Risk Assessment of a Power Transmission Network to Severe Winds

Bruce Harper[1], Henry Hawes[2]
[1] Systems Engineering Australia Pty Ltd, Bridgeman Downs, Qld.
[2]Powerlink Queensland, Virginia, Qld.
E-mail: seng@uq.net.au

1 Introduction

Severe winds from thunderstorms and tropical cyclones have the potential to compromise the security of transmission line networks, where a single line break can affect many thousands of consumers remote from the location of the damage. For the past 45 years, an average of at least one major transmission line failure has occurred annually in Australia and New Zealand due to severe wind storms. Each of these failures has caused up to seven transmission line towers to collapse, resulting in significant disruption of electricity supply and costs to the electricity supply industry and its customers. In Queensland, severe thunderstorms have caused three major line failures during the past 15 years. Damage from tropical cyclones has also occurred but to date has been less disruptive.

Systems Engineering Australia Pty Ltd (SEA) was commissioned by Powerlink Queensland to develop a statistical wind risk model that assesses the dual impacts of severe thunderstorms and tropical cyclones on the electricity transmission network structures across Queensland. The model results have been incorporated into a sophisticated management tool that identifies line segments at high risk, and allows Powerlink to better ensure a reliable electricity supply to the Queensland community. The sophisticated modelling and management system developed as a result of this project received an Engineers Australia Engineering Excellence Award in 2003.

2 The Network and its Vulnerability

The security and reliability of electricity transmission networks is a major issue, not only in Australia but world-wide, as a result of the increasing demand for electrical energy. Powerlink Queensland is a government-owned corporation that owns, develops, operates and maintains one of the world's largest and most reliable high voltage electricity transmission networks. The A$2.5B network features 8,000 km of transmission lines comprising approximately 29,000 individual line structures. It extends 1,700 km from north of Cairns in Queensland south to the New South Wales border and extends some 400 km inland. The network traverses a range of terrain types, and is subject to varying climatic conditions.

The electricity supply industry's design practice for the structural design of high voltage transmission lines differs from the approach applied to other engineered structures. Transmission lines are spatially linear structures that are supported by multiple towers over distances of up to 250 km, traverse varying topography, and experience a wide range of exposure to wind risks. The traditional design approach is to adopt an appropriate level of reliability for each particular transmission line, and to adjust service duties for each structure according to local topographical and weather conditions. As a result of this, there are cases where sections of a line could carry a higher risk of failure if site conditions changed. These scenarios include land clearing adjacent to a line, and construction of major buildings adjacent to a line. Older lines that might also have been designed to different standards and construction practices can result in varying levels of reliability. The wind risk management support tool developed during this project enables a designer to consider segments of a transmission line (as short as 2.5 km) and assess the design wind velocity for its given topographical and terrain conditions. The model includes search facilities to locate positions or feeders with respect to a given wind velocity, wind return period, terrain category, topographical multiplier, and line voltage. Complete details of the transmission line and the sector location can be generated from the wind risk management system.

3 Modelling Wind Risks

SEA has developed extensive experience in the numerical and statistical modelling of wind risk from tropical cyclones and severe thunderstorms throughout Queensland in the past 10 years (e.g. Harper 1996, 1999; Harper and Callaghan 1998). The wind storm risk model developed for this project is based on the Monte Carlo Insurance Risk Assessment Model (MIRAM) originally developed by SEA for tropical cyclone risk modelling in 1994, which itself is a derivative of techniques from SEA's offshore and ocean engineering design experience. It is a combined deterministic and stochastic model, meaning that it deals with predicting the magnitude and direction of wind speeds, as well as the probability of those wind speeds occurring. The risk model can simulate tens of thousands of separate wind storm events that might cross a transmission line system over many years, using a statistical description of the storm climatology of the region combined with analytical models of severe thunderstorms, describing downburst winds and tornados, and tropical cyclone wind fields.

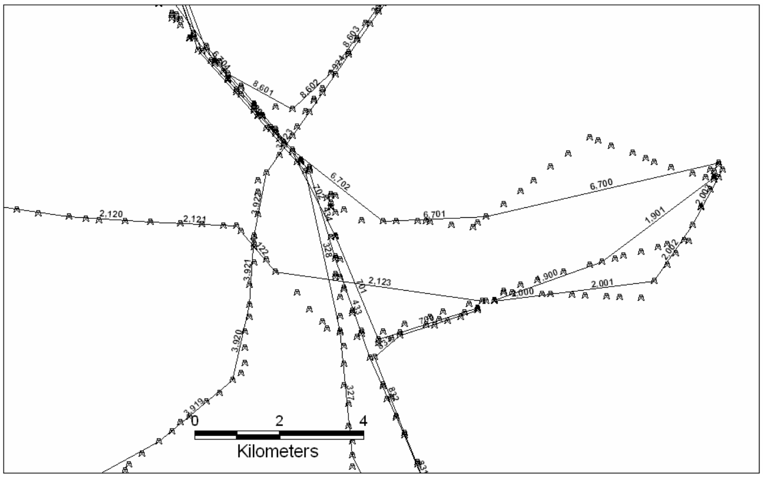

Figure 1 Model representation of a complex section of the transmission network.

4 Network Vulnerability Model

To provide an objective mathematical description of the vulnerability of the entire Powerlink network, a sophisticated tower exposure algorithm was developed using Powerlink GPS tower coordinates, state-wide digital elevation models, and satellite thermatic surface imagery of the power corridors to identify vegetation types. The model considered each logical transmission line (e.g. Figure 1) and recorded its exposure to thunderstorm and tropical cyclone winds over an extended period of simulated model time, including the effects of local topography, surface terrain roughness and the alignment of the target transmission lines relative to the expected peak winds. The cumulative distribution of exceedance of wind speeds was assembled and the average return period (or average recurrence interval) of any given wind speed acting perpendicular to the line was obtained.

5 Conclusion

The wind risk model results have been incorporated into Powerlink's GIS network and mapping database to provide a dynamic design tool that can be used to evaluate wind storm risk impacts on existing or planned future transmission lines. This enables Powerlink to pinpoint areas of the network that are at higher risk, or that require upgrading, to ensure reliability of electricity supply to customers. Knowing these impacts will assist Powerlink to realise long-term potential cost savings associated with future transmission line failures.

In summary, the study has identified that:

• Wind risks to the network in South East Queensland are dominated by severe thunderstorm events;

• The risk of wind gusts > 55 ms^{-1} from thunderstorms may be greater than previously estimated;

• Highest tropical cyclone wind gusts are in the coastal region extending from Townsville to Cairns;

• Gusts > 60 ms^{-1} are likely once every decade on average somewhere on the state-wide network.

6 References

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