AUTORITI ELEKTRIK NEGARA BRUNEI DARUSSALAM

MINISTRY OF ENERGY

BRUNEI DARUSSALAM

CODE OF PRACTICE FOR LARGE SCALE SOLAR PHOTOVOLTAIC PLANT CONNECTION TO DISTRIBUTION GRID

Revision Record

Revision	Description	Reviewed by	Issued by the Authority	Date
00	First Issue	EO17 Task Force	[signature]	21/7/2020

FOREWORD

Code of Practice for Large Scale Solar Photovoltaic Plant Connection to Distribution Grid is an initiative by Autoriti Elektrik Negara Brunei Darussalam (AENBD), Ministry of Energy, in regulating the generation, transmission and distribution of electricity; and safe use of electricity in accordance to the Electricity Order 2017 (EO17).

This Code of Practice is a technical document meant to facilitate or assist prospective Large Scale Solar (LSS) developers who wishes to seek connection to the distribution grid; and also the relevant Distribution Service Providers (DSP), whose network is to be connected with the LSS power plant. Distribution connected LSS power plant generation capacity range between $1MW_{ac}$ to $30MW_{ac}$.

This Code of Practice does not contain a comprehensive details or information required in the designing of the LSS facilities. It is solely the responsibility of the prospective LSS developer for the interpretation of the information in this Code of Practice.

This Code of Practice is subject to periodical review to keep abreast with the development of technologies, standards, best practices to suit the changing needs of the electricity industry and its stakeholders. Any suggestion or recommendations are most welcomed and to be submitted to AENBD for consideration.

ACKNOWLEDGEMENT

Autoriti Elektrik Negara Brunei Darussalam (AENBD), Ministry of Energy, would like to thank and extend its sincere appreciation to the Electricity Order 2017 Task Force (EO17TF) members, which comprises of officers from AENBD, Department of Electrical Services (DES) and a special review panel invited from the Berakas Power Company Sdn. Bhd. (BPC), for their continuous support, contributions, time and effort which they have put into making this Code of Practice.

DES:

1. Awg. Muhd. Robin Yong bin Abdullah;
2. Awg. Muhd. Farid bin Abdullah;
3. Awg. Asrin bin Haji Muhd. Salleh;
4. Pengiran Shamsuddin bin Pengiran Haji Tuah;
5. Awg. Haji Yusri bin Haji Ali;

BPC:

6. Mr. Stephen Turner;
7. Mr. Caius Yong;

AENBD:

8. Dyg. Hjh Nuriryanty binti Hj Muhd Shah Al-Islam;
9. Dyg. Ayesha binti Abdullah Manggau;
10. Awg. Shaikh Mohd Dzulamali bin Shaikh Hj Abdul Mutalib;
11. Awg. Mohd. Fikri Hasbullah bin Johari.

ELECTRICITY ORDER 2017

CODE OF PRACTICE FOR 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 Code of Practice:

Citation and Commencement

1. This Code of Practice may be cited as the **Code of Practice for Large Scale Solar Photovoltaic Plant Connection to the Distribution Grid**.

2. This Code of Practice shall come into effect on the issued date and will be revised as deemed necessary with a new revised issuance date.

Application of this Code of Practice

3. This Code of Practice is applicable to

   i. any person or entity who wishes to develop a large scale solar power plant and seeking connection to the distribution network;

   ii. the relevant Distribution Service Providers (DSP), whose network is to be connected with the Large Scale Solar (LSS) power plant

Amendment and Variation

4. This Code of Practice at any time, may be updated, modified or revoked as deemed necessary.

Table of Contents

Abbreviations

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

Abbreviations	Description
AC	Alternating Current
AVQC	Automatic Voltage and Reactive Power Control
COD	Commercial Operation Date
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
LILO	Loop-In Loop-Out
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
PSS	Power System Study
PV	Photovoltaic
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition

Abbreviations	Description
THDI	Total Harmonic Distortion Current
VCB	Vacuum Circuit Breaker
VT	Voltage Transformer

Glossary of Terms

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

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;
Authority	Autoriti Elektrik Negara Brunei Darussalam (AENBD);
Commercial Operation Date	Means the date at which all relevant condition precedents under the PPA have been satisfied;
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 Capacity	Means the capacity of solar photovoltaic energy to be generated and delivered to the Grid system at the connection point from the facility for each contract year;

Term	Definition
Contract Year	Means, the date on which the Commercial Operation Date begins and which ends on December 31 of the same year. Each subsequent period during the Term which begins January 1 and ends on December 31 of the same year for a 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, who operates 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 11kV consisting of electric lines or cables, substations and associated equipment and buildings for transporting electricity to any person;

Term	Definition
Distribution System	The system of electric lines with voltage level of 11kV and below, within the Area of Supply operated by a Distribution Service Provider, for distribution of electricity from the Grid Supply Points or Generating Units to Customers or other Distributors and include any electrical plant and meters owned or operated by the Distribution Service Provider 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 Facility or IF	The components that interconnect the LSS and the distribution network. This includes the substation at the LSS, underground cables where the connection to the distribution network is made;
Initial Operation Date or IOD	The date on which the LSS installation first delivers Net Electrical Output to the DSP network for testing purposes;

Term	Definition
Inverter	A machine, device, or system that changes DC power to AC power;
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 LSS	Solar PV Plant connected to 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 11kV;
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 Output or NEO	Means for any period, the amount of solar energy generated and delivered to the DSP at the metering point;

Term	Definition
Power Purchase Agreement or PPA	Agreements between the Distribution 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;
Prudent Utility Practice	The exercise of such degree of skill, 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 Code of Practice is a technical document meant to facilitate or assist prospective LSS developers who are seeking connection to the DSP's Distribution Grid. MW described in this Code of Practice refers to the AC side of the LSS plant. LSS developers and DSP are to comply with the technical requirements in this Code of Practice, in ensuring safety requirements of the LSS PV Plant connection to the distribution grid, all associated equipment and works, operation and maintenance personnel and DSP's distribution grid are met and safe.

2 Scope and Limitation

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

This Code of Practice is 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. 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 the LSS.

The 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 and is fully responsible to obtain right of way (ROW) and permits from relevant local authorities (and/ private land owners if applicable) required for the construction of the Facility, SPP IF, SPP Interconnector, DSP IF and network reinforcement up to the Point of Common Coupling; also design, construct, test, commission and complete the LSS power plant, unless otherwise exempted by the Authority.

3 Connection to the Grid Distribution System

3.1 Background

The connection of the LSS plant is to be made at the existing DSP's substation or a new substation built by the LSS developer. 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 station loading and voltage rise due to power generation could determine the limit of capacity allowed for the LSS power penetration.

3.2 Connection Voltage Level

The LSS plant can be connected to the 11kV 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.

Output from LSS is connected to the DSP's grid. 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 of the LSS plant is to be made at the existing DSP's substation or a new substation built by the LSS developer.

For the purpose of facilitating potential LSS developer, nodal points have to be identified by the DSP 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 panels 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 Power System Study (PSS) which is to be undertaken by the LSS developer at its own cost. The Authority and/ DSP has the rights to review and update/ approve the potential nodal points.

The demarcation of ownership of the plant and system is as illustrated in Figure 1 and Figure 2.

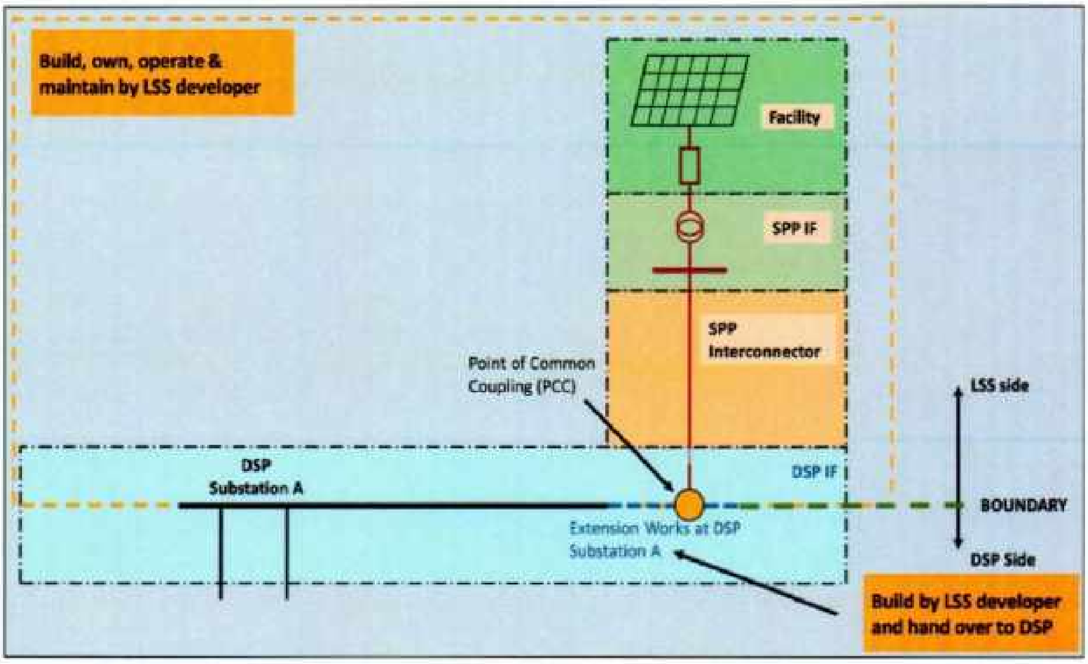

Figure 1: Illustration of Asset Demarcation (Typical connection to existing DSP substation A)

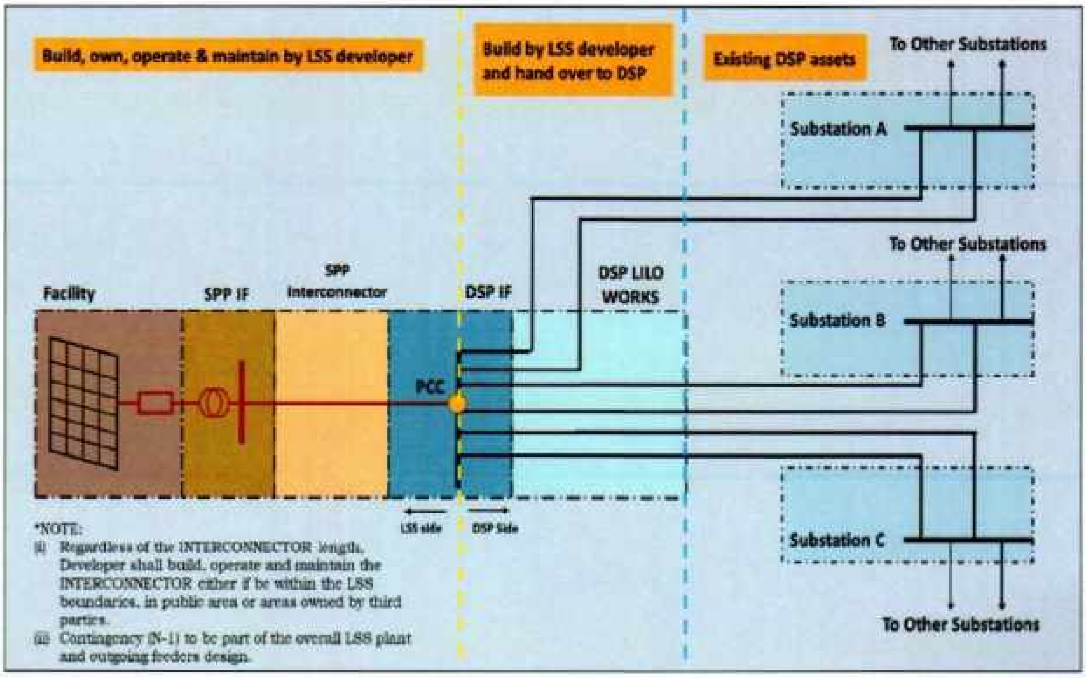

Figure 2: Illustration of Asset Demarcation (Typical connection to existing DSP networks and substations A, B & C)

3.5 Connection Schemes

The interconnection feeder shall be using circuit breaker which shall be provided by the LSS developer (specifications approved by DSP and supplied by vendor in DSP's vendor list). All costs including any modification/extension to the existing substation (Figure 1) in order to accommodate connection of LSS to the distribution 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.

Table 1: Typical Scope of Works for Upgrading

Upgrading at substation	Upgrading at substation
• Replace existing Ring Main Unit (RMU) • Remote Control Box (RCB) • Direct Current(DC) system • Building works as necessary • Meter room	• Extension to existing switchgears (VCB/GIS) • Control Relay Panel (CRP) • SCADA/RTU • Arc protection (where applicable) • Building works as necessary • Meter room

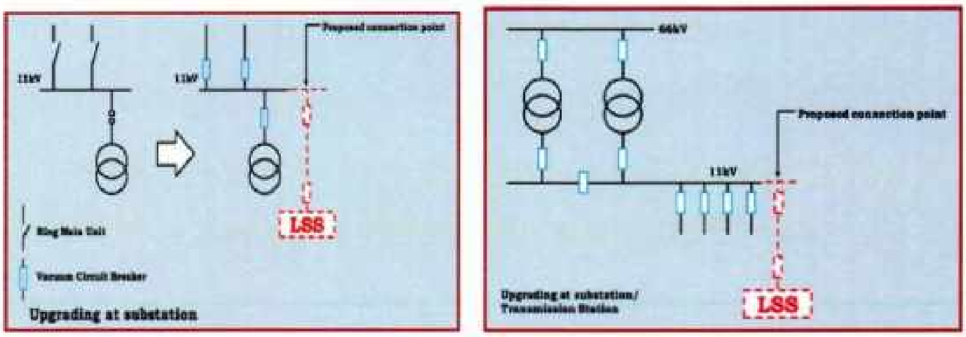

Figure 3: Upgrading of the Switchgears at PCC

3.6 Scope of Interconnection Facilities & Asset Demarcation

The interconnection feeder which connects the LSS plant to the DSP substation shall consists of underground cable to carry only the generated (solar) 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, unless otherwise exempted by the Authority, for the underground cable route and any related land acquisitions.

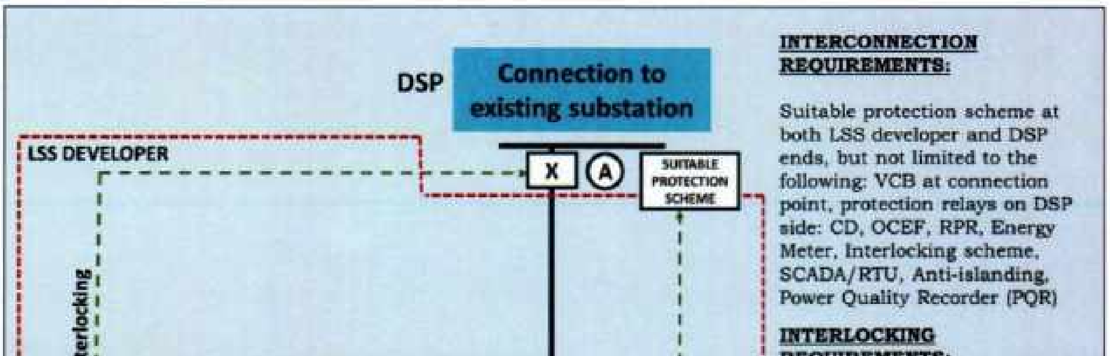

Figure 4: DSP-LSS Interconnection Feeder Scheme

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

(i) Supply of interconnection facilities for LSS and DSP side (Figure 4);

(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 shall be placed at the switchgear 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 Code of Practice are to ensure that the connection of LSS to the distribution system is harmonized 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.

Table 2: Steady State Voltage Limits

Nominal Voltage	Steady state voltage limits
11kV	±5%

4.1.2 Voltage fluctuation

The maximum voltage fluctuation range allowed on the DSP's network due to varying solar radiation is ±10% (IEC 61000). This requirement differs from that for voltage flicker.

4.1.3 Frequency

LSS developer shall maintain plant frequency in accordance to the National Grid Code, to operate in synchronism with distribution system. Nominal system frequency is 50 Hz with normal range of ±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.

Table 3: Distortion limit for Odd Harmonics

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

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.

Table 5: Acceptable Permissible Value at PCC for Voltage Fluctuation and Harmonics

Type Of Disturbance	Indices	Acceptable permissible values at Connection Point	Reference Document
Voltage Flicker	Absolute Short Term Flicker Severity (Pst)	1.0 p.u (132kV and below)	UK's Engineering Recommendation P28
	Absolute Long Term Flicker Severity (Plt)	0.8 p.u (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

p.u = per unit

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

LSS developer is required to ensure that its installation has satisfactory power factor correction and should use reasonable endeavors to maintain its average power factor between Unity and 0.9 lagging as measured at the Connection point, i.e. in compliance with the National Grid Code Section 5.8.4.

4.1.8 Transient Over voltages

Typical Basic Impulse Insulation Levels (BIL) of the distribution system is as indicated in Table 6. 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	95

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	Rated Voltage	Fault Current
11kV	12kV	25kA, 3 second

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 = 0.05 Hz

(iii) Voltage magnitude difference < 2%

(iv) Voltage angle difference = 8 degrees

(v) Pulse duration = 0.2s

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 requirements in this Code of Practice and/ as set by the DSP for connection to distribution grid. DSP shall review the recommended or proposed smart inverters from LSS Developers which are to be used or installed in the LSS PV Plant connection to distribution grid. DSP and/ Authority to approve the proposed smart inverter, upon reviewed by DSP, within due time.

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. Smart inverter functions are outlined in **Attachment A**.

4.1.12 Standard compliance

The LSS plant and its interconnection shall primarily comply with the National Grid Code and the latest IEC standards where applicable.

4.2 Network Support

The LSS plant shall provide support during normal operation to the network to ensure that the system is stable by not disconnecting from the grid.

4.2.1 Low Voltage Ride Thru

During disturbance on the DSP's distribution and transmission system, the 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 5 below.

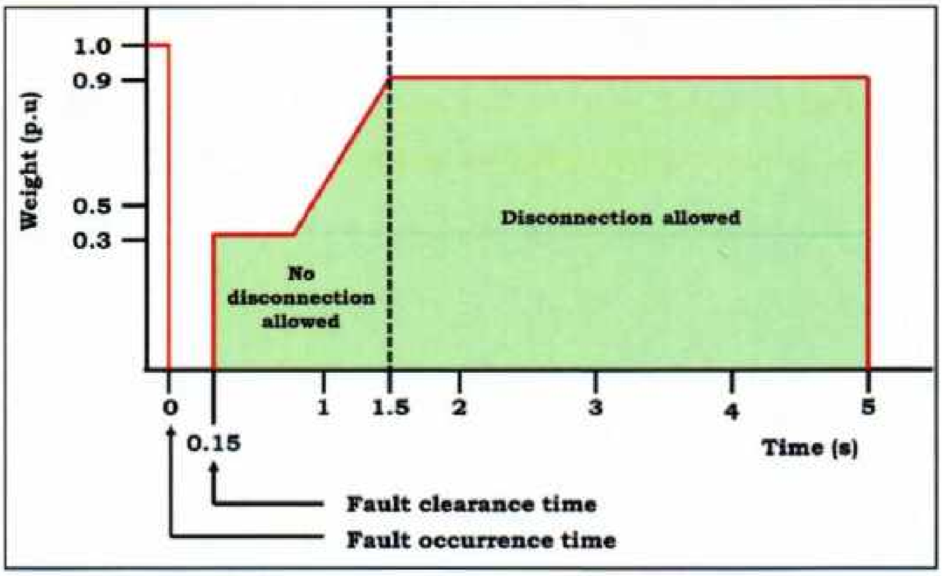

Figure 5: Distribution system voltage fluctuation

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 6.

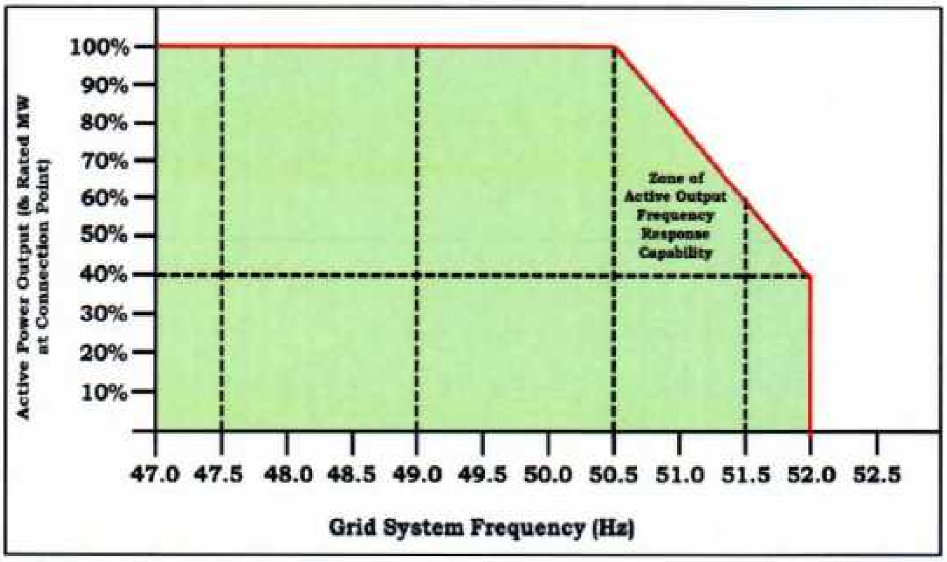

Figure 6: Frequency Disturbance Curve

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 specified 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 Droop curve

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

4.2.5 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 submit the protection scheme and settings to the DSP for approval.

4.3.1 Connection point feeder protection at DSP.

Connection point feeder protection at DSP, the LSS developer shall provide the necessary protection interfacing requirements.

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 the DSP's related networks shall follow the recommendations made by the Power System Study (load flow, fault flow, protection scheme and protection setting) carried out by the LSS developer.

4.3.4 Interlocking of the interconnection feeder

The LSS plant interlocking scheme is under the LSS developer's responsibility and the LSS developer shall submit the interlocking scheme and settings to the DSP for approval.

4.3.5 Protection equipment

The protection relay and Power Quality Recorder (PQR) equipment to be used in the LSS plant shall be communicated to DSP for coordination purposes.

4.3.6 Protection coordination study

LSS developer shall carry out the internal protection coordination study to simulate internal and external faults.

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 (not limited to):

- 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 stated in Section 4.3.3 above (based on Power System Study conducted by LSS Developer).

4.3.8 Reconnection time

The reconnection time of LSS plant to the distribution network shall be more than thirty (30) minutes, communication between LSS developer and DSP is required to ensure no Operation and Maintenance (O&M) personnel working on the network prior to LSS plant reconnection to DSP network or as agreed between the LSS developer and DSP.

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 7 (typical example) to ensure the plant does not contribute zero sequence current to DSP network during fault.

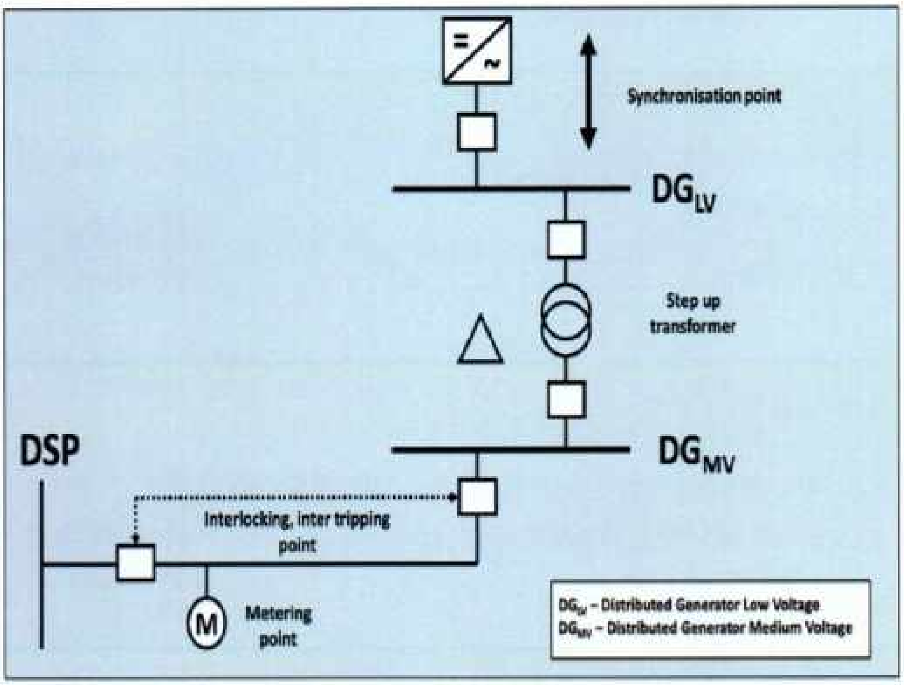

Figure 7: Step up Transformer Earthing Scheme

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;

(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 by LSS developers for each interconnection point and 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 grid is normalised. Contingencies include scheduled and unscheduled outages (not limited to):

i. Network upgrading;

ii. Maintenance;

iii. Shutdown;

iv. Breakdown.

4.5.3 Declared Annual Quantity (DAQ)

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

4.6 SCADA

All equipment wirings (approved by DSP) shall be prepared by the LSS developer. SCADA communication protocol is to be specified by DSP.

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 point of common coupling (connection point) at DSP's distribution system.

4.7.1 Transfer of interconnection facilities

Upon 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 DSP of all rights, title and interests of 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.

4.7.2 Defects in interconnection facilities

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

(i) 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 National Grid Code and/ 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) The defects liability period (DLP) of the defects as defined shall be twelve (12) months from the COD.

5 Metering

5.1 General

All energy meters used for measuring the import and export of electricity shall comply with DSP's specifications and approved by the Authority. DSP shall determine the point at which every supply line shall terminate in order to allow for 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 if and when there is a requirement to do so, at any time, for the purpose of maintenance and meter reading.

5.2 Energy Meter

The Main and Check meters installation at the LSS PV Plant by the LSS developer are subject to DSP's approval, to measure the energy import and export to the distribution grid. The cost borne by the LSS developer will be inclusive of supply and installation for both meters.

5.3 Metering Point

Energy meters are to be installed at the connection point in a dedicated meter room or compartment 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

Any remote communications i.e. fibre optic/Ethernet or latest generation of mobile communication standards relating to the metering equipment and Meters, and connection equipment for remote reading and alarm monitoring will be the responsibility of the DSP.

5.5 Metering Voltage Transformer for 11 kV

The details or specifications for the Inductive type VTs is shown in Table 9.

Table 9: Metering Voltage Transformer

Parameters	Description
Ratio	Vs / √3: 110 / √3V * where Vs is the voltage at metering point
Class	0.5
Burden	50 VA, sharing can be allowed provided separate fusing is provided for each meter
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

5.6 Metering Current Transformer for 11 kV

The details or specifications for the metering current transformer are shown in Table 10.

Table 10: Metering Current Transformer

Parameter	Description
Ratio	Is / 1A * where Is = the secondary 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

5.7 Meter Application and Approval

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

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.

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 Meter Testing

The LSS developer will undertake routine testing of the Meters and of the CTs and VTs every three (3) years or whenever there are any significant deviations in the monthly readings.

In addition, the LSS developer will be required to undertake calibration testing upon request by the Authority and/ DSP. LSS developers are to communicate with the Authority and/ DSP on meter calibration testing and related document. The cost of routine test shall be borne by the LSS developer.

5.10 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 tests as per the DSP requirements.

The LSS developer shall maintain the meter panel or cubicle and its accessories except for the energy meters 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 (not limited to) for IOD as the following:

(i) A practicing certificate (PC) from a Professional Engineer (PE) with a valid practicing certificate (PC) issued by the Board of Architects Professional

Engineers, Quantity Surveyors (BAPEQS) Brunei stating that the interconnection facilities have been designed and constructed in accordance with the current local regulations, guidelines and best practices;

(ii) Copies of approved as-built drawing of the interconnection facilities;

(iii) Copies of IOM approved by the Authority and/ DSP;

(iv) Test results of the Interconnection Facilities;

(v) LSS developer to propose metering scheme for DSP's 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, with only minor outstanding issues (punch list items to be rectified within the mutually agreed timeline).

The submission of a complete IOD document to the Authority and/ DSP, shall be made not more than ninety (90) days of the proposed IOD. The commissioning notification shall be issued by the DSP 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 required 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 and the DSP shall jointly prepare the IOM for the interconnection and approved by the Authority.

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 period 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 Interconnection Facilities' tests are to be carried out by competent personnel engaged by the LSS developer and supervised by the Original Equipment Manufacturer (OEM) or third party authorized by OEM.

6.4 Commissioning Tests for IOD

Commissioning Tests for IOD shall include all related testing for Inverter compliance and Interconnection compliance tests.

All test results shall be certified by competent person engaged by LSS developer and to be submitted to DSP.

6.5 Power Quality Measurements

6.5.1 Pre and 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 the 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 not be 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.

Measurements shall capture the following (not limited to) parameters :

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 not be less than 7 days. The verification tests shall be performed by competent persons engaged by the LSS developer 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) LSS control device equivalent to a 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 11.

Table 11: 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 the DSP the report for COD confirmation consisting of:

(i) Verification for COD – Section 7.1

(ii) Permanent Power Quality Measurements – Section 6.5.2

Upon receipt of the above reports and the necessary approvals from all relevant agencies/authorities, the DSP shall issue a letter of confirmation on COD to the LSS developer.

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 respective side of the connection point;

(ii) The LSS developer shall have their own safety rules and/ safety regulations which shall comply with the Electricity Order 2017 and/ or any other laws in Brunei Darussalam and/ prudent utility practices.

(iii) The LSS developer shall designate a competent 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 Facilities) and thereafter, submit the report of such testing, which shall be certified by the relevant local authorities to the DSP, according to the terms & conditions, intervals, etc. of the LSS developer/DSP Power Purchase Agreement (PPA).

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
1	Anti-islanding Protection	Automatically disconnect from the grid during power outage within certain duration. The duration is adjustable. Anti-islanding protection is to ensure inverter does not back-feed a disabled grid
2	Voltage and Frequency Ride-through Capability	Inverter must meet the mandatory and permissive operation requirements as well as the must trip limits when the AC grid voltage and frequency high or low 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 Control	The rate of power increase when first ramping (start ramp) and subsequent increases in offsetting or selling (normal ramp)
		To help smooth transitions from one output level to the next. Supports grid by ramping up slowly giving the grid time to adjust to the PV energy coming back online.
4.	Reactive Power Control Functions	Inverter is able to supply or absorb reactive power to/from the grid to maintain stable grid voltage when fluctuations are prevalent. Variable Power Factor provides active 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 The reactive power control can be achieved using 3 main controls: (a) Dynamic Volt/VAr Mode (voltage control) (b) Fixed power factor (pf control) Fixed reactive power (e.g.: using

		switched reactor)
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
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)

Disclaimer:

This Code of Practice specifies the technical requirements for distribution-connected LSS. It does not contain a comprehensive information required in designing the LSS facilities. Whilst all reasonable care has been taken into consideration in the preparation of this Code of Practice, the Authority and/ the DSP do 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 Code of Practice. Therefore, the Authority and/ the DSP disclaims all or any responsibility whatsoever to anyone for information contained in this Code of Practice 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 Code of Practice. All such persons expressly disclaims any obligation or duty (whether in contract 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 Code of Practice or based on or relating to the use of the Code of Practice or any other written or verbal communication transmitted to or information provided to or otherwise acquired by a prospective LSS developer.

A prospective LSS developer shall be solely responsible for the interpretation of the information provided to or otherwise acquired by the prospective LSS developer. The prospective LSS developer certifies that it understands, accepts and agrees to the disclaimer on this page. Nothing contained in any other provision of this Code of Practice, nor any statement made orally or in writing by any person or party have the effect of negating or superseding any of the disclaimers on this page.