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

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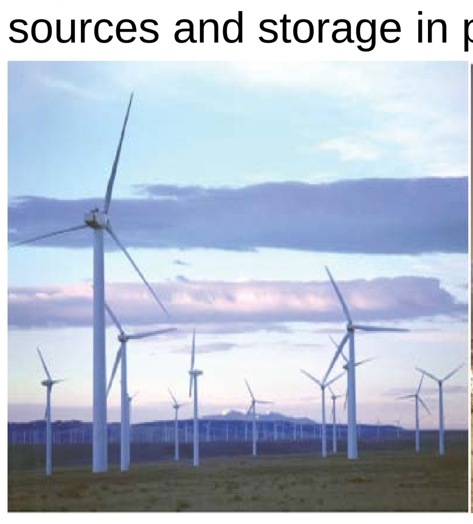
I. AIMS

- To propose an aggregate demand model considering Demand Response (DR) for the performance and stability assessment of the future grid scenarios.
- To study the influence of the proposed DR model on the performance and steady-state voltage stability of the Australian National Electricity Market (NEM) with the increasing intermittent renewables penetration in 2020.

II. INTRODUCTION

- High penetration of diverse Renewable Energy (RE) sources 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 has proposed the FG of Australia in 2020, considering economic issues, and selecting the wind and solar sites with the highest probability of annual wind speed and solar radiation and close to the existing grids [1].
- Relying 100% on REs in the NEM is technologically feasible within the specified NEM reliability standard. Winter peak load can be met through delaying CSPs dispatch and/or demand reduction [2].
- High penetration of REs results in electricity price increases over decades due to grid upgrades and the carbon price [3].
- There are some similar studies on the PJM, California and Europe power systems.

Those studies have demonstrated aggressive reduction in fossil fuel use is possible, and provide a vision of the FGs. 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.

Table 1

Technology	Fuel cost ($/GJ)	Capital cost ($/kW)	FO&M ($/kW/yr)	VO&M ($/MWh)
Brown coal	0.7-2.00	7766	91.5	15
Black coal	1.47-2.42	5434	73.2	12
GT	0.95-12.25	2772	17	9
CSP with 6 hrs thermal storage	-	6973	65	20
WF	-	2530	40	14
Biomass	1.3-9.3	3000	150	10
Geothermal	-	7000	200	0

Table 2

Scenario	Unserved hours (%)	Spilled hours (%)	Average loadability (GW)	Average $\sigma_{\min}(J)$
1	0	0.43	26.69	0.2551
2	0	0.26	27.04	0.3560
3	0	0.11	27.97	0.3572
4	0	0.01	27.35	0.3570
5	0.56	18.74	27.20	0.2580
6	0.45	18.29	27.47	0.3614
7	0.31	17.12	28.24	0.3652
8	0.25	16.10	27.72	0.3625

III. NETWORK TOPOLOGY

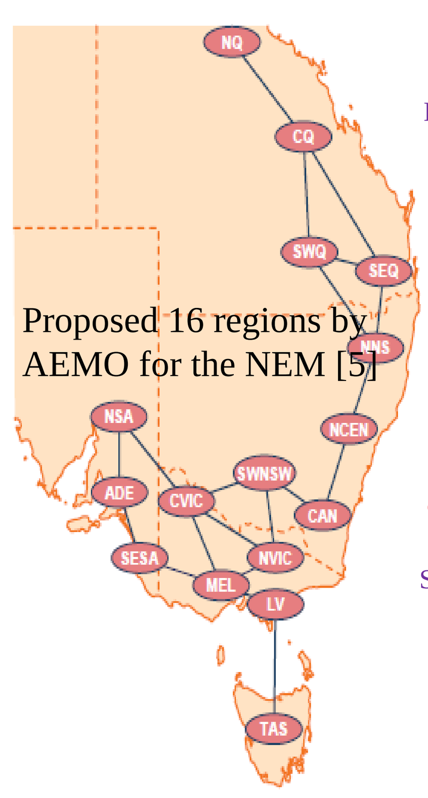
14-Generator model of the NEM [4]- Area 1: Snowy, Area 2: NSW, Area 3: VIC, Area 4: QLD, Area 5: SA

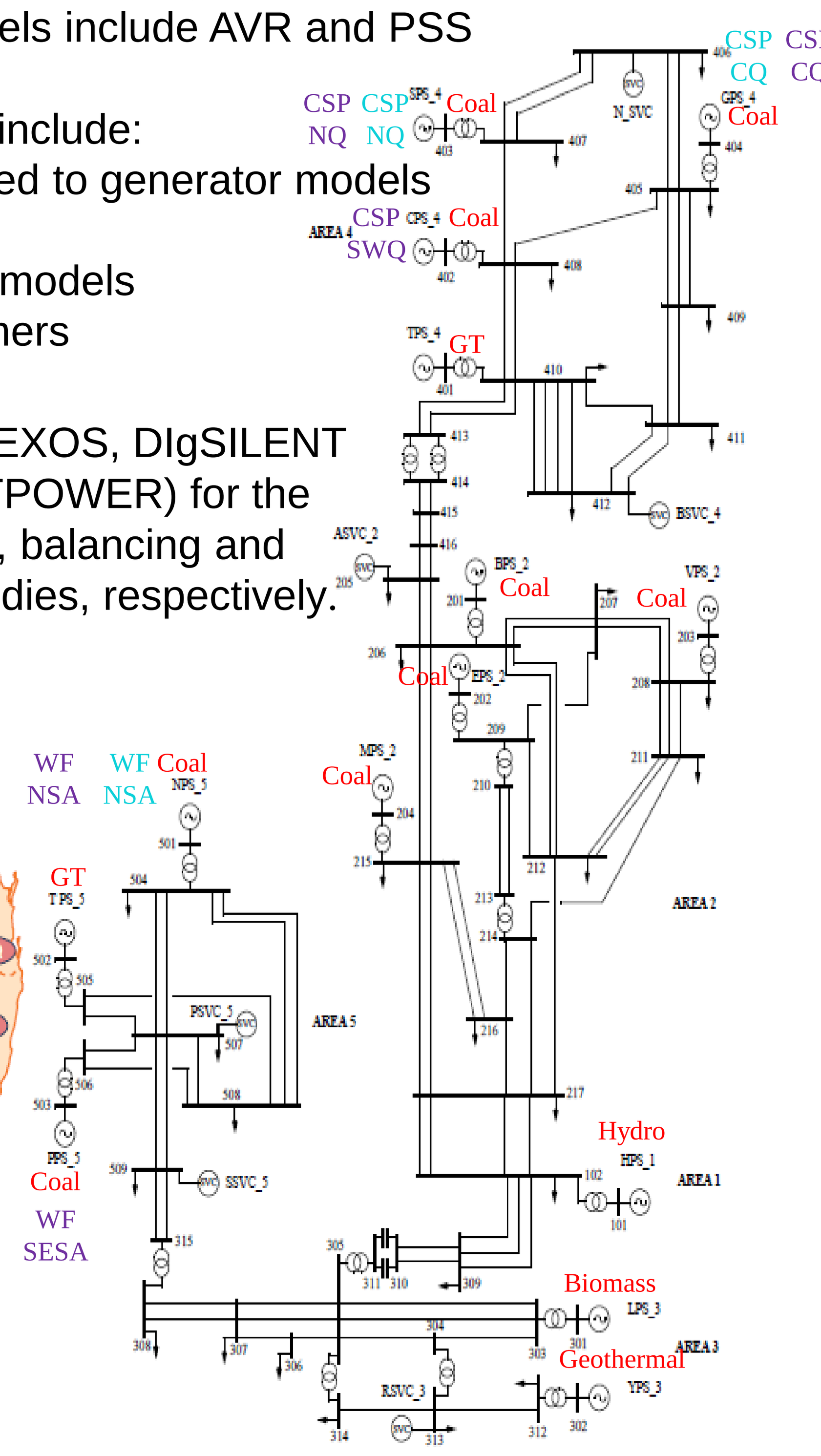
- Inspired by the NEM
- Proposed for the small-signal stability
- Generator models include AVR and PSS

The modifications include:

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

It is modeled in PLEXOS, DIgSILENT and MATLAB (MATPOWER) for the market simulations, balancing and voltage stability studies, respectively.





Simplified 14-generator, 50 Hz system.

IV. Aggregate DR Modeling

- Conventional models are invalidated by DR. However, we still want to be able to represent demand in an aggregated manner for the stability analysis.
- DR model is inspired by the smart home concept [6].

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

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

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

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

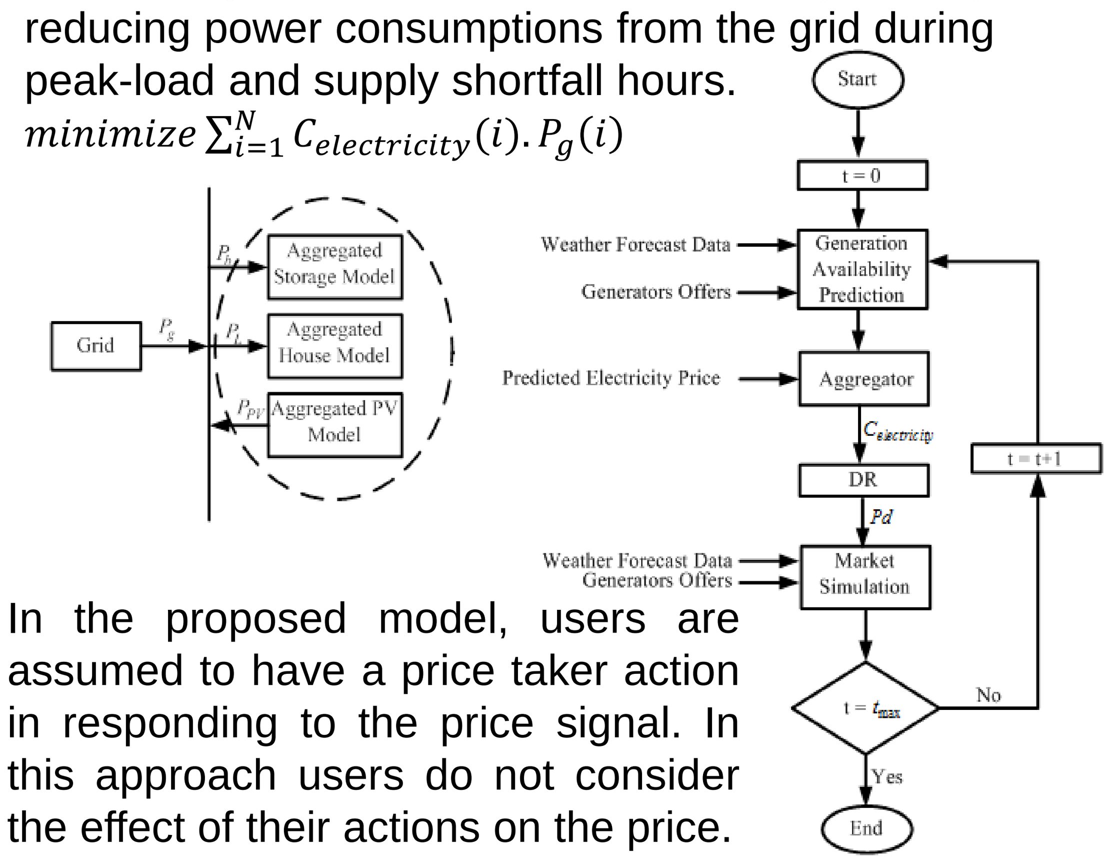
Balancing equation:

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

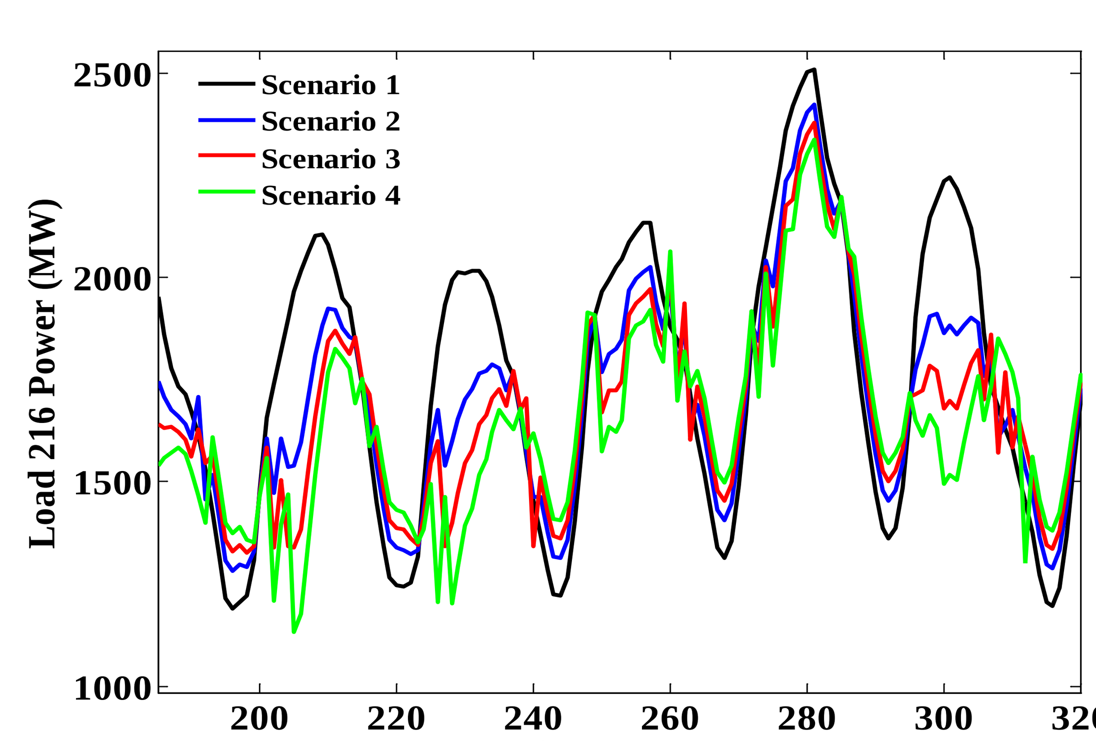
Objective Function:

The main goal is to minimize the electricity cost by reducing power consumptions from the grid during peak-load and supply shortfall hours.

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



In the proposed model, users are assumed to have a price taker action in responding to the price signal. In this approach users do not consider the effect of their actions on the price.



V. MARKET MODELING

- For each hour, PLEXOS dispatches less controllable generation (e.g. WFs) before more controllable generation (e.g. coal, gas, etc.).
- The generator offers to the market are calculated from the annualized capital cost, fixed and variable O&M costs, which are reported in the **Table 1** [5].
- The market model considers minimum stable level, generator offer, line flow limits.

VI. SIMULATION RESULTS

- In scenarios 1-4, WF capacity is 3000 MW and CSPs have the capacity of 4000 MW each. In scenarios 5-7, WFs have the capacity of 3000 MW each, and CSPs have the capacity of 4500 MW each.(**Table 2**)
- PV penetration for low, medium and high DR are considered 20%, 30% and 40% in 2020 for residential and commercial loads, respectively.

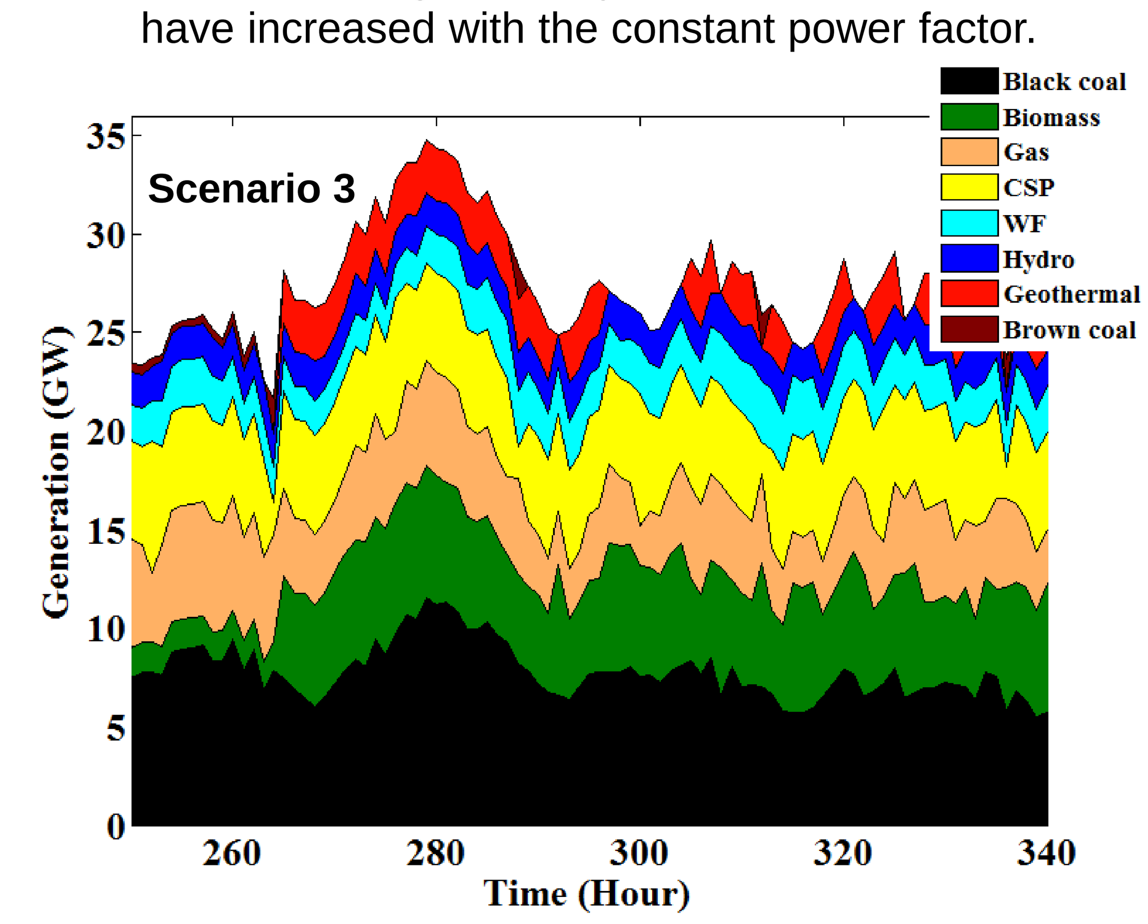
Scenario 1: Conventional loads
Scenario 2: Low-DR
Scenario 3: Medium-DR
Scenario 4: High-DR

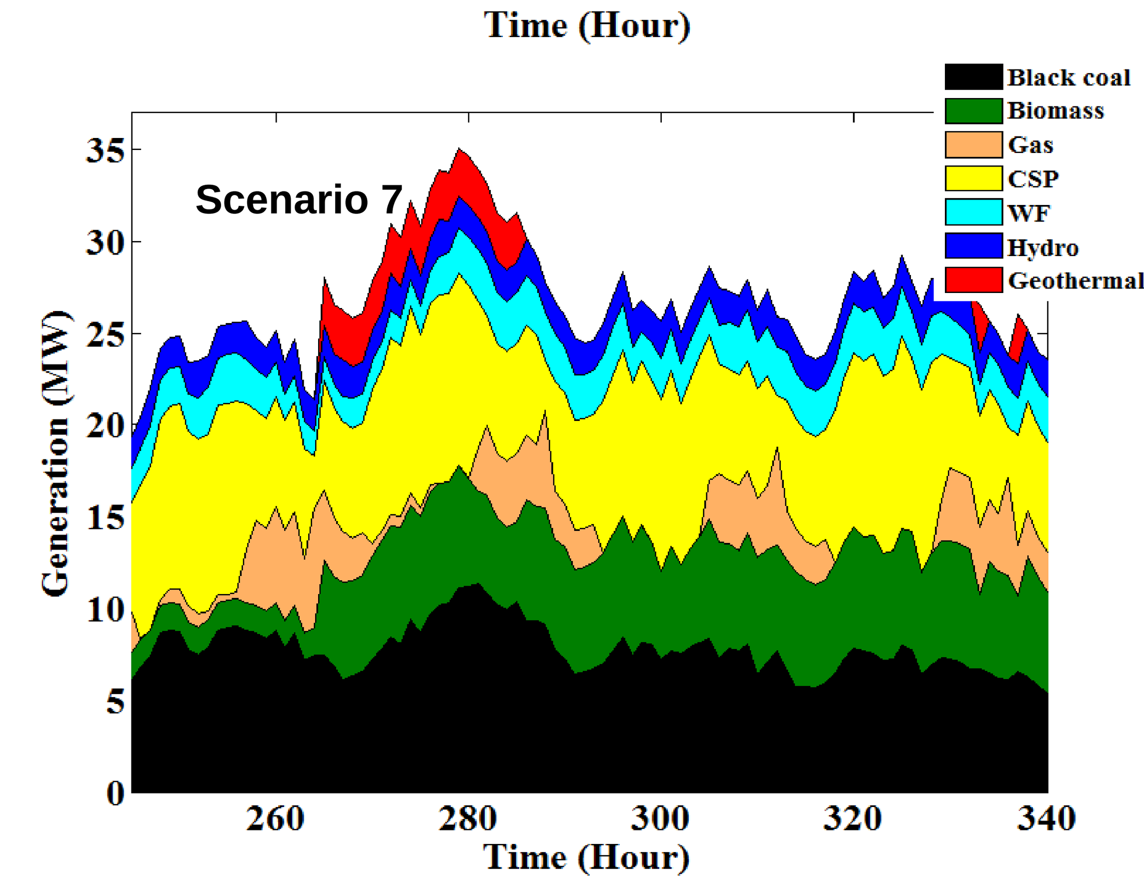
Generation technology is written in BLUE in SA and QLD CSPs are dispatched with 11 hrs delay

Scenario 5: Conventional loads
Scenario 6: Low-DR
Scenario 7: Medium-DR
Scenario 8: High-DR

Generation technology is written in PURPLE in SA and QLD CSPs are dispatched with 6 hrs delay

- For the voltage stability, all loads in the NEM have increased with the constant power factor.





VII. CONCLUSION

- DR likely to decrease the required storage and electric energy from GT for balancing.
- DR improves balancing, loadability and steady-state voltage stability of the system.
- Medium-DR scenario can improve steady-state voltage stability and loadability better than other DR scenarios (price taking action).

VII. REFERENCES

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