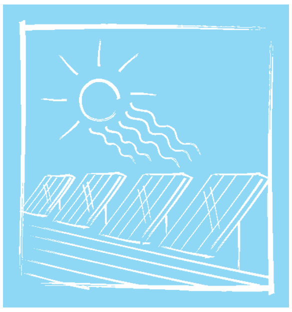
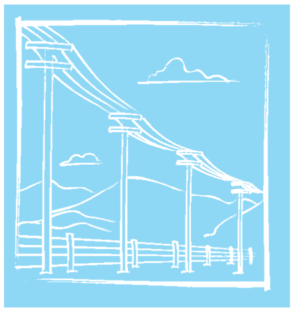
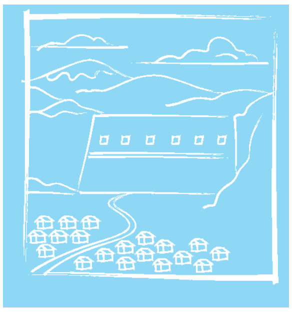
2007 Professional Development Award Report

Ray Brown, Meridian Energy

June 2008







Engineering Excellence

Electricity Engineers' Association

2007 Professional Development Award Report

European Wind Energy Association

Annual Conference and Exhibition

Brussels April 2008

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Electricity Engineers Association of New Zealand
Professional Development Award 2007

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1 Introduction

The European Commission is concerned that the European Union's current energy supply is unsustainable. The fuels which Europe depends upon are finite. Prices are rising steadily and oil exceeded $100 a barrel in early 2008. The EU relies on only a few energy exporting countries, raising energy security issues. EU countries importing fuels who transfer more and more of their citizens' wealth abroad would reap benefits if this currency was expended in their own countries. Demand for oil and gas would drop as a result easing inflationary pressures.

In March 2007, the 27 European Union heads of state unanimously adopted a binding target of 20% of EU energy to come from renewables by 2020. In January the European Commission released its draft renewables legislation that would reduce administrative barriers and prioritise grid access for renewables. If the 20% energy target is to be met, Europe needs to increase its production of renewable electricity from 15% of consumption today to over one third in 15 years. The EC estimates that for this to happen, wind energy's share of Europe's electricity must climb from its current level of 3.7% to 12%.

Ambitious wind targets are being set in Europe and billions of Euro are being spent on wind research and developments. Electricity supply is undergoing major changes, from well known dispatchable central power plants maintaining voltage and frequency, to the newer wind technology. At the end of 2007, 56,535 MW of wind generation had been installed in the EU (22,247 MW in Germany and 15,145 MW in Spain alone). Spain now obtains 10% of its electricity from wind and Germany 7.2%. New Zealand can leverage off the progress being made.

One of the most significant challenges facing the New Zealand power industry today, and in particular lines companies, is the integration of wind energy into the power system. New Zealand wind power is in its infancy and there are many misconceptions about wind technology and its application. In order to address climate change, energy security, energy price and inflation concerns it is important that the New Zealand electricity supply industry catches up with international technical developments and enables the rapid uptake of wind in New Zealand. This award assisted Ray to attend the most comprehensive annual international conference on wind energy internationally, the European Wind Energy Conference in Brussels in March 2008. 61% of the world's wind energy capacity is installed in Europe. While in Europe, Ray also visited Siemens and GE wind turbine generator factories in Denmark and Germany.

Ray's role as Meridian's Transmission Manager is to manage the connection of new generation proposals and influence regulatory and appropriate authorities to enable the efficient development and integration of new generation. As the wind sites with relatively simple power system integration issues are developed, and wind penetration levels increase, the power system integration issues may become progressively more difficult to overcome. It is therefore important that skills in the New Zealand Electricity Supply Industry are enhanced.

2 Conference Programme

In this section is a brief rundown of key takeaways from the conference and sessions that may be of interest to the EEA readers. I have listed papers that I have taken material from.

Keynote Speakers, CEO's forum and Technology needed to meet the 2020 Target:

The main barriers to increasing levels of wind generation are:

1) Transmission

2) Regulator (adding bureaucracy)

Various European government ministers spoke. Their focus is on the legislated 20% renewables target by 2020. They see wind as the only medium term solution. They are quite fearful of fossil fuel security and price and are very focused on finding alternatives. All seemed to agree that subsidies for renewables won't be needed in the future as fossil fuel prices go through the roof, however for the meantime, in order to secure a reliable power supply they see subsidies as necessary.

Potentially by 2020 wind energy will be the preferred generation technology of choice due to increased fossil fuel prices. US$200 oil prices are predicted within 2010/11. Coal will be linked to this price.

"The biggest change in human history is about to occur due to the demise of fossil fuels."

Belgium minister for Energy Paul Magnette likened the 20% European target for renewable electricity generation to the Industrial Revolution. A fundamental change is occurring similar to the Industrial Revolution.

2050 renewables targets are being discussed. These will require energy storage technologies to become economic.

2007 European statistics show that the energy contribution from wind and gas increased, and coal and nuclear reduced. Wind was the clear winner for new installed capacity. 4% of electricity is currently being generated by wind in Europe. Europe has 1100 MW of offshore wind today.

According to the nuclear industry's predictions, nuclear's contribution to the European energy mix will not expand significantly pre 2020 due to development lead times. So wind is the current European focus, and in particular offshore wind. The European Energy Commissioner stated that the European focus is now on offshore wind. A 7 MW off-shore wind turbine generator is currently being built in Belgium (on-shore).

Statistics were presented to prove that wind is the main immediate answer between now and 2020 for climate change mitigation.

China will be the top WTG producer in 2009. 3000 MW were installed last year in China. Quality however will be the key.

WTG supply is a significant limitation to wind uptake. The main issues here are sub-supplier limitations and limited human recourses.

All CEOs agreed that the European grid needs to be augmented hugely. It is the primary limitation of the 2020 20% renewable target. Local governments have too much power and will prevent the target from being met.

The agreed view appeared to be that "grid monopolies do not serve their customers. They tend to see them as the enemy." "The American experience in Texas is that grid price is reduced by half when transmission monopoly control is removed. If the grid is opened up to competition then innovation will occur and prices will come down."

BW1 International Integration Studies

Hannele Holttinen – Transmission and Interconnection aspects in EU Synchronous Zones,
Achim Woyte – Market Design for Large Scale Integration in EU Synchronous Zones,
Wilhelm Winter – European Wind Integration Study…:
The challenges Europe faces are not dissimilar to those being faced in NZ. Planning for 2020 is to be able to manage up to 45% wind contribution in low load, high wind periods over Europe. Future

simulations have included 33 GW of offshore wind. Figure 1 shows three wind growth scenarios that have been modelled.

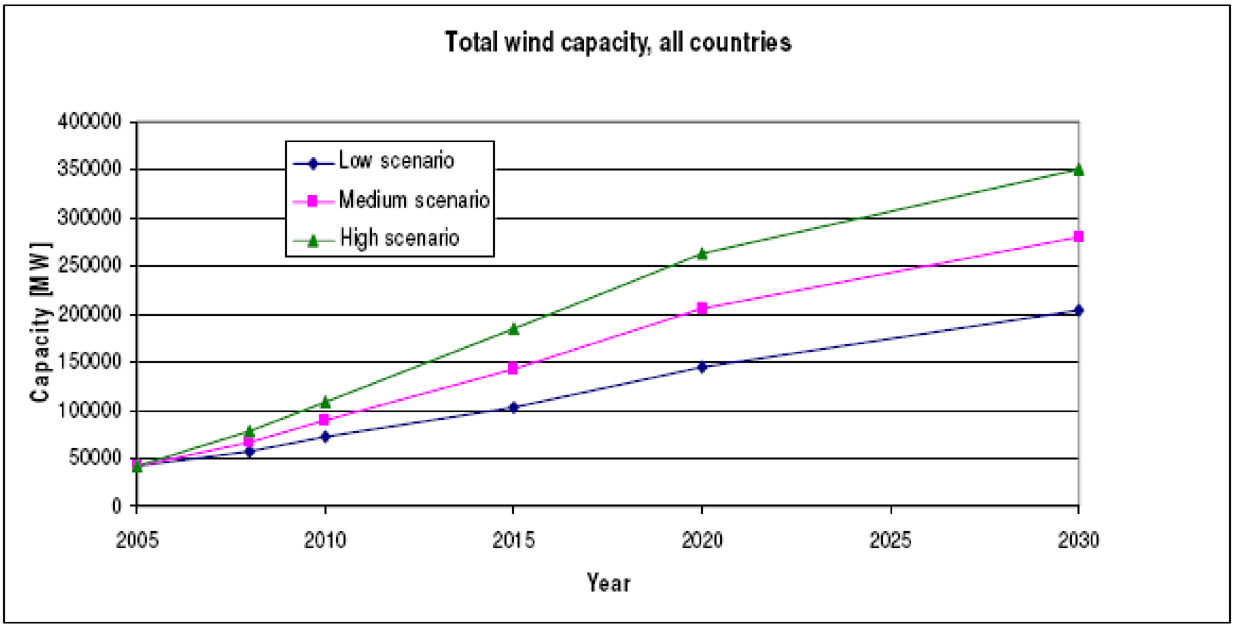

Figure 1 – Europe Wind Growth Scenarios

Wind data was analysed from across Europe to derive the locational time series variation in power output across Europe as shown in figure 2.

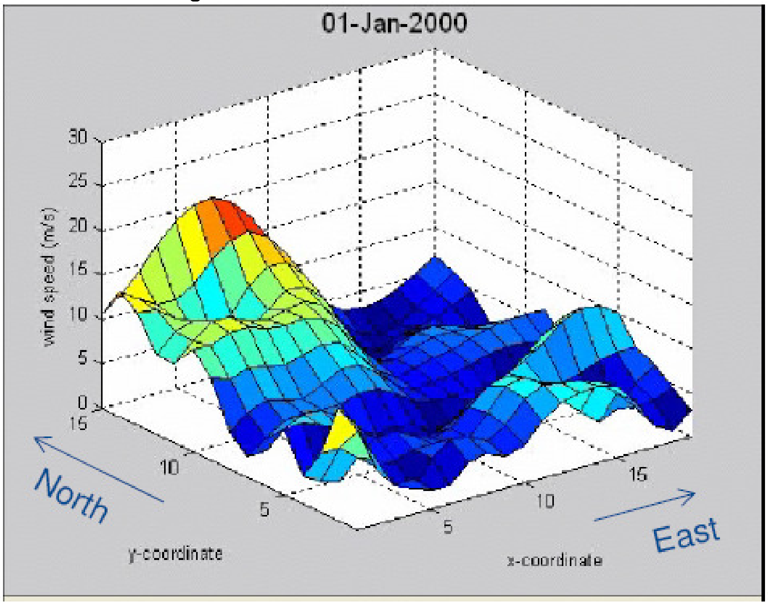

Figure 2 – A point in time – Locational Wind/Power Output

Grid capability studies are conducted in a similar manner to Meridian's advanced analysis. Time series analysis is conducted and load flow resolved for a future year on an hourly basis across all of Europe. However DC load flow time series analysis is predominantly used in Europe instead of AC load flow analysis. Power flow directions in the grid tend to change as weather patterns move. Grid constraints and an understanding of variability is gained from this.

Studies have suggested that in general provided that cross border exchanges limitations can be fixed and the grid improved, wind will provide a more reliable and slowly varying source of generation. Locational diversity smoothes the power output far more than can be provided by one country as figure 3 shows.

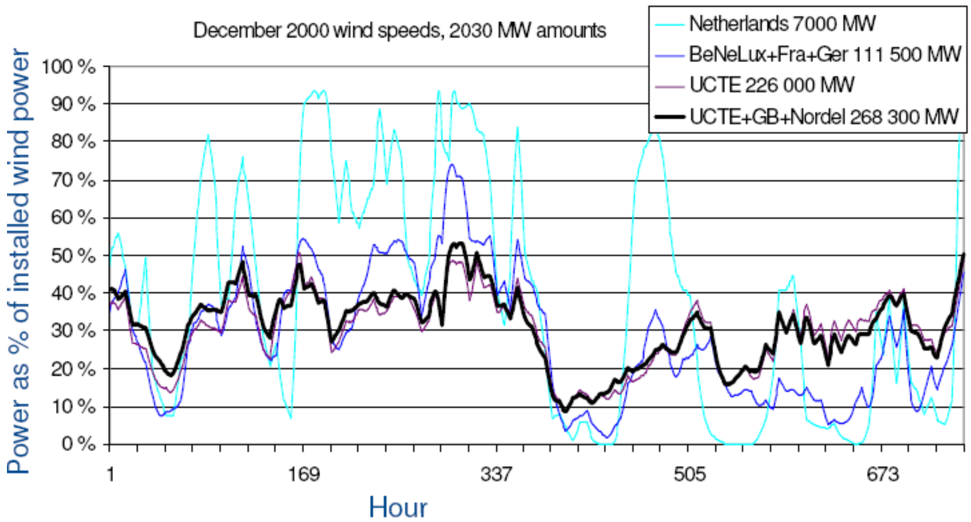

Figure 3 – Improved Smoothing from Combined Countries Wind

Now that wind farms are reliable and provide excellent power quality, the next step is to provide ancillary services (similar to services procured in NZ such as fast and slow instantaneous reserves, frequency keeping and voltage support). This however is challenging in Europe due to cross-border limitations, and so regulatory change will be needed.

BW2: European UpWind Project: Exploring design Limits of Very Large Wind Turbines
Thierry D'Estaintot – European Perspective of Wind Energy Resaerch
Peter Hjuler Jensen – Update on Upwind
Ben Hendriks – Upscaling: Consequences for Concepts and Design,
Jan Hemmelmann – Latest Results on Transmission and Conversion

Approximately €28.2 m is being spent on European cooperative wind research projects ranging in duration from 28 to 60 months. A further €18.3 m was committed to cooperative projects starting in 2008 ranging in duration from 30 months to 48 months.

The Upwind project is a €22.34 m 60 month research project that began in 2006, on up-scaling of wind turbines, primarily for the offshore context. The primary focuses of this project are turbine up-scaling, improving cost efficiency and large offshore wind farms. Transmission is included across each area.

Coordinated deep offshore (> 50 m) wind farm research will begin in 2010.

Currently WTGs (Wind Turbine Generators) of 5 MW and 120 m rotor diameter are in operation. WTGs up to 20 MW with 250 m rotor diameters are the goal by 2020. Initial thoughts suggest that 20 MW off-shore WTGs are feasible from all aspects including manufacturing, transportation, installation and operation. The economics of doing this are however presently shakey. It is thought that there will be a number of technology shifts needed with increased size and that simple up-scaling by improving around the edges of existing technology is suboptimal.

There appears to be no winning WTG technology for up-scaling at this stage. Most research however is focused on full converter output WTGs. Examples of the technology shifts that might be needed include cluster coupled variable speed WTGs. Here the rectified output of a cluster of WTGs might be inverted at a single point. Two bladed designs will be looked at again in regards to installation advantages. New power electronic converter topologies are being examined.

BB4: Integrating wind in Electricity Markets
Marian Klobasa – Analysis of Demand Response and Wind Integration in Germany
Reinhard Mackensen - No Limits for a Full Electricity Supply by Renewables

Although the installed capacity of wind farms in Europe will eventually exceed the peak demand, it is predicted that wind will provide from 10% to 50% of the market's generation capacity (see figure 3). This however assumes no transmission constraints.

Power variability and predictability are two major challenges. Flexible demand response is being analysed in Germany however they may be a little bit behind NZ in this area e.g. night storage and water heating control is generally not controlled remotely in Germany. Remote control of heating and cooling is the immediate focus, air conditioner control is likely to play a big part. Cost estimates for demand response vary from 30-500 €/MW. Norway currently pays customers 5-50 €/MW. Capacity payments are needed and payment if capacity is dispatched.

Is 100% renewable electricity supply possible in Europe? Studies are purely academic at this stage. The main issues are the amount of installed capacity possible and the ability to always meet peak demand. One study suggests that over five times the peak load may need to be installed in renewable energy generation in order to meet 100%. This consisted of predominantly wind, PV, hydro, and biogas. Large amounts of storage capacity would also be needed and the ability to interchange with other countries would add valuable diversity. Curtailment (spill) of wind would be necessary at times.

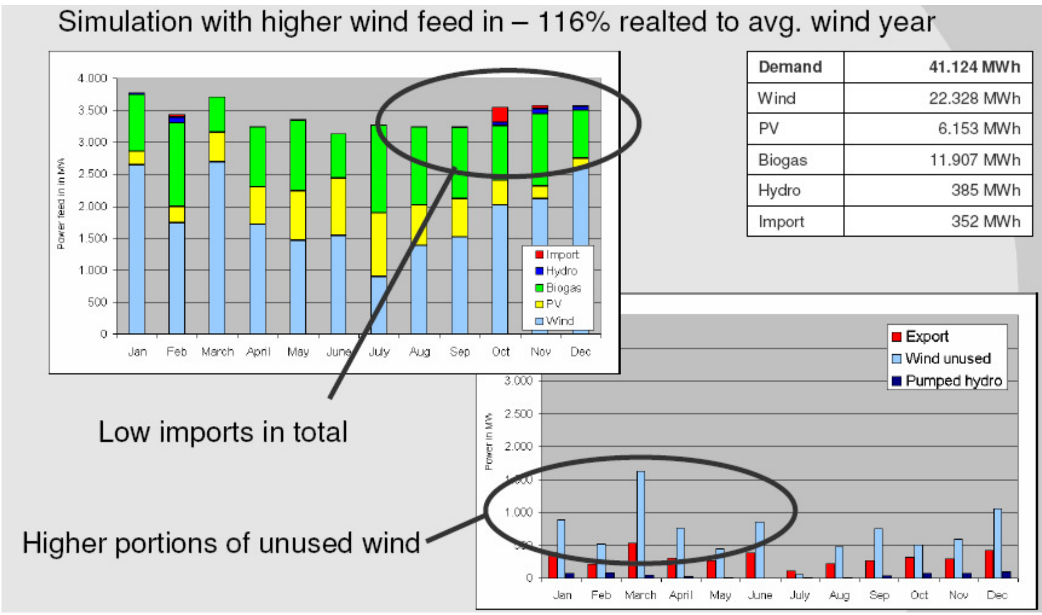

Figure 4 – Simulations with 100% Renewables - Germany

CS1 Electrical Systems and Components

Nicolaos Antonio – Wind Turbine Structural Loads During Fault Ride Through Operation
Ranjan Sharma – Laboratory Investigation of …. Boost Converter for Wind Turbine Applications
Stavros Papathanassiou – Operating Policies for Hybrid Wind Hydro Power Stations in Grid Islands

Significant effort is being expended examining the impacts on structural loadings during power system transient events. Proprietary programmes and more common applications such as DigSilent are being used. Problems arise in that analysis is conducted between differing disciplines i.e. power system simulation on the one hand and aeroelastic simulation on the other.

Energy storage in various forms is being investigated. Some jurisdictions are providing capacity credits in order to enable storage. In many cases integrated wind and storage systems are becoming economic and enabling higher levels of wind penetration. A surprising result is that the storage is beneficial for conventional plant. Storage smoothes load changes, controls rates of change, reduces start/stops and allows efficient thermal operating points to be used.

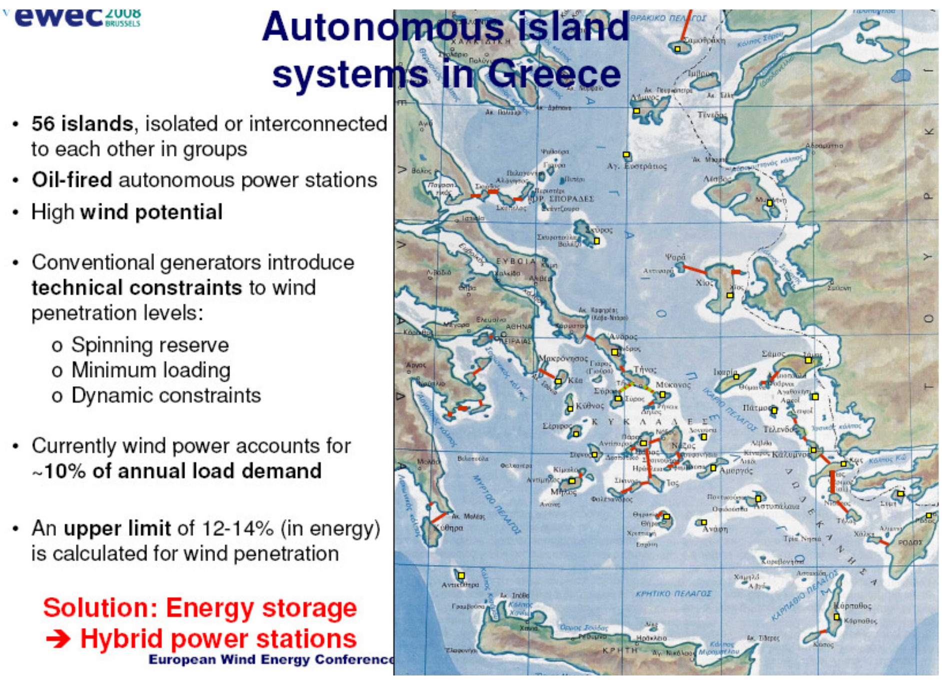

Figure 5 – Storage and Wind May be Economic in Island Systems

CS2 Wind Power Plants and Grid Integration
Pierre Pinson – On the Potential Magnitude of Power Fluctuations at Large Offshore Wind Farms
Martin Braun – Reactive Power Supplied by Wind Energy Converters – Cost – Benefit Analysis
Bernhard Lange – Operational Control of Wind Farm Clusters for Transmission System Operators
Gabriele Michalke – Variable Speed Wind Turbines – Modelling Control and Impact on Power Systems

Further innovations in grid integration are likely to include inertial boosts. Variable speed turbines could rapidly slow down the turbine during frequency drops in order to convert inertia into a short term boost of power output above the normal full output rating in order to slow the rate of frequency drop. Boosts of up to 30% for 4 seconds were discussed (see also figure 6).

The ability to provide Power System Stabilisers on wind farms was also discussed. Although wind farms with asynchronous generation do not generally contribute to angular instability and can provide passive damping it appears that active damping of angular instability through the use of PSS's on wind farms is possible. The challenge will be detecting that oscillations are occurring as normally PSS's damp the oscillatory contribution of the machine they are installed on, so it will be more difficult to determine control methodologies for inherently stable wind turbine generators.

A FERC 2005 statement reads: "inadequate reactive power leading to voltage collapse has been the causal factor in major outages worldwide." Given the low capacity factors of wind turbines and that they remain connected even when generating low levels of power, the advanced turbines that provide voltage support that is superior to conventional power plant, could improve power system dynamic stability significantly if WTGs become widely distributed and grid connected.

Studies suggest that it is cheaper to provide reactive power from the WTGs themselves rather than install capacitors if the WTGs use converter technology and the converters are oversized. The WTGs provide the added advantage of STATCON like dynamic support. Using WTGs to provide dynamic support has lower losses when compared to using additional STATCONs. It should therefore be economic to upsize converters for code compliance. However a barrier is the widely varying international grid code reactive power requirements. WTG suppliers need to standardise their equipment and can not vary designs across jurisdictions (see also figure 8). It should be noted that the reactive power does not come free though. As with conventional generators, reactive power production increases losses and mechanical and thermal stresses.

It is anticipated that by 2015 there will be times when wind provides up to 95% of Germany's instantaneous electricity requirements. In these cases wind will need to provide reserve and frequency keeping services. Methodologies to enable this are being developed. Partial wind curtailment will become necessary and not only will day ahead wind generation forecasts be used, but day ahead forecast uncertainties. This will show how much wind generation can be relied upon on a day ahead basis so that wind reserves can be accurately forecasted.

CT3 Distributed Generation and Autonomous Systems
This session focused on small electricity networks with high wind penetration such as the Belgian Antarctic Research Station. Storage was also discussed. Thermal (hot/cold) storage at the consumer level is generally the lowest cost form of energy storage.

CW4 System Operation with Large Amounts of Wind Power
Kurt Rohrig - Fluctuations and Predictability of Wind Combined with Other Renewables
Mark O'Malley – The All Island Grid Study – Results and Conclusions
Charles Smith – Transmission and Grid Operation Implications of the US 20% Wind Vision
Hannele Holttinen – Wind Power Balancing Costs From Producer and System point of View – Nordpool and Finland
Bart Ummels – Energy Storage Options for System Integration of Off-shore Wind Power in the Netherlands

Generally transmission was seen as the single biggest barrier to high wind penetration levels. Although the cost of transmission is relatively low compared to the cost of generation capital and fuel costs, its approval process is seen as a significant hurdle. Improved transmission linkages result in lower reserve requirements due to fuel diversity. Transmission constraints are generally leading to a lack of generation competition in some regions.

The theoretical potential for 100% renewables supply in Germany was explored further. One investigation suggested that Ireland renewable generation could be lifted to 42% with only 7% increase in market costs. Most of the new renewables would be wind. The US is looking at a 765 kV "grid overlay" to enable renewables.

Two papers from different countries showed that energy storage was not logical for wind integration in Europe provided that the transmission system was significantly improved to enable diversity, however storage was found more useful for the optimisation of conventional plants' operation.

DT1 Verification and Modelling of Wind Power Plant Capabilities
Jose Amenedo – Procedure for Measuring and Assessing the Response of Wind Farms to Voltage Dips
Barry Rawn – Wind Turbine Rotor Inertia and Variable Efficiency… Power System Stabilisation and Power Smoothing
Leif Christensen – Power Quality in Large Offshore Wind Farms….
Stephan Wachtel – Certification of Wind Energy Converters with FACTs Capabilities

Spain is implementing a grid code change that will require WTGs to ride through faults. Old WTGs will require retrofits by 2010. This is necessary so that Spain can install more WTGs.

Converter output fast blade pitching WTGs still have a largely untapped technical potential for grid integration. Spinning reserve and frequency regulation are the near term services starting to be provided by wind. Power system damping control methodologies for wind farms were discussed further and inertial pulses on underfrequency events of up to 130% output were found to be possible with return to 98% of pre-fault power following the pulse.

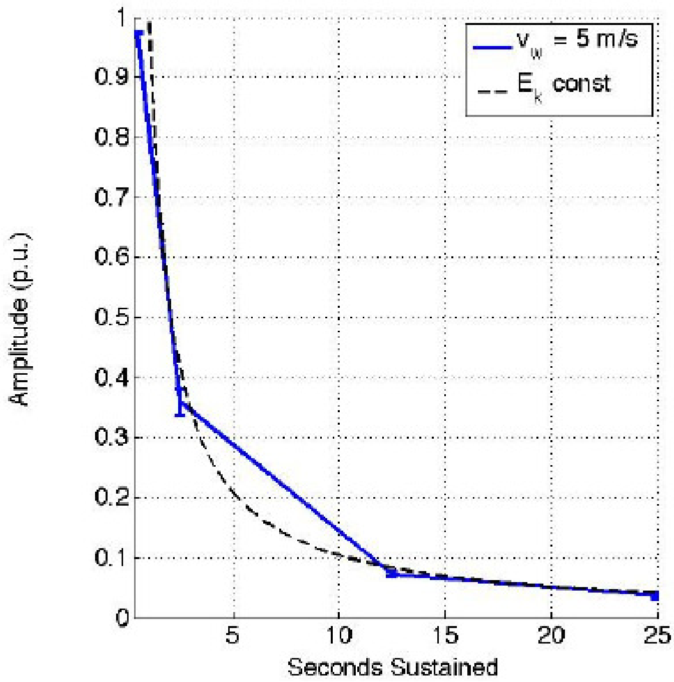

Figure 6 – Inertial Pulse Magnitude and Duration

One WTG supplier claims its WTGs can ride through 5s disconnection auto-reclose operations even when the auto-reclose islands the wind farm briefly. Full scale tests have been completed including earth faults on this WTGs output.

DW2 Grid Codes and Wind Power Plant Capabilities

Harmonising of grid codes is thought to be necessary in order to achieve economic WTG supply. Generic codes are however difficult due to differences between grids. The Australian method with automatic access standards and minimum access standards is thought to be a step in the right direction if a common standard can be adopted.

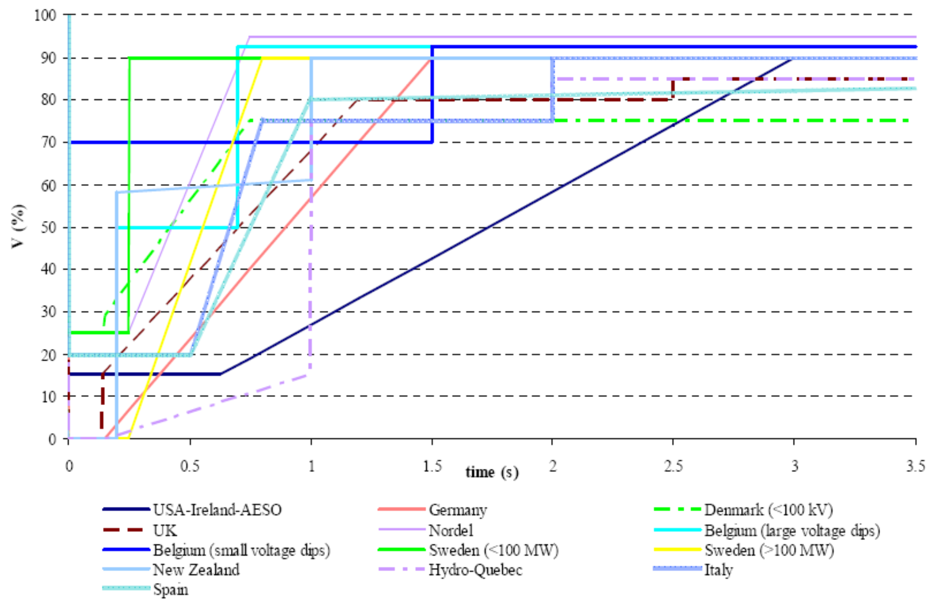

Figure 7 – Various International Codes for Low Voltage Ride Through

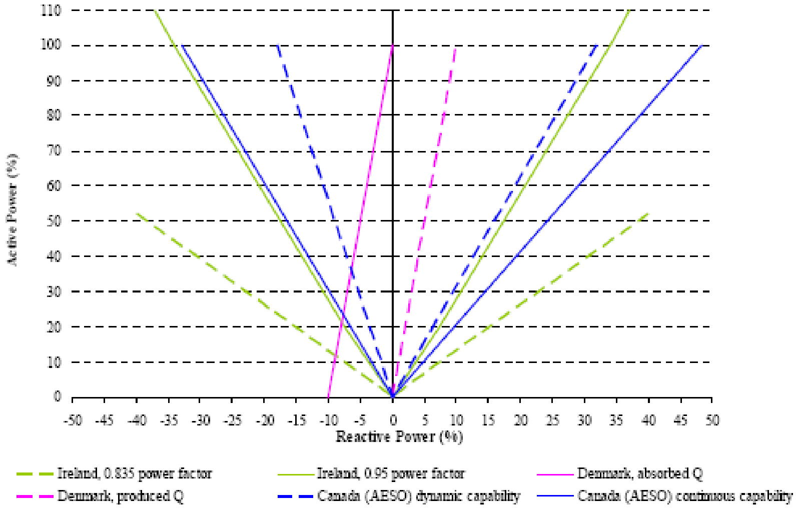

Figure 8 - Comparison of Reactive Power Requirements from Various Grid Codes

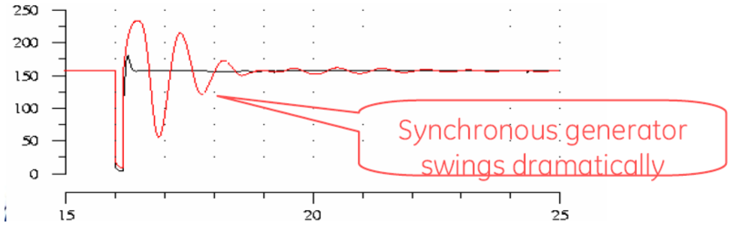

Figure 9 – Comparison of Conventional Generator with Full Converter Output WTG

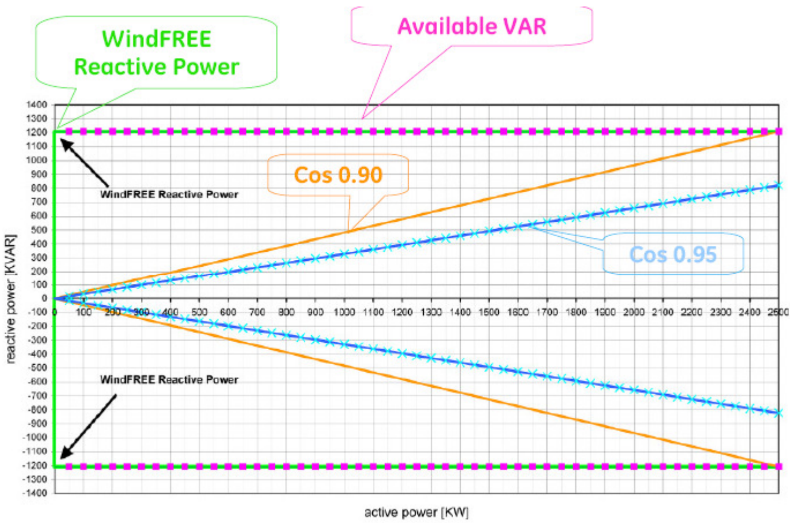

Figure 10 – Reactive Power Capability for One WTG Type – Includes Synchronous Compensate Mode

Now that many common WTGs provide better undervoltage performance than many conventional synchronous generator plant it is thought that power system damping will improve over time as modern wind turbines become more widespread.

3 Factory Visits

I visited the GE Energy WTG factory in Salzbergen, Germany and the Siemens Wind WTG factory in Brande, Denmark. Unfortunately it is difficult to disclose much without risking breaking confidentiality, so my comments are general in nature.

Perhaps because I have worked in industry related factories and design offices in Europe, I found the factories relatively unimpressive. With adequate capital it should be possible to build efficient and competitive plants in Australasia to supply our fledgling wind industry. Given the lack of human resource and component supply which is hampering the industry, new factories in Australasia would be welcomed by the industry.

Both Siemens and GE supply full converter output WTGs. However they appear to be not short of orders and small operators may find it difficult to secure orders. The capabilities of these WTGs is impressive however it should be noted that some of the features that are at the cutting edge may not be fully available, understood or verified yet. This is typical for an industry whose technology is still maturing, however it is exciting to see what is just around the corner.

4 Issues Relevant to New Zealand Electricity Supply Industry

I have covered most of the points of interest in my notes above.

Although we tend to think of the New Zealand power system as being unique from a wind integration perspective, the European wind experience is more advanced than ours and because of the very high targets for wind penetration across Europe, there is much we can learn from the research, development and operational experience gained in Europe.

In a world where fossil fuel is becoming increasingly valuable, wind will have an important part to play in NZ's supply mix in order to provide economic security. However, the main barriers to wind (adequate transmission and regulatory delays) are common between Europe and NZ.

We have ridden on Europe's coat-tails to date with our adoption of wind technology, and due to the huge amount of research and development being invested in Europe; we may continue to do so for some time.

In order to ensure that NZ receives these benefits we should ensure that our standards and codes are harmonised with European codes as closely as practical.

5 Passing the Message On

Following my return from Europe I have given presentations on wind integration at various New Zealand venues summarising my experiences and acknowledging the EEA's partial sponsorship of my European trip. Events so far have included:

- New Zealand Wind Energy Association Annual Conference, 8th April 2008, Wellington
- Electricity Commission Transmission Advisory Group, 10th April 2008, Wellington
- Internal Meridian Energy presentations, 18th April, Wellington, 21st April, Christchurch
- IPENZ, CIGRE event, Canterbury University, 7th May

Further planned events this year:

- IET, CIGRE event 24th June, Wellington
- IET, ESR event 24th July, Auckland University

5 Acknowledgement

I would like to acknowledge the EEA for their generous support without which I would not have made this educational trip. The conference and related visits gave me a wider view of the wind generation industry which has assisted me in my work in the industry and will be of benefit when influencing the New Zealand supply industry environment.