load is high, there is high wind to take away excess heat.

3.3 Optimal Load (TNSP equation) vs Hard Limit

The TRIS (Western Power's Transmission Ratings Information System) rating profile is the standard that Western Power uses to rate transmission lines. Dependent on the max temperature of the day, the max rating of the line is defined accordingly (typically 900-1000 A for this particular line). The max conductor limit or "Hard limit" for this particular line is 1200A.

By allowing the transmission line conductor temperature to be a max of 85 degrees C, the TNSP equation can determine the maximum rating of the line depending on the weather.

The following shows the increase in rating above the hard limit in January 2007.

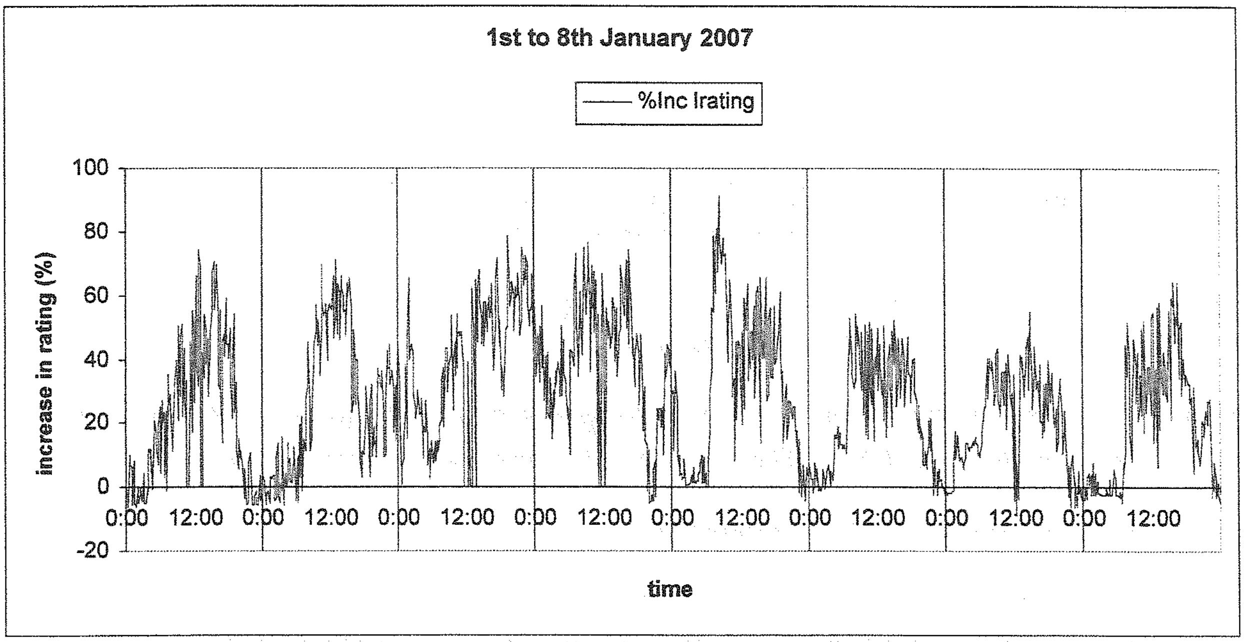

Figure 3: Percentage increase in Maximum load allowed according to TNSP equations

In many occasions, the line may increase its rating by 20% above the hard limit, sometimes may increase up to 90% in certain weather conditions. The weather seems to be very ideal and that this particular transmission line can be pushed harder. During the daytime when the load is highest, there is a trend that the rating can increase by about 20% or more. During the late night to early morning when the load tends to be less, the graph shows a low available increase in rating.

4.0 Conclusion so far

Western Power should be able to push their transmission lines harder and may be able to defer many line up-ratings. The close relationship between sag and ambient temperature does suggest that the weather is very ideal to push the line. This is further proven by the relationship between load demand and wind speed. The rest of the year's results yield almost identical patterns as the sample graphs shown above. Historically (in the last 10 years) there seems to be very similar results in weather patterns and the same pattern in load demand. However, there are some occurrences of occasional bad weather where it would be risky to push the line.

5.0 Further Work

To gain a more accurate outlook there is the need to measure the conductor temperature instead of using IEEE 738 or the TNSP equations to calculate it.

There is still the need to examine the other months of the year more closely, comparing the seasonal differences and similarities. There is much more bad weather occurrences during the winter and a risk analysis will need to be set up.

6.0 References

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