Demand Response Modeling for Performance and Stability Assessment of Future Grid Scenarios

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I. Aims

- To study the influence of Demand Response (DR) on balancing, loadability and voltage stability of future grids with increasing wind penetration.

II. Introduction and Existing Studies

Introduction

- High penetration of diverse Renewable Energy (RE) systems and storage in power systems

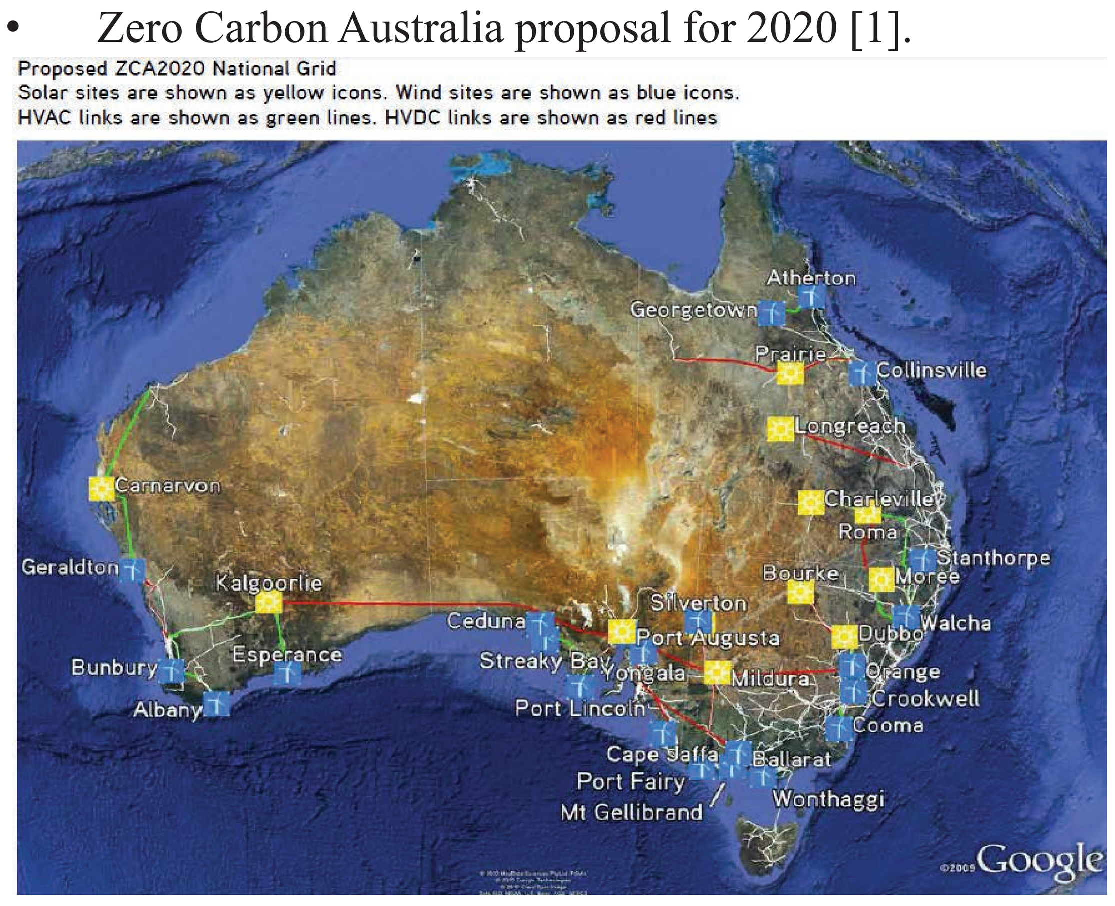
- Evolution of power systems:

Old	New
Conventional generation	High penetration of diverse RE and storage
Generation follows load- dispatch	Load/storage follows generation- DR

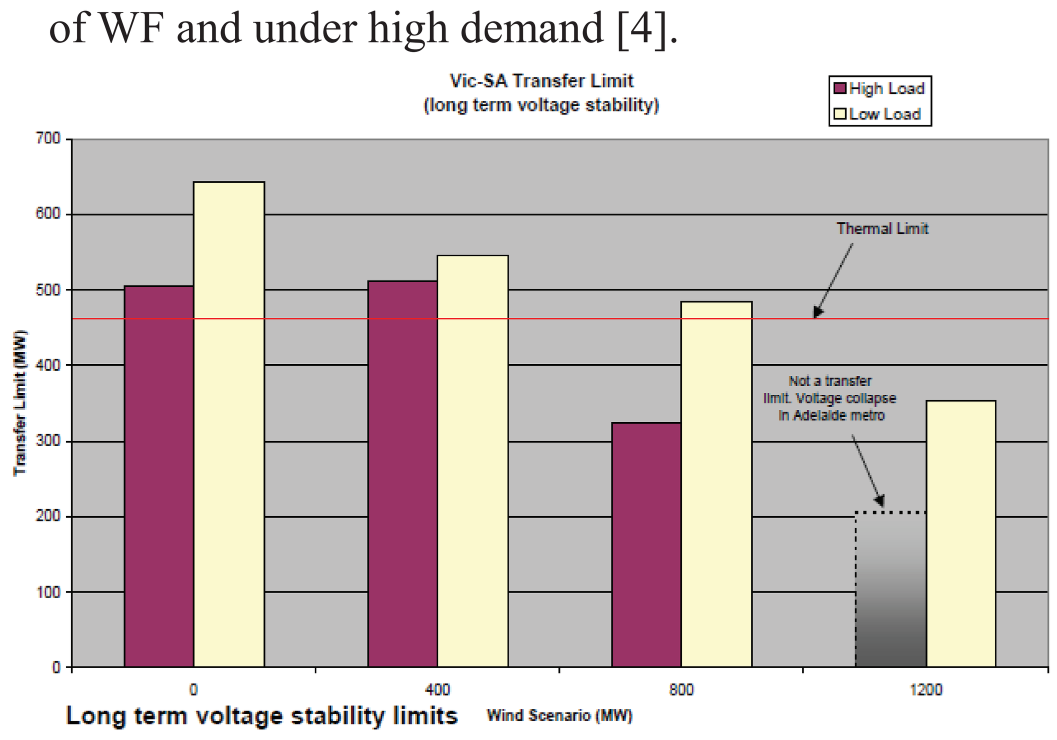
- What the future grid will look like? Is it stable? What control is needed?

Existing Studies

- Zero Carbon Australia proposal for 2020 [1].



- To rely 100% on RE in the NEM is technologically feasible. Winter peak load can be met through delaying CSPs dispatch and/or demand reduction [2].
- High penetration of RE results in electricity price increases over decades due to grid upgrades and the carbon price [3].
- With high penetration of wind in SA (1200 MW), system voltage stability margin reduced and voltage collapse occurred in Adelaide due to high penetration of WF and under high demand [4].



- There are some similar studies on PJM, California and Europe power systems.
- However,
  - Transmission system is mostly ignored and copper plate model has been used.
  - Conventional load models (linear or nonlinear) are used and DR has been neglected.
  - Stability assessment has been ignored.

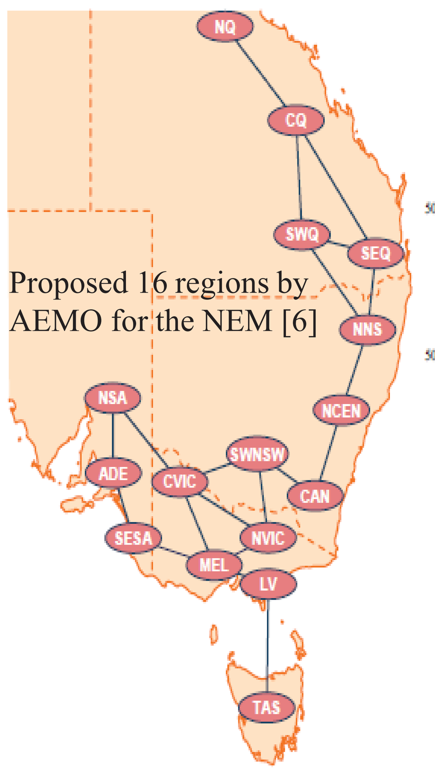
III. Network Topology

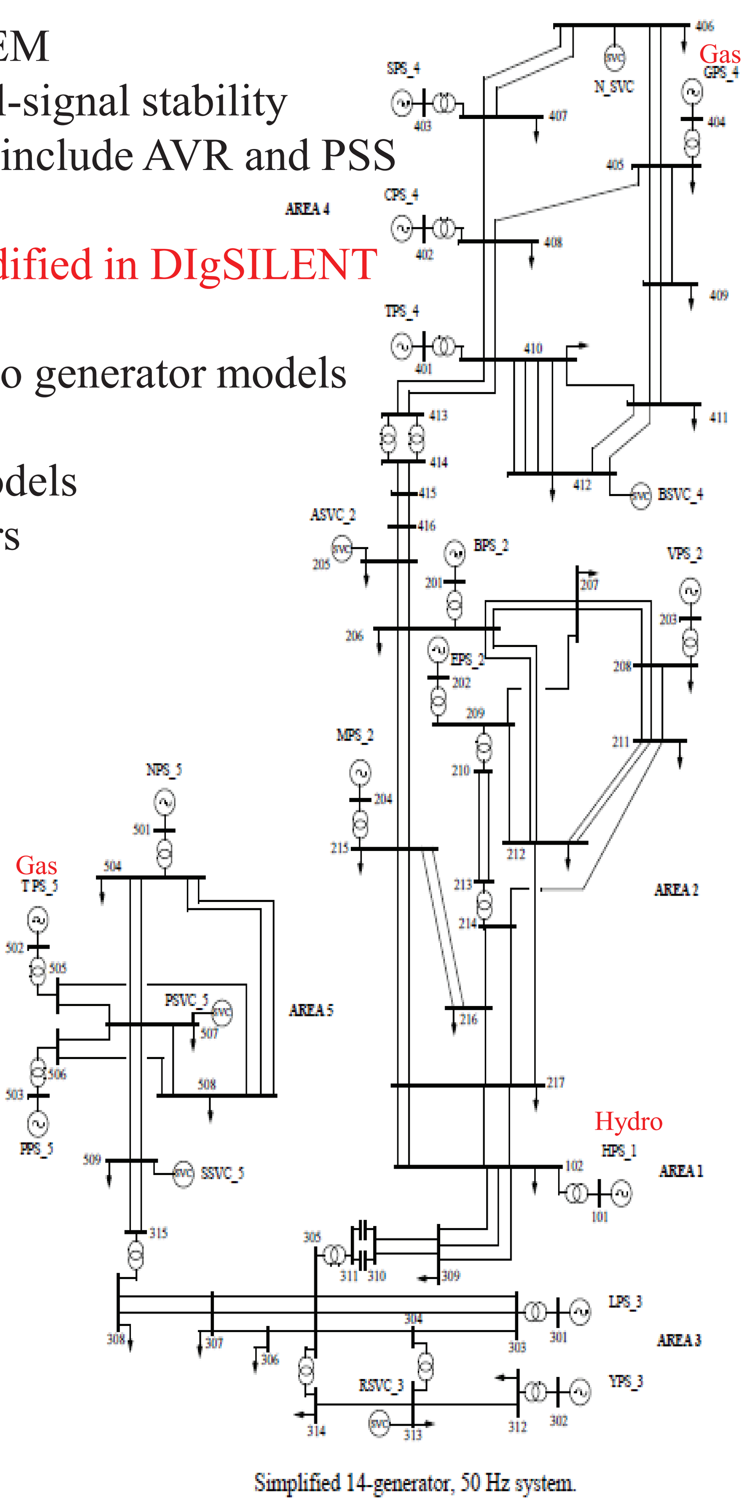
14-Generator model of the NEM [5]
Area 1: Snowy, Area 2: NSW, Area 3: VIC, Area 4: QLD
Area 5: SA

- Inspired by the NEM
- Proposed for small-signal stability
- Generator models include AVR and PSS

It is modeled and modified in DIgSILENT

- Governors added to generator models
- AGC
- Nonlinear load models
- ULTC transformers





IV. Demand Modeling Considering DR

- Conventional models are invalidated in presence of PV, DR, etc. However, we still want to be able to represent demand in an aggregated manner for stability analysis.
- DR model inspired by the smart home concept [7].

Grid: $P_{grid}^{min} \leq P_g(n) \leq P_{grid}^{max}$

PV: $0 \leq P_{PV}(n) \leq P_{PV}^{max}$

Household: $0 \leq P_L(n) \leq P_L^{max}$

Battery: $B_{rate}^{dis} \leq P_b(n) \leq B_{rate}^{cha}$

$$B_{soc}(1) = B_{soc}^{min}$$

$$B_{soc}(n) = B_{soc}(n-1) + P_b(n-1), n > 1$$

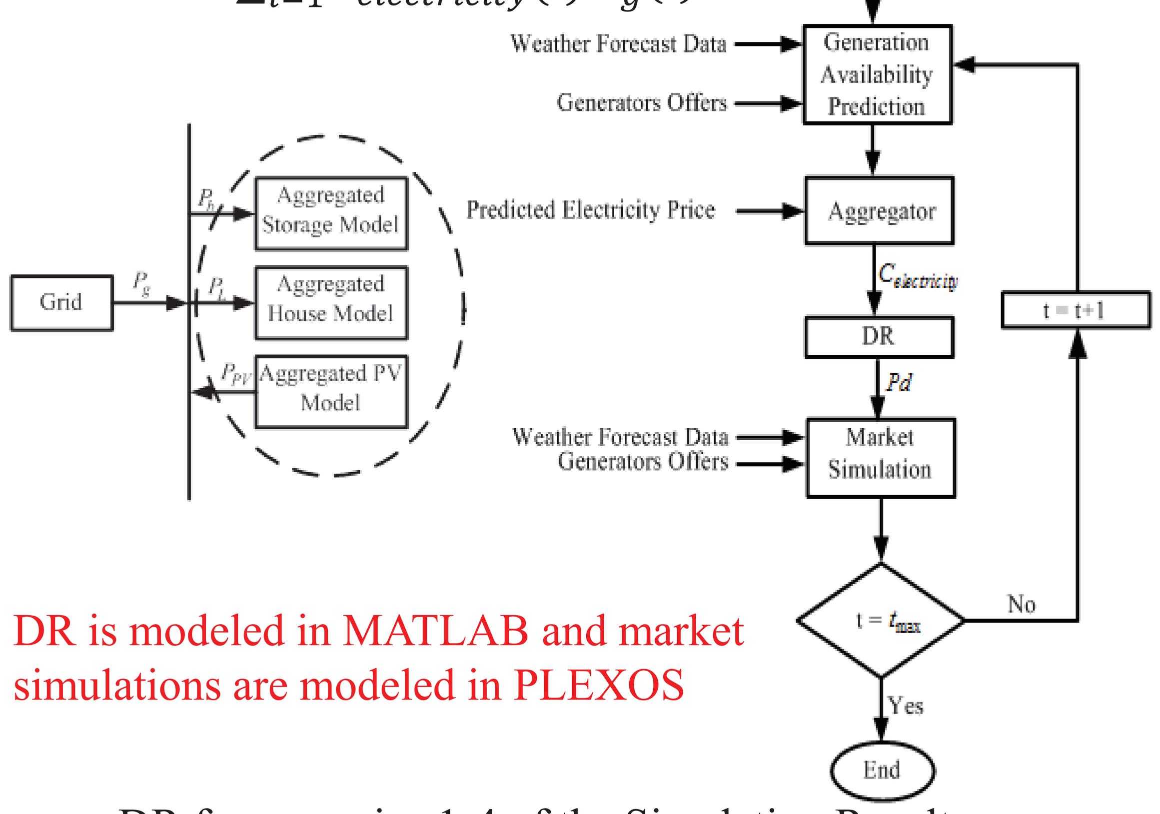
$$B_{soc}^{min} \leq B_{soc}(n) \leq B_{soc}^{max}$$

Balancing equation:

$P_g(n) = P_L(n) - P_{PV}(n) + B_{eff} P_b(n)$

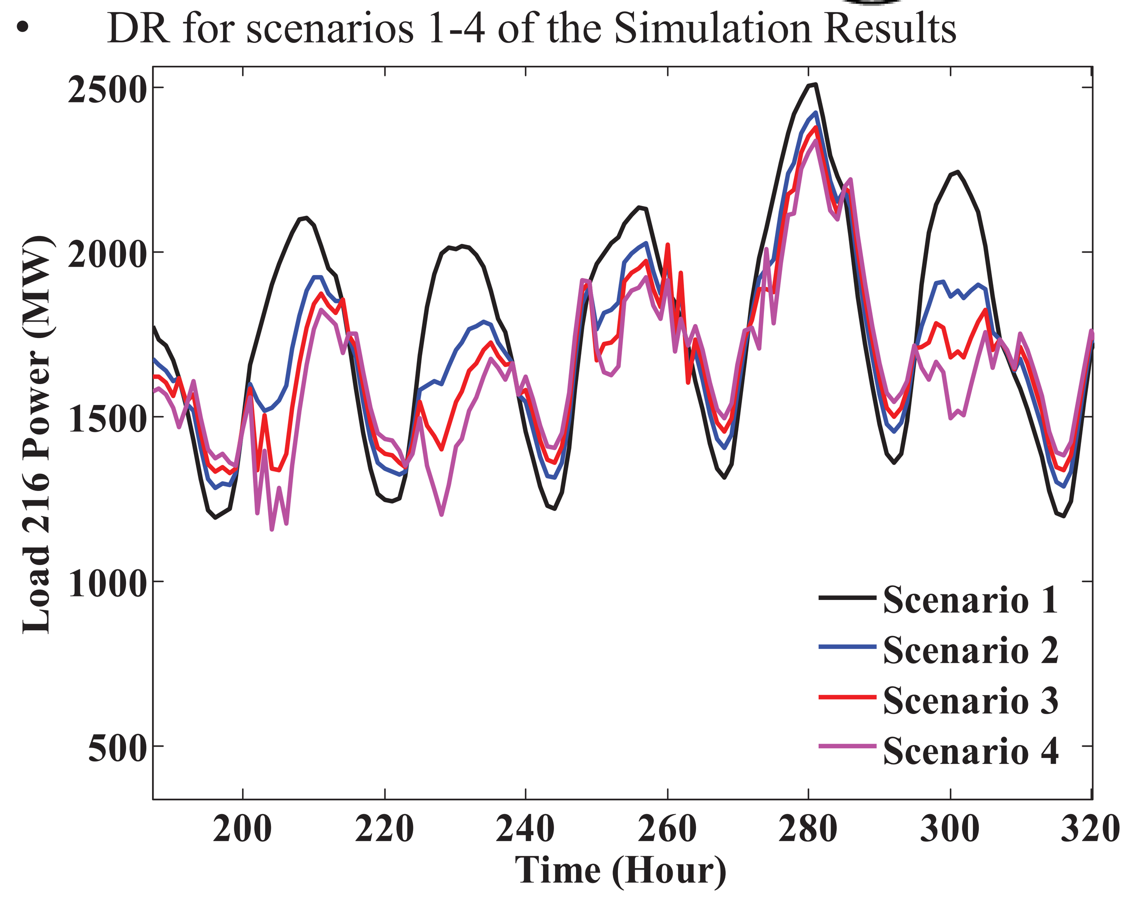
Objective Function:

$minimize \sum_{i=1}^{N} C_{electricity}(i).P_g(i)$



DR is modeled in MATLAB and market simulations are modeled in PLEXOS

- DR for scenarios 1-4 of the Simulation Results



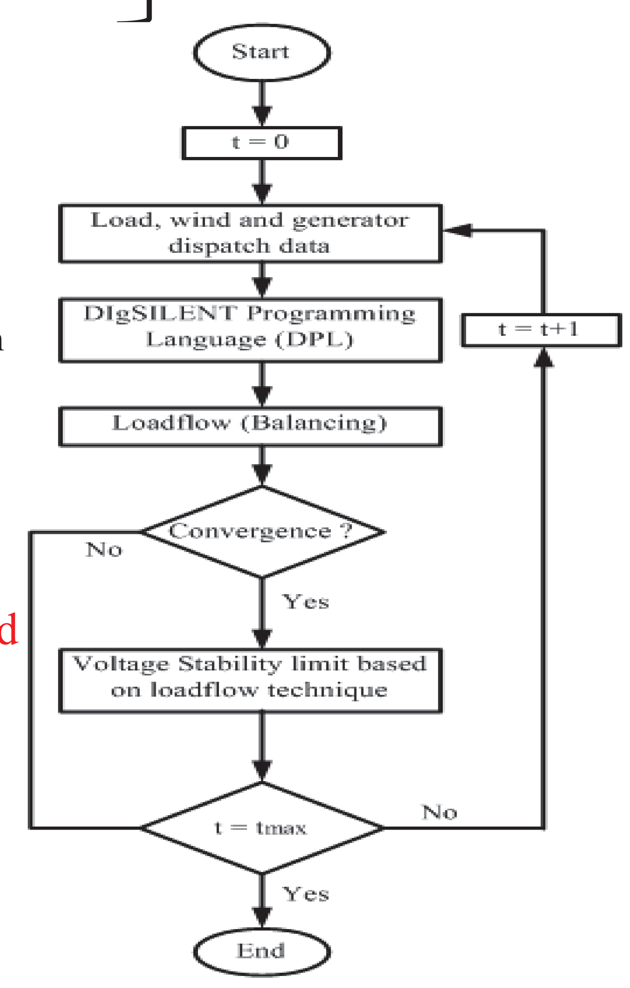
V. Simulation Results

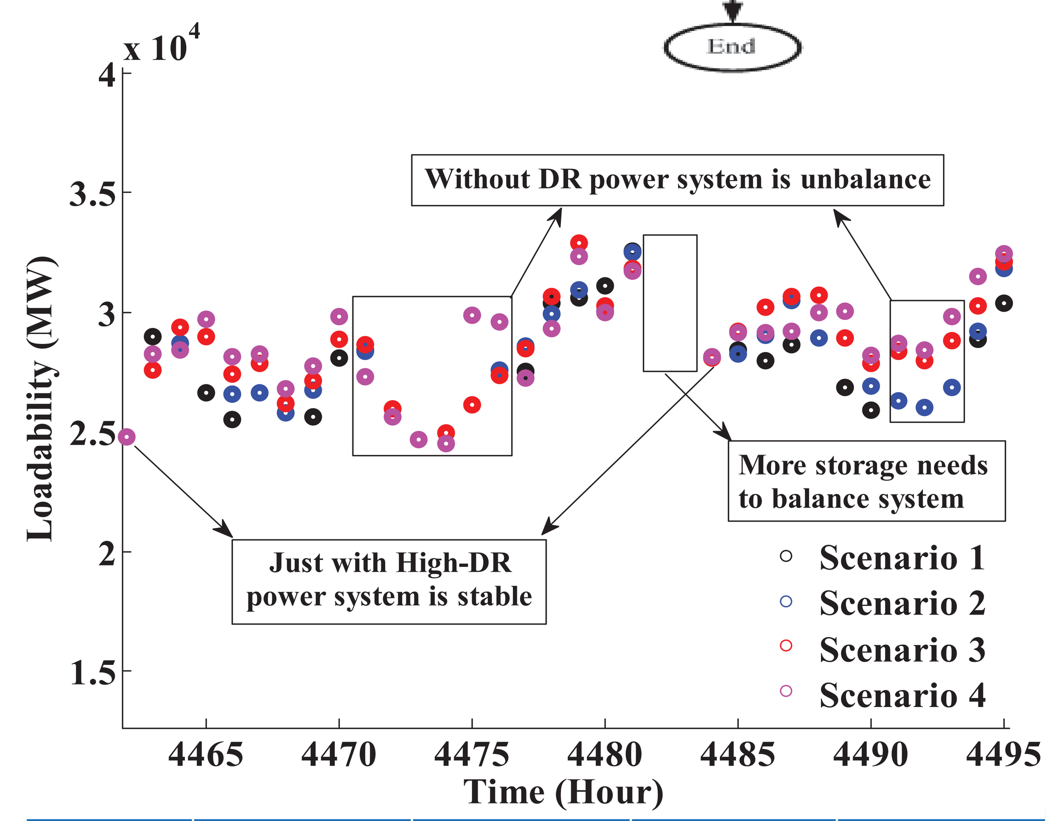
- In scenarios 1-4, NPS_5 and PPS_5 were replaced with two wind farms with capacities of 900 MW and 2330 MW, respectively. We used NSA and SESA wind data in 2020, respectively.
- In scenarios 5-7, TPS_5 was also replaced with a wind farm with 700 MW capacity. ADE wind data in 2020 (100% wind scenario for SA) was used.
- PV penetration for low, medium and high DR are considered 20%, 30% and 40% in 2020 for residential and commercial loads, respectively.

Scenario 1: Conventional loads
Scenario 2: Low-DR
Scenario 3: Medium-DR
Scenario 4: High-DR
} High penetration of wind in SA

Scenario 5: Low-DR
Scenario 6: Medium-DR
Scenario 7: High-DR
→ 100 per cent wind penetration in SA

Balancing and voltage stability analysis performed in DIgSILENT





Scenario	Unbalanced cases (%)	Average loadability (MW)	Min loadability (MW)	Max loadability (MW)
1	15.62	25136.04	14885.68	35610.07
2	12.27	26894.73	15340.47	35664.11
3	11.43	27248.76	15484.75	36378.33
4	10.34	27612.04	15666.18	36670.31
5	40.99	25938.1	14240.57	35186.74
6	37.98	26292.47	14984.09	35753.99
7	34.31	26603.09	15661.94	36478.53

VI. Conclusion and Future Work

- DR likely to decrease the required storage for balancing.
- DR can improve balancing, loadability and voltage stability of the system.
- More scenarios and DR strategies will be evaluated for longer time horizons.

VII. References

[1] M. Wright and P. Hearps, Australian Sustainable Energy: Zero Carbon Australia Stationary Energy Plan: Melbourne Energy Research Institute, 2010.

[2] B. Elliston, M. Diesendorf, and I. MacGill, "Simulations of scenarios with 100% renewable electricity in the Australian National Electricity Market," Energy Policy, vol. 45, pp. 606-613, 2012.

[3] AEMO 100 Per Cent Renewables Study – Draft Modelling Outcomes, April 2013.

[4] 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.

[5] Mike Gibbard & David Vowles, "14-generator model of the SE Australian power system", The University of Adelaide, South Australia 30 June 2010

[6] AEMO planning report, "2012 Modelling And Assumptions", 30 January 2012.

[7] Henning Tischer, Gregor Verbič, "Towards a Smart Home Energy Management System - A Dynamic Programming Approach", Innovative Smart Grid technologies Asia 2011, Perth, Australia.