Technical Requirement for the Connection of Solar Photovoltaic Installation for Self-Consumption in Kulim Hi-Tech Park

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1.0 Objective of the Technical Requirement

1.1 This Technical Requirement shall be based on the requirement set forth by the Energy Commission ("Commission") and is applicable to any parties who are taking part in the development and interconnection of self-consumption solar PV system to NUR's distribution network.

1.2 This Technical Requirement is to outline the SELCO Power System Study scope of work and methodology. The BESS requirement, SELCO PSS scope of work will include the relevant standards and technical threshold limit which must be met. Mitigation plan in the form of general recommendation with consideration shall be included for outcomes beyond the threshold limit.

1.3 This Technical Requirement is based on the requirements set forth by Owner/Utility/NUR for SELCO connection to NUR distribution network.

2.0 Application and Purpose of Technical Requirement

2.1 This Technical Requirement shall apply to the following:

(a) solar PV developers;
(b) service providers, operators; and
(c) parties otherwise involved in the installation and commissioning of SELCO solar PV generation to the grid and Connections at Medium Voltage (MV) and Low Voltage (LV) networks.

2.2 The purpose of these Technical Requirements are as follows:

(a) to identify connection configurations for the distribution-connected SELCO plants to be connected to the Distribution System, taking into account the existing distribution infrastructure within the vicinity of the SELCO plant;

(b) to investigate the impact of the new interconnection to NUR network as well as the impact of NUR network to the operations of the SELCO plant; and

(c) to assess the ability of the distribution-connected SELCO plants to comply with the Technical Requirements as stated in the Grid Code for Peninsular Malaysia and Distribution Code for Peninsular Malaysia, specifically with the solar PV technology to be installed.

2.3 To ensure that the addition of indirect Solar PV power generation system does not adversely impact the quality of supply, these Technical Requirements shall be adhered to by the SELCO consumer.

3.0 Interpretation

In this Technical Requirement, the following terms shall bear the following meanings:

Term	Definition
Act	means the Electricity Supply Act 1990 [*Act 447*];
Apparent Power	means the product of voltage and alternating current measured in kVA or MVA;
Active Power	means the product of voltage and the in-phase component of alternating current measured in units of watts and standard multiples thereof, i.e.: 1000 Watts = 1 kW; 1000 kW = 1 MW; 1000 MW = 1 GW; 1000 GW = 1 TW;
Apparatus	means all types of equipment in which electrical conductors are used, supported or of which they may form a part or **High Voltage** electrical circuits forming part of a **System** on which safety precautions may be applied to allow work and/or testing to be carried out;
BESS	means battery energy storage system which is a device that stores energy;
Bulk Supply Points	means for the purpose of defining the boundaries between the **Main Interconnected Transmission System** and **Bulk Supply Point** transformer circuits, the **Bulk Supply Point** is taken to be the connection point between the **User System** and the **Transmission System**;
Busbar	means the common connection point of two or more transmission circuits;
Commission	means the Energy Commission;
Connection Point	means the interface point on a consumer's installation with the licensee's electricity supply network;

Consumer	means an owner or occupier of a premises who is supplied or requires to be supplied with electricity by the licensee;
Damping Ratio	means a term used to describe the rate at which the amplitude of a power system oscillation frequency, represented by a complex pair of eigenvalues (σ±jω), will decay as given by the expression: $\zeta\,(\%) = \frac{-\sigma}{\sqrt{\sigma^2 + \omega^2}} \times 100$ where ζ is termed as the **Damping Ratio**;
DC Converter	means all items of **Plant** and **Apparatus** connected together on the direct current side of a **DC Converter**;
Demand	means the demand of MW or MVAr of electricity (i.e. both **Active Power** and **Reactive Power** respectively) unless otherwise stated;
Demand Supply Point	means a point of supply from the **Transmission System** to **Distribution Networks**, **Network Operators** or **Non-Embedded Customers**;
Directly Connected Customers	means **Users** connected directly to the **Transmission System** without any connection through and intermediate **Distribution System**;
Distributed Generator	means **Generating Units** directly connected to the **Distributor**'s **Distribution System** and not having any connection with the **Transmission System**;
Distribution Equipment	means any item for such purposes as generation, conversion, transmission, distribution or utilization of electrical energy, such as machines, transformers, **Apparatus**, measuring instruments, protective devices, wiring materials, accessories and appliances at distribution voltage level;
Distribution System (or Distribution Network)	means the **System** consisting wholly or mainly of electric lines which are owned

	or operated by a **Distribution Licensee** and used for the distribution of electricity from **Bulk Supply Points** or **Generating Units** or other connections to **External Systems** to the point of delivery to customers and includes any **Plant** and **Apparatus** and meters owned or operated by the **Distribution Licensee** in connection with the distribution of electricity, typically operating at voltage levels of 132kV, 11kV and 415V, but does not include any part of the **Transmission System**;
Distributor	means a person who is licensed under section 9 of Act 447 and is connected to the **Grid System** and distributes electricity for the purpose of enabling a supply to be given to any premises. "Distribute" means to operate, maintain and distribute electricity through the electricity distribution network;
Distribution Licensee	means a holder of a licence to distribute issued by the **Commission** under section 9 of Act 447;
Engineering Recommendation P28	means the "Engineering Recommendation P28, Issued by The Electricity Council of UK in 1989 entitled "Planning Limits for Voltage Fluctuation Caused by Industrial, Commercial and Domestic Equipment in the United Kingdom"";
Equipment	has the meaning assigned to it under the Act 447;
Electric Power System	means all the elements encompassing the production, transmission, distribution, and delivery electric power to **Users**;
Externally Interconnected Party	means a person who operates an **External System** which is connected to the **Transmission System** or a **Distribution System** by an **External Interconnection**;

External Interconnection	means **Apparatus** for the transmission of electricity to or from the **Transmission System** or a **Distribution System** into or out of an **External System.** For the avoidance of doubt, a single **External Interconnection** may comprise several circuits operating in parallel;
External System	means in relation to an **Externally Interconnected Party** means the transmission or distribution system which it owns or operates which is located outside Peninsular Malaysia and any **Apparatus** or **Plant** which connects that system to the **External Interconnection** and which is owned or operated by such **Externally Interconnected Party**;
Fault Outage(s)	means an outage due to an event occurring on electric system such as a short circuit, a broken wire or intermittent correction;
Flicker	means the sensation experienced by the human visual system when subjected to changes occurring in the illumination intensity of light sources. Persistent and rapid varying illumination due to the **System** voltage changes caused by rapidly varying **Loads** such as arc furnaces can cause annoyance and adverse effects;
Flicker Severity (Long Term)	means a value derived from 12 successive measurements of **Flicker Severity (Short Term)** (over a two-hour period) and a calculation of the cube root of the mean sum of the cubes of 12 individual measurements, as further set out in **Engineering Recommendation P28**;
Flicker Severity (Short Term)	means a measure of the visual severity of **Flicker** derived from the time series output of a **Flicker** meter over a ten-minute period and as such provides an

	indication of the risk of customer complaints;
Fluctuating Load	means the types of non-linear **Loads** connected to **Electric Power Systems** causing rapid voltage fluctuations due to rapid variations in their active and reactive requirements dictated by the nature of the associated process or the process control requirements. Typical examples of such **Loads** are resistance welding machines, rolling mills, arc furnaces, arc welders, saw/woodchip mills, rock crushers and large-scale lasers;
Frequency	means the number of alternating current cycles per second (expressed in Hertz) at which the **Transmission System** is running;
Generation Circuit	means the sole electrical connection between one or more **Generating Units** and the **Main Interconnected Transmission System**, i.e. a radial circuit which if removed would disconnect the **Generating Units**;
Generating Unit	means any **Apparatus** which produces electricity;
Generator	means a person or company who generates electricity under a licence granted by the **Commission** under Act 447 acting in its capacity as a **Generator** in Peninsular Malaysia;
Grid Owner	means the party to use, work or operate the **Transmission System** and **Distribution System** in Kulim Hi-Tech Park which is represented by NUR Distribution;
Grid System	means the **Transmission System** with directly connected **Generating Unit** including **Power Park Module** and **Directly Connected Customers**;
Harmonic Distortion	means the cyclic departure of a waveform from the sinusoidal shape. This can be described by the addition of

	one or more harmonics to the fundamental;
High Voltage	means a voltage normally exceeding medium voltage but equal to or not exceeding 230 000 volts;
IEC	means the International Electrotechnical Commission;
IEEE	means the Institute of Electrical and Electronics Engineers;
Immunity Level	means the maximum level of a given electromagnetic disturbance on a particular device, equipment or system for which it remains capable of operating with a declared degree of performance;
Installation	has its meaning assigned thereto in the Electricity Supply Act 1990;
Intermittent Power Source	means the primary source of power for a **Generating Unit** that cannot be considered as controllable, e.g. wind or solar;
Licensee	has the meaning assigned to it under the Act 447;
Load	means the **Active Power**, **Reactive Power** or **Apparent Power**, drawn by the particular installation or equipment connected to the **Transmission or Distribution System**;
Low Voltage	has the meaning assigned to it under the Electricity Regulations 1994;
MITS	means the **Main Interconnected Transmission System** which comprises all the 500kV and 275kV elements of the **Transmission System** but excludes **Generation Circuits**, transformer connections to lower voltage **Systems** and **External Interconnections** between the **Transmission System** and **External Systems**;
Main Protection	means the protection equipment or system expected to have priority in initiating either a fault clearance or an

	action to terminate an abnormal condition in an **Electric Power System**;
Medium Voltage	has the meaning assigned to it under the Electricity Regulations 1994;
MW	means megawatt or 1,000 kW in a.c. rating;
MWh	means megawatt-hour;
Network Operator	means a person with a **System** directly connected to the **Transmission System** to which customers and/or **Power Stations** (not forming part of that **System**) are connected, acting in its capacity as an operator of that **System**, but shall not include a person who operates an **External System**;
Non-Embedded Customer	means a customer in Peninsular Malaysia, except for a **Network Operator** acting in its capacity as such, receiving electricity direct from the **Transmission System** irrespective of from whom it is supplied;
NUR	means NUR Distribution Sdn Bhd (Company No: 407806-X), a company with the address at Lot 30, Jalan Hi-Tech 4 Kulim Hi-Tech Park 09000 Kulim, Kedah, Malaysia;
Operational Planning	means planning through various timescales the matching of generation output with forecast **Demand** together with a reserve of generation to provide a margin, taking into account outages of certain **Generating Units** or **Power Park Modules**, of parts of the **Grid System** and of parts of **User Systems** to which **Power Stations** and/or **Consumers** are connected, carried out to achieve, so far as possible, the license standards;
Phase Unbalance	means the inequality between the magnitudes of the three phase voltages

	at a specific point on the **Transmission System** where there is an appreciable difference due to either the inequalities between the **Load** connected to each phase and/or the inequalities of transmission line impedances in each phase due to their geometry;
Plant	means fixed and movable items used in the generation and/or supply and/or transmission of electricity, other than **Apparatus**;
PCS	means Power Conversion Subsystem or Power Conversion System;
Point of Common Coupling	means a point of connection of **Fluctuating Loads** to the NUR **Electric Power System** where other customers which may be adversely affected by such **Loads** are also connected;
Point of Interconnection	means the point where the electrical installation of the **SELCO Consumer** is physically connected to the **Supply System**, where: (a) for supply at **Low Voltage**, the point is at the cutoff fuse; and (b) for supply at **Medium Voltage**, the point is at the incoming switchgear at the **Premises** of the **SELCO Consumer**;
Power Factor	means the ratio of **Active Power** to **Apparent Power**;
Power Park Module	means a collection of one or more non-synchronous **Generating Units** (registered as a **Power Park Module** under the **PC**) that are powered by an **Intermittent Power Source**, joined together by a **System** with a single electrical point of connection directly to the **Transmission System**. The

	connection to the **Transmission System** may include a **DC Converter**;
Power Station	means an installation comprising one or more **Generating Units** (even where sited separately) owned and/or controlled by the same **Generator**, which may reasonably be considered as being managed as one Power Station;
Pre-disturbance Voltage Limits for Planning Studies	means the voltage limits applicable in planning studies are as defined in section 4.2.2 of the Transmission System Reliability Standard;
Premise	means any building together with its land, outbuildings and any structures within the same compound occupied or used by the **Consumer**;
Prevailing System Conditions	means conditions on the **Transmission System** prevailing at any given time and will therefore normally include arranged outages (e.g. for maintenance) and unplanned outages (e.g. fault);
PSS	means Power System Study, a technical analysis or system check carried out or caused to be carried by the **Grid Owner** or any other party endorsed by **Grid Owner** to assess the potential impact of the proposed solar PV installation under the **SELCO** programme on the planning and operation of the network of the **Grid Owner**, covering both the Consumer's network and the entire network of Kulim Hi-Tech Park, to which the solar PV installation will be connected;
PV	means photovoltaic;
Reactive Power	means the product of voltage and current and the sine of the phase angle between them measured in units of volt-amperes reactive and standard multiples thereof, i.e.: 1000 VAr = 1 kVAr;

	1000 kVAr = 1 MVAr;
Secured Contingency Event	means a contingency which would be considered for the purposes of assessing system security and which must not result in the loss of supply/demand and cause the remaining **Transmission System** to be in breach of the **Security Criteria** with respect to performance limit;
Security Criteria	has its meaning assigned thereto in the Transmission System Reliability Standards Clause 3.2.1;
SELCO	means self-consumption;
Solar PV System	means solar photovoltaic system, a system converting sunlight directly to electricity which comprise of PV cells, PV modules, solar inverter, the associated switching, protection and control devices, cables, and other related equipment and devices;
Steady State	means a condition of a power system in which all automatic and manual corrective actions have taken place and all operating quantities that characterises it can be considered constant for the purpose of analysis;
Supply System	means the **Distribution System** and/or **Transmission System** used, worked or operated by the **Grid Owner** within Kulim Hi-Tech Park;
System	means any **User System** and/or the **Transmission System**, as the case may be;
Thermal Rating	means the maximum amount of electric current that a transmission line or electrical facility can conduct over a specific time period before it sustains permanent damage by overheating or before it sags to a point that it violates public safety requirement;

Total Harmonic Distortion	means the departure of a waveform from sinusoidal shape that is caused by the addition of one or more harmonics to the fundamental. **Total Harmonic Distortion** is the square root of the sum of the squares of all harmonics expressed as a percentage of the magnitude of the fundamental;
Transmission Circuit	means part of the **Transmission System** between two or more circuit-breakers which includes, for example, transformers, reactors, cables and overhead lines but excludes **Busbars** and **Generation Circuits**;
Transmission System	means NUR's **Transmission System** which comprises all the 132kV elements but excludes **Generation Circuits**, transformer connections to lower voltage **Systems** and **External Interconnections** between the **Transmission System** and **External Systems**;
TSRS	means the Transmission System Reliability Standards;
Unacceptable Voltage Conditions	means the voltage is unacceptable for Steady State voltages if it is outside the limits as set out in section 5.1.2.2 and section 5.1.7.2 of this Technical Requirement. For Voltage Step Changes and secured contingency events, the voltage is unacceptable if it changes by more than the limits set out section 5.1.3.1 and section 5.1.8.1 of this Technical Requirement;
Unsecured Contingency Events	means a set of rare unplanned simultaneous or multiple contingencies which would be considered for the purposes of assessing system security and robustness, which could cause

	disruption to parts of the **System** and cause loss of customer demand against which special protection and defence measures are incorporated in planning and operating the **Transmission System**. These types of contingency event are listed in category C and D of**Error! Reference source not found.** Table 5.4: Summary of System Performance Requirements Following Events Involving Loss of Single or More Grid System Elements under Both Normal and Emergency Conditions of this Technical Requirement;
User	means any person connected to and using the **Transmission or Distribution System**;
User System	means any **System** owned or operated by a **User** comprising **Generating Units** and/or **Systems** consisting (wholly or mainly) of electric lines used for the distribution of electricity from **Demand Supply Points**;
Volt	means voltage;
Var	means volt-amps reactive;
Weak System	means a system condition at minimum generation with short outages of transmission lines or Kulim Hi-Tech Park operating in islanded mode;

4.0 Battery Energy Storage System (BESS) Requirement

4.1 The installation of a BESS alongside the Solar PV system is required and mandatory for the provision of BESS for SELCO application in Kulim Hi-Tech Park.

4.2 The BESS capacity, measured in MWh, should be sufficient to support at least one hour of full export capacity (MWac) of the Solar PV system.

For instance, if the Solar PV system has an export capacity of X MWac, it shall be paired with a BESS of not less than 1 x X MWh with X MWac of BESS output active power.

The sizing of the BESS may be higher depending on the specific application and requirements of the BESS and the PSS study outcome. The sizing of output active power of BESS and capacity shall be based on the application that the BESS are intended for, lifetime and ageing of components, possible performance degradation of BESS over the lifetime etc. The applications of BESS shall include but not limited to frequency regulation, voltage regulation, power factor correction, and PV smoothing.

4.3 BESS to be connected to the Distribution System and at the Consumer interface shall adhere to the technical standards outlined in IEEE 1547 and IEC 62116 and shall be compatible with the parameters of the Distribution System, which include voltage, frequency, current rating, short circuit current rating, and insulation level.

4.4 The installed capacity of the BESS shall not result in any power export to NUR grid and an appropriate limiting device must be implemented to prevent any unintentional export.

4.5 A site acceptance test of BESS shall be carried out to demonstrate that the BESS is in accordance with the applicable system specifications and installation instructions.

4.6 A BESS site acceptance test report shall be prepared and a copy of the site acceptance test report shall be submitted to NUR.

4.7 In the site acceptance test, test and checks shall be performed such as test of the monitoring functionality, inspection and recording of operation conditions, partial and complete inspection of protection function of BESS, and inspection for the operating environment of the BESS. In addition to the above test items, other functional tests shall include but not limited to frequency regulation, voltage regulation and power quality support can be conducted.

4.8 The maintenance and operation tests of the BESS shall be carried out annually by referring to the manufacturer's manual.

4.9 A maintenance plans shall be established and include maintenance items to be inspected and commissioned.

4.10 A maintenance report shall be prepared and a copy of the maintenance report shall be submitted to NUR and shall include but not limited to—

(a) the date of creation of maintenance report;
(b) the information on the responsible individual for the preparation and submission of the maintenance report;
(c) the periodical maintenance items; and
(d) the documentation of executed maintenance works, such as visual inspections, installation status maintenance, protection status maintenance, measurement of operation metrics, and functional test.

4.11 The operation metrics and measured values (energy capacity in MWh, output active power in MW etc.) of the BESS and its subsystems shall be within the normal range and functional test shall be conducted. Specific maintenance requirements in terms of BESS technologies shall refer to IEC TS 62993-3-2 Annex C.

5.0 PSS Requirements for SELCO Solar PV System Installation

PSS Scope of Study

The aim of this study is to assess the proposed SELCO Solar PV System capability to comply with the Grid Code for Peninsular Malaysia – Main Code and Additional Codes ("MGC"), Distribution Code for Peninsular Malaysia, Sabah and F.T. Labuan (MDC), the TSRS and NUR Tariff Booklet. The scope of the PSS Study covers the Consumer's network and the entire network of Kulim Hi-Tech Park. The studies required for SELCO Solar PV system are tabulated as below:

No	Item	Description / Requirements	Standards/ Guide
1	Power Flow Analysis	*(a)* to evaluate the Grid System's adequacy to accommodate the energy delivered by the facility without violating the thermal loading and voltage level of distribution and transmission elements for example the overhead line, underground cable, transformer etc. under normal conditions; and *(b)* the power flow shall consider various operating conditions or scenarios to reflect the facility's intermittent behaviour.	TSRS Clause 4.2, TSRS Clause 4.10, MDC Clause 5.4.4.1 and MDC Clause 6.5.2.1
2	Power Factor Correction	Evaluating the power factor at the consumer's NUR meter with the proposed plant to ensure the consumer's power factor are kept at a minimum of 0.85 for electricity supply less than 132kV and 0.90 for electricity supply 132kV and above.	NUR Tariff Booklet Clause 4.2

3	Contingency Analysis	to identify the performance of the Grid System with respect to the power flow and voltage during loss of distribution and transmission element.	TSRS Clause 4.11, MDC Clause 5.4.4.2 and MDC Clause 6.5.2.1
4	Short Circuit Analysis	*(a)* to provide short circuit ratings data for the selection of equipment. *(b)* to identify mitigations to ensure short circuit fault level remains within limits. *(c)* to calculate the maximum short circuit fault current contribution from the facility at the Interconnection Point in the event of single-phase fault to ground fault and bolted three-phase fault events. *(d)* the IEC 60909 calculation method is to be used.	TSRS Clause 4.7 and MDC Clause 5.4.9
4	Transient Stability Analysis	to identify the Grid System's capability to remain stable and maintain synchronism following a relatively large disturbance arising from loss of distribution and transmission elements or generation facilities.	TSRS Clause 4.5 and 4.11
5	Fault Ride-Through Capability	*(a)* to identify the fault ride-through capability of the facility (monitored at the Interconnection Point) for faults that may occur in the Grid System including three phase fault for 150ms at the Interconnection Point. *(b)* to identify solar PV inverters' and/or BESS bidirectional inverters' performance upon fault clearance. *(c)* to verify the AC voltage recovery of the facility under dynamic conditions and such scenarios as	MDC Clause 6.5.5.1

		mutually agreed by NUR and Consumer. *(d)* to verify the capability of high voltage ride-through (HVRT) feature in inverter during high voltage condition (1.1pu) at the Point of Interconnection. *(e)* the scheme of low voltage ride-through/high voltage ride-through (LVRT/HVRT) in dynamic simulation shall reflect the actual protection scheme for the actual plant testing & commissioning.	
6	Quality of Service (Power Quality Requirement)	*(a)* to assess power quality (PQ) at the interconnection point during parallel operation of the facility in the Grid System and to determine mitigations and/or modification to ensure the PQ at the interconnection point remains within the allowable limits as specified in the following standards: (i) Voltage harmonics (Engineering Recommendation ER G5/4-1); (ii) Phase voltage unbalance (Engineering Recommendation P29) (iii) Voltage fluctuation and flicker (Flicker Severity (Long Term) and Flicker Severity (Short Term)) (Engineering Recommendation P28) (iv) Current harmonics (as per IEC 61727-2004 Table 1) *(b)* the study shall utilize PQ data from the first field measurement	Engineering Recommendation ER G5/5, ER P29, ER P28, IEC 61727-2004 Table 1

		test by the PQ tester. Such test shall be conducted at the existing NUR's substation(s) to consumer. The study shall also utilize the inverter's current harmonics spectrum. *(c)* to determine the necessity (if any) of modification to the design of the facility and/or to install filters/compensation equipment to meet the PQ requirements.	

Note: The Inverter dynamic model shall represent the actual installed inverter characteristic in the solar PV plant.

5.1.1 Power Flow Analysis

5.1.1.1 Pre-disturbance Voltage Limits for Planning Studies and Unacceptable Voltage Conditions are defined as set out in Clause 4.2.2 of the Transmission System Reliability Standards.

5.1.1.2 The System's operation is planned within the timeframes of Operational Planning, ensuring compliance with the Pre-disturbance Voltage Limits for Planning Studies listed in Table 5.1.

Furthermore, the System is operated under Prevailing System Conditions to prevent the occurrence of any Unacceptable Voltage Conditions during a Secured Contingency Event such as a Fault Outage.

However, in rare instances of Unsecured Contingency Events, certain sections of the System may encounter Unacceptable Voltage Conditions, potentially leading to a complete loss of supply voltage in specific areas.

5.1.1.3 The voltage limits that are relevant to planning studies for the pre-disturbance or pre-fault condition of the Transmission System can be found in Table 5.1 below:

Nominal voltages	Maximum	Minimum (Note 2)
132kV	139kV (+5%)	132kV (-0.0%) (Note 1)

Table 5.1: Pre-disturbance voltage limits for planning studies

Note 1: There is no specific minimum voltage requirement for planning purposes, as long as it is feasible to achieve at least 105% of the nominal voltage at the Busbar of the same nominal voltage, typically through means such as tap changing, at the Demand Supply Point where the voltage is derived from.

Note 2: During the planning stage, it is assumed that the load power factor at the 132kV bus is not less than 0.9.

5.1.1.4 The thermal loading limits of equipment in planning timescales for transmission system is defined in Table 5.2 below:

Equipment	Planning
Lines	No thermal overloading allowed
Underground cables	No thermal overloading allowed
Transformer	No thermal overloading allowed
Switching and Isolation Equipment	Strict observation of equipment continuous rating

Table 5.2: Thermal loading limits on transmission components

5.1.1.5 During normal operation, when all circuit elements are active, the voltage levels at all locations within the Distributor's Distribution System, including points before the Consumer Connection Point, should be planned to be maintained as follows:

(a) Medium Voltages of 11 kV and 33 kV should be within ± 5% of their nominal voltage; and

(b) Low Voltages of 400 V and 230 V should be within +10% and -6% of their nominal voltage.

5.1.1.6 During normal operation, the loading on the Distribution System remains within the continuous ratings of the Distribution Equipment.

5.1.2 Contingency Analysis

5.1.2.1 During these operational activities, it is essential to ensure that switching any element or equipment does not result in unacceptable voltage step changes. A voltage change is considered unacceptable if it exceeds the limits specified in

5.1.2.2 Table *5.3* below:

System Condition	**Planning Timescales** ***Note 1***	
	Voltage Rise	**Voltage Fall**
Following Secured Contingency Events	+10%	-5% for others ***Note 2***
Otherwise	According to ER P28	

Table 5.3: Unacceptable voltage step changes in planning and operation

Note 1**:** These limits apply at all demand conditions and only to the interfaces between the Transmission System and Consumers and must be applied with the Load response to voltage change taken into account.

Note 2**:** This is relaxed to -12% if the fault involves the loss of a section of Busbar, or a mesh corner.

5.1.2.3 Table *5.4* provides a summary of the performance expectations and requirements for the transmission system in relation to four (4) categories of contingencies.

For each category, the table outlines:

(a) the specific initiating events and contingency elements, and
(b) the defined system performance requirements and expected impacts.

Category	Contingencies		System Limits or Impacts	
	Initiating Event(s) and Contingency Element(s)	**System Stable & both Thermal and Voltage Limits within Applicable Rating *Note (a)***	**Loss of Demand or Curtailed Firm Transfers**	**Cascading Outages**
A No Contingencies	All Facilities in Service	Yes	No	No
B Event resulting in the loss of a single element	Single Line Ground (SLG) or 3-Phase (3Ø) Fault with Normal Clearing (***Note (e)***):			
	1. Generator	Yes	No	No
	2. Transmission Circuit	Yes	No	No
	3. Transformer	Yes	No	No
	Loss of an Element without a Fault	Yes	No ***Note (b)***	No
C Event(s) resulting in the loss of two or more (multiple) elements	SLG Fault, with Normal Clearing			
	(***Note (e)***): 1. Bus Section	Yes	Planned/ Controlled	No

	2. Breaker (failure or internal fault)	Yes	Planned/ Controlled ***Note (c)***	No
	SLG or 3Ø Fault, with Normal Clearing (***Note (e)***). Manual System Adjustment, followed by another SLG or 3Ø Fault, with Normal Clearing (***Note (e)***): 3. Category B (B1, B2, B3 or B4) contingency, manual system adjustments, followed by another Category B (B1, B2, B3 or B4) contingency	Yes	Planned/ Controlled ***Note (c)***	No
	SLG Fault, with Delayed Clearing (stuck breaker or protection system failure) ***(Note (e)***):		***Note (c)***	

	6. Generator	Yes	Planned/ Controlled	No
	7. Transformer	Yes	Planned/ Controlled	No
	8. Transmission Circuit	Yes	Planned/ Controlled	No
	9. Bus Section	Yes	Planned/ Controlled	No
D Extreme event resulting in two or more (multiple) elements removed or Cascading out of service *Note (d)*	3Ø Fault with Delayed Clearing (stuck breaker or protection system failure) **(Note (e)**): 1. Generator 2. Transmission (Circuit) 3. Transformer 4. Bus Section 3Ø Fault with Normal Clearing (**Note (e)**) : 5. Breaker (failure or internal Fault) 6. Loss of tower with three or more circuits 7. Loss of all transmission lines on a common right-of way 8. Loss of a substation (one voltage level plus transformers) 9. Loss of a switching station (one voltage level plus transformers) 10. Loss of all generating units at a station. 11. Loss of large Load or major Load centre 12. Failure of a fully redundant Special Protection System to operate when required 13. Operation, partial operation, or misoperation of a fully redundant Special Protection System in response to an event or abnormal system condition for which it was not			Elevate for risks and consequences: • May involve substantial loss of Consumers Demand and generation in a widespread area or areas • Portions or all of the interconnection systems may or may not achieve a new, stable operating point. • Evaluation of these events may require joint studies with neighbouring systems.

	intended to operate 14. Impact of severe power swings or oscillation from Disturbances in another Interconnected Systems	

Table 5.4: Summary of System Performance Requirements Following Events Involving Loss of Single or More Grid System Elements under Both Normal and Emergency Conditions

Note:

(a) the term "Applicable rating" refers to the Thermal Rating (normal and emergency) applicable to the facility or the system voltage limit, as determined and consistently applied in accordance with Table 5.7 of this Technical Requirement. It may also include emergency ratings for short durations, which are necessary for maintaining system control.

(b) in certain areas, the planned or controlled interruption of electric supply to radial Consumers or local network Consumers connected to or supplied by the faulty element or affected area may occur without significant impact on the overall reliability of the interconnected transmission systems. System adjustments, including curtailing contracted firm power transfers, are allowed to prepare for the next contingency.

(c) depending on the system design and expected impacts, controlled interruption of electric supply to Consumer (load shedding), planned removal from service of certain generation, and/or curtailment of contracted firm power transfers may be necessary to maintain the overall reliability of the interconnected transmission systems.

(d) Critical extreme contingencies listed under Category D will be selected for evaluation. It is not expected to evaluate all possible facility outages for each listed contingency in Category D.

(e) Normal clearing refers to the expected fault clearance time when the protection system functions as designed and clears the fault within the normal timeframe as set out in Table 5.6 of this Technical Requirement.

Delayed clearing occurs when a fault is not cleared within the normal timeframe due to failure of any protection system component, such as a relay, circuit breaker, or current transformer. Three-phase delayed clearing refers to a scenario where a three-phase fault is cleared within the normal clearing time, followed by a single line-to-ground fault cleared after a delay (representing a stuck breaker or protection system failure). Typical delay times are around 250 milliseconds.

5.1.2.4 During contingency situations, where one or more circuit elements are experiencing outages, the Steady State voltage levels at all locations within the Distributor's Distribution System, including points before the Consumer's Connection Point, should be planned to be maintained as follows:

(a) Medium Voltages of 11 kV and 33 kV should be within ± 10% of their nominal voltage; and

(b) Low Voltages of 400V and 230 should be within +10% and -6% of their nominal voltage.

5.1.2.5 In the event of any single circuit outage, the loading on the Distribution System remains within the continuous ratings of the Distribution Equipment.

5.1.3 Power Factor Requirement Analysis

5.1.3.1 Consumers shall adhere to the requirement of maintaining a minimum load power factor of 0.85 for voltage levels below 132kV, and a minimum load power factor of 0.90 for voltage levels of 132kV and above.

5.1.4 Short Circuit Analysis

5.1.4.1 The planning of the Transmission System shall ensure that the maximum sub-transient three-phase symmetrical short circuit fault levels do not exceed 90% of the short-circuit ratings of the switching equipment. Additionally, the breaking and making capacities of the switching equipment should not be surpassed during the most severe system short circuit scenario.

5.1.4.2 The maximum sub-transient short circuit fault levels for both three-phase and single-phase-to-earth faults should not exceed the values specified in Table 5.5 as per the planned requirements.

System Voltage (kV)	Circuit Breaker Short Circuit Rating Break Capacity
132	40kA, 3s
33	31.5kA, 3s
11	25kA, 3s

0.400 and 0.230	31.5kA, 3s

Table 5.5: Short circuit limits

Note: Generally, the closing-and-latching (momentary) capability of a circuit breaker, measured as an rms current, is typically not greater than 1.6K times the symmetrical short circuit rating. Alternatively, if measured as an instantaneous peak current, it should not exceed 2.7K times the symmetrical short circuit rating. In the case of most circuit breakers, the value of K is equal to one.

5.1.4.3 The planning of the Distribution System shall ensure that the maximum sub-transient three-phase symmetrical short circuit fault levels do not exceed 90% of the design short circuit break and make capacity of the switchgear connected to the Distribution System. Additionally, these fault levels should be within 90% of the short time current rating of the Equipment connected to the Distribution System.

5.1.4.4 Short circuit levels shall be calculated following the guideline outlined in the IEC 60909 and the calculations should consider the contribution of Generating Units and motors to the short circuit level.

5.1.4.5 The Consumer is responsible for ensuring that the Equipment to be connected to the Distributor's Distribution System has a short circuit rating that is equal to or higher than the design fault level at the point of connection.

5.1.4.6 Upon the Consumer's request, the Distributor shall furnish information about the design short circuit level. Additionally, the Distributor shall share any anticipated future changes in these parameters.

5.1.4.7 Upon the request of the Distributor, the Distributed Generator shall provide details regarding the design short circuit level and the actual prospective maximum short circuit level.

5.1.4.8 The Distributed Generator shall reduce its fault current contribution upon reasonable request from the Distributor in the event of high fault current in Distributor’s Distribution system.

5.1.5 Transient Stability Analysis

5.1.5.1 The relative rotor angle of any two Generating Units in the System shall be maintained within 180 degrees at any time.

5.1.5.2 After any disturbance occurs, it is imperative that the Damping Ratio of power, angle, or voltage oscillation remains at a minimum of 5% or higher.

5.1.5.3 The performance expectations and requirement for the transmission system in relation to four categories of contingencies as per stated in section 5.1.2.3. The table outlines specific initiating events, contingency elements, defined system performance requirements, and expected impacts for each category.

5.1.5.4 The Main Protection equipment installed in the Transmission System is anticipated to provide the following maximum fault clearance times, as indicated in Table 5.6 below:

System Voltage (kV)	Fault Location	Fault Clearance Time (ms)
132	Substation	150
	Overhead Line/Cable	150

Table 5.6: Maximum Fault Clearing Times

5.1.5.5 During planning studies, the fault clearance time of 150ms should be utilized for systems with a nominal voltage of 132kV. Fault clearance time refers to the duration between the inception of a fault and the complete disconnection of the faulty equipment from the Transmission System.

5.1.5.6 Once a fault has been cleared and the faulty equipment has been disconnected from the Transmission System, but before reaching Steady State conditions as described in sections 5.1.2.1 above, any voltage outside the limits specified in Table 5.7 below is considered unacceptable at any location within the MITS.

Low voltage	High voltage
0.7 p.u. for not more than 400ms	1.2 p.u. for not more than 30s

Table 5.7: Dynamic voltage excursion limits

5.1.5.7 Under normal Steady State operational conditions, it is required to maintain the Frequency within a range of ±1% of the nominal value. This means that the Frequency should be maintained between 49.5Hz and 50.5Hz.

5.1.5.8 In extremely rare and exceptional circumstances, the system frequency may experience an increase up to 52Hz or a decrease down to 47Hz. Therefore, it is essential for both transmission Network Operator and Consumer's Plant and Apparatus to be designed in a way that allows for their operation within this frequency range, as specified in Table 5.8 below:

Frequency Range	Requirement
47.5Hz - 52Hz ***Note(a)***	Continuous operation is required
47Hz - 47.5Hz	Operation for a period of at least 10 seconds is required each time the Frequency is below 47.5Hz

Table 5.8: Frequency excursion limits

Note: If evidence can be presented to demonstrate that operating the generating unit beyond 51.5Hz would affect the safety of the plant, the frequency threshold may be reduced to 51.5Hz.

5.1.6 Fault Ride-Through Analysis

5.1.6.1 As disturbances occur within the transmission system, the distribution system may encounter temporary low voltage/sag.

5.1.6.2 The Consumer’s Solar PV system is anticipated to operate continuously during these voltage fluctuations in the distribution system, as demonstrated in Figure 5.1.

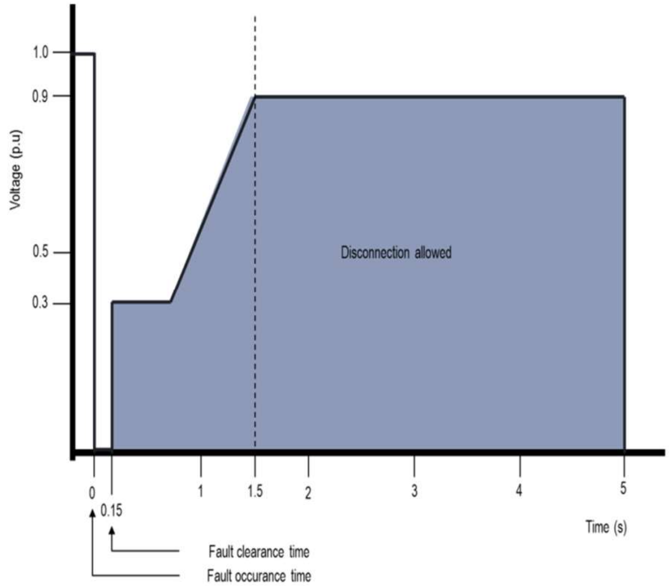

Figure 5.1: Low Voltage Ride Through Curve

5.1.7 Quality of Service Requirement Analysis

5.1.7.1 The acceptable limits of voltage flicker on the Transmission System are determined in compliance with the "Engineering Recommendation P28" issued by The Electricity Council of the UK in 1989, titled "Planning Limits for Voltage Fluctuation Caused by Industrial, Commercial, and Domestic Equipment in the United Kingdom" (ER P28).

5.1.7.2 The Transmission Division of NUR Power utilizes the procedures outlined in this document for planning the connection of fluctuating loads, and the prescribed limits are applied to measure and monitor Flicker levels at these connection points.

5.1.7.3 As per ER P28, voltage fluctuations at a Point of Common Coupling where a fluctuating load is directly connected to the Transmission System should not exceed the following limits:

(a) for step changes, which may occur repeatedly, the voltage fluctuations should not exceed 1% of the voltage level.

In cases of larger voltage excursions that are not step changes or occur less frequently, fluctuations up to a level of 3% may be allowed, provided that it does not pose a risk to the Transmission System or any other party connected to the System in NUR's assessment.

(b) the planning limits for Flicker Severity (Short Term) and Flicker Severity (Long Term) applicable to fluctuating loads connected to the Transmission System and Distribution System are outlined in the Table 5.9 below:

Transmission System Voltage Level at which the Fluctuating Load is Connected	Absolute Short Term Flicker Severity (Pst)	Absolute Long Term Flicker Severity (Plt)
132kV	0.8	0.6

Table 5.9: Maximum allowable flicker severity

5.1.7.4 The connection of multiple fluctuating loads at the same Point of Common Coupling or the addition of another fluctuating load at the same location follows a "first come first served" approach on the Transmission System and Distribution System.

This means that if the first fluctuating load remains within the allowable flicker limits and does not necessitate any flicker mitigation or compensation equipment, the second fluctuating load, which may exceed the Flicker limits, will be required to invest in suitable flicker mitigation or compensation equipment. During the planning stage, when assessing the total flicker resulting from the connection of multiple fluctuating loads at specific Points of Common Coupling, NUR employs the methodology described in the Engineering Recommendation P28.

This methodology ensures a comprehensive evaluation of the total Flicker considering the combined impact of multiple Fluctuating Loads at the given location.

5.1.7.5 During the planning stage, when assessing the level of Flicker caused by a fluctuating load, the assessment is conducted under a realistic Weak System operating condition.

5.1.7.6 This condition under section 5.1.8.5 reflects the minimum number of connections at which the specific point on the System can operate within normal voltage limits during maintenance outages or after Secured Contingency Events. This condition is considered representative of the System conditions that would yield the highest Flicker value for the Fluctuating Load. It ensures that the voltage fluctuations resulting from the fluctuating load are at their peak under such conditions.

5.1.7.7 Under the operating conditions described in section 5.1.7.5, the Flicker resulting from a fluctuating load exceeds the specified limits, Flicker compensation must be installed to reduce the Flicker to an acceptable level.

5.1.7.8 It is important to clarify that the acceptance criteria for Flicker is based on the 95% values of Short and Long Term Flicker Severity (Pst and Plt), which should fall below the limits outlined in the aforementioned table. In this context, the 95% values refer to the 95th percentile of the cumulative probability function calculated from the observed and measured values of Flicker Severity throughout the entire observation period.

5.1.7.9 The System overall performance yardstick for the level of Flicker reduction to be achieved shall be based upon enabling connection of other similar Fluctuating Load and/or permitting for future extension and development of the location with further Fluctuating Load installations.

It is essential that the chosen Flicker compensation method and equipment do not cause resonance issues with the existing Transmission System and Distribution System or any planned future developments.

5.1.7.10 If the permissible Flicker limits cannot be achieved, even with the installation of Flicker compensation at a specific Point of Common Coupling and System voltage level, alternative options for connecting the Fluctuating Load should be considered. This may involve connecting the Fluctuating Load at a higher voltage level or at a different location within the System.

The chosen connection point must demonstrate lower voltage fluctuations compared to the initially considered connection point, as per the operational conditions outlined in section 5.1.7.5.

5.1.7.11 The acceptable limits of harmonics on the Transmission System are determined according to the guidelines specified in Engineering Recommendation G5/4, titled "Planning Levels for Harmonic Voltage Distortion and the Connection of Non-Linear Equipment to the Transmission Systems and Distribution Networks in the UK." NUR Transmission utilizes the procedures outlined in this document for planning the Generating Units and Loads that generate harmonics.

The prescribed limits are also applied when measuring and monitoring the levels of harmonics at the points of connection within the system.

5.1.7.12 All equipment and facilities connected to the Transmission System, as well as the relevant section of the Transmission System at each connection site, should be capable of withstanding specific distortions of the voltage waveform caused by harmonic content.

The maximum permissible levels of Harmonic Distortion at any connection point on the Transmission System, considering all sources under planned outage and Secured Contingency Event conditions (unless abnormal conditions occur), should not exceed the following:

(a) at 132kV, the maximum planning limit for Total Harmonic Distortion is 3%, with no individual harmonic voltage exceeding the values specified in Table 5.15.

(b) consumers are responsible for ensuring that the Immunity Level of their equipment and facilities is compatible with the electromagnetic disturbances present on the System, including harmonics.

5.1.7.13 During the planning stage, when assessing the level of Harmonic Distortion and individual harmonic levels, the evaluation will be conducted under a realistic Weak System operating condition.

This condition represents the minimum number of connections at which the specific point on the System can operate within normal voltage limits during maintenance outages or after Secured Contingency Events. It is considered as a representative scenario that reflects the System conditions where the Harmonic Distortion and individual harmonic levels will reach their highest values.

5.1.7.14 Under the operating conditions specified in section 5.1.7.13, the Harmonic Distortion and individual harmonic level resulting from the load exceed the limits, it is necessary to install harmonic filters to reduce the harmonics to an acceptable level within the specified limits.

The overall performance objective of the System is to enable the connection of additional similar harmonic-producing Loads and/or facilitate future expansions and developments at the location with further installations of harmonic-producing Loads. The selected harmonic filters must be of a type that does not introduce resonance issues with the existing Transmission System or any intended future developments.

Odd Harmonics (Non-multiple of 3)		**Odd Harmonics (Multiple of 3)**		**Even Harmonics**	
Order "h"	Harmonic Voltage (%)	Order "h"	Harmonic Voltage (%)	Order "h"	Harmonic Voltage (%)
5	2.5	3	2.0	2	1.0
7	2.0	9	1.0	4	0.8
11	1.8	15	0.3	6	0.5
13	1.5	≥21	0.2	8	0.4
17	1.2			10	0.4
19	1.0			≥12	0.2
23	0.8				
≥25	0.6*(25/h)+0.2				
The total harmonic distortion level is 3%					

Table 5.10: Planning Levels for Harmonic Voltage in 132kV Systems

5.1.7.15 When determining the thresholds for voltage unbalance, reference is made to the "Engineering Recommendation (E/R) P24" issued by the Electricity Council of the UK in 1984, which addresses "AC Traction Supplies to British Rail." Additionally, consideration is given to its successor document, P29, issued in 1990, titled "Planning Limits for Voltage Unbalance in the United Kingdom."

5.1.7.16 During the planning stage, all equipment and plants connected to the Transmission System, along with the corresponding part of the system at each connection site, should be designed to withstand specific voltage waveform distortions related to Phase Unbalance, as follows:

(a) under normal planned outage conditions, the maximum negative phase sequence component of the phase voltage on the Transmission System should remain below 1%, with the exception of abnormal conditions, where it may go up to 2% for a maximum of one minute (as per P29 guidelines); and

(b) at the terminals of a Consumer's installation or specific load, the voltage unbalance should not exceed 1% for more than five occasions within any thirty-minute time period.

5.1.7.17 The MV Distribution System and LV Distribution System follows the guidelines set by IEC Standards 61000-3-7 for voltage flicker severity. Table 5.11 provides the specific limits specified in these standards.

Distribution System and Transmission System Voltage Level at which the Fluctuating Load is Connected	**Absolute Short Term Flicker Severity (P_{st})**	**Absolute Long Term Flicker Severity (P_{lt})**
Medium Voltage	0.9	0.7
Low Voltage	1.0	0.8

Table 5.11: Maximum allowable voltage flicker severity

Note: The terms (P_{st}) and (P_{lt}) are defined in the IEC Standards 61000-3-7.

5.1.7.18 The applicable standards for harmonic voltages distortion are Standards 61000-3-6 for the MV Distribution System and IEC Standard 61000-2-4 for the LV Distribution System.

5.1.7.19 The maximum total levels of Harmonic Distortion at any Connection Point on the Distribution System from all sources under both planned outage and unplanned outage conditions, unless abnormal conditions prevail, shall not exceed:

(a) at 33kV and 11kV and: a Total Harmonic Distortion of 6.5%; and
(b) at 400V and below, a Total Harmonic Distortion of 5%.

The limits for individual components of harmonic voltage distortion are given in the IEC Standard 61000-3-6 at MV and IEC Standard 61000-2-4 at LV.

Odd Harmonics (Non-multiple of 3)		**Odd Harmonics (Multiple of 3)**		**Even Harmonics**	
Order "h"	Harmonic Voltage (%)	Order "h"	Harmonic Voltage (%)	Order "h"	Harmonic Voltage (%)
5	5.0	3	4.0	2	1.8
7	4.0	9	1.2	4	1.0
11	3.0	15	0.3	6	0.5
13	2.5	21	0.2	8	0.5
17≤ h≤ 49	1.9 x (17/h)-0.2	21< h≤ 45	0.2	10≤ h≤ 50	0.25 x (10/h)+0.22
The total harmonic distortion level is 6.5%					

Table 5.12: Planning Levels for Harmonic Voltage in 33kV and 11kV Systems

Odd Harmonics (Non-multiple of 3)		**Odd Harmonics (Multiple of 3)**		**Even Harmonics**	
Order "h"	Harmonic Voltage (%)	Order "h"	Harmonic Voltage (%)	Order "h"	Harmonic Voltage (%)
5	3.0	3	3.0	2	2.0
7	3.0	9	1.5	4	1.0
11	3.0	15	0.3	6	0.5
13	3.0	21	0.2	8	0.5
17	2.0	21< h≤ 45	0.2	10	0.5
17< h≤ 49	2.27 x (17/h) - 0.27			10<h≤ 50	0.25 x (10/h) + 0.25
The total harmonic distortion level is 5%					

Table 5.13: Planning Level for Harmonic Voltage in 400V

5.1.7.20 The planning limits for voltage unbalance in this Distribution Network are established according to the guidelines provided by the United Kingdom Energy Networks Association Engineering Recommendation P29.

5.1.7.21 The voltage unbalance, represented by the maximum negative phase sequence component of the phase voltage on the Distribution System, shall not exceed 1% unless abnormal conditions are present.

5.1.7.22 The unbalance voltage at a Distribution Consumer's installation terminals should not exceed 1% for more than five instances within any 30-minute time period.

5.1.7.23 In case all studies reveal a violation of the harmonic and flicker planning limits, the Consumers is required to install an appropriate compensator/filter capable of up to 100% compensation. This compensator/filter should be implemented to reduce the overall distortion and flicker below the permissible limits.

5.1.7.24 The Total Harmonic Distortion current distortion at the inverter's rated output should be maintained below 5%. The point of measurement for THD is at the combiner box of the inverters.

Additionally, each individual harmonic should conform to the percentage limits specified in the table below (Current distortion limits referenced from IEC 61727-2003 Table 1). Furthermore, even harmonics within these ranges must be lower than 25% of the lower odd harmonic limits as listed in the Table 5.14 below:

Odd harmonics	**Distortion limit (%)**
3 – 9	**< 4.0**
11 – 15	**< 2.0**
17 – 21	**< 1.5**
23 – 33	**< 0.6**
Even harmonics	**Distortion limit (%)**
2 – 8	**< 1.0**
10 – 32	**< 0.5**

Table 5.14: Planning Levels for individual current harmonic

PSS Study Methodology

No.	Item	Methodology
1.	Power Flow Analysis	*(a)* to evaluate the voltage and thermal loading of transmission and distribution elements (eg. overhead line, underground cable, transformer etc.) under both peak and trough load conditions for load flow. *(b)* at different inverter power output (i) 100% inverter power output (ii) 0% inverter power output
2.	Contingency Analysis	To evaluate the voltage and thermal loading of transmission and distribution elements (eg. overhead line, underground cable, transformer etc.) under both peak and trough load conditions for contingencies. *(a)* N-0 of circuit elements (11kV, 33kV, 132kV NUR network) *(b)* N-1 of circuit elements (11kV, 33kV, 132kV NUR network) *(c)* N-1-1 of circuit elements (132kV NUR network) *(d)* N-2 of circuit elements (132kV NUR network) Note: Circuit elements are such as Overhead lines, Underground cables, and Transformers
3.	Power Factor Requirement Study	The consumer must be capable of maintaining the consumer premise load power factor in accordance with NUR Tariff Booklet Clause 4.2 *(a)* Before interconnection of Solar PV; and *(b)* After interconnection of Solar PV.
4.	Short Circuit Analysis	*(a)* To simulate single & three phase fault under both peak and trough load conditions (i) Before interconnection of Solar PV (ii) After interconnection of Solar PV *(b)* To identify the fault current contribution of the solar PV to the grid.

		(c) To ascertain the fault level at grid connection point and the solar facilities are within the short circuit rating. *(d)* To identify/ propose mitigation options for violation of criteria (if any)
5.	Transient Stability Analysis	*(a)* Category A - All facilities in service *(b)* Category B - Events resulting in loss of a single element (i) 3-phase fault with normal clearing (150ms) followed by loss of a single element (B1, B2, B3, B4) A. B1 - Generator B. B2 - Transmission Circuit C. B3 - Transformer D. B4 - Hot connection to TNB Grid (ii) Up to three buses away, where applicable *(c)* Category C - Events resulting in loss of two or more elements (i) 3-Phase fault with normal clearing (150ms) followed by simultaneous loss of three elements (B1, B2, B3, B4) connected to the faulted bus. (ii) Up to three buses away, where applicable.
6.	Fault Ride-Through Capability	*(a)* The network file for the NUR network, proposed and existing inverter, and developer network will be modelled in software. *(b)* To simulate a 3-phase fault for different durations at the transmission system for different fault impedances (total of three case studies), and to identify the fault ride-through capability of the solar photovoltaic inverters' performance upon fault clearance.

		(c) To verify the AC voltage recovery of the facility under dynamic conditions according to DC 6.5.5.1 voltage pattern.
7.	Quality of Service (Power Quality Requirement)	*(a)* To verify that the system voltage harmonic levels at the point of common coupling remains within the allowable limits with the connection of the solar PV. *(b)* The actual measured existing background harmonics data at point of common coupling, as well as inverter current harmonics spectrum are required. *(c)* The network file for the NUR network, proposed and existing inverters and developer network are to be modelled in software. *(d)* Software will be utilized to conduct the harmonic load flow study. (i) The results of the Total Voltage Harmonic Distortion (VTHD) at the point of common coupling will be assessed against the harmonics system planning limits as specified in ER G5/4. (ii) Based on the results, mitigation in the form of filters/other feasible methods will be proposed if the VTHD exceeds the specified limits.
8.	Flicker Analysis	*(a)* To verify that the system voltage flicker severity index at the point of common coupling remains within the allowable limits with the connection of the solar PV. *(b)* The actual measured existing background voltage flicker data at point of common coupling, as well as inverter voltage flicker severity index are required. *(c)* The network file for the NUR network, proposed and existing inverters and developer network are to be modelled in software. *(d)* Software will be utilized to conduct voltage flicker analysis.

		(e) The results of the long term and short term voltage flicker at the point of common coupling will be assessed against the voltage flicker severity index limits as specified in ER-P28. *(f)* Based on the results, mitigation will be proposed if the voltage flicker severity index exceeds the specified limits.
9.	Frequency Response Analysis	*(a)* To investigate system frequency response under sudden loss of all solar PV plants condition in the Kulim Hi-Tech park. *(b)* The network file for the NUR network, proposed and existing inverters and developer network are to be modelled in software.

General Mitigation Plan for Technical Violation

5.1.8 General mitigation plan for over-voltage

5.1.8.1 To adjust the reactive power production or power factor of PV units based on their terminal voltage.

5.1.8.2 Communication techniques to synchronize groups of PV units, regulate power distribution, and control critical buses.

5.1.8.3 Voltage regulation in medium-voltage (MV) networks can be achieved through two-way communication between transformer tap changers, capacitor banks, and distributed generation units.

5.1.8.4 Employing inverters with static synchronous compensator (STATCOM) or similar features to regulate voltage variations caused by other sources or loads, particularly during night time.

5.1.8.5 To employ PCS within BESS with volt/var support capability by sinking reactive power to the Distribution System.

5.1.9 General mitigation plan for under-voltage

5.1.9.1 PV units' reactive power production or power factor will be adjusted based on their terminal voltage.

5.1.9.2 Communication techniques will synchronize groups of PV units, regulate power distribution, and control critical buses.

5.1.9.3 Two-way communication between transformer tap changers, capacitor banks, and distributed generation units will achieve voltage regulation in medium-voltage (MV) networks.

5.1.9.4 Inverters with static synchronous compensator (STATCOM) or similar features will be used to regulate voltage variations caused by other sources or loads, particularly during night time.

5.1.9.5 To employ PCS within BESS with volt/var support capability by sourcing reactive power to the Distribution System.

5.1.10 General mitigation plan for thermal overloading

5.1.10.1 The engineering design for the renewable energy installation should include engineering calculations supporting the chosen current carrying capacity, claimed efficiencies, and in consideration of equipment de-rating factor.

5.1.10.2 To address increased demand and prevent thermal overloading, utilities may consider either upsizing existing equipment in the grid or adding another set of equipment in parallel.

5.1.11 General mitigation plan for low power factor

5.1.11.1 Power factor correction capacitor banks mitigate low power factor occurrences in consumer sites resulting from the installation of solar power systems.

5.1.11.2 To utilize the BESS PCS with the capability of operating at a variable power factor.

5.1.12 General mitigation plan for short circuit violation

5.1.12.1 The Current Limiting Reactor (CLR) introduces higher impedance through series-connected reactance, reducing short circuit current to both consumer and utility electrical system during fault conditions.

5.1.12.2 The fuse type fault current limiter is a rapid and efficient device designed to detect and limit short circuit currents. The fuse effectively suppresses the short circuit current, preventing short circuit current damage to consumer and utility electrical system and equipment.

5.1.13 General mitigation plan for voltage harmonic distortion limit violation

5.1.13.1 Active harmonic filters serve the purpose of reducing harmonics caused by non-linear consumer load and inject equal but opposite harmonic compensating counter current to cancel out the harmonic current introduced by solar PV system.

5.1.13.2 Passive harmonic filter provides a low impedance path for the harmonic at a specific tuned frequency to mitigate harmonic distortion.

5.1.14 General mitigation plan for over-frequency

5.1.14.1 To utilize the frequency regulation capability of BESS by increasing active power charging rate to counteract or partially mitigate the frequency deviation.

5.1.14.2 To curtail the generation of solar PV system supply into the Distribution System using frequency-watt control function of PV inverters.

5.1.14.3 To install and operate a dump load bank to absorb solar PV system generation.

5.1.15 General mitigation plan for under frequency

5.1.15.1 To utilize the frequency regulation capability of BESS by increasing active power discharging rate to counteract or partially mitigate the frequency deviation.

5.1.15.2 To increase the generation of solar PV system supply into the Distribution System using frequency-watt control function of PV inverters.

5.1.16 General mitigation plan for voltage unbalance

The STATCOM mitigates voltage unbalance by injecting or absorbing reactive power as needed, which helps maintain balanced voltages and improves the stability and quality of the power system.

5.1.17 General mitigation plan for over voltage flicker severity index

A static-synchronous compensator (STATCOM) is able to mitigate flickering by controlling the reactive power flow from the grid.

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