The Utilities Perspective: renewable integration issues and solutions

Dr James Darbyshire

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Innovative Solutions for Electrical Engineering Applications

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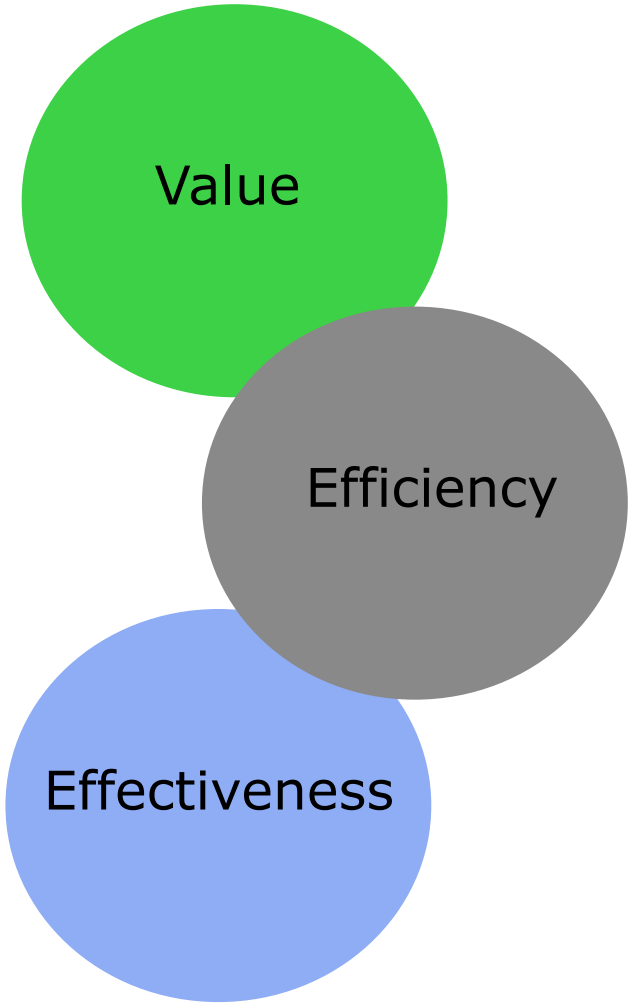
The Balance Approach



Our focus is on delivering energy solutions which:

- Provide best lifecycle value
- Taking a holistic approach to service provision by balancing a range of needs and competing priorities
- Create both commercial and technical flexibility
- Make the business case easy for our clients through transparency of options analysis and of life cycle costs
- Will operate to a required standard of performance and cost over their life

Our experience at Balance, over many remote projects, is:

- The lowest capital cost solution often does not offer best value over the lifecycle of the solution
- That innovative solutions, both in the assets created and in the long term approach to operations, can pay massive dividends in value

Renewable Generation Pros and Cons

Advantages of Renewable Generation

- No generation fuel cost
- Reduce existing fuel costs
- Reduce conventional plants maintenance costs
- Reduces CO2 emissions
- Produce green credits
- With a high certainty can reduce peak load for most systems
- Can be distributed across the geographic area
- Generation can be closer to loads reducing transmission losses

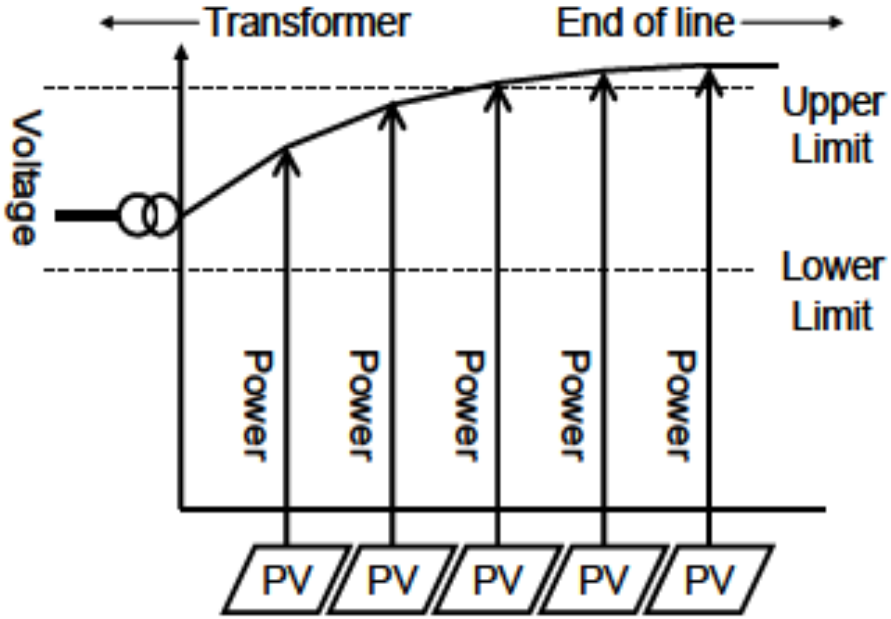
Disadvantages of Renewable Generation

- Intermittent capacity
- Cannot be classed as firm capacity
- Higher capital cost than conventional plant
- Theoretically cannot reduce peak load
- Power fluctuations destabalise the network
- Low fault current capability
- Human link between fluctuating generation and decreasing system reliability

Distributed renewables make network management more difficult

Distributed Renewable Generation

- **Voltage rise on networks**
  - Isolated and controllable issue
  - Carry out network impact study for >5kW systems
  - Keep impedances between PV systems and network low
- **Transformer back feeding**
  - May cause protection issues for existing systems
  - Solvable problem with modeling
- **Inverters sized for unity power factor**, utility must make up the reactive requirements
  - Utilities need to realise where there network is venerable
  - Use new inverters reactive power capabilities for Q control based upon V or P
- **Transformer tap changing with clouds**
  - Use reactive power features in inverters to control voltage as permissible

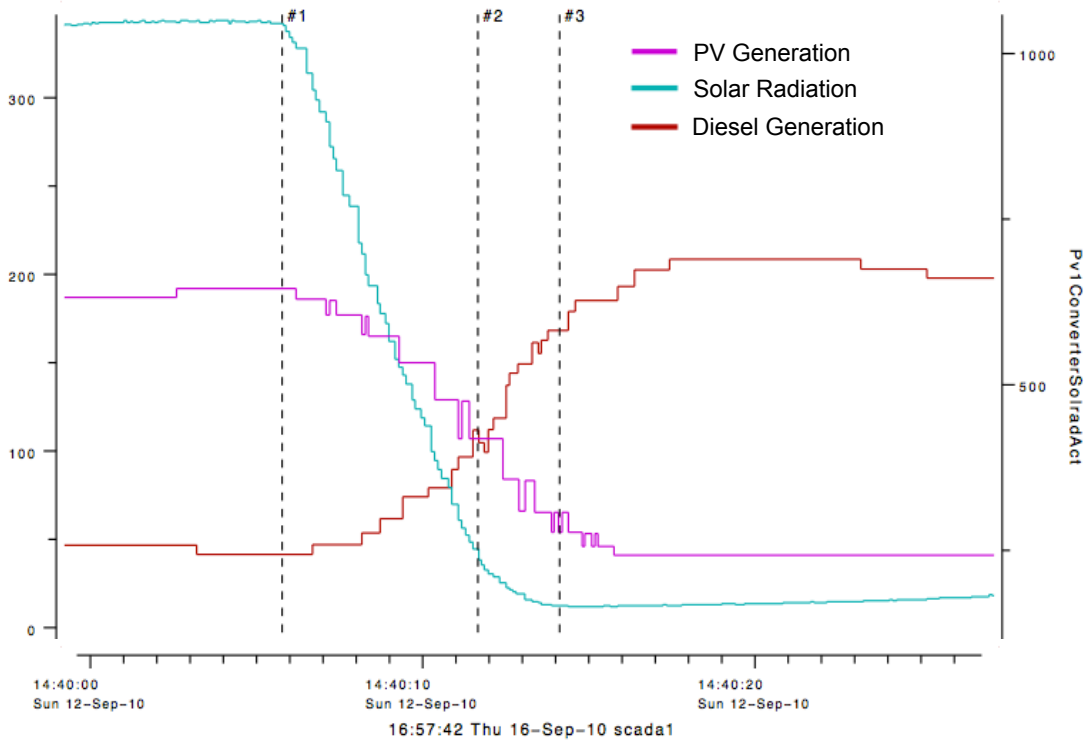


Y.Ueda, T. K. (2009). *Detailed Performance Analyses Results of Grid-Connected Clustered PV Systems in Japan.* Tokyo: University of Agriculture and Technology.

Distributed renewables make network management more difficult

Distributed Renewable Generation

- **Cloud effects**
  - Cloud shear causes increase before steep decrease in PV power output
  - Better for geographically sparse PV systems
  - Network capacity must be able to tolerate dP/dt of systems
  - Can be difficult to define
- **Simultaneous inverter disconnection (biggest issue!)**
  - Loss of generator or feeder would cause under/ over frequency event causing all distributed inverters to trip simultaneously
  - Network must have spare capacity for this situation
  - Evidence of this happening but only for a proportion of the inverters, not all inverters are set up the same!
  - Utilities need to define these set points for there individual network characteristics.



Worst Cases

dP/dt < 9%

dS/dt < 12%

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Centralised renewables make network management easier

Centralised Renewable Generation

- Single interconnection point
    - Can engineer point of common coupling to ensure voltage rise issues are mitigated
- System can be controlled by the operator to manage network conditions
- Cloud shear effects are worse due to smaller geographic footprint
- Open to investment opportunities when backed with Utility PPA, with green benefits and performance guarantees

EMC Solar Farm, Carnarvon

Limitations on renewables for isolated power stations

Isolated Power Stations Limitations

- As the proportion of renewable energy increases the difficulty to control, stabalise and maintain reliability also increases
- Currently all standard renewable installations are taking advantage of the power stations spinning reserve philosophy
- Power stations are designed to provide power to slowing changing and predictable load profiles. All power stations have an instantaneous increase in load limit (dP/dt) that cannot be breached
- Power stations must maintain control of voltage and frequency of the network
- Power stations cannot absorb power at any point in time
- Fewer online generators create lower fault currents which can cause protection systems to fail

Firming up the renewable resources

Two proposed solutions

Increase the power stations tolerance to changes in power

- Increase the operating reserve
  - Increases generator operating hours
  - Decreases fuel efficiency
- Control centralised renewables to fit within current operating reserve
- Move operating reserve to another device
  - Rotary UPS (high parasitic loss)
  - Inverter coupled flywheel (high parasitic loss)
  - Battery UPS (high maintenance cost)

Make renewable interconnections look like normal system load variations

- Utility set maximum permissible ramp rate for renewables (W/s)
- Must be worked out for all likely future systems
- Must know existing generators dynamic responses

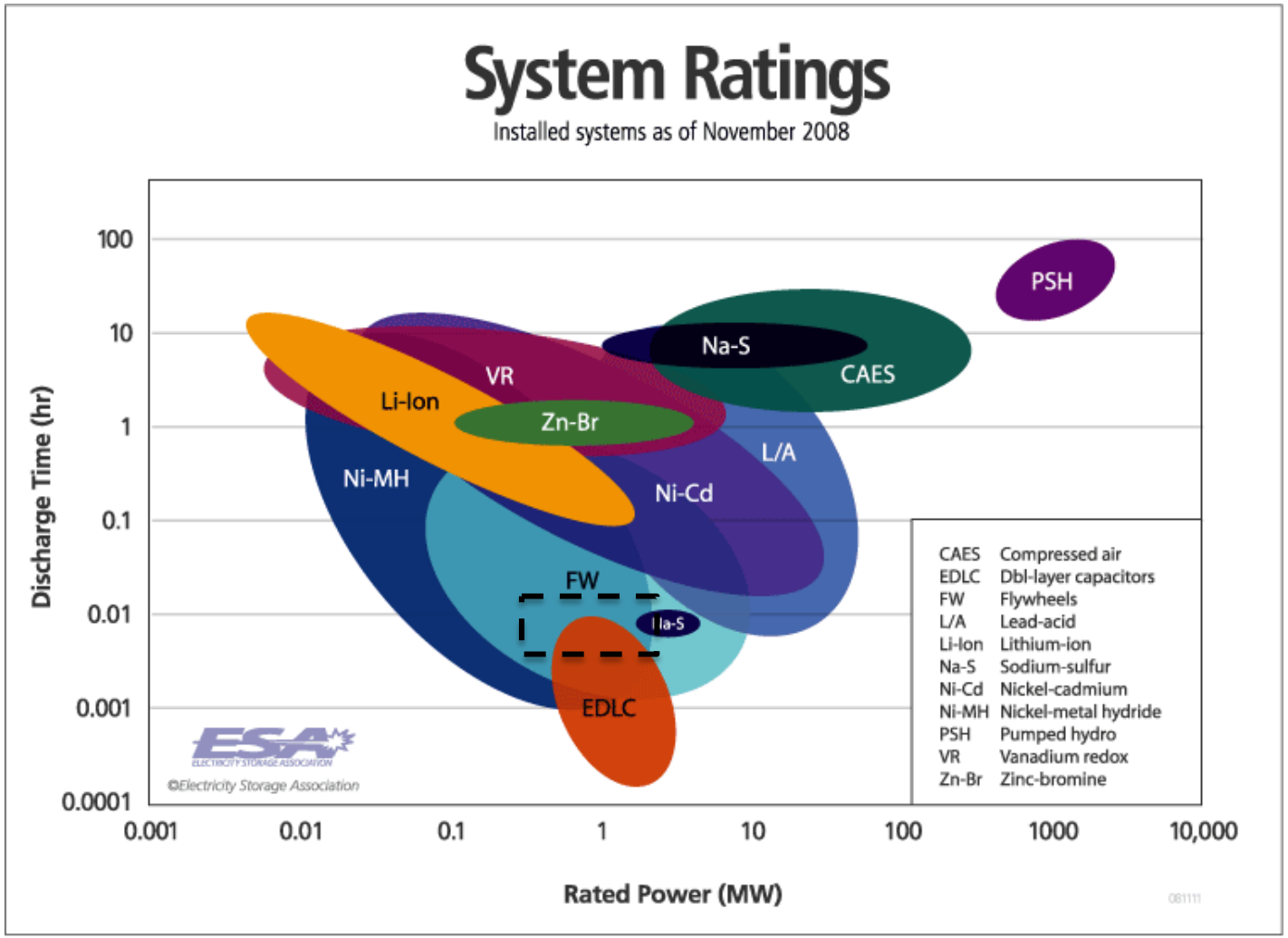
The solution is energy storage

But……not a lot of it!

The energy storage requirements are enough to provide time to bring a generator online, synchronise and pick up load

Conservatively this can be done in 90 seconds for a diesel machine (0.025 hr)

The power rating needs to be that of the largest generator or distributed renewable resource



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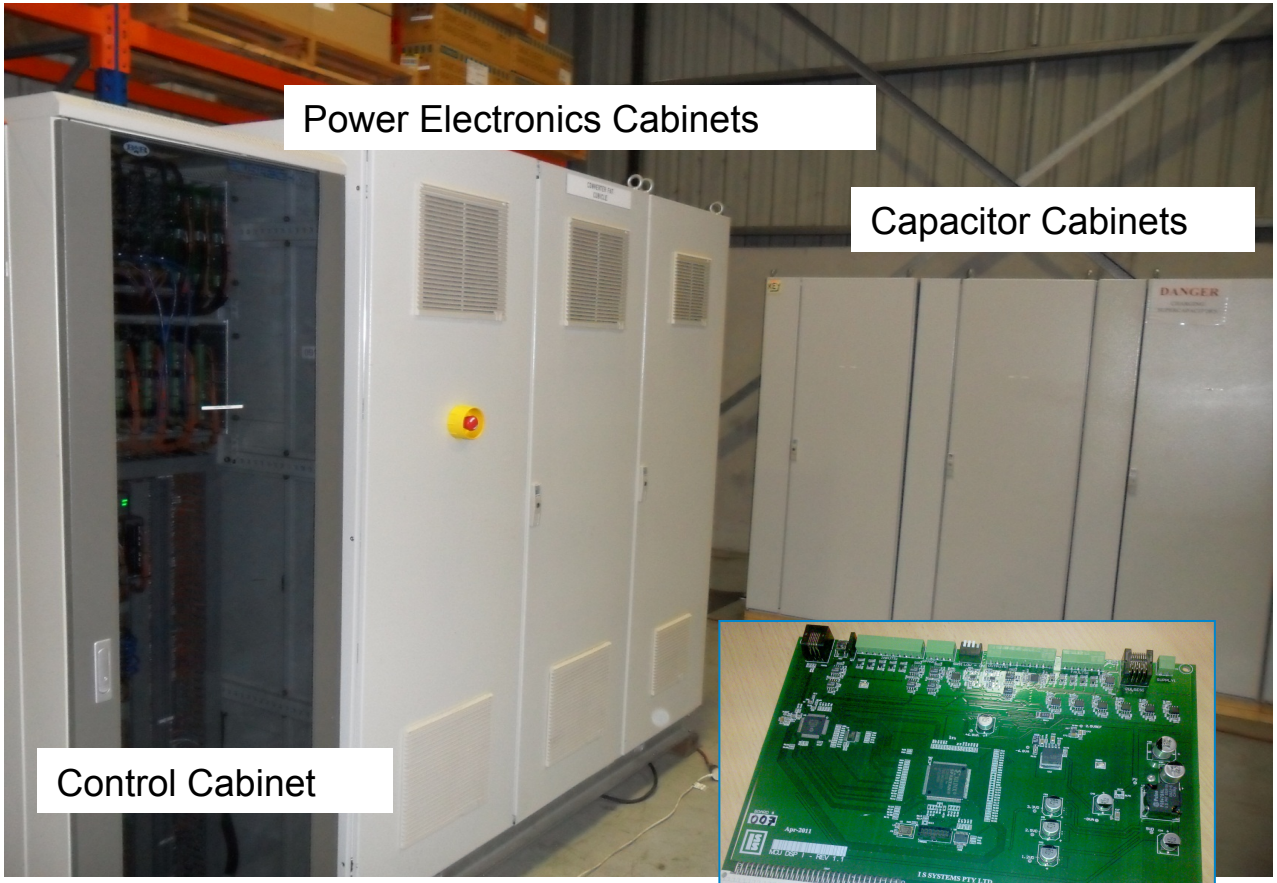
Joulenergy

Specifications

- Super-capacitor based short term energy storage device
- Very low parasitic losses
- High charge/discharge rates
- Instantaneous response (100us)
- Up to 6 x rated fault current capability
- Modular construction for 25kW to 10MW, 2MJ to 100MJ
- Low maintenance – passive device
- Specifically designed for utility scale applications
- Active and reactive power control

Applications

- **Renewable smoothing**
- **Power station static operating reserve**
- **End of line reliability issues**
- **Enabling technology for island systems to increase renewable penetration**



Microcontroller PCB – DSP & FPGA

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Joulenergy 150kW, 8MJ demonstration system

Super-capacitor rack

8MJ Storage Capacitor Bank – 20 * Modules – 960 * Capacitors

2400W * 2000H * 800D

Intellectual Property

1. AUS 2008323597 (pending)
Electrical Energy & Distribution System
PCT AU2008/001542, Published in US & Europe

2. AUS 2009904038 (pending)
Electrical Energy & Distribution System with Ride Through Energy
PCT AU2010/001061, Published in US & Europe

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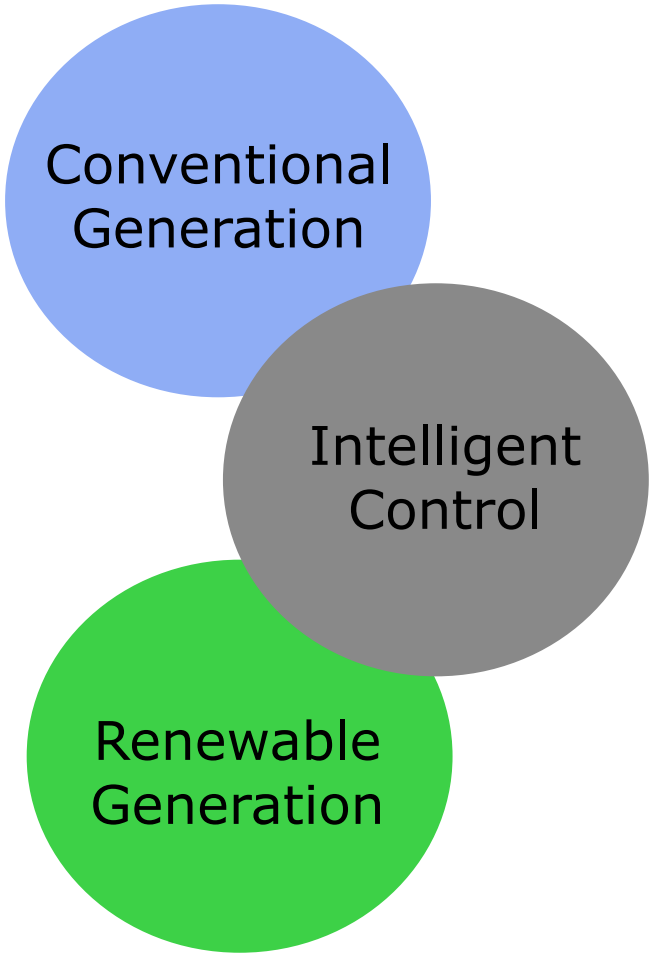
Early Contractor Engagement Strategy



Work with the client to develop the best solution

- Renewable integration studies
- Work out the most cost effective mix of renewable generation
- Model energy resource mix with cost variable over asset life
- Define any stability issues which will occur
- Model system limiting cases
- Site study to assess and recommend installation locations
- Provide detail of required interconnections and control

Infrastructure Development

- Balance Utility Solutions will operate as Owner's engineer
- Work with client to define tender packages
- Balance Utility Solutions can turnkey, EPC as required
- Develop and deliver demand side management programs
- Project manage construction
- Build Own Operate solutions if requested

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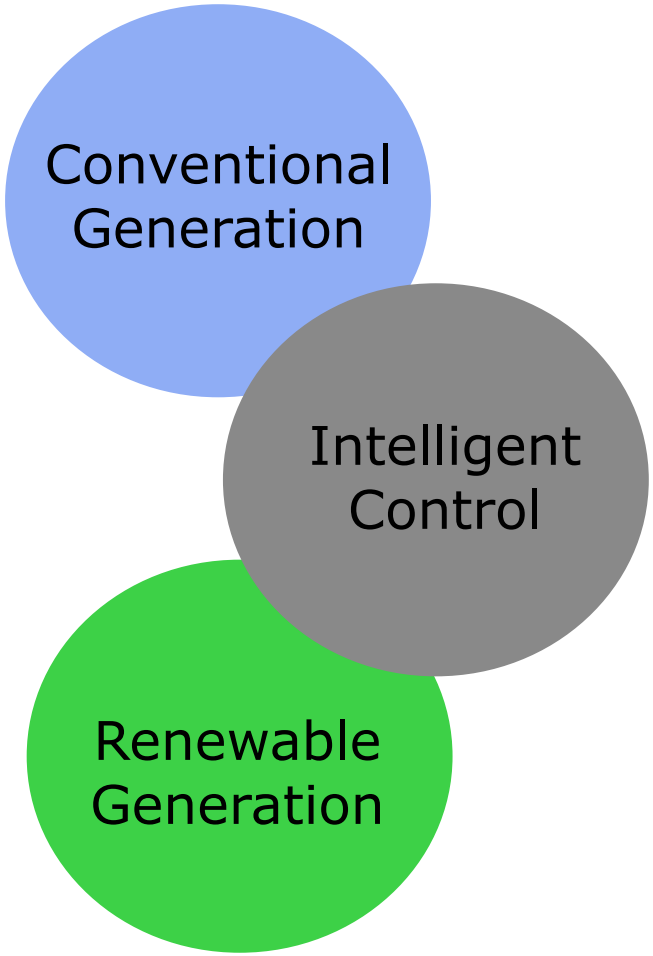
Why choose Balance?



- We are experienced professionals from Australian Utility backgrounds
- We have designed, managed and executed many high penetration renewable hybrid systems in remote Western Australia
- We are deliberately technology agnostic
- We understand the renewable resources and how to "Balance" the differing energy forms
- We will take responsibility of the integration problems caused by renewables from the start
- We have over 70 years combined experience in operating power stations
- We have real world working knowledge of hybrid renewable power stations
- We understand the operating and maintenance costs of your systems
- Our emphasis is on building and supporting local capacity

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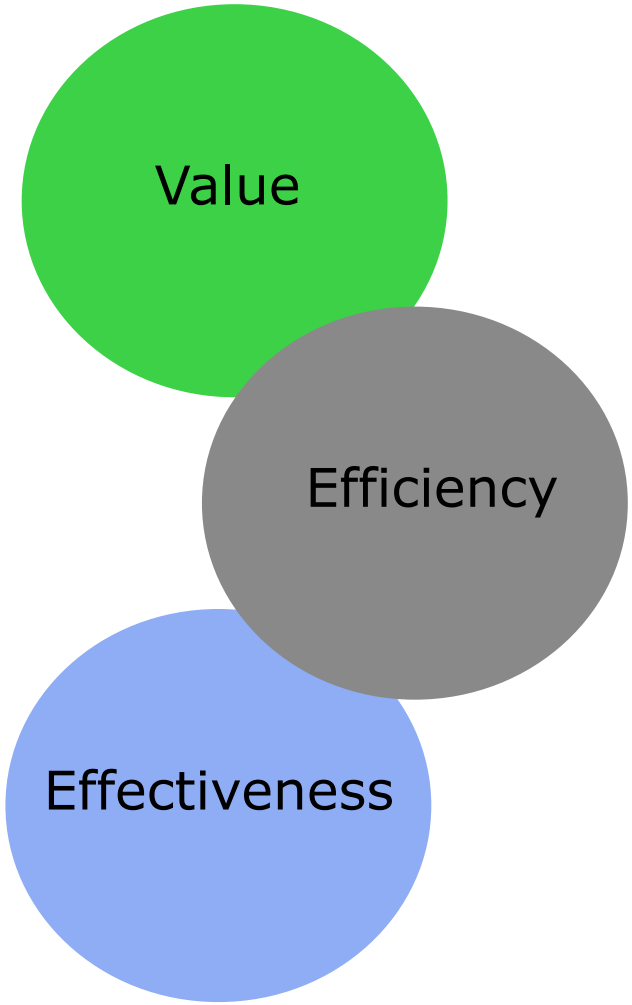
Thank you



Questions?

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