Synchrophasors in the New Zealand Grid: Operational Experience and Future Applications

NASPI Working Group Meeting
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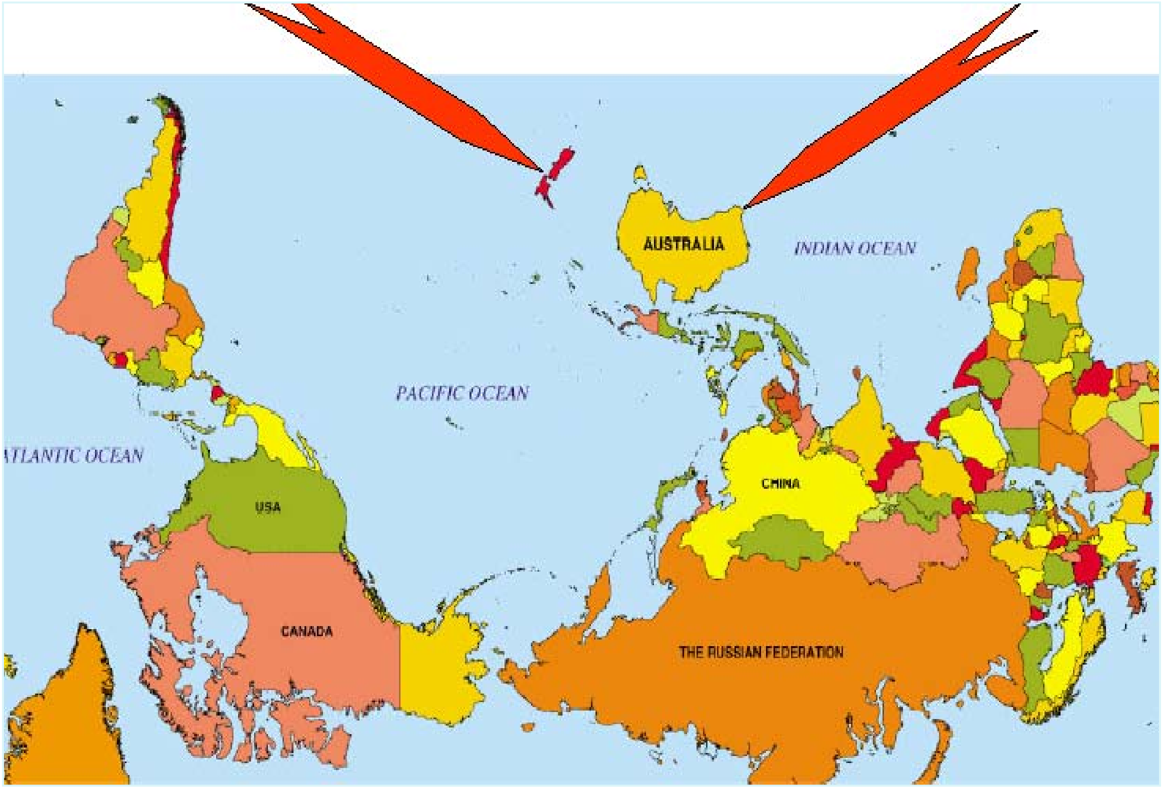
Presentation Outlines

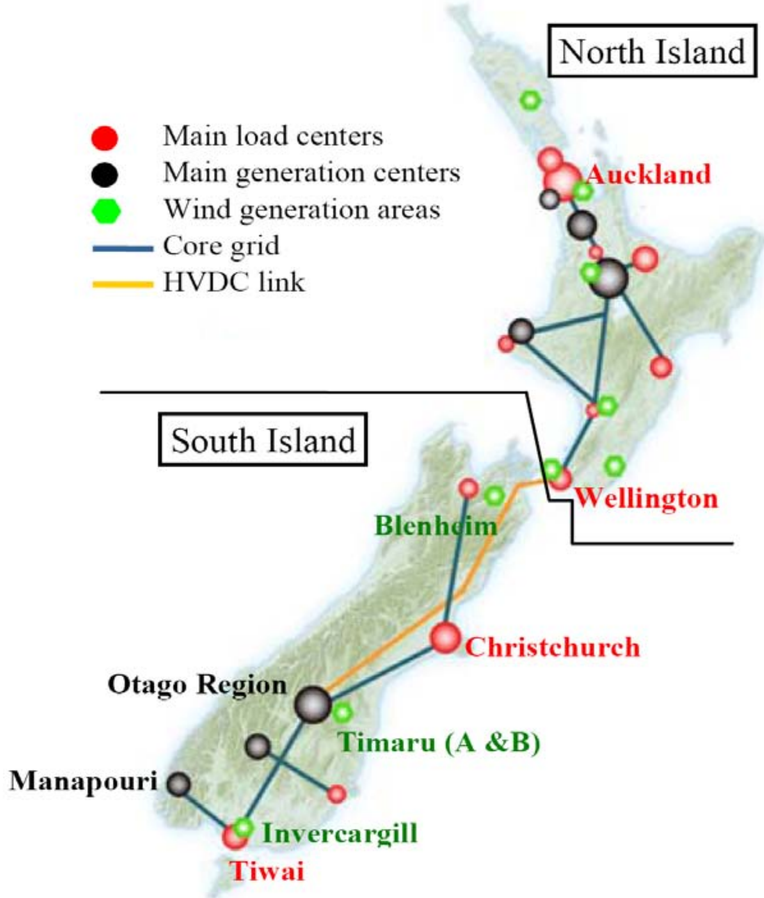
- New Zealand (NZ) power systems
- NZ WAMS project
  - Implementation
  - Operational Experience
- An example: monitoring oscillations
- Future projections
- Concluding remarks

Where are we?



What are we known for? Sheep; Anti-nuclear legislation; Clean & Green; Kiwi ingenuity (e.g. ripple control, SWER lines); All-Blacks; Kiwi fruit; Sav Blanc wines; Bungy; World's fastest indian; Lord of the Rings; High rating: transparency, peace, quality of life etc. consistently

NZ Power System



		North	South
Installed Capacity (MW)	Sync.	5300	3400
	Async.	260	58
Demand (MW)	Peak	4620	2330
	Min.	1680	1300
HVDC link capacity (MW)	N -> S	626	600
	S -> N	960	1040

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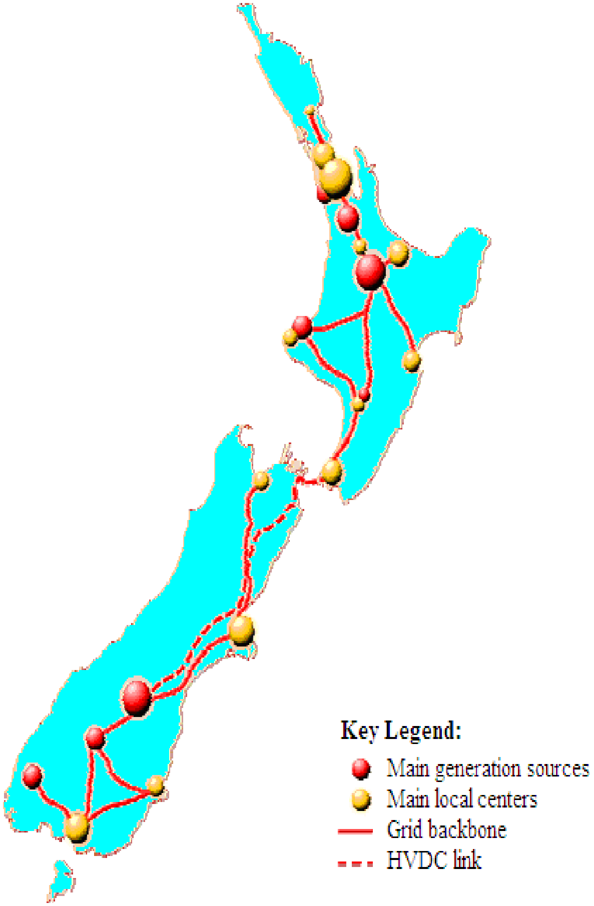
NZ Power System

- Power flows from South Island (SI) to North Island (NI) via 350 kV, 1050 MW HVDC interlink
- Total annual electricity consumption ~ 40 TWh
- Expected increase to average ~2% per year (without EV's off course)
- Major portion from hydro generation : ~24 TWh (55-60%): SI 100% renewable
- Wind: 3% and increasing; Geothermal: 9% and increasing
- Transmission levels: 220 kV, 110 kV, 66 kV, 50 kV
- Large NI Load (Auckland): Voltage stability constrained



Structure

- Electricity wholesale market since 1996. Very first of its kind as a second generation market structure
- LMP market model (about 244 pricing nodes)
- GenCos, DisCos, Retailers, Electricity Commission (2004-10)
- Current additions: FTR's, EnergyHedge, Scarcity Pricing
- Grid Upgrades: Reliability and Economic Investment Framework
- Transmission Demand Side Participation Trials
- Around 28 DIStribution line Companies: Smart-meter rollout since 2008
- 2009 Electricity Market Review: Regulatory structure change, DisCo can own DG upto 100 MW recommendation, ETS kicks-in 1 July 2010

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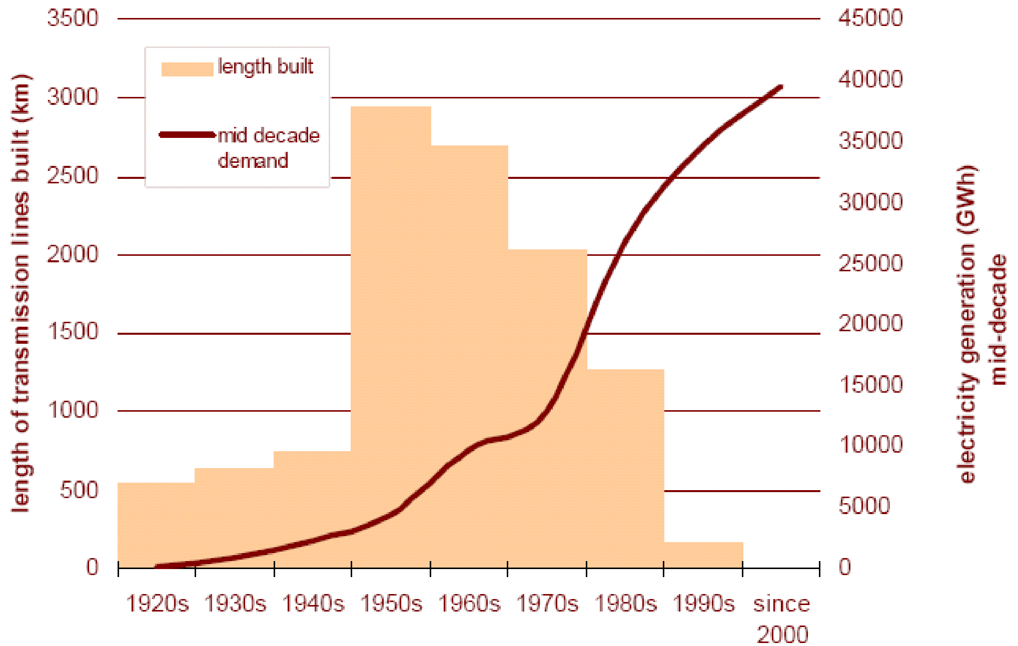
Meeting the Demand: Transmission



- Increase in transmission stress
- Grid is prone to small-signal instability (Focus of existing PMU infrastructure)
- 400 kV NI core grid upgrade ongoing: (Initially to be operated at 220 kV)
- Transmission for Renewables : Approved (2009)
- Power Electronics: HVDC, SVC, plans for Series Capacitor and STATCOMS

Implementation

Motivations of WAMS

- Validate models
- Enhance network visibility
- Optimize grid investment
- Explore opportunities for protection

History

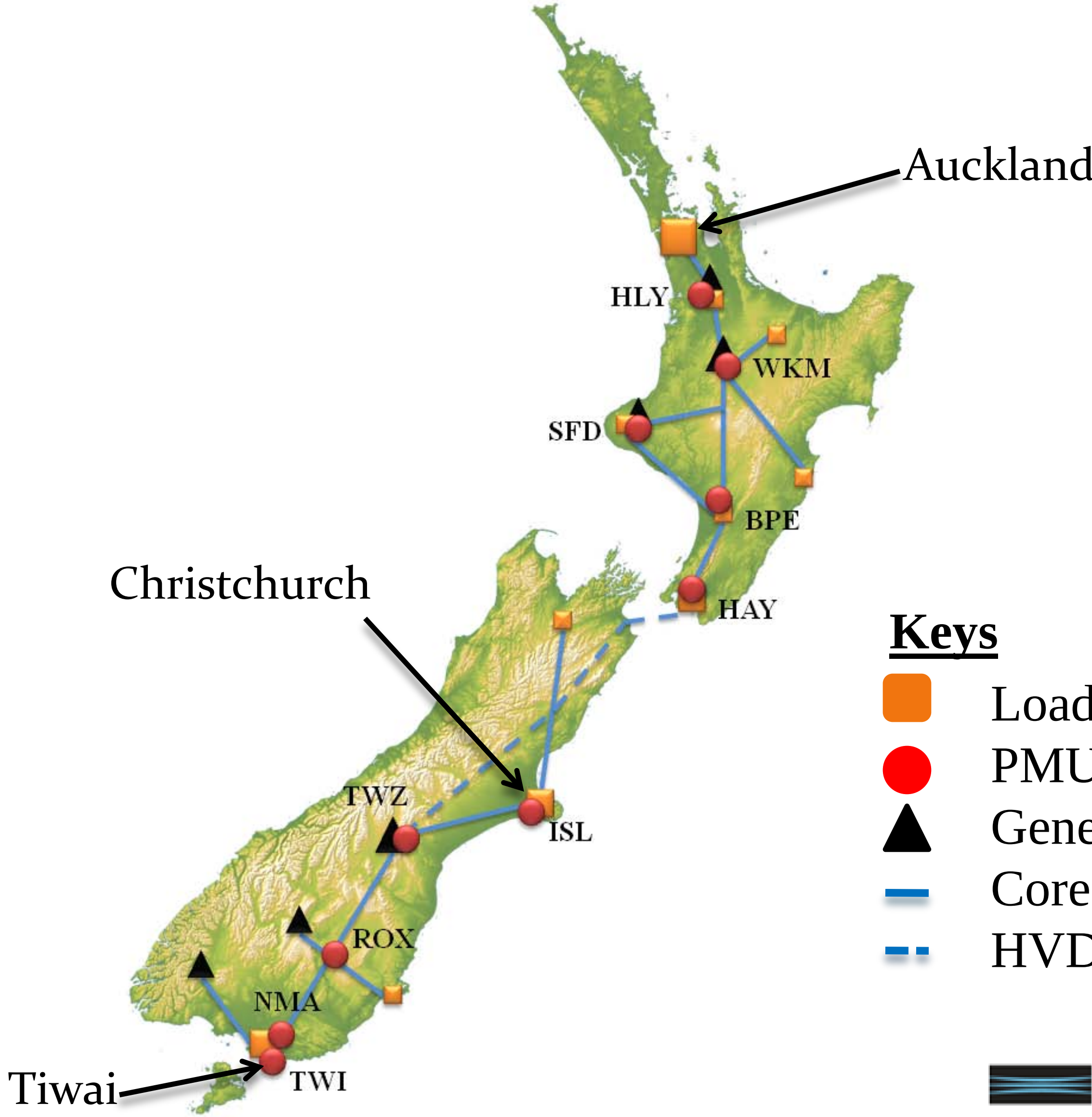
- Began in April 2007
- Initial planned 9 PMU sites
- The 9 PMU were installed and testing commenced in November 2007
- The sites entered service from January 2008, all were in service by April 2008
- Currently 10 PMUs are in service, with plans to add 3 more per year.
- Oscillation monitoring and model planning applications are currently operational [offline]

Installation of PMU

- PMUs are part of line protection relays
  - Pros: Reduce network investments
  - Cons: Lose visibility during line outages; standardization
  - Looking at installing for all lines in the future

- Operational sites:
  - Huntly (HLY), Whakamaru (WKM), Stratford (SFD), Bunnythorpe (BPE), Haywards (HAY)
  - Islington (ISL), Twizel (TWZ), Roxburgh (ROX), North Makarewa (NMA) and Tiwai (TWI)

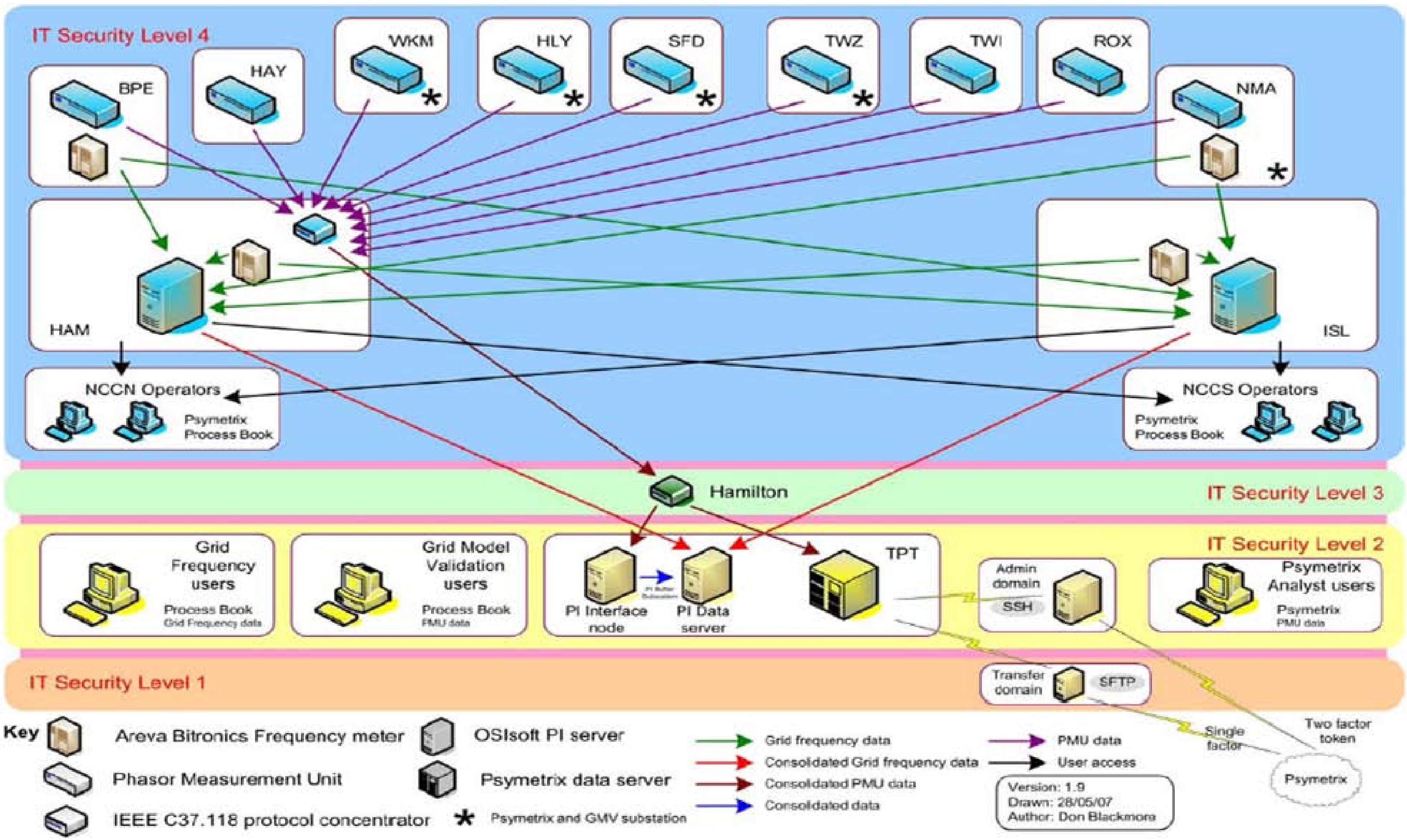
Installed locations



Keys

- Load
- PMU
- Generation
- Core Grid (220 kV)
- HVDC Link

WAMS Infrastructure



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PMU Communication

- Communication bandwidth
  - Causing congestion in existing communication channels
  - Burden over bandwidth amongst data acquisition platforms
  - Currently, communication upgrades (fibre) are underway

- Setting and synchronizing GPS clock
  - Example: North Makarewa PMU went off-line when day-light saving ended
    - Cause of the malfunction is being investigated – the GPS clocks had passed clock change tests (and handled it the year before)
    - Possible solution is to store PMU data using universal time and convert times locally if needed

Operational Experiences

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Model Validation (offline)

- Enhance confidence of simulation results and allow more accurate determination of project timing, control requirements and operational limits
- Ageing equipment with deteriorating performance could be identified more swiftly by monitoring the results of their control actions
- Reductions in testing and commissioning costs by introducing non-invasive evaluation of performance
- PMU installed at Islington (Christchurch) to model the dynamic behaviour of a newly installed SVC

Monitoring Objectives

- Monitor known oscillatory behaviour
- Identify system behaviour that may otherwise be unknown
- Maximize network power transfers (additional wind generation is planned)
- Establish early warning system

Oscillation Monitoring

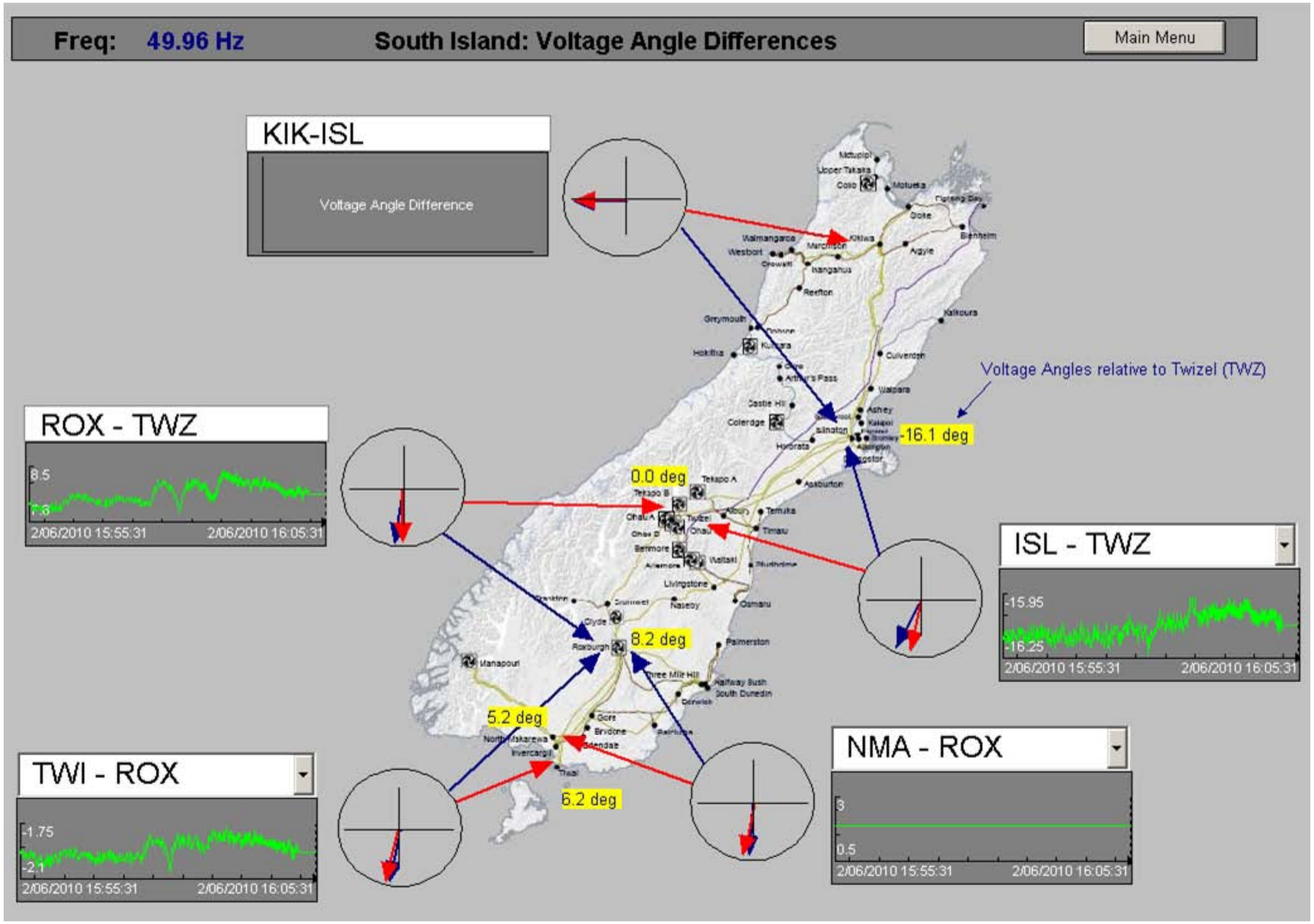
- Transpower criteria is that electro-mechanical oscillations must decay within 12 seconds
- Most of the recorded system event type oscillations (‘ring- downs’) to date have a decay time constant well below 12 seconds
- The existing criteria does not exclude system oscillations of very low magnitude – these will be detected by the monitoring equipment

Oscillation Monitoring (Cont.)

- Warnings are issued when:
  - Monitored time decay constant larger than 12 seconds
  - Oscillatory amplitude of the associated mode is greater than 1 MW

- Present known oscillations are:
  - 0.7 - 0.8 Hz (South Island)
  - 1.1 Hz (South Island)
  - 1.6 Hz (North Island)

Monitoring Snapshot



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Monitoring Example

- 5 February 2008 between 12:30 pm to 12:40 pm
  - 1 lightly damped inter-area oscillations are building up in the South Island: 0.7 Hz
  - Phasor data collected from Twizel (Central South Island) substation
  - Extended Complex Kalman Filter (ECKF) proposed by UoA authors has been explored

Algorithm Formulation

- Summary of the Extended Complex Kalman Filter [*References*]

$$\hat{x}_{k|k} = x_{k|k-1} + K_k (y_k - H x_{k|k-1})$$

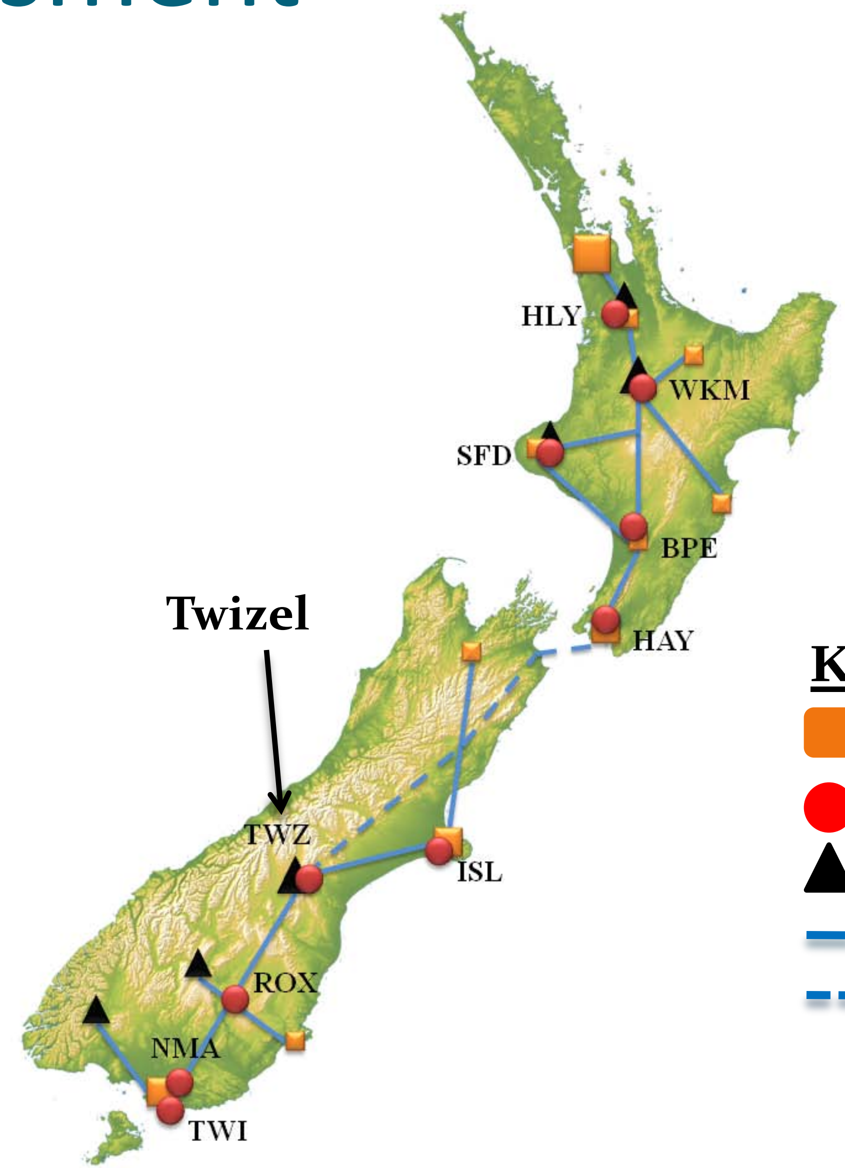
$$\hat{x}_{k+1|k} = f\left(x_{k|k}\right)$$

$$K_k = \hat{P}_{k|k-1} H^H [H P_{k|k-1} H^H + R_k]^{-1}$$

$$\hat{P}_{k|k} = P_{k|k-1} - K_k H P_{k|k-1}$$

$$\hat{P}_{k+1|k} = F_k P_{k|k} F_k^H + Q_k$$

Assessment



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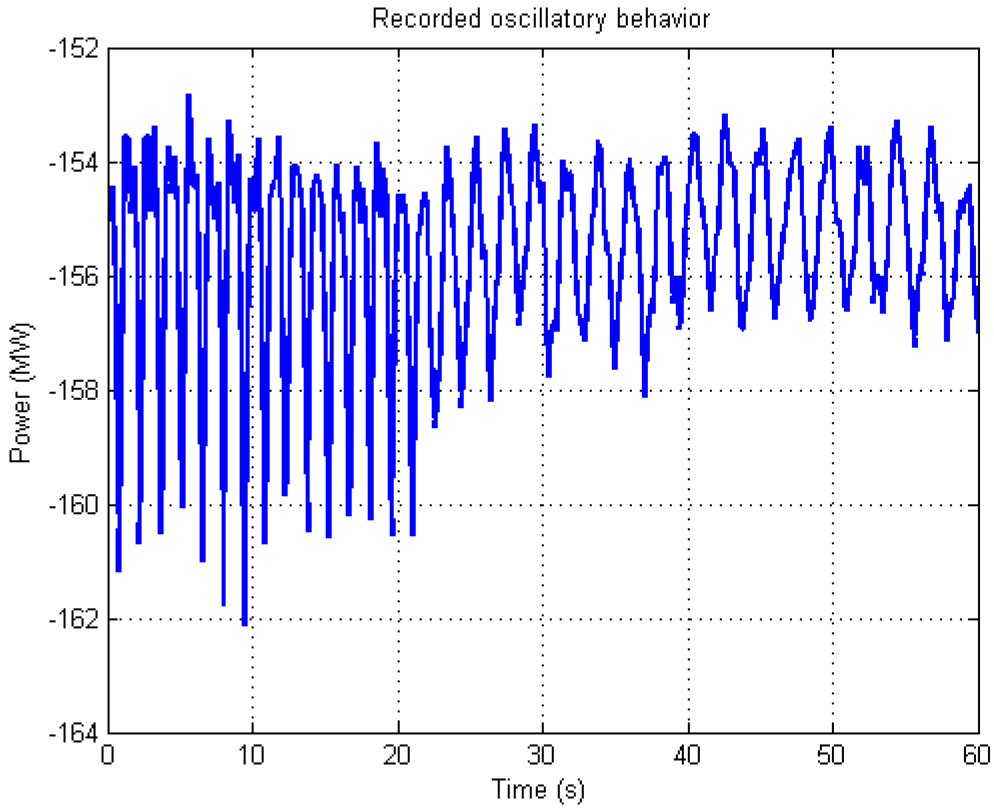
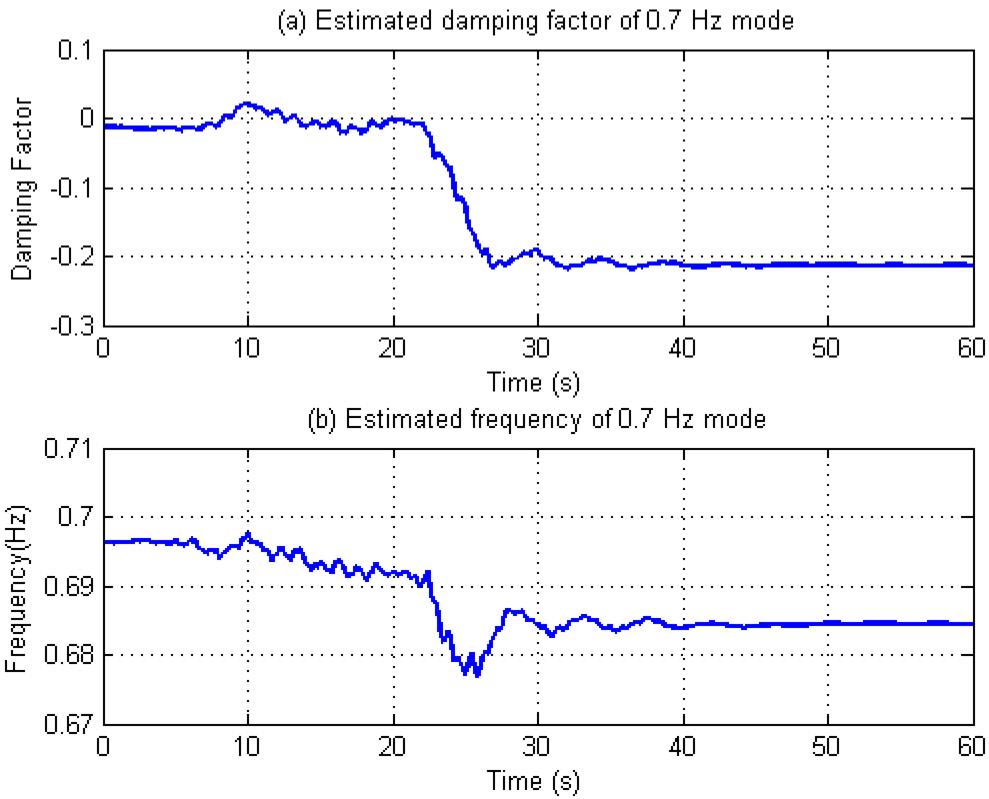
Captured Active Power Transfer



0.7 Hz modal parameters



Future Projections

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Future Projections

- Current plan:
  - At least 3 PMUs per year
- Potential plans:
  - PMU data to be used during HVDC upgrade commissioning and testing (2012)
  - Tuning PSS for enhancing damping performance (both local and inter-area)
  - Apply to smarter reactive compensation
  - Exploring potentials of smarter protection (Transmission 2040 project)

Challenges/Opportunities Ahead

- Enhance operational confidence
- Ability to establish consensus with all stakeholders
- Linking with SCADA / state estimator ?
- Standardization
- Engage/share international experience

Conclusions

- Promising experiences around model validation and oscillation monitoring
- Objective in near future is to continue to install PMU and achieve near or total visibility of NZ grid enabled by fibre communication rollout
- Wide Area Monitoring and Control applications being explored in the context of grid upgrades, reactive compensation and wind dynamics
- Research focus: Coordinated reactive power controller; Back-up/special protection schemes; Standardization (PDC, IEC61850, CIM)
- Engage internationally through IEEE (PES), CIGRE SCs, IET publications and presentations

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