

MINISTRY OF ENERGY

GUIDELINES ON LARGE SCALE SOLAR PHOTOVOLTAIC PLANT CONNECTION TO DISTRIBUTION GRID

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ELECTRICITY ORDER 2017

GUIDELINES ON LARGE SCALE SOLAR PHOTOVOLTAIC PLANT CONNECTION TO DISTRIBUTION GRID

In exercise the power conferred by **Part 3 of the Electricity Order 2017**, the Authority issues the following guidelines:

Citation and Commencement

- 1. These Guidelines may be cited as the **Guidelines on Large Scale** Solar Photovoltaic Plants Connection to the Distribution Grid.
- 2. These Guidelines shall come into effect on the issued date and will be revised as deemed necessary with a new revised issuance date.

Application of these Guidelines

- 3. These Guidelines is applicable to
 - any person or entity who wishes to develop a large scale solar power plant and seeking connection to the transmission and/ distribution electricity network;
 - ii. the relevant Distribution Service Providers (DSP), whose network is to be connected with the Large Scale Solar (LSS) power plant;

Interpretations

4. In these Guidelines, the term used have the same meaning as in the Electricity Order 2017, regulation or codes made under it. In addition, the following words and expressions shall have the meanings assigned to them.

Term	Definition
Authority	Autoriti Elektrik Negara Brunei Darussalam
	(AENBD);
Commercial	means the date on which all relevant conditions
Operation	precedent under the Power Purchase
Date (COD)	Agreement (PPA) have been satisfied or waived;
Directly	as defined in the National Grid Code;
Connected	
Customers	
Distribution	as defined in the National Grid Code;
Network	
Energy rate	means the approved rate or any other rate as
	may be adjusted in accordance with the terms
	of the PPA;
Facility	means a solar photovoltaic generating facility
	and its ancillary equipment;
Grid Owner	means the party that owns the high voltage
	Transmission or Distribution Network and is
	responsible for maintaining adequate Grid
	System capacity in accordance with the
	provisions of the National Grid Code;

Term	Definition
Grid System	means the Transmission or Distribution
	Network with directly connected generating
	unit including Directly Connected Customers;
Interconnecti	means the demarcation line for ownership and
on Point	maintenance;
Large Scale	means any solar photovoltaic plant connected
Solar (LSS)	to either the Transmission Network or
	Distribution Network;
National Grid	means the National Grid Code for Negara Brunei
Code	Darussalam;
Point of	means the point on the Transmission or
Common	Distribution Network which is electrically
Coupling	closest to the user installation at which either
(PCC)	demands (loads) are, or may be connected;
Power	means agreement between Transmission or
Purchase	Distribution Service Provider and LSS
Agreement	Developers relating to the financial and
(PPA)	technical conditions for the purchase of the
	energy output and technical conditions relating
	to connection and performance on the Grid
	System;
Shortlisted	means tenderer who is shortlisted to comply
Tenderer	with conditions imposed and to finalize the
	project documents;
SPP	means the new 11kV substation owned by a
Interconnectio	LSS developer as further described in the PPA
n Facility (IF)	to enable LSS developer to deliver solar PV
	energy from the Facility to the Grid System;

Term	Definition
SPP	means the transmission or distribution line(s)
Interconnector	or underground cable(s) (including any
	associated facilities) that interconnect the SPP
	Interconnection Facility and Transmission or
	Distribution Service Provider's
	Interconnection Facility;
Successful	means the Shortlisted Tenderer who is issued
Tenderer	a letter of award or notice of compliance upon
	execution of the Project Document;
Distribution	means the existing DSP's substation
Service	(including but not limited to any extension
Provider's	works required to be completed by the LSS
Interconnection	developer at the DSP's substation) or a new
Facility (DSP IF)	switching station to be completed by the LSS
Facility	developer;
Distribution	The next on of the electrical Orid encoded of
Distribution	The portion of the electrical Grid operated at
Network	voltages of 11kV and under - as defined in the
	National Grid Code;

Key Principles of LSS Framework

- 5. The key principles of LSS framework shall be as follows:
 - The participant of the LSS program must be of a local company of which the Bruneian equity interest in such local company is at least 30% or a consortium of legal entities which includes a minimum of one local company and which has Bruneian equity interest in the consortium of at least 30%;
 - ii) The connection to the electricity network, whether to the Transmission Network or Distribution Network, shall be based on technical criteria and evaluation through a comprehensive power system study;
 - iii) The PPA shall be based on take and pay, energy only under Build, Own and Operate (BOO) concession;
 - iv) The PPA duration is 25 years with fixed energy price throughout;
 - v) The offers by the Shortlisted Tenderers shall be based on the optimum output, final yield and specific yield of the proposed LSS power plant in accordance with the design and technology used.
 - vi) The LSS developer shall declare the plant's energy production for 25 years. In the PPA, the LSS developer is entitled to be paid the Energy Rate up to the LSS power plant's Maximum Annual Allowable Quantity (MAAQ).

Potential Connection Points (Nodal Points)

6. Potential connection points (nodal points) to the electricity Transmission and Distribution Networks to be identified, to facilitate prospective tenderers. Any alternative connection point may be proposed but its approval is up to the Distribution Service Provider. All costs associated with the connection of LSS power plants, shall be borne by the LSS developer. The demarcation of ownership of the plant and system is as depicted in Figure 1, Figure 2 and Figure 3.

Responsibility of the LSS developer

- 7. The LSS developer is fully responsible to:
 - i. obtain right of way (ROW) and permits from relevant local authorities required for the construction of the Facility, SPP IF, SPP Interconnector, DSP IF and network reinforcement up to the Point of Common Coupling as Figure 1, Figure 2 and Figure 3; and
 - ii. design, construct, test, commission and complete the LSS power plant.



Figure 1: Illustration of Asset Demarcation









Award of the Project

8. Letter of acceptance of offer or notice of terms and conditions for development of project would be issued to the Shortlisted Tenderers, and the Shortlisted Tenderers is to finalise the PPA with the Transmission Service Provider or Distribution Service Provider.

Upon satisfaction of the terms and conditions in the letter of acceptance of offer or notice of terms and conditions, a letter of award or notice of compliance to the Successful Tenderer and the Successful Tenderer must fulfill all Conditions Precedents (CPs) under the PPA, particularly on the submission of certified and executed site agreement.

Critical Milestones to Commercial Operation Date (COD)

9. As shown in Figure 4 below, the critical milestones for successful completion of LSS power plant shall take place prior to COD.



Figure 4: Timeline from post PPA to COD

Licensing Requirement

10. All LSS power plants shall be licensed as per Part 3 Section 5(1) and(2) of the Electricity Order 2017.

Amendment and Variation

11. This Guidelines at any time, may be updated, modified or revoked as deemed necessary.

APPENDIX A

Technical Specification for Distribution-Connected LSS

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Abbreviations

This section describes a list of abbreviations used in this document.

Abbreviations	Description
AC	Alternating Current
AVQC	Automatic Voltage and Reactive Power
	Control
BOO	Build, Own and Operate
COD	Commercial Operation Date
СТ	Current Transformer
DAQ	Declared Annual Quantity (in MWh) of Solar PV
	energy for each Contract year which shall not
	exceed the MAAQ
DSP	Distribution Service Provider
GIS	Gas Insulated Switchgear
IF	Interconnection Facility
IOD	Initial Operation Date
kV	Kilo-Volt
LSS	Large Scale Solar
MAAQ	Maximum Annual Allowable Quantity (in kWh)
MW	Mega-Watt
NGC	National Grid Code
NEO	Net Energy Output (in kWh)
PCC	Point of Common Coupling
PPA	Power Purchase Agreement
PV	Photovoltaic

Abbreviations	Description
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
THDI	Total Harmonic Distortion Current
VCB	Vacuum Circuit Breaker
VT	Voltage Transformer

Glossary of Terms

This section describ	oes a list of terms	used in this docume	ent.
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Term	Definition
Anti-Islanding	During loss of mains, the inverter
	should cease to operate in islanded
	mode. Inverter should be equipped with
	anti-islanding protection;
Commercial	Means the date at which all relevant
Operation Date	conditions precedent under the PPA
	have been satisfied or waived;
Connection Point	Means the point of common coupling
	where LSS is connected to the
	distribution system;
Contingency	Under contingency condition, when one
	or more circuit elements are on outage,
	scheduled or non-scheduled;
Contracted	Means the capacity of solar
Capacity	photovoltaic energy to be generated
	and delivered to the Grid system at the
	interconnection point from the facility
	for each contract year;

Term	Definition
Contract Year	Means, the date on which begins the Commercial Operation Date of the Increment and ends on December 31 of the year in which the Commercial Operation Date of the Increment occurs, each subsequent period during the Term which begins January 1 and ends on December 31 of the same year and the period of twelve (12) months or less which begins on January 1 and ends on the last day of the PPA Term;
Distribution Service Provider	Means distribution grid owner, operator and maintains the distribution grid appropriately;
Distribution Network	The system consisting of electric lines which are owned or operated by a Distribution Service Provider (and used for the distribution of electricity from Grid Supply Points or Generating Units or other entry points to the point of delivery to Customers. "Distribution electricity network" means a system or part of a system at nominal voltage of less than 11kV of electric lines or cables, substations and associated equipment and buildings for transporting electricity to any person;

Term	Definition		
Distribution	The system of electric lines with voltage		
System	levels below 66 kV, within the Area of Supply owned or operated by the DSP, for distribution of electricity from Grid Supply Points or Generating Units or other entry		
	points to the point of delivery to Customers and includes any electrical plant and meters owned or operated by the DSP in connection with the distribution of		
	electricity;		
Demand or Load	Means demand of MW/kW and MVar/kVar of electricity (i.e. both active power and reactive power), unless otherwise stated;		
Facility	means a solar photovoltaic energy generating facility, its ancillary equipment and facilities;		
Interconnection	The components that interconnect the LSS		
Facility or IF	and the distribution network. This includes the substation at the LSS, overhead lines or underground cables where the connection to the distribution network is made;		
Initial Operation	The date on which the LSS installation		
Date or IOD	first delivers Net Electrical Output to the DSP network for testing purposes;		
Inverter	A machine, device, or system that changes DC power to AC power;		

Term	Definition		
Islanding	A condition in which a portion of the utility		
	system that contains both load and		
	distributed resources remains energized		
	while isolated from the remainder of the		
	utility system;		
Large Scale Solar or	Any solar PV Plant connected to either		
LSS	transmission or distribution network in		
	Brunei Darussalam;		
MAAQ	means the maximum annual allowable		
	quantity (in kWh) determined as a product		
	of the Established Capacity, the capacity		
	factor and the number of hours in a year;		
Medium Voltage	A voltage equal to or exceeding 1kV but		
	not exceeding 50kV;		
National Grid Code	National Grid Code is a document		
	containing a set of technical rules and		
	procedures that facilitate coordinated		
	planning, design, development, and		
	coordinated operation of the Grid System;		
Net Energy	Means for any period, the amount of solar		
Output or NEO	energy generated and delivered to the DSP		
	at the metering point;		
Power Purchase	Agreements between the Distribution		
Agreement or PPA	Service Provider (DSP) and LSS Developer		
	relating to the financial and technical		
	conditions relating to the purchase of LSS		
	output and technical conditions relating		
	to its connection to and performance on		
	the Grid System;		

Term	Definition		
Prudent Utility	The exercise of such degree of skill.		
Practice	diligence, prudence and foresight which		
	would reasonably and ordinarily be		
	expected from a skilled and experienced		
	operator engaged in the same type of		
	undertaking under the same or similar		
	circumstances;		
Trans Transf	Trat of one on more devices mode to a		
Type Test	lest of one or more devices made to a		
	certain design to demonstrate that the		
	design meets certain specifications;		
Prudent Utility	The exercise of such degree of skill,		
Practice	diligence, prudence and foresight which		
	would reasonably and ordinarily be		
	expected from a skilled and experienced		
	operator engaged in the same type of		
	undertaking under the same or similar		
	circumstances;		
Type Test	Test of one or more devices made to a		
	certain design to demonstrate that the		
	design meets certain specifications;		
Power Factor	Power factor (PF) is calculated by dividing		
	the Real Power, P, in the W unit by the		
	Apparent Power, S, in the VA unit.		

1. Introduction

This guideline has been prepared as guidance only to facilitate prospective LSS developers seeking connection to the DSP's Distribution Network. MW described in this guideline refers to the AC side of the LSS plant.

2. Scope and Limitation

Large Scale Solar (LSS) PV Plants described in this document refer to those connected to the distribution network at 11kV.

The Guidelines are not intended to cover all required authorizations, permits and/or licenses which the LSS developer is required to obtain from the relevant bodies and/or authorities for the purpose of the development of LSS.

The LSS developer shall, at its own costs, be fully responsible for the inspection, examination, checking and verifying the accuracy, correctness and completeness of any and all data as to the site and its surroundings and the nature of the climatic, geological, soil and general conditions of the site as well as the potential nodes as identified by the DSP in order to meet the requirements of the Power Purchase Agreement. The LSS developer is also at its own costs, be responsible to obtain, maintain and renew all authorizations, permits and licenses necessary for it to develop the LSS and to otherwise perform its obligations under the Power Purchase Agreement or any other Project Documents and comply with all conditions and requirements as may be imposed or prescribed by any relevant bodies and/or authorities which has jurisdiction over the development of LSS.

Each LSS developer shall accept full responsibility for conducting an independent analysis of the accuracy, correctness and completeness of any and/ all data; and for gathering and presenting all necessary information.

3. Connection to the Grid Distribution System

3.1 Background

The connection of the LSS plant is to be made only at the existing DSP's substation. The evaluation of connection requirements is subject to the terms and requirements of the DSP and the National Grid Code.

The limiting factors at the substation such as fault level, transformer daytime loading are important for the assessment of the connected generation capacity. Impact such as substation loading and voltage rise due to power generation could determine the limit of capacity allowed for the LSS power generation.

3.2 Connection Voltage Level

The LSS plant can be connected to the 11kV and 415V distribution voltage level.

3.3 Penetration Limit

Distribution network is operated in lateral feeders with off-point located strategically. To cater for the n-1 contingency requirement, feeders are loaded at only 50% of its thermal capacity. Therefore, to determine the capacity of connected LSS, the 50% feeder loading is to be adopted.

Output from LSS connected to distribution network is to be consumed locally. Therefore, the penetration limit of LSS to a substation is limited to the daytime loading level of the substation. The loading level is to be determined by the DSP based on its record of recent substation demand trend. Estimation of future demand growth shall not be considered.

3.4 Nodal Points

The connection to the distribution network is to be done only at the existing substations owned by the DSP.

For the purpose of facilitating the potential LSS developer, nodal points have to be identified for connection to distribution network. The nodal points were selected based on the following considerations:

- a) Fault level
- b) Adequate daytime trough load

Other possible constraints include the availability of space for the new switchgear including the associated control panel and the metering room.

The potential nodal points as identified shall be used as guidance only as actual feasibility study depends on the findings of the PSS. The DSP has the rights to review and update the potential nodal points.

3.5 Connection Schemes

The interconnection feeder shall be using circuit breaker which shall be provided by the LSS developer. All costs including any modification/extension to the existing substation in order to accommodate connection of LSS to the grid shall be borne by the LSS developer.

Typical scope of works for the interconnection feeder is described (not limited to) in Table 1. However, the actual works shall be determined based on the actual site requirements.

	Upgrading at substation	U	pgrading at Main Intake Station
•	Replace existing Ring Main Unit (RMU) to VCB	•	Extension to existing switchgears (VCB/GIS)
•	Remote Control Box (RCB)	•	Control Relay Panel (CRP)
•	Direct Current(DC)		

Table 1: Typical Scope of Works for Upgrading

system	• SCADA/RTU
 Building works as necessary 	• Arc protection (where applicable)
• Meter room	 Building works as necessary
	• Meter room

Figure 5: Upgrading of the Switchgears at PCC



3.6 Scope of Interconnection Facilities & Asset Demarcation

This section describes the feature of the interconnection feeder which connects the LSS plant to the DSP substation. The connecting cable consists of underground or aerial cable to carry only the generated power and fibre optics cable for differential protection relay and interlocking communications.

All costs including any modification or extension to the existing substation in order to accommodate connection of LSS to the grid shall be borne by the LSS developer.

The LSS developer is responsible in acquiring the right of way for the underground or aerial cable route and any related land acquisitions.

Figure 6: DSP-LSS Interconnection Feeder Scheme



An LSS developer scope of works (not limited to) are to include the following:

- (i) Supply of interconnection facilities for LSS and DSP side (refer to Figure 6)
- (ii) The interconnection works shall be designed, built, owned, operated and maintained by the LSS developer
- (iii) All works for interconnection is under the responsibility of LSS developer
- (iv) Interconnecting power cable capacity and fibre optics based on PSS
- (v) The equipment is to match existing or DSP's required specifications
- (vi) Protection scheme is to meet DSP's requirement
- (vii) Energy meters and dedicated metering room
- (viii) Interlocking scheme
- (ix) SCADA requirements
- (x) Anti-islanding shall be provided at the LSS plant
- (xi) Install and maintain PQ Recorder at LSS plant
- (xii) Submission of drawings and manuals

4. Technical Requirements

4.1 General

The technical requirements outlined in this guidelines are to ensure that the connection of LSS to the distribution system is harmonised with the existing system characteristics.

4.1.1 Voltage range

Distribution network voltage fluctuates in response to the feeder length and the load level. Table 2 describes the limits to be complied for the planning of the interconnection.

Nominal Voltage	Steady state voltage limits
230V, 400V	+10%, -6%
11kV	±5%

Table 2: Steady State Voltage Limits

4.1.2 Voltage fluctuation

The maximum voltage fluctuation range allowed due to varying solar radiation is 6%. This requirement differs from that for voltage flicker.

4.1.3 Frequency

LSS developer shall maintain plant frequency to operate in synchronism with distribution system. Nominal system frequency is 50 Hz with normal range of $\pm 1\%$ which is between 49.5Hz and 50.5Hz. Grid frequency may temporarily deviate due to large changes in load, the tripping of a generator, or system faults. Limits for these various conditions are as follows:

- Normal Operating Conditions: 49.5 Hz to 50.5 Hz
- During System Stress: 49.0 Hz to 51.0 Hz
- Maximum deviation during faults: 48.75 Hz to 51.25 Hz

- Tripping values for generators 51.5 Hz or above and 47.5 Hz or below

4.1.4 Current Harmonics

Total Harmonic Distortion Current Distortion (THD) shall be <5 % at inverter rated output. The point of measurement is at the Point of Common Coupling.

Each individual harmonic shall be limited to the percentages listed in table below (Current distortion limits referenced to IEC 61727-2003 Table 1). Even harmonics in these ranges shall be less than 25% of the lower odd harmonic limits listed.

Odd harmonics	Distortion limit (%)
3 - 9	< 4.0
11 – 15	< 2.0
17 – 21	< 1.5
23 - 33	< 0.6

Table 3: Distortion limit for Odd Harmonics

 Table 4: Distortion Limit for Even Harmonics

Even harmonics	Distortion limit (%)
2 – 8	< 1.0
10 - 32	< 0.5

4.1.5 Voltage Fluctuation and Harmonics

Table 5 highlights the acceptable permissible values for voltage fluctuation and harmonics. The point of measurement is at the Connection Point normally at the DSP substation.

Type Of Disturbance	Indices	Acceptable permissible values at Connection Point	Reference Document
Voltage Flicker	Absolute Short Term Flicker Severity (Pst)	1.0 (at 132kV and below)	UK's Engineering Recommendation P28
	Absolute Long Term Flicker Severity (Plt)	0.8 (at 132kV and below)	
Harmonic Distortion	Total Harmonic Distortion Voltage (THDV) %	4 % at 11kV	Engineering Recommendation ER G5/4
Voltage Unbalance	Negative Phase Sequence Voltage %	2% for 1 minute	UK's Engineering Recommendation P29

Table 5: Acceptable Permissible Value at PCC for VoltageFluctuation and Harmonics

4.1.6 DC injection

LSS plant shall not inject DC current more than 1% of the rated inverter output current under any operation condition.

4.1.7 Power factor

Each External party is required to ensure that its installation has satisfactory power factor correction to ensure that, the power factor as measured at the Connection point and should use reasonable endeavors to maintain its average power factor between Unity and 0.9 lagging.



Figure 7: Voltage versus power factor curve

4.1.8 Transient Over voltages

Typical Basic Impulse Insulation Levels (BIL) of the distribution system is as indicated in Table 7. The LSS Plant and its apparatus shall be compatible with the insulation levels of the distribution system.

Table 6: Basic Impulse Insulation Levels (BIL)

System Voltage (kV)	BIL (kV)
11	75

4.1.9 System Fault Level

Table 7 below shows the rated equipment to be used to withstand the maximum sub- transient three phase symmetrical short circuit fault levels.

Table 7: Short Circuit Withstand Rating for Power Equipment

Nominal Voltage [kV]	Rated Voltage [kV]	Fault Current [kA]
11	12	20/25

4.1.10 Synchronization

Synchronization devices shall be provided and maintained by the LSS developer. During operation, synchronization is at the LSS plant side by matching with the distribution system parameters as mentioned below:

- (i) Interlocking logics are satisfied
- (ii) Frequency difference <0.2 Hz
- (iii) Voltage magnitude difference < 10%
- (iv) Voltage angle difference < 10 degrees

Inverter shall be capable of synchronizing with the grid automatically within the specified reconnection time.

4.1.11 Inverter

The LSS plant shall use type of inverters that have advanced or smart inverter functions. The inverter shall comply with the technical requirement for connection to distribution network as required by the DSP. Smart inverters are PV inverters that stay connected and provide additional functions to help actively support the grid - mainly voltage and frequency. Traditional inverters simply disconnected when the grid voltage or frequency went out of range. Broadly, smart inverters provide some additional benefit to the grid beyond simply converting direct-current (DC) electricity to alternating current (AC) from PV systems. The smart inverter functions are outlined in **Attachment A**.

4.1.12 Standard compliance

The LSS plant and its interconnection shall comply with the standards set as requirement and also to comply with the National Grid Code.

4.2 Network Support

The LSS plant shall provide support to the network to ensure that the system is stable by:

- (i) To not disconnect
- (ii) To support network voltage by feeding reactive power

4.2.1 Low Voltage Ride Thru

During disturbance at transmission system, distribution system will experience temporary low voltage or sag. The LSS plant is expected to continuously operate during distribution system voltage fluctuation as shown in Figure 8 below.



Figure 8.: Distribution system voltage fluctuation

4.2.2 Frequency disturbance

The LSS plant is expected to be uninterrupted within the frequency range of 49.5 to 50.5Hz.

During frequency disturbance, when the frequency increases more than 50.5Hz, the LSS plant shall reduce its power output as shown in Figure 9.



4.2.3 Power output management

The LSS plant shall have the capability to manage its power generation:-

- The LSS plant shall be able to reduce its power output or disconnect from the distribution system during system contingencies.
- LSS plant shall reduce its generation output to avoid voltage rise above the limit.
- The LSS developer shall monitor and ensure that the power generation of the plant does not exceed the contracted capacity.
- The inverter shall have the capability to perform active/reactive power control and/or voltage control for voltage regulation.

4.2.4 Reactive power

The LSS plant shall be able to deliver the reactive power requirement at the connection point as shown in Figure 10. Full range of reactive power 0.85 lagging to 0.9 leading shall be achieved at 20% output.



Figure 10: Active power output versus power factor curve

4.2.5 Droop arve

The LSS plant shall be fitted with a droop controller or equivalent control device to provide frequency response under normal operational conditions as in 4.1.3.

4.2.6 Power Ramping

The LSS plant shall be able to automatically and manually control the ramp rate and limit the real power. This is to ensure stability of the system and prevent any power surge caused by sudden injection by the Facility.

The LSS plant shall be capable to control the increase and decrease of power delivery within ramp rate of 15% per minute of rated capacity.

The Facility shall be able to regulate the ramp rate of the active power output for the following scenarios:

- Dispatch Instruction (if required);
- Normal load variation;
- Facility startup (black start); and
- Facility shutdown.

4.3 Protection Requirements

The LSS plant protection scheme is under the LSS developer's responsibility and the LSS developer shall declare the protection scheme and settings to the DSP.

4.3.1 Connection point feeder protection at DSP.

The protection interfacing requirements are as follows:

- Unit Protection (Current Differential)
- OCEF / Non Directional OCEF
- Interlocking scheme
- Reverse Power Relay

Where applicable, the following protection schemes may be required:

- (i) Arc protection
- (ii) Busbar protection
- (iii) Automatic transfer scheme

4.3.2 Feeder requirements at LSS plant

The LSS feeder shall be equipped with the following equipment:

- Current Differential Relay
- PQ recorder

The PQ recorder shall measure THDI, voltage fluctuation and flicker. Data storage capacity for the PQ recorder is to last at least for 1 month. The sampling rate shall be at least 128 samples per cycle.

4.3.3 Fault clearing time

The fault clearing time for 11kV network is as depicted in Table 8.

Table 8: Fault Clearing Time

Type of fault	11kV
Substation & transformer faults	150ms
Overhead line & cable faults	600ms

4.3.4 Interlocking of the interconnection feeder

The interlocking facilities shall operate in the following manner (subject to the approval of the DSP), referring to Figure 10 below.

- A open B to open
- B close position A cannot close
- A open position B cannot close
- Earth Switch (ES) B ON A cannot close



Figure 11: Interlocking of the interconnection feeder with DSP

4.3.5 Protection equipment

The protection relay and PQR equipment to be used is subject to the approval by DSP.

4.3.6 Protection coordination study

LSS developer shall carry out the internal protection coordination to mitigate internal and external fault.

For any internal fault, the LSS plant shall not cause problems to the utility system and its customers. The failure of the LSS plant equipment includes:

- Failure of protection equipment
- Failure of control equipment
- Loss of control power
- Interconnection power and fibre optics cables

For any distribution network fault outside the LSS plant, the LSS plant shall be protected from any damaging effect. LSS plant shall be disconnected from the grid during any of above the conditions.

4.3.7 Anti-islanding

During loss of mains, the inverter shall cease to operate in islanded mode. The anti-islanding protection is required to mitigate the following events:

- Safety
- Power quality
- Inverter technical limit
- 4.3.7.1 Anti-islanding detection

Inverters shall have the following anti-islanding capabilities:

- (i) Under Voltage
- (ii) Over Voltage
- (iii) Under Frequency
- (iv) Over Frequency
- (v) 1 additional active or passive anti-islanding detection

4.3.7.2 Isolation time

Upon detection of the loss of mains, LSS plant shall be isolated within the time as in Table 8.

4.3.8 Reconnection time

The reconnection time of the LSS plant to the distribution network shall be more than 5 minutes after DSP connection has been stabilized.

4.3.9 Earthing scheme

The LSS plant earthing scheme shall not cause mal-operation to the DSP protection scheme.

The zero sequence components between the DSP network and LSS plant shall be isolated. The LSS plant step up transformer(s) shall have delta (Δ) configuration on DSP side as illustrated in Figure 12 to ensure the plant does not contribute zero sequence current to DSP network during fault.



Figure 12: Step up Transformer Earthing Scheme

4.4 Meteorological Monitoring Facilities (MMF) and Pyranometer

The LSS developer shall provide the following:

- (i) Install Meteorological Measuring Facilities (MMF) and pyranometer at the site.
- (ii) 1 set (MMF & pyranometer or solar cell sample) per 1MW
- (iii) Meteorological station has an independent and backup power source.
- (iv) LSS must maintain historical data of readings for throughout the term.
- (v) Minimum data resolution: Every 15 minutes.
- (vi) Submit meteorological report to the Authority and DSP as and when required
- 4.5 Operational Requirements
- 4.5.1 Preparation of Interconnection Operation Manual (IOM)

The documents to be prepared for each interconnection shall address (not limited to) the following:

- (i) Interconnection Facilities
- (ii) Communication
- (iii) Switching Procedures
- (iv) Fault Reporting
- (v) Outage Program
- (vi) System Emergency or Collapse
- (vii) Sequence of Operation
- (viii) Boundaries and Ownership

4.5.2 Contingencies

During contingency, the LSS plant may be isolated until the system is normalised. Contingencies include scheduled and unscheduled outages:

i. Network upgrading

- ii. Maintenance
- iii. Shutdown
- iv. Breakdown
- 4.5.3 Declared Annual Quantity (DAQ)

The LSS developer is required to declare annual output to the Authority and the DSP.

4.6 SCADA

All cost for the SCADA facility is to be borne by the LSS developer including RTU cubicle and associated cards and SCADA ready switchgears. SCADA equipment to be used is subject to the approval by DSP.

The following parameters are required to be made available to the Authority and DSP, for monitoring purpose.

- (i) Frequency (Hz)
- (ii) Voltage (V)
- (iii) Current (A)
- (iv) Real Power Energy flow (kW or MW)
- (v) Reactive Power Energy flow (kVar or MVar)
- (vi) Circuit Breaker status

(vii) Relay indications

All interfacing wirings shall be prepared by the LSS developer with DSP's supervision.

4.7 Ownership and Boundaries

All equipment which are to be transferred to the DSP is required to comply with the DSP's specifications. The ownership boundary of the LSS developer is up to and including the cable termination at the Connection Point at DSP Distribution System.

4.7.1 Boundaries

Determinations of boundaries are as shown in Table 9.

Item	Ownership	Control	Operation	Maintenan ce
	DSP substation			
Primary	DSP	DSP	DSP	DSP
Secondary				
• OCEF + RPR	DSP	DSP	DSP	DSP
• CD + communica tion	LSS	LSS	LSS	LSS
 Interlocking 	LSS	LSS	LSS	LSS
LSS substation				
Primary	LSS	LSS	LSS	LSS
Secondary				
• OCEF + RPR	LSS	LSS	LSS	LSS
+CD • PQR	LSS	LSS	LSS	LSS

 Table 9 : Boundaries and Ownership Between DSP and LSS developer

OCEF – Overcurrent Earth Fault, CD – Current Differential, RPR – Reverse Power Relay, PQR – Power Quality Recorder

The LSS developer shall own and be responsible for the costs of operation and maintenance of all installations located within their boundary.

4.7.2 Transfer of interconnection facilities

Upon the completion of the interconnection facilities, the LSS developer shall transfer the interconnection facilities beyond his or its ownership boundary to the DSP and take all necessary actions to transfer to the DSP of all rights, title and interests to the interconnection facilities so that the DSP shall become the owner of such interconnection facilities.

The DSP henceforth shall be responsible for the operation and maintenance of the interconnection facilities.

4.7.3 Defects in interconnection facilities

If the DSP discovers that the interconnection facilities or any part of the IF that has been transferred to it:

- Was not designed, constructed, installed and tested in accordance with prudent utility practices; or
- (ii) Contains any defect in its design, materials or workmanship

The LSS developer is required, at his or its own cost, make all necessary repairs or replacements so that the interconnection facilities conform to the requirements of prudent utility practices and shall be free from any such defect.

However, the obligation of the LSS developer shall not apply in respect of any non-conformance or defect arising:

- (i) From the DSP's failure to operate and maintain the interconnection facilities in accordance with the operation and maintenance manuals and prudent utility practices;
- (ii) From the effects of ordinary wear and tear or erosion or corrosion which such facilities were not designed for; or
- (iii) After an initial period of twelve months from the COD, and in respect of any part of such facilities that was repaired or replaced during such IOD, after a period of twelve months from the date of completion of such repair or replacement.

5. Metering

5.1 General

All energy meters used for measuring the import and export of electricity shall comply with DSP's specifications. DSP shall determine the point at which every supply line shall terminate in any premise in view of ease of accessibility to DSP's personnel. The LSS developer is required to provide meter panel according to DSP's specifications for the installation of meter and their accessories. DSP may change any meter and its accessories or their positions in any premise as deemed necessary at any time for purposes of maintenance and meter reading.

5.2 Energy Meter

The main and check meters are to be installed by DSP to measure the energy import and export. The energy meters shall be procured from DSP. The cost will be inclusive of supply and installation for both meters.

The energy meters shall be mounted on the metering cubicle. The dimension and specifications of the meter cubicle are to comply with the latest DSP electricity supply application or installation guideline or specification. All drawings is to be endorsed by a Professional Engineer.

5.3 Metering Point

Energy meter is to be installed at the connection point in a dedicated meter room at DSP's substation. The LSS developer is required to provide a Switch Socket Outlet (13 Amps) at the meter room.

5.4 Communication Signal

DSP uses wireless mode of communication between energy meter and DSP data centre. Location of the meter room must have adequate reception of the wireless signal to enable data transmission. LSS developer shall provide signal booster equipment whenever the communication signal is weak.

5.5 Metering Voltage Transformer for 11 kV

The details for the Inductive type VTs is shown in Table 10.

Parameters	Description	
	<u>Vs / √3 V</u> 110 / √3V	
Ratio	* where Vs is the voltage at metering point	
Class	0.5	
Burden	100 VA, sharing can be allowed provided	
	separate	
	fusing is provided	
Voltage factor	1.9 for 8 hours	
Unit	3 nos. for each feeder	
Standards	IEC 60044-1 Edition 1.2 2003-02 and IEC 60044-2 Edition 1.2 2003-02	

Table 10: Metering Voltage Transformer

5.6 Metering Current Transformer for 11 kV

The details for the metering current transformer are shown in Table 11.

Parameter	Description	
Ratio	Is / 5A	
	* where Is = the primary ratio of the metering CT	
Class	Class 0.2	
Burden	15 VA	
Unit	3 Nos. for each feeder	
Standards	IEC 61869-2:2012 and IEC 61869-1:2007	

Table 11: Metering Current Transformer

5.7 Meter Application and Approval

The LSS developer is required to liaise with the DSP on the requirements for meter application and approval.

Test certificate and wiring diagram of the current transformers and voltage transformers shall be supplied by LSS developer. The CTs and VTs shall have a valid test certificate from an accredited laboratory.

5.8 Meter Reading

The LSS developer is to read the revenue meter with DSP (joint inspection) on a monthly basis and not later than 7 days after reading the revenue meter, the LSS developer is required to prepare and submit an invoice to DSP for payment.

The LSS developer may at any time submit a written request to the DSP to inspect or test the energy meters. If the meters are found to be defective or inaccurate, both DSP and the LSS developer are to recalculate and agree on the amount payable during the period of inaccuracy. However, if the meter is accurate, the cost for energy meter testing shall be borne by the LSS developer.

5.9 Metering Panel

The meter panel or cubicle shall be designed by LSS developer and endorsed by DSP. LSS developer is to prepare the wiring for the meter and conduct the relevant test as per the DSP requirements.

The LSS developer shall maintain the meter panel or cubicle and its accessories except for the energy meter and test terminal block.

6. Testing and Commissioning for IOD

6.1 General

The LSS developer is to notify DSP in writing once the LSS plant installations and the interconnection facilities is ready to be commissioned. The LSS developer is required to submit all the documents for IOD as the following:

- (i) A certificate from a Professional Engineer stating that the interconnection facilities have been designed and constructed in accordance with prudent utility practices.
- (ii) Copies of approved as-built drawing of the interconnection facilities
- (iii) Copies of IOM approved by DSP
- (iv) Test results of the Interconnection Facilities
- (v) A copy of metering scheme approval

- (vi) Transfer documents for DSP substation and land if applicable
- (vii) Electricity Licence from the Autoriti Elektrik Negara Brunei Darussalam (AENBD)

(viii) Approval letters from authorities on right of ways for cable routes

(ix) Written confirmation from DSP on the completion of site work without any outstanding issues

The submission of a complete IOD document shall be made not less than 60 days of the proposed IOD. The commissioning notification shall be issued upon receipt of the complete IOD documents.

6.2 Interconnection Operation Manual (IOM)

The purpose of the IOM is to outline the duties and the responsibilities of both parties at the interconnection between DSP and the LSS plant. The IOM is also to set out the necessary procedures to be followed to ensure safety to the operating personnel and to avoid any damage to the equipment at the interconnection point. The LSS developer shall prepare the IOM for the interconnection and jointly agreed by the DSP.

The IOM has to be completed before the commissioning process could be considered.

6.3 Testing for Interconnection Facilities

Testing shall be carried out during the shutdown stage which involves the connection of the LSS plant to DSP network. Such test includes and not limited to the following:

- (i) Electrical protection scheme
- (ii) Protection coordination study
- (iii) Cable and/or overhead test result
- (iv) SCADA
- (v) VCB and DC system

All tests is to be carried out by a qualified tester and with a valid calibration certificate.

6.4 Commissioning Tests for IOD

There are 2 levels of testing required:

- (i) Inverter compliance tests
- (ii) Interconnection compliance tests

The scope of testing during IOD shall cover:

- (i) The LSS plant shall cease to energise during loss of mains. Antiislanding test must comply with the following time:
 - Disconnection time: ≤2s and
 - Reconnection time: >5min
- (ii) Functional tests of all equipment
- (iii) Any resetting of factory-set parameters at site requires testing to be redone.

All test results shall be certified by Professional Engineer to be submitted to DSP.

6.5 Power Quality Measurements

6.5.1 Pre/Post Initial Operation Date (IOD)

Power quality measurements are to be done at the point of connection to ascertain the existing power quality before commissioning and after the connection of LSS plant. The recording period shall be 7 days before commissioning to capture the base voltage regulation profile without LSS plant and 7 days after commissioning with the LSS plant connected. The recording interval shall be not less than 10 minutes.

Measurement shall capture the following parameters and not limited to:

(i) Total harmonic distortion (THD) voltage

- (ii) Unbalanced voltage
- (iii) Flicker voltage
- (iv) RMS Voltage
- (v) Power Generation (kW)
- (vi) Reactive Power (kVAr)
- (vii) Power factor
- (viii) Energy kWh (daily)

6.5.2 Permanent Power Quality Measurements

The LSS developer shall install a permanent power quality recorder at the LSS circuit breaker and to submit the PQ report as and when requested by DSP.

Measurement shall capture the following parameters and not limited to:

- i. Total harmonic distortion (THD) Current and each individual current harmonic
- ii. Total harmonic distortion (THD) Voltage
- iii. Unbalanced voltage
- iv. Flicker voltage
- v. RMS Voltage
- vi. Power Generation (kW)
- vii. Reactive Power (kVAr)
- viii. Power factor
- ix. Energy kWh (daily)
- x. Voltage dip and swell events

7. Commercial Operation Date (COD)

7.1 Verification for COD

The verification for COD shall be conducted after IOD and the minimum duration shall be not less than 7 days. The verification tests shall be performed by a Professional Engineer and witnessed by the DSP. The verification test parameters include the following:

- (i) Grid Frequency Variation
- (ii) Reactive Power Control (voltage control and power factor control modes)
- (iii) Grid system voltage variation
- (iv) Grid system fault level
- (v) Protection System
- (vi) Voltage support (AVQC) & Active Power Control
- (vii) Equivalent control device to speed governor (Droop curve)
- (viii) Frequency MW Response
- (ix) Power Quality
- (x) Fault ride through (LVRT)
- (xi) Power ramping (up and down)
- (xii) Inverter functional tests and verifications

The COD verification methods are depicted in Table 12.

Table 12: Interconnection Facility Verification Methods

Test method	Description	
Factory test	Valid test certificate/results from the factory	
Site test	Electrical and functional tests of the interconnection facility	
Site verification	Confirmation against approved drawings or Specification	

7.2 Confirmation for COD

The LSS developer is to submit to the Authority and DSP the report for COD confirmation. The report shall consist of:

- (i) Verification report
- (ii) PQ report

Upon receipt of the reports, the Authority shall issue a letter of confirmation on COD to the LSS developer and DSP to initiate payment.

8. Safety and Performance Sustainability Requirements

The safety requirements to be adopted by the LSS developer and DSP for work or testing at the interconnection facilities shall include the following:

- (i) The LSS developer shall provide the as-built single line diagrams of the interconnection facilities at the respective side of the connection point;
- (ii) The LSS developer shall have their own safety rules and/ safety instructions which comply with the Electricity Order 2017 and/ or any other law in Brunei Darussalam and prudent utility practices.
- (iii) The LSS developer shall designate a competent Licenced Electrical Worker to operate the interconnection facilities within their boundary.

The LSS developer shall at its own cost conduct the testing of LSS plant (including the Interconnection Facility) and thereafter, submit the report of such testing, which report shall be certified by a Professional Engineer, to the Authority and DSP on the 10th and 15th year of the contractual Term.

ATTACHMENT

ATTACHMENT A: Smart Inverter Functions

- Continuous growth of PV generation puts more challenges on grid infrastructure designed for distribution from centralized energy sources. Advanced or smart inverter functions can help address the grid stability problems posed by high levels of variable distributed generation
- Smart inverters are PV inverters that stay connected and provide additional functions to help actively support the grid mainly voltage and frequency.
- Broadly, smart inverters provide some additional benefit to the grid beyond simply converting direct-current (DC) electricity to alternating current (AC) from PV systems. They typically support overall grid reliability by offering the following functions:

No	Functions	Description	Setting
1	Anti-islanding Protection	Automatically disconnect from the grid during power outage	LV:
		within certain duration. The duration is adjustable.	Disconnect 2secReconnect 2min
		Anti-islanding protection is to ensure inverter does not back-feed a disabled grid	MV: • Disconnect 2sec • Reconnect 5min

No	Functions	Description	Setting
2	Voltage and	Inverter must meet the mandatory and	
-	Frequency	permissive operation requirements as	
	Ride-through	well as the must trip limits when the AC	
	Canability	grid voltage and frequency high or low	
	Capability	limits are exceeded	
		Inverters are to support the grid	
		during brief voltage or frequency	
		excursions. This function will help the	
		grid to self-heal from a disturbance.	
		During periods of deviations in grid	
		voltage and/or frequency, smart	
		inverters are designed to remain	
		connected to the grid and adjust their	
		output to act as a counterbalance to	
		frequency or voltage changes	
3	Ramp Rate	The rate of power increase when first	Does not exceed
	Control	ramping (start ramp) and subsequent	15% of rated
		increases in offsetting or selling	capacity per
		(normal ramp)	minute.
		To help smooth transitions from one	Applicable for
		output level to the next. Supports grid	LSS capacity of
		by ramping up slowly giving the grid	5MW and above
		time to adjust to the PV energy coming	
		back online.	

NO	Functions	Description	Setting
NO 4 .	Functions Reactive Power Control Functions	DescriptionInverter is able to supply or absorbreactive power to/from the grid tomaintain stable grid voltage whenfluctuations are prevalent.Variable Power Factor provides active	Setting Voltage range: (MV-11kV) ± 5% (LV- 230V & 400V)
		 voltage stabilization: Grid voltage nominal, purely active power Grid voltage high, add 'inductive' reactive power Grid voltage low, add 'capacitive' reactive power Adjusting VARs keeps grid voltage from oscillating; acts like a shock absorber 	-6% +10% Power Factor range: 0.85 lagging to 0.9 leading
		 The reactive power control can be achieved using 3 main controls: (a) Dynamic Volt/VAr Mode (voltage control) (b) Fixed power factor (pf control) (c) Fixed reactive power (eg: using switched reactor) 	

NO	Functions	Description	Setting
5.	Active Power Control Functions Frequency- Watt (Droop Curve) and Volt-Watt	 Support grid frequency and voltage by changing inverter wattage output. Help to stable the grid during an under/over frequency and voltage event by controlling the real output of the solar system. Grid frequency/voltage nominal, inverter at max output Grid frequency/voltage high, inverter curtails power Grid frequency/voltage low, inverter increases power 	Frequency range: 47Hz to 50.5Hz Voltage range: (MV-11kV) <u>+</u> 5% (LV- 230V & 400V) -6% +10%
6.	Data log/Memory card for event logs	Capture profile of networks parameters – Voltage, Current, Frequency, Power (active & reactive), power factors and events log. The data log can be used for troubleshooting and monitoring purposes.	
7.	Remote monitoring and configurability	Able to control remotely using SCADA system (for capacity 1MW and above)	

References:

- Guidelines On Large Scale Solar Photovoltaic Plant for Connection to Electricity Networks by Suruhanjaya Tenaga
- (ii) TNB Technical Guidebook on Grid-interconnection of Photovoltaic Power Generation System to LV and MV Networks
- (iii) Electricity Order 2017
- (iv) National Grid Code

Disclaimer:

The Appendix A of these Guidelines specifies the technical specifications for distribution-connected LSS that has been prepared for guidance and information purposes only. It does not contain comprehensive information required in designing the LSS facilities. Whilst all reasonable care has been taken in the preparation of the Guidelines, the Authority does not make any representation, warranty or undertaking, expressed or implied, in or in relation to the completeness and or accuracy of information contained in this Guidelines. Therefore, the Authority disclaims all or any responsibility whatsoever to anyone for information contained in the Guidelines or for any representation or statement herein, whether expressed or implied, or for any responses given in response to any queries on or in relation to the Guidelines. All such persons expressly disavow any obligation or duty (whether in contract, tort or otherwise) to any prospective LSS developer and disclaim any and all liabilities based on or relating to any such information or representations or warranties (expressed or implied) contained in, or errors or omissions from, the Guidelines or based on or relating to the use of the Guidelines or any other written or oral communication transmitted to or information provided to or otherwise acquired by a prospective LSS developer.

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