Synchronous Condenser Design Information

1.1 Network data:

Nominal voltage	275	kV =	1.0	pu
Max. cont. voltage	302.5	kV =	1.1	pu
Min. cont. voltage	247.5	kV =	0.9	pu
Operating voltage	288.75	kV =	1.05	pu

The frequency variation withstand requirements as per NER S5.2.5.3, Must be capable of continuous uninterrupted operation for frequencies in the following ranges

Frequency range (Hz)	Duration
47 to 49	2 minutes
51 to 52	2 minutes
49.0 to 49.5	10 minutes (1)
50.5 to 51	10 minutes (2)
49.5 to 50.5	Continuous

1) 10 minutes includes the time when the frequency was between 47 Hz and 49 Hz
(2) 10 minutes includes the time when the frequency was between 51 Hz and 52 Hz

Nominal frequency	50	Hz
Maximum continuous frequency	50.5	Hz
Minimum continuous frequency	49.5	Hz

The below fault levels are proposed to be used for the AVR and not for other design packages such as earth grid, plant rating or protection settings

Listed below are the existing system normal maximum fault levels at Robertstown Substation 275 kV bus, excluding the contribution from committed generation or the synchronous condensers.

Existing System Normal 275kV Fault Level		3phase		1phase	
Max. short-circuit power		4530	MVA	3380	MVA
Max. short-circuit current		9.5	kA	7.1	kA

Listed below are the system normal fault levels at Robertstown Substation 275kV bus for minimum demand system case with contributions from non-synchronous generation sources neglected

Existing System Normal 275kV Fault Level		3phase		1phase	
Min. short-circuit power		1670	MVA	1770	MVA
Min. short-circuit current		3.5	kA	3.7	kA

Note: Network data is presented on the high voltage network side to which the synchronous condenser step-up transformer will be connected to.

1.2 Performance Requirements:

1.2.1 Steady-state Performance Requirements:

1.2.1.1 Short-circuit contribution

				Spec Item/ Page	Remarks
Short-circuit power of	At least 575	MVA	at step-up transformer HV side		

The Synchronous Condenser system shall be rated in the following modes at the step up transformer HV side (HV Bus)

a. Overexcited – i.e. capacitive capability
b. Under excited – i.e. Inductive capability

HV Bus Voltage [p.u.]	0.90	0.95	1.00	1.05	1.10
Capacitive Capability [MVAr]	>70 MVAr capacitive				
Inductive Capability [MVAr]					>45 MVAr inductive

1.2.2 Dynamic Performance Requirements:

1.2.2.1 Fault-ride through

Fault ride through capability as per NER S5.2.5.5 (b) the synchronous condensers capabilities shall be:

1. The Synchronous Condenser must remain in continuous uninterrupted operation for system disturbances including:
    i. a three phase fault in the transmission system cleared by primary protection systems
    ii. a two phase to ground, phase to phase or phase to ground fault in the transmission system cleared in approximately 0.5 sec which represents the longest time expected to be taken for a relevant breaker fail protection system to clear the fault

iii. a three phase, two phase to ground, phase to phase or phase to ground fault in the distribution system cleared in the longest time expected to be taken for a relevant breaker fail protection system to clear the fault

iv. The Synchronous Condenser should not be subjected to Auto-Reclose conditions on its connection circuit

v. The Supplier will have to choose an AVR that can cope with system response mentioned, i.e. 0.5 sec

vi. The condenser should not be subjected to Auto-Reclose conditions on its connection circuit

vii. The Supplier will have to choose an AVR that can cope with system response mentioned in this document providing the event would not disconnect the unit from the power system by removing network elements from service.

2. The Synchronous Condenser must remain in continuous uninterrupted operation for a series of up to 15 disturbances within any five minute period caused by any combination of the events described in subparagraph (b)(1) where:
   i. up to six of the disturbances cause the voltage at the connection point to drop below 50% of normal voltage;
   ii. in parts of the network where three-phase automatic reclosure is permitted, up to two of the disturbances are three phase faults, and otherwise, up to one three phase fault where voltage at the connection point drops below 50% of normal voltage;
   iii. up to one disturbance is cleared by a breaker fail protection system or similar back-up protection system;
   iv. up to one disturbance causes the voltage at the connection point to vary within the ranges agreed by AEMO and the Network Service Provider under subparagraphs (a)(7) and (a)(8) of clause S5.2.5.4 (between 70% and 90% of normal voltage);
   v. the minimum clearance from the end of one disturbance and commencement of the next disturbance may be zero milliseconds; and
   vi. all remaining disturbances are caused by faults other than three phase faults,
   vii. provided that none of the events would result in:
   viii. the islanding of the generating system or cause a material reduction in power transfer capability by removing network elements from service;
   ix. the cumulative time that voltage at the connection point is lower than 90% of normal voltage exceeding 1,800 milliseconds within any five minute period; or
   x. the time integral, within any five minute period, of the difference between 90% of *normal voltage* and the *voltage* at the *connection point* when the *voltage* at the *connection point* is lower than 90% of *normal voltage* exceeding 1 pu second;

   Subject to any changed power system conditions or energy source availability beyond the Generator's reasonable control, a generating system comprised solely of synchronous generating units, and each synchronous generating unit within a generating system, in respect of the types of fault described in subparagraphs (1) (ii) to (iv), must supply to or absorb from the network:

   (i) to assist the maintenance of power system voltages during the application of the fault, capacitive reactive current of at least the greater of its pre-disturbance reactive current and 4% of the maximum continuous current of the generating system including all operating synchronous generating units (in the absence of a disturbance) for each 1% reduction (from the level existing just prior to the fault) of connection point voltage during the fault;

(ii) After clearance of the fault, reactive power sufficient to ensure that the connection point voltage is within the range for continuous uninterrupted operation (0.9pu to 1.1pu);

1.2.2.2 Open Circuit Response

Performance to be consistent with NER S5.2.5.13(b) Automatic Access Standard for Voltage and Reactive Power Control, including (but not limited to) the following requirement:

i. Has settling time of less than 2.5 seconds for a 5% voltage disturbance with the unit not synchronised.

As per the NER: settling time means in relation to a step response test or simulation of a control system, the time measured from initiation of a step change in an input quantity to the time when the magnitude of error between the output quantity and its final settling value remains less than 10% of:
(1) if the sustained change in the quantity is less than half of the maximum change in that output quantity, the maximum change induced in that output quantity; or
(2) the sustained change induced in that output quantity.

1.2.2.3 Closed Circuit Response

Performance to be consistent with NER S5.2.5.13(b) Automatic Access Standard for Voltage and Reactive Power Control, including (but not limited to) the following requirements:

i. Regulates voltage at the connection point to within 0.5% of the set point;

ii. For a 5% voltage disturbance that would not result in the operation of a limiting device, reactive power and voltage settling times of less than 5 seconds;

iii. In respect of a limiting device (e.g. OEL or UEL), settling times for reactive power and voltage less than 7.5 seconds for a 5% voltage disturbance with the unit synchronized, when operating into a limiting device from an operating point where a voltage disturbance of 2.5% would just cause the limiting device to operate

As per the NER: settling time means in relation to a step response test or simulation of a control system, the time measured from initiation of a step change in an input quantity to the time when the magnitude of error between the output quantity and its final settling value remains less than 10% of:
(1) if the sustained change in the quantity is less than half of the maximum change in that output quantity, the maximum change induced in that output quantity; or
(2) The sustained change induced in that output quantity.

1.3 Step-up Transformer Requirements:

ElectraNet preference is to utilise two winding transformer with the auxiliary supply taken from the LV bus.

Number of windings	2	
Vector group	YNd1	
Primary winding		
Nominal voltage	275	kV
Nominal rating	130	MVA
Secondary winding		
Nominal voltage	TBA	kV
Nominal rating	130	MVA

Short-circuit impedance* *primary to secondary		% on		MVA	base
Tap-changer required (2)	☒	YES	☐	NO	
Type of tap-changer (2)	☒	On-load	☐	Off-load	
Number of Taps: Supplier to propose the number of taps for ElectraNet to assess					

Note (2) all other step-up transformer parameters, if not specified by the client, should be specified by basic design study based on the requirements of section 1.2.1

2 Site Conditions

Civil works will be required for synchronous condensers foundations, the transformers foundations, the cooling fans, control and auxiliary plant rooms. The Synchronous Condensers Supplier to advise requirements.

2.1 Climatic and Regional Conditions

Maximum ambient temperature*	55	°C
Minimum ambient temperature*	-0.6	°C
Maximum wind speed	46	m/s
Maximum snow load	N/A	m
Maximum wind speed	46	m/s

Maximum snow load	N/A	m
Maximum ice covering	N/A	mm
Humidity range	51 to 91	%
Site altitude above sea level	310	m

*of high importance for designing the maximum rated power

2.2 Seismic Conditions

Earth acceleration in vertical direction	Z greater than 0.11	g
Earth acceleration in horizontal direction	0.4	g

3. Synchronous Condenser

3.1 Basic design data for the synchronous condenser

Standard for generator design[1]	☒	IEC 60034	☐	IEEE C50.13
Installation of the generator	☒	Indoor	☐	Outdoor
Protection class	☒	IP54	☐	IP55
Nominal frequency	☒	50 Hz	☐	60 Hz

Rated capacitive reactive power at nominal voltage at the generator terminals	At least 80 MVAr capacitive	MVAr
Rated inductive reactive power at nominal voltage	At least 40 MVAr inductive	MVAr
Operating voltage range	refer below for continuous and short term voltage requirements	%
Frequency range		%
Inertia constant H	1100	MWs
Short time capacitive overload capability		MVAr
Duration of short time overload capability		s
Maximum saturated subtransient reactance xd" [2]		%

Note (2) : Supplier to provide the maximum saturated subtransient reactance value

Normal is +/- 0.5 Hz from nominal. Contingency could be as high as +/- 3Hz

The NER requires generators to withstand the following:

i. 47Hz to 49 Hz for 2 minutes
ii. 51Hz to 52 Hz for 2 minutes
iii. 49Hz to 49.5Hz for 10 minutes
iv. 50.5Hz to 51Hz for 10 minutes
v. 49.5 to 50.5 Hz continuously
vi. ROCOF limits of 3Hz/s are legislated in SA
vii. Equipment should withstand 4Hz/s for .25 seconds
viii. And 3Hz/s for 1 second

These requirements shall also apply to Synchronous Generators

Continuous uninterrupted operation requirements for voltage disturbances

Overvoltage (p.u)	Duration
>1.3	At least 20 ms
1.25 to 1.3	At least 200 ms
1.2 to 1.25	At least 2 seconds
1.15 to 1.2	At least 20 seconds
1.1 to 1.15	At least 20 minutes
0.9 to 1.1	Continuous operation
0.8 to 0.9	At least 10 seconds
0.7 to 0.8	At least 2 seconds

Note: These requirements to be applied when selecting the equipment, i.e. every equipment forming part of the synchronous condensers units to withstand an overvoltage of 1.2 p.u for 20 mins.

Cooler type(3)	☐	DAC	☒	TEWAC
IC81W (TEWAC) Squirrel cage motor INFORM IF COOLING TOWER IS NEEDED If cooler type is TEWAC - maximum rated output power if one cooler element is out of service	☐	100%	☐	67% **(5)**
Sound pressure level at 1m distance from machine(4)	☒	85 dB(A)	☐	90 dB(A)

(1) With IEEE C50.13 class B the admissible rated output power will be lower than with IEC 60034 class B

(2) If not provided a low value will be assumed to achieve a high short circuit power

(3) Explanation: DAC = direct air cooler and TEWAC = total enclosed water cooler

(4) The given sound pressure level are plus measurement tolerance. Values may differ within a tolerance acc.to ISO 3744 and ISO 1680.

(5) Please provide duplicated cooling systems for redundancy purposes

3.2 Excitation system

Type of excitation system	☒	Brushless	☐	Static

Ceiling factor for brushless excitation	1.5 with rise time of 0.5 seconds

3.3 Start-up and Braking systems

Maximum start up time including synchronization			20	min
Maximum stopping time			10	min
Start-up-frequency converter + static excitation			☐	
Pony motor + static excitation (INCLUDING FREQUENCY INVERTER, TRANSFORMER AND CUBICLE)			☐	
Pony motor + brushless excitation			☒	
Braking with pony motor or SFC by feeding power back to the aux power network	☒	Yes	☐	No
Emergency braking system*	☒	short circuit device	☐	freewheeling run down

*needed for redundancy if excitation system or converter or pony motors is out of service

Note: The units shall have the ability to re-start after a fault or a trip without having to stop.

Secondary Systems

4.1 Protection System

Specific requirement of protection system

1. Redundant protection system: X and Y
2. Protection devices
3. Protection philosophy and specific protection functions of the Synchronous Condenser
4. Communication protocol for the protection devices (IEC 61850, IEC 65870-5-103, and DNP3) to communicate with ElectraNet's SCADA system , DNP over IP
5. Interlocking allowed via IEC61850 protocol

4.2 Control System

Specific requirements for the control system

1. Architecture of the control system – please see interface diagram in Appendix A
2. Redundant paths to ElectraNet Control Centre
3. Communication protocol for remote control center (IEC 65875-5-101/104, DNP....) DNP over IP
4. All alarm and commands are required to have GPS clock time stamps

4.2.1 Synchronous Condenser Control/Protection

Specific requirements for the synchronous condenser control/protection

1. Redundant protection system: X and Y
2. Vibration protection - NECESSARY
3. Temperature monitoring of bearings and windings - NECESSARY

5. Auxiliary Supplies

External source of primary aux power available ☐ Yes ☒ No

Voltage level of primary source of aux power	To be determined by supplier - to feed a station transformer with a secondary voltage of 400 V
Available power of primary source of aux power	Estimated is 2 MVA Sufficient to provide full aux supply to both sets of synchronous condensers plus to the substation loads estimated at 400 kVA

Secondary source of aux power available	☐	Yes	☒	No

Voltage level of secondary source of aux power	to be determined by supplier - to feed a station transformer with a secondary voltage of 400 V
Available power of secondary source of aux power	Estimated is 2 MVA Sufficient to provide full aux supply to both sets of synchronous condensers plus to the substation loads estimated at 400 kVA

DC Battery System Voltage	110 V DC

Diesel Emergency Generator	☒	Yes	☐	No

Provided by ElectraNet but to be integrated in Supplier's overall AC automatic changeover scheme. The diesel to be sized only for emergency loads and connected to the Essential bus

Lube Oil System

Special requirement of lube oil system (Main oil pumps and jacking oil pumps)

- AC pumps – 400VAC – 3phase
- DC pumps - 220VDC

The synchronous condensers will need an oil circulation system for bearing lubrication and cooling as well as bearing shaft jacking to cover unit start-ups and shutdowns when boundary bearing lubrication conditions occur below 1000 rpm.

Jacking oil will also make pony motor driven start-ups easier.
Redundancy in oil pumps, filters and coolers will be required with DC motor driven pumps required for both services as back up for AC motor driven pumps.

4.5 External Generator Cooling System

TEWAC Generators

- Requirement of redundancy for water pumps 2 x 100% duty pumps

Note:
This unit will require cooling water circuit (preferably totally enclosed complete with circulating water pumps, closed cooling towers, make up supply tank, chemical dosing and this circuit has to service the condenser air cooler elements as well as oil coolers.

Equipment level should include 100% redundancy on all major components of the cooling water system external to the condenser ie pumps, closed cooling towers. One of the reasons for this is the peak daytime temperatures mentioned and the condenser operating on heavy current loads and consequent I2 R losses.

5. Additional Information

International and/or specific standards to be used	As per clause 3.1 of this document
Others	National Electricity Rules (Australia)

Pony Motor Requirements

Pony motor operation should only be initiated once the condenser is ready for run up, supply kV switch is available, lube and jacking oil is available, cooling circuit is available.

Included in auxiliary systems will be DC power supplies for oil pump operation, electrical switch gear operation, protection circuits, emergency lighting etc. Consideration will have to be given regarding fire protection for transformers, oil systems, equipment rooms etc.

The synchronous condenser electrical equipment including excitation, the switch at the LV kV and associated protection, synchronising, and metering equipment will have to be confirmed by the supplier after confirmation of suitability by the owner.