



# Grid Connection Standard of Renewable Energy Systems

Only English version is available for this document. You can contact us by email ([CSD@clp.com.hk](mailto:CSD@clp.com.hk)) or on telephone no. (2678-0322) and we are happy to arrange our Engineer to discuss the technical details of your proposed large renewable energy/battery energy storage system.

本文檔僅提供英文版本。您可以透過電郵（[CSD@clp.com.hk](mailto:CSD@clp.com.hk)）或電話號碼（2678-0322）與我們聯繫。我們很樂意安排相關的工程師與您討論您建議安裝的大型可再生能源系統的技術細節。

Technical design notes for Renewable Energy/Battery Energy Storage Systems (Generation capacity up to 1MW on inverter-based connection and non-inverter-based RE/BESS Systems with generation capacity of up to 200kW) can be found in “Technical Design Notes for Grid Connection of Small Renewable Energy/Battery Energy Storage Systems”.

可再生能源/電池儲能系統的技術設計指引（以逆變器連接及發電容量達 1 兆 瓦或以下，和以非逆變器連接及發電容量達 200 千瓦或以下的可再生能源/電池儲能系統）可參考“小型可再生能源/電池儲能系統與電網接駁的技術設計指引”。

## Table of Contents

<b>FIGURES .....</b>	<b>4</b>
<b>TABLES .....</b>	<b>4</b>
<b>ABBREVIATIONS AND ACRONYMS.....</b>	<b>5</b>
<b>1. GENERAL PROVISIONS (GP) .....</b>	<b>7</b>
GP.1 INTRODUCTION .....	7
GP.2 SCOPE OF APPLICATION.....	7
GP.3 GLOSSARY AND DEFINITIONS.....	9
<b>2. GENERATOR TYPES (GT) .....</b>	<b>13</b>
GT.1 GENERAL PROVISIONS FOR GT.....	13
GT.2 GENERATOR CATEGORY AND CONNECTION NETWORK.....	13
<b>3. CONNECTION SCHEMES (CO).....</b>	<b>15</b>
CO.1 GENERAL PROVISIONS FOR CO.....	15
CO.2 CONNECTION SCHEMES FOR SE, SS AND SI GENERATORS.....	15
<b>4. ASSET DEMARCATION (AD).....</b>	<b>16</b>
AD.1 ASSET DEMARCATION.....	16
<b>5. APPLICATION REQUIREMENTS (AR) .....</b>	<b>17</b>
AR.1 NEW APPLICATION PROCESS.....	17
AR.2 INFORMATION SUBMISSION .....	17
<b>6. CONNECTION STUDY (CS).....</b>	<b>20</b>
CS.1 GENERAL PROVISIONS FOR CS .....	20
CS.2 SCOPE OF CS FOR NEW GENERATOR.....	20
CS.3 CS SUBMISSION REQUIREMENTS AND APPROVAL PROCESS .....	21
<b>7. TECHNICAL REQUIREMENTS (TR) .....</b>	<b>23</b>
TR.1 GENERAL REQUIREMENTS .....	23
TR.2 FREQUENCY OPERATION RANGE .....	23
TR.3 LOW FREQUENCY RIDE-THROUGH CAPABILITY .....	23
TR.4 FAULT CURRENT REQUIREMENT.....	23

TR.5	EARTHING SYSTEM REQUIREMENT.....	24
TR.6	METERING AND TELEMETRY REQUIREMENTS.....	25
TR.7	INSULATION COORDINATION.....	27
TR.8	OPERATION AND MAINTENANCE .....	27
<b>8.</b>	<b>TECHNICAL REQUIREMENTS FOR SE, SS AND SI GENERATORS (TRS)</b>	<b>29</b>
TRS.1	VOLTAGE OPERATION RANGE .....	29
TRS.2	REACTIVE POWER CAPABILITY .....	29
TRS.3	FREQUENCY RESPONSE .....	32
TRS.4	PRIMARY AND SECONDARY FREQUENCY RESPONSE .....	35
TRS.5	STABILITY REQUIREMENTS .....	35
TRS.6	STEADY STATE STABILITY REQUIREMENT.....	35
TRS.7	TRANSIENT STABILITY REQUIREMENT .....	35
TRS.8	FAULT RIDE-THROUGH REQUIREMENT .....	35
TRS.9	CURRENT INJECTION DURING RIDE-THROUGH MODE.....	37
TRS.10	RESTORATION AFTER VOLTAGE RIDE-THROUGH.....	38
TRS.11	POWER QUALITY.....	38
TRS.12	ACTIVE POWER CONTROL .....	39
TRS.13	VOLTAGE AND REACTIVE POWER CONTROL.....	40
TRS.14	DISCONNECTING SWITCH AND POINT OF CONNECTION.....	41
TRS.15	TELEMETRY AND COMMUNICATION .....	42
TRS.16	DATA SECURITY .....	42
TRS.17	PROTECTION SYSTEM.....	42
TRS.18	FEED-IN MANAGEMENT (FIM).....	43
TRS.19	SYNCHRONISATION .....	43
<b>9.</b>	<b>APPENDIX.....</b>	<b>45</b>
APPENDIX AR1	APPLICATION PROCESSES .....	45
APPENDIX AR2	INFORMATION TO BE SUBMITTED FOR PROTECTION SYSTEM OF THE GENERATOR.....	46
APPENDIX AR3	LIST OF DATA REGISTRATION SCHEDULE .....	48
APPENDIX CS1	TYPICAL SIMULATION PROGRAMS FOR CONNECTION STUDY	
53		
APPENDIX TM1	TELEMETRY REQUIREMENTS FOR GRID CONNECTION .....	54
APPENDIX TM2	TELEMETRY PRE-COMMISSIONING TEST .....	57

APPENDIX FIM1    TELEMETRY REQUIREMENTS FOR FEED-IN MANAGEMENT  
AND DEMAND SIDE MANAGEMENT ..... 58

## Figures

Figure 1-1 Umbrella diagram of Energy Resource(s) .....7  
Figure 3-1 SE, SS and SI Generators Connection Scheme to the Grid .....15  
Figure 4-1 Asset Demarcation for SE, SS and SI Generators Connected to the Grid .....16  
Figure 8-1 Q/P<sub>MAX</sub> reactive power range for SI Generator .....30  
Figure 8-2 Q/P<sub>MAX</sub> reactive power range for SS Generator.....30  
Figure 8-3 P/Q-P<sub>max</sub> Profile for SI Generator .....31  
Figure 8-4 P/Q-P<sub>max</sub> Profile for SS Generator .....31  
Figure 8-5 Active Power Frequency Response in LFSM-O for SI Generator.....33  
Figure 8-6 Active Power Frequency Response in LFSM-O for SS Generator.....34  
Figure 8-7 High and Low-Voltage Ride-Through Requirements for SE and SI Wind Generators  
.....36  
Figure 8-8 High and Low-Voltage Ride-Through Requirements for SS, SE and SI Solar  
Generators .....37  
Figure 8-9 Volt-Var Control Mode Setting for SE, SS and SI Generator .....41  
Figure 8-10 Volt-Watt Control Mode Setting for SE, SS and SI Generator .....41  
Figure 10-0-1 I/O Relationship .....54

## Tables

Table 2-1 Registered Capacity Limit for Different Generator Types.....13  
Table 5-1 Technical Information Submission Requirements .....18  
Table 6-1 Connection Study (CS) Scopes for New Generator .....20  
Table 7-1 Frequency Operation Range for Generator .....23  
Table 8-1 Operational Voltage Limit.....29  
Table 8-2 Over and Under Voltage Protection Settings for SE, SS and SI Generators.....29  
Table 8-3 Over Frequency Response for SS and SI Generators.....32  
Table 8-4 Voltage Ride-Through Settings for SE and SI Wind Generators.....36  
Table 8-5 Voltage Ride-Through Settings for SS, SE and SI Solar Generators.....37  
Table 8-6 Compatibility levels for P<sub>st</sub> and P<sub>lt</sub> in LV and MV power system (IEC 61000.3.7) ..39

## ABBREVIATIONS AND ACRONYMS

<b>ABBR.</b>	<b>Descriptions</b>
AD	Asset Demarcation
AGC	Automatic Generation Control
AR	Application Requirements
CCGT	Combine-cycle Gas Turbine
CFCT	Critical Fault Clearing Time
CLP	CLP Power Hong Kong Limited
CO	Connection Schemes
CS	Connection Study
CT	Current Transformer
DB	Deadband
DER	Distributed Energy Resources
DERMS	Distributed Energy Resource Management Systems
DRM	Demand Response Management
ESS	Energy Storage System
FACTS	Flexible AC Transmission Systems
FIM	Feed-in-Management
FiT	Feed-in Tariff
FRT	Fault Ride Through
GCA	Grid Connection Agreement
GCS	Grid Connection Standard of Renewable Energy Systems
GP	General Provisions
GT	Generator Types
HV	High Voltage
HVRT	High Voltage Ride Through
IBG	Inverter-Based Generator
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IO	Input Output
K <sub>OF</sub>	Over-frequency Droop
K <sub>UF</sub>	Under-frequency Droop
LFSM-O	Limited Frequency Sensitive Mode - Overfrequency
LFSM-U	Limited Frequency Sensitive Mode - Underfrequency
LV	Low Voltage
LVRT	Low Voltage Ride Through
MV	Medium Voltage
NDA	Non-Disclosure Agreement
NEM	National Electricity Market
NER	National Electricity Rules
OEL	Over-excitation Limit
OF	Over-frequency

---

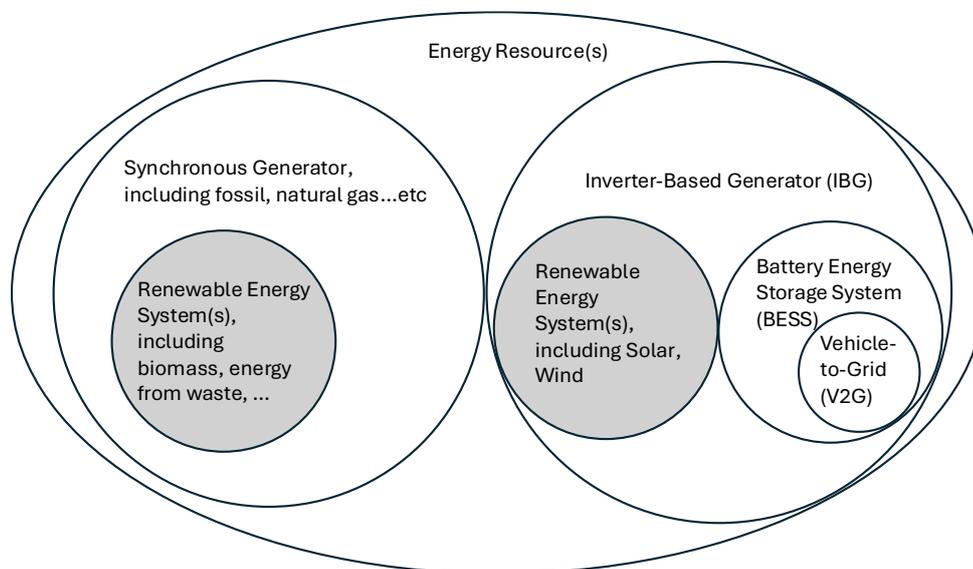
PF	Power Factor
PFR	Primary Frequency Response
PLC	Programmable Logic Controller
POCC	Point of Common Coupling
POC	Point of Connection
POM	Point of Measurement
POR	Primary Operating Reserve
PV	Photovoltaic
RE	Renewable Energy
RES	Renewable Energy System
RoCoF	Rates-of-Change-of-Frequency
SCADA	Supervisory Control & Data Acquisition System
SE	Small Embedded Generator
SG	Synchronous Generator
SI	Small Inverter-Based Generator
SOR	Secondary Operating Reserve
SS	Small Synchronous Generator
STATCOM	Static Synchronous Compensator
SVC	Static VAR Compensator
TETRA	Terrestrial Trunked Radio
THD	Total Harmonic Distortion
TR	Technical Requirements
TRS	Technical Requirement for SE, SS and SI Generators
UEL	Under-excitation Limit
UF	Under-frequency
UPS	Uninterruptable Power Supply
V2G	Vehicle-to-Grid
VT	Voltage Transformer

---

## 1. General Provisions (GP)

### GP.1 INTRODUCTION

GP.1.1 This Grid Connection Standard (GCS) provides the grid connection standard for connecting various types of Generators (Registered Capacity  $\leq$  1MW); Synchronous Generators and Inverter-Based Generators to the Grid.



**Figure 1-1 Umbrella diagram of Energy Resource(s)**

### GP.2 SCOPE OF APPLICATION

GP.2.1 The connection requirements apply to all new Generators and shall be fulfilled in order to connect to the Grid.

GP.2.2 The GCS is applicable to the Generators/Energy Resource that are electrically connected to the Grid:

- (a) Synchronous Generators (SG) including but not limited to hydro, biogas, biomass, geothermal, and energy from waste (including landfill gas or sewage gas).
- (b) Inverter-Based Generators (IBG) including but not limited to rooftop solar, small scale solar, large scale solar, tidal, wave, offshore wind and onshore wind.

GP.2.3 The GCS is not applicable to:

- (a) Generators that are connected to the Grid through grid-to-grid connection;
- (b) Generators that are located outside of the Company's supply area;
- (c) Generators that are installed only to provide backup power during maintenance and system outages, and not operated in parallel with the Grid while the system is in a normal state;

- (d) Emergency Generators including uninterruptable power supply (UPS) that do not run in parallel to the Grid and are used to temporarily provide power when normal system capacity is partly or completely unavailable.
- GP.2.4    The Company reserves the right not to consider the application of the Generators that cannot comply partially or in full of the requirements as stated in the document referring to the information formally submitted by the Generator Owner for the application. Please refer to the APPENDIX AR1 for details of basic information that needs to be submitted to the Company as part of the application to connect to the Grid.

**GP.3      GLOSSARY AND DEFINITIONS**

GP.3.1      In this GCS, the following words and expressions shall bear the following meanings:

- (1) 'Active Power Control Set-point' refers to the maximum amount of active power in kW or MW, set by the Company's system operator, that the Generator is permitted to export.
- (2) 'Active Power Control Set-Point Ramp Rate' refers to the rate of increase or decrease of the active power output of a Generator in response to the Active Power Control Set-point instruction.
- (3) 'Check Meter' refers to the energy meter installed at the points between the Generator and the Grid for recording the energy flows of the Grid connection. It is installed in the same circuit of the Main Meter to confirm the quantities consumption measured.
- (4) 'Company' refers to CLP Power Hong Kong Limited.
- (5) 'Control System' refers to the control system in the Generator which provides for active power control, frequency response, ramp rate control and other Generator control features.
- (6) 'Customer' refers to the customer who already is an owner of a Company electricity supply account.
- (7) 'Demarcation Point' refers to the boundary point which separates the asset ownership of the Generator Owner and the Company.
- (8) 'Energy Storage System' refers to technologies that capture and store energy for later use, enabling the balancing of supply and demand in electrical grids. Battery Energy Storage System and Vehicle-to-Grid are the examples of Energy Storage System.
- (9) 'Energy Resource(s)' refers to all types of Synchronous Generator, Inverter-Based Generator, electrically parallel connected to the grid for the purpose of generating, storing, or managing electrical energy covered in the GCS.
- (10) 'Fault Disturbance' refers to any type of fault which includes a single line to ground, line to line and three-phase faults, anywhere in the Generator plant or the Grid where the operation of the protection will not disconnect the Generator from the existing or planned system under normal or scheduled outage conditions.
- (11) 'Fault Ride-Through (FRT)' refers to the ability of a Generator to remain connected to the network and operate through periods of low and high voltage during and following a Fault Disturbance.
- (12) 'Fault Ride-Through Time' refers to the required fault duration that a Generator shall remain connected to the Grid for a particular Fault Disturbance.
- (13) 'Frequency Response Ramp Rate' refers to the minimum rate of increase or decrease of active power output of a Generator when acting to control the system frequency.

- (14) 'Generation System' refers to all installations and plant provided for the purpose of generating electricity. The coverage is from the Generator up to RE meter.
- (15) 'Generator' refers to all types of Energy Resources including Synchronous Generator, Inverter-Based Generator, Energy Storage System (ESS), and their associated equipment covered in the GCS.
- (16) 'Generator Owner' refers to the owner of the Generator and its associated equipment.
- (17) 'Generator Tie Line' refers to the electrical transmission equipment that connects the busbar of Generator side to the Point of Common Coupling (POCC) at the Grid, and is used exclusively to exchange power between a Customer's equipment and the Grid.
- (18) 'Grid' refers to the electricity networks of all voltage levels of the Company.
- (19) 'Grid Connection' refers to the parallel connection between the Energy Resource and the Grid.
- (20) 'Governor Control System' refers to a system that results in active power output of a Generator changing, in response to a change in system frequency, to assist in the recovery to Target Frequency.
- (21) 'Governor Droop' refers to the percentage drop in the frequency that would cause the Synchronous Generator under free governor action to change its output from zero to its full capacity. In the case of an Inverter-Based Generator (IBG), it is the percentage drop in the frequency that would cause the IBG to increase its output from zero to its full Registered Capacity.
- (22) 'Inverter-Based Generators' (IBG) refers to resources such as the small and large scale solar photovoltaic, offshore and onshore wind farms, and Battery Energy Storage System which connect to the Grid.
- (23) 'Limited Frequency Sensitive Mode – Over-frequency (LFSM-O)' refers to the Generator operating mode which will result in active power output reduction in response to a change in system frequency above a certain value.
- (24) 'Limited Frequency Sensitive Mode – Under-frequency (LFSM-U)' refers to the Generator operating mode which will result in active power output increase in response to a change in system frequency below a certain value.
- (25) 'Main Meter' refers to the energy meter installed at the points between the Generator and the Grid for recording the energy flows of the Grid connection.
- (26) 'Meter Data' refers to any data which include, but not limited to, meter readings and load profile, collected by the meter such as voltage, current, powers in energy quantities (kWh, kVAh and kVA), power factors, phase angle, events, etc. and associated equipment.
- (27) 'Operator' refers to the Operator who operates the Generator.

- (28) 'Point of Common Coupling (POCC)' refers to the point on the Grid electrically nearest to the customer load installation. The POCC is a point located upstream of the considered installation.
- (29) 'Point of Connection (POC)' refers to an electrical point of connection between the Grid and the Generator.
- (30) 'Point of Measurement (POM)' refers to an electrical point between the Grid and the Generator. It may be at the Grid side of the Generator transformer for measurement purposes. e.g. test and commissioning of Grid Connection.
- (31) 'Power Interface' refers to the electrical distribution equipment that is connected between the Customer's equipment and the Grid.
- (32) Primary Operating Reserve (POR)' refers to the additional MW output required at the frequency nadir (minimum), compared to the pre-incident output, which is fully available and sustainable between 10 seconds and 30 seconds after an event and where the nadir occurs between 10 and 30 seconds after the event.
- (33) 'Ramp Down Rate' refers to the maximum rate of decrease in a Generator's output after the end of start-up period. The Ramp Down Rate applies over the output range from the Registered Capacity to minimum generation. The rate of change depends on the MW output of the Generator.
- (34) 'Ramp Up Rate' refers to the maximum rate of increase in a Generator's output after the end of start-up period. This rate of increase continues until the Generator reaches the level of output instructed by the System Control. The rate of increase depends on the MW output of the Generator.
- (35) 'Rate of Change of Frequency
- (36) (RoCoF)' refers to the rate of increase or decrease of frequency as measured at the POCC/POC over the time period.
- (37) 'Registered Capacity' refers to the maximum capacity, expressed in whole kW or MW, that Generator(s) can deliver on a sustained basis, without accelerated loss of equipment life, at the POCC/POC.
- (38) 'RE Meter' refers to the energy meter for recording the energy generated from the Generator. A RE Meter is generally fixed with a specific label for easy user identification.
- (39) 'Remote Terminal Unit (RTU)' refers to a telemetry equipment that currently used by the Company to terminate all I/O, control and command ports of electrical devices, through the telecommunication link to transmit/exchange the data/information and commands with control centres.
- (40) 'Resource Following Mode' refers to a mode of operation of a Generator where the system frequency is within normal range and the Generator is not under active power control, allowing the Generator to produce up to 100% of its available active power, depending on the Power-Frequency Curve in operation.
- (41) 'Resource Following Ramp Rate' refers to the maximum rate of increase of active power output of a Generator in response to an increase in resource availability.

- (42) 'Revenue Meter' refers to the energy meter for recording the usage of electricity. The revenue owed to the Company is calculated from this meter.
- (43) 'Rise Time' refers to the length of time from fault inception for IBG reactive current to reach 90% of its steady-state value.
- (44) 'Secondary Operating Reserve (SOR)' refers to the additional MW output required compared to the pre-incident output which is fully available by 30 seconds from the time of the start of the frequency fall and sustainable up to 30 minutes following an event.
- (45) 'Settling Time' refers to the length of time from fault inception for IBG reactive current output to settle within  $\pm 10\%$  of its steady-state value.
- (46) 'Start-Up' refers to the action of bringing a Generator from shutdown to synchronous speed.
- (47) 'Synchronous Generators' refers to the coal-fired, gas-fired, combine-cycle, steam-turbine, hydro, biogas and biomass Generators.
- (48) 'System Strength Impact Assessment' refers to the system studies required to be performed when there is a fault level shortfall at the proposed connection point, to assess the impact of a Generator connection on the stability of the power system and assess the ability to Generation Systems, considering normal system condition and system contingency events.
- (49) 'Terrestrial Trunked Radio (TETRA)' refers to a European standard for a critical communication trunked radio system. It is a professional mobile radio and two-way transceiver specification. TETRA was specifically designed for use by government agencies or emergency services for safety networks.
- (50) 'Total Harmonic Voltage Distortion (THV-D)' refers to the RMS value of the sum of all individual Harmonic Voltage Distortion Levels up to a specified order H, where H is set to be 50.
- (51) 'Type SE Generator' refers to the Small Embedded Generator with a connection less than or equal to 200kW at the POC, including the Generator/ Energy Resource in GP.2.2.
- (52) 'Type SI Generator' refers to the Small Inverter-Based Generator, such as rooftop solar, small-scale onshore wind turbine and Generator coupled with or without a Battery Energy Storage System (BESS), greater than 200kW and up to 1MW at the POC.
- (53) 'Type SS Generator' refers to the Small Synchronous Generator such as coal-fired, gas-fired, combine-cycle, steam-turbine, hydro, biogas, biomass and geothermal Generators, with connection greater than 200kW and up to 1MW at the POC.
- (54) 'Intelligent Electronic Device (IED)' refers to a microprocessor-based power system equipment used by the Company as telemetry equipment to interface with electrical devices. It terminates all input/output (I/O), control, and command ports of electrical devices, serving as an alternative to RTUs.

## 2. Generator Types (GT)

### GT.1 GENERAL PROVISIONS FOR GT

GT.1.1 The general requirements for new Generators, including Inverter-Based Generators and Synchronous Generators are based on the maximum generation capacity and the voltage level of the connection point according to the Generator types set out below.

**Table 2-1 Registered Capacity Limit for Different Generator Types**

Generator Type		Registered Capacity Limit	Voltage Level
<b>SE</b>	Small Embedded Generators	$\leq 200\text{kW}$	220V or 380V
<b>SS</b>	Small Synchronous Generators	$> 200\text{kW}$ and $\leq 1\text{MW}$	380V or 11kV <sup>#</sup> or 22kV <sup>#</sup>
<b>SI</b>	Small Inverter-Based Generators		

<sup>#</sup> The Company reserves the right to request a higher voltage level of connection due to result of Connection Study, e.g. the fault level contribution

### GT.2 GENERATOR CATEGORY AND CONNECTION NETWORK

GT.2.1 The Generator within the following categories is considered based on the proposed generation capacity at the Point of Common Coupling (POCC) / the Point of Connection (POC):

- (a) **Type SE:** Small Embedded Generator with Registered Capacity less than or equal to 200kW at the POC;
- (b) **Type SS & Type SI:** Small Synchronous Generator and Small Inverter-Based Generator with Registered Capacity greater than 200kW and up to 1MW at the POC.

GT.2.2 The limitation on the proposed Registered Capacity may be required for Generator connections, as the allowable Registered Capacity is dependent upon network characteristics that change over time; as per the Connection Study (CS) result conducted by the Generator Owner and submitted to the Company for acceptance; after the applicant confirmed all technical parameters of the Generators and its system to be connected to the Grid are finalized without further change. The factors to be considered in determining the Registered Capacity include, but are not limited to:

- (a) fault current withstand or breaking capability of the electrical equipment
- (b) power quality at the relevant network locations
- (c) existing and forecast renewable energy penetration at the relevant network location
- (d) existing peak and off-peak demands
- (e) the latest technology on Generators in the market

GT.2.3 The voltage level and technical requirements may vary in accordance with the overall

Registered Capacity of the Generator. The Connection Study (CS) and technical requirements for each of the Generator types shall refer to “section 6. Connection Study”, and “section 8. Technical Requirements for SE, SS and SI Generators”.

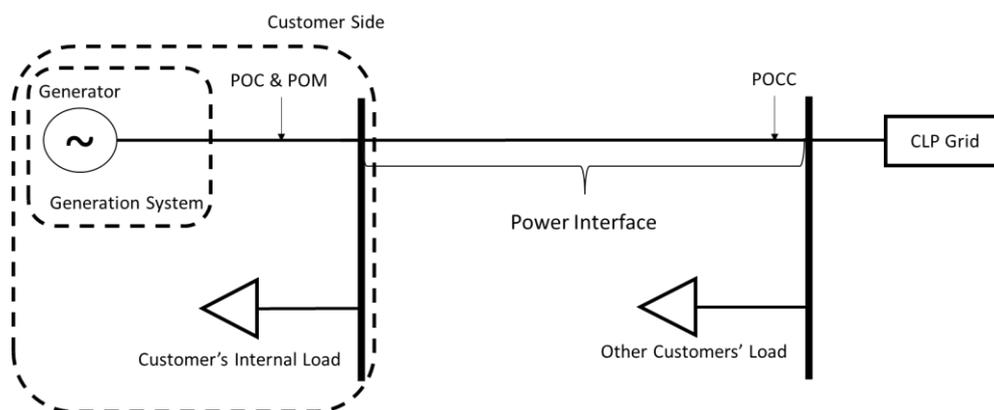
### 3. Connection Schemes (CO)

#### CO.1 GENERAL PROVISIONS FOR CO

- CO.1.1 The connection of the Generator to the Grid shall be determined by the capacity, the fault current contribution, the location, and type of Generator and the metering arrangement shall be submitted to the Company for consideration in the early design stage.
- CO.1.2 The connection of the Generator shall be designed such that it can respond to abnormal conditions of the Grid. The response shall be designed by the Generator Owner and agreed with the Company. This response contributes to the safety of operators of the Generator, the Company and the general public, as well as the avoidance of damage to connected equipment including the Generator.
- CO.1.3 The cable rating and the number of cables for the connection of the Generator to the Grid shall be designed based on the Registered Capacity of the Generator agreed with the Company.
- CO.1.4 The Connection Schemes in the sub-sections below demonstrate how the typical single line arrangements of various types of Generators to Grid shall be followed.
- CO.1.5 Except as otherwise stated in this GCS, the reference point for all technical requirements and CS shall refer to the POC.

#### CO.2 CONNECTION SCHEMES FOR SE, SS AND SI GENERATORS

- CO.2.1 For SE, SS and SI Generators at LV network away from the Power Interface, the POM shall be at the POC of the Customer side, as shown in the figure below.

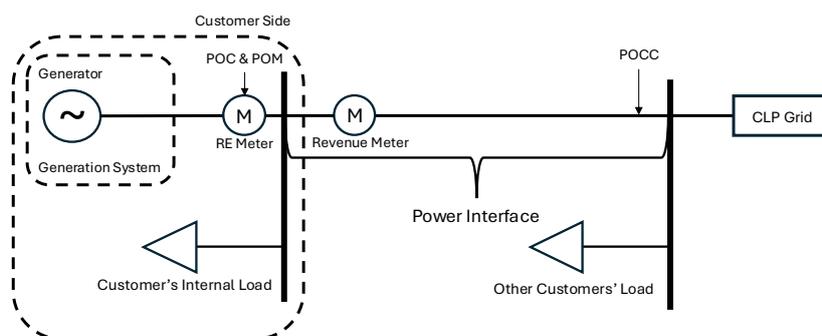


**Figure 3-1 SE, SS and SI Generators Connection Scheme to the Grid**

## 4. Asset Demarcation (AD)

### AD.1 ASSET DEMARICATION

- AD.1.1 The following requirements are applicable to all Generator types per the GCS.
- AD.1.2 The demarcation of ownership with respect to certain assets to be owned by the Generator Owner and the Company shall be mutually agreed. The typical asset demarcation between the Generator, the Generator Tie Line / Power Interface and the Grid is shown in the Figure 4-1 for SE, SS and SI below.
- AD.1.3 Since the ownership of assets is agreed upon, the asset owner shall be solely responsible for the future maintenance and repair of the asset owned at his/her own cost.
- AD.1.4 The Company shall source / program the meters and remote meter data acquisition equipment. The Company shall provide and install the Revenue /RE meters for the Customer and is responsible for the future maintenance and repair of the Revenue /RE meter in the custody of the Generator Side. For access requirements related to the FiT applications, refer to TRS.15. For non-FiT applications, refer to the details provided in the GCA.
- AD.1.5 The Company has the right to amend, modify, or include additional conditions in this document for safety, system security, and power quality reasons by written notice to the Generator Owner in advance. The Generator Owner shall accept and abide by such amendment, modification or additional conditions specified in the Company's notice, which shall become effective on the date specified in the notice.
- AD.1.6 The Generator Owner shall design, install, maintain and operate its Generator facility in accordance with applicable laws, international standards, good utility practices, applicable ordinances, regulations and guidelines, including the Electricity Ordinance, Code of Practice for the Electricity (Wiring) Regulations, Technical Guidelines on Grid Connection of Renewable Energy Power Systems issued by the Electrical and Mechanical Services Department (EMSD), and this GCS.
- AD.1.7 At the POC, a diagram shall be displayed showing all electrical infeeds. This diagram should indicate the limits responsibility of the Company and the Generator Owner.
- AD.1.8 Figure 4-1, below show the typical demarcation points in relation to the Generators connected to the Grid.



**Figure 4-1 Asset Demarcation for SE, SS and SI Generators Connected to the Grid**

## 5. Application Requirements (AR)

### **AR.1      NEW APPLICATION PROCESS**

AR.1.1      The application processes for Grid Connection are provided in APPENDIX AR1.

AR.1.2      The fault level is the potential maximum fault current that flows when a fault occurs. This increases as new Generators are connected to the Grid. It is known increasing fault level exceeding the safe margin of the Grid would lead to safety concerns. The increasing fault level of the Grid is needed to be controlled from time to time. The Generator Owner shall confirm the maximum possible fault current contribution to the Grid in the early application stage. The Company reserves the right not to consider the application or counter-propose to a lower limit on the fault current contribution to the Generator Owner if the system fault level may reach the safety margin at the Grid Connection.

### **AR.2      INFORMATION SUBMISSION**

AR.2.1      The Generator Owner shall submit the design of the Generator to the Company to assess its technical viability in connecting to the Grid in stages per Table 5-1 Technical Information Submission Requirements. The documents to be submitted shall include at least below.

1. Technical drawings and layout diagrams illustrating the physical locations of the Generation System and any other major electrical equipment installed or to be installed, including the location of the isolation switch, and the proposed location of the meter to be supplied by the Company for the measurement of the generation output of the Generation System. For applications in respect of an alteration to an existing Generation System, the layout diagrams must differentiate between the existing part and the proposed additional part of the Generation System
2. Single-line electrical diagrams of the Generator showing details of the proposed Grid Connection
3. Electrical schematic diagrams with proposed setting calculations for the electrical protective, control, synchronising, alarm/monitoring, data acquisition and metering system/equipment
4. Arrangement (including sealing facilities), ratio, rating accuracy class and markings of metering VTs and CTs (where applicable), metering and its associated communication facilities to support measurement and remote meter data collection via Public Switched Telephone Network (PSTN) or mobile data network communication technology
5. Drawing showing Operator's earthing system connection and bonding arrangement
6. Operator's present and projected load and generation profile
7. Details of the Generator including maximum fault current contribution as mentioned in Section "AR.1 New Application Process" above, description of generating capacity, functions, parameters, testing reports, etc

8. Typical output curve showing the generated power versus weather data. Weather data shall include solar irradiance, wind speed, and temperature, where appropriate for the Type of Generation
9. Connection study reports as per Section 6 (e.g. load flow, fault currents, voltage/current distortion and interference)
10. Simulation models in PSS®E and PSCAD file (refer to CS.2) format representing the Generation System
11. Voltage control characteristics
12. A List of Data Registration schedule with relevant control diagram as in APPENDIX AR3
13. The design of protection systems of the Generator as in APPENDIX AR2

AR.2.2      The optimal way for soliciting Generator data within the framework of the Grid Connection Standard entails classifying requests based on early, mid-way and late submissions. Except for the basic information per the paragraph above, more technical information about the Generator, as shown in the Table 5-1, approved by the Generator Owner shall be submitted to the Company for assessment.

AR.2.3      The design of the Generator in relation to connecting to the Grid requires approval from the Company prior to the installation of the Generator.

AR.2.4      The Generator Owner shall ensure the Operator provides the Company with all details of any proposed modification to the Generator and shall obtain written approval from the Company prior to making any change to the Generator including its capacity.

**Table 5-1 Technical Information Submission Requirements**

Stage of Project Development	Submissions
Application Stage	<ul style="list-style-type: none"> <li>• Application Form</li> <li>• AR.2.1 Item 1 – Technical drawings and Layout diagrams</li> <li>• AR.2.1 Item 2 – Single-line electrical diagrams</li> <li>• AR.2.1 Item 3 – Electrical schematic diagrams</li> </ul>
Mid-stage – prior to equipment purchase	<ul style="list-style-type: none"> <li>• AR.2.1 Item 4~ Item 13</li> <li>• Updated submission on AR.2.1 Item 1~ Item 3 if any changes</li> <li>• Major electrical equipment specification</li> <li>• Turbine or inverter certificate of compliance</li> </ul>
Late stage – during construction and prior to commissioning	<ul style="list-style-type: none"> <li>• Final submission of AR.2.1 Item 1-13 if any changes</li> <li>• Finalized technical data of major electrical equipment, e.g. factory test results, characteristics curves of Generator control, etc</li> </ul>

	<ul style="list-style-type: none"><li>• Earthing study (for SS only), i.e. Rise of Earth Potential (ROEP), step and touch voltage analysis on shared assets</li><li>• Test and commissioning requirements</li></ul>
--	---

## 6. Connection Study (CS)

### CS.1 GENERAL PROVISIONS FOR CS

CS.1.1 The Generator Owner is responsible for conducting Connection Study (CS) for a new Generator connection application to:

- (i) identify the feasible generation capacity, connection point and connection scheme to connect the new Generator to the Grid;
- (ii) identify the impact of connecting the new Generator to the Grid and propose mitigation options to mitigate the identified technical violation;
- (iii) assess the impact of the Grid condition on the operations of the Generator and vice versa; and
- (iv) assess the ability of the Generator to comply with the technical requirements as stated in the GCS.

### CS.2 SCOPE OF CS FOR NEW GENERATOR

CS.2.1 The Generator Owner shall conduct an CS assessment upon submitting the initial application. Disregarding the connection voltage at the POCC, the CS scopes and modelling requirements shall include the Generator Tie Line / Power Interface up to POCC, unless otherwise specified.

The simulation programs for modelling employed shall be the same as that PER APPENDIX CS1.

CS.2.2 The following CS scopes are mandatory for different Types of Generators. The CS scopes are assigned mainly based on the proposed Registered Capacity of the Generator at the POCC.

**Table 6-1 Connection Study (CS) Scopes for New Generator**

CS Scopes	Generator Type		
	SE	SS	SI
<b>Pre-Feasibility Assessment:</b>			
1) Load Flow	x	√	√
2) Fault Level*	x	√	√
3) System Strength Impact Assessment	x	x	x
4) Reactive Power*	x	√	√
5) Dynamic Stability	x	√	x
6) Critical Fault Clearing Time	x	√	x
7) Small Signal Stability	x	x	x
8) Power System Stabilizer Tuning	x	x	x
9) Fault Ride Through	x	x	√
10) Power Quality	x	√	√
11) Insulation Coordination	x	x	x
12) Protection	x	√	√

13) Earthing study	x	x	x
14) Islanding Risk Evaluation	√ <sup>#</sup>	√	x

√ Required  
 X Not required

<sup>#</sup> Only for SE(SG)

\* Simulation may be required subject to the assessment of the Company

### **CS.3      CS SUBMISSION REQUIREMENTS AND APPROVAL PROCESS**

CS.3.1      The Generator Owner shall provide the initial report for review and comment before carrying out the CS. The initial report shall be completed and submitted to the Company in the early design stage with:

- (1) Introduction
  - A brief introduction to Generator Owner
  - Generator plant-up location and area
  - Target commissioning date
  - Proposed connection point, POCC and POC locations, Generator export capacity at the POCC.
- (2) CS scopes
- (3) Study methodology for each CS scope
- (4) Passing criteria
- (5) Maximum fault current contribution of the Generator
- (6) Reference materials (optional), e.g. technical background of the design team, successful commissioning of renewable energy projects in the past, consultant proposed for the CS, etc

For details on the Connection Study for Inverter-Based Generator (IBG), please refer to the [Connection Study Report template](#).

CS.3.2      The CS findings, including the final version of the initial report above and at least the items listed below; shall be submitted to the Company for review. With the consent of the Company on all Grid Connection Standards per the CS findings submitted, the Generator Owner shall complete a final report to finalize all technical details of the Generator and its Grid Connection accordingly. The final report shall be duly approved by the Generator Owner and submitted to the Company on compliance check of being connected to the Grid.

- (1) Generator and facility designs
- (2) Simulation models
- (3) Study findings per CS scopes required for the appropriate Generator type and its possible Generator running modes, i.e. single Generator and combinations of different parallel operations of Generators in service and islanding modes
- (4) Generator running models
- (5) Recommendations
- (6) Conclusion

- CS.3.3      Generator Owner for SE and SI Generator shall submit the following final plant data and simulation results after completion of the Final Report:
- (a) Generator System design
- CS.3.4      Generator Owner for SS Generator shall submit the following final plant data and simulation results after completion of the Final Report:
- (1) Generator System design
  - (2) Steady state and dynamic models in the simulation software version that is used by the Company per APPENDIX CS1 or IEEE standard.
  - (3) Dynamic library-link (.dll) file, source code, block diagram and user manual for any user model used in the simulation.
  - (4) Recommended stability parameters for the Generator
- CS.3.5      Each submission of the final plant data and simulation/actual results shall be compared with the CS findings of the version with the consent of the Company given before. The Generator Owner shall submit a new complete version of CS report if any final plant data adopted is changed compared with the previously agreed one. The Company has the right not to accept the Grid Connection if any result of CS cannot meet the requirements of the GCS and/or that with the consent of the Company given before.
- CS.3.6      The Company has the right to check the compliance of a Generator with the requirements of this GCS by carrying out its simulations based on the provided simulation models and CS reports.
- CS.3.7      Notwithstanding the minimum requirements listed in the CS scopes, the Company is entitled to:
- (1) request the Generator Owner to carry out an alternative set of simulations, provided that those simulations are efficient and sufficient to demonstrate compliance of a Generator to the requirements under this GCS document; and
  - (2) request the Generator Owner to carry out an additional or alternative set of simulations in case information supplied to the Company by the Generator Owner with CS under the provisions of this section are not sufficient or changed to demonstrate compliance to the requirements under this GCS document.

## 7. Technical Requirements (TR)

### TR.1 GENERAL REQUIREMENTS

TR.1.1 All Generator shall fulfil the requirements listed in this GCS and the requirements from the related document from EMSD.

### TR.2 FREQUENCY OPERATION RANGE

TR.2.1 The nominal operation system frequency is 50 Hz.

TR.2.2 All Generators shall be capable of supplying rated power between 47 – 52 Hz frequency.

TR.2.3 The Generator shall remain in continuous operation and connected to the Company's network when the system frequency deviates from the nominal frequency for a minimum time below:

**Table 7-1 Frequency Operation Range for Generator**

Frequency range	Duration
47 – 47.5 Hz	Operation for a period of at least 20 seconds
47.5 – 49 Hz	Operation for a period of at least 90 minutes
49 – 51 Hz	Continuous operation required
51 – 51.5 Hz	Operation for a period of at least 90 minutes
51.5 – 52 Hz	Operation for a period of at least 15 minutes

TR.2.4 The Generators shall be capable of staying connected in case of rapid frequency changes of up to 2 Hz/s.

### TR.3 LOW FREQUENCY RIDE-THROUGH CAPABILITY

TR.3.1 The Generator shall maintain constant active power output during system frequency fluctuation within the range between 49 Hz and 51 Hz.

TR.3.2 The Generator shall maintain pre-disturbance active power output when the system frequency drops between 47 Hz and 49 Hz, unless one of the following conditions is met:

- Outside of the frequency operating range and duration as stated in the TR.2 - Frequency Operation Range Section above where disconnection of the Generator from the Company's network is allowed;
- Activation of Loss-of-Main protection.

### TR.4 FAULT CURRENT REQUIREMENT

TR.4.1 The Company shall define the maximum allowable fault level contribution for the Generator.

TR.4.2 The Company reserves the right to disconnect the Generators without prior notice if the fault level exceeds limits under all operating and emergency conditions of the

Grid, for example, in service, the change in network configuration, switching, system fault clearing, etc.

- TR.4.3 For SE(SG) and SS Generators, the Generator selected shall be of fault current contribution less than 6 times of its Registered Capacity and within the maximum allowable fault current contribution approved by the Company.
- TR.4.4 For SE(IBG) and SI Generator, the Generator selected shall be of fault current contribution less than 1.6 times of its Registered Capacity and within the maximum allowable fault current contribution approved by the Company.
- TR.4.5 To fulfil the allowable fault contribution determined by the Company, the Generator Owner shall consider using a Generator of less fault current contribution or install a fault current limiting device that reduces the fault current contributed to the Grid. A conventional fault current limiting device could be a series reactor between the Generator and the Grid.
- TR.4.6 The fault current contribution from the Generator to a fault in the Grid shall not affect the normal operation of the protective relays in the Grid.
- TR.4.7 The Generator Owner shall consider both three-phase fault current and single-phase-to-ground fault current in the CS. The fault current study parameters and procedures shall comply with IEC Standard 60909 - Short Circuit Calculation on Three-phase A.C. Systems.

## **TR.5 EARTHING SYSTEM REQUIREMENT**

- TR.5.1 The Generator Owner shall provide an adequate earthing system in the Generation System to ensure the safety of personnel and equipment and the reliable operation of the protection equipment. The Generator Owner shall ensure the Generation System is adequately earthed even when operating in isolation from the Grid.
- TR.5.2 The earth grid design shall cover not only the floor areas and levels related to the electrical facilities of the Generator and the Grid Connection but the whole premises / building from the electricity safety point of view on meeting the requirements stipulated in the IEEE SA P80 Guide for Safety in AC Substation Grounding.
- TR.5.3 The Generator Owner shall ensure that the earth loop impedance (including the earth electrode) at any point of the installation is sufficiently low to ensure the operation of earth fault protection.
- TR.5.4 The Generator Owner shall ensure that an independent earth electrode is provided for the Generation System, the neutral point of the Generation System can be connected to earth, either directly or through an impedance. The total zero sequence impedance shall be agreed with the Company in advance.
- TR.5.5 The Generator Owner must ensure the continuance of safe conditions if any neutral point connected with the earth in any apparatus operated at high voltage becomes disconnected from the earth.
- TR.5.6 No connection shall occur until an authorised person acting on behalf of the Generator Owner, has certified that the specification and design of the neutral grounding

system complied with the requirements of the GCS and those neutral grounding systems have been put in place.

- TR.5.7 If the Generator (LV) is connected to the Grid (11kV or 22kV) via a Generator transformer, the Generator side of the transformer shall be in "star" connection with neutral earthed while the Grid side should be in "delta" connection. Connection of the Generator transformer with different winding arrangements (include total zero sequence impedance) shall be agreed with the Company.
- TR.5.8 An earthing transformer (e.g. Zigzag transformer with Neutral Earthing Resistor) with backup protection (e.g. Neutral Voltage Displacement protection) shall be provided if the Generator is directly connected to the Grid at 11kV or 22kV voltage level. The total zero sequence impedance of the earthing transformer shall be agreed with the Company in consideration of overall fault clearing in coordination with that of the Grid. Different in-service arrangements of the earthing transformer and its protection shall be agreed with the Company.
- TR.5.9 No connection to the Grid shall occur until the Company has approved the specifications, and detailed plans of the neutral grounding system have been provided and put in place. The Rise of Earth Potential (ROEP) shall be less than 650V according to the International Telegraph and Telephone Consultative Committee's Directives.

## **TR.6      METERING AND TELEMETRY REQUIREMENTS**

### **Metering**

- TR.6.1 The Company shall design, supply, own and maintain all necessary meters and associated equipment to record power (including kW/kWh demand) and energy import to and export from the Company's system and the Generator.
- TR.6.2 Metering equipment shall be installed at the demarcation point and the Generator terminals to record measurements. The Generator Owner shall install the metering voltage transformers (VTs) of the secondary voltage of 110V and current transformers (CTs) of secondary nominal current of 1A or 5A at the Generator side with the provision of interface point to support field operation, i.e. measurement and maintenance.

CTs and VTs, intended for use with meters, shall not exhibit a percentage error exceeding 0.5% at their rated current and/or voltage when tested without a connected meter. This requirement is waived if the transformers are matched to meters in a manner that ensures the total error of the meter system remains within acceptable limits.

The VT is only applicable for HV metering of the Company / Generator Owner at voltage above 220V/380V.

The burden of CTs and VTs for HV metering shall be at least 15VA and 75VA per phase respectively and dedicated for metering purpose.

Unless otherwise specified and provided by the Company, the Customer / Generator Owner shall supply both VTs and CTs for installation. and also provide suitable accommodation on his premises as agreed by the Company for the installation of all

- the meters of the Company and other equipment. Subject to the final design of supply connection and to meet the latest Company's requirement from time-to-time manner.
- TR.6.3 Standard metering requirements for feed-in-tariff scheme for the Customers of the Company / Generator Owner are detailed in the [Feed-In Tariff Scheme Standard Metering Requirements](#).
- TR.6.4 The technical guide for accepting Customer's internal distribution system in conjunction with the connection to the Grid is detailed in the [Guide to Supply and Metering Arrangement on Customer's Internal Distribution System](#).
- TR.6.5 The Generator Owner shall supply, build and install all metering facilities in related to grid connection solely for metering purposes. i.e. metering cubicle, wall-mounted meter board, telephone socket outlet, conduit / trunking for cables, etc. The metering position shall be adjacent to the corresponding meter cubicle and agreed with the Company. Safe and unrestricted access, adequate space and lighting shall be provided for the installation, testing, operation and maintenance of the Revenue/RE meters.

### **Telemetry**

- TR.6.6 Telemetry requirements cover the data transfer, control and monitoring functions for metering, communication and SCADA, protection and feed-in management of the Generator and its associated telemetry facilities connected to the Grid.
- TR.6.7 The Generator Owner shall provide all telemetry facilities, outgoing cables, terminals and connections of status, alarm, measurements and control of related to the Generator, associated switches and other equipment up to the asset demarcation per the GCS. The general telemetry requirements and their corresponding detailed functionalities of different Generator types are detailed in APPENDIX TM1. A typical example of a telemetry pre-commissioning report for the Generator is shown in APPENDIX TM2.
- TR.6.8 The telemetry facilities of the Generator shall be interfaced with the Company's RTU/IED through hardwired signal connection for the signal exchange. The Generator Owner shall supply, build and install the telemetry facilities and outgoing cables up to the asset demarcation as declared in the GCS. The Generator Owner or the asset owner, if specified shall be solely responsible for the future operation, maintenance and repair of the telemetry facilities and outgoing cables installed by the Generator Owner. The technical specifications of the outgoing cables to be connected to the RTU/IED shall be agreed by the Company. If interfacing with the RTU/IED through hardwired signal connections is not practicable, the Generator Owner shall mutually agree on the connection means with the Company.
- TR.6.9 The data security aspects are the scope and responsibility of the Generator Owner. The Generator Owner shall implement controls to ensure high level of data security compliance to the relevant regulations of Hong Kong and international standards.

**TR.7      INSULATION COORDINATION**

- TR.7.1      The insulation level of the Generator side's equipment shall be compatible to that of the Grid and in accordance with the latest version of IEC Standards 60071 on Insulation Coordination.
- TR.7.2      Proper lightning protection systems shall be installed for the outdoor Generator and equipment to protect personnel and equipment from lightning stroke and transient over-voltages.

**TR.8      OPERATION AND MAINTENANCE**

- TR.8.1      The Generator Owner shall operate and maintain the Generator in good order and repair at all times in conformity with good electrical practice and shall keep complete records in relation to the same. The Company may review all such records at all reasonable times.
- TR.8.2      The Generator must be operated and maintained only by persons who are authorised by Generator Owner and competent to carry out the job.
- TR.8.3      The Generator Owner's representative shall be available at all times to receive communications from the Company's representative so that emergencies requiring urgent action by the Generator Owner can be dealt with adequately.
- TR.8.4      The Generator Owner shall, when requested by the Company, inform the Company's representative of any abnormalities that occur on the Generator (e.g. the Generator oscillates against the system) which have caused, or might cause, disturbance to the Grid.
- TR.8.5      The Generator Owner shall ensure that active and reactive power will only be supplied to the Company's system on terms agreed between the Company and the Generator Owner.
- TR.8.6      The Generator Owner shall not energise any section of the Company's system. Where the Generator Owner requires its Generator to supply a temporarily disconnected section of the Company's system, this may only occur in accordance with arrangements agreed between the Company and the Generator Owner.
- TR.8.7      The Company has automatic switching and automatic re-closing schemes adopted in its system. During the switching operations, the Grid may be subjected to interruption of 0.2 second to more than 10 seconds without prior notification. The Generator shall be designed and operated so that it shall decouple with the Grid by opening the incoming circuit breaker at Generator Owner side such that out-of-phase re-closing does not occur, or alternatively, by the internal disconnect or breaker within the inverter, provided that such device reliably and promptly disconnects the Generator from the Grid in accordance with anti-islanding protection requirements. After the disconnection of the Generator to the Grid, it could be reconnected to the Grid when the system voltage and frequency return to a normal and stable condition.
- TR.8.8      If improvement on the Company's re-closing and automatic switching scheme or additional equipment is required, the Generator Owner shall accept and comply with such requirements. The Company shall not be liable for damage caused to the Generator Owner's equipment as a result of such re-closing and switching operation.

- TR.8.9    The Generator Owner shall notify the Company in advance of any operation and maintenance or repair work on the metering VTs and CTs systems or the telemetry facility and promptly confirm to the Company upon completion of work.
- TR.8.10   The Generator Owner shall not at any time import power from or export power to the Company's system at the POC exceeding the mutually agreed limits.
- TR.8.11   Notwithstanding anything to the contrary contained in the Technical Guidelines on Grid Connection of Renewable Energy Power Systems issued by the EMSD, the Generator Owner shall ensure that periodic inspection of the Generator is carried out by an appropriate Registered Electrical Worker (REW). The Generator Owner shall follow the frequency of inspection required under the Code of Practice for the Electricity (Wiring) Regulations by EMSD. The Generator Owner shall keep a record of all inspection results and make available such records when requested by the Company.
- TR.8.12   The Generator Owner shall organize to conduct tests at the Generation System to prove compliance on the technical requirements stated in this Grid Connection Standard and the Generator Owner shall submit the results to the Company at least one (1) month prior to the Operation Commencement Date or as reasonably requested by the Company from time to time.
- TR.8.13   All tests specified under Section TR.8.14 shall be carried out on the Generation System. The tests shall be witnessed and certified by the Generator Owner or her representatives. The Company shall have the right to witness any tests the Operator is required to conduct. All costs related to the tests shall be borne by the Generator Owner.
- TR.8.14   Tests shall be conducted to prove compliance on requirements stated in this Grid Connection Standard. The tests shall include, but not limited to the following:
- Tests shall be referred to [Testing and Commissioning \(T&C\) Report](#)
  - Any other tests as required by the Company / the Generator Owner to demonstrate the compliance of the Generation System.

The Testing and Commissioning (T&C) Report shall be updated with the latest witness checks prior to final submission.

## 8. Technical Requirements For SE, SS and SI Generators (TRS)

### TRS.1 VOLTAGE OPERATION RANGE

TRS.1.1 The voltage profile of the Grid is kept within the operational limits as shown below under normal and contingency conditions.

**Table 8-1 Operational Voltage Limit**

Voltage Level	Operational Voltage Limit
220/380V	± 6%
11kV	± 6%
22kV	± 6%

TRS.1.2 The Generators shall provide continuous operation to the Grid when the voltage at 220/380V, 11kV, or 22kV system fluctuates within ± 6%.

TRS.1.3 Voltage fluctuation during the synchronization operation of the Generators should be limited to below 3%.

TRS.1.4 After the connection of the Generator to the Grid, the voltage fluctuation due to the variation of Generator's power output should not exceed 1%.

TRS.1.5 The Generators can provide over-voltage and under-voltage protections with the following settings:

**Table 8-2 Over and Under Voltage Protection Settings for SE, SS and SI Generators**

Voltage at the Connection Point	Maximum Trip Time (second)
$V > 1.20$ p.u.	0.16
$1.10$ p.u. $< V \leq 1.20$ p.u.	1
$0.20$ p.u. $\leq V < 0.70$ p.u.	2
$V < 0.20$ p.u.	0.16

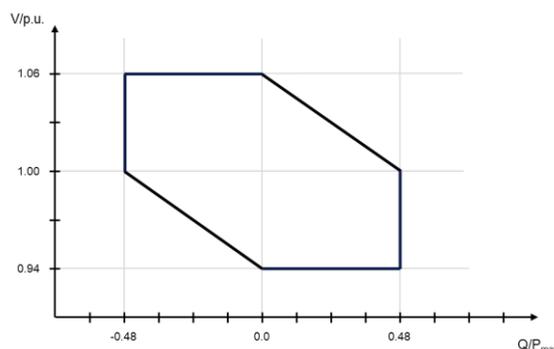
### TRS.2 REACTIVE POWER CAPABILITY

TRS.2.1 The reactive power capability of the Generators depends on the nominal capacity of the Generator and the grid voltage.

TRS.2.2 For SE Generator, the 0.9 power factor leading to 0.9 power factor lagging is required for maximum active power output.

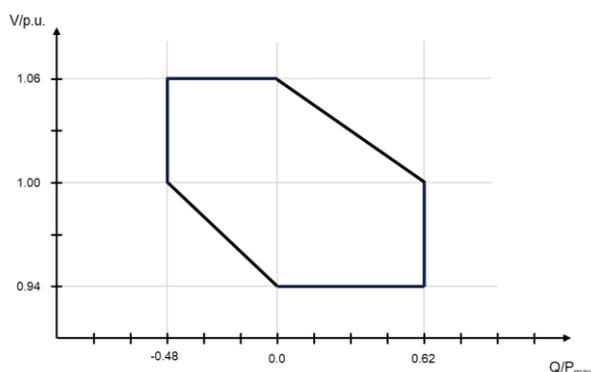
TRS.2.3 The SI Generator that exports power to the Grid shall have the reactive power capability range of  $-0.4843 Q/P_{MAX}$  to  $+0.4843 Q/P_{MAX}$  (which is equivalent to 0.90 power factor leading to 0.90 power factor lagging), and independency on the Grid voltage as shown in the following Figure 8-1. The minimum range of reactive

power the generator shall be able to supply or absorb, relative to its maximum active power. Notes:  $P_{MAX}$  = The generator's maximum rated active power output,  $Q$  = Reactive power that the generator is supplying (+ve  $Q$ ) or absorbing (-ve  $Q$ )



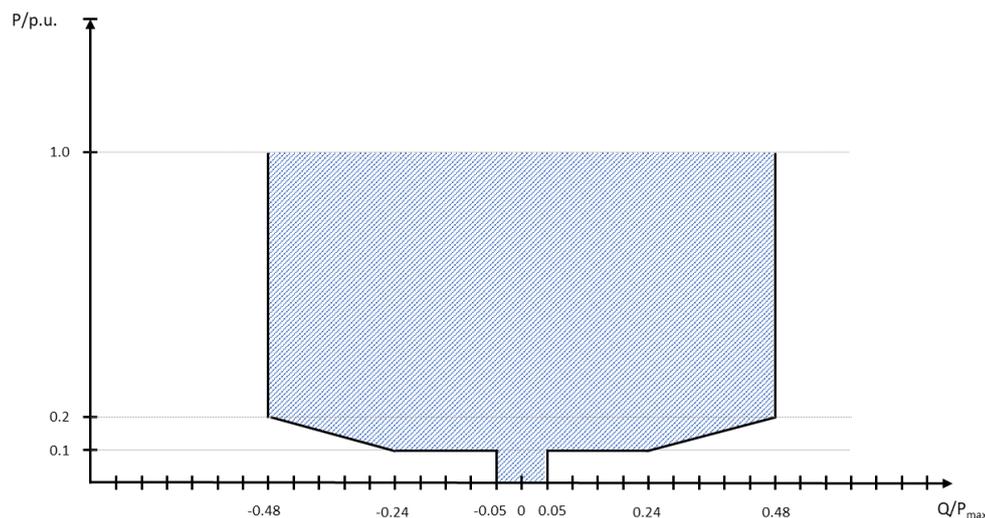
**Figure 8-1  $Q/P_{MAX}$  reactive power range for SI Generator**

TRS.2.4 The SS Generator that exports power to the Grid shall have the reactive power capability range of  $-0.4843 Q/P_{MAX}$  to  $+0.6197 Q/P_{MAX}$  (which is equivalent to 0.90 power factor leading to 0.85 power factor lagging), and independency on the grid voltage as shown in the following Figure 8-2.



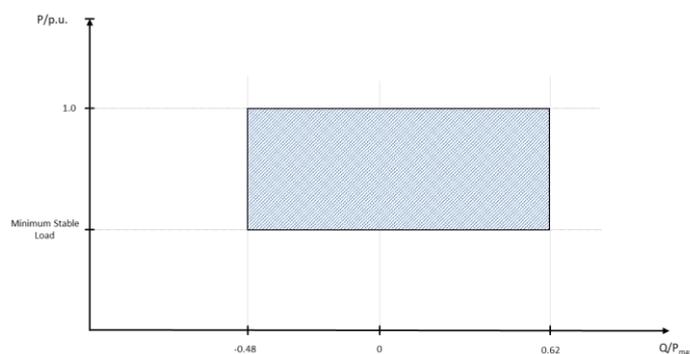
**Figure 8-2  $Q/P_{MAX}$  reactive power range for SS Generator**

TRS.2.5 According to the technical capability of some SI Generators (e.g. wind turbines), the Generator Owner shall maintain unity power factor or a wider range if requested by the Company at low capacity output scenarios of less than 10%  $P_{MAX}$ . A higher power factor may be introduced at lower generation capacities. The profile is shown in the following Figure 8-3.



**Figure 8-3 P/Q-Pmax Profile for SI Generator**

TRS.2.6 The reactive power requirement for the Synchronous Generator is only applicable for SS Generator that operates at maximum active power output down to the minimum stable operation level of the Generator. The profile is shown in the following Figure 8-4.



**Figure 8-4 P/Q-Pmax Profile for SS Generator**

TRS.2.7 The SI Generators shall be provided with a power factor controller acting through the automatic voltage regulator to control the power factor between 0.90 leading and 0.90 lagging with reference to the system voltage of the Grid. The power factor must be dynamically controlled within a step width of +/- 0.01. The effective response time of the power factor controller should be adjustable.

TRS.2.8 The adjustment in accordance with the Company requested reactive power supply mode is set within 5 seconds.

TRS.2.9 The reactive current response from the SI Generators shall be supplied within the rating of the Generator, with a Rise Time no greater than 100 ms and a Settling Time no greater than 300 ms. For the avoidance of doubt, the Control System may provide this reactive response directly from individual Generation Units, or other additional dynamic reactive devices on the site, or a combination of both.

TRS.2.10 The precision of the reactive power setting should be less than or equal to 5% of an absolute error of  $Q/P_{MAX}$ .

TRS.2.11 If the static or dynamic reactive power compensation equipment is used for the improvement of the reactive power range, such equipment should be adequately incorporated in the system model for its correct consideration in power quality assessments. Besides, the compensation equipment shall not cause any excessive voltage disturbance, inrush current, overvoltage or resonance with other system components.

**TRS.3      FREQUENCY RESPONSE**

TRS.3.1 Frequency control device shall be provided for SS and SI Generators. A high-frequency response may be required for SE Generators if feed-in-management is implemented for SE Generator.

TRS.3.2 The SS and SI Generators are capable of operating stably during Limited Frequency Sensitive Mode-Over-frequency (LFSM-O) operation.

TRS.3.3 The SS and SI Generators are capable of activating the provision of active power frequency response outside the over-frequency ( $\Delta f_{OF}$ ) and under-frequency ( $\Delta f_{UF}$ ) Deadband according to Figure 8-5 and Figure 8-6 below at a frequency threshold and droop settings specified. The default over-frequency deadband is  $\pm 0.002$  pu ( $\pm 0.1$  Hz) for SS and SI Generators. The frequency thresholds and droop settings of over-frequency are shown in Table 8-3

TRS.3.4 The over-frequency droop ( $k_{OF}$ ) settings of the SS and SI Generators are between 2% and 5%. The default droop settings to be set in the Generator is 4%. The final droop settings to be placed in the Generator shall be agreed upon with the Company.

TRS.3.5 Over Frequency Response Mode (LFSM-O):

**Table 8-3 Over Frequency Response for SS and SI Generators**

	<b>Default value</b>	<b>Setting range</b>
<b>Droop setting</b>	4%	2% - 5%
<b>Frequency setting</b>	50.1 Hz	50.0 – 52.0 Hz

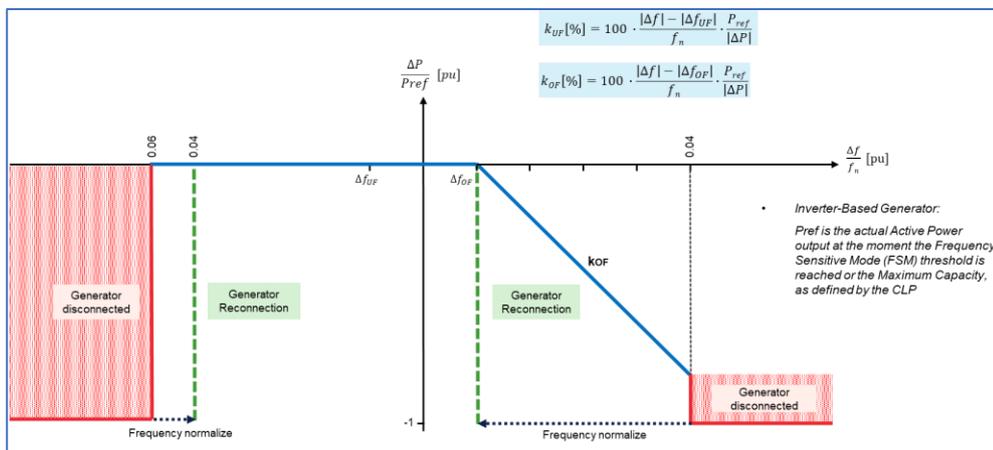
TRS.3.5.1 When LFSM-O is active, the LFSM-O setpoint will prevail over any other active power setpoint. Based on the over-frequency droop ( $K_{OF}$ ) settings and measured frequency, the SI Generator shall allow for 100% active power reduction in response to a rise in the power system's frequency. In contrast, the power reduction for SS Generator is limited either down to the minimum stable operation load or is limited by the high frequency response of the SS Generator.

TRS.3.5.2 In case of reaching the operating limit of the Generator, the Generator should be set to exclude from reducing its active power output to the Grid.

TRS.3.5.3 The over-frequency response mode settings of the Generator shall be allowed to adjust locally and/or remotely as specified by the Company from time to time to suit system operation needs.

TRS.3.6 The SI Generator shall be capable of reconnection automatically to the network with the fulfilment of the conditions as follows: -

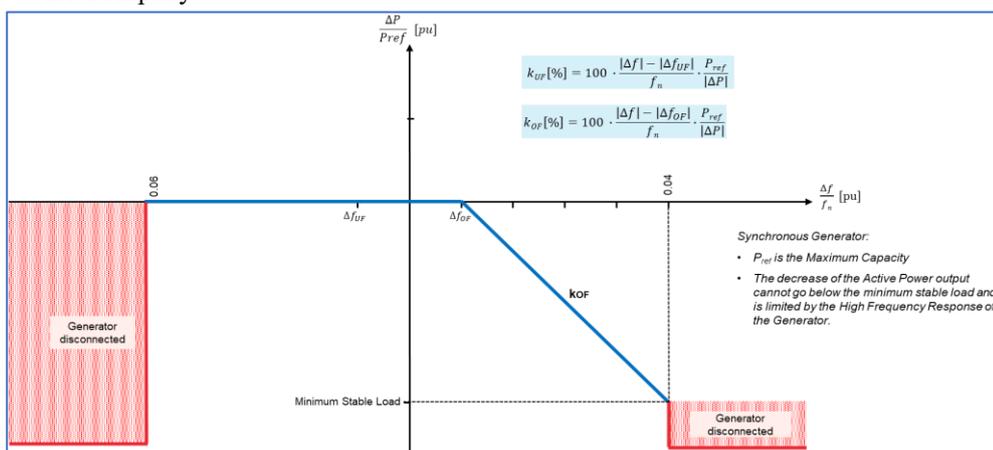
- (i) frequency ranges within which an automatic connection is admissible, and a corresponding delay time;
- (ii) the maximum admissible gradient of increase in active power output; and
- (iii) automatic connection is allowed unless otherwise specified by the Company.



**Figure 8-5 Active Power Frequency Response in LFSM-O for SI Generator**

Note:

- $P_{ref}$  is the actual active power output at the moment in LFSM-O threshold is reached or the Maximum Capacity, as defined by the Company.  $P_{ref}$  is the reference active power to which  $\Delta P$  is related and may be specified differently for SI Generator.
- $\Delta P$  is the change in active power output from the Generator.
- $f_n$  is the nominal frequency (50 Hz) in the network and  $\Delta f$  is the frequency deviation in the network.
- At over frequencies where  $\Delta f$  is above the over-frequency deadband ( $\Delta f_{OF}$ ), the Generator has to provide a negative active power output change according to the over-frequency droop ( $K_{OF}$ ), which will be 4%. When frequency increases above 52 Hz, the Generator will be disconnected.
- At under frequencies where  $\Delta f$  is below the under-frequency deadband ( $\Delta f_{UF}$ ), the Generator shall be capable of maintaining constant output at its target active power value by not providing active power output change. When the frequency drops below 47 Hz, the Generator will be disconnected.
- The SI Generator shall remain disconnected until the Grid returns to normal condition continuously for at least 5 minutes, and automatic reconnect at the frequency value agreed with the Company.



**Figure 8-6 Active Power Frequency Response in LFSM-O for SS Generator**

Note:

- $P_{ref}$  is the actual active power output at the moment in LFSM-O threshold is reached or the Maximum Capacity, as defined by the Company.  $P_{ref}$  is the reference active power to which  $\Delta P$  is related and may be specified differently for SS Generator.
- $\Delta P$  is the change in active power output from the Generator.
- $f_n$  is the nominal frequency (50 Hz) in the network and  $\Delta f$  is the frequency deviation in the network.
- At over frequencies where  $\Delta f$  is above the over-frequency deadband ( $\Delta f_{OF}$ ), the Generator has to provide a negative active power output change according to the over-frequency droop ( $K_{OF}$ ), which will be 4%. The active power reduction is limited either by the Generator's high frequency response or by the SS Generator's minimum stable operating level. When frequency increases above 52 Hz, the Generator will be disconnected.
- At under frequencies where  $\Delta f$  is below the under-frequency deadband ( $\Delta f_{UF}$ ), the SS Generator shall not reduce the active power output and at the minimum, shall be capable of maintaining constant active power output at its existing level. When frequency drops below 47 Hz, the Generator will be disconnected.

TRS.3.7 The SS Generators shall remain constant power transfer during falls in the frequency of the power system.

TRS.3.8 The SI Generators shall remain constant power transfer based on the resource availability during fall in the frequency of the power system.

TRS.3.9 The remote controllability of SS and SI shall be catered for future provision as specified by the Company from time to time. The SS and SI Generators may be required to allow the Company to determine and set individual settings for the over-frequency deadband and over-frequency droop.

TRS.3.10 The SI Generators shall be capable of activating a power frequency response with an initial delay of not greater than 2 seconds or other period the Generator Owner agreed with the Company.

TRS.3.11 Based on the system frequency measurement, the SS and SI Generators shall automatically reduce its active power output continuously and linear proportionally within 10 seconds, at a constant ramping down rate to minimise the existing power transfer output down to the new target power output within the high frequency response time.

TRS.3.12 The SS and SI Generators may be required to receive and automatically respond to signals delivered from the Automatic Generation Control (AGC) for FIM provision in APPENDIX FIM 1. This functionality is expected to be updated at every 4 seconds.

TRS.3.13 The SS and SI Generators may be required to equip with a logic interface (input port) as specified by the Company for FIM provision, enabling cessation of active power output within 5 seconds of receiving an instruction at the input port or within a timeframe to be determined by the Company.

TRS.3.14 The control system for the frequency response of the Generator must be activated without undue delay and adequately damped.

TRS.3.15 The exact mode of operation and the corresponding setting value would be decided based on the types and scale of the Generator and could be changed from time to time depending on the Company's system and operational requirements.

**TRS.4      PRIMARY AND SECONDARY FREQUENCY RESPONSE**

TRS.4.1 There is no requirement for the SE, SS and SI Generators to provide primary and secondary operating reserves.

**TRS.5      STABILITY REQUIREMENTS**

TRS.5.1 The Generator Owner shall ensure the stable operation of the Generator under normal and contingency conditions in the Grid.

TRS.5.2 In exceptional situations which could endanger system stability and security, the Company would instruct the SS and SI Generators to adjust the active and reactive power output in a way that allows the Company to meet the system security.

TRS.5.3 Adequate information exchange between the Company and the Generator Owner is a prerequisite the Operator to support on maintaining the system stability and security of the Grid. Real-time information on the operating conditions of the SS and SI Generators, as well as the possibility to communicate with the SS and SI Generators in order to direct operational instructions shall be provided.

**TRS.6      STEADY STATE STABILITY REQUIREMENT**

TRS.6.1 The Generator Owner shall ensure that loss of synchronism between different Generator groups does not occur under normal conditions in the Grid. The Generator Owner is responsible for performing necessary power system studies to ensure voltage stability and frequency stabilities are maintained.

**TRS.7      TRANSIENT STABILITY REQUIREMENT**

TRS.7.1 The Generator shall remain stable when the Grid is subjected to a solid three-phase fault followed by the subsequent tripping of the faulted element.

TRS.7.2 The Generator controls shall be designed such that the loss of synchronism between Generators does not occur upon fault cleared within the main protection fault clearing time.

TRS.7.3 The Generators shall provide supplementary stability control functions such as fast ramp up/down and frequency limit control.

TRS.7.4 The Generators shall remain connected to the Grid in case of rapid frequency changes (RoCoF) of up to 2 Hz/s.

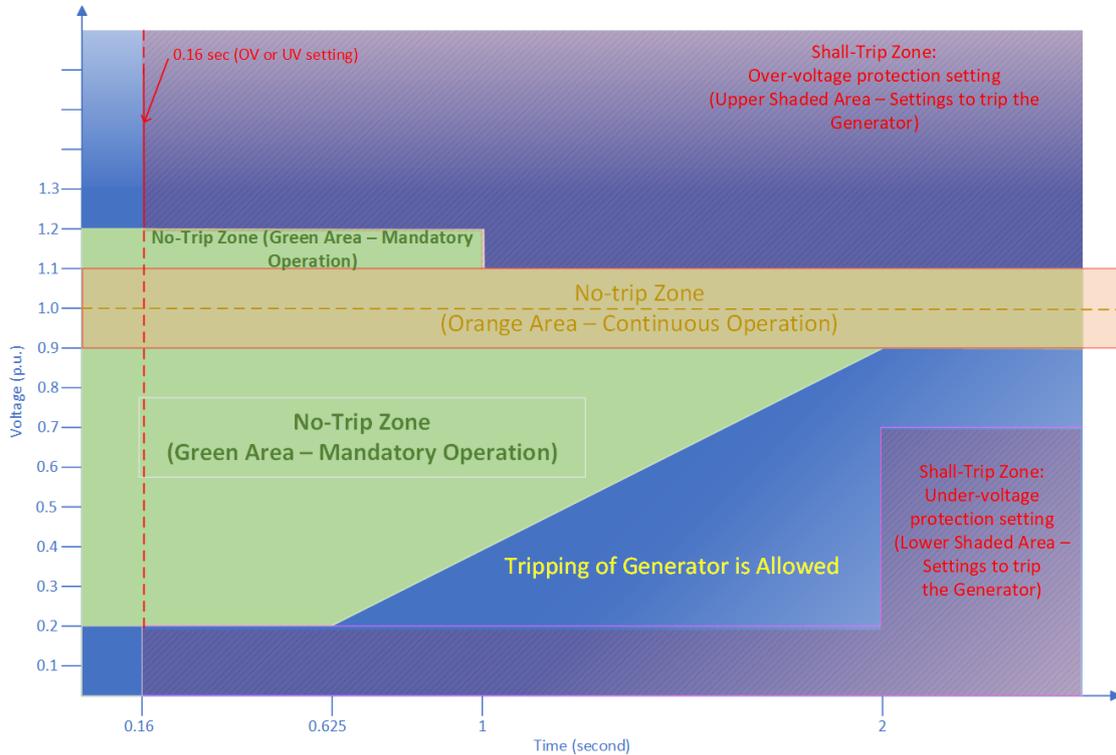
**TRS.8      FAULT RIDE-THROUGH REQUIREMENT**

TRS.8.1 The FRT requirements shall be provided for SE, SS and SI Generators.

TRS.8.2 Voltage ride-through requirement shall be provided for SE, SS, and SI Generators such as solar and wind Generators, which is in hybrid connection with the solar or wind plant. The SE, SS, and SI Generators shall be designed to ride through the

Grid's temporary low and high voltages. The Generator Owner shall submit the technical information (e.g. test report) to the Company.

TRS.8.3 The SE and SI Wind Generators shall provide continuous operation during a disturbance at the Grid and shall ride-through the temporary over and under voltages according to the HVRT and LVRT requirements as shown in the Figure 8-7 and Table 8-4 below.

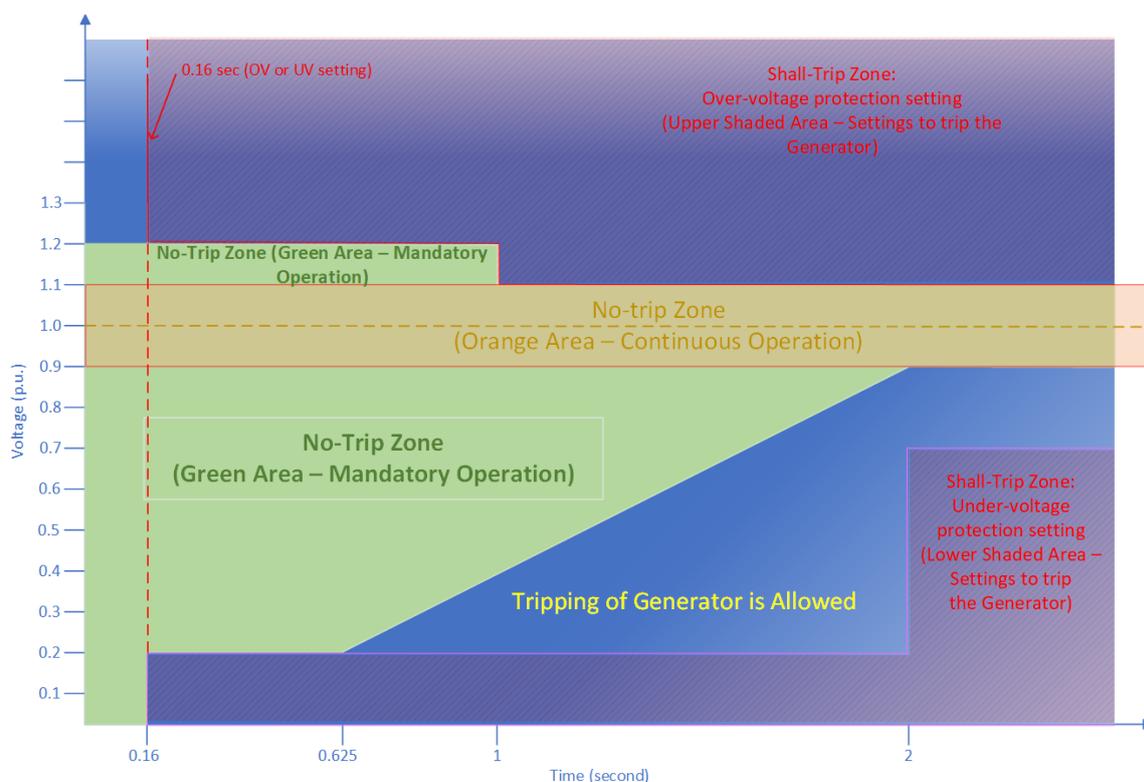


**Figure 8-7 High-Voltage and Low-Voltage Ride-Through Requirements for SE and SI Wind Generators**

**Table 8-4 Voltage Ride-Through Settings for SE and SI Wind Generators**

Voltage	Minimum Ride-Through Time (second)
$1.10 \text{ p.u.} \leq V \leq 1.20 \text{ p.u.}$	1.00
$0.90 \text{ p.u.} \leq V \leq 1.10 \text{ p.u.}$	Infinite
$0.20 \text{ p.u.} < V < 0.90 \text{ p.u.}$	$0.625 < \text{Time Slope} < 2.00$

TRS.8.4 The SS, SE and SI Solar Generators shall provide continuous operation during a disturbance at the Grid and shall ride-through the temporary over and under voltages according to the HVRT and LVRT requirements as shown in the Figure 8-8 and Table 8-5 below.



**Figure 8-8 High and Low-Voltage Ride-Through Requirements for SS, SE and SI Solar Generators**

**Table 8-5 Voltage Ride-Through Settings for SS, SE and SI Solar Generators**

Voltage	Minimum Ride- Through Time (second)
$1.10 \text{ p.u.} < V \leq 1.20 \text{ p.u.}$	1.00
$0.90 \text{ p.u.} \leq V \leq 1.10 \text{ p.u.}$	Infinite
$0.20 \text{ p.u.} \leq V < 0.90 \text{ p.u.}$	$0.625 < \text{Time Slope} \leq 2.00$
$0.00 \text{ p.u.} \leq V < 0.20 \text{ p.u.}$	0.16

TRS.8.5 Any tripping of the SS, SE, and SI Generators or failure in providing the voltage ride-through capability due to the Generator self-protection as a direct or indirect result of a voltage disturbance within the ride-through region (No-Trip Zone) shall constitute non-compliance with this requirement. The Generator shall satisfy the HVRT and LVRT requirements unless tripping of the Generator is required to clear the faults.

**TRS.9 CURRENT INJECTION DURING RIDE-THROUGH MODE**

TRS.9.1 The reactive current injection shall be available depending on the penetration of RE in the system.

TRS.9.2 The current injection during ride-through mode shall be required for SS and SI Generators.

TRS.9.3      When the Generator enters a ride-through mode where the voltage drops to below 0.90 per unit, the Generator shall be able to select operation in either active or reactive current priority mode during a high (HVRT) or low-voltage ride-through (LVRT) events. By default, the Generator is operated in active current priority mode during high and low-voltage ride-through events. If necessary, the system operator of the Company will request the Operator to switch to active or reactive current priority mode. The appropriate settings required for the two modes shall be agreed with the Company/OEM.

TRS.9.4      The total active and reactive current injection to the Grid during a HVRT or LVRT event shall not exceed the fault level margin of the Grid and should not exceed the maximum currents contribution by the Generator. This refers to the Generator performance under fault condition and abnormal operation.

## **TRS.10      RESTORATION AFTER VOLTAGE RIDE-THROUGH**

TRS.10.1    The SE, SS, and SI Generators shall fulfil the following requirements for system restoration:

- (i)    The Company shall specify the conditions under which a Generator is capable of reconnecting to the network after an incidental disconnection caused by a network disturbance; and
- (ii)   Installation of automatic reconnection systems shall be subjected both to prior agreement with the Company and to the reconnection conditions specified by the Company.
- (iii)   The Generator shall remain disconnected until the Grid returns to normal condition continuously for at least 5 minutes.
- (iv)   The Generator shall have an anti-islanding function to cater for auto-switching reclosing operation initiated from the Grid. The typical auto-switching / reclosing time of the Grid at 11kV or 22kV voltage level is from 0.2 to 10 seconds after supply loss. The Generator shall be designed and operated so that it shall decouple with the Grid.
- (v)    For the Generator allowed to operate in island mode when disconnected to the Grid, individual assessment of the reconnection scheme shall be required.

## **TRS.11      POWER QUALITY**

TRS.11.1    The quality of power provided by the Generation System for the on-site AC loads and power delivered to the utility must be governed by practices and standards on voltage, flicker, frequency, harmonics and power factor. Deviation from these standards represents out-of-bounds conditions and may require the Generation System to sense the deviation and properly disconnect from the utility system.

TRS.11.2    Harmonic voltage limits permitted to be injected into the distribution system shall be as agreed with the Company and harmonic current emission limits shall be allocated per guidelines set in IEEE 519.

- TRS.11.3 The level of negative phase sequence voltage at the point of common coupling on a three-phase system shall not exceed 1.3% of the positive phase sequence voltage, assuming an initially symmetrical of the Company’s system at this point.
- TRS.11.4 The Company may use the power quality levels specified in the tables below at POC:

**Table 8-6 Compatibility levels for  $P_{st}$  and  $P_{lt}$  in LV, 11kV and 22kV of power system (IEC 61000.3.7)**

	Compatibility levels
Short term flicker severity, $P_{st}$	1.0
Long term flicker severity, $P_{lt}$	0.8

- TRS.11.5 DC current injection into the AC network shall not exceed 0.5% of rated inverter output under normal and abnormal operating conditions. An isolation transformer is considered as one of the effective measures to meet this requirement, in accordance with the Code of Practice for the Electricity (Wiring) Regulations issued by EMSD or related EMSD’s latest standard/requirement.

**TRS.12 ACTIVE POWER CONTROL**

- TRS.12.1 The Active Power Control specifies the ability of the Generator to increase or decrease its active power transfer when required by the Company.
- TRS.12.2 There are no mandate Active Power Control requirements for SE Generator. SS and SI Generators shall require engaging in Feed-in Management in future as shown in APPENDIX FIM1.
- TRS.12.3 SS and SI Generators shall be required to provide the Active Power Control with the following requirements:
- (i) able to receive dispatch instructions and implement them within 5 minutes, including settling time;
  - (ii) able to automatically limit its active power output;
  - (iii) able to ramp its active power output linearly from one dispatch level to another. This could be achieved using a Power Plant Controller (PPC) in an aggregated system;
  - (iv) where energy source is predictable: able to receive and automatically respond to signals from the AGC, updated every 4 seconds or at a frequency to be determined by the Company;
  - (v) able to reduce or disconnect in response to control request signals as agreed with the Company. This includes events where danger, overload, islanding, network stability, safety and management are critical;
  - (vi) the active power output needs to be capable of being reduced in 10% per step and the target output to be realised within one minute of receipt of the signal from the Company or period as agreed with the Generator Owner.

TRS.12.4 Information supplied by the SS and SI Generator Owner should include details of the active power control system via drawings and a description detailing how the Generator will respond to dispatch targets of the Company.

**TRS.13    VOLTAGE AND REACTIVE POWER CONTROL**

TRS.13.1 The following guidelines apply to Inverter-Based Generators and Synchronous Generators of the same size.

TRS.13.2 The Company System Operator may request an Inverter-Based Generator to control Reactive Power Output within their capability to maintain the connection point voltage to an agreed target or operate at an agreed power factor such that voltage variations are maintained within prescribed limits.

TRS.13.3 The Inverter-Based Generator must be controlled within an agreed range. A Generation System would typically be expected to be capable of continuously supplying or absorbing reactive power to achieve a set power factor as measured at the connection point. Subject to the appropriate network studies, Generation Systems not able to meet these typical reactive power capabilities may still be considered acceptable.

TRS.13.4 To maintain satisfactory network voltages, the Generating System's controllers will need to operate with a tolerance of 2% of the maximum reactive power generation range.

TRS.13.5 The final operating reactive power requirements for the Inverter-Based Generator will be identified by the network studies and included within the engineering report.

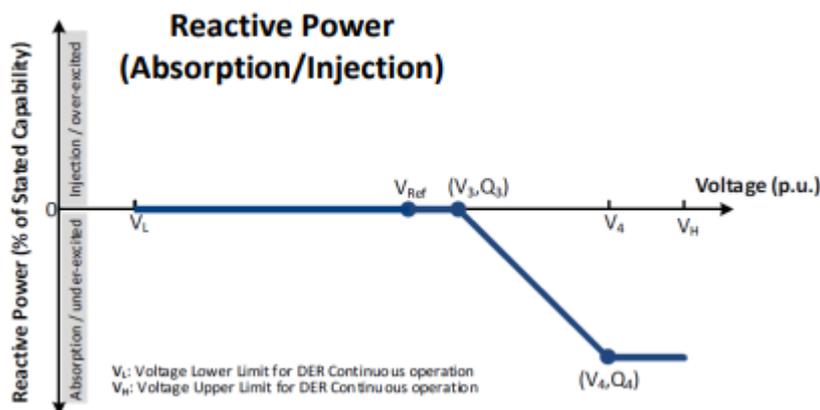
TRS.13.6 In case a Generation System is connected to a connection point that also supplies electrical load, the reactive power requirements at the connection point will be a combination of the supply and generation requirements.

TRS.13.7 When the Generator is exporting electricity, the Generation System would typically be expected to be capable of continuously supplying or absorbing reactive power to achieve a power factor of  $\pm 0.9$  as measured at the connection point.

TRS.13.8 The Generator shall be designed with the capability of controlling the power and reactive power at the Generator terminals at Voltage-Reactive Power (Volt-Var) and Voltage-Active Power (Volt-Watt) control mode.

TRS.13.9 Requirement for Volt-Var and Volt-Watt Control Mode Setting:

- (a) Volt-Var Control Mode where the SE, SS and SI Generator shall vary the reactive power output with the voltage at the Generator terminals with characteristic curve as illustrated below:



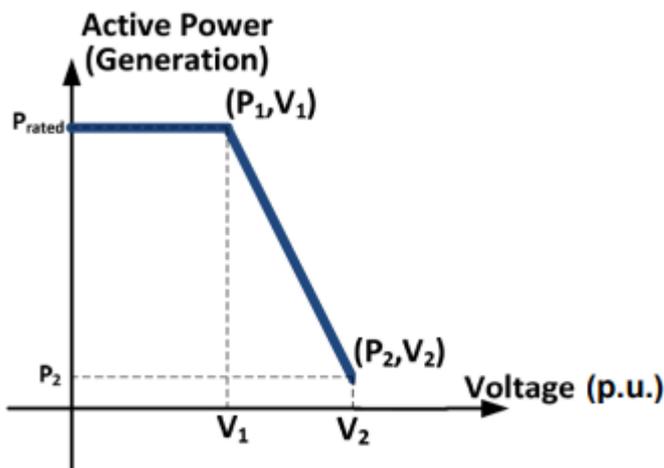
**Figure 8-9 Volt-Var Control Mode Setting for SE, SS and SI Generator**

Default setting:

$V_3 = 103\%$ ,  $Q_3 = 0\%$  rating of the RE System

$V_4 = 105\%$ ,  $Q_4 = Q_{max} \geq 43\%$  rating of the RE System

- (b) Voltage-Active Power (Volt-Watt) Control Mode where the SE and SI Generator shall limit the active power output with the voltage at the Generator terminals with characteristic curve as illustrated below:



**Figure 8-10 Volt-Watt Control Mode Setting for SE, SS and SI Generator**

Default setting:

$V_1 = 106\%$ ,  $P_1 = 100\%$  rating of the RE System

$V_2 = 110\%$ ,  $P_2 = P_{MIN} \leq 20\%$  rating of the RE System

**TRS.14 DISCONNECTING SWITCH AND POINT OF CONNECTION**

TRS.14.1 The Operator shall furnish and install a manual disconnect device that has a visual break capable of disconnecting the Generator from the Company’s system.

TRS.14.2 The disconnect device must be accessible to Company personnel, and capable of being locked by a separate padlock in the open position. Access to the points of

isolation should be kept clear and unobstructed. The Generator Owner shall follow the Company's switching, isolation and earthing procedure.

- TRS.14.3 The Operator must grant the Company rights of access to the means of isolation without undue delay and the Company must have the right to isolate the Operator's infeed at any time should such disconnection become necessary for safety reasons and in order to comply with statutory obligations.
- TRS.14.4 At POC, or as near as practicable to it, a diagram shall be displayed showing all electrical infeeds. This diagram should indicate the limits of responsibility of the Company and the Operator.
- TRS.14.5 Access requirements for the Grid Connection can be found in the terms and conditions.

### **TRS.15    TELEMETRY AND COMMUNICATION**

- TRS.15.1 The Generator Owner shall provide such control, command signals, voltage, current, frequency, active power and reactive power measurement outputs, plant status indications and alarms to the SCADA interface equipment as required by the Company. In general, the SCADA interface equipment shall be the RTU/IED of the Company; which is interfaced with the telemetry equipment of the Generator. The appropriate telemetry requirements for SE, SS and SI Generators are detailed in APPENDIX TM1.
- TRS.15.2 The SCADA communication protocol currently used by the Company are DNP3.0. To enable the provision of telemetry data to the Company's RTU/IED, the design of the Generator Owner's telemetry facilities, including equipment, the intelligent electronic devices (IED) and associated schematics involve SCADA interface with the Company's RTU/IED, and shall be mutually agreed between the Generator Owner and the Company. These requirements may be updated over time to reflect evolving technical standards, operational requirements and regulatory guidelines.

### **TRS.16    DATA SECURITY**

- TRS.16.1 The Generator Owner shall ensure data security in accordance with the appropriate regulatory requirements in Hong Kong.

### **TRS.17    PROTECTION SYSTEM**

- TRS.17.1 The detailed design of the protection in relation to the Grid Connection purposes shall be provided to the Company for study and consent sought from the Company in the design stage. The protection, commonly provided by the inverter for the Grid Connection, shall be accommodated in control panels if practicable. The Generator Owner shall design, supply and install the control panels in the Generator Owner's premises adjacent to the major plants of the Grid Connection as well as the Generator. Reasonable access to the equipment or the Customer's installation for the purpose of inspection or any other purpose shall be provided by the Generator Owner.
- TRS.17.2 The following protection requirements shall be commonly applied to SE, SS and SI Generators, both Synchronous Generators and Inverter-Based Generators.

- (1) The Generator must incorporate over-voltage protection, under-voltage protection and voltage ride-through capability.
- (2) The Generator must be equipped with a protection system that interrupts any fault current fed into the Grid by the Generator, including both short-circuit and earth-faults.
- (3) The Generator shall have an anti-islanding function to cater for auto-switching reclosing operation initiated from the Grid. The typical auto-switching / reclosing time of the Grid at an 11kV or 22kV voltage level is from 0.2 to 10 seconds after supply loss.
- (4) The protection system must not interfere with the requirements on fault ride-through or operational ranges for voltage and frequency.
- (5) The Generator Owner shall install a protective device of standards acceptable to the Company to prevent damage to the Grid.
- (6) The Generator Owner shall submit the setting calculations of each electrical protective device to the Company for review and approval before testing and commissioning of any part of the Generator.

TRS.17.3 For SS and SI Generators, in addition to the minimum protection above, the following is recommended:

- (i) Reverse power protection, to protect the Generator from a motor operation.
- (ii) It is also advised to include a Disturbance recorder and Device for power quality supervision for larger Generators. Generally, the one who has an interest in the installation has to be responsible for the installation. In this case, the Company should have a clear interest in the disturbance recorder and the power quality supervision. The Company can install these devices in the facilities close to the Generator, or request the client to do the installations and to make the recordings and outputs available to the Company.

TRS.17.4 Direct transfer trip channels may be required to trip SE, SS and SI main switches to disconnect all or parts of the SE, SS and SI when:

- (i) the Company's automatic re-closing and automatic switching are activated;
- (ii) protective devices of SE, SS and SI fail to clear primary system faults that occur on SE, SS and SI; or
- (iii) operation of the SE, SS and SI jeopardises the security, reliability or supply quality of the Grid.

## **TRS.18    FEED-IN MANAGEMENT (FIM)**

TRS.18.1 See APPENDIX FIM1.

## **TRS.19    SYNCHRONISATION**

TRS.19.1 Automatic synchronising and synchronisation check closing protection shall be installed at all locations where it is intended that parallel operation of a Generator

will occur, to prevent non-synchronised connection to the Grid. If the power producing unit is inverter based and of the grid following type, synchronization is inherent in the design.

TRS.19.2 Connection of the Generator in parallel with the Grid shall be prevented unless all phases are energised.

TRS.19.3 Synchronisation of a power producing unit, a rotating machine or a grid forming unit interfaced by an inverter, is a sensitive and important process and should be performed with care to avoid damage or transients. The following requirements apply to both conventional Generators and inverter connected electricity generation.

- (a) The Generator Operator shall be responsible for synchronisation to the Grid. In case the Generator is disconnected from the system due to an out-of-bounds event in the Grid, the Generator should remain disconnected until the voltage and frequency of the Grid have been maintained at the normal values continuously for a minimum period of 5 minutes.
- (b) Before paralleling the Generator with the Grid, it is necessary to minimise the voltage, phase angle, and frequency difference between the Generator and the Grid. Automatic synchronising equipment shall be installed for the circuit breakers to parallel the Generator and the Grid. For circuit breakers not equipped with synchronising equipment and that could become a possible parallel point with the Grid, mechanical key interlocking must be applied to prevent unsynchronised closure.
- (c) Closing of the coupling circuit breaker for paralleling the Generator with the Grid shall normally be triggered by automatic synchronising equipment. Where manual synchronising is provided the acceptability of switching procedures and operational staff is subject to agreement with the Company.
- (d) Telemetry of the status of the synchronous point, active and reactive outputs and other operational information of the Generator shall be provided and connected to the corresponding RTUs of the Company.
- (e) Operation procedures of synchronising and de-coupling the Generator shall be agreed with the Company before the commissioning of the Generator.
- (f) The voltage fluctuation on the Grid during synchronisation should at most times not exceed 3% at the POCC.

## 9. APPENDIX

### APPENDIX AR1      APPLICATION PROCESSES

Please refer to the latest version of documents / links in CLP / EMSD websites.

#### **The application processes for Grid Connection**

1. Fill in the application form
  - a. [Feed-in Tariff \(Online\)](#);
  - b. [CLP Renewable Energy/Battery Energy Storage System Non-Feed in Tariff Grid Connection Application Form](#); or
  - c. [CLP Renewable Energy/Battery Energy Storage System Grid Connection Application Form](#).
2. To design the Renewable Energy System (RES) fits for grid connection, you will need to consider the following:
  - a) Grid Connection Standards (This Document)
  - b) Metering Requirements
    - [RE/BESS Grid Connection](#)
    - [FiT](#)
  - c) [Samples for schematic drawings](#) (in the appendix of Technical Guidelines on Grid Connection of Renewable Energy Power Systems issued by EMSD)
3. Before testing and commissioning of your RES, please send us the following information:
  - a) [Operation procedure](#) for RES without power export. For RES with power export, operation procedure shall be agreed with the Company case-by-case.
  - b) [Testing and Commissioning Procedure](#) for SE and SI Grid Connection. For other Generators, appropriate testing and commissioning procedures shall be agreed with the Company case-by-case

The Company may witness the site testing of the BESS and RE meter installation, which is subject to completion of Customer's technical documents submission such as Operation procedure and Testing and Commissioning Procedure.

4. If testing result is satisfactory, the Company will ask the Generator Owner to sign the Grid Connection Agreement agreed with the Company. Standard Grid Connection Agreement for small size RES is referred to this [link](#) in CLP website.

Remarks: The Standard Grid Connection Agreement is applied for RES rating at above 1MW.

**APPENDIX AR2      INFORMATION TO BE SUBMITTED FOR PROTECTION**  
**SYSTEM OF THE GENERATOR**

General requirements for accessing the protection design of the Generator that required for Grid connection: -

- Protection philosophy
- Totally segregated 2 x main & backup protection, unit and non-unit design
- Timing requirement
- Reliability and security measures
- Trip block diagram in single line diagram
- Relay model selection
- Protection design report & setting calculation
- Fault simulation & system grounding
- Drawing submission
- Protection grading and coordination (e.g. OCEF grading, reclose, etc)
- CT & VT specification design (e.g. type, class,  $V_k$ ,  $I_e$ ,  $R_{ct}$ , coordination with instrument/metering type, etc)
- Communication media requirement (e.g. fibre optic (FOC) or pilot, etc)
- Inter-tripping scheme requirement

The electrical protective devices that are required to protect each Generator will depend on its design and capacity of each Generator. In general, the protective devices shall consider:

- Generator differential for protection of phase-to-phase or three-phase stator windings faults
- Stator earth fault protection for detection of stator winding earth faults if the stator winding is earthed via an earthing resistor
- Neutral voltage displacement for detection of stator winding earth faults if the stator winding is earthed via a distribution transformer
- Reverse power to detect the loss of prime mover
- Voltage dependent overcurrent for system back-up protection if a fault in the system is not cleared by other protection
- Under-voltage and over-voltage used to back-up the speed control governor and automatic voltage regulator
- Under-frequency to detect overloading of Generator caused by various system disturbances or operating conditions
- Over-frequency used to back-up the speed control governor if over-speeding occurs
- Sensitive directional earth fault to detect Generator internal earth faults
- Field failure to protect Generator against high value of reactive current drawn from power system should there is loss of excitation.
- Voltage fuse detection to block protection devices that are affected by the loss of voltage
- Loss of mains to detect a failure of the mains, an auto-reclosing or autoswitching of the Grid and disconnect the Generator immediately

- Reversed power alarm to detect possible loss of mains and to monitor the power flow direction

**APPENDIX AR3      LIST OF DATA REGISTRATION SCHEDULE**

Information to be provided at the time of early application stage

Description	Remarks / Units	
Annual load consumption in the plant		
General information related to the whole Generator plant		
Address of the Generator		
Site Boundary plan	Indicative map	
Target date of commissioning	Quarter / Year	
Generator's Primary Energy source	(eg. Solar/Wind/ Waste to Energy, etc.)	
Proposed single line diagram		
Maximum Active Power Export	kW/MW	
Maximum Standby Import Active Power	kW/MW	
Total Fault contribution <ul style="list-style-type: none"> <li>• Three phases fault</li> <li>• Single phase fault</li> </ul>	RMS value kA (at LV/11kV/22kV)	
Details of Generator parameters		
Type of Generator	(Synchronous / Inverter-Based Generator)	
Number of Generator		
Rated terminal voltage	kV	
Rated terminal current	A	
Apparent power rating	kVA/MVA	
Rated Active power output	kW/MW	
Minimum Active power output	kW/MW	
Maximum Reactive Power export	kVAr/MVAr	
Maximum Reactive Power import	kVAr/MVAr	
Number of generating units connected to a single step-up transformer		
Rated apparent power of single step-up transformer	kVA/MVA	
Details of AC-DC-AC or DC-AC Parameters		
Manufacturer / Product Name / Model		
Converter Type		

Converter Current		kA
Converter Current Limit		kA
Number of Individual Converters		
Nominal DC Voltage		V
Maximum and Minimum DC Voltage		V
Rated DC Current		A
Voltage Angle Reference (Voltage Signal used for Reference Angle)	Text / Diagram	
Grid-side Converter (GSC) Type		
Rated AC Voltage (GSC)		V
Rated AC Current (GSC)		A
Switching Frequency (GSC)		kHz
Filter Stages, Values and Filter Type (front and back-end) (GSC)		

Information to be provided prior to Late Stage

Description	Parameter	Remarks / Units
Details of Synchronous Generator parameters		
Type of Generator		(eg. wound rotor, salient pole)
<b>Impedances:</b>		
Armature resistance ( $R_a$ )		Per unit
Direct axis unsaturated synchronous reactance ( $X_d$ )		Per unit
Direct axis saturated synchronous reactance ( $X_d$ )		Per unit
Direct axis unsaturated transient reactance ( $X'd$ )		Per unit
Direct axis saturated transient reactance ( $X'd$ )		Per unit
Direct axis unsaturated sub-transient reactance ( $X''d$ )		Per unit
Direct axis saturated sub-transient reactance ( $X''d$ )		Per unit
Quadrature axis unsaturated synchronous reactance ( $X_q$ )		Per unit
Quadrature axis saturated synchronous reactance ( $X_q$ )		Per unit
Quadrature axis unsaturated transient reactance ( $X'q$ )		Per unit
Quadrature axis saturated transient reactance ( $X'q$ )		Per unit
Quadrature axis unsaturated sub-transient reactance ( $X''q$ )		Per unit
Quadrature axis saturated sub-transient reactance ( $X''q$ )		Per unit

Negative sequence unsaturated reactance (X2)		Per unit
Negative sequence saturated reactance (X2)		Per unit
Zero sequence unsaturated reactance (X0)		Per unit
Zero sequence saturated reactance (X0)		Per unit
Stator leakage reactance (Xl)		Per unit
Short Circuit Ratio		
Open circuit and short circuit saturation curves and air gap line		Graph
Saturation factor S(1.0) and S(1.2)		
<b>Time Constants:</b>		
Direct axis short circuit transient time constant (T'd)		Seconds
Direct axis short circuit sub-transient time constant (T''d)		Seconds
Direct axis open circuit transient time constant (T'do)		Seconds
Direct axis open circuit sub-transient time constant (T''do)		Seconds
Quadrature axis short circuit transient time constant (T'q)		Seconds
Quadrature axis short circuit sub-transient time constant (T''q)		Seconds
Quadrature axis open circuit transient time constant (T'qo)		Seconds
Quadrature axis open circuit sub-transient time constant (T''qo)		Seconds
<b>Frequency and Excitation:</b>		
Exciter category, e.g. Rotating Exciter, or Static Exciter etc		
Details of Excitation System (including PSS if fitted) described in block diagram form showing transfer functions of individual elements		Diagram
Details of Over-excitation Limiter described in block diagram form showing transfer functions of individual elements		Diagram
Details of Under-excitation Limiter described in block diagram form showing transfer functions of individual elements		Diagram
Where possible a PSS®E representation should be provided which must include values for all relevant parameters		
Frequency response droop setting in LFSM-O		%
Frequency response droop setting in LFSM-U		%
Frequency response droop setting in FSM		%
Governor and prime mover model		Diagram

Inertia Constant (Generating unit and prime mover)		(kWsec/kVA)/(MWsec/MVA)
--	--	-------------------------

Description		Remarks / Units
Details of Inverter-Based Generator parameters		
<b>Voltage control:</b>		
Voltage control mode setting		V
Power factor control mode setting		
Reactive power control mode setting		kVAr/MVAr
Generating unit voltage control performance chart		
<b>Frequency control:</b>		
Frequency response droop setting in LFSM-O		%
Frequency response droop setting in LFSM-U		%
Frequency response droop setting in FSM		%
<b>Active Power control:</b>		
Active Power Control Set-Point Ramp Rate		(kW/MW) per (min. / sec.)
<b>Fault Ride-through:</b>		
Over and Under Voltage Ride-through Settings		
Details of Step-up transformer parameters		
Rated MVA		MVA
Rated Voltage Ratio (Principal tap)		
Vector group		
Type of cooling		
No-load loss		kW
Load loss at rated tap and 75°C		kW
Positive Sequence Resistance (R1):		
- Max Tap		Per unit
- Nominal tap		Per unit
- Min tap		Per unit
Positive Sequence Reactance (X1):		
- Max Tap		Per unit
- Nominal tap		Per unit
- Min tap		Per unit
Zero phase sequence resistance (R0):		
- Max Tap		Per unit
- Nominal tap		Per unit
- Min tap		Per unit
Zero phase sequence reactance (X0):		
- Max Tap		Per unit
- Nominal tap		Per unit
- Min tap		Per unit
Tap change range		+% / -%

No. of taps		steps
Tap changer type, on-load or off-circuit		On/Off

**APPENDIX CS1      TYPICAL SIMULATION PROGRAMS FOR CONNECTION STUDY**

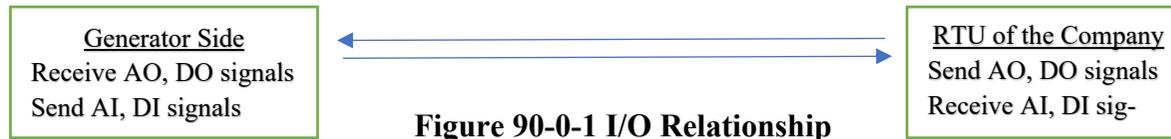
The Company uses PSS®SINCAL and PSS®E Version 34.X as the primary simulation tool for Root Mean Square (RMS) modelling for distribution and transmission networks, while PSCAD™/EMTDC™ is used for Electromagnetic Transients (EMT) modelling. The Generator Owner shall use the following simulation tools to perform the Connection Study (CS) assessment: -

- For SS and SI Generators, PSS®E Version 34.X or PSS®SINCAL software shall be used to perform the CS scopes.

**APPENDIX TM1 TELEMETRY REQUIREMENTS FOR GRID CONNECTION**

All status, measurements, commands, data and information to be transmitted to and sent from the RTUs of the Company shall be in real time. The ‘Description’ column of the table describes the sources of signals to and from the Generator side up to the RTUs of the Company. The sources of signals are classified in 4 types of signals to be collected per the ‘Type’ column of the table as follows: -

- AI and DI – Analog Inputs and Digital Inputs to be transmitted from the Generator side to the RTU of the Company
- AO and DO – Analog Outputs and Digital Outputs to be sent from the RTU of the Company to the Generator side



The Company will finalise the specific telemetry requirements based on the site location, ensuring that the details of individual points are coordinated during the project phase.

**1.1.GENERATION TIE LINE / POWER INTERFACE MEASUREMENTS/ LOCKABLE ISOLATING SWITCH**

No.	Signals	Type	SE (Y/N)	SS (Y/N)	SI (Y/N)	Description
1.1.1	Active Powers at Generator Side	AI	N	Y	Y	Active powers in kW or MW collected from measuring devices on collecting voltage and current measurements from CT and VT at Generator side of the Generator Tie Line / power interface
1.1.2	Reactive Powers at Generator Side	AI	N	Y	Y	Reactive powers in kVAr or MVAr collected from measuring devices on collecting voltage and current measurements from CT and VT at Generator side of the Generator Tie Line / power interface
1.1.3	Voltage at Generator Side	AI	N	Y	Y	Line voltage measured from the VTs of the incoming feeder panel at Generator side of the Generator Tie Line / power interface
1.1.4	Current at Generator Side	AI	N	Y	Y	Line current measured from the CTs of the incoming feeder panel at Generator side of the Generator Tie Line / power interface
1.1.5	CB Status	DI	N	Y	Y	On/off status of the CB

**1.2.GENERATOR TRANSFORMER / GENERATOR MEASUREMENTS**

No.	Signals	Type	SE (Y/N)	SS (Y/N)	SI (Y/N)	Description
1.2.1	Active Powers of Generator Transformer (Preferred) /Generator	AI	N	Y	Y	Active powers in kW or MW collected from measuring devices on collecting voltage and current measurements from CT and VT at HV side of Generator transformers or the Generator
1.2.2	Reactive Powers of Generator Transformer (Preferred) /Generator	AI	N	Y	Y	Reactive powers in kVAr or MVAr collected from measuring devices on collecting voltage and current measurements from CT and VT at HV side of Generator transformers or the Generator
1.2.3	Voltage of the Generator Transformer (Preferred) /Generator	AI	N	Y	Y	Line voltage measured from the VT outputs of the HV side of Generator transformer or the Generator
1.2.4	Current of the Generator Transformer (Preferred) /Generator	AI	N	Y	Y	Line current measured from the current transformer outputs of the HV side of Generator transformer or the Generator
1.2.5	Generator CB Status	DI	N	Y	N	On/off status of the CB of Generator transformer / Generator

**1.3.GENERATOR MEASUREMENTS AND CONTROL**

No.	Signals	Type	SE (Y/N)	SS (Y/N)	SI (Y/N)	Description
1.3.1	Voltage Control System Mode and Setpoint					Please refer to 1.3.1.1 to 1.3.1.6 below
1.3.1.1	Volt-Var Control Mode default	DI	N	Y	Y	This alarm is triggered when existing setting of V4 and Q4 of Volt-Var Control Mode is the same with the value shown in

No.	Signals	Type	SE (Y/N)	SS (Y/N)	SI (Y/N)	Description
	setting identification					Figure 8-9 or agreed with the Company
1.3.1.2	Voltage setting of the inverter when under-excited (V <sub>4</sub> )	AI	N	Y	Y	The current Generator's voltage setting (V <sub>4</sub> ) of Volt-Var Control Mode of the Generator, corresponds to operation at a reactive power level equal to or larger than 43% of its maximum capacity.
1.3.1.3	Reactive Power setting of the inverter when it is below 43%	AI	N	Y	Y	The current Generator's reactive power setting (Q <sub>4</sub> ) of Volt-Var Control Mode of the Generator corresponds to operation at a voltage level reaches 105% of nominal.
1.3.1.4	Volt-Watt Control Mode default setting identification	DI	N	Y	Y	Verify the Volt-Watt Control Mode is set to its default setting
1.3.1.5	Voltage setting of the inverter when active power below 20%(V <sub>2</sub> )	AI	N	Y	Y	Send out the existing voltage setting (V <sub>2</sub> ) of Volt-Watt Control Mode of the Generator
1.3.1.6	Active Power setting of the inverter when it is below 20%(P <sub>2</sub> )	AI	N	Y	Y	Send out the existing reactive power setting (P <sub>2</sub> ) of Volt-Watt Control Mode of the Generator

1.4.GENERATOR SHUNT DEVICES MEASUREMENTS AND CONTROL (FOR PROVISION)

1.5.ACTIVE OR REACTIVE POWER INJECTION MEASUREMENTS AND CONTROL (FOR PROVISION)

**APPENDIX TM2      TELEMETRY PRE-COMMISSIONING TEST**

1. The applicant (the Generator Owner or his/ her representative) should provide methods of statement, a schematic and wiring diagrams for injection test with an indication of signal interfacing point.
2. The applicant should confirm that the analog signal comes from Direct Digital Controller (DDC) instead of CT.
3. The applicant should provide the telemetry results (see [link](#) example & text in red) and photos (for required analog signals in kW, kVar, Amp & kV, and digital signals in circuit breaker status, etc.).
  - i. Secondary Injection test at DDC (e.g. analog signal error  $\leq \pm 1\%$  or  $\leq \pm 0.1\text{mA}$ )
  - ii. Real time generation (e.g. analog signal error  $\leq \pm 5\%$  or  $\leq \pm 0.5\text{mA}$ )
4. End-to-End checking with the Company in accordance with Item 3 (After connecting the telemetry circuit to the Company's side and completing FiT meter installation).

**APPENDIX FIM1    TELEMETRY REQUIREMENTS FOR FEED-IN MANAGEMENT  
AND DEMAND SIDE MANAGEMENT**

The Feed-in Management is for future provision. The following areas applicable are identified as follows: -

- (A) Automatic Generation Control (AGC)
- (B) Automatic Voltage Control (AVC)
- (C) Customer Demand Reduction
- (D) Voltage Reduction
- (E) Automatic Low Frequency Demand Disconnection
- (F) Emergency Manual Demand Disconnection
- (G) Demand Response Management (DRM)

The appropriate telemetry point requirements shall be updated in APPENDIX TM1 after review.