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# An Evolutionary Programming Tool for Assessing the Operational Value of Distributed Energy Resources Within Restructured Electricity Industries

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## The emerging electricity industry –a key role for DRs

- Drivers
  - market-based restructuring
  - growing climate change concerns
  - emergence of new distributed & decentralised technologies; alternatives to conventional, centralised, supply options
- Distributed resources
  - *technologies within Dx system that actively participate in EI operation*
  - renewable energy sources including solar thermal, photovoltaics (PV) smaller-scale wind, biomass
  - small-scale fossil fuelled generation, combined heat and power (CHP) plants powered with engines, gas turbines or fuel cells,
  - direct energy storage; chemical 'battery' technologies, super-conducting magnetic systems, flywheels
  - electrical end-uses that actively respond to changing conditions; eg. 'smart' buildings that control heating & cooling to exploit their inherent thermal energy storage.

# DRs challenge existing EI arrangements

- Different characteristics from conventional centralised supply resources
  - technical operation; eg. intermittent renewable resources
  - small unit scale yet large numbers could aggregate to significant resources
  - potential environmental benefits; renewables, efficient end-use; eg. Cogen
  - location near end-users & in Dx system
  - potential ownership by end-users & close integration with their processes & equipment; eg. Cogen





# Operational 'energy value' of DRs

- Operational energy value
  - For any resource, combined outcome of changing costs/ benefits of all participating generation, network elements & end-users *=> varies wrt time, location, QoS & s.t. uncertainties including contingencies*
- **Possible energy value of DRs** includes timely energy provision, potential to reduce network costs & improve QoS for end-users
- These not yet appropriately valued
  - eg. Australian NEM reasonably successful yet restructuring to date largely at wholesale level; retail mkts don't have good time, location, contingency & QoS signals
- Maximising DR value requires mkt changes & formal integration into processes

# Tools for assessing possible DR energy value

- **Question:** potential value of large DR penetrations actively participating within restructured EI
  - Operational decision making wrt hourly scheduling for days to weeks
- A challenging optimisation even without DRs
  - competing participant objectives, potential market power, inter-temporal links wrt unit commitment & fuel scheduling, uncertainty
- With DRs
  - Far greater numbers of participants, some with primary objectives not related to electricity production
  - potentially complex operation: eg. intermittent renewables, integration within industrial processes.



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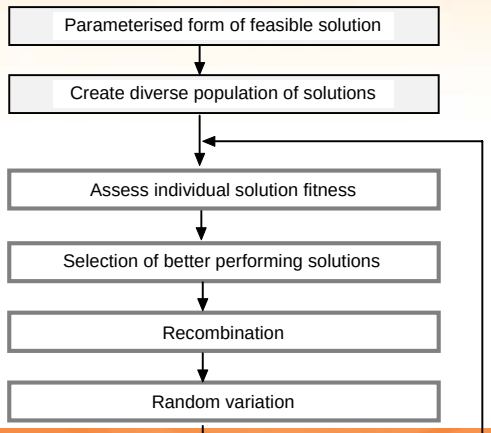
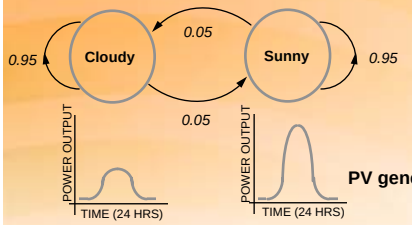
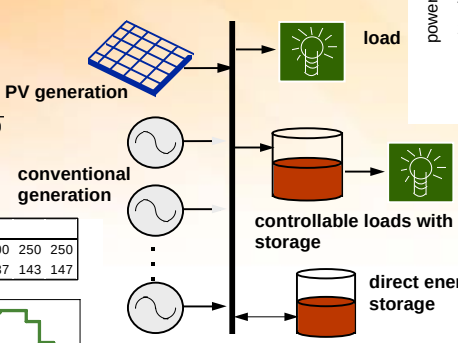
# Dual Evolutionary Programming

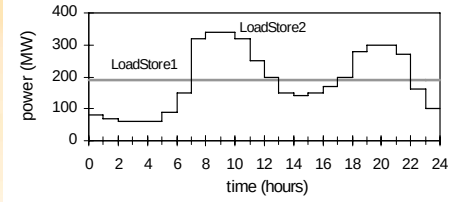
- Based on power system simulation & decentralised system coordination
  - DR agent managing direct control & communications
- To model decision making of agents
  - Benefit function incl. impacts of decisions on future
  - Declared benefit function - agent's communications
- Find best functions using evolutionary computation
  - Agent objectives profit maximising, collaborative
  - Requires only power system simulation & assessment
- Natural evolution a robust optimisation approach
  - Elements of both global & local search methods but 'black box, no guarantee of optimality



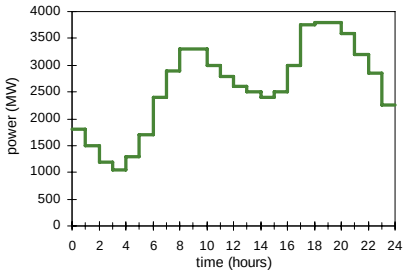
# Case study: PV & distributed storage




| Conventional generation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Capacity (MW) | 1200 | 600 | 500 | 400 | 300 | 300 | 250 | 250 |
| Cost ($/MWh) | 26 | 29 | 78 | 85 | 132 | 137 | 143 | 147 |



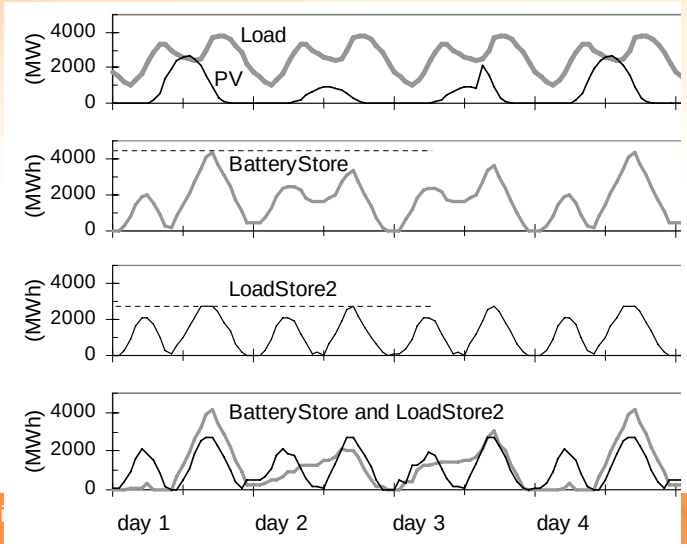

| | storage capacity (hrs of load) | time (hrs) for full charge/discharge | dis/charge efficiency (%) | self-discharge %stored energy/h |
|---|---|---|---|---|
| LoadStore1 | 12 | 12 / 12 (set by load) | 100 / 100 | 0.2 |
| LoadStore2 | 7 (av. load) | 2.7 / - (varying load) | 100 / 100 | 2.0 |
| BatteryStore | | 7 / 7 | 90 / 90 | 0.2 |





# Results – optimal DR storage operation

- Storage DR agents 'evolved' to optimise their contribution to maximising system value: behaviour changes wrt
  - changes in PV 'forecast'
  - presence of other types of DR storages



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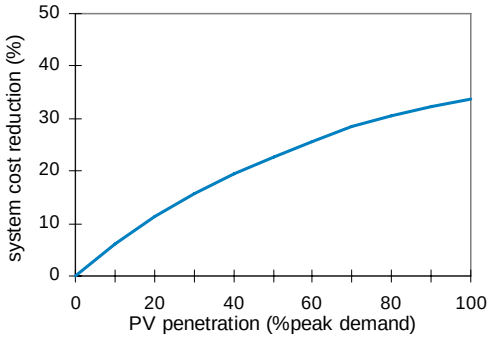
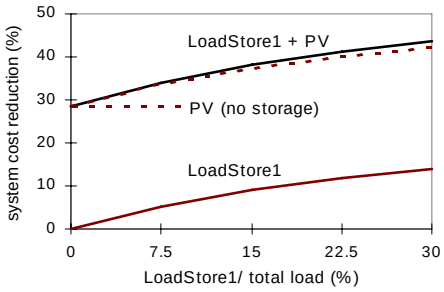
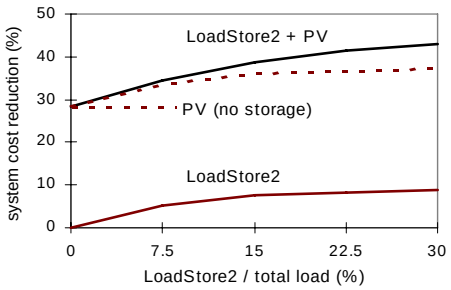
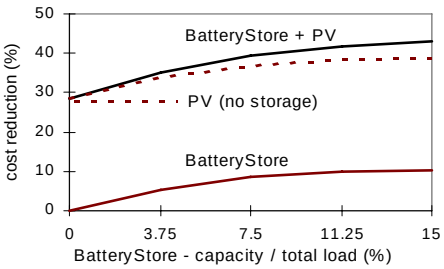
# Results – synergies b/n PV & different DR storages

- Key factors
  - PV generation available for relatively short time period so quick charging adds value
  - PV generation just before evening peak so adds value for 'leaky' storages

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# Conclusions

- Potentially valuable synergies between high PV penetrations & different types of DR storage, especially inherent load storage
- DEP appears to be a useful approach for better understanding these types of potential DR synergies
- DRs currently remain an emerging but highly promising suite of technologies
- Achieving their full potential will likely require their integration into electricity industry operational arrangements
- Now seeing proposed changes to Australian NEM to better reflect DR value