Power Systems with High Penetration of Wind and Electric Vehicles

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Overview

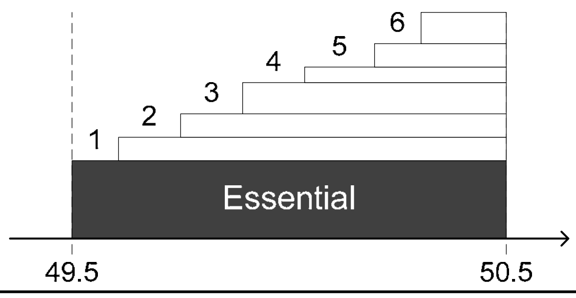
- Introduction to DDC
- Proposed System
- Small scale simulation
- Small scale experiment
- Larger scale simulations
- Conclusions

Dynamic Demand Control

- Type of Demand Side Management
- Smart Grid
  - Information carried by frequency
  - Fast response across the network

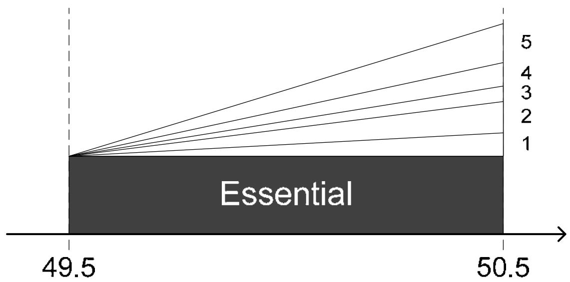
Original Concept for DDC

- All loads are:
  - Essential
    - E.g. security, medical, lighting
  - Prioritised
    - E.g. water heating, drying



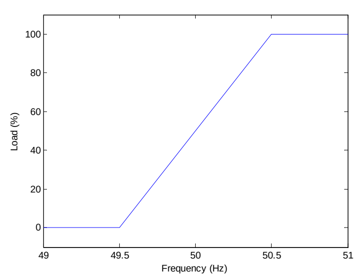
New Concept for DDC

- Add in wind power
  – Available power now stochastic
- Divide loads into essential and controllable
- Make loads variable not on/off

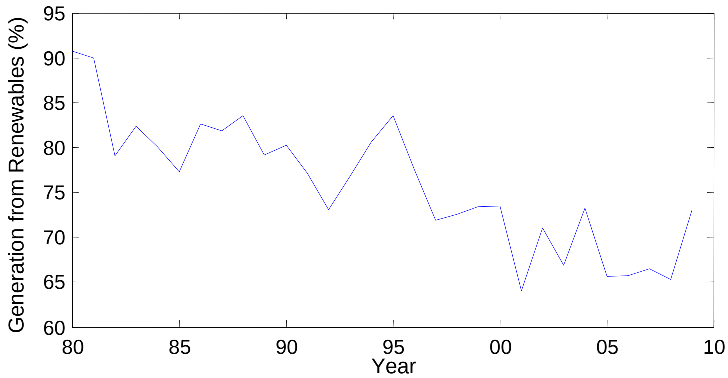


Dynamic Demand Control

- The philosophy:
  – Appliances & energy consumers **adjust their load**
  – Helps balance varying supply & demand
- Achieved:
  – Via mains frequency response



New Zealand's Energy Supply



- 4.9% From wind in 2009

Properties of Wind Power

- Intrinsically unpredictable
- Can sell full amount generated now
  - More problematic with more wind
- Can't all provide frequency and voltage regulation
- More reliable than Hydro (total energy per year)

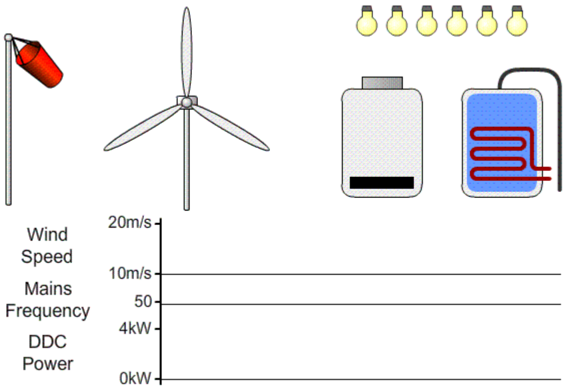
Potential uptake of EVs

- EVs widely available in next few years
- Projected to become cost effective in 10-15 years
- Present a significant burden on network if not managed
- Problematic with synchronised switch on
- Have the potential to improve our power system

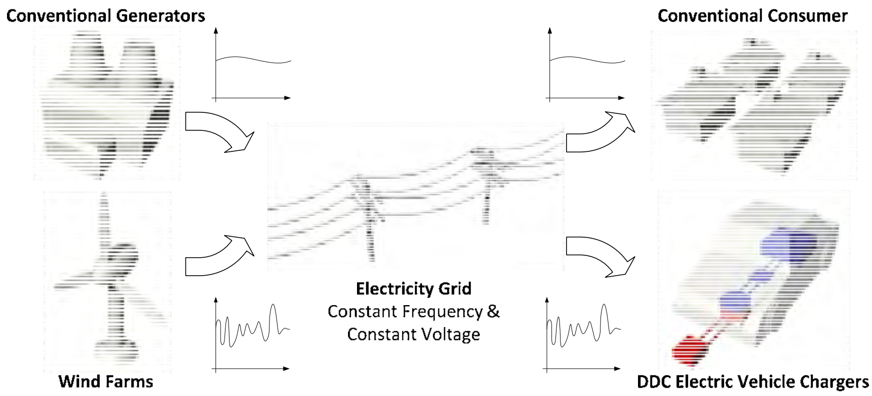
Other applications of DDC

- Any load that is storing energy
  - Refrigeration
  - Water heating
- And load that can be deferred
  - Air conditioning
  - Washing machines / dishwashers

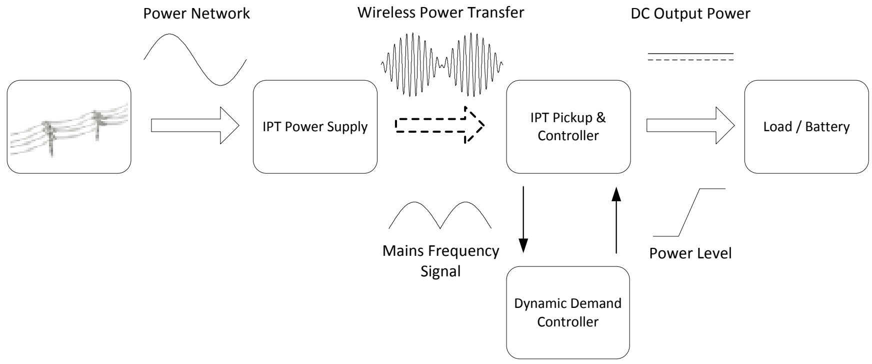
Overview of Dynamic Demand Control (DDC)



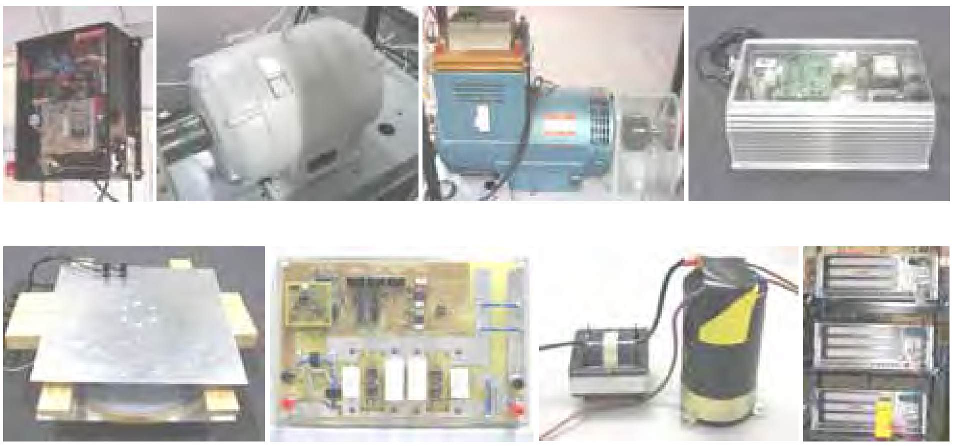
System Overview



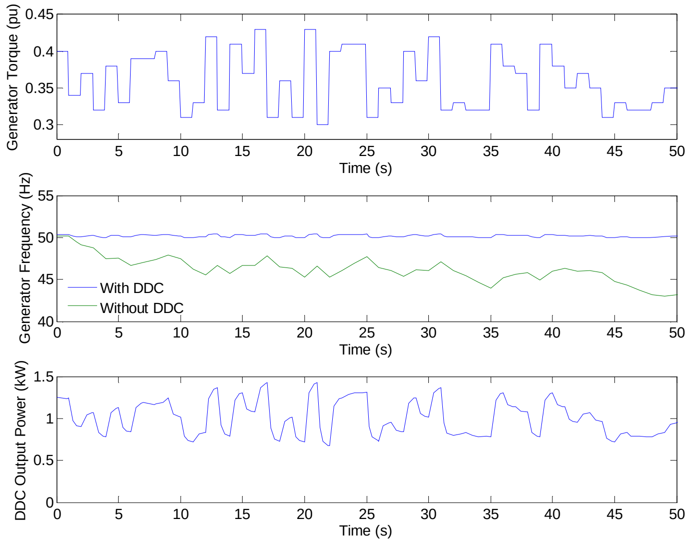
Laboratory scale experiment on motor-generator set



Experimental Setup



Simulation Results



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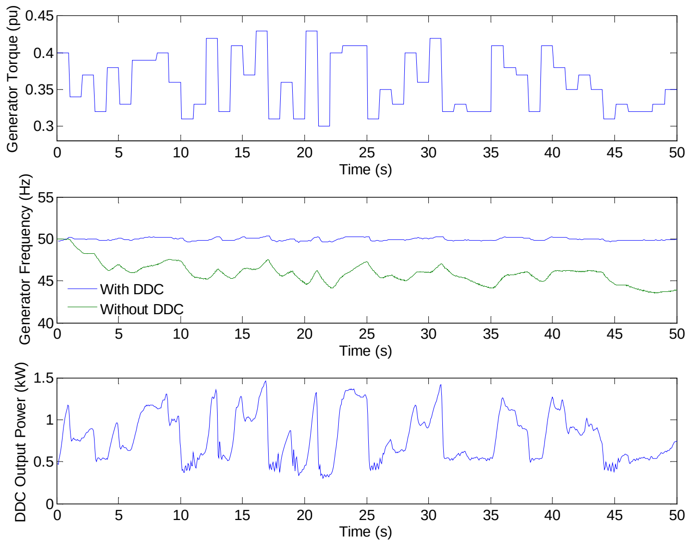
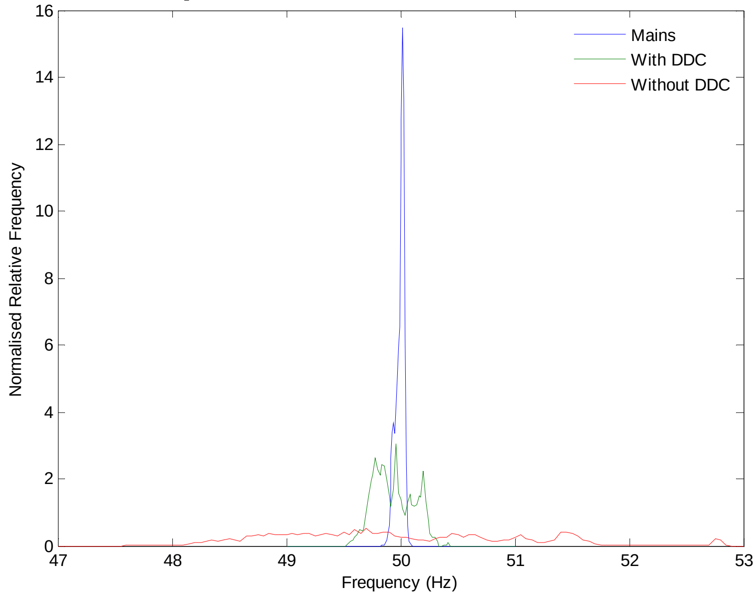


Experimental Results



Experimental Outcome

- 1.6 kW system implemented successfully with Dynamic Demand Control
- System frequency successfully stabilised despite highly variable generation
- **The variable energy can be wheeled through the grid with minimal disturbance**

Larger Scale Simulations

40kW Fixed Diesel Generation

50Hz System Frequency
2% Droop

75kW Average Wind Generation
200kW Maximum Generation

25kW Fixed Load

35kW Average Water Heating Load
300kW Maximum Consumption

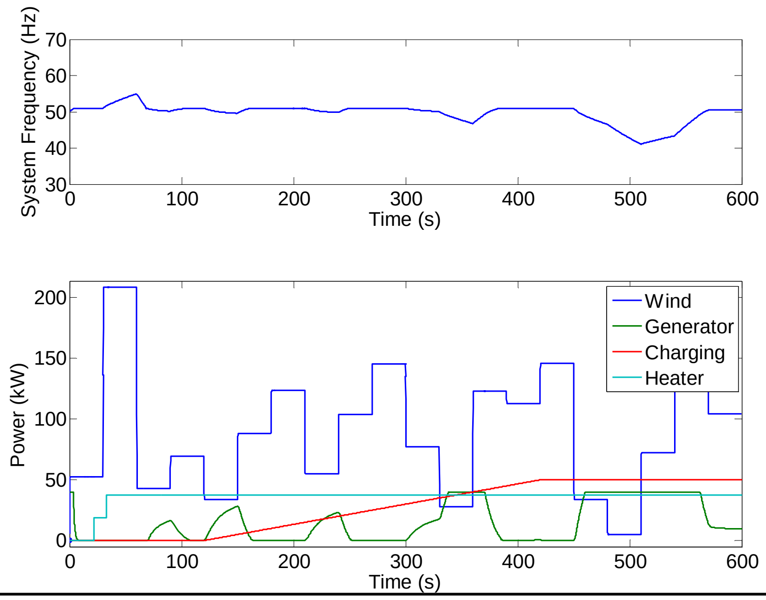
40kW Average EV Charging
60kW Maximum Consumption

EV Switch-on Model Setup

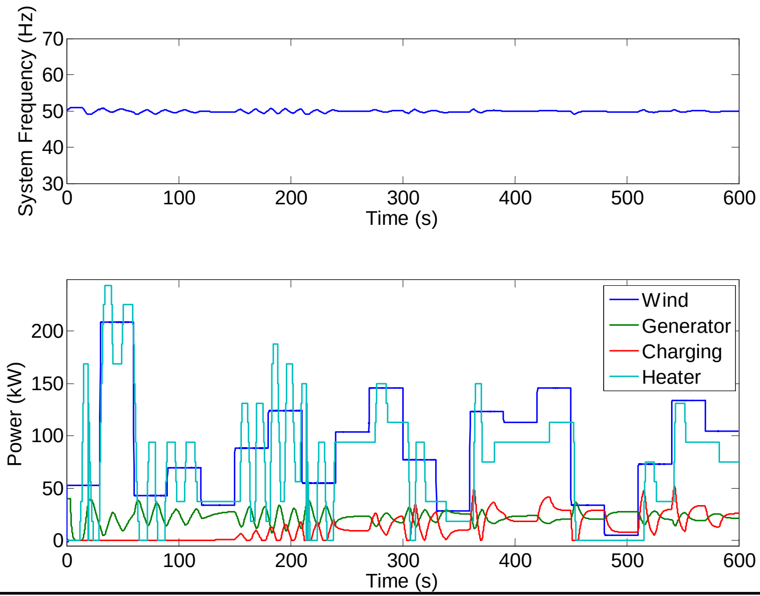
- 40kW Diesel generator
- 75kW Wind generation (average)

- 50kW EV charging (online in 5min)
- 35kW Water heating
- 25kW Fixed load

Switch-on without DDC



Switch-on with DDC

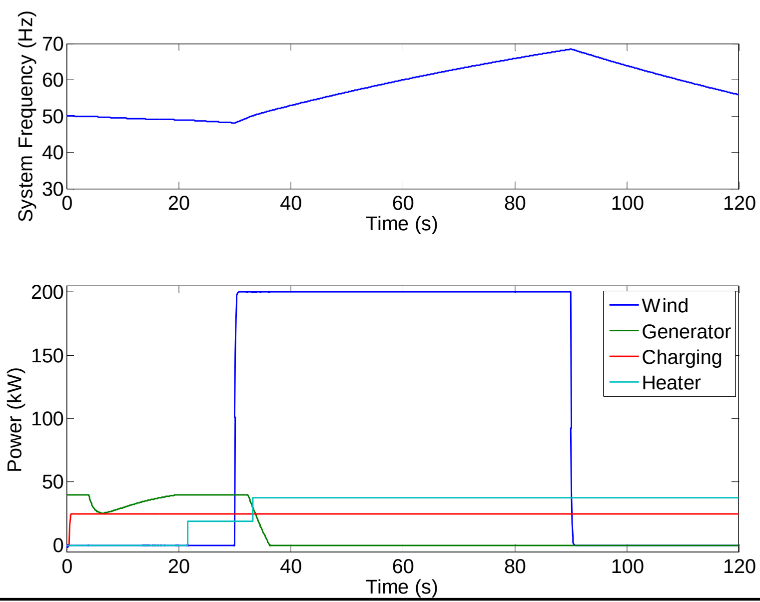


Wind Gust Model Setup

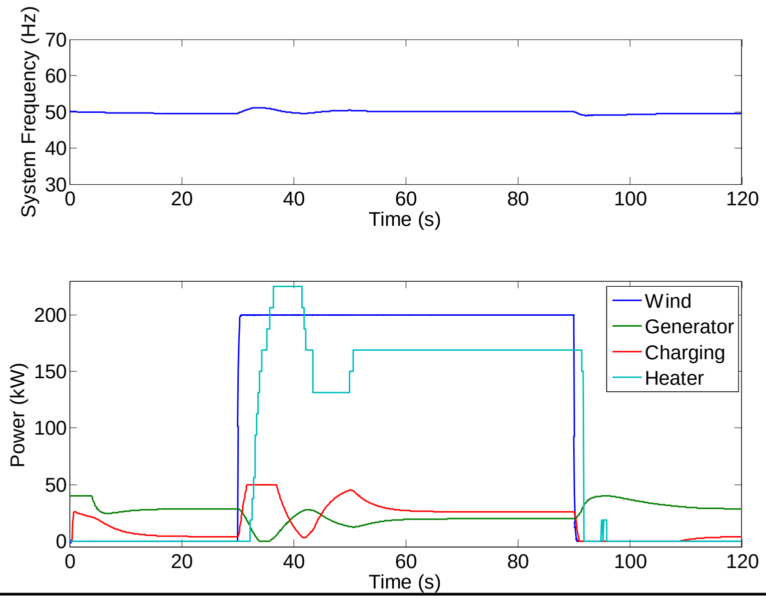
- 40kW Diesel Generator
- 200kW Gust of wind

- 25kW EV charging
- 35kW Water heating
- 25kW Fixed load

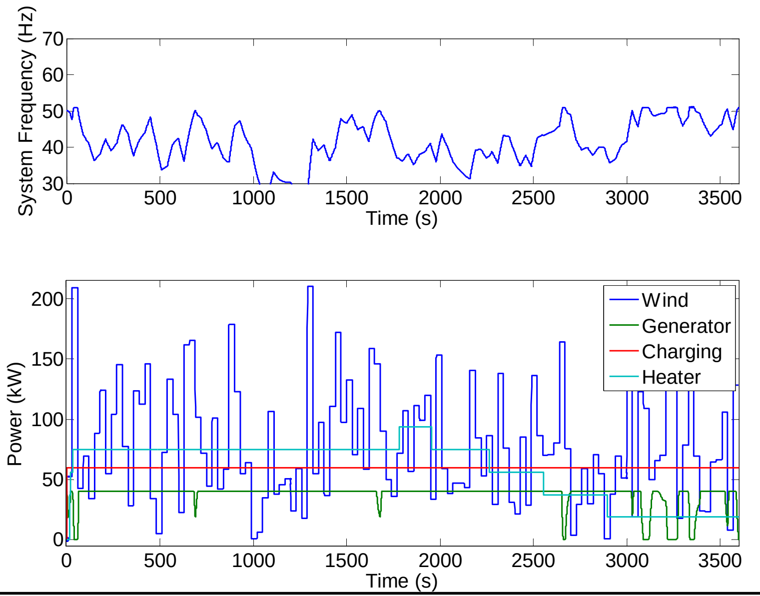
200kW Gust without DDC



200kW Gust with DDC



60min Simulation without DDC



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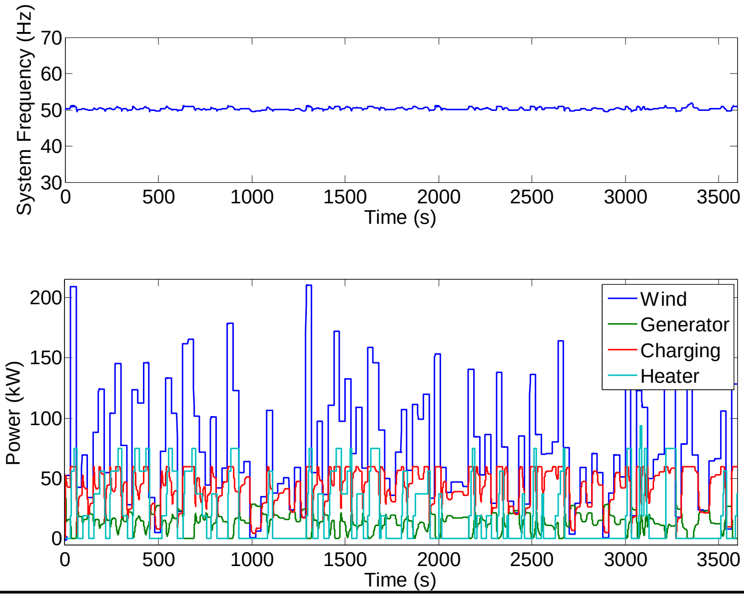

Simulation Results

- A sudden switch-on of EVs can be managed
- A large gust of wind can be absorbed
- Wind is fully utilised so less fuel consumed
  - Generator average: 30kW vs. 14kW

Technology Required

- Smart DDC controllers in appliances
  - Can retrofit or include in new appliances
  - Could have specific DDC circuits in homes
- Smart meters to incentivise DDC usage
  - Capable of metering in order of seconds

Other Advantages

- Controllable load can be identified
  - Measuring response to frequency changes
- Frequency limits set remotely
  - Use smart meter or IT solution
  - Can give priority to specific devices / areas

Conclusions

- Variable and constant power in same network
- Allows inertia-less changes of power
- Controllable load can be determined
- Can create market for wind without backup
- Much higher proportion of wind can be integrated