GREEN Grid

Future Proofing New Zealand's Electricity Supply

Managing Renewable Energy Variability

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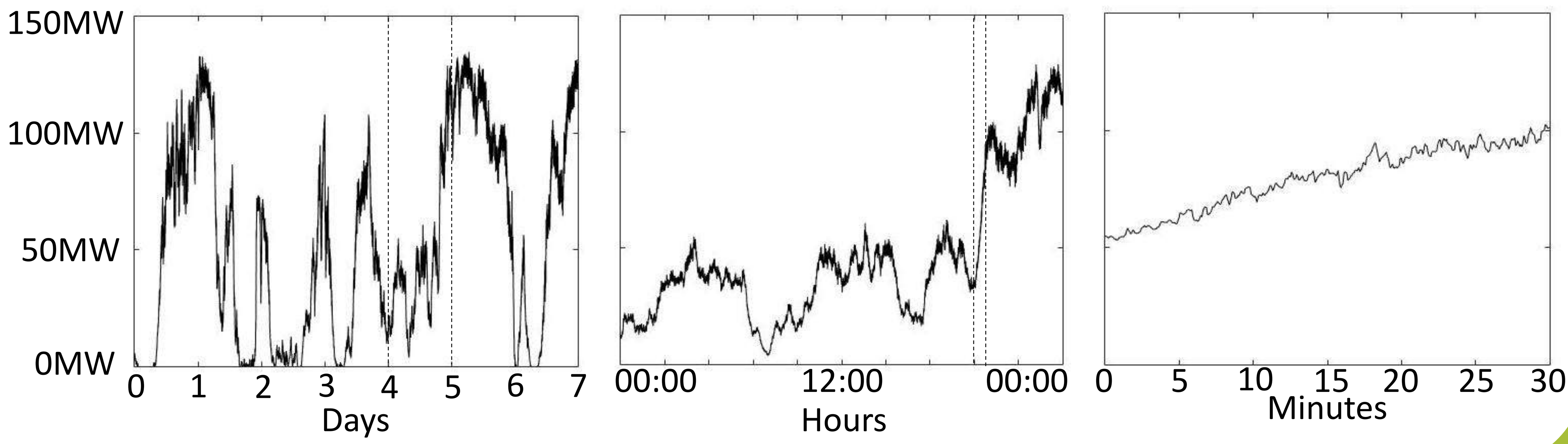
Renewable Energy Variability

Wind energy and solar energy are variable sources of power. The conversion technologies used are designed to extract the maximum amount of power out of the system to achieve the best efficiency. However the energy source fluctuates with the conditions and therefore results in a variable output. For example, the amount of energy extracted out of the wind is dependent on the wind speed. For each wind speed there is one blade speed that will achieve the highest power output, and so the wind turbine adjusts the speed of the blades to achieve this output. The output for a New Zealand wind farm is shown in the adjunct figures for different time scales.



The Problem of Variability

The nature of electricity flow in a grid means that energy cannot be stored for longer than one electrical cycle. Hence all the power drawn by the loads is instantaneously supplied by the generators. This power is supplied through the synchronous generator which slows down the rotating turbine and rotor. To maintain synchronous speed the generator supplies mechanical power through the turbine. However if there is a mismatch between the mechanical and electrical power the power difference is supplied by the kinetic energy stored in the rotating mass. If the load is larger than the supply then the turbine speed slows down. However if the supply is larger than the load then the turbine speeds up. This relationship is expressed in the swing equation, as shown to the right.

The speed of the rotating mass is directly coupled to the electrical frequency of the grid. If the speed of the rotating mass fluctuates then the frequency will fluctuate as well. The frequency is maintained close to a constant value of 50 Hz, and if the frequency fluctuates too far away from 50 Hz then generators will start to disconnect from the grid to minimize damage. By this point it is very difficult to stabilize the grid and a blackout is imminent. Blackouts come as a large economic and social cost and the engineers managing the grid minimize the risk of a blackout as much as economically possible. In the North Island, generators are not obligated to remain connected to the grid if the frequency falls below 47 Hz.

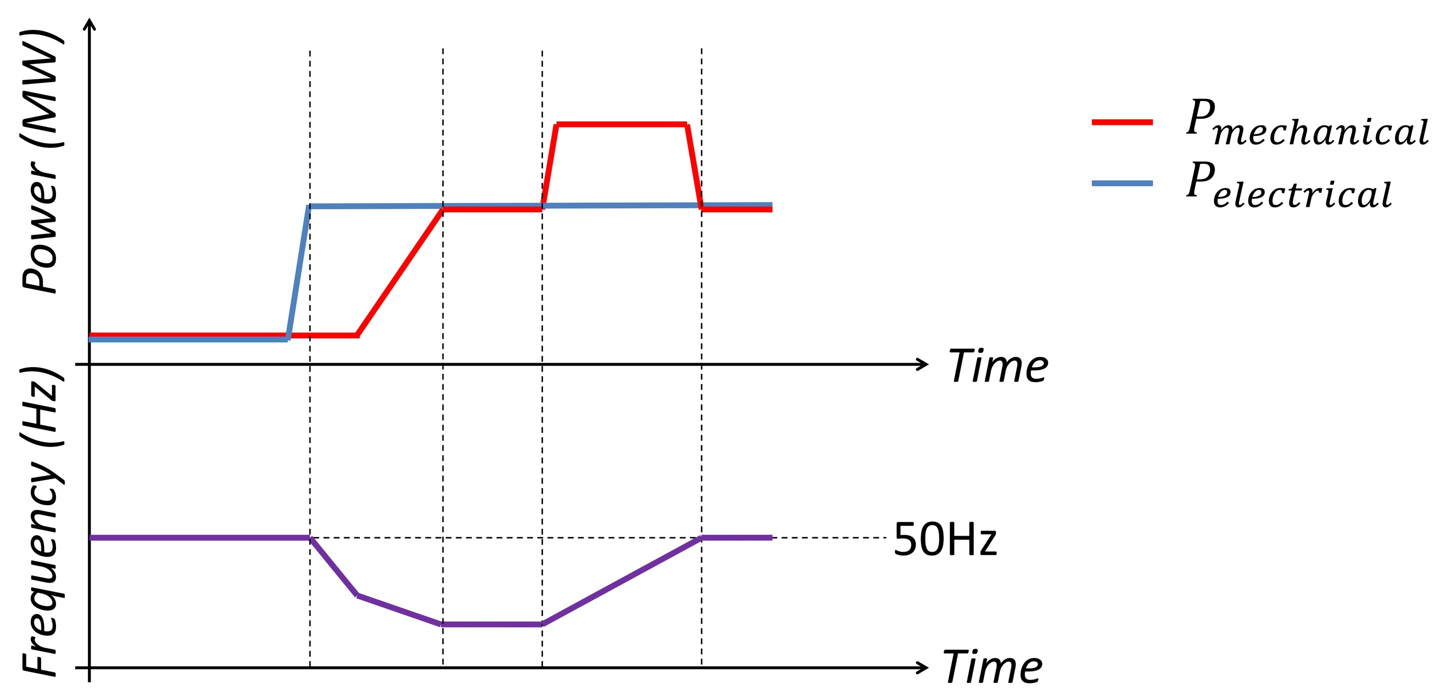
Therefore it is important to minimize frequency fluctuations to reduce the risk of blackout. This is achieved by maintaining a close match between mechanical and electrical power. The matching is achieved by accurately dispatching generation every five minutes to predicted demand, and then using real time balancing to satisfy any differences that the dispatch could not achieve. Variable renewable energy makes the task of matching more difficult both for the dispatch and for the real time balancing because there is uncertainty in the power output of the generator.

Swing Equation

$$2H\frac{d\omega}{dt} = P_{mechanical} - P_{electrical}$$

H *is the Inertia*
ω *is the Angular Velocity*

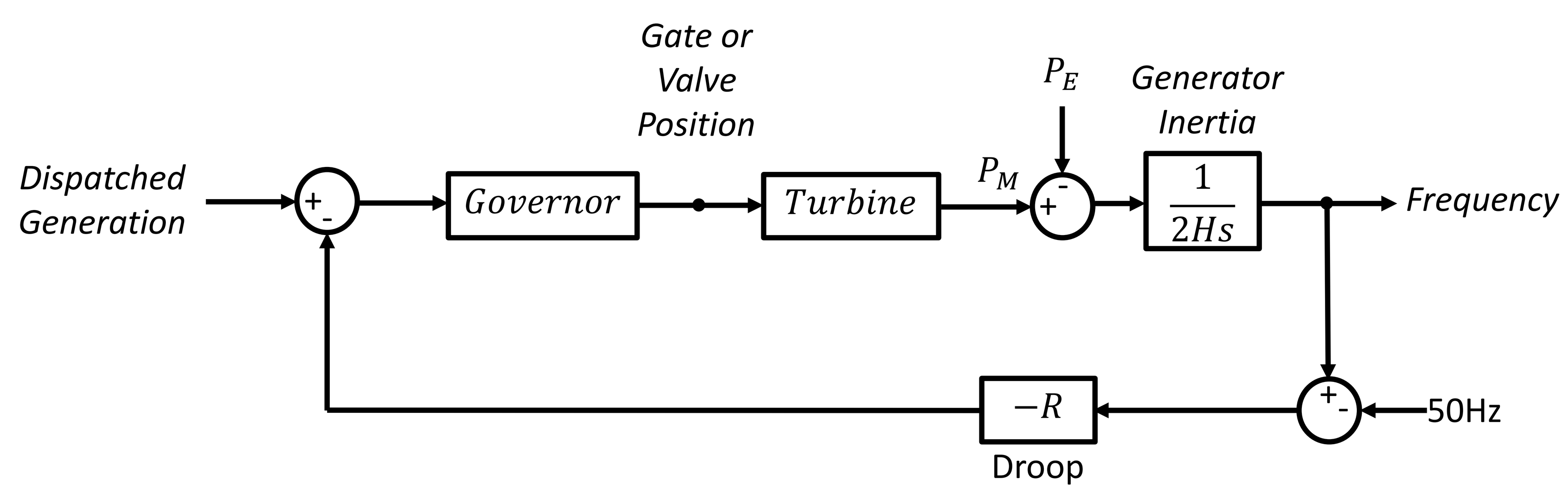
Frequency Fluctuation



Real Time Balancing

The real time balancing of the New Zealand electricity grid is achieved by three services, of which two are procured through a market. The one that is not procured through a market is Frequency Keeping Control which is the adjustment of HVDC power flows to maintain equal frequencies between the North and South Islands. This effectively makes the two islands synchronous with each other and able to share the imbalances between them. The other two are Droop Response and Frequency Keeping. Droop Response is the response of a localized proportional controller on every generator. The purpose of Droop Response is to ensure a fast matching between generation and demand, especially if a large generator is disconnected from the grid unexpectedly. Frequency Keeping is the centralized control of a couple of generators dispatch points. The purpose of Frequency Keeping is to return the frequency back to 50 Hz.

Droop Response

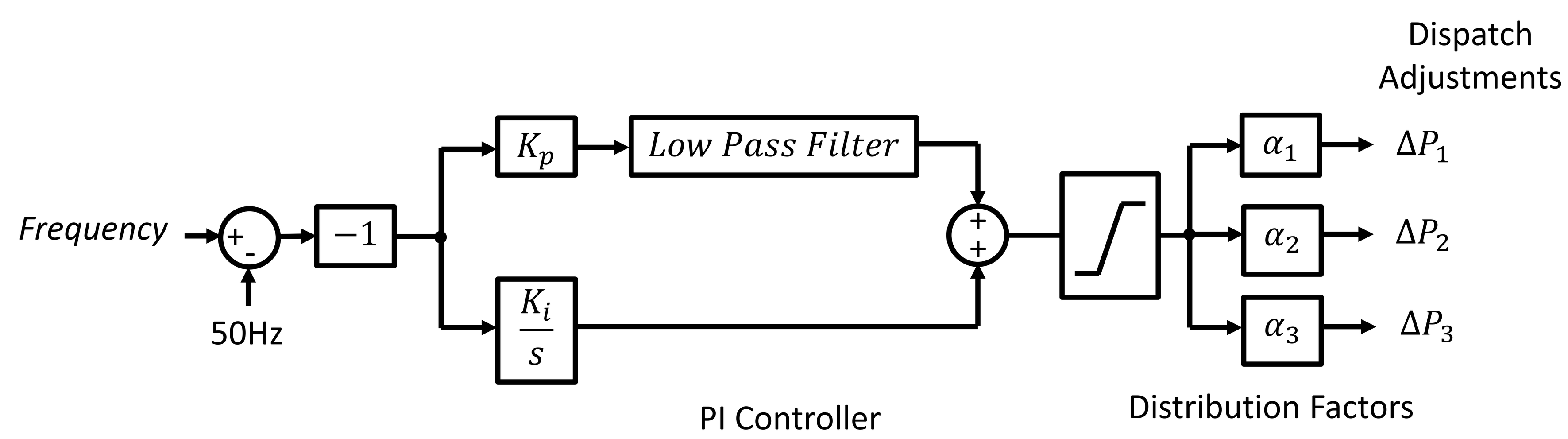


Research

The research looks to develop the procurement methods of Droop Response and Frequency Keeping to allow for non-conventional methods to participate in providing these services. These none conventional methods could be Dynamic Demand Response, Energy Storage Devices, and artificial responses from variable renewable energy sources. The new method will provide a more efficient way of procuring these services. The research will also assess the value and cost of the current services and determine whether the costs are significant enough for new technologies to enter the market.

Dynamic Demand Response is of particular interest because no energy source is required to provide it, and therefore most infrastructure is already there. Dynamic Demand Response works by adjusting the cycling of thermal loads in response to the frequency to emulate droop response, which is achieved by aggregating several smaller loads together.

Multiple Frequency Keeping



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