Value of Smart Power Generation for utilities in Australia

A white paper by Wärtsilä and Roam Consulting

Executive summary

This study analyses the potential of Smart Power Generation (SPG) power plants in a large utility portfolio in South Australia, operating in the National Electricity Market (NEM). State-of-the-art modelling framework shows that an SPG peaking power plant can provide significant gross margin to the utility, compared to open cycle gas turbine (OCGT) alternatives. Simultaneously, SPG decreases the risk exposure of the utility by reducing the volatility of daily returns. The benefits are based on the inherent operational flexibility of the internal combustion engine (ICE) technology, especially the capability of starting to full load in less than 5 minutes. Agile operation enables a superior position in the 5-minute market, compared to slower peaking plant technologies.

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The analysis shows that a 200 MW SPG power plant generates an additional gross margin of AUD 12.4 million for the selected utility per year, compared to the aeroderivative OCGT case. The gross margin is AUD 14.6 million compared to the heavy duty OCGT case. In a year-long operation regime, the SPG plant is started 1054 times with 933 running hours, while the heavy duty OCGT is started 434 times with 395 running hours. The difference is due to the SPG plant's capability to capture more market opportunities in the 5-minute electricity market.

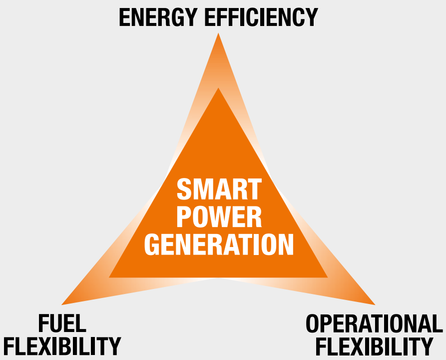
In addition, the results show system level benefits. A single 200 MW SPG power plant, as a part of a utility portfolio, decreases the average wholesale electricity price in NEM by 4% compared to the heavy duty OCGT case, with market prices of 41.3 AUD/MWh and 42.9 AUD/MWh, respectively. The price drop is a result of the SPG plant being used to prevent disadvantageous price spikes in the market. The SPG case produces 23 price spikes of over 10,000 AUD/MWh per year, compared to 36 spikes in the heavy duty gas turbine case.

This study is made in co-operation with ROAM Consulting[1].

Figure 1. Smart Power Generation power plant.

What is Smart Power Generation?

Wärtsilä's Smart Power Generation power plants are ultra-flexible generation units up to 700 MW, based on multiple internal combustion engines (ICEs). Common applications are baseload, peaking, wind-balancing and industrial generation.



ENERGY EFFICIENCY

- High baseload efficiency, regardless of ambient conditions.
- High plant efficiency over a wide load range due to the modular ICE design.

FUEL FLEXIBILITY

- Operation on any liquid or gaseous fuels, including biofuels.
- Improved fuel security by continuous choice of the most feasible fuel.

OPERATIONAL FLEXIBILITY

- Fast start to full load in less than 5 minutes regardless of plant size.
- Unlimited starting and stopping with no impact on maintenance.

1 ROAM Consulting business has been acquired by EY in October 2014 with all of the ROAM Consulting professional staff joining the EY Valuations & Business Modelling group.

1. National electricity market – introduction

The market design of the National Electricity Market (NEM) is a gross mandatory pool, where all generators are obligated to sell all produced electricity to the market. Correspondingly, electricity is bought by retailers from the pool. The market aggregates all generation and simultaneously schedules generators to meet the demand. This is managed through a central dispatch process, operated by Australian Energy Market Operator (AEMO). Based on generation offers and demand bids, AEMO defines the most cost-efficient dispatch for every 5 minutes. The first indicative dispatch is computed a day ahead before delivery. Re-dispatching, based on the adjusted bids, continues until 5 minutes before the actual 5-minute dispatch interval. At the gate closure, the final dispatch and the dispatch interval prices are defined for the five NEM regions across Australia. Six consecutive 5-minute dispatch interval prices are averaged every half-hour to determine spot prices for each 30-minute trading period.

Market rules define the market cap and floor price, which are currently 13,500 AUD/MWh and -1000 AUD/MWh respectively. Negative market floor price enables generators to pay to stay online. This can occur when the cost of staying online is lower than the cost of shutting down and re-starting a plant. High market price cap serves as an incentive to new power plant investments. Most of the utilities in NEM are so-called gentailers (generator + retailer). They have generation assets and load to serve. One important task for gentailers is to balance their own thermal generation according to intermittent output of wind and solar power. The balancing causes active re-bidding close to the gate closure, occasionally creating significant price spikes.

Spot prices are highly volatile in NEM, and market participants have to manage their risks exposure to the price volatility. Generators and retailers manage their market price risk by using long- and short-term financial contracts which secures a firm price for electricity. These contracts are so called Contracts for Differences (CfDs) including: swaps, caps, options and futures. In addition, majority of gentailers owe flexible peaking plants as a physical hedge against price spikes in the market.

2. Modelling framework and assumptions

The whole NEM was modelled in this study, but the main focus is on South Australia (SA) market region in the fiscal year of 2020–2021. SA has the highest share of intermittent renewable generation, and historically high levels of market price volatility. The potential of SPG is tested as a part of a large utility portfolio. The selected utility has a wide mix of thermal and renewable assets and large retail position in the market.

Analysis was carried out with ROAM Consulting's 2-4-C market modelling software, which replicates closely the real dispatch executed by AEMO. To capture the effects of the inflexibility of the current generation assets, the whole NEM is modelled with 5-minute granularity, just as it is dispatched in real life. In the model, generation is dispatched according to the generation offers to meet the demand. Dispatch is also subject to certain constrains, such as limited transmission capacity. Electricity price for each 5-minute dispatch interval, in each NEM region, is defined by marginal generator.

Based on historical bidding data, multiple bidding strategies were developed for each utility in NEM. For example, a utility can bid its whole generation with the marginal cost, withhold capacity by moving bids to higher price bands or bid all generation at the market floor price to ensure maximum generation volume after a price spike. Each utility chooses the best bidding strategy for each 5-minute dispatch interval while trying to maximise the portfolio value over a 30-minute trading period (Figure 2.1).

The total cost to serve the load includes revenues from frequency control ancillary services (FCAS). The bidding optimisation is implemented as a blind bidding game, instead of seeking the Nash equilibrium which is commonly used in market modelling (even though it does not represent the real life market behaviour very well, especially in scarcity situations). The model attempts to simulate the decision-making process with imperfect foresight of price and dispatch for the current and remaining 5-minute dispatch intervals within the actual 30-minute trading period. A whole year bidding simulation is executed with five different swap and cap contract levels. These are defined according to historical load and generation profiles.

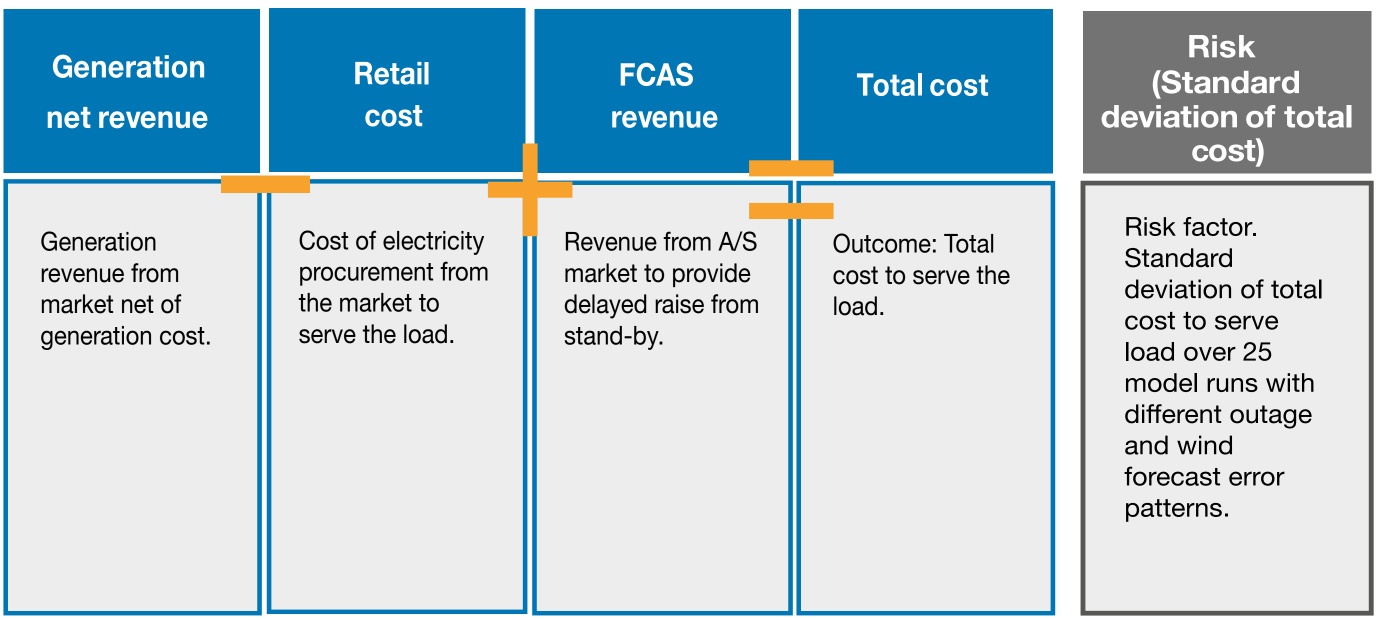


Figure 2.1. Quantified value components of portfolio analysis.

Each gentailer has its own load to serve. The load is based on the forecasted regional demand profile and expected market share of the utilities in the SA retail market. Revenues of retail are excluded from the analysis, as they are relatively fixed.

The additional risk analysis is essential to ensure that the added value of SPG was not produced at the expense of increased risk for the utility. For the assessment of a portfolio risk, 25 separate Monte Carlo simulations are conducted for the selected year. Monte Carlo simulation varies generators' and interconnectors' forced outage pattern as well as wind, large-scale and rooftop solar PV generation time series. Standard deviation of the total cost to serve the load, over multiple Monte Carlo simulations, is used as a risk factor. (Figure 2.1)

To analyse the NEM in 2020–2021, certain future forecasts and assumptions are needed. The forecasts used are conservative regarding the value of SPG: e.g. modest demand growth, reduced renewable energy target and no carbon tax. Detailed assumptions are listed below.

DEMAND GROWTH:

- AEMO, National Electricity Forecasting Report, 2013, medium demand, 10% probability of exceedance.
- Peak demand same as in 2013. Annual energy 500 GWh lower than 2013.

OPERATIONAL:

- Northern coal plant returns to full annual operation.
- No new thermal retirements or investments in SA.
- 190 MW Heywood (between South Australia and Victoria) interconnector upgrade has been implemented.

FUEL PRICING:

- After existing gas contracts have expired, gas generators are assumed to pay spot prices for gas according AEMO, Planning studies, 2013, Planning scenario: AUD 7–8/GJ gas in SA.
- Open cycle gas turbine (OCGT) and SPG generation pay a 10% premium over spot price for gas to reflect low volume requirements.

RENEWABLE GENERATION POLICIES AND CARBON MARKET:

- Reduced Large-scale Renewable Energy Target (LRET), 27,000 GWh for 2020.
- Repealed carbon price.

Three different future cases of the utility portfolio are analysed separately. 200 MW of the oldest existing capacity will be demolished and replaced by either a new heavy duty OCGT GE 9E plant, an aeroderivative OCGT GE LM6000 or SPG plant. Special focus is in OCGT 9E case, because it has been typical choice for the gentailers in the past. (Figure 2.2)

OCGT 9E case	OCGT LM6000 case	SPG case
Replace 200 MW of utility's capacity by a new OCGT GE 9E plant	Replace 200 MW of utility's capacity by a new OCGT GE LM6000 power plant	Replace 200 MW of utility's capacity by a new SPG power plant

Figure 2.2. Three modelling scenarios of the utility's generation portfolio in 2020–2021.

Detailed and accurate power plant parameters are required to evaluate all cases transparently. Flexibility parameters and forced outages of OCGTs are based on the historical operation of similar existing plants in NEM. SPG values are based on Wärtsilä's in-house data. Thermal efficiency, summer derating and minimum load of all alternative plants are derived from the neutral and commonly used Thermaflow GTPRO plant design software (Table 2.1).

Table 2.1. Operational parameters of the new 200 MW power plants in the three cases.

	OCGT 9E	OCGT LM6000	SPG
Number of units	2	4	10
Thermal efficiency (HHV[1] as-generated)	30.7%	37.4%	41.4%
Auxiliaries	1.1%	1.3%	2%
Part-load efficiency	90% at 80% load 75% at 50% load	92.4% at 80% load 81% at 50% load	100% at all loads
SRMC[2] ($/MWh delivered)	106.3	84.8	77.6
Forced outage rate	1.5%	1.5%	1.0%
Summer derating	12%	9%	0%
Minimum load	40%	35%	0%
Unit ramp up/down (MW/min per unit)	10	8	20 (large enough to ramp between min and max load in a DI[3])
Fast-start inflexibility profile [T1, T2, T3, T4][4] (minutes)	[7, 8, 29, 7]	[6, 6, 29, 5]	[1, 2, 0, 0]

[1] HHV = Higher heating value
[2] SRMC = Short-run marginal cost
[3] DI = Dispatch interval
[4] T1 = time to synchronise, T2 = time to ramp to min load, T3 = minimum time above min load and T4 = time to ramp down

3. Value analysis

SPG has higher thermal efficiency than both OCGT solutions. This enables more profitable running hours for SPG in the market. However, when the peaking plant is running at full output, the value of operational flexibility is already being utilised. This is because flexibility derives from the capability to increase generation as quickly as possible. From a gentailer portfolio point of view, the value of additional energy is sometimes minor compared to the value of flexibility. Therefore, the utility has to do a trade-off between flexibility (withholding capacity) and profitable generation (running the plant against the market). When comparing the three cases, SPG has superior flexibility as well as the highest thermal efficiency. Examples of how flexibility can create added value for a gentailer are explained below.

3.1 PREVENTING A DISADVANTAGEOUS PRICE SPIKE

As shown in the Figure 3.1, in this particular 30-minute trading period, prices are high, but during the previous 30-minute period they were low. The utility does not have any generation online and therefore is exposed to possible high prices. In the OCGT 9E case, the plant is not capable of providing energy during the first 5-minute dispatch interval. Hence, it is not able to prevent the price spike. After the first 5-minute interval, the OCGT 9E is brought online to maximize generation during the 30-minute trading period. Since trading period price is averaged in the end of the period, one 5-minute price spike rises the price of trading period as high as AUD 2193/MWh. During this trading period the gentailer is strongly in a net load position, meaning that their retail load is larger than own online generation. During the 30-minute trading period, maximized generation revenue and hedging contract settlement cannot compensate the high retail cost. As a result, the total cost to serve the load over this 30-minute period is as high as AUD 251,101. (Figure 3.1)

	Price ($/MWh)		Generation (MW)	
Dispatch interval (5min)	OCGT 9E case	SPG case	OCGT 9E case	SPG case
1	12,962.20	78.00	0	92
2	62.64	70.37	30	0
3	46.73	63.70	80	0
4	31.36	59.65	176	0
5	28.78	62.83	176	0
6	26.32	74.38	176	0
	2,193.01	68.16	106	15

30-minute portfolio settlement		
	OCGT 9E case	SPG case
Retail cost ($)	968,786	30,109
Contract revenue ($)	414,601	1,223
Generation revenue ($)	315,724	3,649
Generation cost ($)	12,640	3,034
Total cost ($)	251,101	28,271
Benefit of SPG ($)		222,830

Figure 3.1. SPG is able to prevent disadvantageous price spike and reduce retail cost when portfolio is net load position.

As shown in the Figure 3.1, in the SPG case, the gentailer bids its capacity with marginal cost, because price spikes would be harmful for its portfolio in a net load position. For the first 5-minute dispatch interval, a part of the SPG plant is dispatched. It is started up just in 5 minutes and the price spike is prevented. On the second 5-minute interval, the price drops below the SPG plant's short run marginal cost and the plant is shut down.

The price spike is avoided and results in significant value for the portfolio in this 30-minute trading period when the utility's net load position is exposed to market prices. Compared to the OCGT 9E case, SPG provides savings of AUD 222,830 for the portfolio during the 30-minute trading period. This is achieved by the capability of starting up the SPG plant to full load in less than 5 minutes. (Figure 3.1)

3.2 CAPTURING A PRICE SPIKE

As shown in the Figure 3.2, In the 30-minute trading period examined here, the market price is low during the first 5-minute dispatch interval, but hits almost the price cap of 13,500 AUD/MWh during the second 5-minute interval. The OCGT 9E plant reacts the price spike immediately, but due to the slow starting time, it can deliver only 48 MWh during the 30-minute trading period. The SPG plant also misses the price spike interval as it is offering capacity with a price too high. On the third 5-minute interval, the utility changes its bidding strategy. It bids the SPG plant on the market floor price and ramps up or starts up the plant immediately to full 200 MW load. The SPG plant runs at full load over the remaining four 5-minute intervals. It is able to generate 133 MWh during the trading period, compared to the 48 MWh by the OCGT plant. As a result, the benefit for the selected utility in the SPG case of is almost AUD 90,000 higher than in the OCGT 9E case. (Figure 3.2)

	Price ($/MWh)		Generation (MW)	
Dispatch interval (5min)	OCGT 9E case	SPG case	OCGT 9E case	SPG case
1	45.44	45.44	0	0
2	12,962.20	12,962.20	0	0
3	47.34	31.06	0	200
4	32.80	27.63	30	200
5	25.47	24.88	80	200
6	23.96	24.88	176	200
	2,189.54	2,186.02	48	133

30-minute portfolio settlement		
	OCGT 9E case	SPG case
Retail cost ($)	669,811	668,734
Contract revenue ($)	407,907	407,203
Generation revenue ($)	75,703	166,874
Generation cost ($)	3,057	5,213
Total cost ($)	189,258	99,871
Benefit of SPG ($)		89,387

Figure 3.2. SPG is able to generate more energy after the price spike and thus increases significantly the benefit for the utility during the 30-minute trading period.

3.3 RESULTS

To maximize portfolio level benefits, SPG and OCGT plants are exposed to extreme operation regime in the model. Due to the limited flexibility of both OCGT solutions, they cannot capture all emerging market opportunities. In addition, they cannot reach full output in the dispatch intervals after a market opportunity (price spike) has emerged. Nevertheless, the OCGT 9E plant is started 434 times per year, and it runs for only one hour per start on average. It reaches 395 running hours during the year. In the summer, when the probability of the price spikes is highest, the output of the OCGT is derated to 180 MW due to high ambient temperature. Similar derating does not affect SPG, due to the heat resistant ICE technology. As a result, the superior flexibility of the SPG plant opens more market opportunities and full output can be employed each time as required. The entire plant is started 1054 times per year, with 933 running hours. The plant is started 433 times to run only a single 5-minute pulse, which demonstrates the value of the quick-start capability in peaking operation (Figure 3.3).

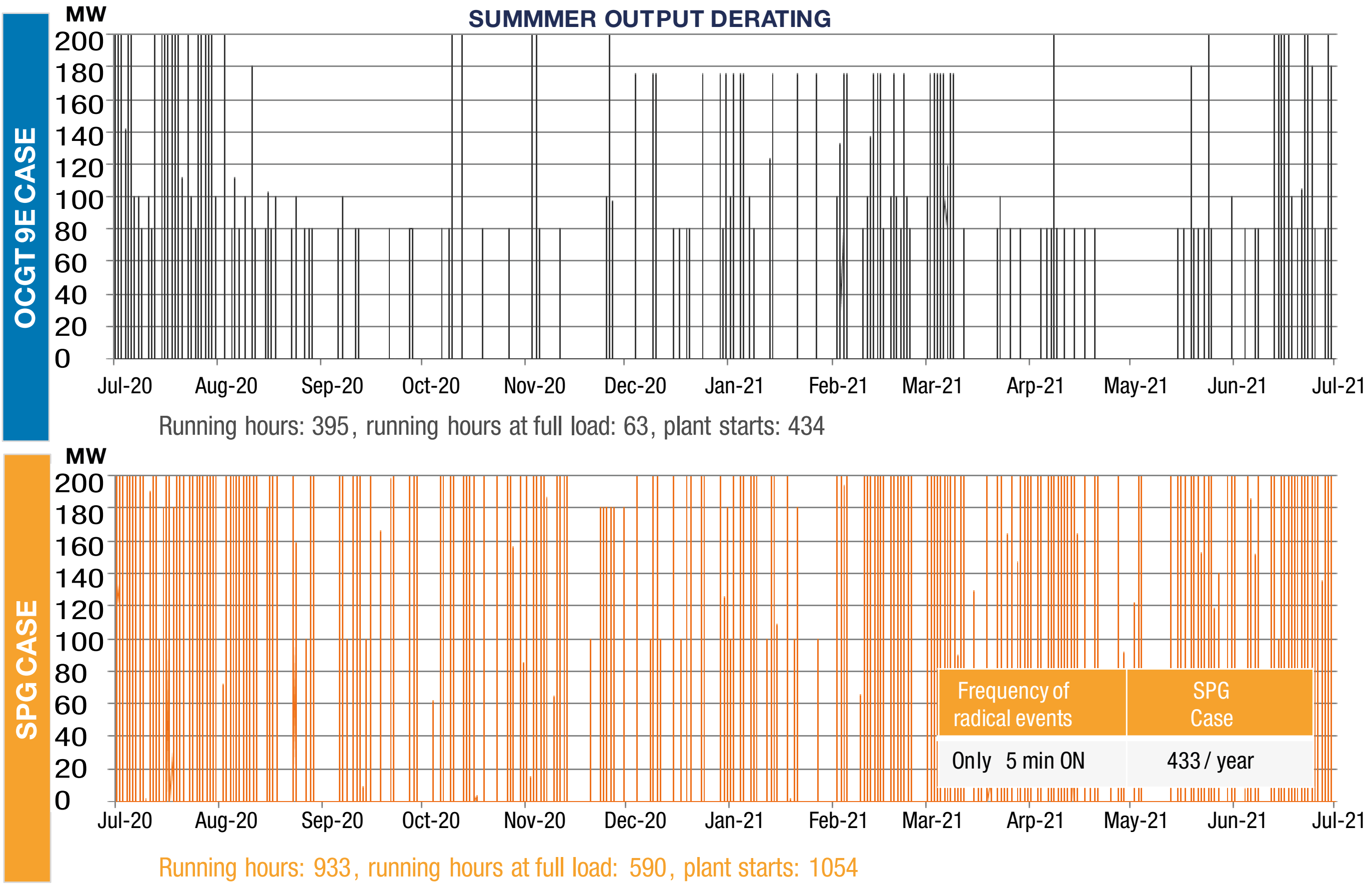


Figure 3.3. Due to superior flexibility SPG, it can capture more market opportunities, which lower portfolio's cost to serve its retail load.

As the study excluded retails side revenues, the cases can be evaluated comparing the total cost to serve the retail load. The analysis indicates that gentailer's annual net generation revenue increases when it invests in SPG instead of OCGT 9E or OCGT LM6000. In addition, the retail cost decreases simultaneously. Only SPG earns FCAS revenues, since it can provide 5-minute delayed rise ancillary services, even when offline. From the risk perspective, the SPG and the OCGT LM6000 cases have the lowest risk, measured as standard deviation of total cost, as per 25 Monte Carlo simulations (Figure 3.4).

Comparing alternative investments, SPG enables AUD 12.4 million additional gross margin per year compared to aeroderivative gas turbine OCGT LM6000 case, and AUD 14.6 million compared to heavy duty gas turbine OCGT 9E case. In addition, the highest saving potential is reached with a portfolio risk similar to the OCGT cases.

The study also shows that SPG capacity can provide benefits on the whole system level by reducing the average market price of the wholesale electricity. As a part of the gentailer portfolio, the 200 MW SPG plant is typically used to prevent disadvantages price spikes. In the SPG case, number of over 10,000 AUD/MWh dispatch interval prices per year drops to 23. In the OCGT 9E case the amount of these price spikes is 36. As a result, using the SPG plant for peaking lowers the average market price of SA region by 4% (1.6 AUD/MWh) in the fiscal year 2020–2021, compared to using the OCGT 9E. In the SPG case, SA market price is on average 41.3 AUD/MWh, and in OCGT 9E case 42.9 AUD/MWh.

Scenario	Generation net revenue	Retail cost	FCAS revenue	Total cost	Difference to SPG	Risk (Standard deviation of total cost)
OCGT – 9E	40,614,553	263,858,275	0	223,243,723	+14,584,067	4,064,677
OCGT – LM6000	46,845,041	267,879,335	0	221,034,294	+12,374,468	3,696,719
SPG	48,257,745	257,459,173	541,772	208,659,656		3,701,101
	Higher net revenue due to lower generation costs and capturing price spikes better	Lower retail cost due to affecting the market prices	Increased FCAS due to the capability to provide delayed rise services from standby	Lower total cost to serve load	SPG offers significant added value compared to the OCGT cases	Marginally lower risk

Figure 3.4. Compared to the OCGT 9E and OCGT LM600 cases, Smart Power Generation enables significant added value due to the higher generation net revenue, lower retail cost and superior revenue in frequency control ancillary services (FCAS).

4. Conclusions

In the National Energy Market of Australia, OCGT plants have traditionally been used as peaking plants. Gentailers have utilized these plants as a physical hedge to protect their retail arm purchases against market price volatility. However, this study shows that the superior flexibility of SPG power plants enables more efficient market price risk mitigation as well as significantly higher generation revenues.

A 200 MW SPG power plant enables AUD 12.4 million additional gross margin per year compared to the aeroderivative gas turbine OCGT LM6000 case, and AUD 14.6 million compared to the heavy duty gas turbine OCGT 9E case. This is due to the SPG plant's capability to capture more market opportunities in the 5-minute electricity market. Being able to start to full load in less than 5 minutes, the SPG plant can take advantage of price spikes.

As a part of the gentailer portfolio, the SPG plant is also used to prevent disadvantageous price spikes. This may be necessary when the gentailer is strongly in a net load position during a 30-minute trading period, meaning that their retail load is larger than own online generation. In a single 30-minute period, SPG can provide savings of AUD 222,830 for the portfolio compared to the OCGT 9E case.

Preventing price spikes brings also system level benefits. In the SPG case, the number of over 10,000 AUD/MWh dispatch interval prices per year drops to 23 compared to 36 in the OCGT 9E case. As a result, the average electricity price for consumers in the SA region falls by 4%, respectively.

Smart power generation power plant's engine hall.

Value of Smart Power Generation for utilities in Australia

WÄRTSILÄ ENERGY SOLUTIONS
IN BRIEF

Wärtsilä Energy Solutions is a leading global energy system integrator offering a broad range of environmentally sound solutions. Our offering includes ultra-flexible internal combustion engine based power plants, utility-scale solar PV power plants, energy storage & integration solutions, as well as LNG terminals and distribution systems. The flexible and efficient Wärtsilä solutions provide customers with superior value and enable a transition to a more sustainable and modern energy system. As of 2017, Wärtsilä has 65 GW of installed power plant capacity in 177 countries around the world.

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