

Operating and planning an electricity transmission grid to maximise the contribution of wind

Problem definition for Mathematics In Industry Study Group (MISG) 2007

This problem is jointly sponsored by New Zealand's grid owner/operator Transpower and the Energy Efficiency and Conservation Authority (EECA)

Logos for website:



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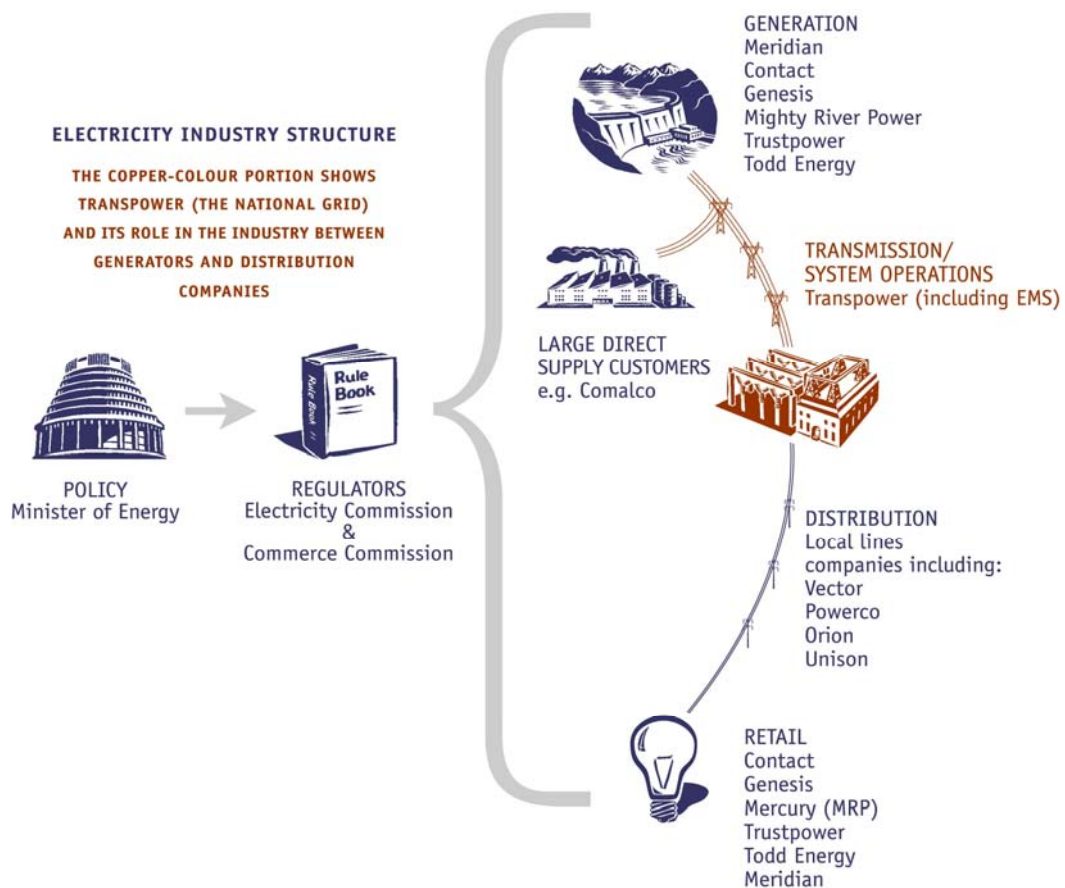
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Transpower

Transpower is owner and operator of New Zealand's National Grid. The National Grid is the network of high voltage transmission assets that transport electricity from areas of generation like hydro dams, geothermal plants, gas or coal-fired stations and wind turbines to the local electricity lines businesses that connect the industrial, commercial and residential electricity consumers.

Transpower is also the System Operator, responsible for coordinating and managing the generation and transmission of electricity across the National Grid.

Transpower sits at the centre of the New Zealand electricity industry and is responsible for working with the Electricity Commission to ensure there is sufficient investment in the National Grid to meet New Zealand's future needs.



For further information visit www.transpower.co.nz

EECA

The Energy Efficiency and Conservation Authority (EECA) promotes a sustainable energy future by changing the way New Zealanders think about and use energy. EECA works to raise community awareness of energy efficiency issues and provides businesses and individuals with the tools to make changes. EECA also develops programmes to meet the needs of specific markets, often working in partnership with other organisations.

A key focus for EECA is the utilisation of energy from our renewable resources. EECA works to remove the barriers and provide information to encourage the uptake of renewable energy in New Zealand. This includes supporting projects through the resource consent process, and working with Regional and District Councils to assess the potential for renewable energy in their regions and to offer guidance on how this potential might be realised.

For further information visit www.eeca.govt.nz.

Background

The National Grid has in essence four main roles:

- Transmission of energy from generation to load;
- Maintain security and reliability of supply;
- Facilitate competition in generation; and
- Facilitate the Government's climate change and renewable energy objectives.

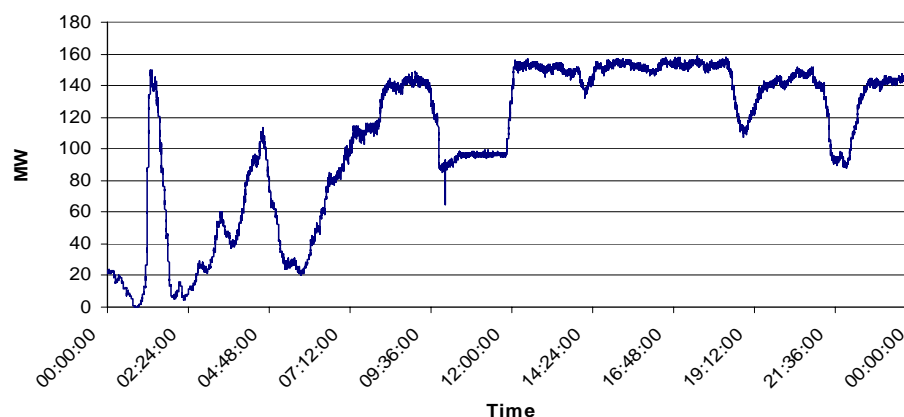
This problem focuses on the fourth role and in particular how to design and operate the grid to facilitate the introduction of significant amounts of wind energy. This is an important issue, as in New Zealand it is estimated that up to 3500MW of wind generation could be installed with high or medium confidence by 2015, some 50% of currently installed capacity. Further, it can be expected that the push for renewable forms of energy will only increase over time, and wind is an abundant resource in many parts of New Zealand (as visitors to Wellington will know!)



A characteristic of wind generation is its variability: clearly it only operates when the wind blows, but within that there are two important issues:

- Wind generation output is proportional to the cube of the wind speed, so the output can increase very rapidly; and
- Wind turbines stop generating when the wind exceeds a certain level, so generation can drop from maximum to nothing very quickly.

**Generation for Manawatu wind farms
15 November 2004**



This graph illustrates an observed day's output for a New Zealand wind farm, albeit chosen to represent a high ramp rate case.

This rate of change of generation is known in electrical parlance as the "ramp rate". The observed ramp rates of wind can exceed that of thermal plant such as gas or coal. Left unmanaged, large wind farms could therefore cause significant and rapid swings in system frequency, which risk for system stability.

The problem

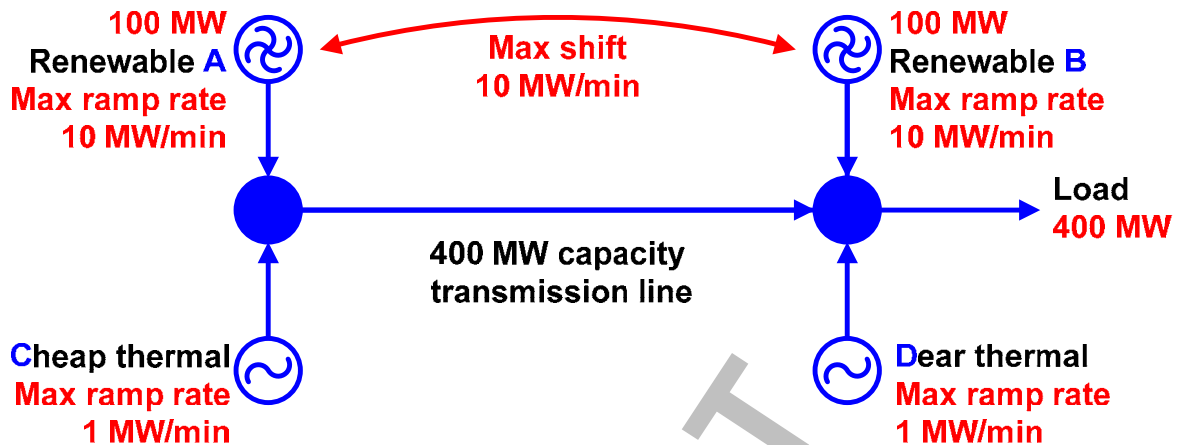
The problem posed to MISG 2007 is to explore the implications of two ways of managing – and exploiting – the unpredictable ramping of wind generation, by:

- **Wind/hydro matching:** by matching each wind station with a hydro station (New Zealand has abundant hydro generation already). Hydro stations have very fast ramp rates, so where the wind farm and hydro stations are co-located this can be a perfect match. The problem is that they are not co-located.
- **Wind sloshing:** by having a large enough portfolio of wind regionally or nationally that "random" changes in one wind farm will, to a degree, be offset by random changes across the portfolio, for which the technical term "sloshing" has been coined.

In both these cases, the problem is:

How much headroom do you need in the transmission grid to allow the synchronised matching of wind and hydro, and to allow the portfolio sloshing of wind and wind?

The simplest way of illustrating this is on a two-node grid with one load and four generators, (and assuming no transmission losses and fictitious ramp rates). Either both renewables can be wind (the sloshing problem), or one can be wind and the other hydro (the matching problem):



With no renewable stations, the least cost dispatch would be all 400 MW from the Cheap thermal station. With the renewable stations but no problem with ramp rates, the least cost dispatch would be all renewables, with the balance of the 400MW load being met from the Cheap thermal station.

However, when ramp rates are taken into account, the situation is more complicated, as it becomes least cost to leave sufficient headroom in the transmission line to allow for some renewable generation to be matched or sloshed between A and B. That is, the balance of the 400MW load being met mostly from the Cheap thermal station, but with some from the Dear thermal station, leaving some headroom in the transmission line

The optimal amount of head room, or equivalently relative dispatch of Cheap and Dear thermal, would depend on:

- The unit costs of each generator;
- Where the renewable stations are within their operating bands (0 to 100MW here); and
- The probability distribution of future changes in wind farms' generation.

The problem posed to MISG 2007 is to determine that relationship for the general case, progressively including:

- Different ramp rates and probabilities for up and down
- Correlations between wind generation outputs
- Multiple generators at each node
- Multiple nodes on a radial system (no loop flows)
- Allowing for system losses (which is typically quadratic to flow).
- Multiple nodes on an interconnected network.

Addressing this question will allow Transpower to design and operate a grid that best facilitates and exploits diverse but also complementary sources of renewable generation, thus contributing to both environmental and economic outcomes.

References and data

While there has been ample research done on many aspects of integrating wind into electrical systems, Transpower is not aware of this specific problem having been addressed in the academic or industry literature.

While the question is being posed for an abstract model, Transpower will provide data for actual wind sites and their correlation, and typical generation ramp rates, so that realistic order of magnitude figures can be used.

For the specific issue of allowing for loop flows, Transpower will provide the relevant algorithms for approximating electrical flow on an interconnected network.

References

Garrad Hassan "Regional Wind Farm Correlations"

<http://www.electricitycommission.govt.nz/pdfs/opdev/comqual/windgen/GH-correlations.pdf>

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