

A black and white photograph of three wind turbines against a dark, clear sky. The turbines are arranged in a diagonal line from the top left towards the bottom right. The blades are long and thin, and the towers are thick and vertical. The overall mood is industrial and clean.

**HARD
SOFT
WARE**

JuMP/HiGHS in the Australian Electricity Market

OUR MAIN PRODUCTS



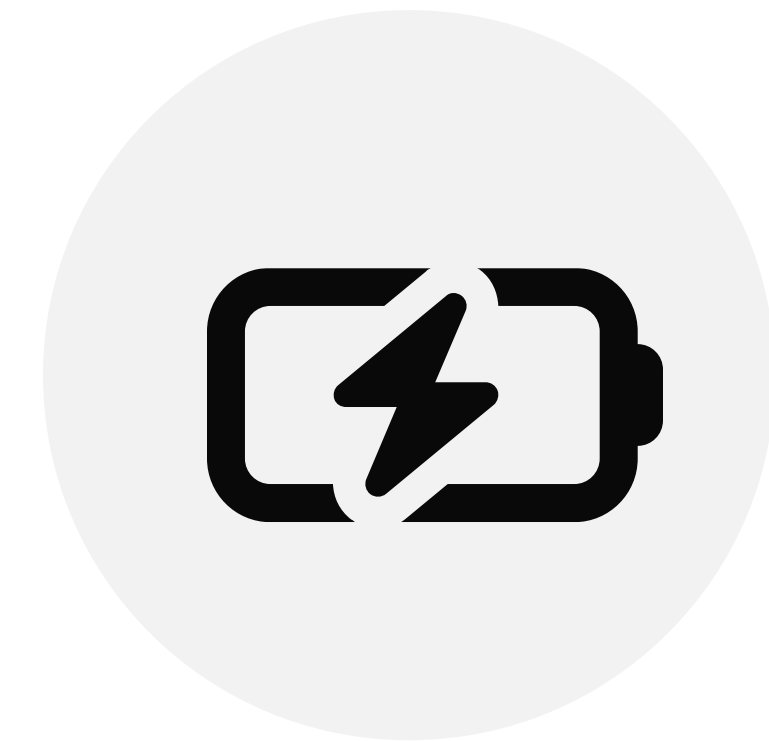
INFOLITE

Infolite a comprehensive solution that provides all the trading and operational requirements for profitably managing and running a renewable wind or solar farm in the Australian NEM.



AUTOMATED VRE TRADING

A recent development is enhancing our Infolite product with an automated bidding solution for solar and wind farms to provide optimized revenue trading at a much cheaper end-user cost than other automated solutions or 24 x 7 trading operations.



OPTIGEN

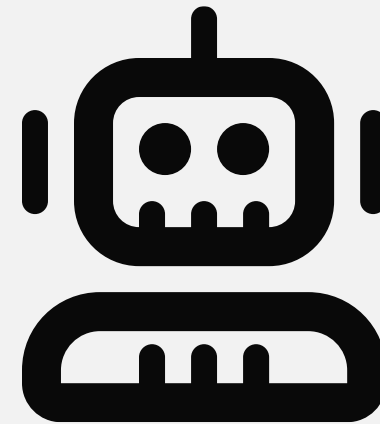
HARD software has recently launched Optigen, which is a cost-effective and reliable solution that seamlessly integrates with renewable energy generation and battery control systems to enhance revenue and manage risk.

COMPETITIVE ENERGY MARKET TRENDS



MULTI-MODAL SYSTEMS

Increasing numbers of renewable generators are looking to integrate BESS into their existing and planned sites. Proposed rule changes will make flexible optimization of these combined generation types necessary for generator profitability.



AUTOMATED TRADING

Automated trading of VRE generators is the most cost-effective solution for both single and multi-modal generation. Many existing alternatives have oversold the benefits or are too costly and many are now being replaced.



SYSTEMS SECURITY

Systems compliance and increasing security requirements for all the NEM trading and operational systems are becoming a priority for the security of the critical national infrastructure. It is expected that audits and penalties for non-compliance will become common.



HORNSDALE TESLA/NEOEN POWER RESERVE

**SOFTWARE DESIGN STARTED 1 AUG 2017
IN PRODUCTION ON 1 DEC 2017**

TESLA HORNSDALE TRADING SOLUTION

T

OVERVIEW

BID VIEW

BID CONTROL

89%

battery_instant_reactive_power0.0

battery_target_power-0.3

battery_instant_power0.0

frequency49.92

battery_nominal_full_pack_energy116.9

max_charge_power87.8

battery_expected_energy_remaining104.3

max_discharge_power104.0

max_charge_power

-5mcurrent

battery_expected_energy_remaining

-5mcurrent

battery_target_power

-5mcurrent

battery_instant_power

-5mcurrent

frequency

-5mcurrent

Auto Bidding

Manual Bidding

Under Direction

NLCAS Activated

active

COMMUNICATION

AEMO

Tesla

Facility

Syd DC

[10:44] Offer id: 114571 version id: 52 for trading date: '2019-01-17' has been successfully submitted and is VALID

[10:44] Offer id: 114571 version id: 52 for trading date: '2019-01-17' has been transferred to AEMO

[10:41] Offer id: 114571 version id: 52 for trading date: '2019-01-17' has been submitted from 'TESLA'

[10:40] Offer id: 114569 version id: 50 for trading date: '2019-01-17' acknowledgment could not be found within: 300 seconds

[10:38] Offer id: 114570 version id: 51 for trading date: '2019-01-17' has been successfully submitted and is VALID

[10:37] Offer id: 114570 version id: 51 for trading date: '2019-01-17' has been transferred to AEMO

[10:36] Offer id: 114570 version id: 51 for trading date: '2019-01-17' has been

DISPATCH - HPRG1

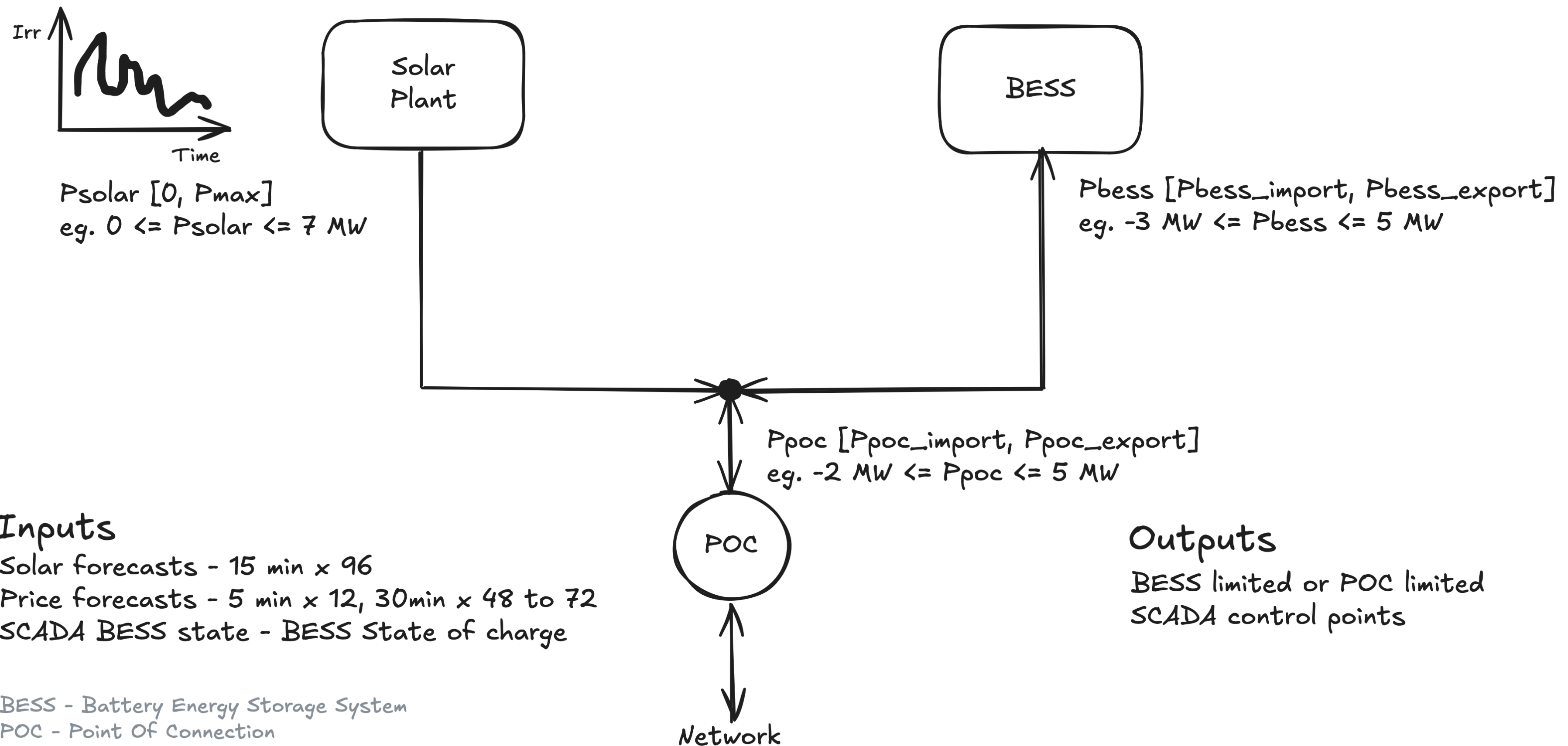
DI HH	RRP	Init	Target	Avail	Conf	RReg	LReg	R6	R60	R5	L6	L60	L5
10:20	\$112.52	0	0	100	0	0	0	63	19	41	0	0	0
10:25	\$115.62	0	0	100	0	0	0	63	19	41	0	0	0
10:30	\$116.60	0	0	100	0	0	0	63	19	41	0	0	0
10:35	\$111.22	0	0	100	0	0	0	63	19	41	0	0	0
10:40	\$112.37	0	0	100	0	0	0	63	19	41	0	0	0
10:45	\$143.72	0	0	100	0	0	0	63	19	41	0	0	0
10:50	\$148.00	0	0	100	0	0	0	63	19	41	0	0	0

DISPATCH - HPRL1

DI HH	RRP	Init	Target	Avail	Conf	RReg	LReg	R6	R60	R5	L6	L60	L5
10:20	\$112.52	0	0	32	0	0	0	0	0	0	0	19	7
10:25	\$115.62	0	0	32	0	0	0	0	0	0	0	19	7
10:30	\$116.60	0	0	33	0	0	0	0	0	0	0	19	7
10:35	\$111.22	0	0	33	0	0	0	0	0	0	0	19	7
10:40	\$112.37	0	0	33	0	0	0	0	0	0	0	19	7
10:45	\$143.72	0	0	34	0	0	0	0	0	0	0	19	7
10:50	\$148.00	0	0	34	0	0	0	0	0	0	0	19	7

TYPICAL GENERATION PLANT SCHEMATIC

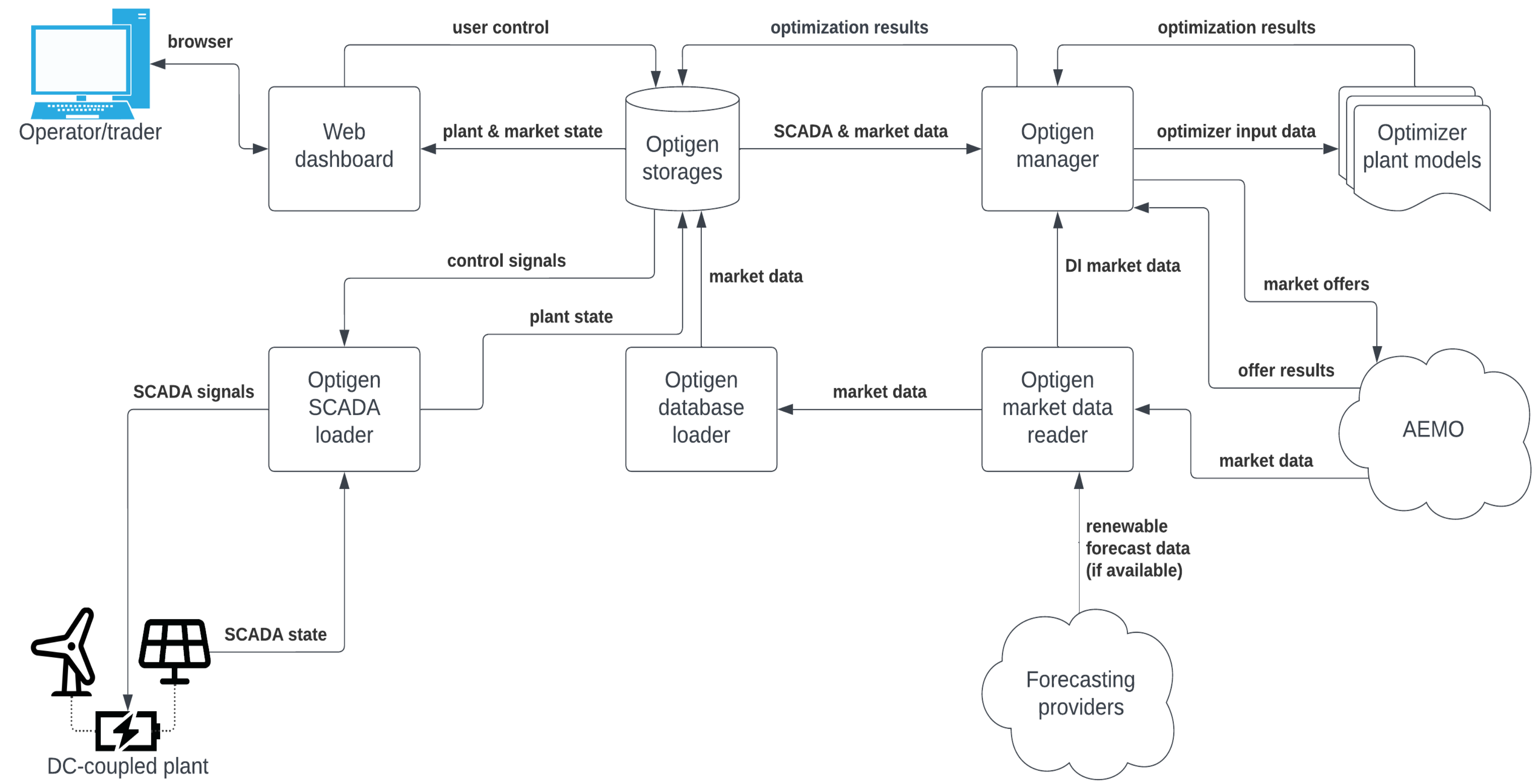
BESS with DC-coupled Solar



BESS - Battery Energy Storage System
 POC - Point Of Connection
 SCADA - Supervisory Control And Data Acquisition

OPTIGEN OPTIMISED TRADING SOLUTION

Optigen scalable hosted solution logical diagram
February 2024



OPTIGEN CONTROL SYSTEM INTERFACE



OPTIGEN TECHNOLOGY

JULIA/JUMP

The optimisation multi-threaded module is written entirely in Julia using JuMP to interface to HiGHS.

DISCRETE MODULES

Each other component of the Optigen framework is entirely independent and uses a unified Python multi-threaded architecture.

MESSAGING

All inter-process communication is implemented using a unified messaging framework and message format.

MULTI-TENANTED

A principal feature of the design is to be able to run multiple site models on a single instance to allow for scaling the solution.





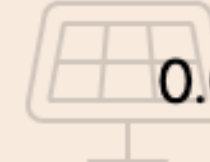
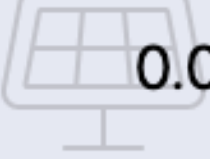


OPEN SOURCE

All programming & modelling languages, application infrastructure & operating systems are open source.

DEPLOYMENT

A small, economical industry standard RTU device is used to provide the interface directly to the plant SCADA.

OPTIGEN OPTIMISED TRADING SOLUTION

<div>  OptiGen Logout </div>	<div> <div>  <div>0.04 MW</div> <div> <div>AUTO MODE</div> <div>MANUAL MODE</div> </div> </div> <div> <div>Units Generating:0 / 4</div> <div>Units Available:0 / 4</div> <div>Possible Power:MW</div> <div>Irradiance:0 W/m²</div> <div>Temperature:0 °C</div> </div> <div> <div>POC Voltage:322.6 kV</div> <div>HSW Setpoint:0.00 MW</div> <div>Plant Setpoint:MW</div> <div>Reason:</div> </div> <div> <div>Last HeartBeat received11 Nov 2025 4:45:15 pm (+11:00)</div> <div>Last SCADA received11 Nov 2025 4:45:15 pm (+11:00)</div> </div> </div>	<div> <div>  <div>0.05 MW</div> <div> <div>AUTO MODE</div> <div>MANUAL MODE</div> </div> </div> <div> <div>Units Generating:0 / 4</div> <div>Units Available:0 / 4</div> <div>Possible Power:MW</div> <div>Irradiance:0 W/m²</div> <div>Temperature:0 °C</div> </div> <div> <div>POC Voltage:106.8 kV</div> <div>HSW Setpoint:0.00 MW</div> <div>Plant Setpoint:MW</div> <div>Reason:</div> </div> <div> <div>Last Heartbeat received11 Nov 2025 4:45:15 pm (+11:00)</div> <div>Last SCADA received11 Nov 2025 4:45:15 pm (+11:00)</div> </div> </div>	<div> <div>Prices</div> <table> <tr> <th>PRICE</th><th>NSW1</th><th>QLD1</th><th>SA1</th><th>VIC1</th></tr> <tr> <td>Energy</td><td>\$-16.00</td><td>\$-17.36</td><td>\$-10.38</td><td>\$-12.94</td></tr> <tr> <td>Raise Reg</td><td>\$7.50</td><td>\$7.50</td><td>\$7.50</td><td>\$7.50</td></tr> <tr> <td>Lower Reg</td><td>\$1.51</td><td>\$1.51</td><td>\$1.51</td><td>\$1.51</td></tr> <tr> <td>Raise 1 Sec</td><td>\$0.00</td><td>\$0.00</td><td>\$0.00</td><td>\$0.00</td></tr> <tr> <td>Raise 6 Sec</td><td>\$0.15</td><td>\$0.15</td><td>\$0.15</td><td>\$0.15</td></tr> <tr> <td>Raise 60 Sec</td><td>\$0.10</td><td>\$0.10</td><td>\$0.10</td><td>\$0.10</td></tr> <tr> <td>Raise 5 Min</td><td>\$0.10</td><td>\$0.10</td><td>\$0.10</td><td>\$0.10</td></tr> <tr> <td>Lower 1 Sec</td><td>\$0.00</td><td>\$0.00</td><td>\$0.00</td><td>\$0.00</td></tr> <tr> <td>Lower 6 Sec</td><td>\$0.38</td><td>\$0.38</td><td>\$0.38</td><td>\$0.38</td></tr> <tr> <td>Lower 60 Sec</td><td>\$0.38</td><td>\$0.38</td><td>\$0.38</td><td>\$0.38</td></tr> <tr> <td>Lower 5 Min</td><td>\$0.39</td><td>\$0.39</td><td>\$0.39</td><td>\$0.39</td></tr> </table> </div>	PRICE	NSW1	QLD1	SA1	VIC1	Energy	\$-16.00	\$-17.36	\$-10.38	\$-12.94	Raise Reg	\$7.50	\$7.50	\$7.50	\$7.50	Lower Reg	\$1.51	\$1.51	\$1.51	\$1.51	Raise 1 Sec	\$0.00	\$0.00	\$0.00	\$0.00	Raise 6 Sec	\$0.15	\$0.15	\$0.15	\$0.15	Raise 60 Sec	\$0.10	\$0.10	\$0.10	\$0.10	Raise 5 Min	\$0.10	\$0.10	\$0.10	\$0.10	Lower 1 Sec	\$0.00	\$0.00	\$0.00	\$0.00	Lower 6 Sec	\$0.38	\$0.38	\$0.38	\$0.38	Lower 60 Sec	\$0.38	\$0.38	\$0.38	\$0.38	Lower 5 Min	\$0.39	\$0.39	\$0.39	\$0.39
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<div> <div>  <div>-0.11 MW</div> <div> <div>AUTO MODE</div> <div>MANUAL MODE</div> </div> </div> <div> <div>Turbines Generating:0 / 12</div> <div>Turbines Available:12 / 12</div> <div>Possible Power:0 MW</div> <div>Wind Speed:11.3 m/s</div> <div>Temperature:11.7 °C</div> </div> <div> <div>POC Voltage:127.5 kV</div> <div>HSW Setpoint:0.00 MW</div> <div>Plant Setpoint:0.00 MW</div> <div>Reason:no generation - lgc: \$10.25</div> </div> <div> <div>Last HeartBeat11 Nov 2025 4:45:17 pm (+11:00)</div> <div>Last SCADA11 Nov 2025 4:45:17 pm (+11:00)</div> </div> </div>																																																															

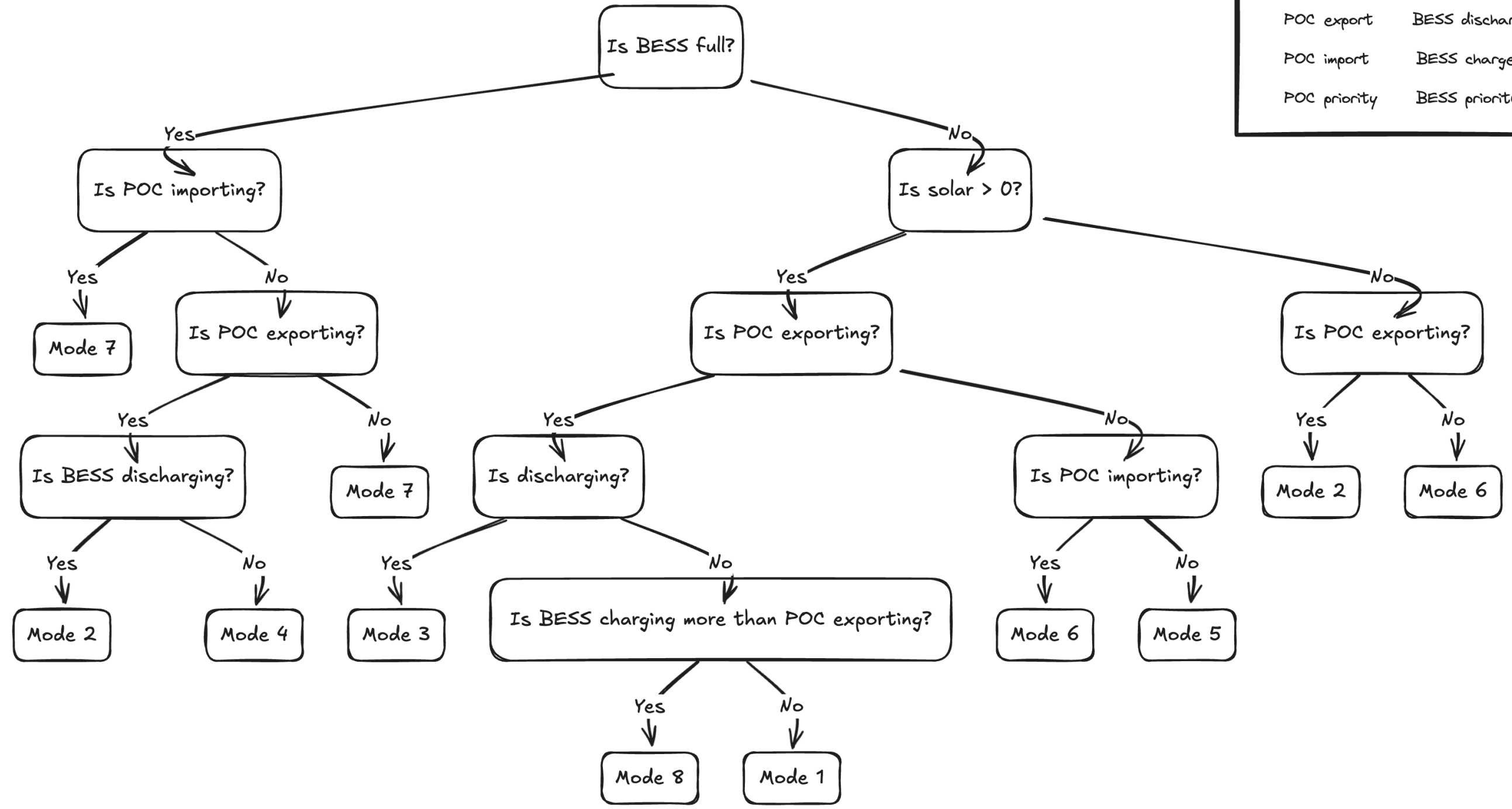
OPTIGEN CONTROL LOGIC

BESS DC-coupled solar optimisation scenarios

29 January 2025 - Dr. Harley Mackenzie
HARD software

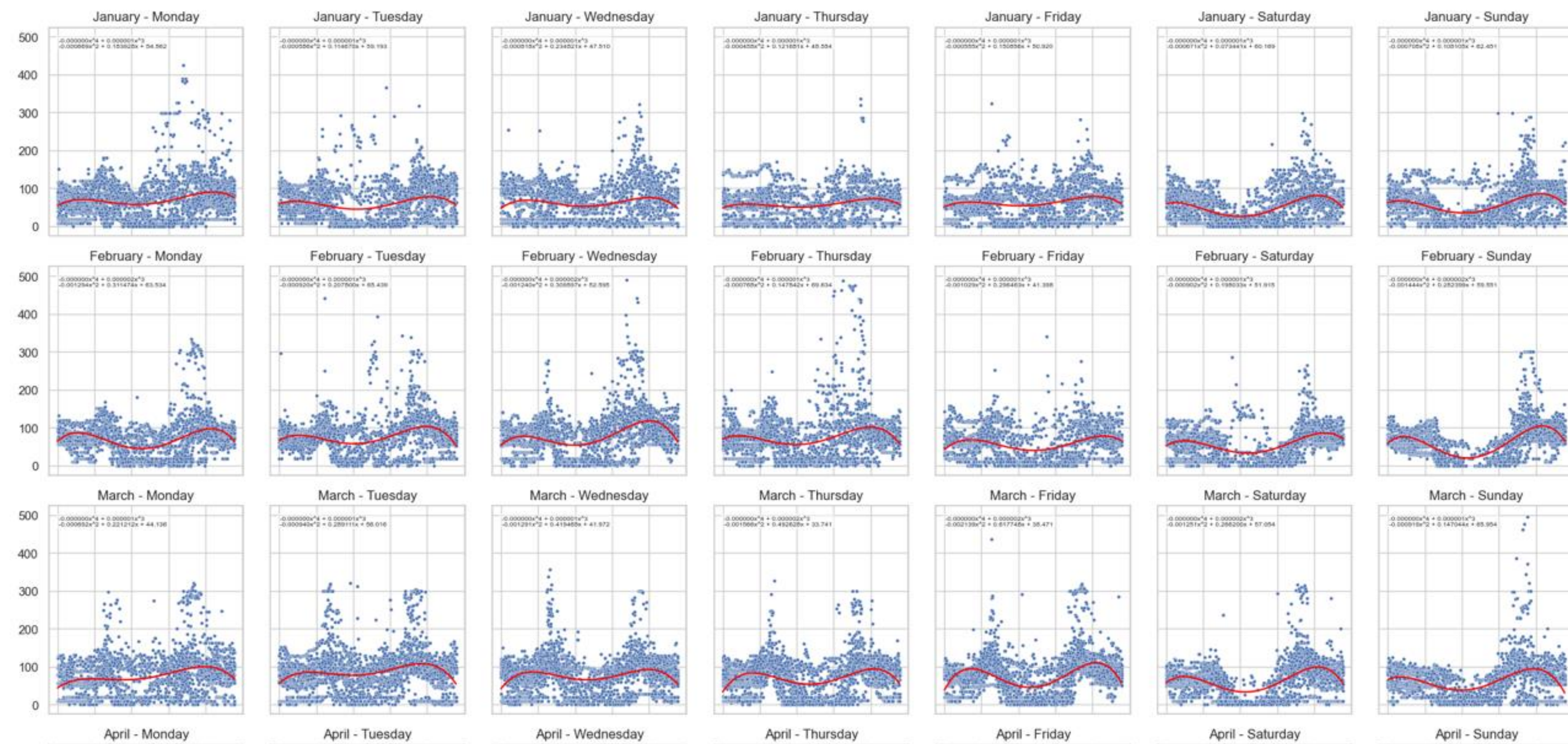
Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Mode 7	Mode 8
max POC exp excess BESS	max POC exp & no BESS imp	max POC exp & BESS exp/imp	No BESS POC export	solar to import BESS	max imp BESS & POC import	No BESS or solar	max imp BESS & POC export
T F F T T F	T T F F T F	T T F T T F	T F F F T F	F F F T F T	F F T T F T	F F F F T F	T F F T F T

SCADA signals legend	
POC export	BESS discharge
POC import	BESS charge
POC priority	BESS priority



STORAGE VALUATION APPROACH

Scatter Plots of RRP by Time of Day for VIC1 since 2022-01-01



OPTIGEN MONITORING DASHBOARD

MQTT Broker: 192.168.32.21:1883 | Client ID: mqtt_dashboard_5818

Market Data

Dispatch Interval: 2025-11-11 14:00

Prices: 2025-11-11 13:55:43 5 MIN forecasts: 2025-11-11 13:57:37

NSW1: -\$16.77 [-\$20.35, -\$20.77, -\$21.01, -\$21.72, -\$21.69, -\$20.98, -\$20.00, -\$21.06, -\$21.45, -\$20.95, -\$20.00, -\$20.00]

QLD1: -\$10.82 [-\$14.53, -\$14.53, -\$14.53, -\$10.82, -\$10.85, -\$14.53, -\$13.89, -\$14.53, -\$15.01, -\$14.53, -\$14.53, -\$14.53]

SA1 : -\$16.77 [-\$19.14, -\$19.88, -\$17.81, -\$17.81, -\$17.81, -\$18.85, -\$17.90, -\$18.94, -\$19.88, -\$20.83, -\$19.98, -\$18.24]

TAS1: \$23.18 [\$23.13, \$23.13, \$23.13, \$23.13, \$23.13, \$21.93, \$23.13, \$22.04, \$21.38, \$20.98, \$20.98, \$20.98]

TOORAWF

Dispatch Interval: 2025-11-11 14:00 Region: VIC1

SCADA readings: 11/11/2025 13:57:37

request: 2025-11-11 13:57:33 response: 2025-11-11 13:57:35

generation: -0.118 MW

no available: 12

solution status: OPTIMAL

HSW setpoint: 0.000 MW

wind speed: 12.30 m/s

no generating: 0

modes: [1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1]

plant setpoint: 21.000 MW

MOBI

Dispatch Interval: 2025-11-11 14:00 Region: SA1

SCADA readings: N/A

request: 2025-11-11 13:57:34 forecast: 2025-11-11 13:43:03

response: 2025-11-11 13:57:35

POC active power: N/A

irradiance: N/A

no available: N/A

BESS storage: N/A

solution status: OPTIMAL

HSW setpoint: N/A

solar generation: N/A

temperature: N/A

no generating: N/A

BESS output: N/A

modes: MODE_6 [0, 0, 1, 1, 0, 1]

POC setpoint: N/A

PORTPIRIE

Dispatch Interval: 2025-11-11 14:00 Region: SA1

SCADA readings: 11/11/2025 13:57:32

request: 2025-11-11 13:57:34 forecast: 2025-11-11 13:43:05

response: 2025-11-11 13:57:35

POC active power: 0.048 MW

irradiance: 1112.00 W/m²

no available: 0

BESS storage: 0.000 MWh

solution status: OPTIMAL

HSW setpoint: N/A

solar generation: 0.045 MW

temperature: 1.9 Deg C

no generating: 0

BESS output: 0.000 MW

modes: MODE_2 [1, 1, 0, 0, 1, 0]

POC setpoint: 0.050 MW

NARRANDERA

Dispatch Interval: 2025-11-11 14:00 Region: NSW1

SCADA readings: 11/11/2025 13:57:20

request: 2025-11-11 13:57:34 forecast: 2025-11-11 13:43:04

response: 2025-11-11 13:57:35

POC active power: 0.066 MW

irradiance: 0.00 W/m²

no available: 0

BESS storage: 0.000 MWh

solution status: OPTIMAL

HSW setpoint: N/A

solar generation: 0.046 MW

temperature: 0.0 Deg C

no generating: N/A

BESS output: -0.003 MW

modes: MODE_2 [1, 1, 0, 0, 1, 0]

POC setpoint: 4.700 MW

MOYHALL

Dispatch Interval: 2025-11-11 14:00 Region: SA1

SCADA readings: 11/11/2025 13:57:40

request: 2025-11-11 13:57:35 forecast: 2025-11-11 13:43:04

response: 2025-11-11 13:57:35

POC active power: 0.046 MW

irradiance: 962.00 W/m²

no available: 4

BESS storage: 0.000 MWh

solution status: OPTIMAL

HSW setpoint: N/A

solar generation: 0.065 MW

temperature: 14.8 Deg C

no generating: N/A

BESS output: 0.000 MW

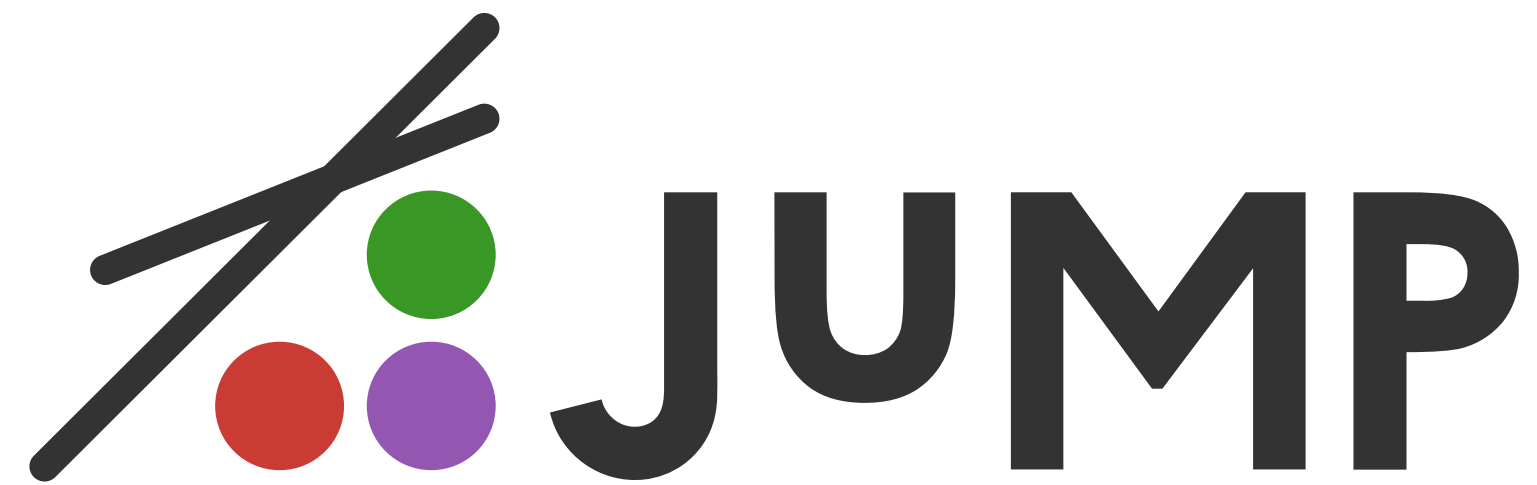
modes: MODE_7 [0, 0, 0, 0, 1, 0]

POC setpoint: 0.004 MW

q Quit r Refresh

Status: Connected & Listening | Total Messages: 2303 | Active Sections: 8/8

JuMP LESSONS FROM OPTIGEN



➤ ENERGY/MARKET OPTIMISATION & JuMP

Energy/market optimisation is a “killer app” for JuMP: many users of JuMP are interested in power-systems modelling, scheduling & market bidding.

➤ DATA QUALITY IS EVERYTHING

Market data needs to “productionised” eg. actual versus forecast data needs to be consistent, and control system interfaces must be reliable and consistent.

➤ CONTINUOUS MONITORING REQUIRED

Data quality and timing need to always be monitored. Issues can arise when delivery of data is inconsistent and variable (prices 20s to 90s into DI, forecasts 90s to 210s).

➤ SOLUTION TIME IS NOT ALWAYS CRITICAL

Model for BESS and solar solution typically runs in under 1s, allowing for multi-tenanted solutions. Mapping optimisation results to controls is not as straightforward.

➤ JuMP MODELLING IS QUICK AND EASY

AMPL is easier to learn only due to the available educational resources and example implementations. JuMP is a serious contender in the Open Source and energy / market modelling community, and the availability & quality of resources are improving all the time.



DR HARLEY MACKENZIE

MANAGING DIRECTOR

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www.hardsoftware.com

