Smart Grids Management and Control: A New Approach to Integrating Isolated Power Systems

Michael Negnevitsky

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Centre for Renewable Energy and Power Systems
UNIVERSITY OF TASMANIA

Prof Michael Negnevitsky

Chair in Power Engineering and Computational Intelligence
Director of the Centre for Renewable Energy and Power Systems
School of Engineering
University of Tasmania
Private Bag 65 Hobart
Tasmania, 7001 Australia

Contents

- Concept of power system security.
- Operating reserves.
- Inertial and primary frequency response.
- Impact of renewable energy generation.
- King Island isolated power system.
- Risk-based security assessment.
- Conclusions.

Introduction

- Electricity in isolated power systems is traditionally generated using diesel generators.
- High cost of diesel fuel supply (the price exceeds US $1/kWh).
- Incentive for introducing renewable energy generation.
- The trend of small networks to lead renewable integration derives primarily from their ability to achieve high renewable penetrations for moderate renewable capacity addition.

Australian experience is typical of progress in transitioning to renewable generation.

King Island isolated power system

Image source: Google Earth

- Small, mostly agricultural island, ideally placed for wind generation.
- Electricity network owned and operated by Hydro Tasmania – opportunity to implement whole system changes.
- Wind energy currently covers 65% of energy needed by the system.
- Instantaneous renewable energy penetration is up to 85%.

King Island power system

- The step change observed in 2004 involves the commissioning of the two Vestas V52 wind turbines (850kW each).
- In addition, King Island was also the first MW scale system to achieve renewable penetrations above 50%. This milestone was achieved via a range of emerging technologies, installed from 2008 to 2014.
- Annual renewable energy penetrations has exceeded 65%. The system is also able to operate for with no diesel generation, achieving diesel off operation for up to 20% of the year.

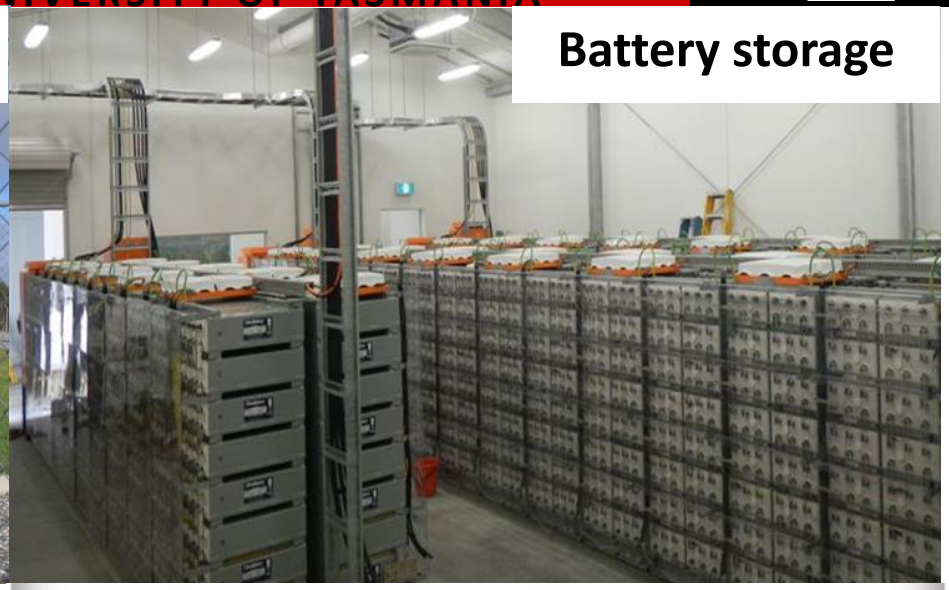
King Island: technology portfolio

Technologies integrated over this period include:

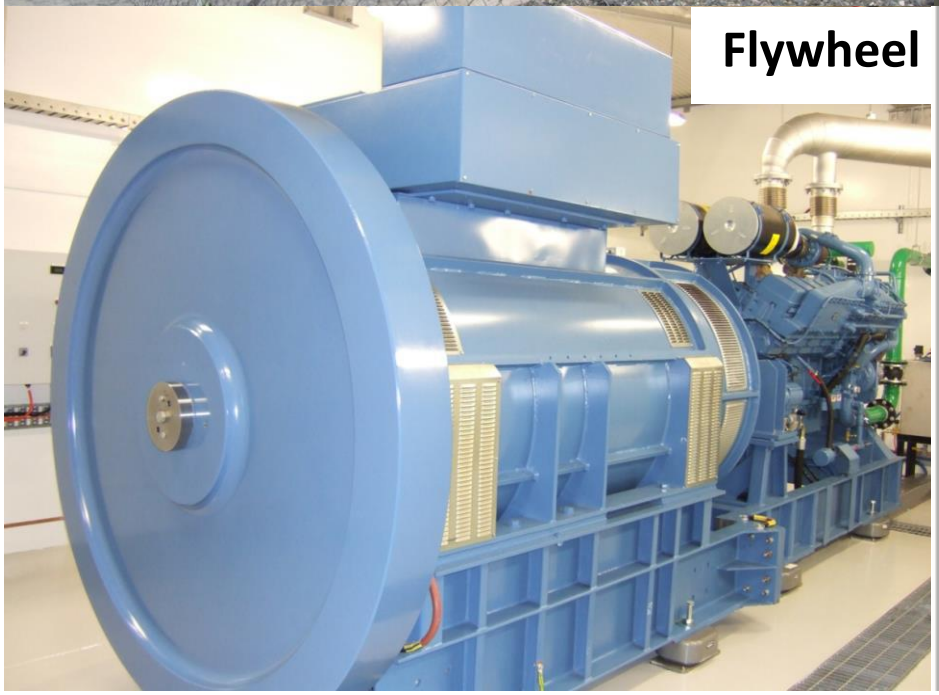
- Dual axis solar PV tracking system (2008).
- Dynamic resistive frequency control (2008).
- Flywheel diesel uninterrupted power supply (2011).
- Biodiesel blending (2012).
- Demand side management (2012-2013).
- Battery energy storage system (BESS) (2014).

Dynamic resistor

Battery storage



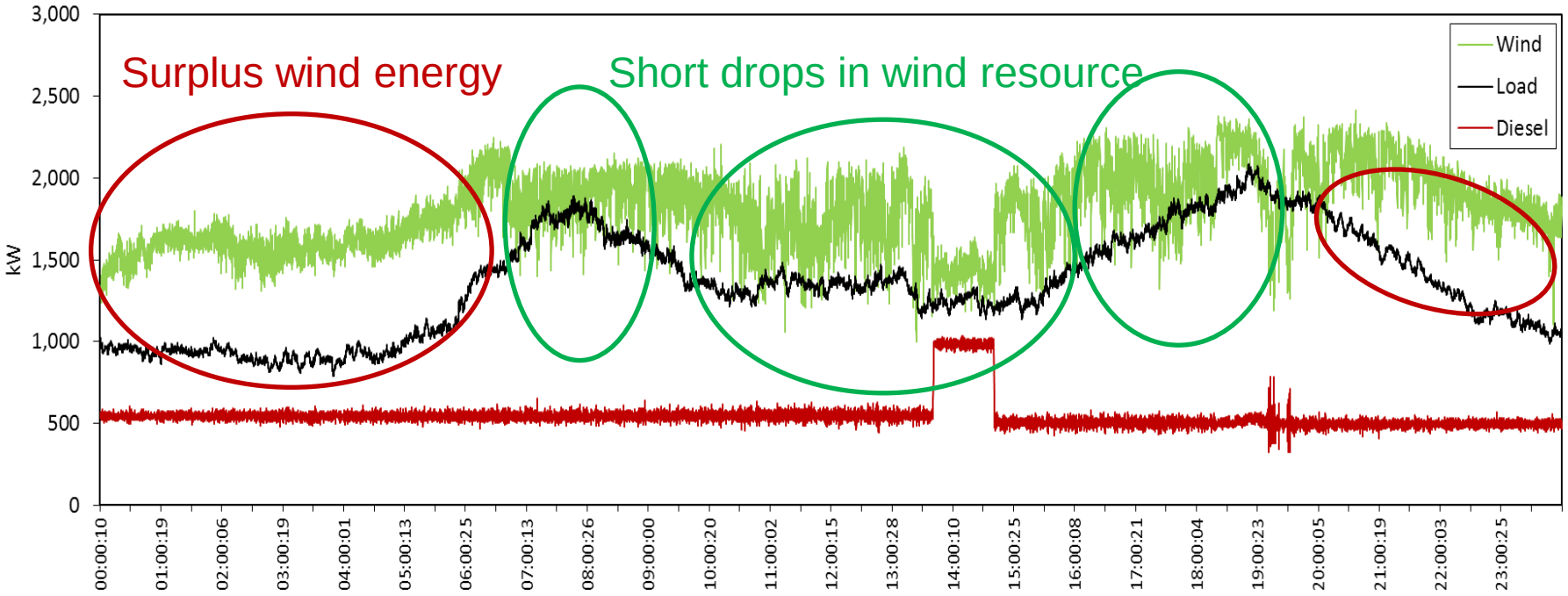
Flywheel



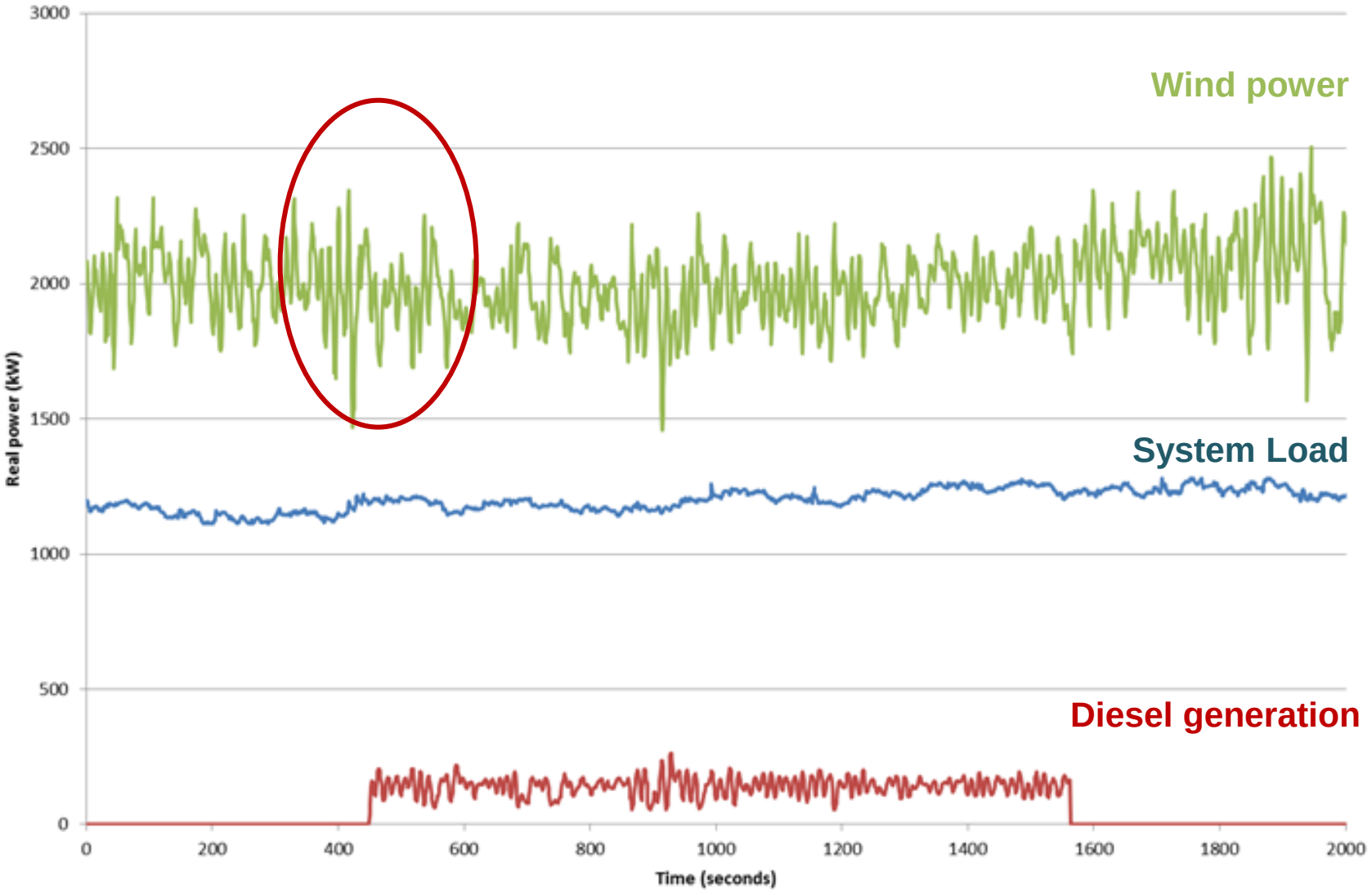
Demand response

King Island: Fast Demand Response

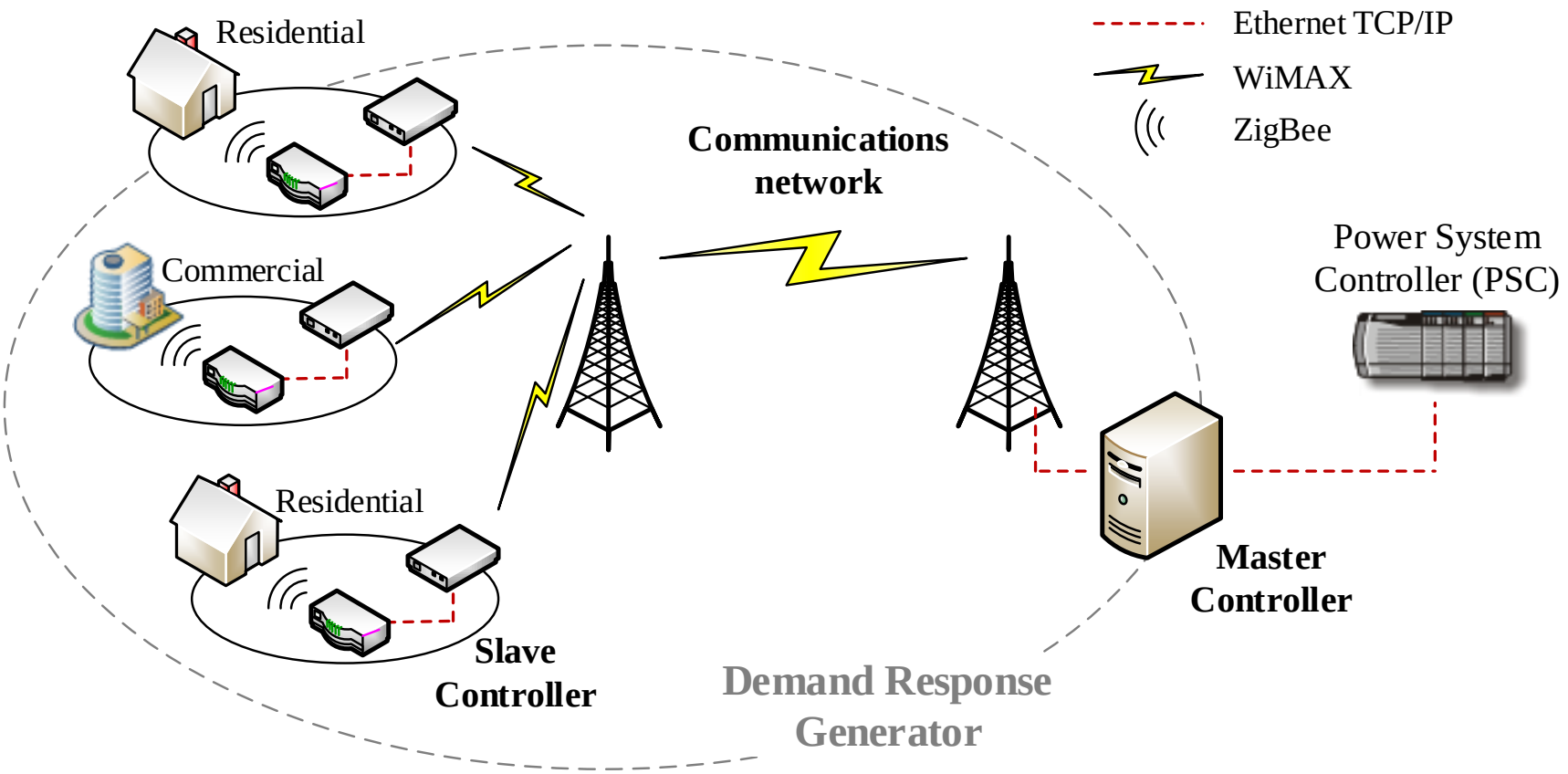
Example day on King Island



Case for short-term power system support

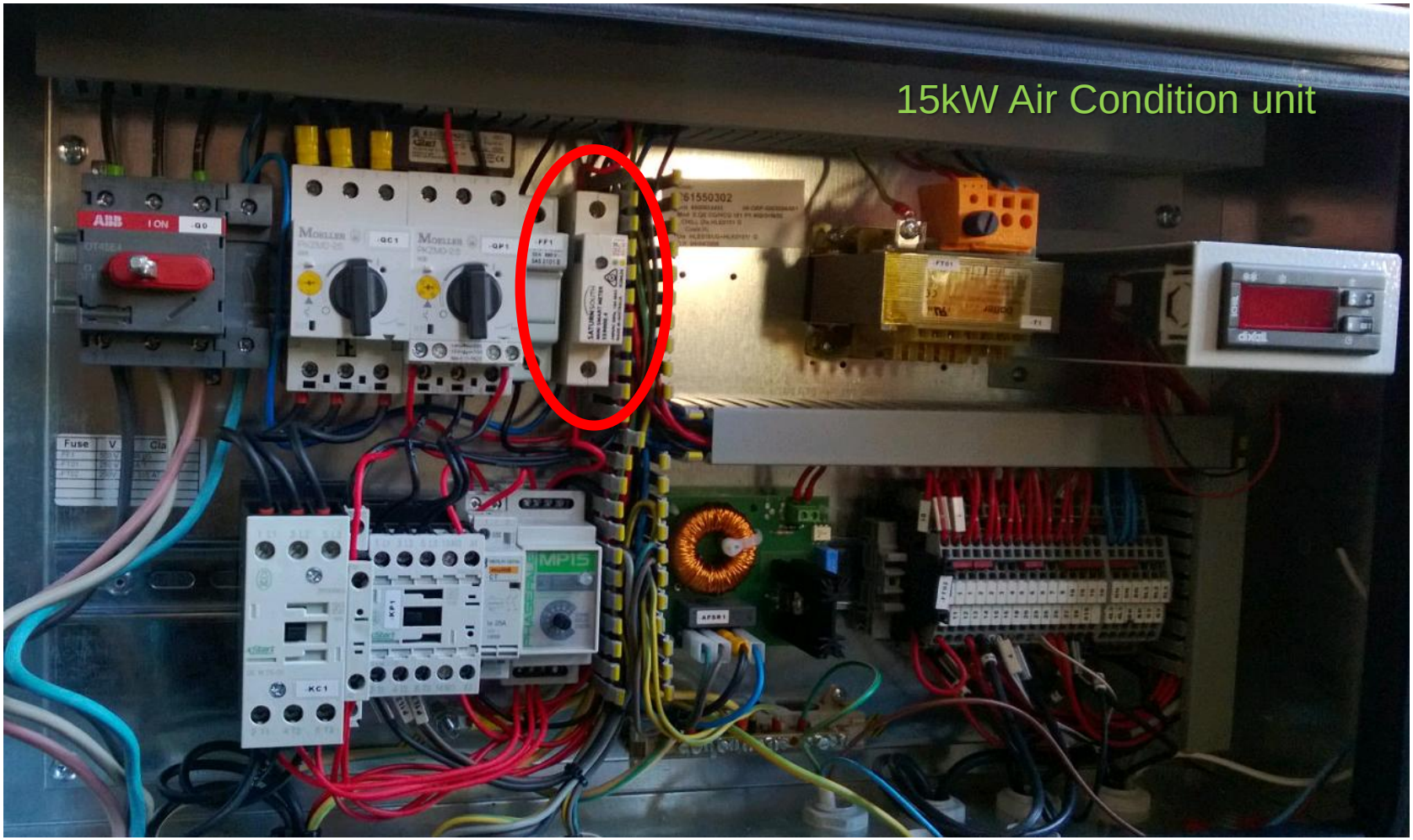


Demand Response Generator



Installation example: Residential

Installation example: Commercial



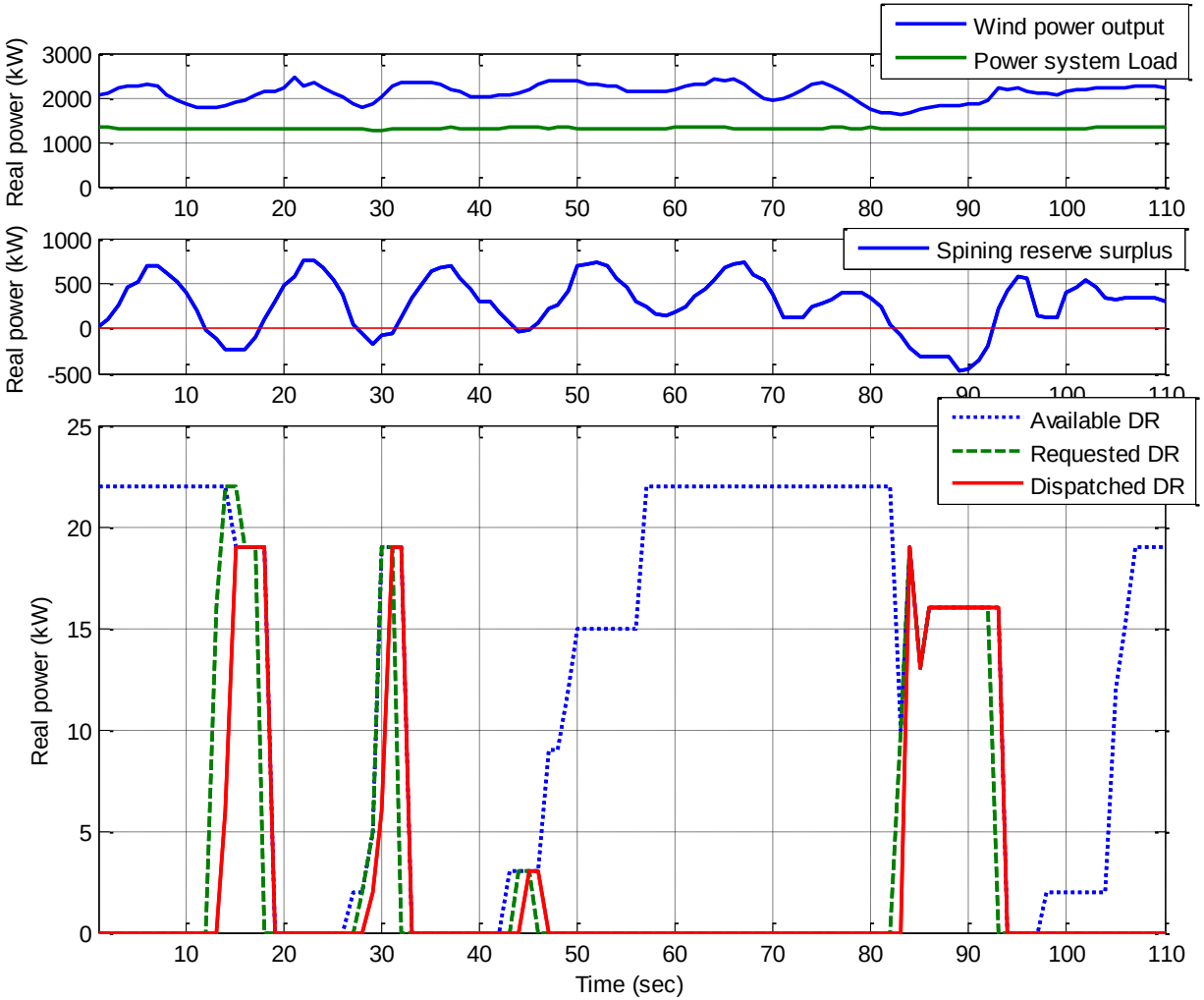
Installation example: Local School

School controllable loads:

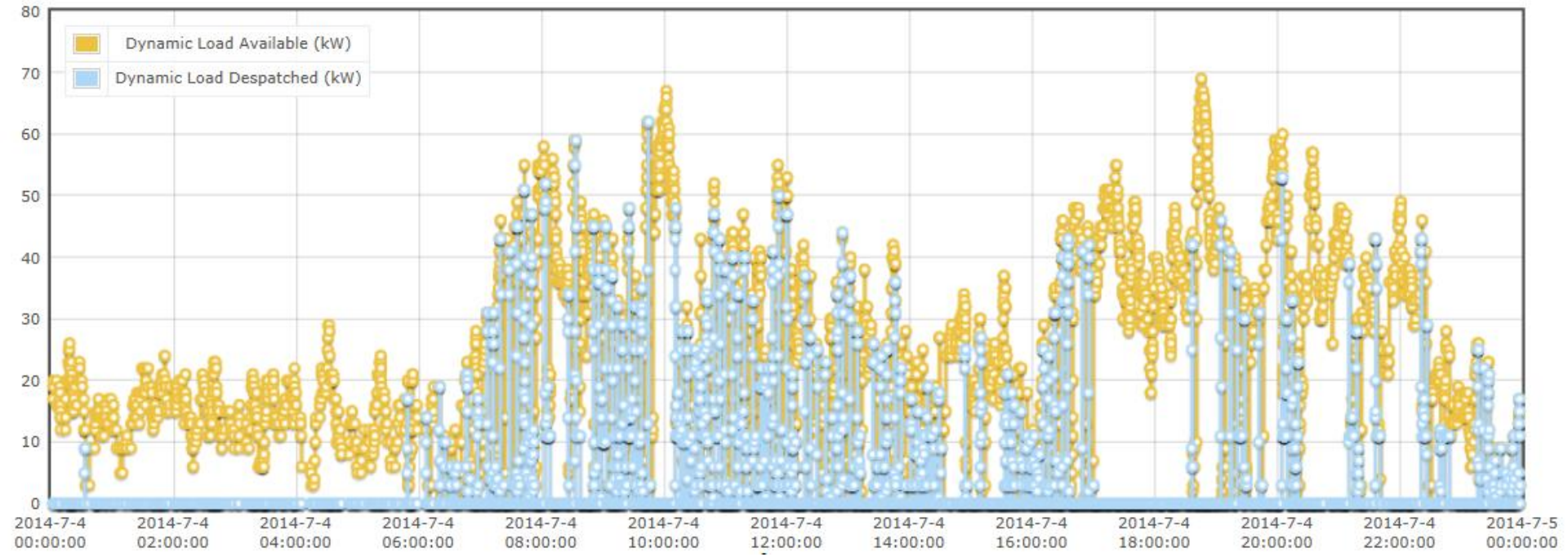
- **3-Phase hot water**
- **3-Phase Pool heaters**
- **3-Phase Heaters**
- **1-Phase Heaters**

Demand response operation

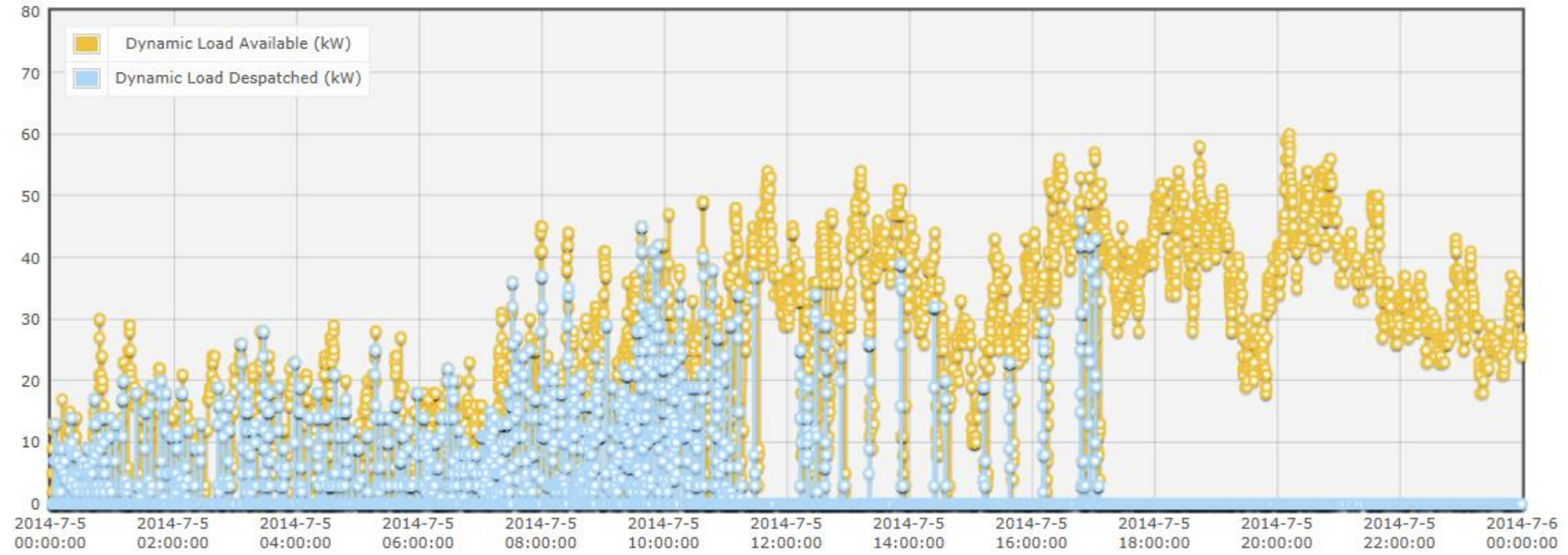
- Demand response automatically initiated during times of low spinning reserve.
- Demand response recorded in within **1 second** from the moment of receiving a command.



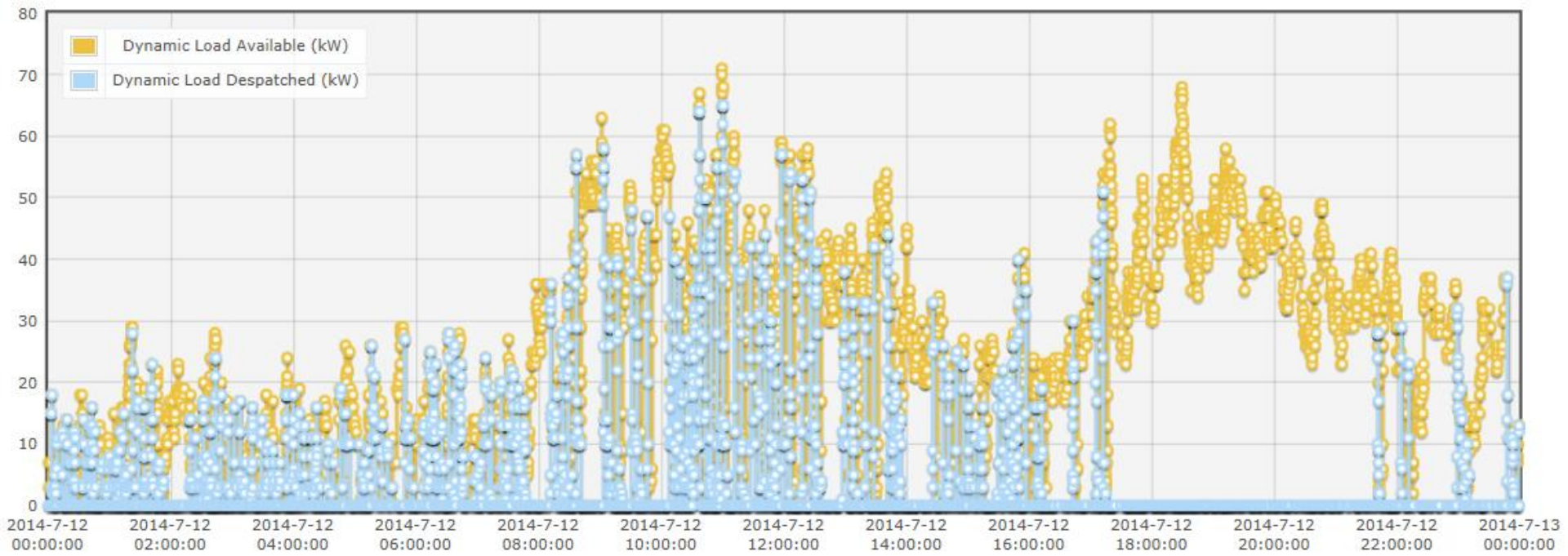
Demand response automated operation (I)



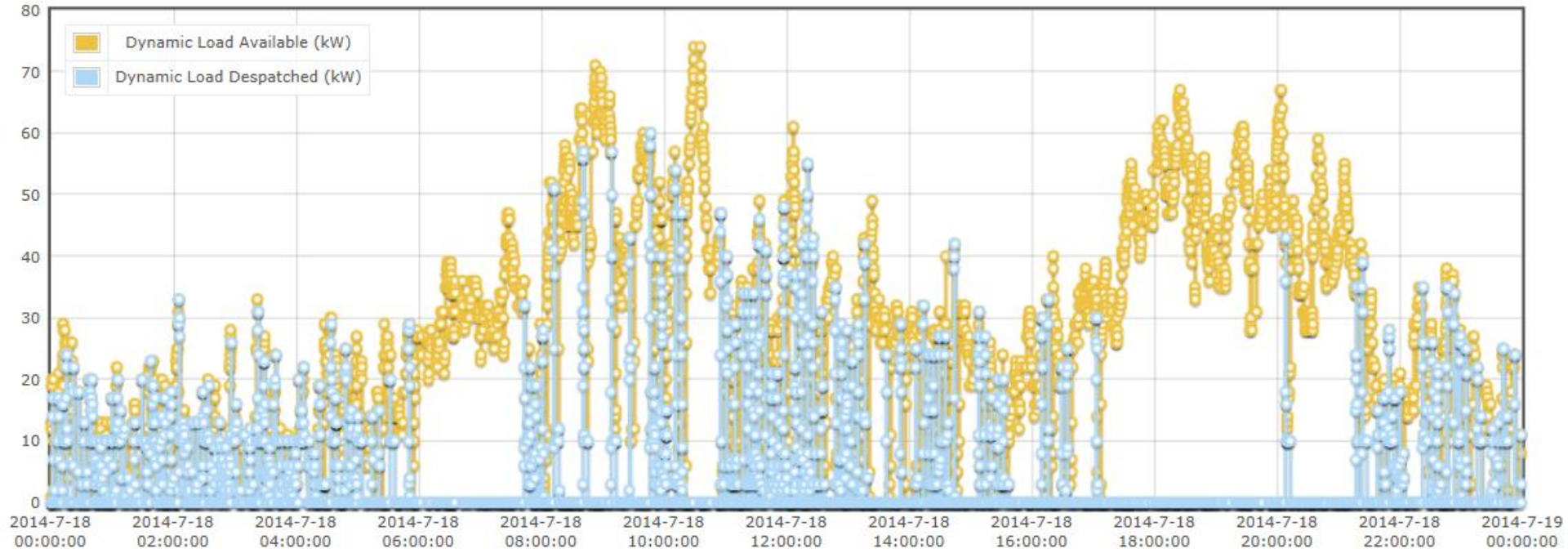
Demand response automated operation (II)



Demand response automated operation (III)



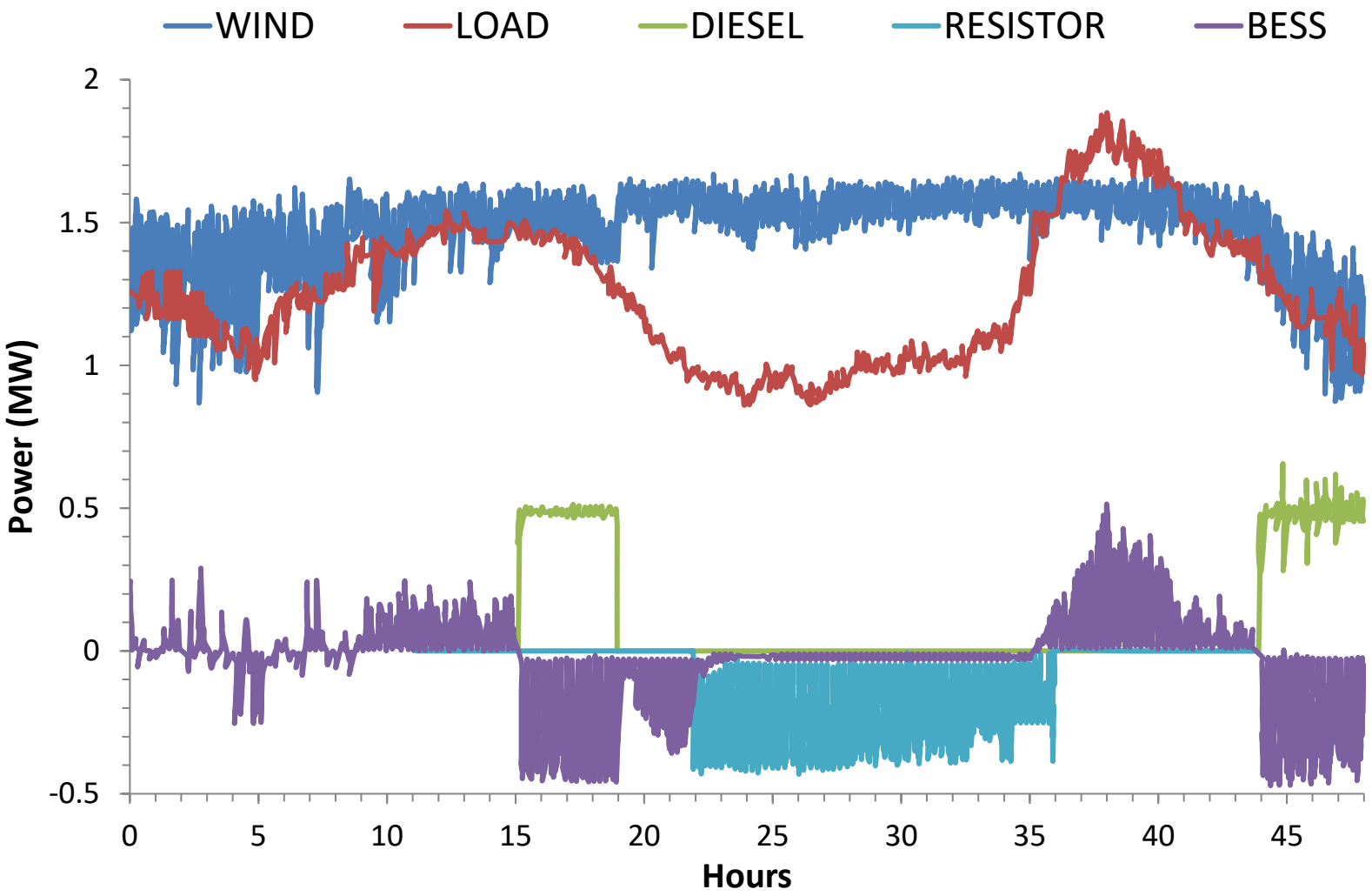
Demand response automated operation (IV)



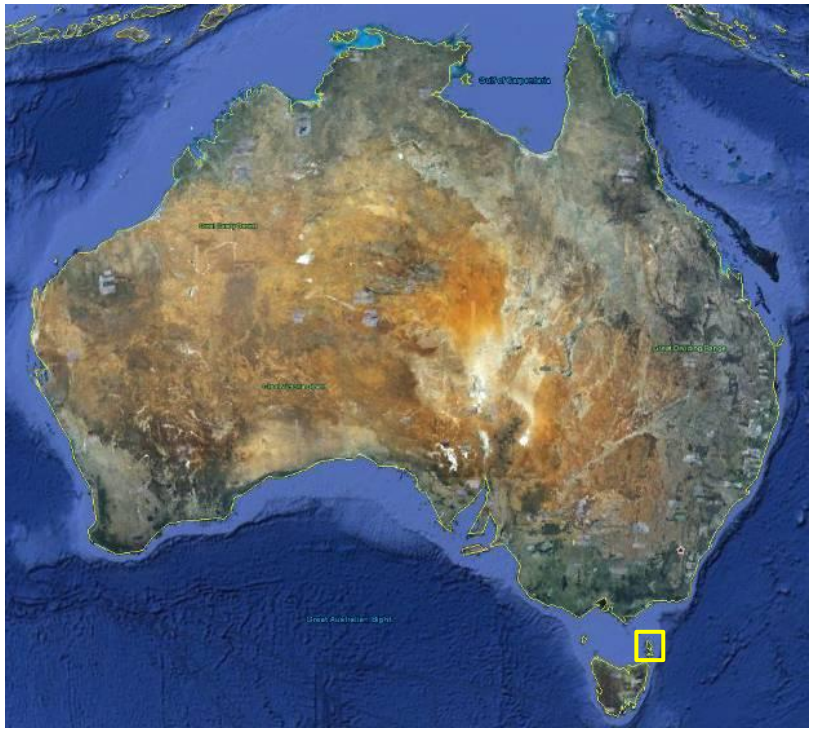
King Island: battery energy storage system (BESS)

- BESS integration was commissioned in 2013. At that time, the BESS represented the largest in Australia – 3 MW / 1.6 MWh.
- The role of the battery is to extend the time for which the island can run diesel off, and to capture some of the spilt renewable generation otherwise sent to the resistive load.

King Island generation showing wind generation, island load, diesel generation, resistor load and battery load



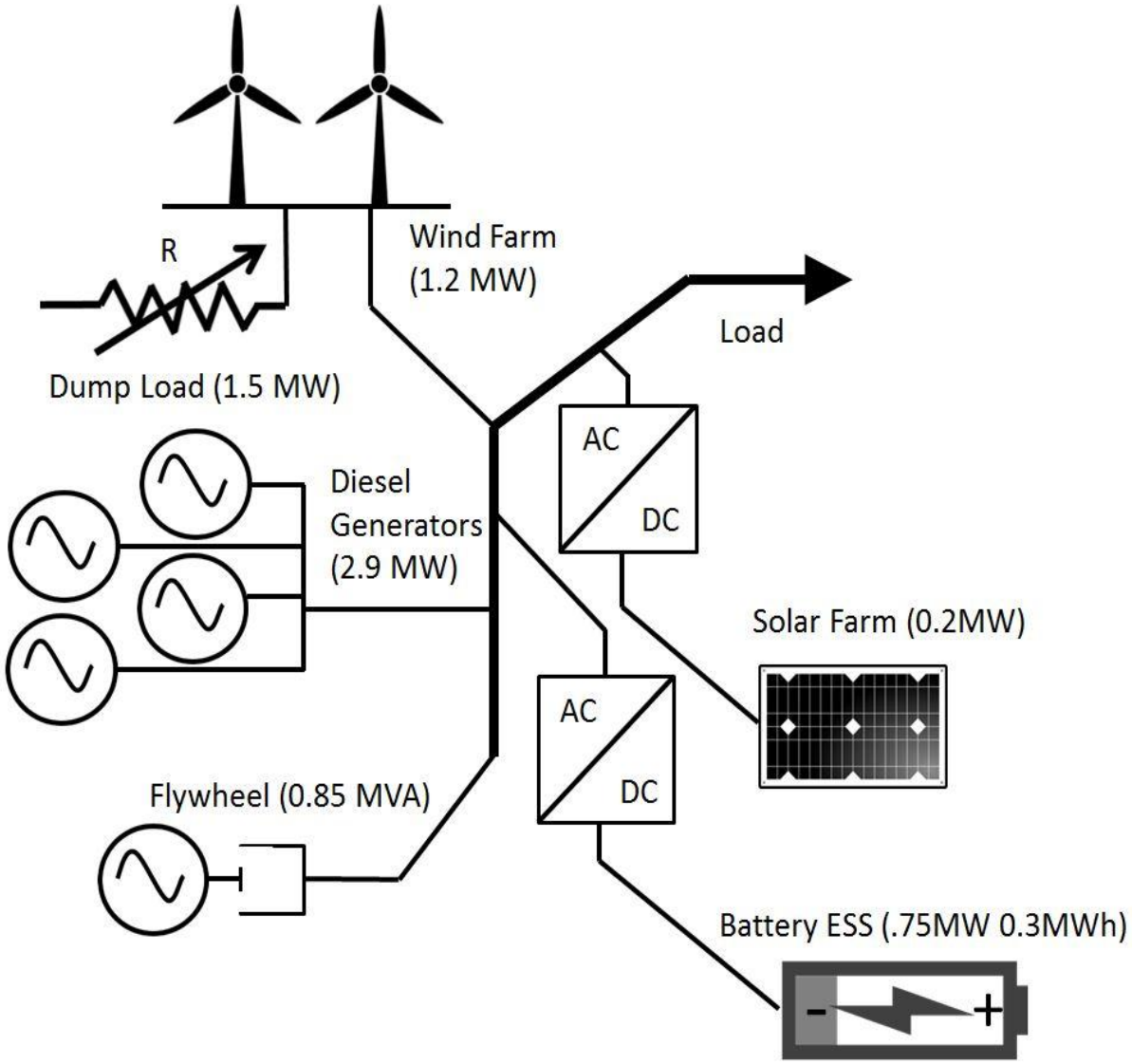
Flinders Island isolated power system

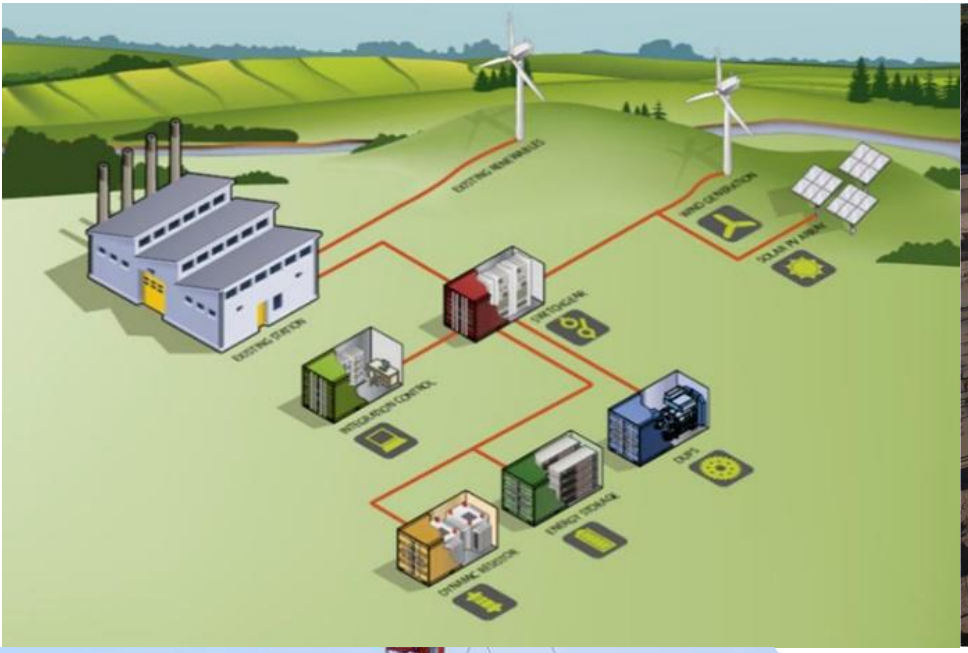


- Population 600.
- 1.3 MW peak load.
- 3 MW diesel.
- 6.7 GWh pa.
- 60% annual renewable generation.

Image source: Google Earth

Flinders Island power system





Modular scalable enabling systems for rapid deployment

Flinders Island: 200kW fix tilt Solar PV

Flinders Island isolated power system

- In contrast to King Island, which employs multiple diesel generator sets of much the same capacity, Flinders Island has been configured with diesel generators of increasing capacity. The station contains four diesel generator sets, 1 x 300kW, 2 x 720kW, and 1 x 1,200kW.
- This configuration allows for the operation of a diesel generation most appropriately sized to the system load.

Rottnest Island isolated power system

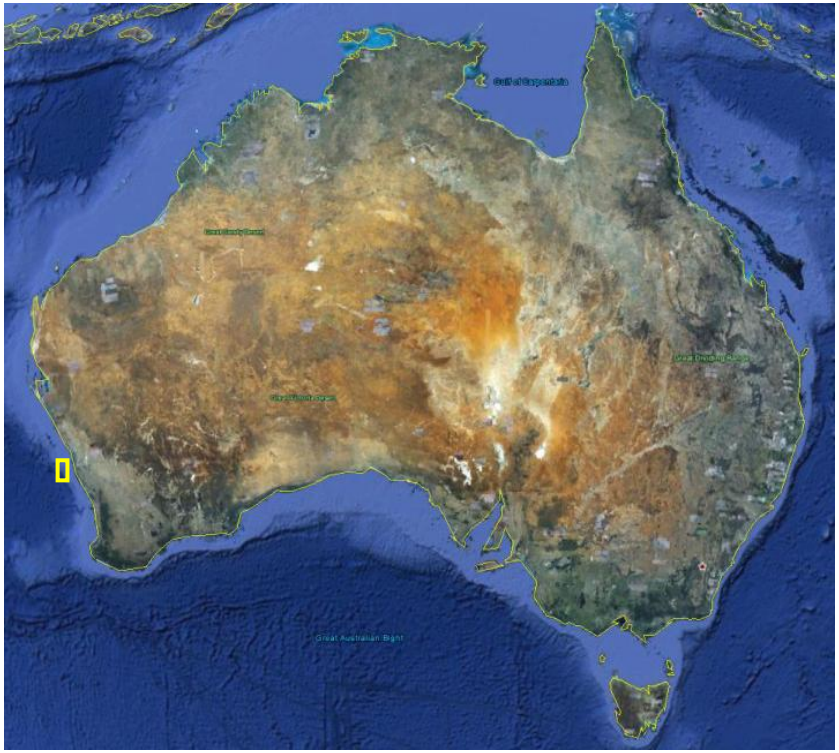
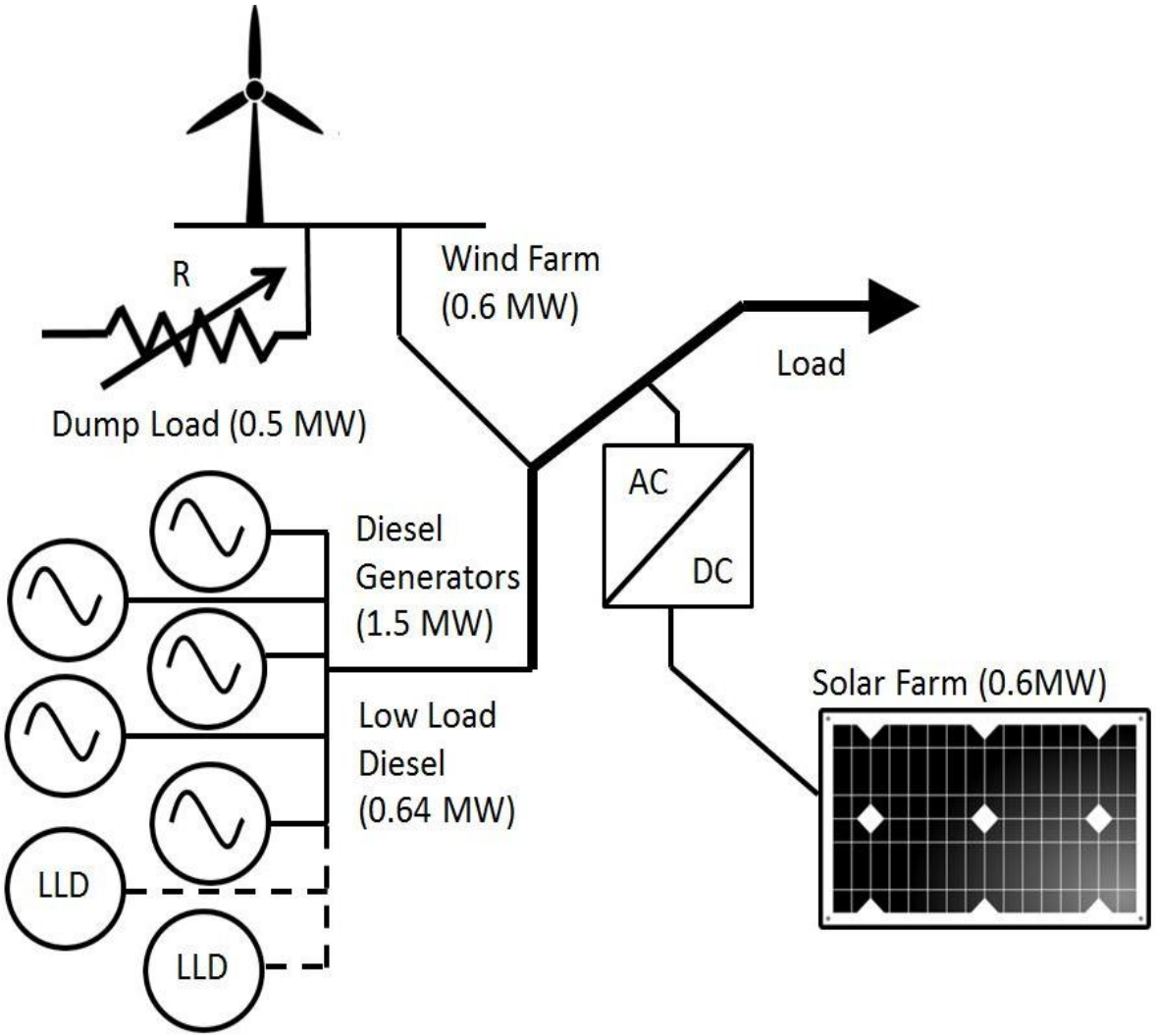


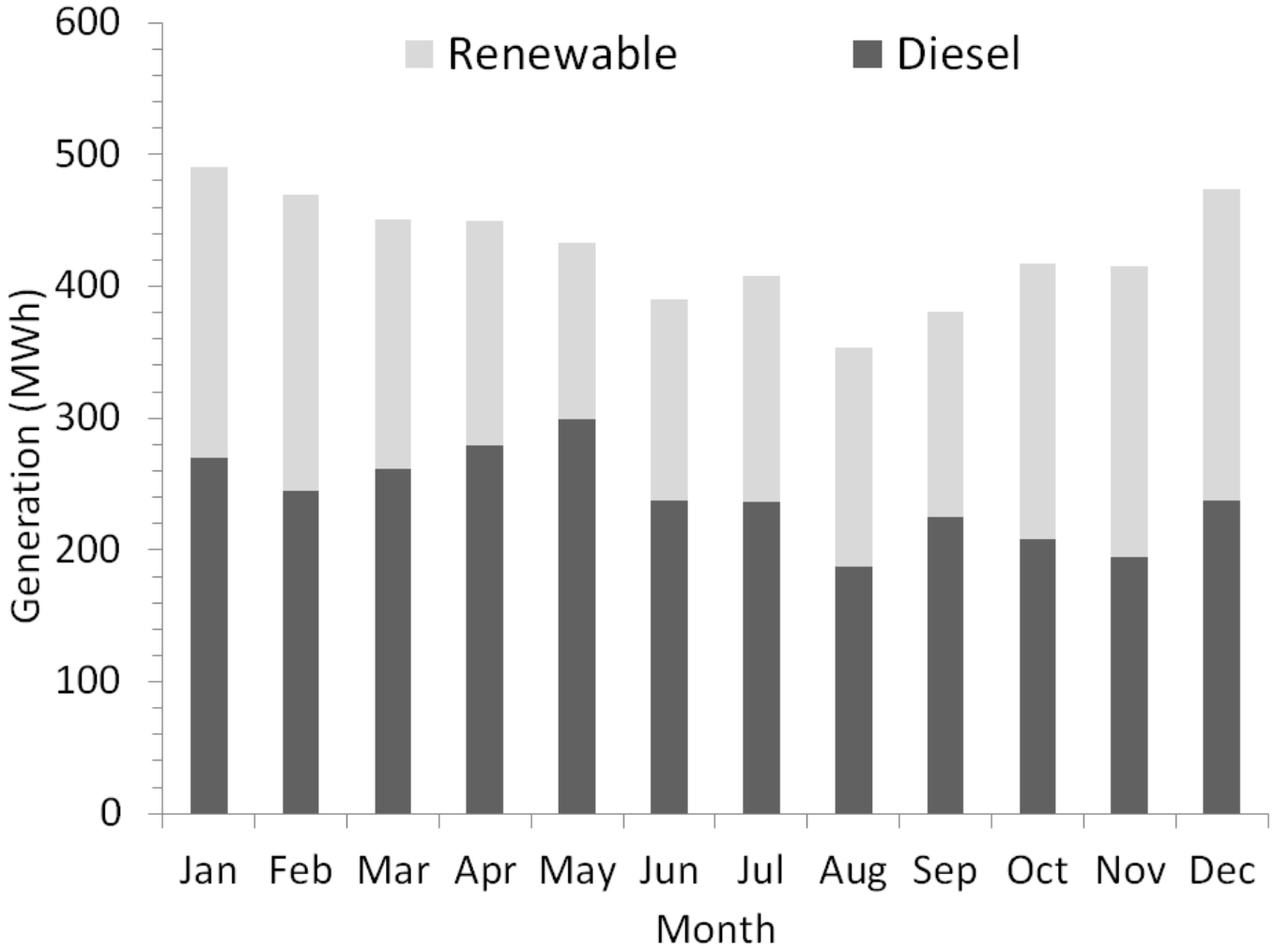
Image source: Google Earth

- Tourist island, 600,000 visitors per year.
- 1.1 MW peak load.
- 2.1 MW diesel.
- 5 GWh pa.
- 45% annual renewable generation.

Rottnest Island power system



Monthly performance of the Rottnest Island power system



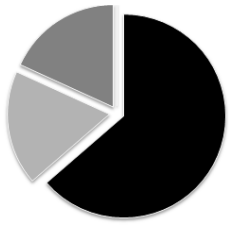
Rottnest Island: demand-side management

- The desalination load is used to shift large blocks of interruptible load into the optimal renewable generation windows.
- The objective of this approach is to reduce or eliminate any diesel generation from the desalination supply to promote maximum renewable energy utilisation.

Future Technology Progression

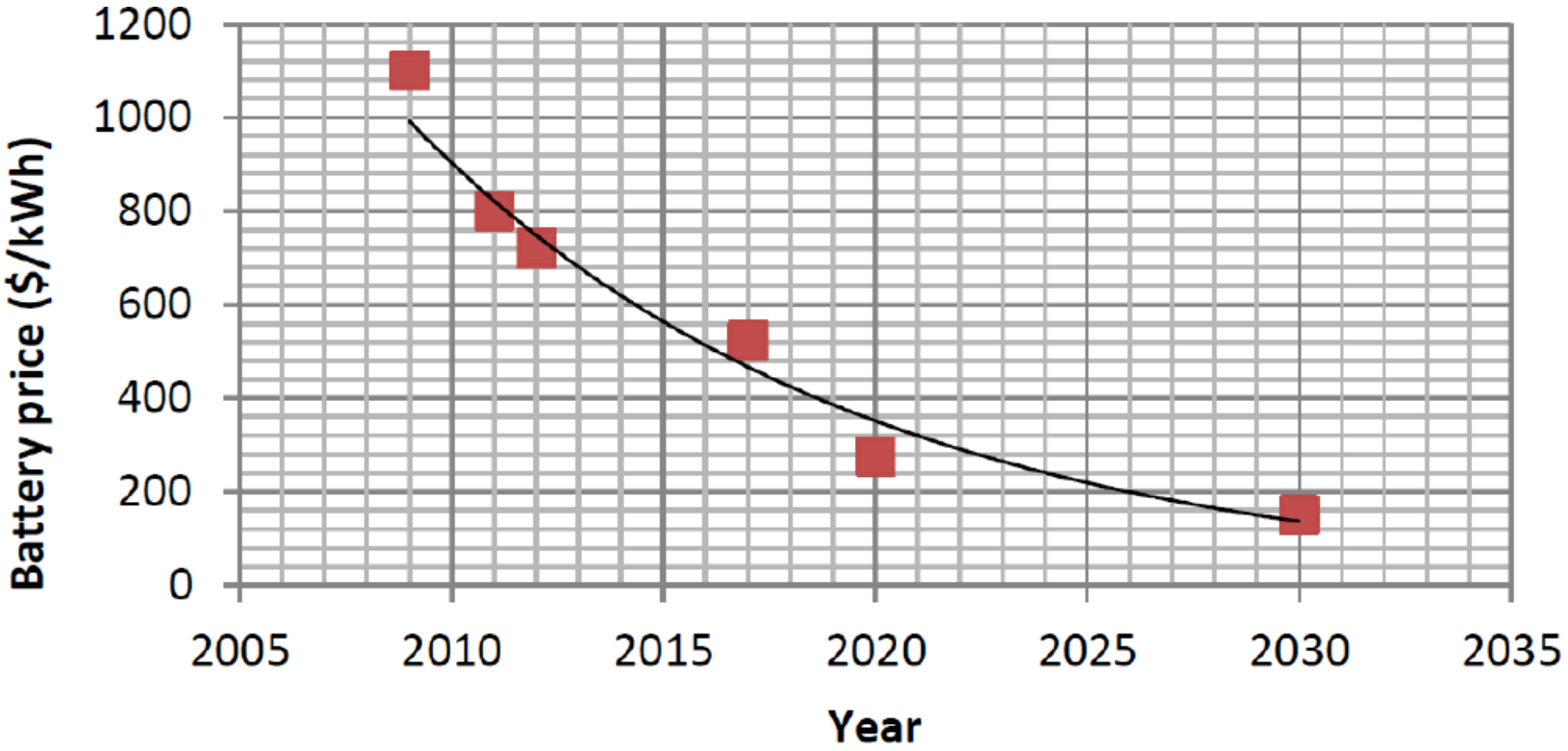
- A range of enabling technologies has been piloted across the presented case studies to improve renewable penetration. Technologies included battery energy storage, flywheel, and thermal storage approaches.
- The increasing use of solar PV.
- Rationalizing the use of battery energy storage, if indeed a battery is required at all, as in the case of Rottnest Island.

Case study metrics

	King Island renewable energy integration project	Flinders Island hybrid energy hub	Rottnest Island water and renewable energy nexus
Generation Configuration	 ■ Diesel (MW) ■ Wind (MW)	 ■ Solar PV (MW)	 ▨ BESS Capacity (MW)
Peak Load (MW)	2.5	1.3	1.2
Average Load (MW)	1.4	0.8	0.6
Annual Generation (GWh p.a.)	12	6.7	5
Generation Capacity Total (MW)	8.35	4.4	3.3
Generation Capacity Renewable (MW)	2.35	1.4	1.2
Renewable Capacity (MW) WIND	2.25	1.2	0.6
Renewable Capacity (MW) Solar PV	0.1	0.2	0.6
Battery ESS Capacity (MW,MWh)	3, 1.6	0.75, 0.3	n/a
Flywheel System	Yes	Yes	No
Renewable Energy Penetration (% p.a.)	65%	60%	50%
Development Period	1998-2015	2014-2017	2016-2017
Utility Network Connection	No	No	No
Capital Cost ($m)	28.15	15.38	9.81
Capital Cost ($m/per MW installed)	**11.98**	**10.99**	**8.18**

Isolated power *systems*… Really?

Li-Ion Battery Cost evolution



Source: Michael De Koster, Laborelec GDF Suez, Battery Cost Evolution, May 2015

Will see batteries everywhere across isolated and remote power systems prior to widespread residential uptake.

- *When the levelized cost of solar PV plus battery storage falls below the evening peak price*

  Then batteries appear in garages and basements

  circa 2025

- When the levelized cost of solar PV and batteries falls below the average cost of power to the consumer

  Then consumers go off-grid

  circa 2030

Want to see a 100% renewable energy island system operating?

https://www.hydro.com.au/clean-energy/hybrid-energy-solutions/success-stories/king-island

Want to learn more about isolated power systems with high renewable energy penetration?

http://ipsconnect.org/