Attachment 6.3

Study into the feasibility of a microgrid at Kalbarri

Access Arrangement Information

2 October 2017

Access Arrangement Information (AAI) for the period
1 July 2017 to 30 June 2022

westernpower

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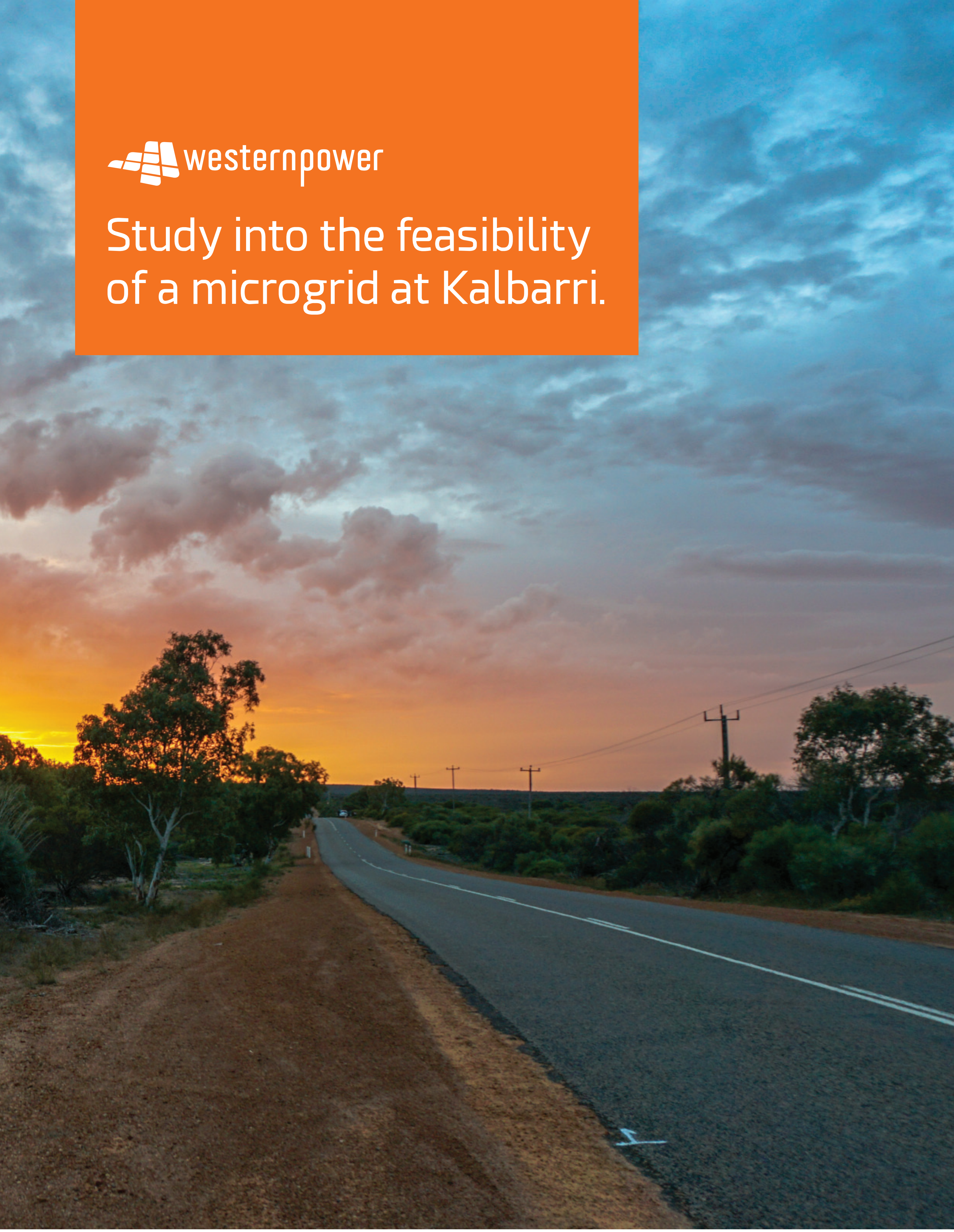
Study into the feasibility of a microgrid at Kalbarri.



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Executive summary

Introduction

The Kalbarri town-site is solely supplied with electricity via the 150km, 33kV radial Kalbarri feeder from Geraldton. The Kalbarri feeder is exposed to environmental factors including wind-borne marine salt and dust pollution which combined with the feeder's length and remoteness can lead to extended outages on the line.

Increased maintenance activities such as silicon application and line washing and more extensive vegetation clearance has had a positive impact on the reliability of the feeder but, ultimately, the radial nature of the Kalbarri supply means that short of duplicating or undergrounding the supply line to Kalbarri (unfeasible at a cost of tens of millions of dollars) the most impactful way to improve the reliability of power supplies at Kalbarri is to introduce local generation that can supply the town in the event of loss of supply from Geraldton.

A microgrid is a often used terminology to describe this situation where the township could continue to be supplied in the event of a fault on the primary feeder.

Kalbarri has abundant natural resources including wind and solar energy. An existing 1.6MW windfarm owned and operated by Synergy and sited approximately 25km south of Kalbarri contributes to the town's power supplies but is unable to supply power during outages of the supply line from Geraldton because of the absence of a reference voltage from the main SWIS supply.

Peak demand in Kalbarri, approximately 3.7MW, only occurs for very brief periods during the Christmas and Easter holiday periods when the town's population is swelled by tourist numbers.

Feasibility study

On the 2nd March, Western Power announced funding had been allocated for the development of a feasibility study (this study) to determine whether a dynamically-connected[1] microgrid would effectively and efficiently mitigate power reliability issues at Kalbarri.

The feasibility study has modelled various iterations of a microgrid model that incorporate the existing Synergy windfarm, a combination of solar PV generation and solar-thermal generation capacity, large-scale energy storage capacity and smart network control that will optimise the use of renewable energy sources while maintaining a secure network link to the main Western Power Network.

The focus of the feasibility study is to understand whether new and emerging technologies, coupled with local generating capacity, might provide a viable improvement to local power supplies that is acceptable to the local community and consistent with Western Power's regulatory obligations.

The range of benefits targeted through the development of a Kalbarri Microgrid include:

- improved reliability of power supplies at Kalbarri
- improvement to Western Power's understanding of the interaction between microgrids and the network
- development of a replicable and adaptable regional power supply model that maximises the value of Western Australia's historical investment in power networks
- improved resilience achieved through the microgrid's islanding capability.

Why Kalbarri

The Kalbarri feeder is one of the worst performing feeders on the Western Power network. The frequency of outages and the duration of outages are both greater than the average targeted by the regulator for long rural feeders.

Table 1: Reliability at Kalbarri (Feeder)

Category	Target SAIDI	Target SAIFI	Actual SAIDI*	Actual SAIFI*
Rural long	724.8	4.51	1127	4.97

**12 months to July 2016*

From a regulatory perspective, committing resources to power reliability would typically be justified on the basis of achieving the biggest over-arching reliability impact for the lowest reasonable investment.

An investment in reliability at Kalbarri in the form of a microgrid may not achieve the biggest over-arching reliability improvement.

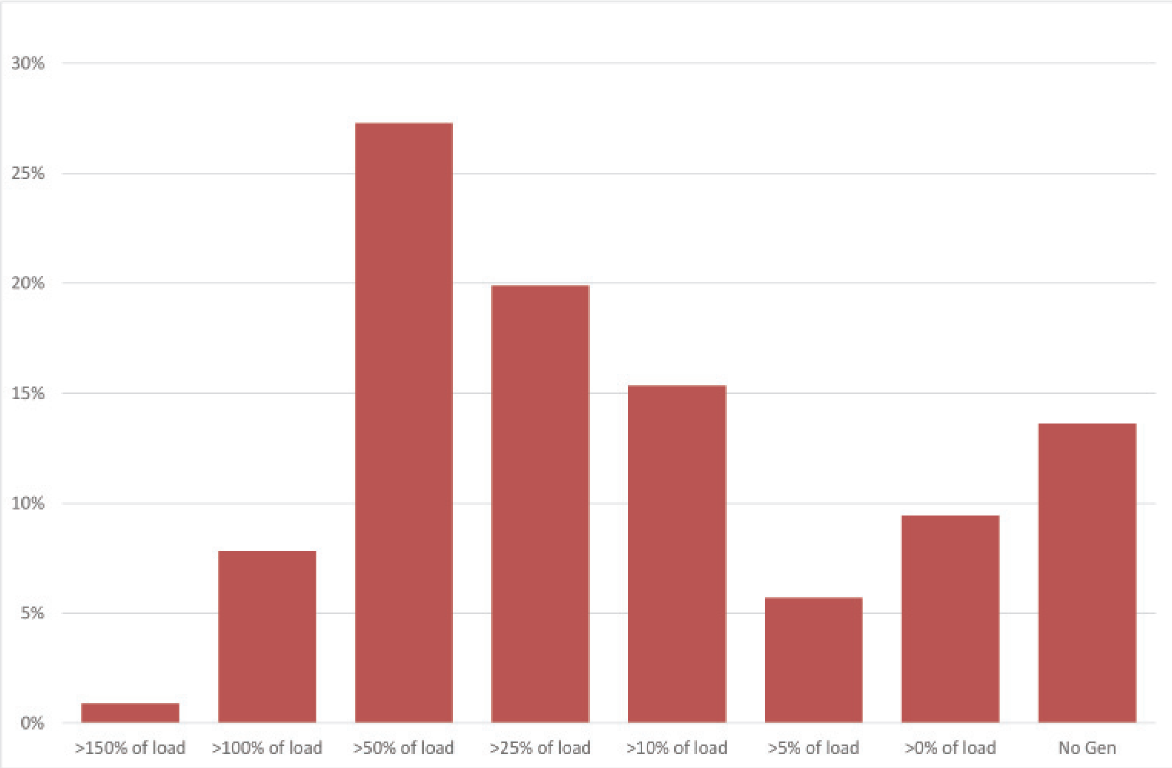
However, Kalbarri has existing generation in the Kalbarri Wind farm that generates sufficient power to meet more than 50% of Kalbarri's load greater than 30% of the time.[2] Generation from the windfarm is currently not available when the feeder between Kalbarri and Geraldton is out of service as the generator relies on the Western Power network to operate.

[1] Dynamic-connection infers the ability for the microgrid to operate in both a grid-connected and islanded mode. The primary operating mode contemplated for the Kalbarri microgrid is grid-connected with islanding occurring during outages of the Kalbarri feeder.

[2] Based on twelve months data from July 14, 2015 to June 15, 2016.

The chart below shows the proportion of Kalbarri's load (proportion of 30 minute intervals over the year) that coincides with generation from the windfarm.

Figure 1: Proportion of Kalbarri load met by the Kalbarri windfarm



Additional new generation in the form of Solar PV and Concentrated Solar Thermal plants are proposed for Kalbarri with enquiries and applications being developed by private generators and processed by Western Power.

If Western Power ultimately decides to deploy a microgrid at Kalbarri, the lessons learnt, coupled with the expected continued decrease in the cost of energy storage systems, may lead to the development of energy storage-based solutions for a number of other edge-of-grid locations that suffer from the same inherent reliability issues as Kalbarri.

While not a typical approach to reliability improvement, the Kalbarri microgrid project may represent a gate-way project that demonstrates the efficiency and efficacy of microgrid projects into the future.

The availability of existing on-site generation and the proposed development of additional generation and being at the end of a very long feeder makes Kalbarri the ideal candidate on Western Power's network for a low-risk approach to trialling alternative technologies in this manner.

Outcome of the feasibility study

The feasibility study considered and assessed a number of microgrid models (based on a range of assumptions regarding the availability of generation (types and capacity) in Kalbarri and the level of community acceptance of each and evaluated them with respect to:

- technical feasibility
- impact on local network conditions (capacity to ride through faults local area resilience)
- regulatory compliance
- community acceptance
- cost.

Ultimately, the feasibility study has determined:

- a microgrid that incorporates energy storage without additional[3] on-site generation is likely to meet benchmark reliability standards in Kalbarri
- a microgrid that pairs additional[4] on-site generation with energy storage is likely to improve reliability in Kalbarri to an even greater extent than energy storage alone.

A microgrid that incorporates energy storage can optimise the performance of renewable generation[5] in the town, manage transient fault and network performance issues and provide a reliable power supply during most periods when the Kalbarri Feeder is out of service.

The local network (33kV Kalbarri Feeder) has sufficient hosting capacity to install up to 6MW of community-scaled generation at the Kalbarri end of the feeder. There are two generation proposals currently in the network access queue for Kalbarri; a 1MW concentrated solar thermal proposal (potentially growing to 4MW) and a 5MW solar PV proposal. There is no formal guarantee either proposal will ultimately connect to the network.

Based on the community consultation conducted as part of the feasibility study the Kalbarri community is supportive of a renewable energy-based solution, many stakeholders in the town would accept a solution that incorporated stand-by diesel generation if that was what was required to improve power reliability. Community engagement activities have canvassed the level of support for a community-owned solution for reliability improvement in Kalbarri with overwhelming support for a Western Power-led and operated outcome that does not require the community to manage electrical assets.

[3] In addition to the existing Synergy windfarm

[4] In addition to the existing Synergy windfarm

[5] Energy storage and management systems can provide the requisite frequency and voltage references to allow renewable generators such as wind and solar PV to continue to generate electricity in the event the Kalbarri feeder is out of service and unable to provide the reference service required

Recommendation of the feasibility study

Western Power undertook the study into the feasibility of deploying a microgrid at Kalbarri in order to form a view on the potential for the business to achieve the successful deployment of an innovative solution to a edge-of-grid reliability problem in a cost-effective manner.

The definition of a successful deployment should be taken to include:

- achieving long rural equivalent benchmark reliability performance
- achieving a successful technical outcome
- demonstration that battery-based solutions are competitive (in terms of cost and impact) with traditional network options
- achieving an acceptable outcome with respect to regulatory compliance obligations
- achieving a commercially acceptable outcome.

The feasibility study was tasked with delivering insight as to whether the business should develop a business case and commit to undertaking detailed planning and procurement activities, on the basis of a range of feasible options for the deployment of a microgrid at Kalbarri.

The detail of the feasibility study is insufficient to support an investment decision.

The feasibility study has reached the following conclusions:

- a microgrid has significant potential to improve the reliability of power supplies at Kalbarri
- a microgrid without additional generation can add to the reliability of power supplies in Kalbarri
- the energy storage component of the microgrid can be installed in a modular fashion that would allow for the redeployment of installed storage capacity should it not be required in future
- the existing regulatory framework does not preclude distribution network service providers from incorporating Battery Energy Storage System (BESS) into their Regulatory Expenditure Submissions
- the requirement to demonstrate the economic efficiency of projects intended to remedy poor reliability for small groups of consumers, particularly when average reliability targets are being achieved across the customer category can be difficult to achieve.

A recommendation on the final optimised design and composition of a microgrid solution, and as such, a detailed forecast of its ultimate cost, was not within the scope of this feasibility study.

This study has identified a range of feasible options for microgrid development which should be assessed as part of the development of a business case of sufficient detail to support an investment decision.

Whilst providing a significant improvement to Kalbarri consumers the impact on the Long Rural Feeders service standard benchmark will only be minor, therefore the demonstration of economic efficiency may still be difficult to achieve.

On the basis of the options outlined in this report, it is recommended that Western Power develop a business case and undertake the detailed planning and procurement processes required to support the development of a microgrid at Kalbarri.

Context

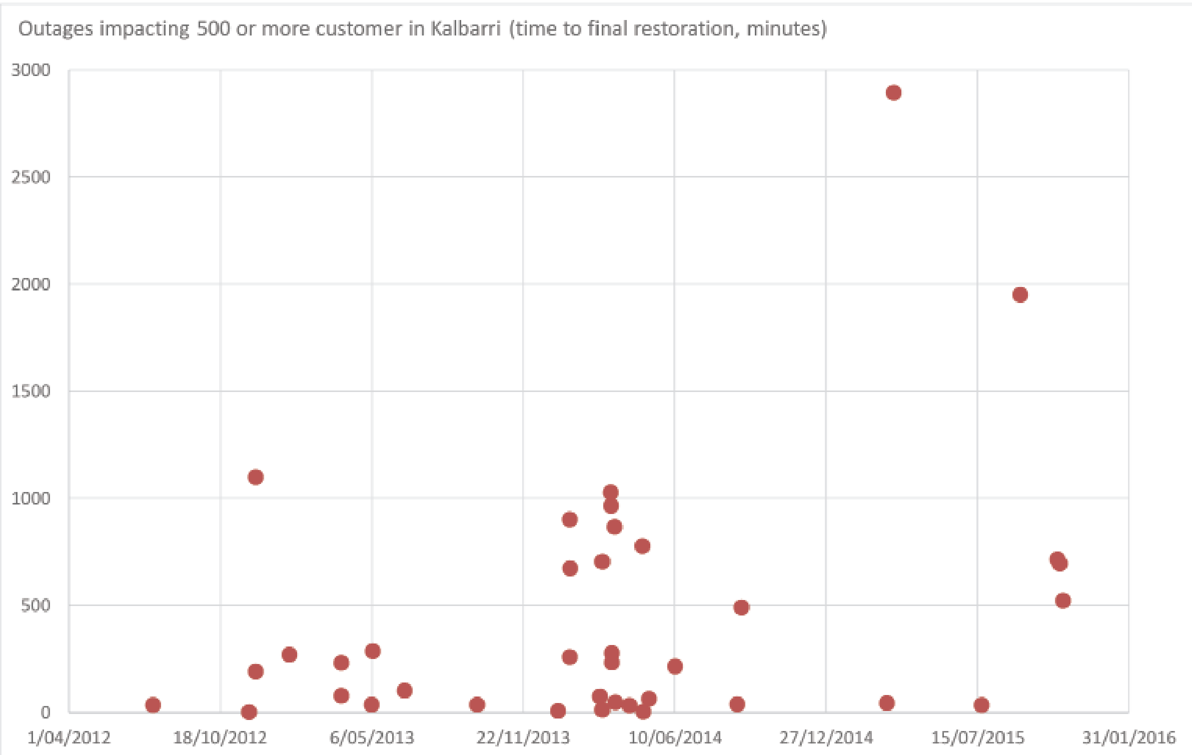
Reliability in Kalbarri

Between November 2014 and November 2015 Kalbarri residents experienced 19 significant power interruptions lasting between 30mins and, in the worst case, more than two days.

Western Power is confident that increased maintenance activities on the Kalbarri feeder should limit the likelihood of a recurrence of the frequent and long-duration outages experienced in this period (particularly during 2014) however the radial nature of the Kalbarri feeder means supply to the township is inherently less secure than towns or regions with multiple sources of supply.

Given the distances fault response staff often have to travel from Geraldton, outages can last between five and eight hours. Maintenance activities that cannot be completed under live-line arrangements result in planned outages to the town that do not feature in fault statistics but contribute to the experience of consumers.

Figure 2: Reliability at Kalbarri



At a community level, poor power reliability is a threat to the Shire of Northampton and Mid West Development Commission's (MWDC) aspirations for the development of the tourism industry in the region.[6] While Western Power can never guarantee a 100%-reliable power supply, Western Power recognises that without power local businesses and communities are impacted. Safety and amenity can be reduced and the appeal of Kalbarri as an internationally attractive nature-based tourism destination is impaired.

Western Power continues to work with individuals and businesses that have critical requirements for power supplies, providing technical advice regarding stand-by generation and back-up options. However over the longer term, emerging technologies point to the ability to respond in a sustainable way to the challenges of edge-of-grid energy supply.

Community/ stakeholder engagement and public contribution to the feasibility study

Throughout the course of the feasibility study Western Power has welcomed the active participation and contribution of the Kalbarri community at a series of public meetings, formal stakeholder engagements and detailed consumer/stakeholder perception and preference workshops.

Western Power is especially grateful for the positive community input contributed through these meetings and the valuable insights this has provided to the feasibility study. At a high-level, the community engagement sessions have identified some important sentiments:

- aggregated reliability statistics often bear no resemblance to the felt-impact of electricity reliability at edge-of-grid locations and dilute the actual impact on communities, day-to-day lives, impact on business and understate the outright frustration customers feel
- consumers are more inclined to trust Western Power to develop alternate supply arrangements than new entrants, local governments or community collectives to the energy industry because they feel an element of ownership and control over Western Power's performance[7]
- there is a strong community preference for renewable-energy based microgrid solutions that contribute to the sustainability of the region; but improved reliability is the strongest motivator for the community.

Ultimately, Western Power takes a measure of comfort that it has the expressed mandate of the Kalbarri community to explore, develop and deploy an emerging technology response to the challenge of edge-of-grid supply reliability.[8]

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[6] Frequent interruptions to power also present a risk to Western Power's ability to meet Service Standard Benchmarks and therefore achieving Service Standard incentive payments (or reduced exposure to penalties for under-performance).

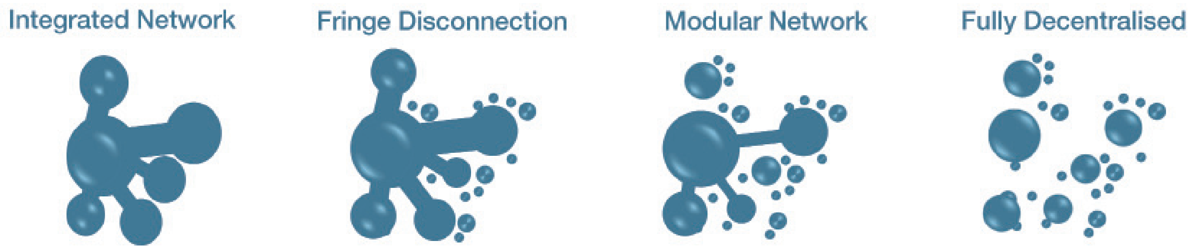
[7] Western Power community engagement research.

[8] Based on R&RT Kalbarri Research Engagements conducted by Western Power on 2016.

Network evolution

Current thinking suggests the Western Power network is likely to evolve into a modular network of dynamically connected microgrids as distributed generation displaces centralised generation over a period of many years.

Figure 3: The Evolution of the network



As networks reach end-of-life conditions and require replacement or intensive maintenance, maintaining reliable and efficient power supplies to individual consumers or small clusters of consumers in locations where customer density is low is most likely to be cost-effectively achieved through the installation of stand-alone power systems like those being trialled by Western Power in farming areas of the Great Southern region.

The closer communities are to the main trunk of the network and as they reach a level of energy demand intensity, the value proposition regarding supplying power, falls back in favour of using distribution networks as the primary mode of supply.

Where large communities are situated at the fringes of the network, the development of distributed generation that meets or exceeds the peak demand of consumers in those locations and exports energy into the broader network, is an alternative supply model that maintains or improves network utilisation and can form the nucleus of dynamically-connected microgrid developments.

Western Power has studied the development of a microgrid opportunity in Kalbarri, fundamentally as a response to a range of existing supply reliability challenges but also as a strategic response to the opportunities and threats presented by network evolution and the increased penetration of distributed generation sources.

By supporting the development of a microgrid in Kalbarri Western Power positions itself to ensure it continues to provide the best possible customer experience across the Western Power Network. As the regulated monopoly network provider on the SWIS, this is not only a prudent response to the challenge of system evolution but also a responsible approach to preserving the value of the Western Power Network.

Through the development of a microgrid that leverages investment by private generation providers (as is contemplated at Kalbarri), Western Power has the opportunity to develop a commercial framework for microgrid development and operation that can be deployed in other locations.

By demonstrating the technical and commercial feasibility and community support for the strategic deployment of microgrids in communities at edge-of-grid locations, Western Power is signalling its view on the long term direction of investment opportunities for distributed energy resources across the SWIS.

As the electricity industry evolves to take on a more decentralised nature, microgrids are expected to play an increasing role in the delivery of electricity to consumers in a way that is more resilient to environmental impacts, less impactful on the environment and potentially, cheaper than the existing centralised model and ultimately better for the community.

By participating in the development of a microgrid and assuming a role in the ongoing management of the system, Western Power will gain a detailed understanding of how microgrid technology might be cost-effectively deployed to improve consumer outcomes.

Detailed consumer engagement throughout the feasibility study period has shown a significant demand for a greater appreciation of the experiences and circumstances of groups of consumers whose reliability experience is significantly worse than the average experience of similar consumers[9] across the network.[10]

[9] In the case of Kalbarri customers; Customers on Long Rural Feeders

[10] This sentiment was supported by feedback to Western Power's customer engagement activities in support of the Regulatory Control Period (RCP1) submission to the AER. https://www.westernpower.com.au/media/1719/customer-insights-report-2016.pdf

Battery centric microgrid technical findings

Physical solution

Kalbarri's power is supplied via a 33kV feeder (No. 603) from the Geraldton substation (GTN). The proposed microgrid will be formed by isolating the Kalbarri township at a suitable point close to the end of this feeder.

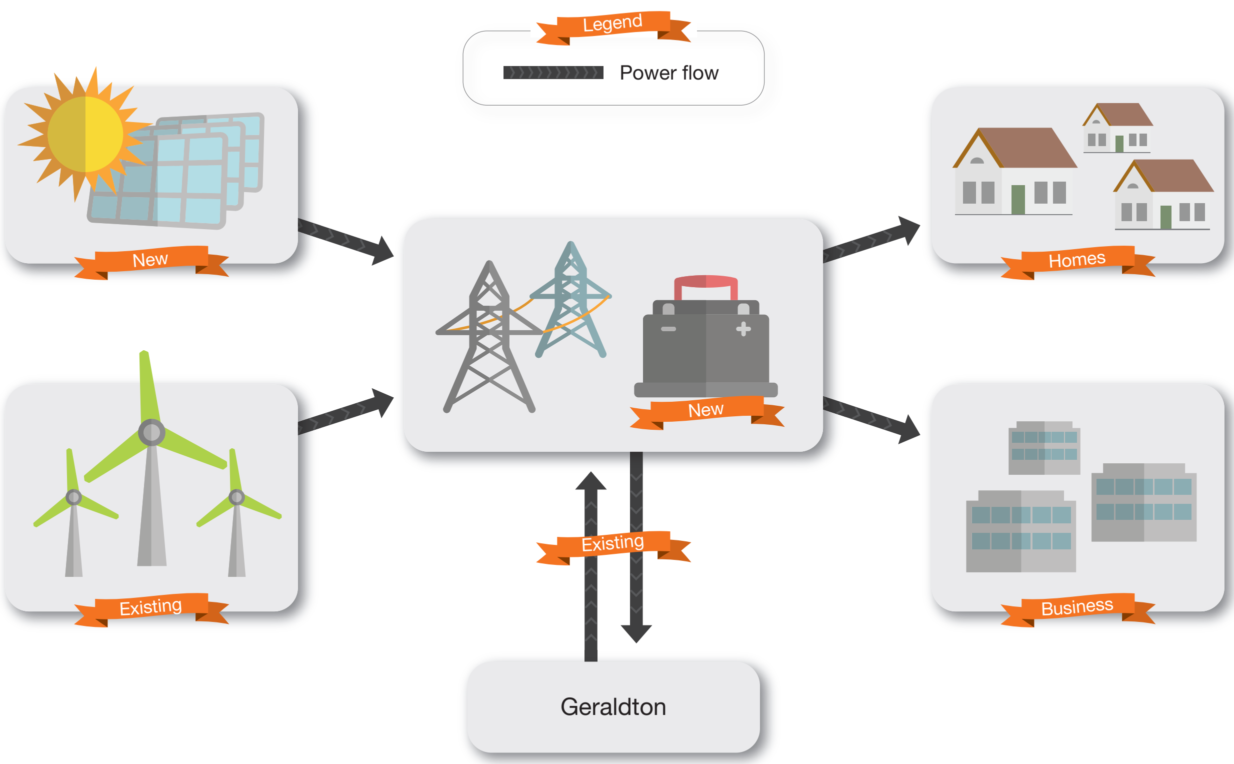
Given Western Power has no control over the development of generation infrastructure in Kalbarri, a range of scenarios, incorporating alternate generation configurations, were contemplated to understand the implications of deploying a microgrid at Kalbarri. In order to present a realistic view of available generation, the scenarios considered in various configurations were:

- the availability of the existing supply from the Kalbarri feeder
- the availability of the existing Synergy windfarm
- the availability of generation from a 5MW solar PV plant
- the availability of generation from a 1MW solar thermal plant.

Various plant configurations were studied to understand the scale of the energy storage capacity required to achieve various reliability outcomes.

Figure 4 demonstrates diagrammatically the components of a battery centric microgrid.

Figure 4: Conceptual model for a battery centric microgrid



Reliability impact

The reliability impact assessment of the technical studies provides a calculation of unserved energy (USE) in the Kalbarri region using the PROPHET (Price Optimising Predictor for Help in Electricity Trading) software tool. The assessment provides an initial indication of the size of the battery storage in Kalbarri required to meet a certain reliability of supply requirement.

USE is a calculation of the total amount of energy that would have been consumed were it not for interruptions to supply. For example if the supply to Kalbarri was interrupted for a period of three hours when the average demand was 1MW, the USE for this period would be 3MWh.

PROPHET is a software tool used primarily to model pricing outcomes for electricity markets.

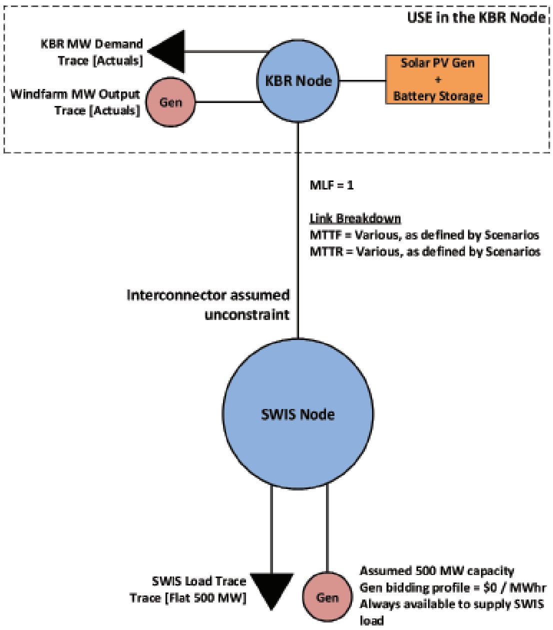
A secondary usage of the tool includes undertaking probabilistic assessments to provide an estimation of USE for different network scenarios.

Load and generation assumptions

The following key assumptions were made with regards to load and generation in Kalbarri:

- traces are used to represent load demand and generation output. Load and generation is assumed to follow a similar profile to actual historical data obtained from 1st July 2014 to 1st July 2015
- data was derived from Western Power's PI System in 30 minute intervals
- load demand represents the sum of the Kalbarri 6.6 kV transformers and based on the following PI Tags:
  - PID_004421840_KW.Display Value
  - PID_004421825_KW.Display Value
- load demand was scaled up by 23% to represent additional load in the region that is not adequately captured by Western Power's PI System
- intermittent generation in Kalbarri is modelled separately as traces
  - the 'GTN ZKW MW' tag was used to measure MW output of the wind farm
  - the 'MGA-MGS 81 MW' tag was used to obtain an existing solar farms output and scaled appropriately to represent a 5MW capacity solar farm in the Kalbarri region
- SWIS Load Data was set at a constant notional 500MW with generation always available to support the load
- no SWIS generator outages are modelled.

Figure 5: Kalbarri study model

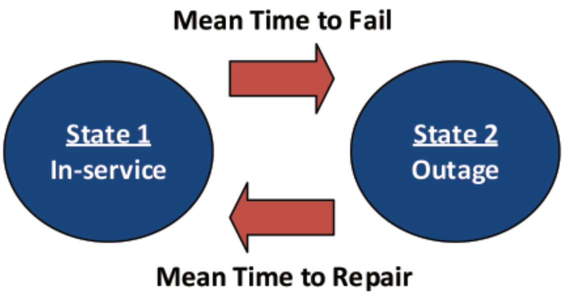


Network assumptions

The following assumptions were made with regard to the network reliability between Kalbarri and the SWIS:

- Network reliability was modelled using state set transitions in PROPHET. A mean time to fail (MTTF) and a mean time to repair (MTTR) is defined between the two state sets representing a network element that transitions from being in-service to out-of-service. Figure 6 provides a diagrammatic representation

Figure 6: State set transitions



- Outage data is based on the 2013, 2014 and 2015 years sourced from Western Power systems
- Breakdown capacity ratio of 100% is defined for State 1 and 0% for State 2. That is when the network connectivity between Kalbarri and the SWIS is either 100% available, or 0% available. No partial breakdown outages are modelled
- MTTF and MTTR values are calculated based upon final restoration times when the network between Kalbarri and the SWIS is fully back in-service. Partial restoration is not modelled, consistent with the state set transitions identified above
- It is assumed that no network constraints exist on the network link between Kalbarri and the SWIS and flow on this part of the network is unconstrained. This is the subject of other steady state and dynamic studies. Ie. No thermal, voltage or dynamic constraints exist which may impact ability to transfer power
- Four MTTF and four MTTR values have been produced, based on the following inclusions of outages into the MTTF and MTTR calculations:
  - MTTF/MTTR #1 – Including all outages (both planned and unplanned)
  - MTTF/MTTR #2 – Excluding planned outages
  - MTTF/MTTR #3 – Excluding pole top fires
  - MTTF/MTTR #4 – Excluding planned outages and pole top fires

Modelled outcomes where developed for all four MTTF and four MTTR. Published results focussed on the worst case situation where all outages are included.

Table 2 below summarises values used.

Table 2 - MTTF and MTTR Data

Scenario description	MTTF (min/year)	MTTR (min/year)
MTTF/MTTR #1 - All outages	11797	116
MTTF/MTTR #2 - Excluding planned outages	13005	99
MTTF/MTTR #3 - Excluding pole top fires in 2012, 2014	12174	111
MTTF/MTTR #4 - Excluding planned outages outages and pole top fires	13462	94

Scenarios simulated

Scatter plots of the maximum daily unserved energy experienced across all iterations run for the defined MTTF/MTTR values in Table 2 were produced. 2,500 iterations were performed for each of the four values of MTTF and MTTR.

Graphs were also produced which represent the maximum daily USE at Kalbarri, expressed as a percentage of the total amount of all simulations performed. Only the top 5% of maximum daily USE has been shown in Figure 7.

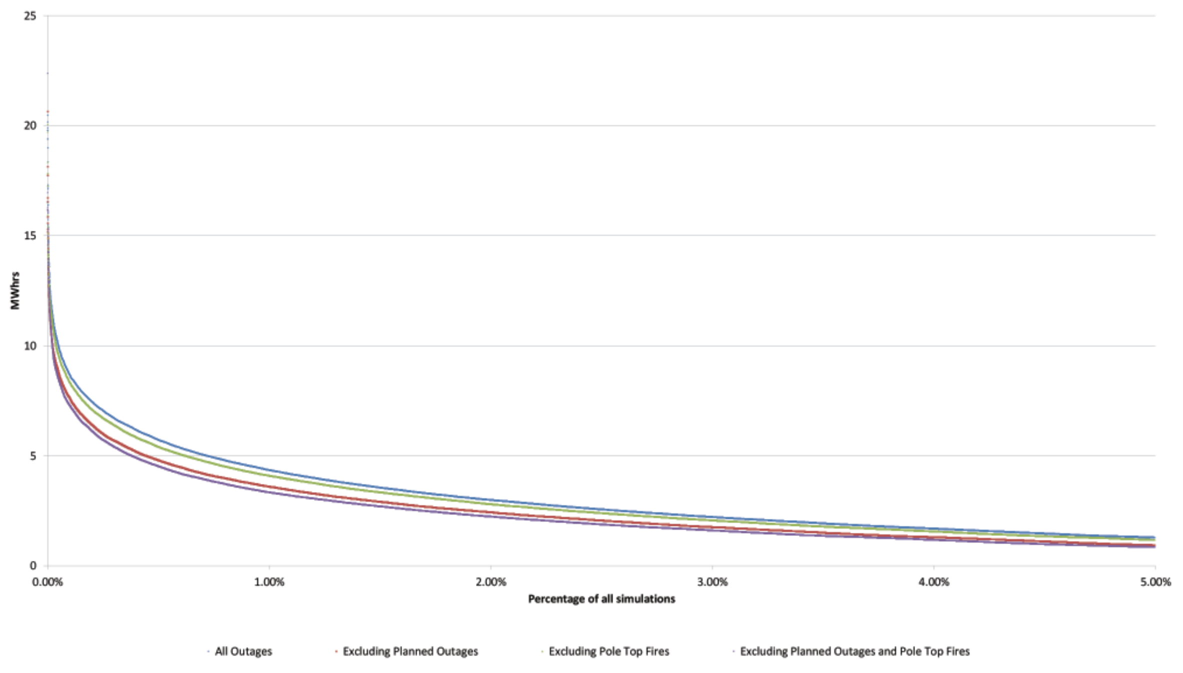
In order to estimate the size of the microgrid battery, PROPHET was used to generate a range of potential fault scenarios to compare against the forecast consumer demand and forecast generation capacity that was likely to have been available at the time of the fault.

A time sequential model was developed which considered the failure rate of various elements in a Monte Carlo environment.

Relative to the capacity of available generation to meet peak demand during various fault scenarios, the battery was variously scaled to cover either 100%, 99% or 95% of all modelled fault scenarios.

For example, PROPHET may have modelled the likely demand and available generation during the period of a fault that began at 2.15pm and lasted four hours and seven minutes until 6.22pm to understand the maximum USE at that time and to size the battery to meet a percentage of the USE.

Figure 7: Maximum daily USE at Kalbarri node expressed as a percentage of all data points; (Sensitivity 1)



Modelling to determine potential battery size was conducted for five different generation scenarios. Three type of generation were modelled across the five scenarios.

Generation Types

Wind: based on the existing 1.6MW Synergy Wind Farm

Solar PV: based on a proposed 5MW generator

Solar Thermal: based on a proposed 1MW generator

Scenarios modelled

Base scenario | Wind generation

Sensitivity #1 | Wind and solar PV generation

Sensitivity #2 | Solar PV generation

Sensitivity #3 | Solar PV and solar thermal generation

Sensitivity #4 | Wind, solar PV and solar thermal generation

This process was repeated by PROPHET 2,500 times for each of the five separate scenarios:

Base scenario

A base-case analysis was performed with only the Kalbarri wind farm output modelled.

With on-site generation insufficient to meet the town's average peak load, generation during fault scenarios will have a greater reliance on the battery and as such the energy storage capacity of the battery is larger for this scenario.

The requirement for a larger battery is exacerbated by the relative unpredictability of the windfarm output across the course of the day.

Under this scenario a 5MW inverter with a 2MWh battery would provide sufficient energy to meet the USE target and likely provide the minimum necessary fault energy (10MVA) for protection when the microgrid is disconnected from the Kalbarri feeder.

Required battery size: 2MWh/5MW

Required fault current: 10MVA

Indicative capital cost: $5-$10M

Indicative reliability improvement: Meets service standard benchmark for long rural feeder reliability performance at Kalbarri.

Sensitivity #1

This sensitivity includes the Kalbarri wind farm and a 5MW solar PV system.

The day-time output profile of the solar PV and wind generation would approximate the demand profile of the town under most circumstances with excess energy being exported to the grid.

Over-night supply would be sourced from the grid connection or local wind generation under non-fault conditions with local wind and energy storage supplying over-night demands under fault conditions.

This scenario would see generation, sufficient to meet peak demand, operating to supply all of Kalbarri's day-time requirements under most scenarios.

This scenario would achieve a high-level of supply continuity while minimising the size of the energy storage capacity required by the battery.

The battery could be located at the site of the Solar PV facility or at the site of the Kalbarri distribution substation.

Under this scenario a 5MW inverter with a 1MWh battery would provide sufficient energy to meet the USE target. However a 2MWh battery is likely required to provide the minimum necessary fault energy (10MVA) for protection when the microgrid is disconnected from the Kalbarri feeder.

Required battery size: 2MWh/5MW

Required fault current: 10MVA

Indicative capital cost: $5-$10M

Indicative reliability improvement: Meets service standard benchmark for long rural feeder reliability performance at Kalbarri.

Sensitivity #2

A sensitivity was performed with respect to the availability of wind in Kalbarri. This was performed by setting wind farm output to zero for the entire year. A 5MW solar PV system is included in this sensitivity.

As per the base scenario, the day-time output profile of the solar PV generation would approximate the demand profile of the town under most circumstances with excess energy being exported to the grid.

Over-night supply would be sourced from the grid connection under non-fault conditions with energy storage supplying over-night demands under most fault conditions.

This scenario would see generation, sufficient to meet peak demand, operating to supply all of Kalbarri's day-time requirements under most fault-free scenarios.

This scenario would achieve a high-level of supply continuity while moderating the size of the energy storage capacity required by the battery though the battery is likely to be scaled at greater capacity to achieve the same fault amelioration impact as the base case.

The battery could be located at the site of the Solar PV facility or at the site of the Kalbarri distribution substation.

Under this scenario a 5MW inverter with a 1MWh battery would provide sufficient energy to meet the USE target. However a 2MWh battery is likely required to provide the minimum necessary fault energy (10MVA) for protection when the microgrid is disconnected from the Kalbarri feeder.

Required battery size: 2MWh/5MW

Required fault current: 10MVA

Indicative capital cost: $5-$10M

Indicative reliability improvement: Meets service standard benchmark for long rural feeder reliability performance at Kalbarri.

Sensitivity #3

A sensitivity was performed assuming the connection of a 1MW solar thermal plant in Kalbarri. This scenario assumes no wind farm output, but does include the forecast output of a 5MW solar PV system.

The combined scale of these plants and the dispatchable nature of the solar thermal plant present a scenario where the scale of the battery is determined less by the requirement for it to provide the majority of Kalbarri's energy requirements during fault scenarios as it is the need for the battery to provide system stability during outages of the Kalbarri feeder.

The ability of the solar thermal generation to contribute to overnight demand also reduces the reliance on the battery to meet demand during fault situations.

Under this scenario a 5MW inverter with a 1MWh battery would provide sufficient energy to meet the USE target. However a 2MWh battery is likely required to provide the minimum necessary fault energy (10MVA) for protection when the microgrid is disconnected from the Kalbarri feeder.

Required battery size: 2MWh/5MW

Required fault current: 10MVA

Indicative capital cost: $5-$10M

Indicative reliability improvement: Meets service standard benchmark for long rural feeder reliability performance at Kalbarri.

Sensitivity #4

This scenario involves the simulation of sensitivity #3, with the inclusion of wind farm output at Kalbarri.

This scenario, with the greatest availability and diversity of generation of all the scenarios modelled, has the lowest reliance on the energy capacity of the battery.

As per the scenario outlined above (Sensitivity #3) the scale of the battery is determined more by the instantaneous power requirements of the microgrid with this generation mix, rather than the energy requirement. As a result, the required battery size is comparable to Sensitivity #3).

Under this scenario a 5MW inverter with a 1MWh battery would provide sufficient energy to meet the USE target. However a 2MWh battery is likely required to provide the minimum necessary fault energy (10MVA) for protection when the microgrid is disconnected from the Kalbarri feeder.

Required battery size: 2MWh/5MW

Required fault current: 10MVA

Indicative capital cost: $5-$10M

Indicative reliability improvement: Meets service standard benchmark for long rural feeder reliability performance at Kalbarri.

Summary of results

Table 3 provides a summary of an indicative battery size to deliver the indicated improvement at Kalbarri as specified.

Table 3 - Summary of results

	Delivering the energy required (theoretical) MWh			Delivering the fault current required MWh		
Generation mix	100%	99%	95%	100%	99%	95%
Base scenario	35.3	4.7	1.4	2.0+	2.0+	2.0+
Sensitivity #1	20.2	2.9	0.6	2.0+	2.0+	2.0+
Sensitivity #2	20.5	4.4	1.3	2.0+	2.0+	2.0+
Sensitivity #3	16.1	2.6	0.7	2.0+	2.0+	2.0+
Sensitivity #4	16.1	1.5	0.1	2.0+	2.0+	2.0+

Note: *Modelled sizes do not incorporate real world battery limitations (e.g. efficiency assumed to be 100%) and as such should be interpreted as a 'lower bound' of potential battery sizes.*

Conclusions of reliability impact assessment

The initial analysis shows that, assuming sufficient charging and discharging capability with no additional generation:

- a battery storage unit with capacity of around 2MWh, could achieve a reliability outcome for Kalbarri in line with the regulated target for consumers on long rural feeders
- a battery storage unit with capacity of around 2MWh,[12] could potentially meet 95% of all outages that are likely to occur
- a battery storage unit with capacity of around 7MWh,[12] could potentially meet 99% of all outages that are likely to occur
- a battery storage unit with capacity of around 40MWh,[12] could potentially meet 100% of all outages that are likely to occur.

[12] Based on a 40% premium above the theoretical performance to allow for real-world operation.

Diesel generation options technical findings

A number of additional non-network options may assist in resolving reliability issues at Kalbarri. Since these represent well understood solutions they were not assessed in detail as part of this study.

It is likely these alternatives will need to be modelled as part of the business case in order to ascertain the lowest-cost solution for the reliability improvement.

Diesel generator purchase

Western Power could purchase, or a 3rd party could purchase, diesel generators to improve the reliability in Kalbarri. These generators would cover the maximum peak demand for the year and be capable of improving the reliability with a greater degree of certainty of outage coverage compared to renewable options.

Alternate deployment options - diesel generator hire

Western Power could also hire a similar generator setup to be used at peak tourist times. This would require the generators being on site for 30 days over the Christmas period and for 30 days over the Easter holiday period.

Technical study overview

System stability, steady stage and system protection studies have been completed as part of the background work to develop this feasibility study report.

A summary of each is provided below.

System stability

The battery system has to be designed to support the grid under islanded and grid-connected operation modes. This includes the operation of the island within frequency and voltage limits set out by the Technical Rules.

System stability studies investigated the voltage and frequency stability within the microgrid for different configurations in islanded and grid connected modes.

Three categories of analysis are covered in the feasibility study:

- Voltage stability
  The voltage stability component of the study covered voltage recovery after faults, voltage step after generation/load trips, voltage recovery on motor starting and black starting on battery. The aim of this element of the technical study was to check if the battery energy storage system is capable of providing acceptable voltage profile in different scenarios as required by the technical rules.
- Frequency stability
  The frequency stability part of the study includes the contingency frequency control capability, battery delays and stored energy and regulatory frequency control. The aim is to confirm the ability of the battery energy storage system to control the frequency within standard parameters outlined by the Technical Rules when Kalbarri is islanded from the rest of the network.
- Frequency sweep
  The frequency sweep is undertaken to observe the resonance frequency at the battery and generation connection point. Two battery and generator layouts were considered which are:
  - Layout 1: The battery and generator are located at different locations, 23km apart (the site of the Kalbarri windfarm)
  - Layout 2: The battery and generator are located at the same location.

Output of the system stability when in islanded microgrid mode assessment

A summary of the findings of system stability study are listed below.

- voltage recovery is acceptable after the majority of worst-case credible contingencies
- for a 50% load shed of Kalbarri's maximum load (as the highest credible load trip level), the voltage step is inside Technical Rules requirements
- direct motor starting on the longest feeder is possible with acceptable voltage recovery
- single step black start at maximum load is not viable due to unacceptable voltage profile along the feeder. A maximum 1.25MW of load could be black started at each step using a battery for acceptable voltage recovery. (This would be achieved via automation that brings load back online sequentially rather than as a single step.)

- the frequency deviation after load/generation is a function of the stored energy in the microgrid, the maximum single infeed/load and the battery's inherent delay in compensating for the energy mismatch. A full load rejection or full 5MW generation trip may result in frequency deviating outside of Technical Rule requirements
- for frequency regulation, the battery output (inverter) has to be sized cognisant of the maximum load/generator
- for frequency regulation, the battery system must be capable of a ramp up and down of at least 2.5MW/min in order to compensate for load, solar and wind power variation 99% of the time
- the frequency sweep of extreme loading conditions and islanded versus grid-connected operation shows the parallel and series resonances are more severe when system is islanded. The resonance frequencies change slightly in islanded operations versus grid-connected mode, but all within acceptable levels.

Conclusions of the system stability assessment

The following considerations are required to support the effective deployment of the microgrid with respect to the management of system stability:

1. Full dynamic voltage support capability for battery and solar inverters
2. Limit the maximum load when black start on battery to 1.25MW
3. Limit the maximum size of single infeed from a potential 5MW generator to 2.5MW to ensure frequency deviation is within Technical Rules requirements after solar trip
4. Consider a minimum 2.5 MW/min ramp up and down capability for battery. (This needs to be coordinated with charge/discharge rate of the battery)
5. Perform a harmonics analysis when allocating the harmonics limits to the battery/Solar system to assure power quality standard is not violated

Ultimately, the system stability study has concluded that with careful planning and management a microgrid can be deployed at Kalbarri in such a manner as to maintain system stability under a range of reasonably foreseeable dynamic and transient.

Steady state and system protection study

The objective of this steady state study is to verify the feasibility of the microgrid generation connection and identify any network reinforcements that are required to ensure the connection maintains compliance with the Technical Rules.

This study covered the following:

1. Steady state voltage level for:
   a. feeder peak and minimum load conditions (with and without Microgrid contribution)
   b. power and voltage control mode (peak & minimum load conditions)
2. Voltage step change
3. Fault current calculations (with and without various generator contribution) for:
   a. equipment fault ratings
   b. generators and network protection study
   i. verification of protection grading, sensitivity, backup and fault rating
   ii. proposal of new settings (if required)

Details of the system protection performance assessment

This study has reviewed relevant distribution protection parameters with respect to the proposed Kalbarri Microgrid and covered the following network performance criteria:

- Voltage Step change - minimum feeder load
- Voltage Step change - maximum feeder load
- existing under fault rated conductors
- additional under fault rated conductors caused by the Microgrid operation
- protection grading and protection reach issues assuming existing protection devices
- protection of Transformer LV network assuming 50% bolted fault at LV terminals.

A 5MW energy source for the proposed microgrid is assumed to be within close proximity to Kalbarri or co-located with a generation source. The minimum output fault level is assumed to be 10MVA for 2 seconds at the 33kV terminal. For safety (protection reach purposes), it was prudent to assume that only a single source, being an inverter connected battery be considered, as this will lead to the minimum fault level situation (at x2 nominal rating due to IGBT thermal limits).

Other generation sources were ignored because there was no guarantee they would be available to contribute energy at the time of fault – this is for a scenario during islanded operation where battery is the primary source and fault current is inside the micro-grid.

In the opposite scenario to the protection reach related minimum fault level condition assumption described above, this time for Under Fault Rated (UFR) maximum fault levels (for safety reasons) it was assumed that all possible generation sources were available and contributing to fault energy.

Conclusions of the system protection performance assessment

The results of the study show that:

1. For sudden, complete failure of the microgrid, the step voltage change at any point in the network would be below 10% with the inverter in Real Power and Reactive Power control mode with Power Factor set to 0.95 capacitive. Hence it is estimated that voltage step change will not be an issue
2. The addition of all possible generation sources would increase the under fault rated conductors by some 2km – and would need to be remedied
3. The fuse rating for 51 transformers will need to be adjusted to operate on 50% bolted faults at the transformer LV terminals
4. To ensure Protection Reach in the 33kV Zone the Microgrid main breaker to the 33kV feeder back bone should be set to trip at 79.5 Amps assuming the use of negative phase sequence protection
5. Alternative and innovative voltage based protection methods need to be implemented in order to achieve protection reach to the end of the low voltage feeder circuit.

Regulatory findings

Regulatory impediments

While Service Standard Targets are intended to provide an incentive for distribution network service providers to achieve and exceed minimum standards in reliability, the averaging of network reliability performance across classes of customers makes it difficult for Western Power to justify expenditure on reliability outliers, particularly when service standard benchmarks for reliability are being met.

As has been outlined earlier in this report, reliability in Kalbarri is poor, however Western Power's performance in reliably supplying customers on Long Rural Feeders (which include Kalbarri residents) typically meets service standard benchmarks.

Given the relatively small number of customers in Kalbarri, even significant improvements in reliability will only have a minor impact on Western Power's reliability performance and its ability to access incentives for improved performance or avoid penalties for underperformance.

Since it is difficult to justify expenditure on reliability outcomes using averaged performance data, Western Power has also assessed the expected improvement to power supplies in terms of the Value of Customer Reliability (VCR) – a customer centric model of assessing the impact of unserved energy, and by implication, the value of reliability, from the consumer's perspective.[13]

Regulatory compliance

The value of the energy storage component of the Kalbarri microgrid lies almost exclusively in the improvement to reliable network services.

There is limited likelihood that the battery could provide peak-shifting, energy arbitrage or LFAS services thereby limiting it to an almost exclusively network purpose.

It is reasonable to assume that Western Power can invest in a battery asset where it demonstrably serves an exclusively network purpose, and is justified as the most prudent investment (and procurement) option.

A procurement process for a third party provided reliability service and/or Western Power owned battery centric microgrid needs to be conducted to confirm costs and regulatory compliance.

[13] As VCR underpins Service Standard calculations, the VCR calculations applied excludes the 5 year Service Standard impact period

Feedback

Western Power welcomes feedback on this report and associated discussion points. A dedicated email address has been setup as a central point for feedback:

kalbarristudies@westernpower.com.au

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