System Strength Options Cost Study

For GFM BESS and synchronous generator mechanical clutches

ElectraNet Pty Limited

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→ **The Power of Commitment**

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GHD Pty Ltd | ABN 39 008 488 373
Contact: David Taddeo, Technical Director, Electrical & Communications | GHD
211 Victoria Square, Level 4
Adelaide, South Australia 5000, Australia
T +61 8 8111 6600 | **F** +61 8 8111 6699 | **E** adlmail@ghd.com | **ghd.com**

The Power of Commitment

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1. Executive Summary

The Australian Energy Market Operator (AEMO), as the National Electricity Market (NEM) operator, is responsible for establishing electricity system strength requirements, as well as other network requirements related to inertia shortfalls, or Network Support and Control Ancillary Services (NSCAS), etc. to ensure secure ongoing operation of the networks.

The energy transition away from fossil fuel based synchronous generation to renewable generation largely based on inverter-based resources (IBR) is resulting in decreasing network system strength. A new system strength framework will be introduced from 1 December 2025, according to which, the Transmission Network Service Providers (TNSPs) will be responsible for meeting the system strength standard published by AEMO three years earlier. During the transitional period AEMO will continue to apply the existing system strength framework. ElectraNet, as the South Australian TNSP, will need to deliver system strength on a forward-looking basis and to standards that will be set by AEMO.

As part of the process of managing the projected system strength requirements of the South Australian transmission network, ElectraNet has initiated a Regulatory Investment Test for Transmission (RIT-T) for System Strength by publishing a Project Specification Consultation Report (PSCR) and seeking non-network options through an Expression of Interest (EOI). The network solution provided in the RIT-T PSCR is the installation of Synchronous Condensers at System Strength Nodes (SSN) Robertstown and Para. In addition to consideration of the network solutions which would be provided by ElectraNet, the PSCR extends consideration to non-network options such as Grid Forming Battery Energy Storage Systems (GFM BESS), and conversion of Gas Turbine powered Synchronous Generators or retrofitting existing or configuring future renewable gas (e.g. H_2 gas) generators by the installation of mechanical clutches to allow the generator to function as a synchronous condenser.

ElectraNet has engaged GHD to conduct a survey of suppliers of grid forming inverters and mechanical clutches and obtain estimates for the capital, operating and incremental costs associated with modifying existing Battery Energy Storage Systems to utilise grid forming inverters, as well as obtain estimates of the additional capital and operating costs associated with including a mechanical clutch on greenfield gas turbine installations to allow the generator to function as a synchronous condenser when not required for generation purposes.

Using the cost information provided by suppliers GHD has calculated estimates for the annual charges which might be levied by providers of non-network system strength services if contracted by ElectraNet. The estimate of costs for each solution will inform ElectraNet to allow consideration of the relative merits of estimates from potential system strength providers obtained as part of the RIT-T expressions of interest process.

2. Introduction

2.1 Background

South Australia's energy transformation is underway, with significant characteristics relating to the increased penetration of inverter-based resources (IBR), the retirement of a substantial number of synchronous generators and an associated decrease in system strength.

From a power system security perspective, Australian Energy Market Operator (AEMO), as the National Electricity Market (NEM) operator, is responsible for establishing the system strength requirements, as well as other network requirements related to inertia shortfalls, or Network Support and Control Ancillary Services (NSCAS), etc.

A new system strength framework will be introduced from 1 December 2025, according to which, the Transmission Network Service Providers (TNSPs) will be responsible for meeting the system strength standard published by AEMO three years earlier. During the transitional period AEMO will continue to apply the existing system strength framework. ElectraNet, as the South Australian TNSP, will need to deliver system strength on a forward-looking basis and to standards that will be set by AEMO.

As part of the process of managing the projected system strength requirements of the South Australian network, ElectraNet is investigating various technical options to address the system strength needs, for the facilitation of a stable voltage waveform for new IBR generators (efficient level) beyond the minimum level of system strength. To address this, ElectraNet has initiated the Regulatory Investment Test for Transmission (RIT-T) for System Strength by publishing the Project Specification Consultation Report (PSCR) and seeking non-network options through an Expression of Interest (EOI). The network solution given in the RIT-T PSCR is the installation of Synchronous Condensers at System Strength Nodes (SSN) Robertstown and Para. However, the PSCR extends consideration of non-network options such as Grid Forming Battery Energy Storage Systems (GFM BESS), and conversion of Gas Turbine powered Synchronous Generators or retrofitting existing or configuring future renewable gas (e.g. H_2 gas) generators by the installation of mechanical clutches.

GHD has been engaged by ElectraNet to provide cost estimates for these non-network solutions (see Table 1), including capital, operating, and incremental costs. This report will deliver the necessary financial insights to support ElectraNet's RIT-T process in addressing system strength requirements on the 275kV high-voltage network in South Australia.

Table 1 – System Strength Options Considered

Plant type	Description
GFM BESS	Implementing grid forming (GFM) function to an existing/committed BESS of 100MW connecting to 275kV network including balance of plant
GFM BESS	Implementing grid forming (GFM) function to an existing/committed BESS of 250MW connecting to 275kV network including balance of plant
GFM BESS	Provision of new 250MW grid forming (GFM) BESS connecting to 275kV network including balance of plant at Robertstown or Para
Mechanical Clutch	New Mechanical Clutch for a Synchronous Gas Generator rated at 200MW, 250MVA
Mechanical Clutch	New Mechanical Clutch for a Synchronous Gas Generator rated at 100MW, 120MVA
Mechanical Clutch	New Mechanical Clutch for a Synchronous Gas Generator rated at 500MW, 600MVA

2.2 Purpose of this Report and Costing Approach

The purpose of this report is to inform the ElectraNet RIT-T process of the estimated costs to enter into service provision contracts with external parties to provide system strength services within the South Australian region of the NEM. Potential suppliers of system strength services may not have operational plant in service for the scenarios discussed herein at this point in time, however, the intent of this report is to provide ElectraNet an understanding of the estimated costs based on information provided by OEMs to implement system strength services.

Based on the bottom-up evaluation of capital costs (including plant and integration works), transmission connection costs, incremental costs, and operating and maintenance costs for each of the GFM BESS and synchronous generator mechanical clutch options, a detailed analysis was conducted. As part of this analysis, capital and operating costs were calculated and contract pricing estimated. The cost estimates were derived from information provided by various OEMs, vendors, agencies, and other sources.

For the mechanical clutches estimates were obtained of the incremental capital and operating costs associated with adding the clutches to greenfield gas turbine synchronous generation systems during the design process to allow them to operate as synchronous condensers when not actively generating power.

2.3 Limitations

This report: has been prepared by GHD for ElectraNet Pty Limited and may only be used and relied on by ElectraNet Pty Limited for the purpose agreed between GHD and ElectraNet Pty Limited as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than ElectraNet Pty Limited arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s) 1.4 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD is not responsible for any qualitative or quantitative errors in its deliverables resulting from errors in the budgetary estimates provided by a third party. All cost related information being in real Australian Dollars with no allowance for escalation or inflation unless otherwise noted.

2.4 Assumptions & Exclusions

The scope will exclude consideration of the following items:

1. Cost of downtime required for gas turbines to be fitted with a clutch and recommissioned. Only greenfield projects have been considered where clutches would be installed during construction and prior to commissioning or operation.
2. Cost of electricity required to operate a generator as a synchronous condenser when a clutch to the gas turbine has been dis-engaged.
3. The cost for reserving capacity for the BESS systems for the provision of system strength is not included in the cost estimates provided in this report.

3. GHD Estimates Approach

4. GHD's approach in determining the estimated costs for the introduction of GFM functionality in BESS systems is described below as follows:
5. Specifying a common reference describing the performance that a GFM-type BESS system would need to attain, such that the desired effects could manifest from a network system strength perspective;
6. Defining specific areas of interest for the estimates;
7. Identifying Original Equipment Manufacturers (OEMs) that:
   a. have the proven experience in deploying GFM-type systems;
   b. would be willing to assist with estimates; and
   c. seeking estimates from those OEMs in alignment with the areas of interest for GFM functionality;
8. Reviewing OEM responses; and
9. Preparing a report summarizing the responses received and the estimates derived from them.

GHD's approach in determining the estimated costs for the addition of mechanical clutches to gas turbine generation systems is described below as follows:

a. Identifying Original Equipment Manufacturers (OEMs) that have the proven experience in deploying mechanical clutches as part of gas turbine generation systems and would be willing to assist with providing estimates of relevant costs;
b. Obtaining OEM responses for capital, operating and incremental costs associated with adding mechanical clutches to the generation system during the design and construction phases of the project prior to commissioning and operation. OEMs were requested to provide estimates for greenfield installations only and to not consider retrofitting clutches to already operating plant;
c. Preparing a report summarizing the responses received and the estimates derived from them.

It has to be noted that although the same queries were sent to all OEMs, some OEMs may view certain technical details or costs as confidential information and consequently, some information has not been shared by some OEMs.

4. BESS

4.1 Options of Interest

One of the technical options under investigation by ElectraNet refers to the capability of Grid Forming (GFM) BESS Facilities to provide system strength services by:

1. either converting Grid Following (GFL) BESS Facilities already connected to the network to GFM functionality; or
2. providing the GFM functionality to upcoming BESS Facilities that would have otherwise been developed / intended to be connected to the network with GFL functionality.

As part of a Regulatory Investment Test for Transmission (RIT-T) process which is currently underway for System Strength requirements in SA, ElectraNet is interested in estimating the potential incremental costs for the introduction of GFM-capability for either existing grid-connected or upcoming grid connections of BESS facilities, with the respective incremental costs to be (generally) determined with reference to the equivalent GFL-based BESS systems.

4.2 GFM Model and Functionality

AEMO's 'Voluntary Specification for Grid-forming inverters'[1] was decided to be used as a reference for the functionality to be provided by GFM-type inverters.

In accordance with the respective specification, 'core, respectively 'additional' capabilities apply to GFM-type inverters.

The queries prepared for OEMs specified that essential for the GFM functionality are the core capabilities, with the 'additional' capabilities being also desirable. The respective functionality is deemed necessary to be implemented in the inverter models (both PSSE and PSCAD) and all associated AEMO modelling requirements.

The GFM functionality as indicated in AEMO's 'Voluntary Specification for Grid-forming Inverters' will be required to be implemented for a GFM-type model conversion or model development both for PSSE and PSCAD models. On the consideration that such changes will need to be reflected in the inverter models, any new or updated models providing the GFM functionality will need to conform to AEMO's Power System Model Guidelines[2], the Power System Design Data Sheets and Power System Setting Data Sheets.

The potential incremental costs for the conversion of network-connected/registered BESS units from GFL to GFM respectively for the specification of GFM functionality for BESS units for which the connection process is intended to be commenced will be of interest particularly for the core capabilities.

4.3 Areas of Interest for Estimates

In order to identify incremental costs for the introduction of GFM functionality to either existing GFL-type inverters, or new BESS facilities, a common set of queries were prepared for OEMs as follows:

Table 2 – Incremental Costs

Item
1. Additional hardware / equipment
2. Model changes development (PSSe and PSCAD models)
3. Modelling support for system studies / registration / performance testing and validation
4. Operational costs – only if additional for GFM vs GFL
5. Maintenance costs – only if additional for GFM vs GFL

[1] https://aemo.com.au/-/media/files/initiatives/primary-frequency-response/2023/gfm-voluntary-spec.pdf
[2] https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-security-market-frameworks-review/2023/power_systems_model_guidelines_2023_published_.pdf?la=en&hash=2DEC33EE3AEC672E9DF409FE596BE604

Item
6. System strength support – recommended upsizing of batteries / energy capacities costs (energy capability increase)
7. System strength support – recommended additional overload capability costs (power overload capability increase)
8. Any other additional costs

4.3.1 Additional hardware / equipment

The OEMs were asked to confirm whether the introduction of GFM functionality as opposed to GFL functionality would require additional physical hardware or equipment - for their inverters / platforms.

The responses received from OEMs confirmed that there are no anticipated additional hardware / equipment costs i.e. neither for GFL to GFM BESS systems conversions, nor for the configuration of new BESS systems with GFM capability.

4.3.2 Model changes development (PSSE and PSCAD models)

It appeared likely that OEMs that can provide GFM functionality would have already developed PSSE / PSCAD models and potentially performed model acceptance testing, together with performance validation of respective models. Nevertheless, the intention was to confirm if any additional costs would be applicable for the PSSE / PSCAD models development, specifically for the inclusion of GFM functionality (e.g. shift from current source to voltage converters / associated control).

It was confirmed that all OEMs contacted for GFM estimates had already developed and have available PSSE and PSCAD models providing GFM functionality. Accordingly, modelling costs were confirmed as nil.

4.3.3 Modelling support for system studies / registration / performance testing and validation

It has been considered that while the OEMs may be able to perform system studies, evaluation of potential changes to the generator performance standards (GPS), changes to registered GPS, performance validation testing and reporting, the typical approach would be to have other organisations (e.g. consulting organisations and not the OEMs) perform the respective studies.

Accordingly, it was indicated that the assumption was to be made that such work would be performed by third parties and OEM’s role would be to provide modelling support during that process. The respective costs were estimated by GHD separately, on the assumption that the respective works would be performed by (typically) consulting organisations, under developers’ direction.

For new BESS systems, such costs were specified to be of interest to the extent to which the commissioning and performance testing of those BESS facilities would attract longer timeframes and higher costs.

Based on OEMs responses, it can be expected that the commissioning / performance testing of GFM-type BESS systems may take anywhere between no additional time and up to 50% longer than the equivalent type GFL-systems.

4.3.4 Control system changes

It has been confirmed by the contacted OEMs that the implementation of changes required for the GFL to GFM conversion (i.e. for existing BESS) will consist of firmware changes and associated verifications.

The approaches available vary from broadcasting the required changes, to implementing the firmware upgrades piecemeal.

4.3.5 Operational costs

Potential incremental operational costs were confirmed to the OEMs to be of relevance only to the extent to which additional time/costs would be involved in the provision of the same services that the equivalent GFL-type inverters would have provided (for instance energy trading, FCAS, voltage / reactive support, etc).

The possibility of increased operational costs for GFM-type systems seemed improbable in case in which same services were intended to be covered, in the same markets as the equivalent GFL-type systems, nevertheless, confirmation was sought from OEMs in this sense.

Based on responses received from OEMs it can be estimated that there will be no anticipated additional operational costs for GFM-type BESS systems, compared to the equivalent GFL-type BESS systems.

4.3.6 Maintenance costs

Similarly to the approach for operational costs, the incremental costs for undertaking maintenance works were specified to the OEMs as being of interest, under the assumption that both the maintenance works for GFL, respectively GFM-type inverters were to be performed in compliance with OEMs recommendations.

If the same equipment / hardware were to be used for GFM-type inverters, it appeared unlikely that any additional maintenance costs would apply to GFM-type systems. The assumption was based on the duration and frequency of events when system strength support would be required, estimated to be of relatively short cumulative duration (hence no presumed additional stress on the BESS equipment which may necessitate additional maintenance). Nevertheless, estimation of such potential additional maintenance costs was raised for OEMs' consideration.

Based on responses received from OEMs it can be estimated that there will be no anticipated additional maintenance costs for GFM-type BESS systems, compared to the equivalent GFL-type BESS systems.

4.3.7 Batteries energy capability upsizing recommendations

OEMs' views were sought regarding the potential need to provide higher energy capability for the batteries of BESS systems, specifically for the provision of system strength support (in this sense, duration of support, frequency of occurrence and magnitude of intervention would be of significance).

Based on responses received from OEMs it can be estimated that the implementation of GFM-functionality will not attract additional significant energy consumption for the associated BESS systems.

4.3.8 Overload capability / upsizing recommendations

As for the energy capability upsizing, OEMs' views were sought in relation to the potential need to provide a higher overload capability for the inverters for the provision of system strength services (in this case, only the magnitude of intervention was considered to be of relevance).

Based on responses received from OEMs it can be estimated that the implementation of GFM-functionality will not require the upsizing of the BESS systems. Nevertheless, the following can be noted:

3. When operating at full capacity (either for power export / discharging, or power import / charging), the BESS systems' potential fault current contribution is limited to the overload capability of the respective inverters, estimated to be approx. 1.2 to 2.0 p.u. (different for different OEMs), for a maximum of (indicatively) 1 sec.
4. Further fault current contribution will require the upsizing of the power stages of the inverters and attract additional costs;
5. In some instances it is possible to reconfigure the same inverters for higher overload levels, but the downside is that due to thermal management considerations, the respective inverters will need to be derated (effectively, a slight decrease in terms of power capability).

4.4 OEMs

The identification of OEMs to which the GFM-related queries were directed considered the need for such OEMs:

6. To have developed GFM-type functionality for their inverters;
7. To have an Australian presence / operation.

OEMs meeting the above criteria were identified, contacted and responded to the BESS GFM queries.

It is to be noted that although the same approach was adopted for queries / requests for information for all contacted OEMs, the responses received varied, based on considerations specific to each OEM (e.g. technical, commercial, confidentiality, IP considerations, etc). In some cases and for some items, the contacted OEMs did not provide responses; accordingly, the compilation of estimates is based on the information as, how and where it was received from OEMs.

4.5 System Studies and Performance Testing

The conversions from GFL to GFM-type inverters were confirmed to involve changes which will constitute the alteration of the generating systems / loads.

The respective changes will require the undertaking of the process outlined in NER 5.3.9 (Procedure to be followed by a Generator proposing to alter a generating system).

It is envisaged that the changes for GFM conversion may be having an impact on some of the following (with reference to the table included in NER 5.3.9):

8. Power converter;
9. Voltage control system;
10. Power control system;
11. Protection system;
12. Remote control and monitoring system.

Consequently, the number of technical requirements which will need to be revisited will be substantial, potentially attracting an effort (studies-wise) not significantly lower than that required for the processing of a new application for connection.

Similarly, once the Generator Performance Standards will be verified, the performance of the BESS system will be required to be validated through hold point testing / R2 testing process.

It is important to note that for GFM-type systems additional work may be required for the simulations / testing of additional features like virtual inertia, black start capability or islanded operation (if such features would be enabled / intended to be activated).

Nevertheless, although such features could be enabled / tested, they are not relevant for the comparative assessment of GFL vs GFM-type systems – from point of view of provision of system strength.

Accordingly, potential associated costs have not been considered relevant for the GFL to GFM conversion from a system strength assessment perspective.

For the case in which a new BESS system would be intended to be deployed, it is estimated that for GFL, respectively GFM systems there would be insignificant / minor additional costs required for the connection study up to the point of submitting the registration application.

The testing of the BESS performance was confirmed by the OEMs to be more demanding for GFM-type systems, when compared to GFL-type BESS systems, with indications that up to 50% more effort may be required for GFM BESS performance testing. This conservative approach has been adopted for the estimation of incremental costs of deploying a new GFM BESS system vs GFL-type system.

4.6 Loss of Revenue

The need of undertaking BESS performance testing for systems undergoing changes under NER 5.3.9 will translate to the need to take the respective (operational) BESS systems out of service, such that the performance testing could be performed.

The time for which the BESS systems would be taken out of service will attract a loss of revenue for BESS systems that had been operating as GFL-capable, until they would return to service at full capacity as GFM-capable BESS systems.

For the purpose of estimates, it has been assumed that the BESS systems undertaking GFM conversion would have been participating in arbitrage and FCAS markets.

For the estimation of potential revenue loss, the following assumptions have been made:

1. The performance testing would be deliberately chosen at a time of the year when the lowest loss of revenue could be achieved;
2. The BESS charging costs would be zero, i.e. occurring at times when the energy costs would be low (but positive) to negative, i.e. an assumed average of zero cost for energy import;
3. No constraints would apply, i.e. the BESS could sell energy at its full registered capacity (100 MW, respectively 250 MW, for the chosen cases);
4. The BESS would be using 1C type batteries, hence the energy capability for the chosen cases will be 100MWh, respectively 250MWh;
5. The BESS may be potentially deriving its revenue through bulk sale of energy (arbitrage) and / or contingency FCAS; based on power considerations concurrent bidding in respective markets is mutually exclusive, so estimates will be based on anticipated loss of revenue through the bulk sale of energy.

The sources of information for energy costs are based on AEMO[3] records for wholesale energy costs.

Two months were selected: February and July 2024 respectively, for which all negative energy costs were eliminated, based on the consideration that the BESS would not bid in the market at a loss. For the remainder, the average values were determined for each month.

For the BESS, the period when loss of revenue would occur will relate to the period when, after the firmware upgrades from GFL to GFM, the performance of the BESS would need to be proven. For the 100 MW BESS it was estimated that the hold point / R2 testing will require seven days, whereas for the 250MW BESS the duration was estimated to be 10 days.

[3] https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/data-nem/aggregated-data

5. BESS Cost Estimates Review

Based on the submissions received from OEMs and on separate costs estimated by GHD.

5.1 Existing 100MW BESS Incorporating GFM Functionality

Table 3 – Existing 100MW BESS Incorporating GFM Functionality[4]

#	Item	Cost Estimate (AUD)	
		Low Range	High Range
1	Additional hardware / equipment	$ -	$ -
2	Model changes development (PSSe and PSCAD models)	$ -	$ -
3	Modelling support for system studies / registration / performance testing and validation	$160k	$190k
4	Control system changes	$ -	$ 80k
5	Firmware updates	$425k	$ 1,370k
6	Operational costs – only if additional for GFM vs GFL	$ -	$ -
7	Maintenance costs – only if additional for GFM vs GFL	$ -	$ -
8	System strength support – recommended upsizing of batteries / energy capacities costs (energy capability increase)	$ -	$ -
9	System strength support – recommended additional overload capability costs (power overload capability increase)	$ -	$ -
10	Any other additional costs	$ -	$75k
11	System studies costs	$300k	$450k
12	NER 5.3.9 – administrative / processing costs	$45k	$45k
13	NER 5.3.9 – performance testing costs	$205k	$350k
14	TNSP fees	$150k	$150k
	Total	**$1,285k**	**$2,710k**
	Revenue loss	**$60k**	**$210k**

[4] Estimate components rounded-up to the nearest $5k

5.2 Existing 250MW BESS Incorporating GFM Functionality

Table 4 – Existing 250MW BESS Incorporating GFM Functionality[5]

#	Item	Cost Estimate (AUD)	
		Low Range	High Range
1	Additional hardware / equipment	$ -	$ -
2	Model changes development (PSSe and PSCAD models)	$ -	$ -
3	Modelling support for system studies / registration / performance testing and validation	$210k	$240k
4	Control system changes	$ -	$80k
5	Firmware updates	$455k	$3,380k
6	Operational costs – only if additional for GFM vs GFL	$ -	$ -
7	Maintenance costs – only if additional for GFM vs GFL	$ -	$ -
8	System strength support – recommended upsizing of batteries / energy capacities costs (energy capability increase)	$ -	$ -
9	System strength support – recommended additional overload capability costs (power overload capability increase)	$ -	$ -
10	Any other additional costs	$ -	$180k
11	System studies costs	$300k	$450k
12	NER 5.3.9 – administrative / processing costs	$45k	$ 45k
13	NER 5.3.9 – performance testing costs	$205k	$350k
14	TNSP fees	$150k	$150k
	Total	**$1,365k**	**$4,875k**
	Revenue loss	**$145k**	**$515k**

[5] Estimate components rounded-up to the nearest $5k

5.3 New 250MW BESS with GFM Functionality

Table 5 – New 250MW BESS with GFM Functionality

#	Item	Cost Estimate (AUD)		Comments
		Low range	High range	
1	Additional hardware / equipment	$ -	$ -	No additional hardware / equipment required
2	Model changes development (PSSe and PSCAD models)	$ -	$ -	Models already developed
3	Modelling support for system studies / registration / performance testing and validation	$ -	$ -	Assumed to be no different between GFL and GFM
4	Control system changes	$ -	$ -	Not required for a new system, included in the package
5	Firmware updates	$ -	$ -	Not required for a new system
6	Operational costs – only if additional for GFM vs GFL	$ -	$ -	Not different GFL vs GFM for same functionality
7	Maintenance costs – only if additional for GFM vs GFL	$ -	$ -	Not different GFL vs GFM
8	System strength support – recommended upsizing of batteries / energy capacities costs (energy capability increase)	Not confirmed	Not confirmed	Assumed to be zero for same power rating
9	System strength support – recommended additional overload capability costs (power overload capability increase)	Not confirmed	Not confirmed	Assumed to be zero
10	Any other additional costs	$ -	$ -	Assumed to be no different between GFL and GFM
11	System studies costs	$ -	$ -	Not different GFL vs GFM for a new system
12	NER 5.3.9 – administrative / processing costs	$ -	$ -	Assumed to be no different between GFL and GFM
13	NER 5.3.9 – performance testing costs	$60k	$70k	
14	TNSP fees	$ -	$ -	Assumed to be no different GFL vs GFM
15	Revenue loss	$ -	$ -	Not applicable to new systems
	Total	**$60k**	**$70k**	

6. Synchronous Condenser Responses

GHD contacted a range of clutch suppliers on behalf of ElectraNet to gather information about the costs associated with system strength options considered in Table 1.

Three sizes of mechanical clutch were considered:

- Synchronous Gas Generator of size 100MW/120MVA;
- Synchronous Gas Generator of size 200MW/250MVA; and
- Synchronous Gas Generator of size 500MW/600MVA.

The costing information required by ElectraNet for each of the sizes includes the following:

- Capital Costs: The cost of the purchase and delivery of all the equipment required to install and operate the clutch (includes the clutch and any auxiliary plant necessary for operation);
- Operating Costs: The costs associated with operating and maintaining the clutch system; and
- Incremental Costs: The additional costs required to add a clutch to a planned greenfield synchronous gas generator.

6.1 Information Provided by Mechanical Clutch Suppliers

6.1.1 Supplier 1

Table 6 – Mechanical Clutch Costs – Supplier 1

Mechanical Clutch - Project Size	Capital Cost (AUD)	Incremental Cost (AUD)	Operation & Maintenance Cost (annual AUD)	Auxiliary Loads (MW)
100MW / 120MVA	Project specific	$2m	$75k	0.7 – 1.4 MW
200MW / 250MVA	Project specific	$3.2m	$120k	2.25 – 4.25 MW
500MW / 600MVA	Project Specific	$5.9m	$150k	4.3 – 8.2 MW

6.1.1.1 Supplier notes and conditions

All rating figures are based on the nameplate rating of each model at ISO conditions. Actual performance varies as ambient conditions change.

All figures are for the gas turbine equipment only and do not consider steam turbines that would be used in combined cycle applications

Ratings assume a generator with power factor capability of 0.85. Generators with higher MVA ratings can be used.

Capital costs: This is highly project specific and is not possible to estimate as actual condition of the site is especially important.

Incremental cost: The additional capital cost that would be added to a new gas turbine to add a clutch and allow syncon operation. The cost includes increasing the size of the gas turbine / generator lube oil system and addition of some instrumentation / controls. It does not consider any additional cost for equipment normally supplied by Design and Construct (D&C) contractors although this is not expected to be substantial.

O&M cost: In general terms the addition of a clutch is not expected to add much to the maintenance cost of the power plant. The lube oil and other systems are shared with the gas turbine / generator and would need to be maintained regardless of a clutch being installed. It is not expected that clutch to change the staffing levels of the power plant. The figure above is a rough estimate of annual maintenance cost in addition to normal gas turbine maintenance.

The more sensitive topic is power consumption to run the lube oil pumps and overcome the system losses during syncon operation. The cost of this power consumption would have to be paid for by the plant owner or passed on to the company that has contracted the plant owner to provide the syncon services.

The numbers indicated above are high level estimates only and not based on specific costing. If ElectraNet is considering service contracts with power plant operators for syncon services the auxiliary loads, and who pays for them, should be established on individual projects. The range is from synchronized no load up to full reactive power.

The above figures do not include any flywheels attached to the rotating shaft.

6.1.2 Supplier 2

Table 7 – Mechanical Clutch Costs – Supplier 2

Mechanical Clutch	Capital Cost (M$)	Incremental Cost	Operation and Maintenance cost	Other remarks/comments
100MW / 120MVA	Not within Scope	$0.75m	Duration per service call approx. 1 week. Cost: see separate hourly rate	Incremental costs budgetary quotation +-20%
200MW / 250MVA	Not within Scope	$1.0m	Duration per service call approx. 1 week. Cost: see separate hourly rate	Incremental costs budgetary quotation +-20%
500MW / 600MVA	Not within Scope	$1.9m $1.6m	Duration per service call approx. 1 week. Cost: see separate hourly rate	Incremental costs budgetary quotation +-20%

6.1.2.1 Supplier notes and conditions

Without detailed engineering example costs are difficult to estimate so these prices have to be seen as first orientation (budgetary, non-binding offer only).

Service from our experience will take approx. 1 week (this depends on accessibility of the overrunning clutch and tools/crane being available).

7. Estimated Contract Pricing

Table 8 provides estimates of the annual contact pricing for each option based on a discount rate of 5.0% and profit margin of 15.0%.

Table 8 – Estimated Annual Contract Costs [6]

System Utilised	Annual Contract Cost $ '000s
BESS GFL to GFM[1]:	
100MW	$290 minimum to $630 maximum
250MW	$326 minimum to $1,163 maximum
Mechanical Clutches:	
100MW / 120MVA	$171 to $490
200MW / 250MVA	$225 to $783
500MW / 600MVA	$354 to $1,389

[6] The minimum and maximum estimates for the GFL to GFM conversion are based on a summary of estimates received from OEMs for the areas of interest described in section **Error! Reference source not found.** and detailed in sections **Error! Reference source not found.** and **Error! Reference source not found.**.

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