Effect of High Penetration of Wind Generation in South Australia on Damping and Oscillation Modes of the NEM

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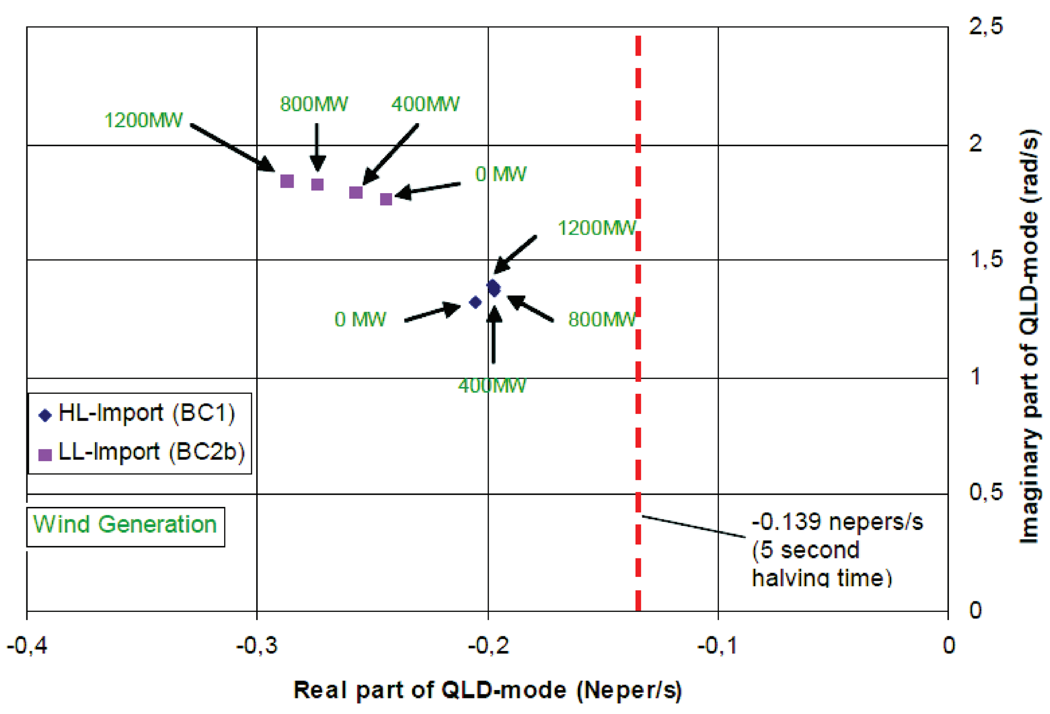
Aim of the Project

- Investigation of high level of wind generation in South Australia on damping ratio and oscillation modes of the 14-generator NEM model.

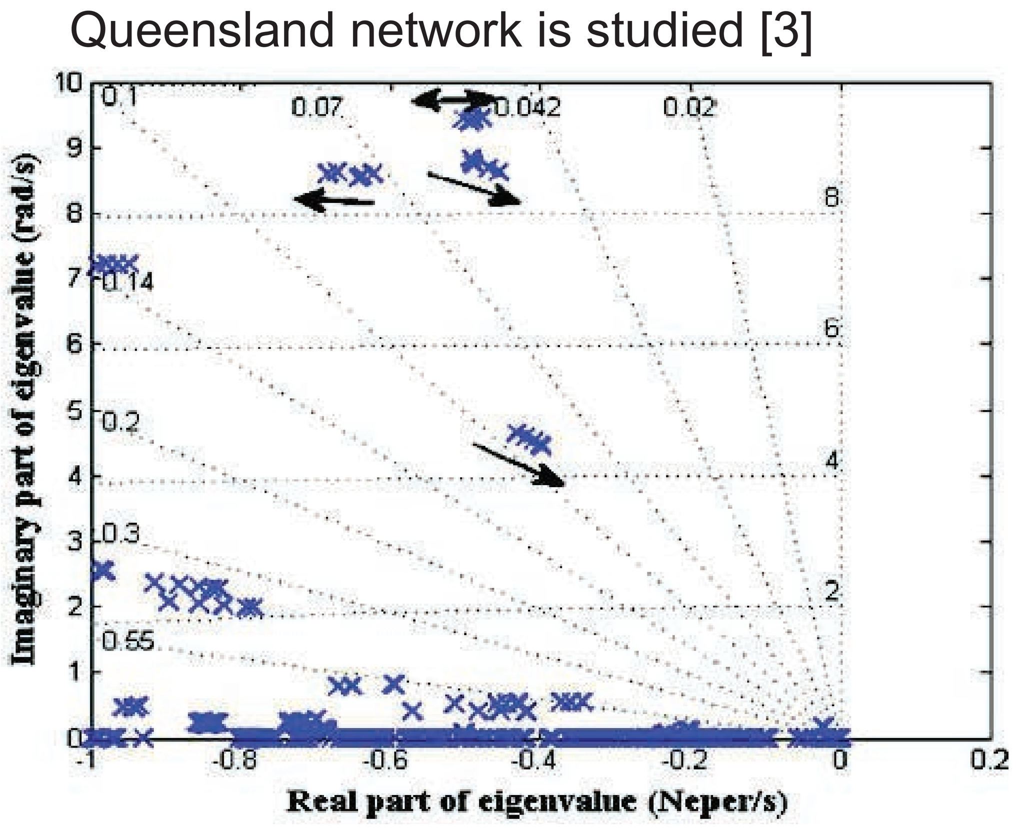
Introduction

- Global warming and Renewable Energy Resources (RES)

- Well-known issues like performance and stability of the power system need to restudied in presence of high penetration of RESs.
- This study focuses on Small signal stability and damping
- NEMCO study in 2005 [1] have studied the effect of high level of wind generation in South Australia.



- Effect of increased wind penetration on Queensland network is studied [3]



Test System

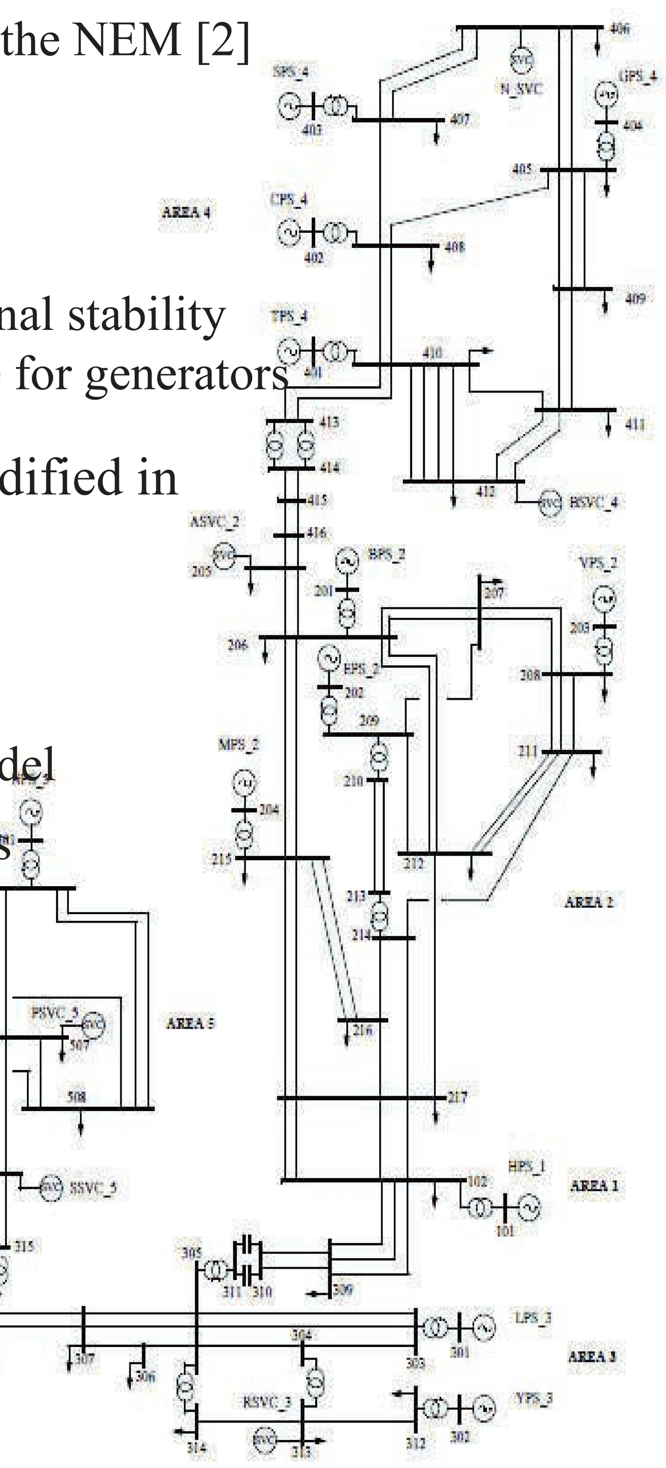
14-Generator model of the NEM [2]

Inspired by the NEM

Proposed for small-signal stability
AVR and PSS available for generators

It is modeled and modified in DIgSILENT

- Governor
- AGC
- Nonlinear load model
- ULTC transformers



Simulation Results and Discussion

Scenario I: Conventional power system

- Heavy Load scenario
- Arnoldi/Lanczos method for modal analysis.
- 8 critical modes are traced in all scenarios.
- Participation factor along with controllability

Dominant Low Frequency Oscillation modes

Mode No.	Frequency (Hz)	Damping Ratio %	Mode Type
1	1.18	5.3	Intra-area 4
2	0.92	7.7	Inter-area 2 & 4
3	0.6	4.4	Intra-area 2
4	0.59	7.9	Intra-area 4
5	0.4	8	Local 3
6	0.27	15.2	Local 4
7	0.26	19.7	Inter area 3, 4 &5
8	0.4	17	Inter area 5 & 3

Wind farm modeling:

- Doubly Fed Induction Generators
- Aggregated wind farm with individual 5 MW wind turbines
- Wind farms operating in P-Q mode

- **Scenario II: Sharing power between wind and conventional generators**
- **Scenario III: Replacing conventional generators with wind**

Scenario II: Sharing power between wind and conventional generators

- Wind turbines are placed on the same busbar as conventional generation.
- Power is shared between conventional generation and wind generation
- Modes 1, 2, 3 and 4 are not affected by wind energy.
- From 0% to 30% modes 5, 6 and 7 are moving toward RHP, making the system less stable. However, increasing wind power sharing beyond 30% in area 5 does not have significant effect on these modes.
- A mode corresponding to inter-area mode for area 5 appears after 30% share of wind power. This mode becomes the dominant mode (lowest damping ratio) after 90% wind penetration.

Scenario III: Replacing conventional generators with wind

- Conventional generators are displaced with wind turbines with the same rating in three steps.
- Modes 1, 2, 3 and 4 are not affected.
- New modes are not necessarily corresponding to base case modes
- General trend is that with increasing wind penetration new modes are appearing closer to RHP .

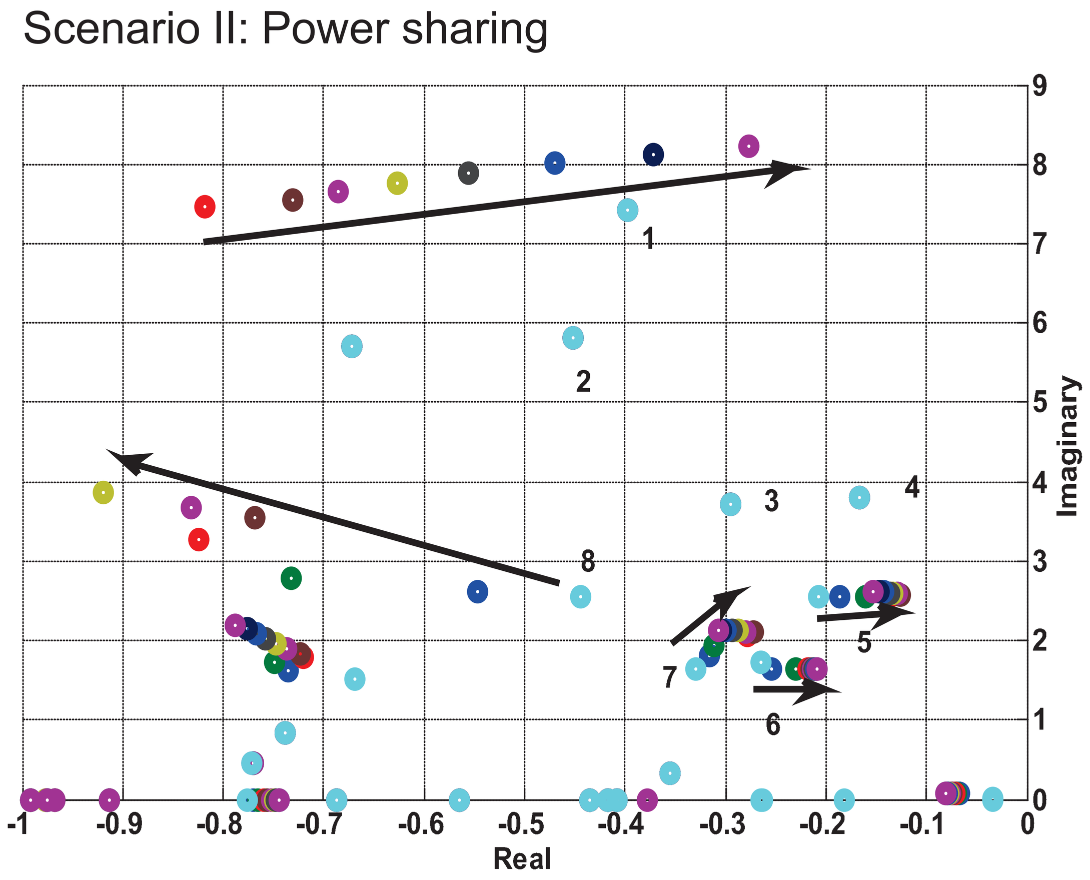
Conclusion and Future Work

- Introduction of wind energy adversely affects local modes as well as inter area modes.
- Highly damped might become a poorly damped mode with increased wind penetration.
- Major effect of increased wind penetration is on neighboring areas
- Sensitivity analysis of diverse RESs on damping and frequency stability.
- Effect of wind farm operation mode on small signal stability and damping

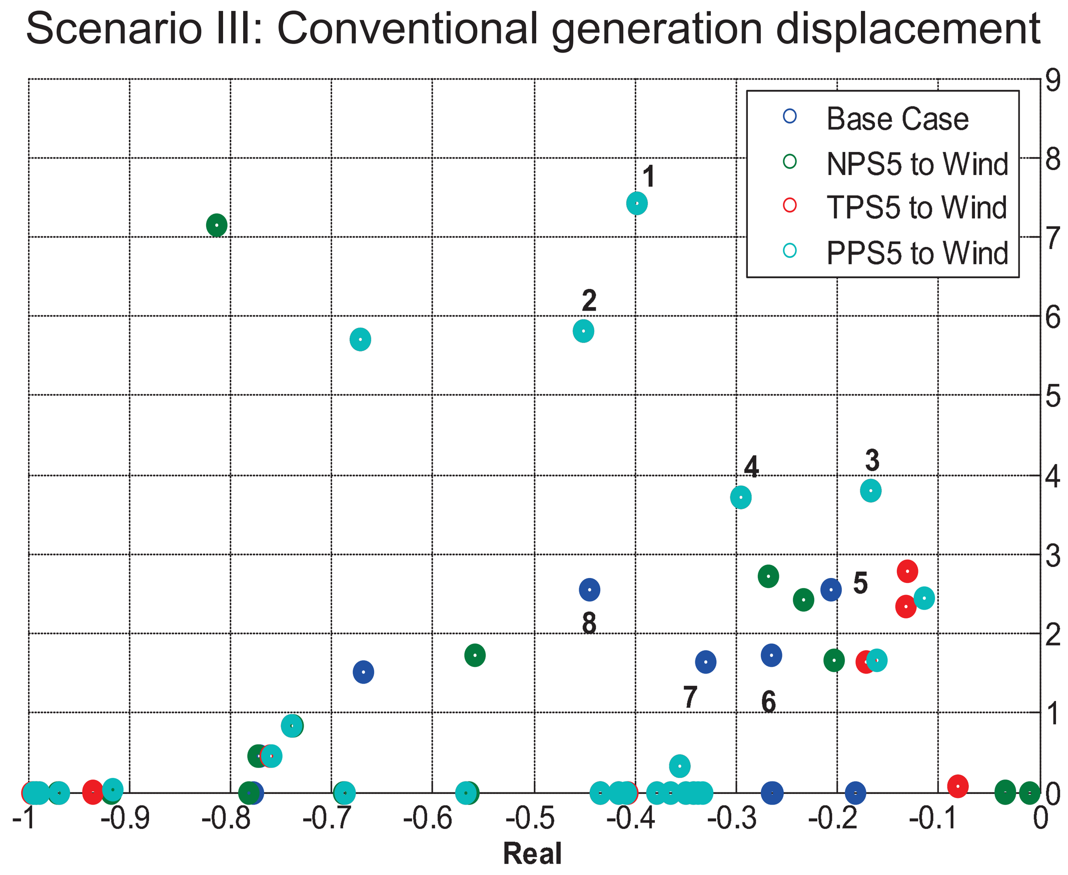
References

[1] H. M. Markus Pöller, et al. "Assessment of potential security risks due to high levels of wind generation in South Australia-Summary of DIgSILENT Studies (Stage1)," NEMMCO 5 December, 2005.
[2] Mike Gibbard & David Vowles, “14-generator model of the SE Australian power system”, The University of Adelaide, South Australia 30 June 2010
[3] N. Modi, et al. "Damping performance of the large scale Queensland trans-mission network with significant wind penetration," Applied Energy, vol. 111, pp. 225-233, 11// 2013.

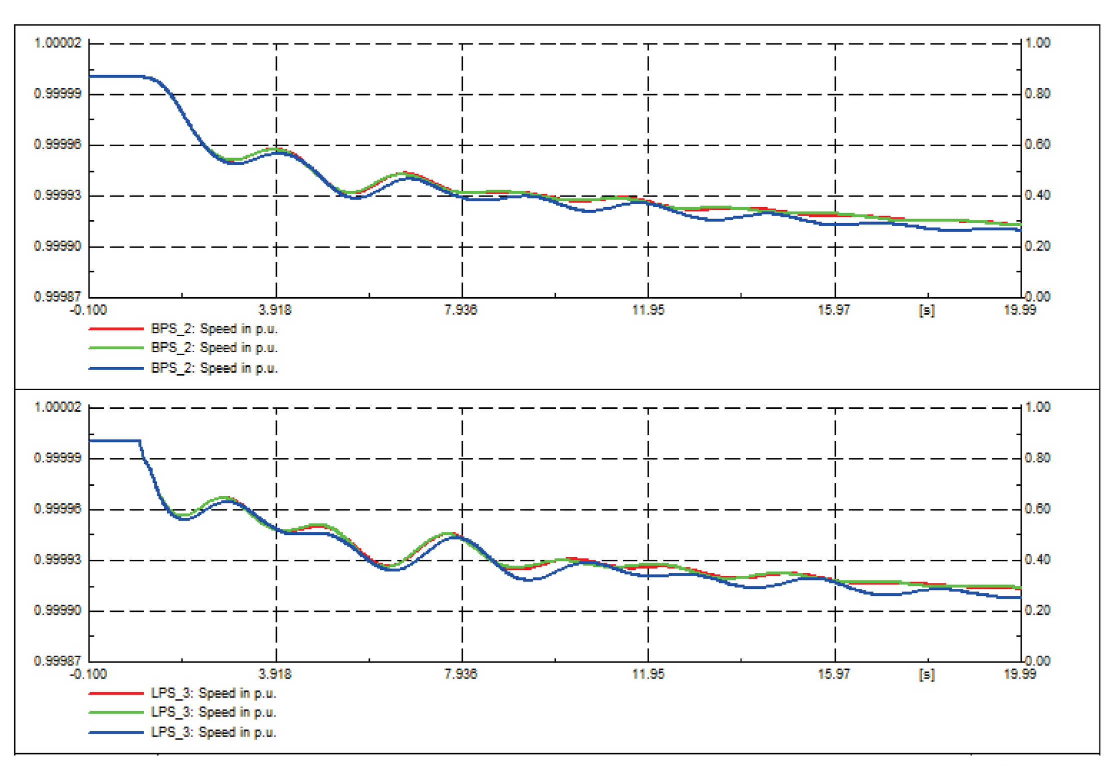
Scenario II: Power sharing



Scenario III: Conventional generation displacement



BPS_2 and LPS_3 rotor speed for three scenarios
Red: scenario I, Green Scenario II, Blue: Scenario III



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