Submission to the Australian Energy Market Commission – Review of Energy Market Frameworks in light of Climate Change Policies.

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1.Key recommendations

- Change the markets so that there is a smoothing and capacity market.
- Allow intermittent generators to source their own supporting generation through a common protocol (visible to system operators) in case their output drops. This could possibly allow the intermittent generator to participate as a schedulable generator as another generator could "guarantee" capacity.
- Thoroughly test the impacts of possible frameworks through a high-fidelity simulation. Existing modelling may only simulate in 5 minute intervals and not detect problems which may happen in between 5 minute intervals.

2.Attachments.

Attachment A – High fidelity modelling of low Emission Fixed Generation Scenarios.

A document detailing an open source simulator which was used to simulate low emissions scenarios using only the New South Wales region of the NEM (including Snowy). In those scenarios, the dispatching algorithm was modified to smooth out fluctuations from the 8GW or so of installed wind capacity. And although the simulation was not detailed enough to allow coal stations to be turned on or off routinely, there was enough solar thermal operating near the end of the simulation that coal stations could have been turned off but remaining commissioned for security of supply.

Attachment B – Intermittent Generator Communications Protocol

A document describing a protocol where intermittent generators could contact a supporting generator (Hydro / Gas / Coal / Another wind farm with a forecast for steady strong winds etc) or controllable demand (Smelter furnace or pumped storage pump), and arrange for it to turn on or off to smooth out supplies.

3.Overview

I would like to make a submission for consideration in the Scoping Paper. Unlike the Ministerial Council for Energy, I believe that increasing the amount of renewable energy being fed into the grid will *require* the market structure to be changed from least cost dispatching to a different structure which takes into account the strengths and weaknesses of each generation technology.

Aside from Photovoltaics, Wind power is the generator type whose output is most determined by the elements. With no storage mechanism, a wind farms output is highly variable and large output swings can happen in a short period of time. The existing Frequency Control Ancillary Services (FCAS) market is capable of handling the current wind farm penetration, but larger penetrations may require a smoothing market to dampen this volatility, receiving dispatching more frequently than 5 minute intervals. Coal power stations like Bayswater and Liddell are fatigued more by changes in output than operating at a continuous output and this could lead to increased failure rates.

Even though its suitable to power stations like hydro-electric plants which can bring online a large amount of power quickly, smoothing need not only be done by conventional power stations, but it would also be possible for a wind farm who received a forecast indicating it would receive around 15 knots for the next four hours to also participate.

As much of this as possible could be automated by allowing generators themselves to negotiate with standby generation and a draft Intermittent Generator Communications Protocol is attached. Intermittent generators communicate with other generators in an attempt to source a back up generator so that the intermittent can provide firm generation and temporarily participate as a schedulable generator.

Demand side management options could also help smooth out output variability. Devices can be interrupted just after rapid output drops, and be brought back online as extra generation is brought online to compensate. Ideally devices could be soft-interrupted like transitioning to a "standby" mode rather than being hard-interrupted like switching off the appliance at the wall so that devices can resume without user intervention.

By having a market structure which allows the participation of an increased amount of cheap renewable generation, it could reduce the overall cost of achieving the given renewable targets.

Solar Thermal generators (with 24 plus hours heat energy storage) may require a capacity market to exist. This could be an extension of the existing facilities used to ensure the network can be brought back online from a "blackstart". While the Solar thermal generations are generally in sunny places, its possible they'll have several days of the year where they cannot operate. The seven day forecast might show cloud at several sites and the baseload generation which the Solar Thermal generation replaced, could be brought back online to ensure system security.

Solar Thermal generators (with only 8 or so hours of heat storage) may benefit from co-operation with other intermittent sources such as wind or hydro where the generation from wind power means that the solar plant is not running at full output and its stored heat can last throughout the night. Achieving this may result in saving a thermal station from turning on for only a few hours in the morning or keeping a baseload station online to only increase output from around 3am until dawn.

To help break the big problem of dispatching up into smaller problems, it maybe be worthwhile for clusters to be created. A cluster is a group of generators who work amongst themselves to generate a nominated output. Imagine one of the owners of a coal power station seeking to lower its companies emissions through the addition of renewable generation.

The cluster could be treated by the central dispatcher as one entity which has been subcontracted to produce its bid output, irrespective of the generators who actually generate. This would allow accommodation for intermittent generators who can operate outside the 5 minute bid periods and possibly allow better utilisation of the generators in the cluster.

Which ever framework is finally adopted, a standardised independent communications network and protocols should be used to allow maximum interoperability.

Before a framework is finalised I hope it will be subjected to extensive modelling using a simulation tool which simulates the network and markets each second. Existing modelling tools use a coarser granularity and may not be able to detect any flaws in the system. You cannot responsibly propose a solution, simulate 5 minute dispatching and hope that everything is ok for the time in between.

4.Other comments

4.1.Smoothing Market - Requirement to withhold generation.

With the scoping paper saying that coal stations may run less frequently, the CPRS may change the least cost generators so that in the future, the cheapest generators have more flexible output profile than the more expensive generators. With rapid changes in demand, this may mean that the most expensive generators may not be able to reduce output to match demand meaning that less expensive generators are also reducing output and least cost dispatching isn't being achieved.

4.2.Demand Side Management - Smart Meters

I believe it is not desirable for only price signals to be only means to see a balance between supply and demand. Recently the Value of Lost Load or maximum wholesale price was increased to $12,500/Mwh. With retailers being fully exposed to this and likely to introduce smart meters to reduce the risk.

I have heard of critical peak prices being around $2/kwh. For low income households running an air-conditioner on a hot day may prove very costly, especially in circumstances similar to the kids getting home from school and turning on the air-con unaware of peak prices.

If Smart meters are not able to be programmed to automatically reduce consumption by interrupting high usage devices like air-conditioners, pool pumps, or similar commercial or industrial equipment, or other forms of remote interruption available, then i feel the market will become more volatile and administrative pricing used more often.

5.Specific Responses to AEMC scoping paper questions

5.1.How capable are the existing gas markets of handling the consequences of a large increase in the number of gas-fired power stations and their changing fuel requirements?

No specific response. I have focused on the electricity market.

5.2.What areas of difference between gas and electricity markets might be cause for concern and how material might the impacts of such differences be?

No specific response. I have focused on the electricity market.

5.3.What are the practical constraints limiting investment responses by the market?

Some constraints I've identified are :-

a) Renewable generators being commanded to constrain output, reducing income via energy sales and RECs
b) A reluctance to operate plants in a manner which creates more fatigue
c) A reluctance to invest in technology which is not yet reached commercial scale

5.4.How material are these constraints, and are they transitional or enduring?

Most of these would be enduring

5.5.How material is the likelihood of a need for large scale intervention by system operators? How likely is it that this will be ineffective or inefficient?

I believe that the likelihood of large scale intervention would increase and become increasingly ineffective over time. This is due to the transition from few large generators which are not fuel constrained to a larger number of generators with less predictable operating patterns.

With wind farms having a output capacity of around 25 – 30%, achieving a 20% renewable energy target with wind power alone would mean all wind farms operating at maximum output would be able to supply 80% of the average demand. This will not be possible to achieve due to the operating requirements of other generators. This means that as more and more wind power comes online, they will be asked more frequently to reduce output. Something which is probably not factored into existing investment decisions.

5.6. How material is the risk of a reduction in reliability if there is a major increase in the level and proportion of intermittent generation?

Very material. If the amount of schedulable generation does not continue to exceed peak demands (minus interruptible demands), then eventually enough wind won't blow / sun won't shine and people fridges won't run and they'll be upset, more so if the shortfall causes a cascading failure throughout the system.

Even though the CPRS & NRET legislation aims to reduce the average emissions, there still needs to be planning in case when intermittent generation output is low and peak demands coincide.

Similarly intermittent output might drop as demand increasing, putting further pressure on generators to increase output quickly.

5.7. What responses are likely to be most efficient in maintaining reliability?

An effective demand side management program would help alleviate the problem of sudden drops in output from intermittent sources. This would allow some time to be bought while other generation is brought online.

Differentiating between types of renewable generation. For example a generator which can predict its output an hour or more into the future give more options to find replacement generation than a generators of the same capacity which could only predict its output only five minutes into the future.

Provide a framework for generators to be able to source their own standby generation and allow standby generators to be rewarded for providing this facility. If the AEMC endorsed a new market where generators were able to negotiate with each other on the provision of support generation using a protocol similar to the Intermittent Generator Communications Protocol (IGCP), then generators like Snowy hydro who are able to bring online large amounts of generation quickly will be able to enter into contracts with intermittent generators to cover any shortfall in generation while not necessarily having to provide any generation.

5.8. How material are the challenges to system operations following a major increase in intermittent generation?

Central operators may be overwhelmed in trying to compensate responses. The generators currently are capable of large output without much fuel constraints.

New low emissions generation is largely intermittent and each technology has different characteristics. Even within technologies, each site may have different characteristics. This challenges the current system because it will be harder to ensure that supplies will be able to meet demands if you cannot predict which generators can firmly provide supply. This combined with the long start up times of some generators could reduce reserve margins and increase the supply disruptions.

5.9.Are the existing tools available to system operators sufficient, and if not, why?

I'd say no. To counter this I'd recommend

- make available forecasts to intermittent generators which would be used for them to lodge non-binding output forecasts. (forecasts for both wind and solar based generation)
- non-binding output forecasts not have to align with existing 5 minute bid periods. E.g a Wind farm my have a weather station in close proximity upwind report a downwards change in wind speed.
- Consider dispatching not just on price, but on firmness of supply to reduce the continual change in output of generators. Preference could be given to a more expensive wind farm in receipt of a forecast indicating relatively steady output for N hours over a cheaper wind farm with no such forecast.

5.10.How material is the risk of large scale intervention by system operators and why might such actions be ineffective or inefficient?

It may be ineffective as operators may not be able to act quickly enough to stop a cascading shutdown. By having system operators outsourcing some of the aspects to the generators e.g. Knowing intermittent generator A will automatically contact standby generator B in case of output fluctuations, This will reduce the system operator workload as their intervention rate should be lower.

Around the time of the 386 Personal Computers, an improvement came out which allowed a more efficient memory transfer. Direct Memory Access (DMA) allowed a memory processing unit to transfer data without involving the Central Processing Unit (CPU). The CPU would still have to "authorise" the copy , and until advent of the DMA controller, the CPU itself had to spend time copying the data around.

5.11.How material are the risks associated with the behaviour of existing generators, and why?

In a market where competition is reduced, such as several fossil-fueled generators being offline (intermittent generation is substituted), there may be abuse of monopoly power in certain markets until other generation can come online.

5.12.How material are the risks of decision-making being "skewed" because of differences in connection regimes between gas and electricity, and why?

No specific response. I have focused on the electricity market.

5.13.How large is the coordination problem for new connections? How material are the inefficiencies from continuing with an approach based on bilateral negotiation?

No specific response.

5.14.Are the rules for allocating costs and risks for new connections a barrier to entry, and why?

No specific response.

5.15.How material are the potential increases in the costs of managing congestion, and why?

No specific response.

5.16.How material are the risks associated with continuing with an "open access" regime in the NEM?

No specific response.

5.17. How material are the risks of "contractual congestion" in gas networks and how might they be managed?

No specific response.

5.18. How material is the risk of inefficient investment in the shared network, and why?

No specific response.

5.19. How material is the risk of changing loss factors year-on-year?

No specific response.

5.20. How material is the risk of an efficient retailer not being able to recover its costs, and why?

With a retailer possibly being forced into the position of being charged $12.50 per kwh, and having price restrictions imposed on them by IPART, then the administrative pricing rules might need a review to ensure retailers don't go out of business due to cashflow problems.

5.21. What factors will influence the availability and pricing of contracts in the short and medium term?

No specific response.

5.22. How material are the risks of unnecessarily disruptive market exit, and why?

No specific response.

5.23. What factors will affect the level of private investment required in response to climate change policies?

No specific response.

5.24. What adjustments to market frameworks, if any, would be desirable to ensure this investment is forthcoming at least cost?

The frameworks should be designed to allow as much intermittent generation participation as possible aim to have limits of technical rather than policy nature.

For example a market which rewards generation which is more responsive will be better able to handle intermittent generation fluctuations then one which doesn't, increasing the amount of intermittent generation participation.

Its a circular argument, but the best market structure will depend on the carbon price. A grid with an higher average dispatch price (excluding carbon costs) but lower emissions may result in a lower carbon price (and lower total price) because of reduced demand for permits.

Any new framework should be scaleable and tested to see what impacts the structure would have should there be a need for a higher amount of intermittent generation participation.

6. Copy of earlier submission sent to the AEMC.

This is a copy of an e-mail sent to the AEMC prior to the scoping paper being produced.

Attention Dr John Tamblyn,

I would like to make some comments regarding the AEMC review. Over the last year I have looked at the effects of adding increased renewable generation onto the grid of my own initiative and using my own funding. If large emissions reductions are not effectively achieved from the stationary energy sector then a bigger burden will be placed upon other sectors to achieve the desired emissions

I have written to the Department of Climate Change and Minister for Energy's office. The response from the Department of Climate Change informed me of your review and suggested I contact the AEMC to discuss the matter further.

With respect to the future generation makeup under the NRET/CPRS, i believe that this schemes will bring online a large amount of wind power to help satisfy requirements until other technologies become mature. The IMO submission to the NRET also said wind power was only two commercially viable renewable energy sources, wind and biomass and it notes biomass has limited scope.

I would like you to consider recommending that there be three markets be made to assist the integration of intermittent generation while ensuring grid stability.

The first is the current 'volume' market where least cost energy is supplied and generators are only paid for by amount generated.

The second is a 'capacity' market, where generators can be paid for the capacity to generate irrespective of the actual amount generated. The intention of this market is to allow stations e.g. coal stations to be turned off should there be sufficient generation e.g solar thermal participating and there is still some volatility in the *output of the renewable generation. e.g. several days of cloud which impact on the energy and capacity outputs of solar thermal plants dropping reserve margins.*

The third is a 'smoothing' market, and this is where generators are dispatched more frequently than the volume market in a bid to smooth out the output of intermittent generators and reduce the wear and tear of plants like coal plants who are fatigued from continual output changes.
In my modelling, an Enhanced Intermittent dispatch algorithm was changed so that "peaking generators" (Hydro & OCGT) were dispatched to
smooth fluctuations. (See page 6 of the attached document).

I would also like it to be considered the changing of rules to require intermittent generators to be able to provide a reserve for themselves. This would be primarily to limit the ramp rate downwards.
Eg. A wind farm of six turbines which is currently receiving a wind speed of 12 knots deliberately reduce the output of two or three turbines so that it can reduce its own output fluctuations and potentially reduce the output fluctuations of other wind turbines.

I have looked into the effect of extra renewable generation coming online to the grid and conducted my own modelling using a program I had created from scratch in the C++ programming language. Attached is a document detailing the modelling methodology and
results of the modelling under three scenarios. While i tried to entice as much renewable generation as possible, there was always still enough non-intermittent generation (Coal, Gas, Hydro, Geothermal) commissioned to meet peak demands.

Finally should the AEMC engage a consultant to model future impacts of the electricity network, I would like to ask that the modelling methodology be detailed to the AEMC and undergo scrutiny to allow detection of any obvious errors. Some modelling programs dispatch every hour, but may not take into account the ouput fluctuations of intermittent generation. They may not also take into account future possible Demand Side Participation like the Western Power trial to remotely control air-conditioner output or they may not be able to adapt the tool to examine the impacts of a change of markets.

I have been working on an open source computer program to simulate the electricity network, and am attempting to do postgraduate research next year, should you feel I would be able to assist your review, feel free to contact me.

Mr Scott George.
[Address withheld]

High Fidelity Modelling of low emission fixed generation scenarios

A look at what the transition to low emission fixed generation could look like through simulation

Mr Scott N. George -
22nd Aug 2008

Abstract

I believe it is important for someone to validate the feasibility of modelled emissions scenarios before committing billions of dollars to projects by running their modelled results through a high-fidelity simulator. The simulation results contained in this paper were created on an open source power network simulation "Contest" which I developed as a prototype to prove that high-fidelity simulations of the network can be done. This paper shows details of the simulator and examines three scenarios of emissions reductions over 41 years using 5 years of historical data.

Modelling which only examines the economics of the power system may include incorrect assumptions because it would not have examined whether the calculated results would actually work. If modelling indicated there would be a large amount of intermittent generation to be connected to meet the targets, but did not include any support generation, then the actual results of the modelling may lead to blackouts, or plants remaining operational past their modelled retirement date to ensure system stability.

The calculation of emissions from fixed electricity generation is complicated because electricity cannot be easily stored and the efficiency and thus carbon dioxide output of a power stations depends on the amount of power they are currently producing. Also calculating that a network remains stable is just as complicated but essential to ensuring a reliable supply of power.

The use of a high-fidelity computer model to do Monte-Carlo simulations would also allow utilities to make mistakes in a virtual world before it happens in the real world. For example a utility could test the impacts of a wind farm at their windiest suitable location. Simulations of the proposed farm might show that sudden frequent drops in wind speed at the site would create a reduction in power greater than the current network can handle. This may result in the addition of a Gas powered generator or the decision to build two farms instead of one to reduce the chance of simultaneous output drops. It could also show the impact on the grid if wind farms reach their high speed cut out, this is where the turbine feathers itself to avoid damage due to the high wind speeds causing a rapid reduction in output of the wind farm.

If an industry expert was to create a computer model of the power network, it could be used to validate the results of modelling, reducing the chances of encountering surprises in 5 or 10 years time that might take years to rectify such as building new plants or upgrading transmission infrastructure.

Such a computer model could have international implications by allowing other countries or utilities to model their network and see the impacts of changes such as adding intermittent generation and its

associated cost, direct carbon dioxide emissions and estimated indirect carbon dioxide emissions. I also believe, to allow maximum usage the program should be open source to allow anyone to "look under the hood" of the program and customise the program if it doesn't meet particular requirements. For example their dispatching algorithms may be different.

Three scenarios have been simulated, the first being focused on clean coal and the second focused on a massive introduction of renewables to reduce emissions. The third was almost identical to the second, with replacement of coal generation with gas due to coal stations being unable to turn off in the simulation and that in later years they were predominantly running a minimum operational speeds.

Simulation Methodology.

The simulation starts with the existing generation portfolio of NSW and attempts to map out what the grid could look like in 41 years by giving a 10 times compression of time for the first 4 years. If something can be done in reality in 5 years, in the simulation it would only take 6 months. The simulation uses data from 2003 – 2007 and is meant to go from 2008 – 2048. The last year uses weather data and demand data from 2007 and allows a comparison from a previous simulation I had done. That simulation indicated that 63,653,234 tonnes of Carbon Dioxide was emitted using just present day generation with least cost dispatching and no renewables.

The 5 years of data came from Historical demand data from 2003-2007 for the NSW pool. This was provided in 30 minute values and extrapolated down to the second with no jitter. The weather data came from the Bureau of Meteorology for all sites in NSW, VIC, SA and ACT. Because NSW has no large scale wind farms, I looked to South Australia and borrowed some of theirs (including layout for Mt Millar) and also added 1GW of wind turbines to Broken Hill where a 1GW farm is currently planned.

Components of the Software

The Communications Network - This allows stations to communicate amongst each other by sending out Bid Requests, Bids and Dispatch messages. A communications Network message is a cross between TCP/UDP. Messages are deemed reliable but as single packets not as a connection stream. A message has the following fields , To, From, Port Number, Time To Live and the Message.

Dispatcher - Every Minute the Dispatcher asks all generators to put in a bid, even Wind Farms (who just report current generation). There were two types of dispatch available, Normal and Enhanced Intermittent. Enhanced Intermittent took into account the change of Wind output and allocated a dampening generation from peaking generators outside the normal least cost dispatching.

Linear Interpolator - This is useful with the power output graphs of turbines. For example the wind turbines have an output graph of output vs wind speed. Loading in X and Y values for the graph allows the Linear Interpolator to determine values in between provided values.

Random Number Helper - A random Number generator taken from Donald Knuth's Art of

Computer Programming and was used for weather generation.

Site - A site holds the turbines and for also returns weather data for sites which have generators depend on weather. Sites are uniquely named and look up weather for the given Simulation time from a file.

Site Controllers - A site controller controls how the generator at a given site behaves. Every second it its doProcessing function is called and it determines what to do.

Site Controller (Coal) - A coal site controller always runs its turbines, bids its generation at a fixed price and always asks to generate around 10MW more than it is currently generation until it reaches a point about 10MW below its maximum output.

Site Controller (HydroElectric) - A Hydroelectric controller bids based upon the dam levels of its Upper reservoir. More water means lower costs and higher Bid amounts. Although it may be dispatched at a higher output than its bid amount (but not its actual maximum) in the case all bid volumes have been dispatched.

SiteController (OCGT) - An Open Cycle Gas Turbine is normally shutdown and turns on when it receives a message from the Dispatcher. When on it also acts to keep the frequency at 50hz.

SiteController (Pump) - A Pump controls the pumps at a pumped storage Hydro facility. It has a given turn on time and will turn on at the off peak times to create extra demand in an effort to avoid a reduction of output from a wind farm.

SiteController(WindFarm) - The wind farm sends output messages to the Dispatcher when bids are requested and it may receive an output cap in MW which will result in turbines being feathered.

Substation - The Substations allow the Simulation to be Hierarchical. At the top of the tree is the Master substation which also deals with extra things like frequency determination and reading in the current demand.

Turbines - The parent class of a turbine. It can have a current output, requested output in percent/ KW etc.

Turbine (Hydroelectric) - A hydroelectric turbine is an extension of a momentum turbine which uses fuel (water) from the upper reservoir and puts it to the lower reservoir.

Turbine (Linear) - Each second this turbine can increase or decrease its output by a linear amount (or less)

Turbine (Momentum) - Each second this turbine builds up momentum when moving from its actual output to its new requested output until it is slowed by a cap value determined by the relative distance from the actual value to the requested value.

Logical View of the Simulation

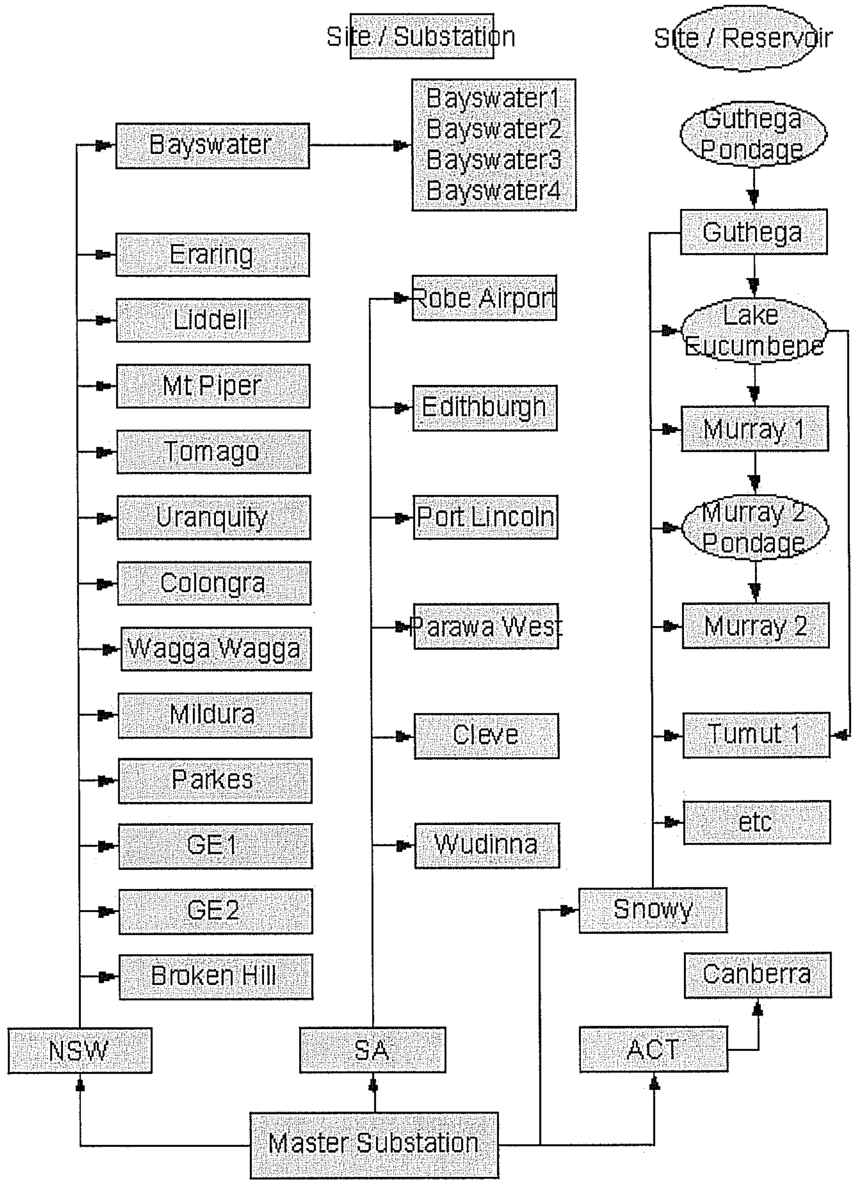


Illustration 1: Logical View of Simulation. Note that some sites do not have generators such as Guthega Pondage. The arrow from Guthega Pondage to Guthega indicate water flow.

Weather information

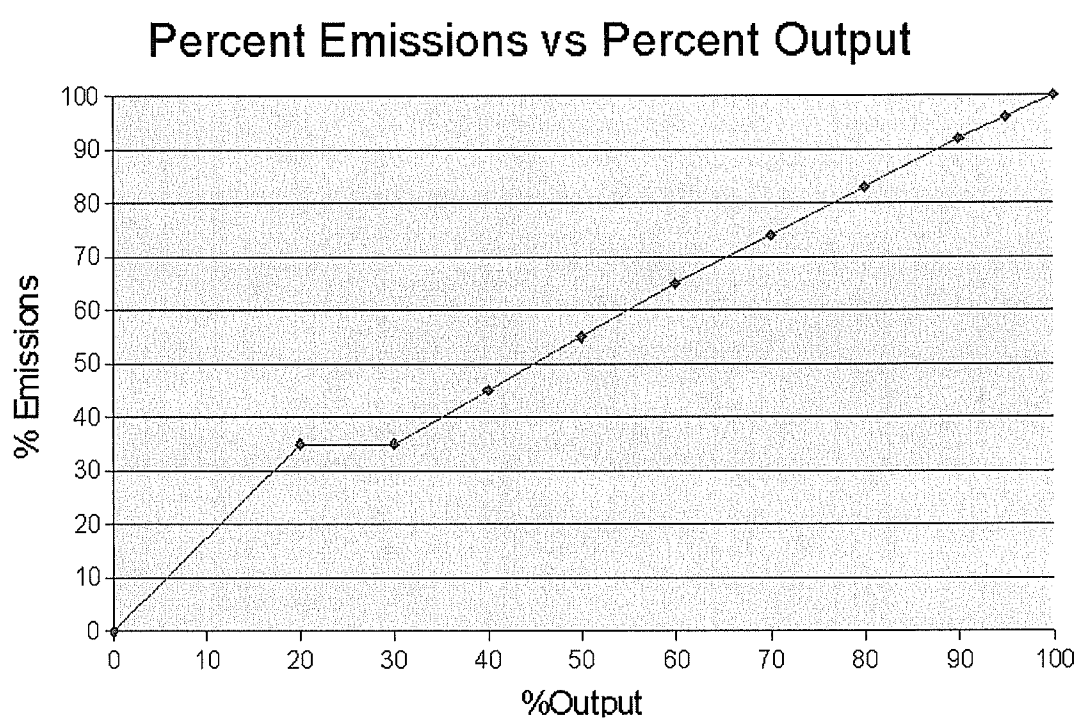
Weather data was synthesized down to the second, but fell within boundaries dictated by historical weather data (average and gust figures) which in most cases was recorded 1/2 hourly. There is a current wind speed and target to which the current speed moves to a few knots per second and every couple of seconds (randomly determines) there is a chance the wind speed target will move up, down or towards the average wind speed but will not exceed the previously mentioned boundaries.

Rainfall was based upon historical data but for the Snowy Scheme, a yearly input figure was split amongst Continuous, Seasonal Snow Melt and Rainfall sources. Solar thermal plants were simulated via Hydro-electric generators with dams with a high evaporation rate which only received rainfall in the day and then based upon the number of reported Oktas of cloud in the sky.

Emissions Calculations

Emissions were calculated for each turbine for each second based upon the percentage output of the turbine. Each turbine had a graph of Percentage output vs Percentage Emissions. Turbines were assigned a CO2 output for full power. The below graph shows the emissions graph used for the Bayswater turbine. With Coal stations being the most efficient at full output, the % emissions value did not decrease at the same rate as the output of the turbine. In this case if the output was between 20 and 30%, the emissions remained at 35% of full power.

%Output	%Emissions
0	0
20	35
30	35
40	45
50	55
60	65
70	74
80	83
90	92
95	96
100	100



Generator Upgrades.

Upgrading generators and other events in the simulation was done via an INI file. All generators which were participating in the simulation were created at the start of the simulation. If a generator was to be retired (or commissioned) in the scenario, it would be replaced with a Sentinel generator (a generator with an output of around 5kw) so that it had no impact on the other generators.

Below is a section of the INI files used in the scenarios.

```
# Bayswater Turbines to 700MW Rerated
#
AT 2003/01/01_01:00:05 REPLACE LINEARTURBINE 001 AT SITE NSW_Bayswater WITH Bayswater_RR700
AT 2003/01/01_01:30:05 REPLACE LINEARTURBINE 002 AT SITE NSW_Bayswater WITH Bayswater_RR700
AT 2003/01/01_02:00:05 REPLACE LINEARTURBINE 003 AT SITE NSW_Bayswater WITH Bayswater_RR700
AT 2003/01/01_02:30:05 REPLACE LINEARTURBINE 004 AT SITE NSW_Bayswater WITH Bayswater_RR700
# Bayswater Turbines to 700MW Rerated Solar Thermal 1%
#
AT 2003/01/15_03:00:05 REPLACE LINEARTURBINE 001 AT SITE NSW_Bayswater WITH
Bayswater_RR700_ST1
# Bayswater Decommission Turbines 3 & 4
#
AT 2004/10/03_09:00:05 REPLACE LINEARTURBINE 003 AT SITE NSW_Bayswater WITH Coal_Null
AT 2004/10/03_09:30:05 REPLACE LINEARTURBINE 004 AT SITE NSW_Bayswater WITH Coal_Null
```

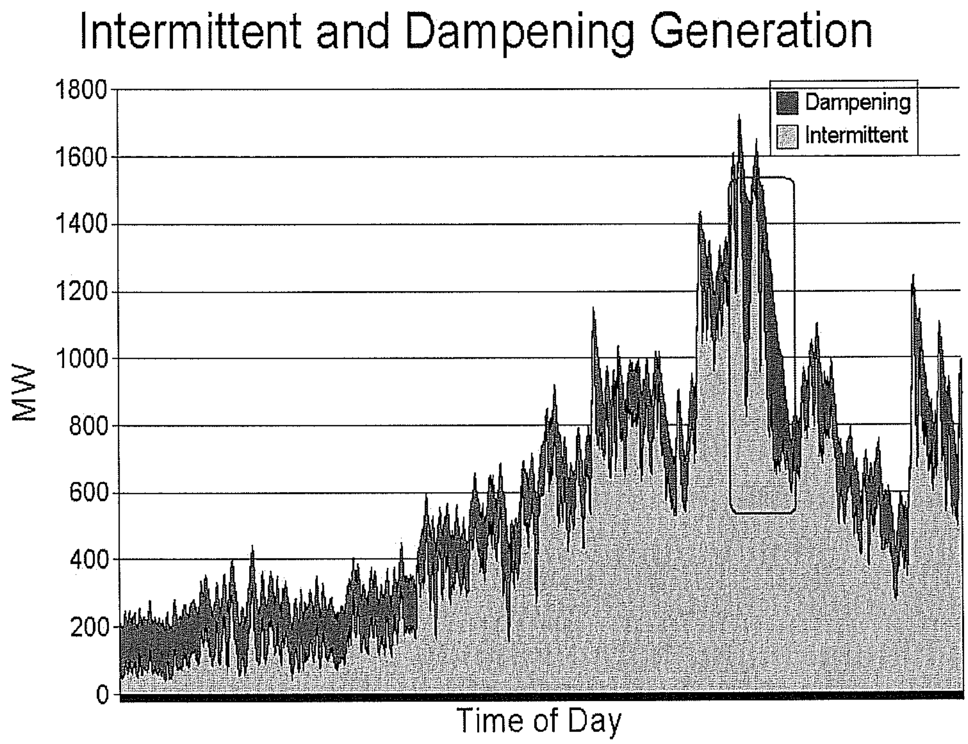
Dispatching algorithm – Enhanced Intermittent Dispatching

In all scenarios there was a recognition that a cooperative approach will be required. Pure least cost dispatching was not used, instead "Enhanced Intermittent Dispatching" was used. Plants indicated whether they were Peaking capable plants (Open Cycle Gas, Hydro etc), and an amount of this was dispatched every minute to help dampen the effects of intermittent generation.

With a given a network comprised of mainly coal based generation which is slow to change output, the addition of significant concentrated intermittent generation may result in changes of output faster than the remainder of the network can handle. Even if the network can handle the rate of the change, its probable the lower cost generators also have to simultaneously reduce their output to ensure the network remains stable. In the simulations I have done peaking generators are dispatched to dampen the effects of large rates of change caused by wind farms.

By specifically building or incorporating a plant with similar characteristics to a Combined Cycle Gas Turbine (CCGT) to operate to dampen out the fluctuations, this can also mean that higher cost peaker units are not used to cover rapid decreases from intermittent generators.

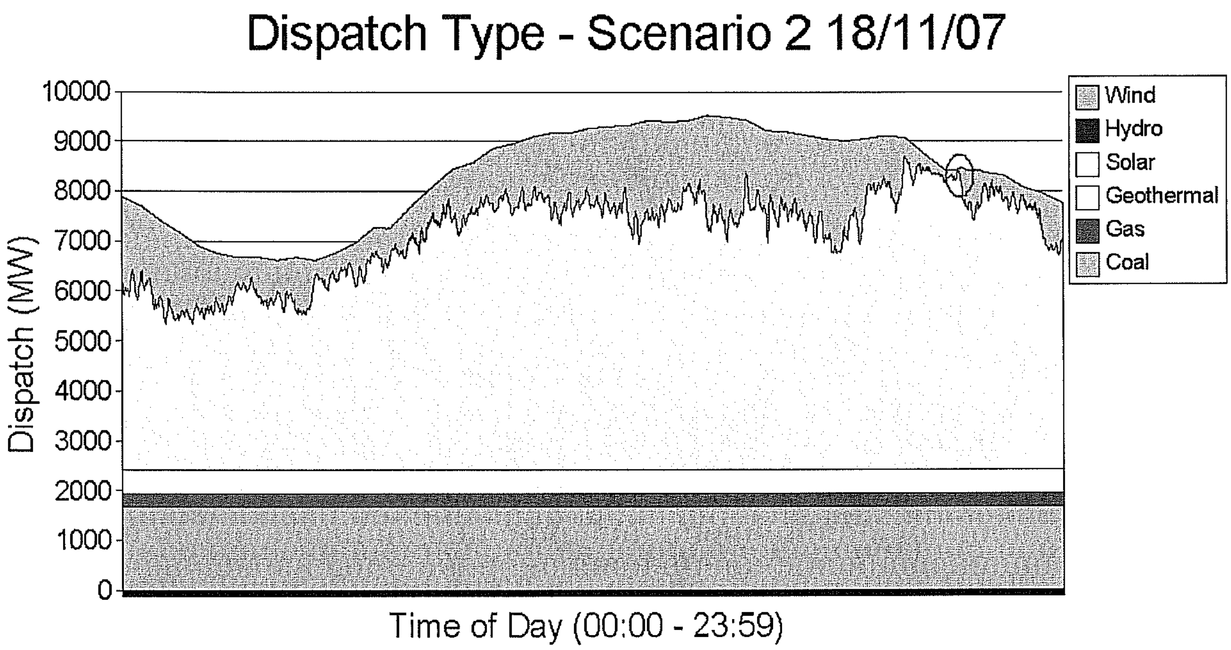
In the scenarios described below, just below 2GW of installed wind capacity is being dampened by other generations who normally produce 150MW of power and adjust their output to ensure the rate of change of the Intermittent plus dampening is not greater than 25MW a minute. This is highlighted in two places on the graph, both in the red box, the first occurrence is a temporary drop in output which is met by around 600MW of Dampening generation, and the second is a rapid drop off shortly after which is smoothed by the dampening generation.



Simulated requirement that demands will always be able to be met without Energy Constrained generators.

The scenarios had to have enough generation available so that demands could be met without relying on energy constrained generators (Wind & Solar Thermal). Hydro turbines had significant storage and bid very high cost and low energy output when the dams were below around 30%, leaving the remaining contents to be used for emergencies.

Today wind power is one of the most mature renewable options but sometimes produces very low amounts of power. Even though Scenario 2 (Explained later) has just over 6GW of installed wind capacity at seven sites, the wind speed was sufficiently low at all sites so that their combined instantaneous output dropped to just 29MW which is highlighted by the red circle in the graphic below. Even though the farms were spread over a large area, other generation still has to be available as a backup.



Simulated Generators

It simulates the current generators of Bayswater, Eraring, Liddell, Mount Piper, Munmorah, Redbank, Vales Point, Wallerawang and Smithfield .

Also added part way through the simulation are the Gas turbines of Tomago, Tallawarra, Uranquity and Colongra

Snowy Hydro is also simulated with Guthega, Tumut 1, Tumut 2, Blowering, Murray 1 and Murray 2 although dam capacities and rainfall was a educated guess on my part.

Potential sites for Geothermal are not specifically named, but its assumed that it will be possible to get 1 GW from GE1 in the Hunter valley, and GE2 and GE3 can also provide 1GW each after the construction of an interconnector to the Cooper Basin.

New South Wales does not have any substantial wind farms with the exception of the proposed wind farm at Broken Hill, therefore weather data for potential sites was taken from sites in South Australia that were close to places with installed wind farms. Cleve, Parawa West, Robe Airport, Port Lincoln, Edithburgh and Wudinna were used.

After looking at the fidelity of cloud data available from the Bureau of Meteorology for sites in New South Wales, Canberra, Wagga Wagga, Mildura, Armidale, Cobar, Hay and Parkes were chosen as potential sites for solar thermal installations. Without knowing specifics of designs, the decision was taken to emulate a solar thermal plant with a Hydro-Electric plant that has a limited storage and only receives rain during the day and the amount of rainfall is based upon the last known cloud coverage at the site in oktas. Depending on the plants type, cloud type which is also available should be used but wasn't.

Scenario overview

The have been three simulations run, Scenario 1 is based upon the entry of clean coal which becomes available around 2020 and Scenario 2 is a highly aggressive attempt to maximise the utilisation of emissions free generation without using clean coal. Scenario 3 is identical to Scenario 2 except 2800MW of open cycle gas generation replaces 2800MW of coal generation. This happened because the coal stations in the final years of Scenario 2 were almost always running at minimum operational speeds and the simulated coal stations never turned off.

The program allows the assignment of Cost and Indirect emissions to events, but I've declined to do that as I couldn't put in accurate figures.

Throughout the simulation, and through indirect means the simulation takes into account energy efficiency measures which means that at any given time X MW are subtracted from the historical MW value. In this simulation energy efficiencies of 2MW per year are made with a saving of 10MW for the last year of the simulation.

Also to simulate transmission losses, the generators have to initially over-generate 5% of what the historical demand figure is to achieve a frequency of 50hz. By the final year of the simulation, the transmission loss figure is reduced to 4% of the historical demand figure due to assumed better transmission networks. Transmission losses were specifically modelled because I did not have enough information to it realistically.

In all simulations the electricity market is changed to allow increased renewable generation. Peaker style plants are considered in dispatching to help smooth out the rapid fluctuations of the wind turbines. Normally the dispatcher will request 150MW of dampening power be generated and this changes to ensure that the intermittent power plus dampening power rate of change is under 25 MW/minute.

Scenario 1 – Clean Coal.

With the view of the government that "You cannot run power stations on renewables" and the view that a heavy investment on more expensive renewable generators would increase the cost of electricity possibly resulting in the movement of jobs overseas. The plan for emissions cuts entails a 20% renewable energy target for 2020 and installation of clean coal generation which becomes available around 2020.

Wind farms are installed to allow existing generation to reduce output when the wind is blowing and quick reaction plants are built to cover shortfalls due to sudden wind drops. By 2011 the Broken Hill site has 1GW of turbines installed (200 x 2MW and 200 x 3MW). With the exception of Cleve, the other sites have about 120 turbines installed per year until they also reach 850MW of turbines installed (200 x 2MW and 150 x 3MW) by 2023. Cleve only has 70 MW of turbines installed and is intended to closely replicate the output of the Mt Millar wind farm by giving each turbine an accurate X and Y coordinate so that wind direction determines the turbines that receive the changes to wind speeds first.

Geothermal resources are found within the state and by 2011 a pilot plant is installed

operating at 1MW, and within a year is upgraded to 50MW. By 2013 the site is producing 500MW and two years later running at 1GW.

A solar thermal pilot project is completed at Canberra in 2012 giving a plant with 175 MW of capacity and a maximum of 4 hours of heat storage if the plant runs at 100%. The stored heat will decay over time even if it is not used. The plant also has enough collectors to receive 10 times the heat required to run the plant on a cloudless day and store that heat.

In 2018 Wagga Wagga has a Gigawatt class plant installed with 1GW of output and 24 hours of heat storage if the plant runs at 100%. In 2023 Armidale has an Gigawatt class plant installed.

A generator modernisation program is undertaken to ensure existing plants are running efficiently. Coal stations are progressively re-rated and coal burning being supplemented with 5% Biomass and 5% solar thermal fuel saver.

Bayswater starts the simulation as 700MW turbines, and shortly afterwards gets a 1% solar thermal fuel saver (similar to that currently being installed at the Liddell plant). In 2010 the fuel saver is upgraded to a 5% fuel saver. By 2015 the plant is also using 5% biomass. In 2020 the plant is upgraded with Post Combustion Capture which captures 60% of the emissions for the loss of 25% output (525MW).

Eraring is upgraded to a 700MW turbine within the year and by 2010 has a 5% solar fuel saver and is using 5% biomass by 2015. In 2021 the plant is upgraded with Post Combustion Capture which captures 60% of the emissions for the loss of 25% output (525MW).

Liddell starts the simulation with 550MW turbines and a 5% solar fuel saver and is using 5% biomass by 2015. In 2022 the plant is upgraded with Post Combustion Capture which captures 60% of the emissions for the loss of 25% output (525MW).

Mount Piper starts the simulation with 700MW turbines and by 2013 has a 5% fuel saver. By 2015 its also using a 5% biomass fuel. In 2022 the plant is upgraded with Post Combustion Capture which captures 60% of the emissions for the loss of 25% output (525MW).

Vales Point turbines are upgraded to 700MW by 2010 and receives a 5% fuel saver by 2013 and starts using 5% biomass by 2015. At 2023 the plant is upgraded with Post Combustion Capture which captures 60% of the emissions for the loss of 25% output (525MW).

Wallerawang turbines are upgraded to 550MW by 2010 and given a 5% fuel saver by 2013 and starts using 5% biomass by 2015. In 2018 the plant is decommissioned.

Munmorah is left unchanged and decommissioned at 2013.

Redbank is left unchanged and decommissioned at 2023

The only upgrade to gas turbines during the simulation is in 2022 where Smithfield turbines are upgraded from 40MW turbines to 45MW turbines.

In 2010 Uranquity comes online with a 540MW open cycle gas plant.

In 2013 Colongra comes online with a 660MW open cycle gas plant.

In 2014 Tallawarra comes online with a 400MW combined cycle gas plant.

In 2017 Tomago comes online with a 790MW combined cycle gas plant.

Scenario 2 – Highly aggressive renewable targets

And with the government's view being that :-

- Nuclear power is not considered a viable option
- Acting now will be cheaper than acting later
- Deeper cuts than 60% may be required
- Carbon capture and storage isn't at commercial usage levels and trials may not be successful.
- Large efforts should be made to reduce emissions before it leaves the stack, allowing other sectors lighter reductions or to reduce the amount of emissions required to be offset and traded.

Research grants are given to promising zero/low emissions technologies to establish pilot plants and gather data for two years on a case by case basis.

Manufacturing plants are set up to build renewable generators. Wind farms are installed to allow existing generation to reduce output when the wind is blowing and quick reaction plants are built to cover shortfalls due to sudden wind drops. By 2011 the Broken Hill site has 1GW of turbines installed (200 x 2MW and 200 x 3MW). With the exception of Cleve, the other sites have about 120 turbines installed per year until they also reach 1GW of turbines installed (200 x 2MW and 200 x 3MW) by 2023. Cleve only has 70 MW of turbines installed and is intended to closely replicate the output of the Mt Millar wind farm. The total installed capacity is 6070 MW. With a capacity factor of 0.25 means that just a little below 20% renewable energy should come from wind power.

Suitable hydro-electric sites have pumps installed to add or increase pumped storage which is also used to help smooth out differences in demand. A (simulated) examination of the Snowy scheme indicated that the Murray scheme can be used as pumped storage as long as the volume of water going from Khancoban pondage to Murray 2 pondage is equal to that pumped up from Murray 2. The project called the Hudson project is completed in 2022 with two pumps at Murray 2 and four pumps at Murray 1.

Sufficient solar thermal generation is added to the grid on the provision that they work cooperatively to ensure that as a group they have sufficient energy stored to reduce the cycling of fossil-fuel generators which are planned to be turned off under favourable conditions such as the 7 day forecast for several sites showing skies clear.

Geothermal resources are found within the state and by 2011 a pilot plant is installed operating at 1MW, and within a year is upgraded to 50MW. By 2013 the site is producing 500MW and two years later running at 1GW.

In interconnector is installed to allow access to the geothermal resources in South Australia's Cooper basin, from which another 2GW is sourced by 2022.

A solar thermal pilot project is completed at Canberra in 2012 giving a plant with 175 MW of capacity and a maximum of 4 hours of heat storage if the plant runs at 100%. The stored heat will decay over time if not used. The plant also has enough collectors to receive 10 times the heat required to run the plant on a cloudless day. In 2018 Wagga Wagga has an Gigawatt class plant installed with 1GW of output and 24 hours of heat storage if the plant runs at 100%. In 2023 Armidale has an Gigawatt class plant installed. In 2028 Hay has an Gigawatt class plant installed. This is shortly followed by the installation of an identical plant at Mildura and Parkes. In 2043 Cobar has an Gigawatt class plant installed and Parkes is upgraded to a 1.6 Gigawatt class plant which has 24 hours of heat storage if the plant runs at 100%.

I considered expanding the simulation to allow solar thermal plants to operate peaker turbines which would have turned on if the storage levels were near 100% and the sun was still shining but that was not done due to time constraints. Also in the simulation, the plants do not cooperate between themselves, instead when the storage levels are low plants bid output is tapered off and bid costs rise to allow other generation to come online.

A generator modernisation program is undertaken to ensure existing plants are running efficiently. Coal stations are progressively re-rated and coal burning being supplemented with 5% Biomass and 5% solar thermal fuel saver.

Bayswater starts the simulation as 700MW turbines, and shortly afterwards gets a 1% fuel saver. In 2010 the fuel saver is upgraded to a 5% fuel saver. By 2015 the plant is also using 5% biomass

Eraring is upgraded to a 700MW turbine within the year and by 2010 has a 5% solar fuel saver and is using 5% biomass by 2015.

Liddell starts the simulation with 550MW turbines and a 5% solar fuel saver and is using 5% biomass by 2015. Liddell is decomissioned in 2020.

Mount Piper starts the simulation with 700MW turbines and by 2013 has a 5% fuel saver. By 2015 its also using a 5% biomass fuel and is decommissioned in 2019.

Vales Point upgraded to a 700MW turbine by 2010 and receives a 5% fuel saver by 2013 and starts using 5% biomass by 2015. At 2018 the plant is decommissioned.

Wallerawang is upgraded to a 550MW turbine by 2010 and given a 5% fuel saver by 2013 and starts using 5% biomass by 2015. At 2018 the plant is decommissioned.

Munmorah is left unchanged and decommissioned at 2013.

Redbank is left unchanged and decommissioned at 2023

Simulation of gas turbines is identical to Scenario 1.

Where the simulation is deficient is that coal turbines are not turned off. In this scenario, there exists sufficient firm generation from Hydro-Electric, Gas, Geothermal and Coal to meet required demand at any time from only these sources. If conditions were ideal coal turbine(s) could be turned off and any unexpected demand/shortfall in generation could be met by increasing Gas/Hydro output. To aid this, future plants could be constructed with a design requirement to be

operational from a cold start in 16 hours or less.

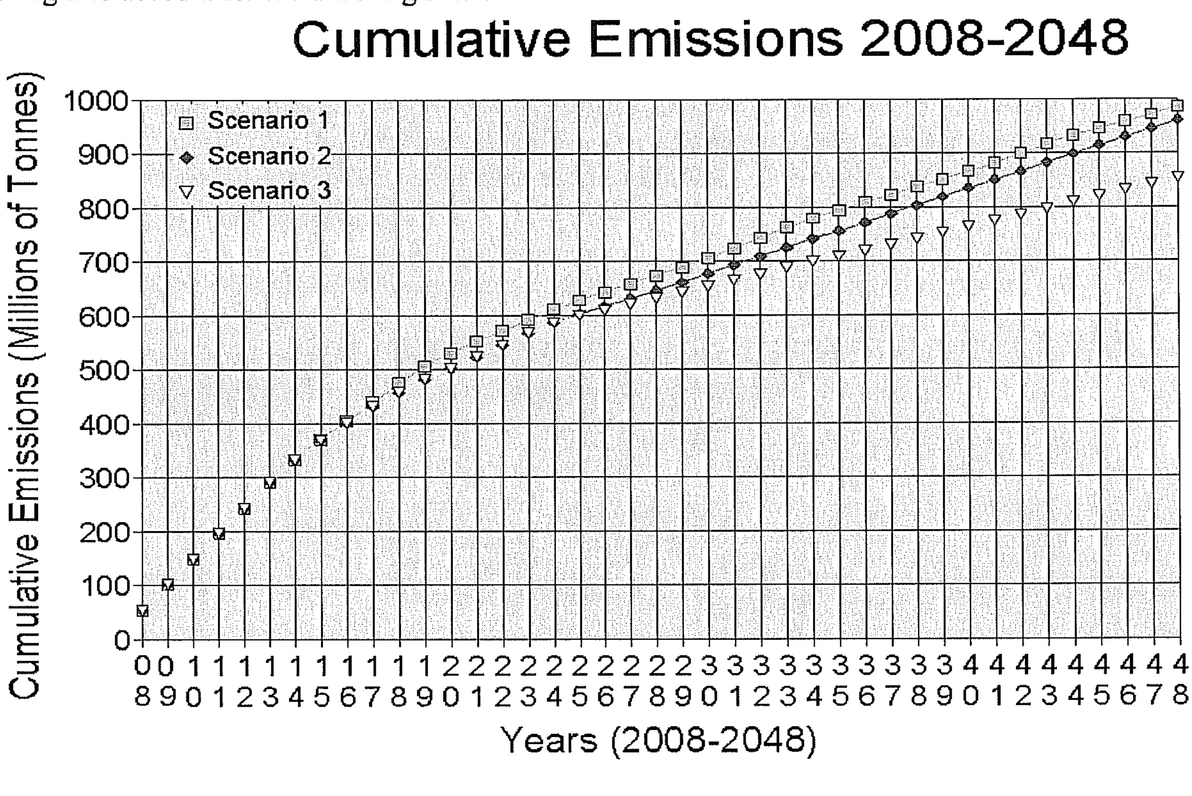
Also left out of the simulation was any future demands on the electricity grid from the transport sector using plug-in vehicles. If demand from vehicles grows, part of it can be added to the network as a demand which can be managed and help with the intermittency problem by being on at night when wind farms could be feathered due to insufficient demand or to increase the charge to a car when the a farms output increases.

Scenario 3 – Highly aggressive renewable targets (Extra Gas)

This scenario is equivalent to Scenario 2 except that the final iteration of Bayswater & Eraring stations only have two 700MW coal turbines instead of four and 2800MW of gas generation is added instead, split between the plants GAS1 and GAS2

Comparison of results

Before results are compared, it should be noted that the CO2 figures used in these simulations are estimates based upon emissions levels of plants quoted in the Newcastle Herald on the 16th of November 2007. Gas plants have 40% of the emissions of the Bayswater turbine after taking into account for the differing size of the turbine.



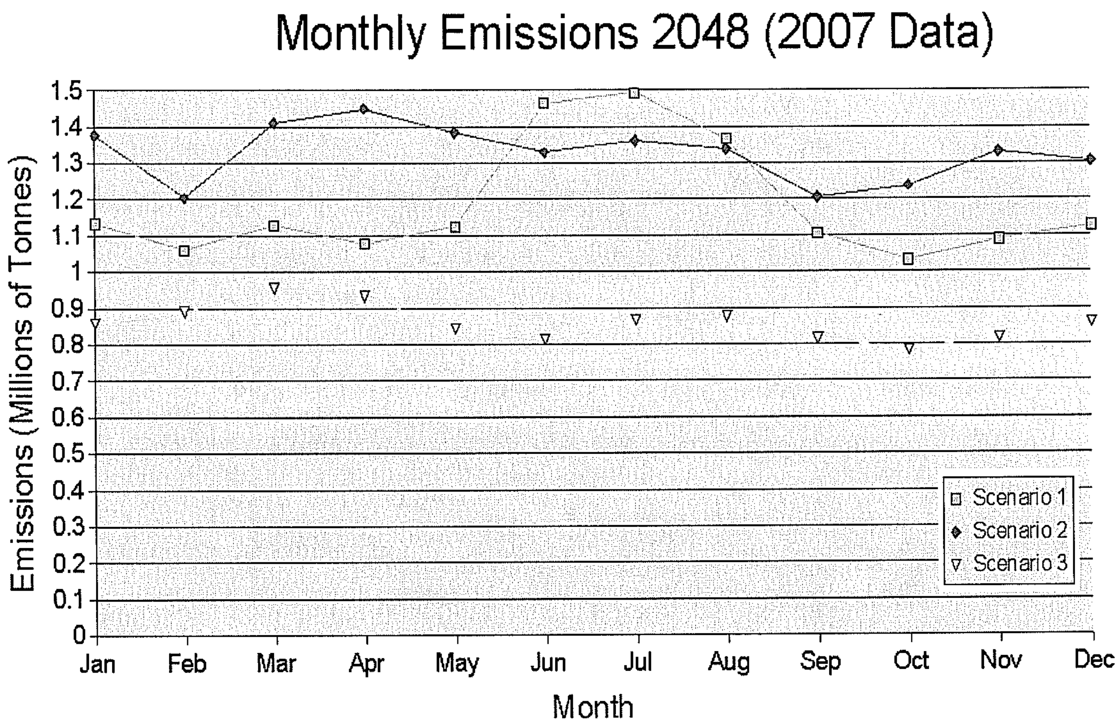
Extrapolated Cumulative Emissions

Due to earlier action on the installation of more renewables, Scenarios 2 & 3 emissions begin to reduce around 2017. Also it should be noted that in the last few years the Scenario 1 Emissions are lower than Scenario 2 Emissions (which does not use clean coal)

From previous testing of a baseline scenario of unmitigated coal generation, the

cumulative value of CO_2 Output if absolutely no action is taken would be around 2,609 Millions of tonnes over the 41 year duration of this graph.

Monthly Emissions for 2048



As there was no changes to any makeup of the grid for the "2048" year which used 2007 demand and weather data direct comparisons can be made between the scenarios.

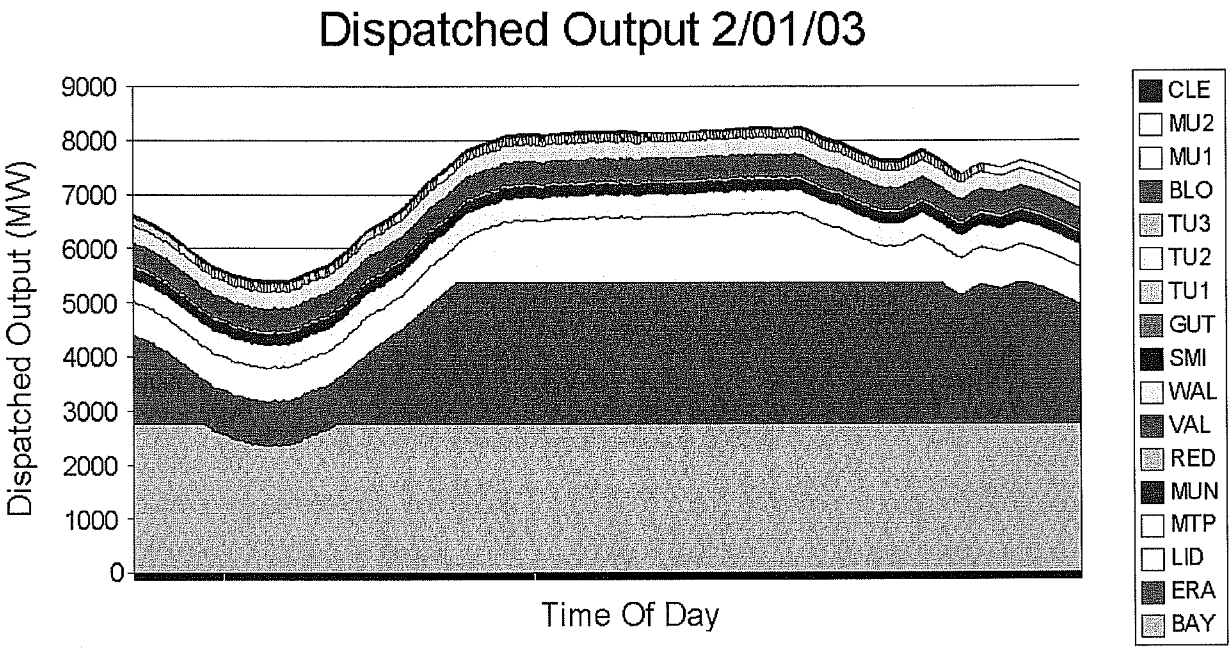
Also from previous testing, in an unmitigated scenario emissions would be around 5.38 Millions of tonnes per month, giving emissions cuts for these scenarios between 75% and 84%.

Daily Dispatching data

Shown below is the graph of generator dispatch on the second day of the simulation. At the top of the graph is the amount generated by the wind farm at Cleve which is a 70MW installation. Slightly below that is a band of generators which make up the 150MW dampening generation. Because this could not be changed throughout the simulation, it had to be in effect at the beginning. This is made up from Tumut 3, Murray 2, Tumut 2 throughout the course of the day.

Below that is the Wallerawang generator which is running at the minimum operational speed (plus 10 MW to allow it to reduce output for frequency control). Below Wallerawang are Vales Point, Redbank, Munmorah, Mt Piper, Liddell, Eraring and finally Bayswater. Note that from midnight Eraring is reducing generation until it also reaches minimum operational speed and then Bayswater reduces output for the trough of the morning.

Around 6am Bayswater is now generating at full capacity and Eraring is increasing its output until it reaches full capacity at about 10am. After that Liddell increases but it doesn't reach full output before demand drops off in the evening.

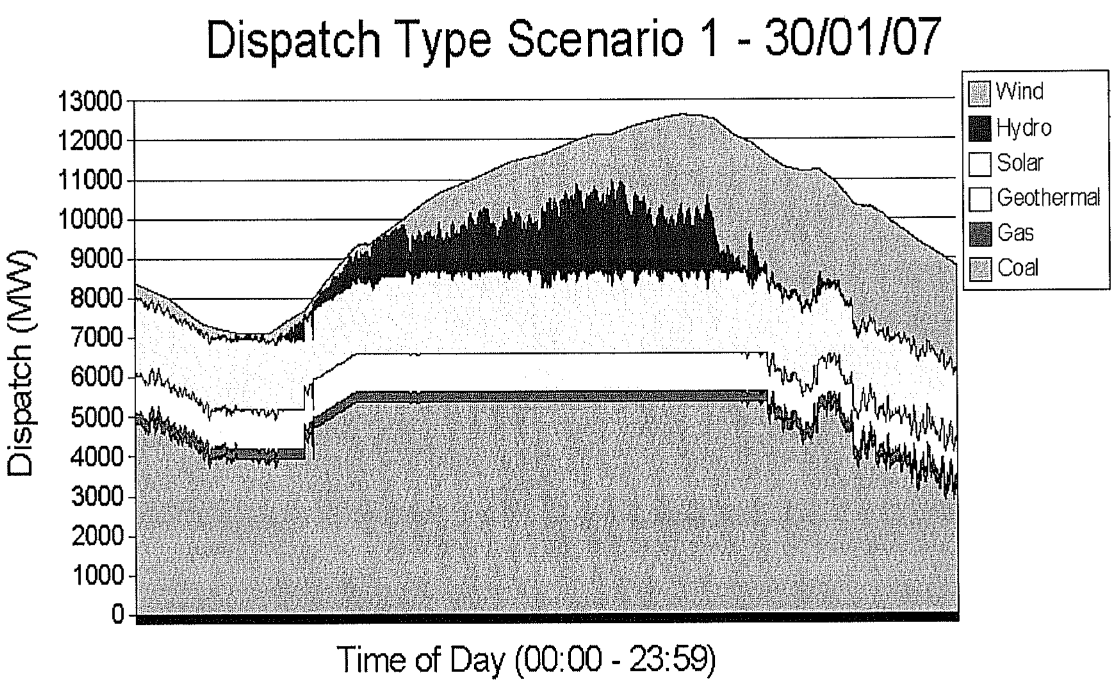


2007 Peak Demand Days.

In 2007 the two days of peak demand for any given ½ hour were January 30th for the summer and July 17th for the winter. The daily dispatch graphs for Scenarios 1 and 3 are shown.

For simplicity, generators have been combined to only show generation type although each generators individual output was calculated.

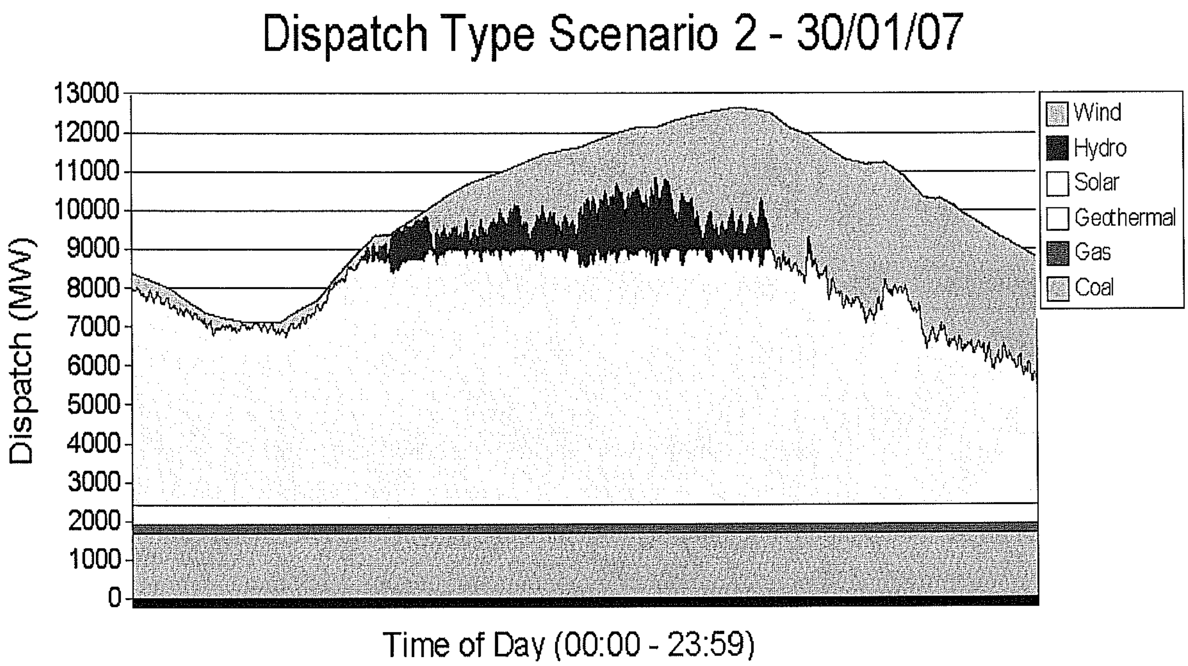
30 Jan 07 – Scenario 1



With the wind dropping off at all sites to a light breeze around the morning trough, the bulk of the generation is left to Coal, Geothermal, and Solar Thermal.

As demand picks up the coal stations increase output until around 5pm where the combined wind output causes a reduction.

30 Jan 07 – Scenario 2

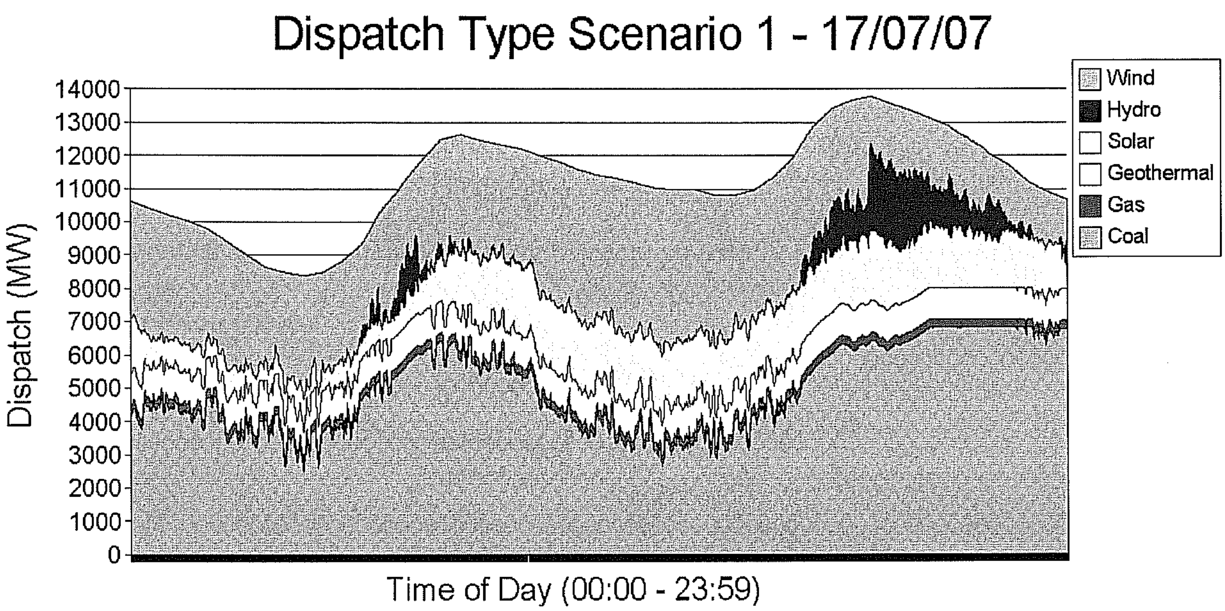


Due to Scenario 2's increased solar thermal generation, over the course of the day the fossil-fuel and geothermal generators never change output past their minimum operational speeds.

With demand increasing over the course of the day, the Hydro-Electric turbines turn on and help fill the gap.

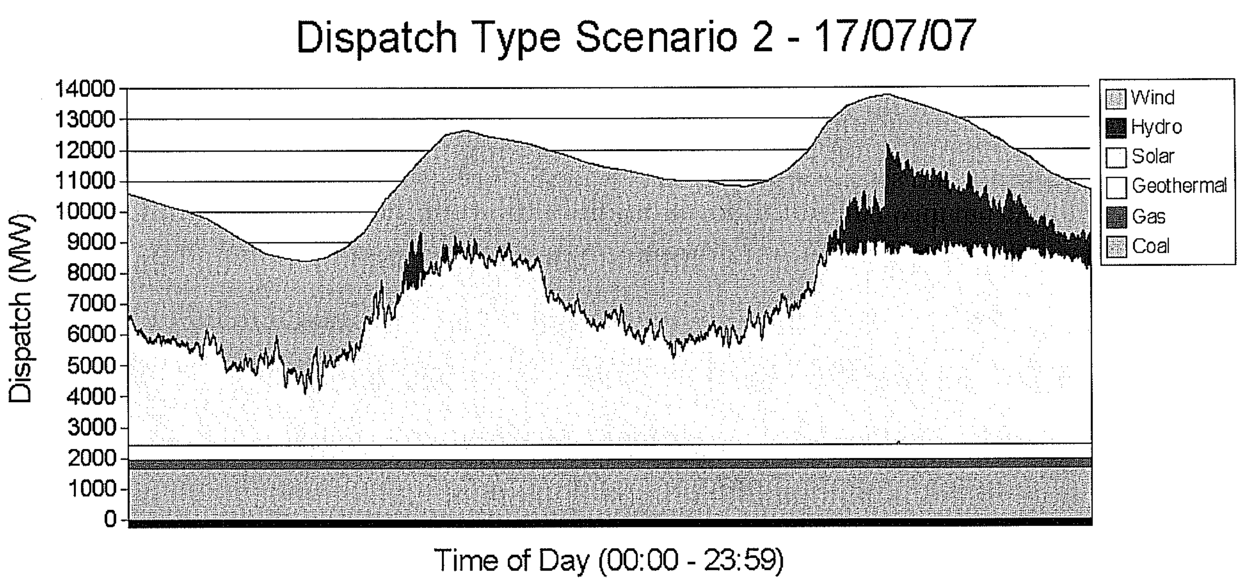
17 **Jul 07 – Scenario 1**

The bulk of the days generation is made up with coal with hydro-electric and solar helping to smooth out the variances in wind output.



17 Jul 07 – Scenario 2

Solar thermal provides the majority of the generation with wind also makes up a substantial part of the days generation, with a sudden decline coinciding with the evening peak which is picked up by hydro. Again the geothermal, gas and coal turbines run almost the whole day without increasing due to sufficient renewable power being available.



Simulation Limitations

Entity economics are not modelled, companies could be trading insolvent.

Transmission losses were not simulated realistically.

Generator bidding was limited and only one bid was allowed (although plants passed their

minimum operational outputs as part of the bid and they were not dispatched below them)

The costs of gas plants were not realistic, the cheapest gas plant simulated bid at $150/MWh.

There were no metrics kept on frequency ranges and times of frequency deviations.

Each scenario was only ran once, to be effective many scenarios would have to be run in a Monte-Carlo analysis.

Solar thermal modelling was simplistic, including times of sunrise/sunset and cloud impacts.

Wind farms operation did not include forecasting (to allow the possibility of wind farms to operate without fossil-fueled backup during favourable forecasts.)

There were no forced or unforced outages (plants were not shut down for maintenance).

To allow many simulations to be conducted quickly, the program could vary between high-fidelity and low-fidelity modes. Eg. Only model the transmission network in high fidelity near peak times of the day or when a transmission constraint is detected. When reserve levels are low, plants could be modelled in high-fidelity.

While not a limitation, it would also be possible to extend the details of the simulation down to the Suburb level, ensuring limits of substations and regional transmission networks were not violated.

Conclusion.

The results contained in this report indicate that significant emissions reductions could be achieved by a large scale overhaul of the electricity generators.

However, these results are still subject to large amount of uncertainties as described in the Simulation Limitations paragraph.

Further work should be done in this area to increase the certainty that emissions reductions plans and technologies are realistic and achieveable before committing billions of dollars to a possible solution which may not be workable when rolled out commercial scale.

Inputs should be sought from industry experts, Market Operators, Transmission companies, Generators etc.

Developing the program as open source would allow maximum input, transparency & use (including adaption for use overseas) without the compromise of confidentiality as the generator performance data could be kept confidential.

For Use with The Contest Model,
Adaptable for use with Internet Communications.

Scott George

October 2007

The Intermittent Generator Communications Protocol
Version 1.0

Status of this Description

Abstract
The Intermittent Generator Communications Protocol (IGCP) provides a framework for passing current and future generation information to other participants on a electricity network. This Protocol will allow a smoothing of generation from intermittent sources between intermittent generators and standby schedulable generators and intermittent generators and intermittent capable loads, thus aiding in maintaining a stable grid.

Table of Contents

1.1 Introduction

People around the world are looking to reduce carbon dioxide emissions from electricity generation, and currently most renewable power generators such as solar and wind are only able to generate power intermittently, and sometimes start and stop with little notice.

The IGCP is aimed at allowing generators to ease this burden by allowing automated communication between intermittent generators and standby generators such as hydro-electric and gas /diesel equipment. Alternatively it could allow communication between an intermittent generator and a intermittent capable consumer such as a irrigation pump, desalination plant or pump in a pumped-storage hydro-electric facility.

1.2 Related Work

This protocol is loosely based upon DHCP in that it looks to lease standby generation instead of Internet Protocol addresses. Sections of this document are copied from the DHCP RFC

There will be a need for another (as yet undefined) protocol, one which allows Intermittent Generators the capability to identify which standby generation and standby demand exists on the network and a rough idea of its existing commitment.

The Contest model is a model of the power network to allow simulations to be conducted to see the effect of possible manipulations to the power network, including increased renewable generation while maintaining reliability and minimal disruption to the usage patterns of the end user. As of OCT 07, it is still in the design stage and when released will be released under the GPL license.

1.3 Problem Definition and Issues

Renewable generators aren't deterministic in their generation given the variabilities in the weather. So accurately predicting the output of such a generator is hard, and sometimes the generator makes too little power (possibly leading to brownouts) or sometimes too much (possibly leading to over voltage).

This problem can be removed by matching up an intermittent generator or generators with reliable standby generator of sufficient responsiveness so their combined output is no greater than that of the standby generator. And once many generators of sufficient geographic or power source diversity are linked to the one standby generator, the total combined output can be lifted on the reliance that there will be some of the intermittent generation generating.

Attacking the problem from the other end is the matching of intermittent capable demands with that of the intermittent generators, if this is possible, it may be possible to avoid the requirement of having a standby power station which may only be used infrequently.

Another issue that could be present would be the standardisation of communication, something this protocol aims to address by ensuring that if the generators are able to communicate effectively, they are more likely to work together co-operatively.

While this protocol is designed for use with the contest model that will have a network simulation similar to that of a TCP/IP network and messages are passed reliably in a similar fashion to a UDP packet, this protocol could be adapted to run on a TCP/IP network or alternatively on a medium such as Internet Relay Chat.

1.4 Requirements

Throughout this document, the words that are used to define the significance of particular requirements are capitalized. These words are:

"MUST" -This word or the adjective "REQUIRED" means that the item is an absolute requirement of this specification.

"MUST NOT" - This phrase means that the item is an absolute prohibition of this specification.

"SHOULD" - This word or the adjective "RECOMMENDED" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.

"SHOULD NOT" - This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.

"MAY" - This word or the adjective "OPTIONAL" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

1.5 Terminology

This document uses the following terms:

"Intermittent Generator" - A electricity generator which is not able to control its minimum output at a future point in time. Examples of this are Photovoltaic Panels, Wind Turbines and Solar Thermal.

"Standby Generator" - A IGCP server running that is able to control (or recommend control to a human operator) of a Electricity generator. An example of this would be a Gas Turbine, Hydro-electric facility or Fuel Cell generator. NOTE: Although a Hydro-electric facility may have limited water and may not be able to generate power continuously, it has control over when that power can be generated.

"Standby Demand" - A IGCP server running that is able to control (or recommend control to an operator) of a Electricity demand. An example of this would be a pump for irrigation or pumped storage, Electrolysis machine or an electric furnace such as those used in cement manufacturing. Instead of being on to cover shortfalls in intermittency, it would modify its usage of electricity to match that of the Intermittent generator.

"Server" - A standby generator or standby demand.

"Client" - An IGCP client which is an intermittent generator.

"Site" - Any site that has a participating IGCP server or client.

1.6 Design Goals

IGCP should be an aid and not a policy. Site administrators must still decide whether their generator or demand will participate and to what level of participation

Once a site controller has configured the controller, there should be no ongoing need for configuration or ongoing input from a site administrator.

Once there has been a commitment between two sites, they should be able to make further commitments, For example a wind turbine should be able to make three commitments to a pumped storage site. 1. for the site to pump up water should there be an unexpected increase in wind, 2. that the site should be able to generate a small amount based upon a small but probable drop off in wind, and 3. that the site should be able to generate a large amount based upon an improbable drop off in wind.

Once an agreement has been made, the response to that agreement should fall within the nominated response time, otherwise reserve generation may be dipped into, an event which must be avoided.

2 Protocol Summary

The protocol has several messages and they are summarised as (in expected order of use):-

REQUEST_STANDBY_GENERATOR - Request that the generator that is the receiver of the message act as a standby generator for the client.

REQUEST_STANDBY_DEMAND - Request that the demand that is the receiver of the message act

as a standby demand for the client.

OFFER - The server has offered to act as a standby generator or demand for the client.

NO_OFFER - The server has rejected to act as a standby generator or demand for the client. A client should wait a reasonable time before sending this server another request. A server may send a NO_OFFER message to the client even though it would be able to fulfil the request. If a NO_OFFER message is sent, the client should be able to re-request with different parameters, such as a longer time to respond or a smaller response.

ACCEPT - The client sends this message to the server to acknowledge the offer and wishes to accept the offer.

REQUEST_STANDBY_GENERATOR_EXTENSION - The client sends this message to the server to request a continuation of the current offer beyond its expiry time using the same terms.

REQUEST_STANDBY_DEMAND_EXTENSION - The client sends this message to the server to request a continuation of the current offer beyond its expiry time using the same terms.

ACCEPT_EXTENSION - The server has accepted the extension until the requested time.

DECLINE_EXTENSION - The server has rejected the extension until the requested time. A server may decline an extension even if it able to fulfil the request.

RESPOND - The server should now start generating the agreed standby power, or start using the agreed standby demand. This will remain in effect until it receives a CEASE_RESPONSE message or the end time of the request has been reached. A standby demand must not automatically start consuming once it has received an acceptance, it must wait for the respond message.

RESPOND_ACKNOWLEDGEMENT - An acknowledgement to the client that it has received the RESPOND message

CEASE_RESPONSE - The server should cease generating the agreed standby power, or cease using the agreed standby demand again. This will remain in effect until it receives another RESPOND message or the end time of the request has been reached.

CEASE_RESPONSE_ACKNOWLEDGEMENT - An acknowledgement to the client that it has received the RESPOND message.

RELEASE_OFFER - The client has offered to terminate the request for standby generation early.

TERMINATE_OFFER - The server has terminated the request for standby generation early. This should only be done in extenuating circumstances and should not be done routinely. For example the standby generator cannot possibly fulfil any requests due to it producing the most it can produce or failure in the generator equipment. Should a TERMINATE_OFFER message be sent, it should be sent with as much notice as possible so that the client can find another server.

2.1 The Client Server Protocol

REQUEST_STANDBY_GENERATOR -
A request message consists of the following :-
A time from when a response may be required from
FROM YYMMDD HHMMSS where YY is Year Year, MM is Month Month, DD is Day Day, HH is Hour Hour, MM is Minute Minute and SS is Second Second.

A time from when a response may be required until
UNTIL YYMMDD HHMMSS where YY is Year Year, MM is Month Month, DD is Day Day, HH is Hour Hour, MM is Minute Minute and SS is Second Second.

The amount of time between when the RESPOND message is sent and the time the response will be needed.
NOTICE HHMMSS where HH is Hour Hour, MM is Minute Minute and SS is Second Second.

The size of the RESPONSE in kilowatts.
SIZE 500

It may contain a guess at the probability of at least one RESPONSE being required during the time of the request
PROBABILITY PPP where PPP must be a number (percentage chance) between 000 and 100.

It may contain a guess at the frequency of a RESPONSE.
FREQUENCY MM a guess at the number of times that a RESPONSE will be required.
NOTE: this does not have any bearing on how long the response will be required.

An example REQUEST_STANDBY_GENERATOR message is below. Comments are to the right after a # and are not part of the message
REQUEST_STANDBY_GENERATOR

```
FROM 071114000000                       # From 2007, November 14th, Midnight
UNTIL 071115000000                      # Until 2007, November 15th, Midnight.
NOTICE 000035                           # 35 seconds notice.
SIZE   250                              # 250 kilowatts.
PROBABILITY 070                         # 70% likely this request will need at least one
                                        # RESPONSE. Optional field
FREQUENCY 02                            # It is expected that the response will be made twice
```

REQUEST_STANDBY_DEMAND - The REQUEST_STANDBY_DEMAND message is of the same format as the REQUEST_STANDBY_GENERATOR with the exception that the server is expected to consume power when the RESPONSE message is issued.

OFFER - The server has offered to act as a standby generator or demand for the client. It must contain an offer number which is unique to the server and must contain an offer expiry time which should be at least 30 seconds from when the offer is made.

An example OFFER message is below. Comments are to the right after a # and are not part of the message

```
OFFER
VERSION_NUMBER 1.0                  # Put in to allow future expansion
OFFER_NUMBER 07111515000003         # This is the Fourth offer I've made since the beginning
                                    #of the 15th hour of Nov 15th 2007.
                                    # At most 1,000,000 offers can be made per hour, the
                                    # first offer will be offer 000000.
OFFER_EXPIRES 071115152359          # This offer will expire if i don't receive an ACCEPT
                                    # before 2007, November 15th 15:23:59.
```

NO_OFFER - The server has not offered to act as a standby generator or demand for the client. It may contain a minimum time before which another request should be made.

An example NO_OFFER message is below. Comments are to the right after a # and are not part of the message

```
NO_OFFER
VERSION_NUMBER 1.0                        # Put in to allow future expansion
REQUEST_AGAIN_AFTER 071115235959          # Please don't ask again until after 2007,
                                          # November 15 23:59:59.
```

ACCEPT -
If the offer time has been expired, the client will receive a TERMINATE_OFFER message. NOTE: for standby demands this does not mean they should start consuming, they must wait for a respond message.

An example ACCEPT message is below. Comments are to the right after a # and are not part of the message

```
ACCEPT
OFFER_NUMBER 07111515000003          # The offer number which is being accepted.
```

REQUEST_STANDBY_GENERATOR_EXTENSION - A client has requested an extension to a previously accepted OFFER It must contain a time that the client wishes the extension to be granted until. While it is generally accepted that an extension will be to modify the end time of an offer some time further into the future, it may be used to reduce the length of an offer.

An example REQUEST_STANDBY_GENERATOR_EXTENSION message is below. Comments are to the right after a # and are not part of the message

```
REQUEST_STANDBY_GENERATOR_EXTENSION
OFFER_NUMBER 07111515000003          # The offer number which is being extended.
UNTIL 071115000000                   # Until 2007, November 15th, Midnight.
```

REQUEST_STANDBY_DEMAND_EXTENSION - The REQUEST_STANDBY_DEMAND_EXTENSION message is of the same format as the REQUEST_STANDBY_GENERATOR_EXTENSION with the exception that the server is expected to consume power when the RESPONSE message is issued.

ACCEPT_EXTENSION - A message to indicate the extension has been accepted.

DECLINE_EXTENSION - A message to indicate the extension cannot been accepted. A server may decline an extension for any reason.

RESPOND - The server should now start generating the agreed standby power, or stop using the agreed standby demand. This will remain in effect until it receives a CEASE_RESPONSE message or the end time of the request has been reached. A standby demand must not automatically start consuming once it has received an acceptance, it must wait for the respond message.

An example RESPOND message is below. Comments are to the right after a # and are not part of the message

```
RESPOND
OFFER_NUMBER 07111515000003          # The offer number which the response is being issued.
```

RESPOND_ACKNOWLEDGEMENT - An acknowledgement to the client that it has received the RESPOND message. This message is a communications acknowledgement only and is not meant to be a statement by the server that the required extra generation or standby-demand is active.

An example RESPOND_ACKNOWLEDGEMENT message is below. Comments are to the right after a # and are not part of the message

```
RESPOND_ACKNOWLEDGEMENT
OFFER_NUMBER 07111515000003          # The offer number which the response is being
                                     # acknowledged
```

CEASE_RESPONSE - The server should cease generating the agreed standby power, or cease using the agreed standby demand again. This will remain in effect until it receives another RESPOND message or the end time of the request has been reached.

An example CEASE_RESPONSE message is below. Comments are to the right after a # and are not part of the message

```
CEASE_RESPONSE
OFFER_NUMBER 07111515000003          # The offer number for which the response is being
ceased.
```

CEASE_RESPONSE_ACKNOWLEDGEMENT - An acknowledgement to the client that it has received the CEASE_RESPONSE message. This message is a communications acknowledgement only and is not meant to be a statement by the server that the required extra generation or standby-demand has ceased.

An example CEASE_RESPOND_ACKNOWLEDGEMENT message is below. Comments are to the right after a # and are not part of the message

```
CEASE_RESPOND_ACKNOWLEDGEMENT
OFFER_NUMBER 07111515000003          # The offer number which the cease response is
                                     # being acknowledged
```

RELEASE_OFFER - The client has offered to terminate the request for standby generation early.

An example RELEASE_OFFER message is below. Comments are to the right after a # and are not part of the message

```
RELEASE_OFFER
OFFER_NUMBER 07111515000003          # The offer number which is to be released.
```

TERMINATE_OFFER - The server has terminated the request for standby generation early. This should only be done in extenuating circumstances and should not be done routinely. For example the standby generator cannot possibly fulfil any requests due to it producing the most it can produce or failure in the generator equipment. Should a TERMINATE_OFFER message be sent, it should be sent with as much notice as possible so that the client can find another server.

An example RELEASE_OFFER message is below. Comments are to the right after a # and are not part of the message

```
RELEASE_OFFER
OFFER_NUMBER 07111515000003          # The offer number which is to be released.
```

2.2 Example Client-Server interaction

An example of this protocols use could be an network consisting of a 2 Megawatt wind turbine which is the intermittent generator, A pumped storage hydro-electric which has auxilliary pumps fitted that are of a lower wattage than the main pumps/turbines and a combined cycle gas turbine which has reserved some turbine generation capacity as standby generation.

The wind turbine has received a weather forecast which indicates that the winds will pick up from 7 knots to 25 knots at around 4pm as a front comes through, and winds are expected to stay around that strength for at least 2 hours, but could be stronger or weaker.

The turbine makes a pledge to the market coordinator that it will be able to reliably be able to put out 1 Megawatt of power for the two hours from 4pm.

For this to happen, it contacts a couple of standby generators and standby demands:-

* It contacts a pumped storage dam and tells it that it is currently putting out about 120Kilowatts and that you can use this to run a 100Kilowatt pump until 4pm when it expects the front to come through.

* It contacts another dam to ensure that if the front is late, that the dam can put 900Kilowatts into the grid on the wind turbines behalf until the front arrives.

* It contacts a gas turbine to see if it can cover any temporary shortfall of a small amount such as a temporary lull in wind.

If around 5pm it receives an update saying that the wind is expected to drop off sooner, it can attempt to contact other sources to ensure there is no shortfall, this could be another pumped storage dam who is concurrently communicating with another intermittent generator or generators which are generating. The dam ceases pump operations to allow the second generators electricity to even out the shortfall by the turbine rather than pump up and at the same time run the turbine.

3 Ideas for Future Revisions

Include in the REQUEST_STANDBY_GENERATOR or REQUEST_STANDBY_DEMAND message the expected duration they will need to RESPOND rather than the currently undefined time period and a parameter to say how long after a CEASE_RESPONSE before they are again required to RESPOND.

Allow RESPONSE message's to be partially responded to.

Include in the NO_OFFER a reason why no offer has been made, too many offers outstanding, too much possible load and possibly a way for the offer to be accepted.

Include fields to allow a payment for services.