وزارة الطاقـــة والبنيـــة التحتيـــة
MINISTRY OF ENERGY & INFRASTRUCTURE

EtihadWE
الاتحاد للماء والكهرباء

DISTRIBUTED SOLAR SYSTEMS
STANDARDS AND GUIDLEINES
For Small-Scale Solar PV System

Version1 - September 2024

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ACRONYMS, ABBREVIATIONS AND TERMS

Acronym/Abbreviation/Terms	Definition/Clarification
AC	Alternative Current
AC Combiner Box	A distribution board that combines the AC output from multiple inverters in the PV system into a single AC output.
Active Power	Active Power refers to the actual component of Apparent Power, measured in units of watts, it will be referred to as P in the context.
Apparent Power	Apparent power measured in volt-amperes (VA), is a combination of both the real power (active power) and reactive power in the circuit. Apparent power is used to quantify the total power flow in an AC circuit, taking into account both the actual energy transferred (real power) and the energy that oscillates back and forth between the source and load (reactive power).
Approved Contractor	A system integrator who is qualified and authorized by ETIHADWE to perform DSS installation, operation, and maintenance in the Northern Emirates.
Application	Application means the request to interconnect a new DSS.
BOS	Balance of System.
CB	Circuit Breaker.
CT	Current Transformer.
Consumption Account	The specific account for metering the electricity imported from the Distribution Network by a meter dedicated for such purpose.
Customer	An entity that has an agreement with ETIHADWE for the supply of electricity.
DC	Direct Current.
DSS	Distributed Solar System – One or more electrical energy generating units that generate electricity exclusively from solar energy connected under one Hosting Account.
DSS Customer	Any entity that generates electrical energy from DSS and connects it to the Distribution Network as per terms and conditions set forth by ETIHADWE.
Distribution Network	The network comprises electrical lines (33kV and below), which are either owned or managed by the Distribution Company and are utilized for delivering electricity up to the point where it reaches Customers' premises. This network consists of all associated infrastructure and equipment, including metering devices, which are owned or managed by ETIHADWE in relation to electricity distribution.
ETIHADWE	Etihad Water and Electricity.

Acronym/Abbreviation/Terms	Definition/Clarification
Enter Service	Begin operation of the DSS with an energized Distribution Network.
Hosting Account	The Consumption Account under which the DSS is connected.
I_{SC}	Short-circuit current.
IP	Ingress Protection.
Interface Protection	The electrical protection necessary to ensure the disconnection of the DSS in the event of any occurrence that could jeopardize the reliability or compromise the safety of the Distribution Network.
Interface Breaker	A circuit breaker that, under the control of an appropriate protection relay, is opened to disconnect the DSS from the Distribution Network.
Islanding	Islanding refers to a situation where a solar PV system continues to generate electricity and feed it into the local electrical grid even when the grid has experienced an outage or has been intentionally disconnected for maintenance or repair. In essence, the solar PV system operates as if it were an isolated "island" of electrical generation within the grid.
LV	Low Voltage – where nominal voltage is 240/415V.
LVRT	Low Voltage Ride Through.
LoM	Loss of Mains.
Material Modification	Material modification means a modification that has a material impact on the cost or timing of processing an Application with a later queue priority date or a change in the Point of Interconnection. A Material Modification does not include, for example, (a) a change of ownership of a DER, (b) a change or replacement of generating equipment that is a like-kind substitution in size, ratings, impedances, efficiencies, or capabilities of the equipment specified in the original Application, (c) replacement of existing inverters with inverters that conform to more recent standards, as long as the Export Capacity does not change; or (d) a reduction in the Nameplate Rating and/or Export Capacity of the DER of ten percent (10%) or less.
Maximum Capacity (P_{ac})	Corresponds to the sum of the maximum active power deliverable by the inverters at the AC side of the DSS.
Maximum Active Power Output	The Maximum Active Power Output is determined by combining the factor that influences power generation (such, as irradiance) with the maximum efficiency of power conversion within the DSS, under the specific operating conditions. It will be referred to as P_{max} in the context.
MPPT	Maximum power point tracking
MV	Medium Voltage – where nominal voltage is 11 kV.

Acronym/Abbreviation/Terms	Definition/Clarification
Overload	The ratings of equipment that is part of the Distribution Network is exceeded.
PTO	Permit to Operate. Granted by ETIHADWE once the DSS has successfully passed the Inspection and Testing to ETIHADWE's satisfaction.
PV	Photovoltaic.
Point of Interconnection (POI)	Is the designated location where the DSS and consumer loads are interfacing with the network. It is also the point where the main meter is positioned.
RoCoF	Rate of Change of Frequency.
RMS	Root Mean Square.
STC	Standard Test Conditions - A predefined set of reference parameters employed for testing and evaluating photovoltaic cells and modules. These standard testing conditions include: a) Maintaining the PV cell temperature at 25 °C. b) Ensuring an irradiance level of 1000 W/m2 in the plane of the PV cell or module. c) Employing a light spectrum that corresponds to an atmospheric air mass of 1.5.
TCP/IP	Transmission Control Protocol/Internet Protocol.
UAE	United Arab Emirates.
VT	Voltage Transformer.
V_n	Nominal voltage.
V_{OC}	Open-circuit voltage.

1. OVERVIEW

PURPOSE & SCOPE

These standards and guidelines establish the governing structure for Distributed Solar PV Systems (DSS), including the interconnection process to the ETIHADWE Distribution Network, and create a standardized framework for grid connection between ETIHADWE and DSS Customers.

The standards and guidelines are created for solar PV system designers and system integrators (Approved Contractors) to ensure the DSS is installed, operated, and maintained effectively and safely in all properties across the Northern Emirates. They also aim to simplify the process of connecting the DSS while preserving the safety and supply quality of the ETIHADWE Distribution Network and they serve as the technical benchmark for ETIHADWE -Approved Contractors, who are required to adhere to these guidelines.

These guidelines:

- Are relevant to ETIHADWE, DSS Customers, Approved Contractors, and any other individuals or entities engaged in the connection of DSS to the ETIHADWE Distribution Network.
- Pertain to small-scale DSS connected to the Distribution Network, provided their combined capacity within a single premises does not exceed 1 MW. They do not encompass large-scale solar PV generation that exceeds 1 MW, nor do they include solar PV systems that are not connected to the Distribution Network.
- May be modified or repealed at MOEI's and ETIHADWE's discretion.

NORMATIVE REFERENCES

The following document found on the ETIHADWE website accessible at https://ETIHADWE.ae/en/About/Regulations consistently serves as an authoritative technical reference:

- The Electricity Wiring Regulation Book by the Federal Electricity and Water Authority – August 2020.

2. TECHNICAL REQUIREMENTS

2.1. GENERAL

- The DSS shall be connected to the Distribution Network per the Interconnection Application Process (see Section 7) as specified in this document (Distributed Solar Systems Standards and Guidelines for Small PV Systems in ETIHADWE) available on ETIHADWE's Solar Platform[1].
- The DSS shall be interconnected to the LV network at 240/415V or to the MV network at 11 kV.
- For LV connections, it is advisable to prioritize the use of three-phase inverters, in alignment with the common configurations found in ETIHADWE network connections. DSS may also consist of single-phase inverters connected to the LV network, the use of single-phase connections shall be as specified in 2.5.1.
- The open-circuit voltage of rooftop DSS shall not exceed 1,500 Vdc at 0°C. The minimum design temperature should either be 0°C or lower than 0°C based on the observed daytime temperature of the specific site. All components, including PV modules, inverters, and cables, shall be able to withstand the system's highest voltage.
- When the open-circuit voltage of the PV system exceeds 1500Vdc, DSS shall not be installed on a building. It shall be considered only for ground-mounted systems, canopies, or any other solutions where access is limited to qualified individuals who are competent, experienced, or have received proper instruction.
- The inverters shall come with an IP65 enclosure suitable for outdoor use and an IP54 enclosure for indoor use. In indoor installations with lower protection ratings, they can only be used if the room is designed to adequately shield the equipment. Additionally, the inverter shall be capable of withstanding elevated temperatures up to 50°C with effective heat dissipation. For outdoor installations, inverters shall not be exposed to direct sunlight. Inverters that do not meet the previously mentioned criteria must be installed in a temperature-controlled room or enclosures equipped with efficient ventilation.
- All DSS main components (such as PV modules, inverters, cables, and interface protection) shall be selected from the List of Approved Equipment available on ETIHADWE's Solar Platform[1] and shall comply with the standards outlined in Section 2.2 - PV System Components where applicable.

2.2. PV SYSTEM COMPONENTS

2.2.1. General

1. A PV cell serves as the fundamental component within a PV module, generally generating approximately 1 to 2 watts of power under standard test conditions (STC). However, the actual power output of a PV cell can vary depending on factors such as its size, efficiency, and the amount of sunlight it receives. Some high-efficiency PV cells can generate more power per unit area than

[1] To be determined.

standard cells. To harness the collective power of these cells, they are connected together to create modules capable of generating higher levels of electric power.

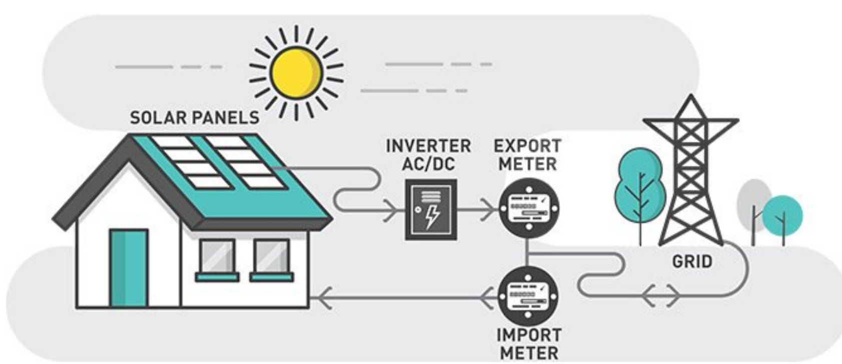
2. PV modules are connected in series to form PV strings. These strings are designed to boost the system's voltage while keeping the current at a level suitable for the inverter. Within a PV string, solar panels are connected in series, meaning the positive terminal of one panel connects to the negative terminal of the next, leading to an increased voltage output. This voltage must align with the inverter's input requirements for efficient DC-to-AC conversion.

3. PV strings are connected in parallel to form PV arrays. The voltage and current output of a PV array depend on the arrangement and connection of the underlying PV strings, and these arrays can be scaled up or down to match the energy needs of diverse applications.

4. A typical PV system consists of the following components:

- Solar PV modules are interconnected using cables and connectors, forming strings and arrays.
- These strings and arrays are subsequently connected to inverters, which convert the DC power generated by the strings and arrays into AC power, making it usable for the electricity needs of the Premises.
- Additionally, the system includes electrical cables, switchgears, monitoring and metering systems, as well as protection and interface modules.
- Mechanical structures designed to support the modules and orient them towards the sun for optimal energy capture.
- A solar PV inverter is a component in a PV system whose primary function is to convert the DC power generated by solar panels or PV arrays into AC power. Figure 2-1 shows a typical installation of a grid-connected solar PV system.

Figure 2-1 — Typical Installation of a Solar PV System [1]



2.2.2. PV Module

Solar PV module functions as an electricity-generating device that generates DC when sunlight is absorbed. Typically, these modules are comprised of interconnected solar cells, enclosed within an aluminum frame, and protected by tempered glass on the front surface. These modules are generally rectangular and can be mounted in either a portrait (vertical) or landscape (horizontal) orientation. The PV modules to be utilized in the Distributed Solar System program of the Northern Emirates should be provided with a minimum product warranty period of 10 years and a performance warranty of 25 years. The modules should retain a minimum of 90% of the nameplate rating in the first 10 years and 80% of the nameplate rating after 25 years. The PV modules will need to comply with the following minimum standards requirements:

Standard	Title
IEC61730-1	Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction
IEC61730-2	Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing
IEC 61215-1-1	Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1-1: Special requirements for testing of crystalline silicon photovoltaic (PV) modules
IEC 61215-1-2	Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1-2: Special requirements for testing of thin-film Cadmium Telluride (CdTe) based photovoltaic (PV) modules
IEC 61701	Photovoltaic (PV) modules – Salt mist corrosion testing
IEC 62716	Photovoltaic (PV) modules – Ammonia corrosion testing
BS EN 50380	Marking and documentation requirements for Photovoltaic Modules
BS EN 50548:2011+A2:2014	Junction boxes for photovoltaic modules
IEC 60068-2-68	Environmental testing - Part 2: Tests - Test L: Dust and sand

2.2.3. Inverter

The key functions and roles of a solar PV inverter are:

- DC to AC Conversion: Solar panels produce DC power when exposed to sunlight. However, most electrical appliances and the electricity grid operate on AC power. The inverter's primary function is to convert the DC power generated by the solar panels into AC power with the same voltage and frequency as the grid or the building's electrical system.
- Voltage Control: Inverters ensure that the AC power they produce is synchronized with the grid's voltage, frequency, and phase to allow for safe and efficient electricity transmission.
- Maximum Power Point Tracking (MPPT): Inverters are equipped with MPPT technology, which continuously adjusts the voltage and current to maximize the power output of the solar panels. This ensures that the PV system operates at its peak efficiency, even under varying sunlight conditions.
- Safety Features: Inverters include safety features like shut-off mechanisms to disconnect the system from the grid in the event of a power outage. They also provide protection against electrical faults and surges.
- Data Monitoring: Some inverters have built-in or optional data monitoring capabilities, allowing users to track the performance of their solar system and diagnose issues remotely.
- Grid Interaction: Grid-tied inverters allow excess electricity generated by the PV system to be fed back into the grid, often resulting in net metering or compensation for surplus energy. This allows DSS Customers to receive credits or payments for the excess electricity they produce.
- The inverters shall be provided with an IP65 enclosure for outdoor application and IP54 enclosure for indoor application. In this latter case, lower protection levels shall only be permitted if the characteristics of the room will be properly conceived to protect the equipment. The inverter shall be able to withstand the maximum temperatures with effective heating dispersion and with a power derating smaller than or equal to 25% of its rated power as determined for an ambient temperature of 60°C at the DC design voltage. This temperature is to be considered the maximum outdoor value at which all equipment, apparatus, materials and accessories used in electrical installations must be capable of operating with satisfactory performance in the climatic conditions of the UAE. In addition, provisions which prevent the increase of the internal heating of the inverters shall be taken for outdoor installation (e.g. Protections against direct exposition to the sun). For those inverters which do not comply with the above set rule, a placement in cooled room or enclosures with effective ventilation shall be required, inside which the ambient temperature will be kept below the value which determines a power derating equal to 25% of the inverter rated power at the DC design voltage.

The inverters to be utilized in the Distributed Solar System program of the Northern Emirates will need to be provided with a minimum warranty period of 5 years and comply with the following minimum standards requirements:

Standard	Title
UL 1741 (Either UL 1741 or IEC 62109-1&2 outlined below)	Standard for safety - Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
IEC 62109-1	Safety of power converters for use in photovoltaic power systems – Part 1: General requirements
IEC 62109-2	Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters
IEC 62116	Utility-interconnected photovoltaic inverters – Test procedure of islanding prevention measures
IEC 61727	Photovoltaic (PV) systems – Characteristics of the utility interface

The Inverters to be utilized in the Distributed Solar System program of the Northern Emirates will need to comply with the following Electro-magnetic Compatibility (EMC) Standards:

Standard	Title
IEC 61000-3-2	Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤16 A per phase)
IEC 61000-3-3	Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection
IEC 61000-3-5	Electromagnetic compatibility (EMC) Part 3.5: Limits – Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 75 A

Standard	Title
IEC 61000-3-11	Electromagnetic compatibility (EMC) – Part 3-11: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems – Equipment with rated current ≤ 75 A and subject to conditional connection
IEC 61000-3-12	Electromagnetic compatibility (EMC) – Part 3-12: Limits – Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤ 75 A per phase
IEC/TR 61000-3-14	Electromagnetic compatibility (EMC) – Part 3-14: Assessment of emission limits for harmonics, inter-harmonics, voltage fluctuations and unbalance for the connection of disturbing installations to LV power systems

2.2.4. Balance of System

1. “Balance of system” (BOS) typically refers to all the equipment found in a solar PV installation, excluding the modules and the inverters. BOS elements include a range of components such as support structures, electrical conductors, connectors, conduit systems, disconnect switches, fuses, mounting hardware, and combiner boxes.

2. The switchgear and control panels shall be adequately shielded from various environmental factors such as temperature, sunlight, dust, saltiness, and any other prevailing weather conditions at the site. They are required to be installed in a secure enclosure.

3. Cables and connectors that are subject to exposure to sunlight, external temperatures, and various weather conditions shall be certified for their specific intended use. In DC circuits, it is essential to employ single-wire cables, with distinct colors assigned to each pole: red for positive and black for negative.

Standard	Title
EN 50618	Electric cables for photovoltaic systems
EN 62852	Connectors for DC-application in photovoltaic systems - Safety requirements and tests

Standard	Title
CEI 20-91	Fire retardant and halogen free electric cable with elastomeric insulation and sheath for rated voltages not exceeding 1 000 V a.c and 1 500 V d.c for use in photovoltaic system (PV)
UL 6703	Standard for Safety - Connectors for Use in Photovoltaic Systems

2.2.5. Racking System

A racking/mounting system, in the context of fixed solar PV installations, is a critical component that supports and secures the solar PV modules in a fixed position on various surfaces like rooftops or the ground.

1. Solar PV arrays shall be mounted using either anodized aluminum or galvanized steel racking systems.

2. Racking systems shall be designed to bear the weight of the solar panels and to withstand the forces exerted by wind (wind-uplift) without compromising safety or system integrity., whether it is a roof, ground, or other structure.

3. Roof penetrations shall be avoided during the installation of the racking system. If that cannot be avoided, all roof penetrations must be sealed to prevent leaks and roof damage, and the Approved Contractor must ensure that the roof is structurally capable of accommodating the additional load of a PV system. Any necessary replacement or repair work on a roof must be done prior to the installation of the solar PV system.

4. Designers of solar PV systems for flat roofs may opt for a ballast mounting approach. This method relies on the use of substantial concrete blocks to anchor the array. Ballasted systems are known for their reduced risk of causing roof membrane leaks; however, they do introduce significant added weight, which might exceed the load capacity of certain roofs.

5. For ground-mounted or rooftop solar PV systems, it is necessary to establish electrical bonding for metal racking to create a continuous path for fault currents. Designers of ground-mounted systems must also consider the soil conditions in their planning. Additionally, voltage drop becomes a relevant consideration for ground-mounted systems, especially those with extended conductor runs.

2.3. DSS RESPONSE TO GRID CONDITIONS

Abnormal situations may occur within the Distribution Network, and it is the responsibility of the DSS to react accordingly. This response is crucial for upholding the stability of the Distribution Network, ensuring the safety of utility maintenance staff and the public, and preventing damages to connected equipment, including the DSS.

Different characteristics and capabilities for response to abnormal Distribution Network conditions are specified in certain parts of this section.

2.3.1. Frequency Stability Requirements

1. Regarding frequency ranges, a DSS must maintain its connection to the Distribution Network and function within the frequency ranges and time periods specified in Table 2-1.

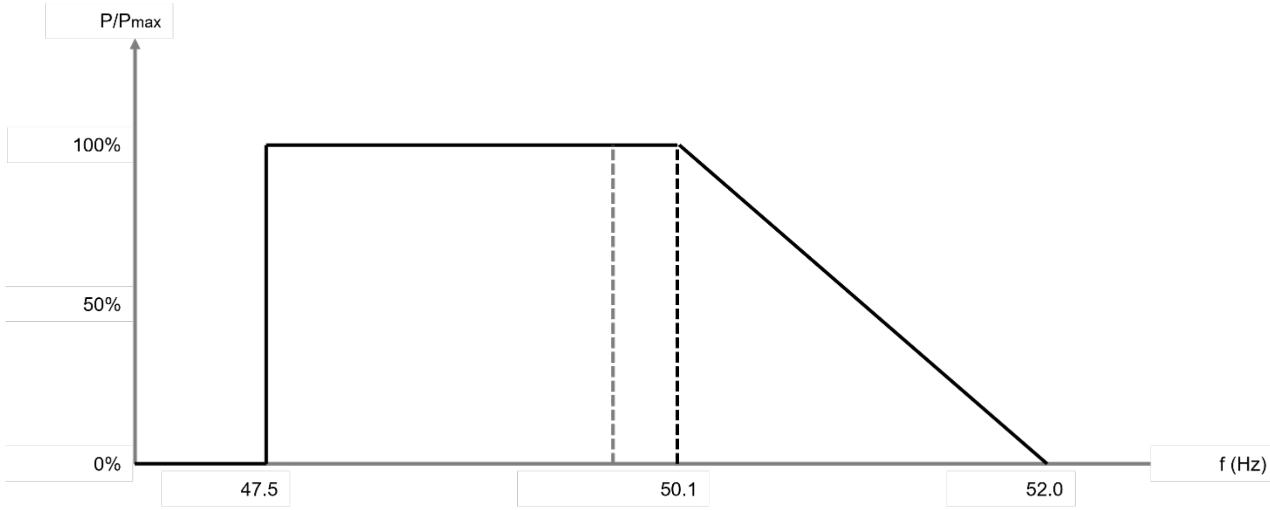
Table 2-1 — Frequency Operational Limits

Frequency Range	Operation Time Period
≤ 47 Hz	0.5 s
47 – 47.5 Hz	20 s
47.5 – 51.5 Hz	Unlimited
51.5 – 52 Hz	90 s
≥ 52 Hz	0.5 s

2. If the network frequency deviates from its nominal value within the specified frequency ranges and time periods as outlined in Table 2-1, the DSS shall adjust its output power to accommodate for the frequency deviation.

3. As a result of over-frequency deviations, the relationship between the Active Power Output and the Maximum Active Power Output of the DSS must be reduced linearly when the frequency exceeds 50.1 Hz until it reaches 52 Hz, as demonstrated in Figure 2-2.

Figure 2-2 — Output Power Reduction Capability with Increasing Frequency



4. When the Distribution Network experiences over-frequency conditions, the output power of the solar inverters shall be controlled to mitigate potential issues and assist in stabilizing the grid during over-frequency events. Under these conditions, solar inverters are instructed to reduce their output power. This reduction in active power generation can help bring the grid frequency back within acceptable limits. To achieve this, the control system of the DSS shall have the capability to receive instructions, which can be provided manually or through an automatic remote-control system by ETIHADWE, specifying the desired set point.

5. In more severe cases of over frequency, for values beyond the limits outlined in Table 2-1, solar inverters must disconnect from the Distribution Network within the specified time. This is to prevent excessive power generation that could worsen grid instability.

2.3.2. Voltage Stability Requirements

1. Regarding voltage ranges, a DSS must maintain its connection to the Distribution Network and function within the voltage ranges and time periods specified in Table 2-2.

Table 2-2 — Voltage Operational Limits

LV Network		MV Network	
Voltage Range	Operation Time Period	Voltage Range	Operation Time Period
≤ 0.8 V_n	0.5 s	≤ 0.7 V_n	0.5 s
0.8 V_n – 0.9 V_n	2.5 s	0.7 V_n – 0.9 V_n	3.5 s
0.9 V_n – 1.1 V_n	Unlimited	0.9 V_n – 1.1 V_n	Unlimited

LV Network		MV Network	
1.1 V_n – 1.15 V_n	1 s	1.1 V_n – 1.2 V_n	1 s
≥ 1.15 V_n	0.5 s	≥ 1.2 V_n	0.5 s

2. To contribute to the preservation of the overall stability and reliability of the entire Distribution Network, DSS inverters shall have the capability to continue operating and remain connected to the grid during periods of voltage dip conditions. During these low-voltage events, a solar inverter with LVRT functionality will adjust its operating parameters to ride through the voltage dip without disconnecting from the grid. The primary objective is to avoid disconnecting DSSs from the Distribution Network unless there is a significant disruption. Unnecessarily disconnecting generation can worsen the under-voltage conditions.

3. Higher voltage levels pose a greater potential risk compared to lower voltages, which is why deviations from the standard range shall be limited, and the time intervals for response shall be shorter.

4. In more severe cases of over-voltage, for values beyond the limits outlined in Table 2-2, solar inverters must disconnect from the Distribution Network within the specified time. This is to prevent excessive power generation that could worsen grid instability.

5. Upon DSS disconnection due to an over or under-voltage condition, the DSS must remain disconnected from the Distribution Network until the voltage at the Point of Interconnection stabilizes within the range of 95% to 105% of the nominal voltage for at least 20 seconds.

2.3.3. Operation During Steady State Voltage

All DSSs connected to either the MV or LV Distribution Network must actively engage in voltage control by generating and absorbing reactive power. This is done to prevent over and under-voltage conditions resulting from the DSS injecting active power into the grid.

The requirements of this subsection apply when the grid voltage is between 0.9 and 1.1 times the nominal grid voltage (V_n).

In response to voltage variations within the normal operating range in the utility grid, solar inverters shall adjust their generation of reactive power to help stabilize the grid as follows:

- **Reactive Power Absorption:** During overvoltage conditions, solar inverters shall be capable to absorb or consume reactive power from the grid. By absorbing reactive power, the inverter effectively acts as a capacitive load, which can help to reduce the voltage levels on the grid. This is often referred to as "VAR support."

- **Reactive Power Generation:** During undervoltage conditions, solar inverters can generate and supply reactive power to the grid. This reactive power injection helps raise the grid voltage levels and support the grid during periods of low voltage.

When the voltage level is stable in the Distribution Network, DSSs shall operate at a power factor (PF) within the range of 0.95 lagging to 0.95 leading.

2.4. DSS ENTER SERVICE

When entering service, the DSS must refrain from energizing the Distribution Network until the voltage and system frequency fall within the specified ranges as outlined below.

1. When the DSS is first entering service, it shall not export power to the Distribution Network until the voltage is within ±5% of the nominal voltage and the frequency is within a range of 49.9-50.1 Hz.

2. The DSS shall have the ability to delay its Enter Service intentionally, with a minimum adjustable delay, when the steady-state voltage and frequency of the Distribution Network fall within the limits specified in clause 1. The adjustable range for this intentional delay shall span from 0 seconds to 600 seconds, with a default minimum delay set at 300 seconds per IEEE 1547. This time delay may be revised by ETIHADWE based on their Distribution Network requirements.

3. The DSS must ramp up its active power output upon entering service, as outlined in this clause. The increase in active power shall follow a linear pattern or a linear ramp with an average rate of change that does not exceed the DSS's nameplate active power rating divided by the entry service period. The entry service period's duration can be adjusted within a range of 1 second to 1000 seconds, with a default time of 300 seconds per IEEE 1547. This time delay may be revised by ETIHADWE based on their Distribution Network requirements. During the entry service period, the maximum active power increase in any single step shall not exceed 20% of the DSS's nameplate active power rating per IEEE 1547. In cases where a stepwise ramp is employed, the rate of change between any two consecutive steps shall not exceed the average rate of change observed over the entire entry service period.

4. The connection of the DSS to the Distribution Network must not result in transient voltage fluctuations exceeding 4% of the rated value.

2.5. POWER QUALITY

2.5.1. General

The connection and operation of DSS can lead to a distortion in the Distribution Network's voltage waveform, leading to voltage fluctuations, harmonic disturbances, or unbalanced phase voltages.

Electronic devices and appliances rely on specific voltage and frequency ranges for their proper operation, making power quality a crucial factor. When the supplied power deviates from these specified limits, it can lead to appliance malfunctions or damage.

DSSs can also consist of single-phase units connected to the LV network, as long as the Maximum Capacity of a facility at the connection point does not exceed 10 kW per phase and the total capacity of these units is evenly distributed among all three phases. This distribution shall not result in an imbalance exceeding the maximum allowable limit of 5 kW. Consequently, it shall be feasible to connect single-phase units, distributed evenly across three phases, with a Maximum Capacity of 3x10 kW.

2.5.2. DC Current Injection

The DSS shall not inject DC greater than 1% of the full rated output current of the inverter at the Point of Interconnection per IEC 61727.

2.5.3. Flicker

Since solar irradiance can fluctuate quickly per weather conditions, leading to corresponding variations in the output power of the DSS, flickering may occur. The operation of the DSS, which includes synchronization, start-up, and shutdown, shall not produce flicker that exceeds the flicker limits specified in IEC 61000-3-3 and IEC 61000-3-11 for LV connections and IEC/TR 61000-3-7 for MV connections.

2.5.4. Harmonic Emissions and Voltage Imbalance

The DSS can generate harmonic voltages and currents that might result in an excessive distortion of harmonic voltages in the Distribution Network.

For DSS connected to the LV network with an output current of up to 16 A per phase, the harmonic components of the current generated and measured at the output terminals must meet the requirements of IEC 61000-3-2. For DSS with an output current ranging from above 16 A up to 75 A per phase, the harmonic components of the current produced and measured at the output terminals shall conform to the guidelines set forth in IEC 61000-3-12.

Regarding all DSSs connected to the LV network, their impact on the quality of voltage measured at the Point of Interconnection must comply with the criteria established in:

- IEC/TR 61000-3-14 for harmonic emissions.
- IEC 61000-3-3 and IEC 61000-3-11 for voltage changes and fluctuations.

For DSS connected to the MV network, the impact of the DSS on the quality of voltage measured at the Point of Interconnection will be assessed with regard to the following factors and standards:

- IEC/TR 61000-3-6 for harmonics and inter-harmonics.
- IEC/TR 61000-3-13 for voltage unbalances.

2.6. EARTHING AND PROTECTION REQUIREMENTS

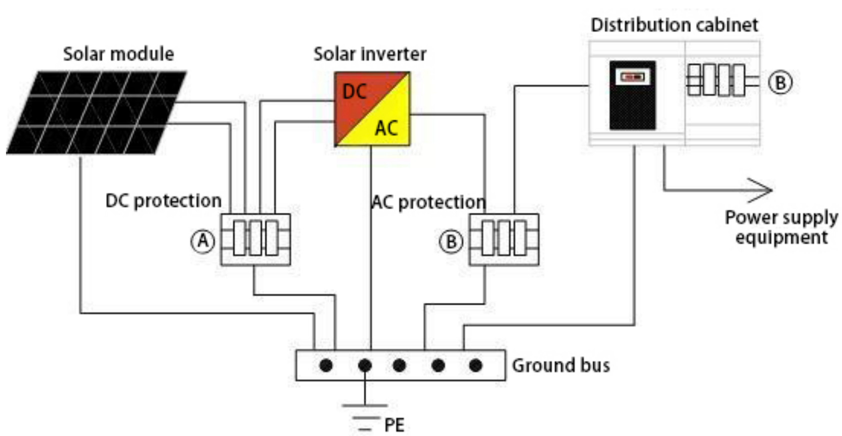
2.6.1. Earthing

Earthing serves as a method to connect exposed conductive components to the primary earthing point. Generally, this refers to connecting the metallic enclosures of equipment to the main earthing terminal through a circuit protective conductor (CPC).

Earthing must adhere to the specifications outlined in The Electricity Wiring Regulation Book by the Federal Electricity and Water Authority – August 2020 and IEC 60364-7-712.

All earthing connections within the PV installation, including both DC and AC sections, shall be integrated into a single earthing system, ensuring proper bonding as shown in Figure 2-3.

Figure 2-3 — Earthing of DSS [8]



Earthing one of the PV array conductors for operational purposes is prohibited, unless there is a basic isolation from the main earth, either internally within the inverter or externally through a dedicated transformer.

Earthing of PV module frames and the metallic structures that support them shall adhere to IEC/TS 62548 and IEC 60364.

Where framed solar modules are utilized, equipotential bonding shall be applied between modules' frames and underlying mounting structure through conductive jumpers and ultimately connected to the existing main earth terminal.

2.6.2. Protection Requirements

2.6.2.1. General

1. The DSS Customer bears the responsibility for ensuring the reliable security of their solar plants, encompassing protections against short circuits, earth faults, and overloads. An Approved Contractor will expertly design and execute the installation of a suitable set of protective mechanisms. In the case of DSSs capable of injecting power into the Distribution Network, these protective measures must also guarantee that the DSS does not unintentionally worsen or prolong network faults.

2. The main function of the protection systems described in this section is to ensure the safety of people, equipment, and the continuity of electrical supply by preventing or minimizing damage and hazards in the event of faults or abnormal operating conditions. Additionally, the protection system is intended to prevent the DSS from supporting an Islanding event of the Distribution Network when it would or could pose a hazard to the Distribution Network or Customers connected to it. The protection system plays a significant role in ensuring the secure and dependable operation of both the network and the electrical infrastructure, encompassing both passive and active components. In accordance with The Electricity Wiring Regulation Book, protection systems must be in place for swiftly resolving short-circuits in electrical facilities, while also maintaining selectivity with the upstream protections mandated by ETIHADWE.

2.6.2.2. Loss of Utility Supply

To prevent the occurrence of Islanding, a DSS connected to the utility grid must promptly stop supplying power to the grid when the distribution line it is connected to becomes de-energized within 2 seconds of loss of power.

A distribution line can lose power for various reasons, such as a substation breaker opening due to a fault or the line being disconnected during maintenance activities.

2.6.2.3. Protection Systems for DSS

The DSS Customer is required to implement the following protective measures:

- Overcurrent Protection.
- Interface Protection to isolate the DSS from the network.

2.6.2.3.1. Overcurrent Protection

Overcurrent protection can serve as a reliable backup protection for the Distribution Network in the event of system faults. It is essential to prevent excessive current from flowing through the system, which can lead to damage or safety hazards.

DC overcurrent protection is required within the solar PV system, positioned between the solar panels and the inverter. Typically, this protection is implemented through the utilization of DC-rated fuses integrated within the inverter itself.

Overcurrent protection is also required on the AC side of the system, between the inverter and the Point of Interconnection. This shall be accomplished using AC circuit breakers and other protective devices.

The standards that shall be used during the selection and installation of overcurrent protection devices based on the Point of Interconnection's voltage level are listed in Table 2-3.

Table 2-3 — Applicable Standards for Overcurrent Protection

Voltage Level	Latest Applicable Standards
LV – 240/415V	IEC 60364 series
MV	IEC 60255-1 and IEC 61936-1

2.6.2.3.2. Interface Protection

In order to protect the distribution grid and not compromise the reliability or undermine the safety of the ETIHADWE Distribution Network, Interface Protection shall be installed. The objective of Interface Protection is to sense abnormal conditions or events on the Distribution Network that necessitate disconnection to prevent further power supply and isolate the DSS facility from the distribution grid.

The Interface Protection shall be positioned as follows:

- In a distinct external unit for DSS with a P_{ac} of ≥ 10 kW.

- It may be integrated into the Inverter for DSS with a Pac of < 10 kW, where number of inverters is ≤ 3.

In the first case, the protection system's activation will result in the Interface Breaker being tripped (refer to DSS Connection Schematics in 0). In the second case, the devices under the control of the DSS (usually integrated into the inverter) will take action to disconnect the unit from the network.

The basic requirements for Interface Protection functions are listed in Table 2-4.

Table 2-4 — Interface Protection Functions Requirements

Protection Function	ANSI Code
UnderVoltage (2 stage)	27
OverVoltage (2 stage)	59
UnderFrequency (2 stage)	81<
OverFrequency (2 stage)	81>
Loss of Mains - Vector Shift	78
Loss of Mains - Rate of Change of Frequency (RoCoF)	81R

For each of the functions mentioned above, except for Loss of Mains (LoM), there must be a minimum of two thresholds. This arrangement is designed to prevent unnecessary tripping by configuring longer time delays for minor deviations and enabling quicker tripping in the event of significant deviations. The LoM protection will operate based on the detection of some suitable parameter, for example, rate of change of frequency (RoCoF), phase angle change, or unbalanced voltages. The thresholds that LoM protection is activated are defined in Table 2-5 for the LV network and Table 2-6 for the MV network.

Table 2-5 — Interface Protection Settings – LV Network

Protection Function	Trip Settings	Trip Delay Setting (Time)
U/V stage 1	0.87 x V_n	2.5 s
U/V stage 2	0.8 x V_n	0.5 s
O/V stage 1	1.14 x V_n	1.0 s
O/V stage 2	1.19 x V_n	0.5 s
U/F stage 1	47.5 Hz	20 s
U/F stage 2	47 Hz	0.5 s
O/F stage 1	51.5 Hz	90 s
O/F stage 2	52 Hz	0.5 s

Protection Function	Trip Settings	Trip Delay Setting (Time)
Loss of Mains (Vector Shift)	12 degrees	0.0 s
Loss of Mains (RoCoF)	0.2 Hz per second	0.0 s

Table 2-6 — Interface Protection Settings – MV Network

Protection Function	Trip Settings	Trip Delay Setting (Time)
U/V stage 1	0.87 x V_n	3.5 s
U/V stage 2	0.7 x V_n	0.5 s
O/V stage 1	1.14 x V_n	1.0 s
O/V stage 2	1.2 x V_n	0.5 s
U/F stage 1	47.5 Hz	20 s
U/F stage 2	47 Hz	0.5 s
O/F stage 1	51.5 Hz	90 s
O/F stage 2	52 Hz	0.5 s
Loss of Mains (Vector Shift)	12 degrees	0.0 s
Loss of Mains (RoCoF)	0.2 Hz per second	0.0 s

The total disconnection time for voltage and frequency protection including the operating time of the disconnection device shall be the trip delay setting with a tolerance of, -0/+ 0.5s.

When used on the MV side of the facility, the Interface Breaker shall comprise either: (i) a three-pole withdrawable motorized circuit breaker activated by an undervoltage release or (ii) A three-pole motorized circuit breaker activated by an undervoltage release, in conjunction with an isolator positioned either upstream or downstream of the circuit breaker.

When used on the low-voltage (LV) side of the facility, the Interface Breaker shall comprise either: (i) a four-pole motorized circuit breaker or (ii) an omnipolar AC3 contactor.

The Interface Breaker shall be automatically reclosed upon clearance of the fault or disturbance on the network that caused its operation. Before reclosure, a time delay shall be incorporated to verify the presence of stable power supply conditions for a minimum consecutive duration of 20 seconds to 5 minutes per IEC 61727 based on the inverter rating and manufacturer. The undervoltage release that operates the motorized interface breaker shall be fed by an auxiliary voltage derived from the network side and not from the DSS side. In cases where multiple DSSs are connected to the same feeder, it may be necessary to synchronize reclosure times. Automatic reclosure must be deactivated in the event of faults within the DSS's installation.

The Interface Protection system shall comply with the following standards where applicable:

- BS EN 61000 (Electromagnetic Standards).
- BS EN 60255 (Electrical Relays).
- BS EN 61810 (Electrical Elementary Relays).
- BS EN 60947 (Low Voltage Switchgear and Control gear).
- BS EN 60044 (Instrument Transformers).

2.7. SHORT-CIRCUIT CONTRIBUTION OF DSS

Because of the DSS's operation, its contribution increases the short-circuit current, especially near the Point of Interconnection. Consequently, the expected short-circuit currents of the DSS at the network connection point shall be provided by the inverter's manufacturer and included when applying for grid-connected DSS.

To ensure accurate calculations, the impedances between the DSS and the Point of Interconnection must be considered.

The equipment rating and insulation specifications of the DSSs, along with their connection setups to the Distribution Network, must be selected to withstand, at a minimum, the currents and voltages of the Distribution Network side specified in Table 2-7.

Table 2-7 — Equipment rating and insulation by voltage level expressed at an ambient temperature of 55° C

Voltage Level	Short Circuit Current	Thermal Current		Dynamic Current	Maximum Line-Line Voltage
(kV)	(kA)	(kA)	(s)	(kA)	(kV)
0.415	40	40	1		
11	25	25	3	63	12
33	25	25	3	63	36

Additionally, when a direct medium voltage (MV) supply is required for a DSS , Connecting DSS to an 11kV network requires careful consideration of technical, protection, and regulatory requirements to ensure both the network and the PV system operate safely and efficiently. Compliance with local grid codes, robust protection mechanisms, proper transformer and inverter design, and grid operator approval are critical to avoid any harm to the network or the PV system

The MV panel is provided by the DSS Customer, the following specified conditions must be adhered to:

- The protection relays for the incoming MV supply must meet the requirements of standard IEC60255 (or an equivalent standard) and shall be supported by both type tests and guaranteed routine manufacturer's works test certificates. The DSS Customer is responsible for providing a certificate confirming that the relays have undergone proper type testing.
- The overcurrent relay shall operate accurately for fault currents up to the specified values in this section.
- The instrument transformers must comply with standard IEC60044 and IEC 61869 (or an equivalent standard) and shall be backed by type tests and guaranteed routine manufacturer's works test certificates. The DSS Customer shall furnish a certificate confirming that the transformers have undergone the necessary type testing.
- The current transformer for the incoming supply shall be sized in a way that ensures the protection scheme operates effectively for fault currents up to the values specified in this section.

Transformer Requirements

- Step-up Transformer: Since PV systems generate power at lower voltages, a step-up transformer is needed to match the 11kV distribution network.
- Transformer Size and Rating: The transformer must be sized to handle the maximum expected output from the PV system with proper insulation and cooling.
- Winding Configuration: Typical configurations include start-delta (Y/Δ) transformers to allow for proper grounding and the reduction of harmonics.

Protection Systems

- Protection Relays: The PV system should be equipped with overcurrent, overvoltage, and earth fault relays.
- Grid Synchronization Protection: Synchronization relays are required to ensure the system is connected to the grid only when it is in phase with the grid voltage and frequency.
- Breaker Systems: Circuit breakers must be installed to isolate the DSS from the grid during faults, maintenance, or abnormal operating conditions. These breakers should have fast-acting mechanisms with adequate fault current ratings.
- Voltage and Frequency Tolerance**:** The DSS must operate within acceptable voltage and frequency ranges defined by the grid operator to prevent disconnection due to minor disturbances.
- The consultant / contractor is responsible for submitting any additional studies that may be required and deemed necessary requested by EtihadWE.

2.8. METERING SYSTEM

A smart metering setup is necessary for the DSS, encompassing both the “Main Energy Meter” for billing purposes and the "DSS Energy Meter” for billing/monitoring purposes.

Existing electricity meter requirements per The Electricity Wiring Regulation Book by the Federal Electricity and Water Authority – Section 8 are also applicable for the DSS metering system.

2.8.1. Required Equipment

The smart metering system shall comprise two components: the Main Energy Meter and the DSS Energy Meter.

The Main Energy Meter measures the electricity consumption from the grid to the customer's load. On the other hand, the DSS Meter measures the energy generated by the solar system and exported 100% to the grid. The Point of Interconnection (POI) will be located after the Main Energy Meter from the customer's side, before the Main Energy Meter from the grid's side.

Both the Main Energy Meter and the DSS Energy Meter must consistently maintain the same levels of accuracy and functionality.

The Main Energy Meter shall be installed and operated to measure the following:

- Import and Export active energy (in units of kWh).
- Import and export reactive energy (in units of kVARh).

Energy is categorized as "import" when it flows from the Distribution Network into the property or premises. It represents the energy consumed from the grid to power electrical devices, appliances, and systems.

Conversely, energy is categorized as "export" when it flows from the meter's output back towards the Distribution Network. Export energy is the energy generated by the DSS.

Both the Main Energy Meter and DSS Energy Meter are required to continuously measure the quantities, display this information, and securely store it in a permanent meter register. Stored data related to measured quantities can be retrieved by ETIHADWE at any time either locally or remotely using proper communication means.

In cases where the DSS Customer has an existing mechanical type of electricity meter (rotatory magnetic desk type), ETIHADWE will provide and replace the existing meter with a smart bi-directional one.

Where applicable, ETIHADWE shall provide CTs or VTs associated with the metering system according to the specifications and accuracy classes outlined in The Electricity Wiring Regulation Book by the Federal Electricity and Water Authority – Section 8.3.

Electricity meters as well as CTs and VTs must be installed, operated, and maintained in compliance with the standards and accuracy classes outlined in The Electricity Wiring Regulation Book by the Federal Electricity and Water Authority – Section 8.

2.8.2. Meter Provision and Approval

Only meters that are included in ETIHADWE's authorized list of meters are permitted for installation. Meters will be supplied by ETIHADWE.

2.8.3. Meter Safety and Protection Degree

Electricity meters shall be designed and built to eliminate any potential hazards during typical use and under standard conditions, ensuring, in particular:

- Preventing the potential spread of fires.
- Protecting individuals from the impacts of extreme temperatures.
- Ensuring the safety of individuals against electric shock.
- Implementing effective protection measures for all components and surfaces prone to corrosion in typical operational conditions.

The meter shall have sufficient mechanical durability and be able to withstand the high temperatures expected in the UAE.

The DSS meter cabinet must have at least IP54 protection degree and shall be designed to prevent the entry of pests and dust. The meter's electronic components will be shielded with a coating that is water and dust-resistant, providing excellent humidity resistance as well.

The DSS meter box should be located in close proximity to the main energy meter box.

2.9. DSS REMOTE MONITORING AND CONTROL SYSTEM

Monitoring and control in DSSs serve several important purposes. It optimizes the performance of the PV installation by providing real-time data on electrical output and environmental conditions. This data allows for adjustments to be made, maximizing energy production and efficiency. Additionally, monitoring systems can provide early fault detection, helping to identify issues, errors, or anomalies in the system's performance. This early detection is vital for timely maintenance and minimizing system downtime, ensuring the longevity of the installation.

2.9.1. Monitoring and Control Requirements

- All DSSs shall have local real-time monitoring capabilities, allowing operators to track the system's performance, including electrical output and overall health.
- A communication connection will be required between the main meter and the DSS meter, and a conduit should be installed between the two boxes.
- The external interface protection relay of DSS shall have remote control capability for systems. This allows ETIHADWE to disconnect the DSS from the Distribution Network when necessary.
- DSS shall be able to record and store performance data, allowing for historical analysis and fault detection.
- The system shall detect, report, and store faults, errors, or performance anomalies to operators or maintenance personnel.

2.10. COMPLIANCE

The DSS Customer is responsible for ensuring that the DSS complies with these guidelines, and this compliance must be upheld for the entire duration of the facility's lifetime.

The DSS Customer must provide data from the DSS monitoring system as required by these guidelines, and this data will be furnished to ETIHADWE upon their request, exclusively for the purpose of compliance monitoring.

3. INSPECTION AND TESTING GUIDELINES FOR DSS

3.1. GENERAL

The purpose of this section is to provide guidelines for Approved Contractors and Etihad Water and Electricity engineers and inspectors for the inspection and testing of Distributed Solar Systems (DSS), which will adhere to the industry standards and guidelines for photovoltaic (PV) system installations.

The primary objective of these guidelines is to confirm the DSS's compliance with the applicable technical standards, as outlined in the established "Distributed Solar Systems Standards and Guidelines For Small-Scale PV Systems in ETIHADWE.

Specifically, this pertains to the test procedures that a certified Testing Engineer, designated by the Approved Contractor, must follow. Their role is to furnish ETIHADWE with comprehensive documentation that verifies the proper installation execution and the correct operational performance of the system.

Within this process, responsibilities are divided among different entities. The Approved Contractor is responsible for conducting the tests and providing the inspection reports, while ETIHADWE is responsible for providing meter(s) and authorizing connections. Additionally, the competent authority, which can include the Municipality, is tasked with issuing building permits and building completion certificates. They are also responsible for assessing the mechanical and structural aspects of the DSS installation. See Section 3.2 for a summary of responsibilities among different parties.

DSS inspections and testing shall be conducted both prior to the interconnection to the Distribution Network (encompassing inspections at the Mechanical Completion stage) and after the interconnection to the Distribution Network.

If the inspection or testing outcome is not accepted, the Approved Contractor must implement the agreed-upon corrective actions with ETIHADWE prior to the reevaluation of the checks and verifications. This reevaluation will occur during a subsequent inspection, and a revised inspection report shall be generated.

Upon the successful completion of the required inspections and tests for the specific DSS, ETIHADWE grants authorization to commence production and issues a connection agreement. This document certifies the installation's compliance with ETIHADWE's guidelines and regulations.

These guidelines are in accordance with IEC 62446-1 standard, “Photovoltaic (PV) systems – Requirements for testing, documentation, and maintenance – Part 1: Grid connected systems – Documentation, commissioning tests and inspection.” [**Error! Reference source not found.**]

In the inspection request, Approved Contractors shall highlight to ETIHADWE any site-specific risks and any special safety measures to be considered during the inspection. Site-specific risks may include hazardous chemical materials, falling, and restricted areas that require safety induction and access permission.

3.2. DIVISION OF RESPONSIBILITIES

Table 2-3 summarizes the process of inspection and testing as well as the roles of each party involved in this process.

Table 3-1 — Division of Responsibilities

Order	Activity	Responsible Party	Supervision Party
1	Inspection at Mechanical Completion	Approved Contractor	Concerned Authority
2	Testing before interconnection	Approved Contractor	ETIHADWE
3	Energy & DSS meter(s) supply, installation, and commissioning	ETIHADWE	Approved Contractor
4	**DSS initial interconnection**		
5	Functional inspection	Approved Contractor	ETIHADWE
6	Power quality test[2]	Approved Contractor	ETIHADWE
7	**DSS final interconnection**		

ETIHADWE may supervise and witness the above inspections and tests at their discretion, except for the civil and structural part of the mechanical inspection, which might require involvement from the relevant Municipality.

3.3. TECHNICAL DOSSIER

It is crucial for the operation of any DSS, especially for maintenance technicians, to have access to as-built drawings, ETIHADWE design approval, documents, and equipment documentation (such as technical specifications, installation guides, user manuals, etc.).

[2] For DSSs with a Maximum AC capacity (P_{ac}) equal to or exceeding 100 kW.

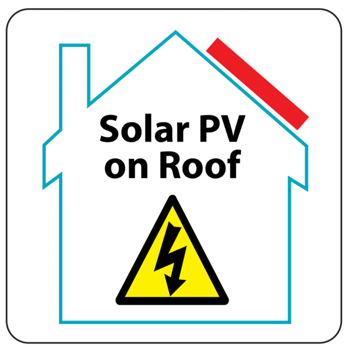
The Approved Contractor shall make the DSS technical dossier available and ready upon request from ETIHADWE during inspection.

3.4. SAFETY CONCERNS

Photovoltaic modules generate electricity when exposed to daylight, and individual modules cannot be switched off. Consequently, unlike most other electrical installation work, PV system installation typically involves working on a live system.

Anything located before a circuit-breaker/isolator switch on the DC section of a DSS (toward the PV array) remains energized during daylight hours, even after the circuit-breaker/isolator switch is opened. Every switchgear and junction box in the DSS's DC section must feature a warning indicating the presence of live components even when the inverter circuit-breaker/isolator switch devices are in the open position. Figure 5-10 shows a sample warning label to indicate the presence of live parts.

Figure 3-1 — DSS Warning Sign [14]



Any work conducted on the energized components of the DSS DC side shall be treated as an operation performed under voltage. This distinction may seem unusual for an installer who is assuming that the system is de-energized when the main circuit breaker is turned off.

Standard precautions like personal protective equipment (PPE), working at heights, manual handling, and handling of glass shall be considered when performing any inspection or testing activities. Also, insulated tools must be employed when conducting electrical tasks. An alternative to using insulated tools is to place an insulating mat designed for electrical purposes under the operator.

When working with live electrical components in an outdoor environment, it is important to avoid any inspection or testing tasks under specific adverse conditions. This includes situations involving fog, rain, snow, or dust storms, primarily because these conditions can severely limit visibility. Additionally, it's advisable to steer clear of such work during very low temperatures or strong winds, as these environmental factors can make it difficult to securely handle and control tools. In all these instances, it is required to exercise caution and consider postponing the work until conditions are more favorable.

Other risks that are associated with inspection and testing work include:

- The risk of falling for rooftop DSS. In such cases, operators shall adhere to safety protocols suitable for the specific scenario. This might involve using safety harnesses securely fastened to stable elements on the roof, such as hooks and safety ropes to prevent falls.
- Contact burns from handling PV modules can occur due to high temperatures when exposed to sunlight. To mitigate this risk, operators are required to wear heat-resistant work gloves capable of withstanding temperatures up to 100°C.

3.5. INSPECTION

During the inspection, a thorough assessment of various aspects is conducted, including:

- Visual examination of the DSS site, encompassing the support structure, PV modules, mounting, and wiring.
- Verification that the DSS installation aligns with the approved electrical and structural design by ETIHADWE and municipality respectively that were submitted with the Connection Application [**Error! Reference source not found.**].
- Visual inspection of the inverter and junction boxes, including their location and mounting.
- Visual inspection of the protection system and labeling by checking for the presence of warning signals for the risk of electric shock.
- Examination of the wiring layout and cable arrangement on the site.
- Verification of the correct rating of the BOS equipment.
- Verification of the proper earthing of the PV array.
- Ensuring the correct placement and positioning of cables and electrical distribution boxes, along with visually inspecting the cabling to and from the inverter.
- Confirming compliance with the standards governing the electrical equipment used in the DSS.
- Ensure a clean site, as debris can pose a fire ignition risk.

3.6. TESTING

Electrical system testing shall be conducted by an Approved Contractor. It is the responsibility of the Approved Contractor to identify appropriate PPE required for testing. Before energizing the PV system, the following electrical measurements must be carried out:

- Verify the correct polarity of the DC circuitry. This shall be done before finalizing the connection to the inverter to prevent potential damage due to reverse polarity.

- Measure the open circuit voltage (Voc) of PV strings to ensure optimal wiring of series PV strings. The Voc variation between PV strings connected to the same inverter (for inverters with single MPPT) or to the same MPPT (for inverters with multiple MPPTs) shall not exceed 5% per IEC 62446-1 and shall be compared to the manufacturer's permitted tolerances.
- Measure the short circuit current (Isc) of typical PV strings to ensure that the short circuit currents of all PV strings involved are within approximately 10% of the average string current per IEC 62446-1.
- Measure the earth resistance of the earthing system which shall not exceed 0.5 Ω per The Electricity Wiring Regulation Book by the FEWA – Section 13.
- Measure the insulation resistance of the DC cables. Acceptable insulation resistance values are provided in section 3.6.2 below.

3.6.1. Polarity Test

This test is essential during the commissioning of any DSS since the correct polarity of string wiring is a critical aspect of PV installations. It is crucial to verify the polarity on the DC side, including all source circuits and PV power sources, before connecting the PV strings to inverters.

Reversed polarity can have significant and potentially dangerous consequences, as it can lead to damage to PV modules or source circuit wiring. While some inverters incorporate rectifiers in their circuit design at the DC input to protect against reverse polarity wiring, many inverters omit rectifiers due to increased design complexity and cost considerations, which means that such inverters can be destroyed by reversed polarity.

To verify the polarity, measuring the voltage of the energized circuits before closing the DC switch disconnect and switching on the system for the first time is required. A digital multimeter is suitable for this task, while analog voltmeters shall be avoided as reverse polarity can damage their needle movement. When the polarity is correct, the multimeter will display a positive sign (+) beside the voltage value. If it is reversed, the sign on the display will be negative (-).

The polarity test shall be conducted on the following components:

- PV modules.
- PV strings.
- DC disconnect switches.
- Input terminations of the inverter.

3.6.2. Insulation Resistance Test

Insulation resistance tests are carried out to confirm the integrity of the DSS and the wiring of its components. This test helps identify the extent of wear and tear on the insulation of wires and can detect faults within PV strings and various system circuits. It is an essential part of commissioning DSSs since many system failures and fire risks result from faulty wiring connections or inadequate insulation, which elevate the potential for electrical arcs or shock hazards.

Before conducting insulation tests, installers responsible for system commissioning must adhere to the following safety measures:

- Testing circuits shall be disconnected by opening disconnect switches, ensuring the circuits are in a de-energized state. The exception to this rule is PV DC circuits, which remain energized in the presence of light.
- The test lead from the insulation testing instrument must always be connected first and be the last one to be disconnected from the circuit after recording the values.
- Insulation resistance tests shall never be carried out on circuits containing inverters since they are designed to function within specific voltage ranges, and subjecting them to higher test voltages can cause irreversible damage.

The following steps are required to conduct an insulation resistance test:

- Test all the individual strings in the DSS.
- Connect one lead from the insulation resistance test instrument to the PV string cables (positive or negative).
- Connect the second lead from the test instrument to the earth.
- Secure the leads in place using cable ties.
- Refer to the instructions provided with the insulation resistance test instrument to ensure the correct voltage values are recorded for each PV string voltage range.
- Record the readings and verify that the PV system is de-energized before removing the test cable and coming into contact with any conductive parts.

In compliance with the IEC 62446 standard, it is recommended that PV systems with a voltage of less than 120 V should exhibit a minimum insulation resistance value of 0.5 MΩ. PV systems exceeding 120 V should have values of 1 MΩ or higher, which are considered acceptable. It is essential to maintain thorough documentation of all recorded values during the commissioning process, as they serve as a reference for subsequent insulation resistance tests conducted over the years to assess the extent of wire degradation.

3.6.3. Open Circuit Voltage Test

The open circuit voltage (Voc) of each PV string shall be examined before closing the DC disconnect switches for PV strings. This voltage shall be compared with the expected design values per the PV module's datasheet. The open circuit voltage test can only be conducted before the strings in the system are connected together in a parallel configuration. Each string's Voc must be measured individually.

Additionally, this test can be used to verify the correct polarity. It is important to note that all commissioning tests are not meant to assess the system's performance; rather, they are conducted to validate the integrity and correctness of the installation process. To perform the Voc test, a voltmeter capable of measuring both DC voltages in the range of 600-1500 V is required based on the system's maximum voltage.

If the measured Voc reading is below the anticipated level, it may be due to incorrect string wiring, module malfunctions, or potential short circuits in bypass diodes. Additionally, it's crucial to confirm that the Voc value falls within the permissible operating voltage range of the inverter.

3.6.4. Short Circuit Current Test

The short circuit current (Isc) test is conducted on PV strings to ensure that the readings align with the expected values per the PV module's datasheet and reveal no significant faults. This test is performed using a digital multimeter capable of measuring DC current values of up to 15 A. However, to measure the current value, the installer will require an appropriate shorting device. Alternatively, PV string short circuit current can be measured by using an appropriate testing instrument (such as a solar I-V tester) which is capable of internally shorting positive and negative string cables.

Isc is directly proportional to the available solar irradiance on PV arrays. As a result, the test shall be executed promptly under optimal clear-sky conditions. It's crucial to confirm that the array is free from contamination or partial shading.

3.6.5. DSS Startup Sequence

After completing the visual inspections of the system and confirming the correct expected measurements explained above for each string, the inverter can be energized. It is essential to carefully follow the manufacturer's provided instructions for the initial startup of the specific inverter in use. Typically, the startup steps will encompass:

- Verification of all DC and AC connections and wiring.
- Confirmation of the accurate value and polarity of DC voltage at the DC disconnect switch terminal.
- Verification of AC voltage at the AC disconnect switch terminal.
- Closure of the AC disconnect switch.
- Measurement and confirmation of AC voltage at the inverter's output AC terminals.
- Closure of all DC disconnect switches.

- Measurement and verification of the correct value and polarity of DC voltage at the inverter's DC input terminals.
- Activation of the inverter and a brief wait for its internal startup.
- Awaiting a minimum of 15 minutes after turning on the inverter for the power point tracking and internal temperature to stabilize.

The purpose of inspection and testing before grid interconnection is to highlight key system characteristics and common installation errors. It also verifies that system installation is completed in accordance with approved design documents. The inspection and testing items described in this section shall be verified by the Approved Contractor to have a chance to apply any necessary corrective measures prior to engaging ETIHADWE in the formal inspection.

Approved Contractors shall consider bringing the following items during the inspection:

- A ladder with non-conductive sides.
- Any necessary tools for safe opening of enclosures.
- A copy of the approved design submitted by the contractor.

3.7. INSPECTION AT MECHANICAL COMPLETION

Upon Mechanical Completion and prior to ETIHADWE’s inspection, a thorough assessment of various aspects shall be conducted by the Approved Contractor, including:

- Visual examination of the DSS site, encompassing the support structure, PV modules, mounting and wiring.
- Verification that the DSS installation aligns with the approved electrical and structural design by ETIHADWE and Municipality, respectively, that were submitted with the application.
- Visual inspection of the inverter and junction boxes, including their location and mounting.
- Visual inspection of the protection system and labeling by checking for the presence of warning signals for the risk of electric shock.
- Examination of the wiring layout and cable arrangement on the site.
- Verification of the correct rating of the balance-of-system equipment.
- Verification of the proper bonding and earthing of the PV array.
- Verification of sufficient protection degree (IP rating) for DSS components.

- Ensuring the correct placement and positioning of cables, protection devices and electrical distribution boxes, along with visually inspecting the cabling to and from the inverter.
- Confirming compliance with the standards governing the electrical equipment used in the DSS.
- Conducting a general site cleaning, as debris can pose a fire ignition risk.

The following items will be inspected by the relevant Municipality:

- Visual inspection of the mounting structure by checking condition of the structural elements (joints, structure members, paint, galvanization, welding quality) as well as bolts tightening for all connections.
- Inspection of civil works for the case of ground mounted DSS.

3.8. TESTING BEFORE INTERCONNECTION

Electrical system testing shall be conducted by the Approved Contractor. It is the responsibility of the Approved Contractor to identify appropriate PPE required for testing. Before energizing the PV system, the following electrical measurements must be carried out:

- Verify the correct polarity of the DC circuitry. This shall be done before finalizing the connection to the inverter to prevent potential damage due to reverse polarity.
- Measure the open-circuit voltage (Voc) of PV strings to ensure optimal wiring of series PV strings. The Voc variation between PV strings connected to the same inverter (for inverters with single MPPT) or to the same MPPT (for inverters with multiple MPPTs) shall not exceed 5% per IEC 62446-1 and shall be compared to the manufacturer's permitted tolerances.
- Measure the short-circuit current (Isc) of typical PV strings to ensure that the short-circuit currents of all PV strings involved are within approximately 10% of the average string current per IEC 62446-1.
- Measure the earth resistance of the earthing system which shall not exceed 0.5 Ω per The Electricity Wiring Regulation Book by the FEWA – Section 13.
- Measure the insulation resistance of the DC cables. Acceptable insulation resistance values are provided in section 3.6.2 below.
- Verification of Interface Protection. This involves the examination and adjustment of thresholds for equipment and protective devices, achieved through simulated intervention tests when feasible. Protection thresholds include over/under voltage and over/under frequency thresholds.

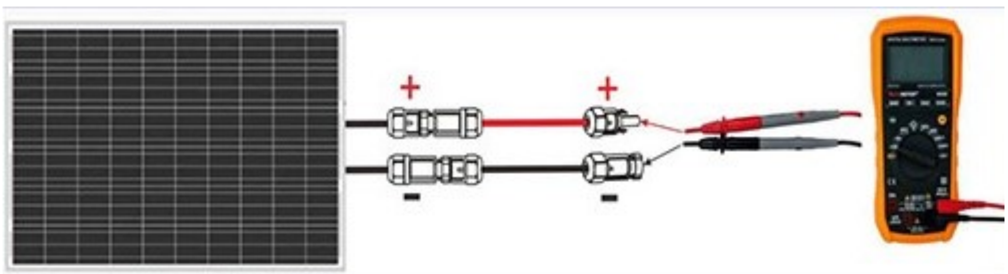
3.8.1. Polarity Test

This test is essential during the commissioning of any DSS since the correct polarity of string wiring is a critical aspect of PV installations. It is crucial to verify the polarity on the DC side, including all source circuits and PV power sources, before connecting the PV strings to inverters.

Reversed polarity can have significant and potentially dangerous consequences, as it can lead to damage to PV modules or source circuit wiring. While some inverters incorporate rectifiers in their circuit design at the DC input to protect against reverse polarity wiring, many inverters omit rectifiers due to increased design complexity and cost considerations, which means that such inverters can be destroyed by reversed polarity.

To verify the polarity, measuring the voltage of the energized circuits before closing the DC switch disconnect and switching on the system for the first time is required. A digital multimeter is suitable for this task as shown in Figure 2-22, while analog voltmeters shall be avoided as reverse polarity can damage their needle movement. When the polarity is correct, the multimeter will display a positive sign (+) beside the voltage value. If it is reversed, the sign on the display will be negative (-).

Figure 3-2 — PV String Polarity Test [Error! Reference source not found.**]**



The polarity test shall be conducted on the following components:

- PV modules.
- PV strings.
- DC disconnect switches.
- Input terminations of the inverter.

3.8.2. Insulation Resistance Test

Insulation resistance (R_{ins}) tests are carried out to confirm the integrity of the DSS and the wiring of its components. This test helps identify the extent of wear and tear on the insulation of wires and can detect faults within PV strings and various system circuits. It is an essential part of commissioning DSSs since many system failures and fire risks result from faulty wiring connections or inadequate insulation, which elevate the potential for electrical arcs or shock hazards.

Before conducting insulation tests, installers responsible for system commissioning must adhere to the following safety measures:

- Testing circuits shall be disconnected by opening disconnect switches, ensuring the circuits are in a de-energized state. The exception to this rule is PV DC circuits, which remain energized in the presence of light.
- The test lead from the insulation testing instrument must always be connected first and be the last one to be disconnected from the circuit after recording the values.
- Insulation resistance tests shall never be carried out on circuits containing inverters since they are designed to function within specific voltage ranges and subjecting them to higher test voltages can cause irreversible damage.

The following steps are required to conduct an insulation resistance test (see Figure 3-3):

- Test all the individual strings in the DSS.
- Connect one lead from the insulation resistance test instrument to the PV string cables (positive or negative).
- Connect the second lead from the test instrument to the earth.
- Secure the leads in place using cable ties.
- Refer to the instructions provided with the insulation resistance test instrument to ensure the correct voltage values are recorded for each PV string voltage range.
- Record the readings and verify that the PV system is de-energized before removing the test cable and coming into contact with any conductive parts.

Figure 3-3 — PV String Cable Insulation Test [Error! Reference source not found.]

In compliance with the IEC 62446-1 Section 6.7.3, it is recommended that PV systems with a string voltage of less than 120 V should exhibit a minimum insulation resistance value of 0.5 MΩ. PV systems with string voltages exceeding 120 V should have values of 1 MΩ or higher, which are considered acceptable. It is essential to maintain thorough documentation of all recorded values during the commissioning process, as they serve as a reference for subsequent insulation resistance tests conducted over the years to assess the extent of wire degradation.

3.8.3. Open-Circuit Voltage Test

The open-circuit voltage (V_{oc}) of each PV string shall be examined before closing the DC disconnect switches for PV strings, per IEC62446-1 Section 6.4. This voltage shall be compared with the expected design values per the PV module's datasheet. The open-circuit voltage test can only be conducted before the strings in the system are connected together in a parallel configuration. Each string's V_{oc} must be measured individually.

Additionally, this test can be used to verify the correct polarity. It is important to note that all commissioning tests are not meant to assess the system's performance; rather, they are conducted to validate the integrity and correctness of the installation process. To perform the V_{oc} test, a voltmeter capable of measuring both DC voltages in the range of 600–1500 V is required based on the system's maximum voltage.

If the measured V_{oc} reading is below the anticipated level, it may be due to incorrect string wiring, module malfunctions, or potential short circuits in bypass diodes. Additionally, it's crucial to confirm that the V_{oc} value falls within the permissible operating voltage range of the inverter.

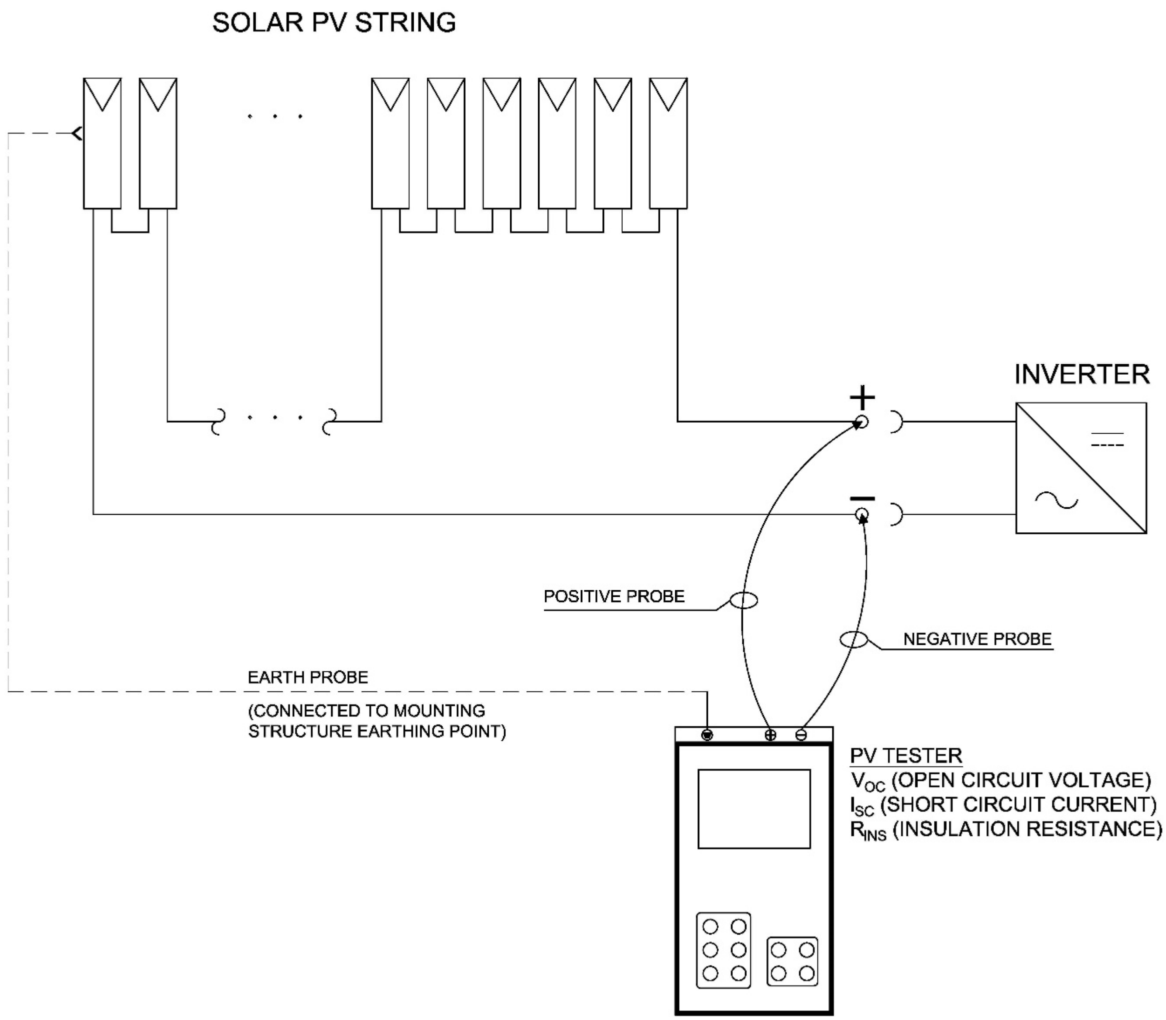
3.8.4. Short-Circuit Current Test

The short-circuit current (I_{sc}) test is conducted on PV strings per IEC62446-1 Section 6.5 to ensure that the readings align with the expected values per the PV module's datasheet and reveal no significant faults. This test is performed using a digital multimeter capable of measuring DC current values of up to 15 A. However, to measure the current value, the installer will require an appropriate shorting device. Alternatively, PV string short-circuit current can be measured by using an appropriate testing instrument (such as a PV tester) which is capable of internally shorting positive and negative string cables.

The I_{sc} is directly proportional to the available solar irradiance on PV arrays. As a result, the test shall be executed promptly under optimal clear-sky conditions ideally above 400 W/m^2 as measured in the plane of the array per IEC62446-1 Section 7.2.3. It is crucial to confirm that the array is free from contamination or partial shading.

For V_{oc}, $I_{sc,}$ and R_{ins} tests, Figure 3- illustrates the connection of a PV tester instrument that can perform V_{oc}, $I_{sc,}$ and R_{ins} tests simultaneously.

Figure 3-4 PV Tester Connection Diagram



3.8.5. Interface Protection Test

The Interface Protection typically includes predefined settings provided by the manufacturer. Nevertheless, it is essential to verify these settings, and make adjustments as needed; this involves potentially modifying the thresholds of equipment and protective devices, and ensuring the correct functioning of Interface Protection through simulated tests at the site.

3.9. TESTING AFTER INTERCONNECTION

The primary goal of inspection and testing after grid interconnection is to confirm that every aspect and function of the system is thoroughly checked and validated. It also helps in identifying and addressing any faults or malfunctions that may arise in the system, such as issues with inverters or monitoring equipment.

Overall, inspection and testing after interconnection aims to ensure that the DSS is functioning efficiently, safely, and as specified.

3.9.1 FUNCTIONAL INSPECTION

3.9.1.1 DSS Startup Sequence

After completing the visual inspections of the system and confirming the correct expected measurements explained in the previous section for each string, the inverter can be energized. It is essential to carefully follow the manufacturer's provided instructions for the initial startup of the specific inverter in use. Typically, the startup steps will encompass:

- Verification of all DC and AC connections and wiring.
- Confirmation of the accurate value and polarity of DC voltage at the DC disconnect switch terminal.
- Verification of AC voltage at the AC disconnect switch terminal.
- Closure of the AC disconnect switch.
- Measurement and confirmation of AC voltage at the inverter's output AC terminals.
- Closure of all DC disconnect switches.
- Measurement and verification of the correct value and polarity of DC voltage at the inverter's DC input terminals.
- Activation of the inverter and a brief wait for its internal startup.

Awaiting a minimum of 15 minutes after turning on the inverter for the power point tracking and internal temperature to stabilize.

3.9.1.2 DSS Alarms Functionality

Checking the functionality of alarms in a DSS after it begins operation is essential for safety, early issue detection, operational reliability, energy production optimization, system longevity, compliance with regulations, data monitoring, and warranty maintenance. It helps ensure the system operates efficiently, safely, and reliably throughout its lifespan.

Functional alarms provide valuable data and insights into the system's performance, helping operators make informed decisions about maintenance, component replacement, or system optimization.

3.9.2 Verification of Energy Meters' Connection

The installation and validation of energy meters are the responsibility of ETIHADWE. During ETIHADWE's final inspection, the following information shall be gathered:

- Identify the nameplate data of any voltage and current transformers (if available).
- Verify the meter's connections to current transformers (CT) / voltage transformers (VT), and confirm CT / VT settings.

Throughout these inspections, inspectors shall evaluate the energy metering equipment within the facility.

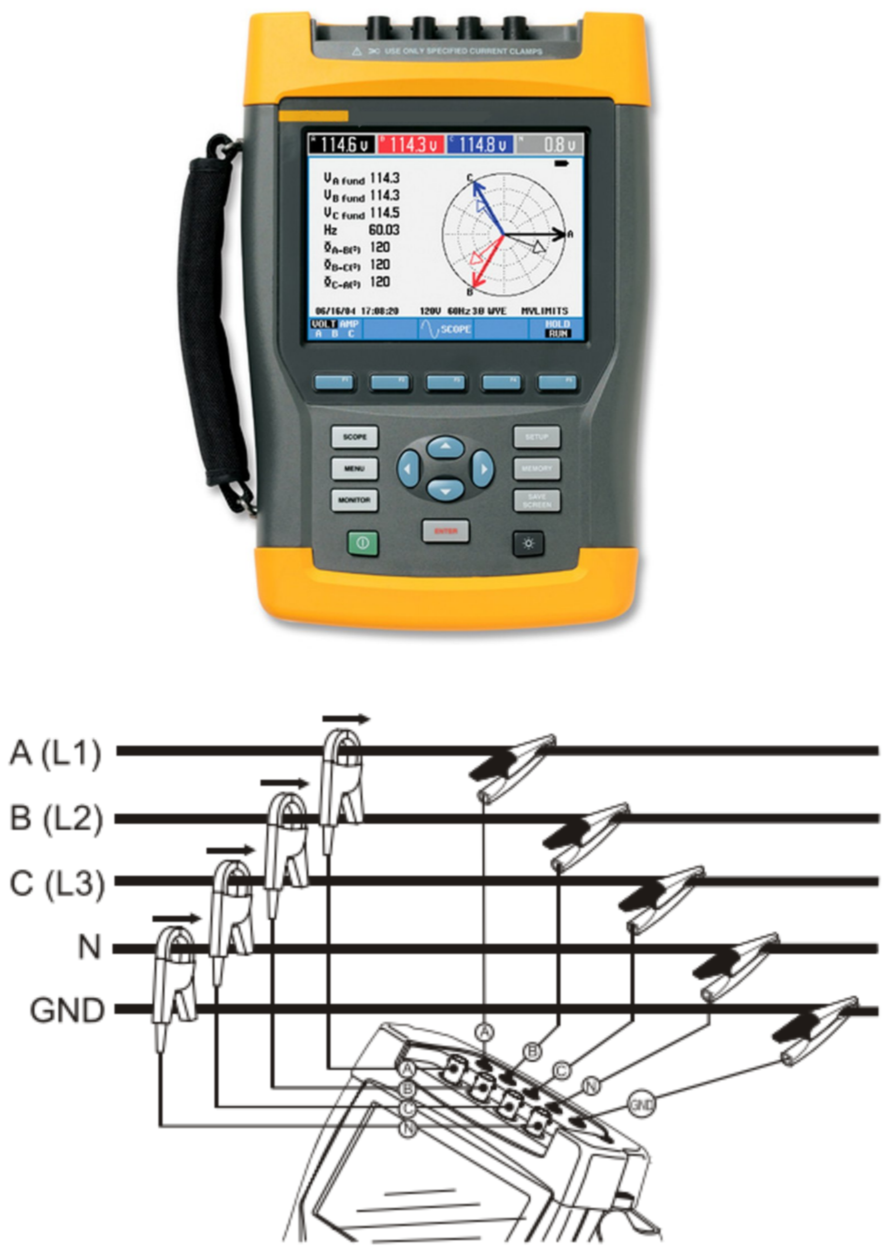
3.9.3 Power Quality Test

For DSSs with a Maximum Capacity (P_{ac}) equal to or exceeding 100 kW, it is necessary to conduct measurements of main system parameters (such as voltage, current, output power, and power factor) as well as the harmonic emissions originating from the system. These measurements are essential for ETIHADWE to confirm that the power quality within the grid aligns with the requirements of BS EN 50160 Section 2.5.4 and that the DSS does not introduce disruptions to other customers. This test is made for the entire DSS at the point of interconnection (POI).

The DSS power quality test can be carried out by utilizing specific instrumentation installed at the POI with an observation period of one week. The test results must be clearly organized in tables for examination by ETIHADWE, allowing them to compare the results with ETIHADWE's planning criteria and thresholds. If any of these thresholds are exceeded, ETIHADWE reserves the right to request further measurements of harmonic emissions from the customer. This additional testing aims to investigate whether any violations of these limits are due to the DSS itself or its interaction with other DSSs.

Figure 3-5 shows an example of a testing instrument that performs a power quality test for the power signal.

Figure 3-5 Example of Power Quality Testing Instrument with its Connection



4. DSS OPERATION AND MAINTENANCE

To ensure the reliable and safe operation of DSSs, routine maintenance is essential. It aims to maintain optimal system performance and address any deviations or discrepancies identified through inspections. Troubleshooting is carried out to rectify any errors and ensure the system's integrity. The frequency and extent of maintenance activities depend on factors like system size, type, location, and performance.

A typical maintenance plan includes the following tasks:

- Inspection of various system components and wiring methods.
- Assessment of the integrity of mechanical structures and weather sealing, particularly for roof installations.
- Removal of accumulated dust and debris on PV modules.
- Performance of electrical insulation test for the PV string cables to check for any degradation.
- Repair or replacement of damaged components.
- Inspection of modules for hotspot areas, which can be done using thermal drones to detect areas with elevated temperatures.

Visual inspections during maintenance are crucial and involve:

- Checking PV modules for any signs of broken or chipped glass, as well as bent frames. A fractured module can allow moisture inside, leading to faults and leakage current, necessitating replacement.
- Inspecting for discolorations or corrosion within module laminates, which could indicate hot spots and potential degradation of internal cell connections, ultimately risking module failure or fire hazards.
- Clearing any fallen leaves or debris on PV modules, which can pose fire hazards or obstruct drainage pathways, especially for roof-based installations.
- Regular cleaning of PV modules, with a frequency depending on the location. Areas with high dust accumulation require more cleaning cycles to maintain an acceptable system performance.
- Inspecting the weather sealing and structural integrity, making necessary repairs based on the extent of damage.

Maintenance tests primarily serve to confirm specific measurements and assess their degradation rate. For instance, voltage and power outputs in most PV modules are expected to degrade between 0.5% and 1% per year, aligning with component manufacturer datasheets and warranties. It is important to note that extra soiling and shading effects can affect these values accordingly.

5. DESIGN REQUIREMENTS

5.9 GENERAL

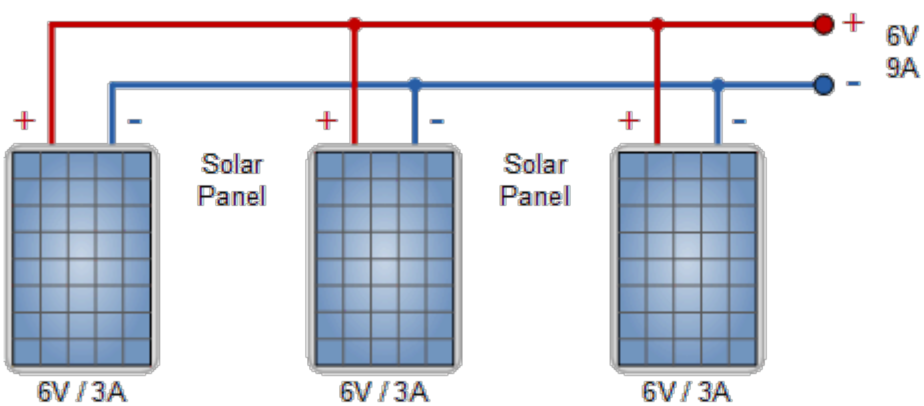
The main DSS components shall comply with the international standards listed in PV System Components and shall be listed on the List of Approved Equipment available on ETIHADWE's Solar Platform[3].

5.10 DC SYSTEM DESIGN

Solar PV modules are usually set up in two configurations as described below:

a. Parallel connection: In this setup, the current of the module is the total of all module currents, while the output voltage remains equal to the module voltage.

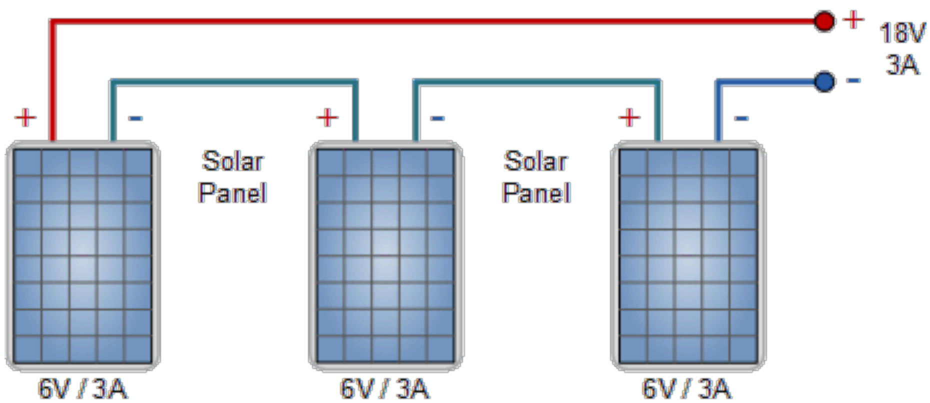
Figure 5-1 — Solar PV Modules – Parallel Connection [9]



b. Series connection: When connected in series, the output voltage becomes the sum of all module voltages, while the output current remains at the module's current level.

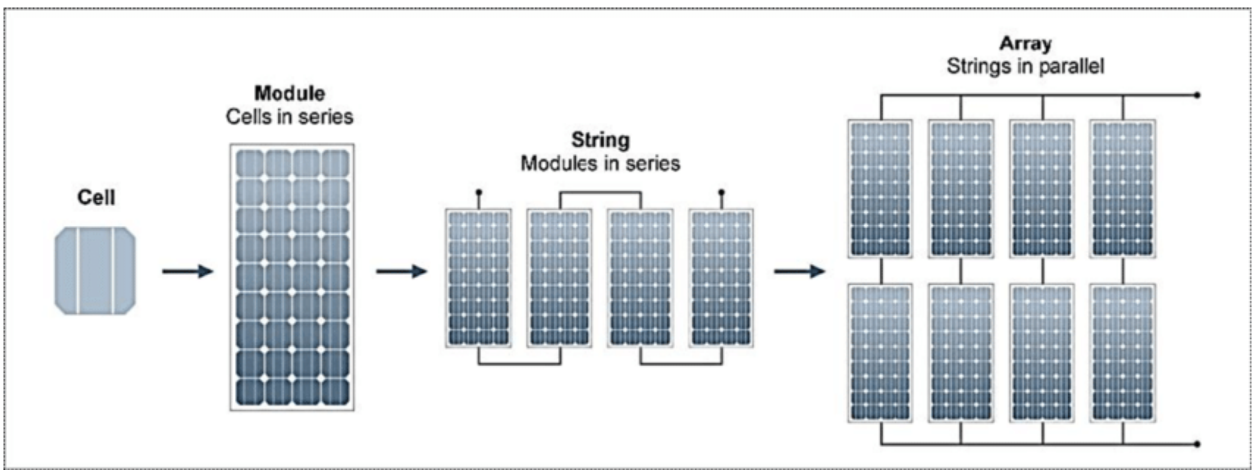
[3] To be determined.

Figure 5-2 — Solar PV Modules – Series Connection [10]



c. When solar PV modules are connected in a series arrangement, they create a PV string, and combining PV strings in parallel results in the formation of a PV array, as depicted below.

Figure 5-3 — Solar PV Array Configuration [11]



- To facilitate electrical connections, every PV module shall be equipped with a set of connecting cables, comprising both positive (+) and negative (-) terminals, extending from a junction box positioned on the rear side of the panel.
- Each PV module must have a label affixed to its rear side. These labels commonly contain data and specifications under standard testing conditions (STC), including details like model type and number, maximum system voltage, power rating (Wp), Open Circuit Voltage (Voc), Short Circuit Current (Isc), voltage at the maximum power point (Vmpp), current at the maximum power point (Impp), and power temperature coefficient.

In a single solar PV system, modules must share a common manufacturer and model number while also possessing similar rated electrical properties

5.10.1 DC Voltage and Current Ratings

All ratings for DC components within the DSS, including cables, isolators/disconnectors, switches, connectors, and more, should be determined based on the maximum voltage and current of the specific segment of the PV array. These values should be adjusted in accordance with safety factors as specified below. This calculation should consider the system's voltage and currents resulting from the series and parallel connection of modules within the array, as well as the maximum output capacity of each individual module.

When assessing the voltage and current requirements of the DC system, it's important to evaluate the potential maximum values that may arise. These maximum values are derived from two key ratings of PV modules: the open-circuit voltage (Voc) and the short-circuit current (Isc), both provided by the module manufacturer. It's worth noting that the manufacturer's values for Voc and Isc are determined under standard test conditions (STC), which include an irradiance of 1000 W/m^2, air mass 1.5, and a cell temperature of 25°C.

However, the actual operating conditions in the field can deviate significantly from these STC parameters, especially in terms of irradiance and temperature. These variations can have a substantial impact on the Voc and Isc values. Therefore, the following multiplication factors are applied to account for the maximum values that may be encountered under UAE-specific conditions.

Mono- and multi-crystalline silicon modules - All DC components must be rated, as a minimum, at:

- Voltage: Voc(STC) x 1.15
- Current: Isc(STC) x 1.25

For all other types of solar modules, it is essential that the DC components have ratings that meet, as a minimum, the following criteria:

They shall be based on precise calculations of the most extreme Voc and Isc values.

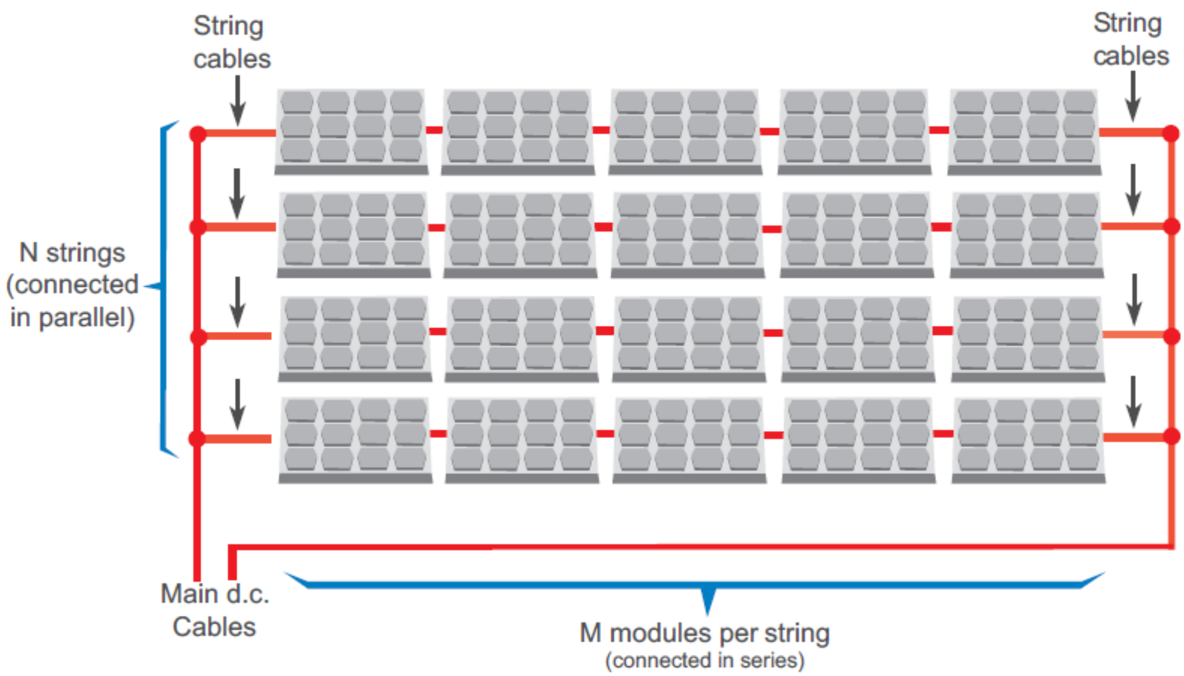
5.10.2 String Cables

For an array of N parallel connected strings, with each string formed of M series connected modules, String cables must be rated as a minimum as follows:

- Voltage > Voc(stc) x M x 1.15
- Current > Isc(stc) x (N-1) x 1.25

- The cable Current Carrying Capacity (Iz) must be calculated according to the requirements of IEC 60364. This shall include factors taking into account installation conditions such as cable installation method, solar gains, grouping, etc.

Figure 5-4 — PV Array Strings [12]



5.10.3 PV String and Array Voltage

While it is generally advisable to maintain low voltages to minimize associated risks, many systems may have DC voltage levels that exceed the threshold typically considered as minimal risk (usually around 120V DC). In such cases, the implementation of double insulation of the DC cables is commonly used as a method of protection against electric shock.

In this case, the selection of appropriately rated cables, connectors, and enclosures, as well as the use of controlled installation techniques, becomes important in providing this protective measure, as outlined in IEC 60364. Additionally, employing double insulation for the DC circuit significantly reduces the potential for unintentional electric shock paths and the risk of fire.

If the voltage of the PV array exceeds 120V, it is mandatory to implement protective measures such as double insulation (comprising both basic and supplementary insulation) or reinforced insulation. These measures shall be applied to all components of the DC circuit to ensure a level of protection as defined in IEC 60364 and IEC 62930.

5.10.4 DC Cables

5.10.4.1 Cable Sizing

Cable sizing shall comply with the guidelines outlined in IEC 60364-5-52. Additional information on cable sizing methods, including any necessary de-rating factors and typical current-carrying capacities for common cable types, can be found in Appendix B of IEC 60364-5-52.

Cables must be sized to ensure that the total voltage drop, occurring at the array's maximum operational power (STC), between the array and the inverter, remains below 1%.

5.10.4.2 Cable Type and Installation Method

DC cables intended to be used in solar PV systems shall comply with the requirements outlined in IEC 62930.

The selection of the DC cables shall be made considering their ability to withstand the various environmental, voltage, and current conditions they may encounter during operation. This includes accounting for the heating effects from both the electrical current and solar exposure, especially when the cables are installed in close proximity to the PV modules.

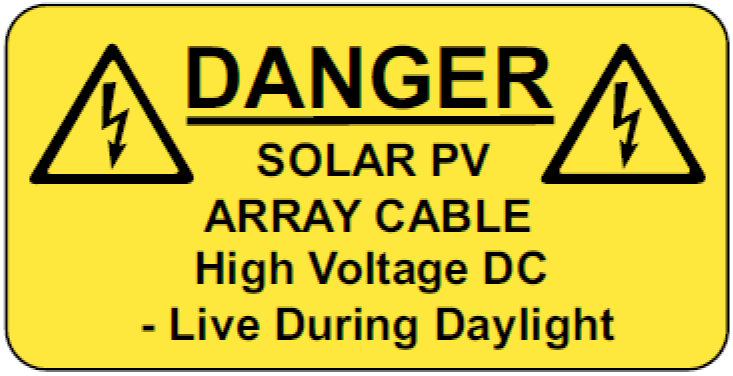
External cables shall be UV and water-resistant. For cables that are likely to experience external movement, especially those positioned directly behind the array, it is advisable to use flexible (multi-stranded) cables to accommodate thermal and wind-induced array/module movements.

As PV array cables primarily rely on double or reinforced insulation for electrical safety, they shall not be concealed within walls or hidden within building structures. Concealment could make it challenging to detect mechanical damage, which could increase the risk of electrical shock and fire.

If concealing cables cannot be avoided, they shall be adequately shielded from mechanical damage. Suitable methods may involve employing metallic trunking or conduit or using steel wire armored cable in accordance with IEC 60364-5-52.

When there is a need for extended cable lengths (e.g., exceeding 20 meters), labels shall be affixed at intervals along the DC cables as shown in Figure 5-5.

Figure 5-5 — Warning Label for Solar DC Cables



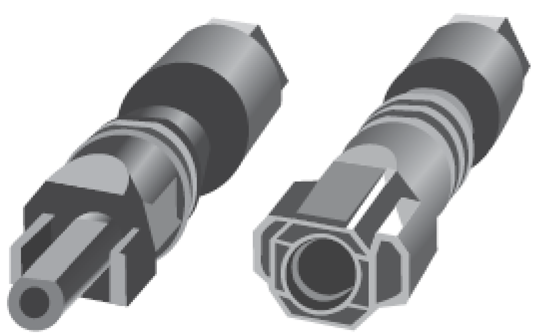
Applying labels every 5 to 10 meters is deemed satisfactory for cable identification along straight runs where clear visibility exists between the labels

When several PV string conductors converge at a junction box, they shall be organized or marked in pairs. This arrangement allows for easy and clear differentiation between positive and negative conductors within the same circuit, making identification straightforward when needed.

5.10.5 DC Connectors

PV module manufacturers commonly fit module cables with specialized PV plug and socket connectors as illustrated in Figure 5-6. These connectors offer a dependable, long-lasting, and efficient electrical connection. They also simplify installation tasks and enhance safety.

Figure 5-6 — DC Connectors [13]



Within a PV system, the plugs and socket connectors that are connected together shall be of matching types and originate from the same manufacturer. They must also meet the standards outlined in IEC 62852. If there is a need to interconnect different brands of connectors, it should only be done with the provision of a test report confirming that the two types are compatible with the requirements set forth in IEC 62852.

Connectors that are easily reachable by non-Approved Contractors shall be of the locking type, necessitating either a tool or two distinct actions for disconnection. These connectors shall also have a warning label attached that states: 'Do not disconnect under load'.

Utilizing cable connectors for DC switching or isolation while under load shall be avoided since DC arcing has the potential to result in causing damage to certain connectors.

When connectors necessitate special tools for proper installation, it is essential to employ these tools to ensure secure and effective connections. Neglecting to use the appropriate tools can result in connections that lack mechanical or electrical integrity, potentially causing overheating and fire hazards. Figure 5-7 shows an example tool required for the termination of connectors.

Figure 5-7 — Crimping Tool for Connectors Termination

5.10.6 PV Array Switch Disconnector

A switch disconnector installed on the DC side shall have the following characteristics:

- The switch shall be capable of isolating all active conductors (typically a double pole switch to isolate both PV array positive and negative conductors).
- The switch shall be rated for DC operation at the calculated maximum system voltage.

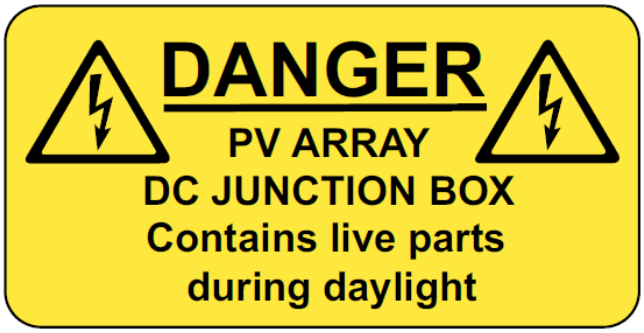
- The switch shall be rated for DC operation at the calculated maximum system current.
- The switch can be integrated with the inverter (built-in within the inverter) or installed in a separate enclosure.
- The switch shall be clearly labeled as 'PV array DC isolator,' with the ON and OFF positions prominently marked. Additionally, switch enclosures shall carry a label indicating 'Danger - contains live parts during daylight.' All labels must be legible, durable, and remain visible for as long as the life span of the installation.

5.10.7 PV Array DC Combiner Box

In scenarios involving the presence of multiple PV strings, the DC combiner box commonly functions as a location for their parallel interconnection, particularly when the selected inverter lacks an adequate number of inputs. This combiner box may also include string fuses and testing points.

The DC combiner box shall be marked with a label that reads, 'PV array DC junction box, Danger contains live parts during daylight' as shown in Figure 5-8.

Figure 5-8 — Warning Label for DC Combiner Box



These labels must be easily readable, clearly visible, made to withstand wear, and securely attached to ensure they remain in place throughout the lifespan of the installation.

The PV system remains energized continuously during daylight hours, and its terminals are always live. It is crucial to make sure that anyone accessing the enclosure is fully informed of this fact.

The cable installation's short-circuit protection, which is consistent throughout the rest of the DC circuit, shall be maintained when designing and assembling the DC combiner box. (Refer to IEC 60536 and IEC 61140 for more details on this requirement).

5.11 AC SYSTEM DESIGN

5.11.1 AC Cables

The PV system inverter(s) must be set up on a dedicated final circuit, complying with the specifications outlined in IEC 60364. This dedicated circuit should meet the following criteria:

- No electrical devices drawing current are attached to it.
- There are no provisions for connecting electrical devices.
- The installation does not include any socket-outlets.

The size of the AC cable that connects the inverter(s) to the AC Combiner Box and the AC cable that connects the AC Combiner Box to the Point of Interconnection at the existing consumer's LV switchgear shall be chosen to minimize voltage drop, with a total of 2%.

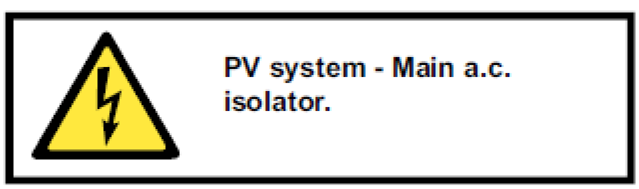
5.11.2 AC Isolation and Switching

The DSS must be connected to an isolation switch meeting these criteria:

- Disconnects both line and neutral conductors, that is 4-pole isolation switch for three-phase installation.
- Can be locked in the OFF position.
- Installed in an accessible location.

This switch shall clearly show the ON and OFF positions and be labeled as 'PV system – main AC isolator' as shown in Figure 5-9.

Figure 5-9 — Warning Label on the AC Side of DSS



The isolation and switching of the AC side of the setup shall also adhere to the guidelines in IEC 60364. This includes installing an isolator near the inverter for disconnecting the inverter from the AC power source.

Note: When installing any AC switch-disconnector, it shall be assumed that the public supply is the source and the PV installation is the load.

5.11.3 Inverters

5.11.3.1 Inverter Sizing

The sizing of an inverter for a grid-connected DSS is influenced by several considerations, which include:

- The inverter's availability in the market.
- Variations in array voltage due to temperature changes.
- The maximum allowable DC input voltage supported by the inverter.
- The MPP (maximum power point) voltage range of the inverter.
- The desired ratio between inverter capacity and PV array power.

In cases where a system incorporates multiple strings or arrays with notably different orientations or inclinations, these strings or arrays shall either be connected to an inverter equipped with multiple Maximum Power Point Tracking (MPPT) capabilities, or separate inverters shall be employed. This becomes necessary when the variations in orientation or inclination are substantial enough that connecting the strings or arrays to a single MPPT input could considerably reduce the overall system performance.

The choice of inverter must ensure its safe capability to handle the highest array voltage and current levels. This shall include any initial overvoltage period that might occur with certain PV module types. It's essential to confirm that the inverter can withstand the maximum open-circuit voltage of the array at the minimum ambient temperature of 0°C.

Power Ratio - It is standard practice for the power rating of an inverter to be lower than that of the PV array. Inverters are typically selected within the range of 100% to 80% of the array capacity, that is 1.0 – 1.25 DC/AC ratio. Nevertheless, in specific situations and based on the type of inverter used, ratios beyond this range may occasionally be employed based on the manufacturer's recommendation.

Inverter ventilation - Inverters produce heat and need to have proper ventilation. It's important to adhere to the clearance distances recommended by the manufacturer, such as those to a heatsink. When selecting locations for inverters, especially in places like plant or boiler rooms or roof spaces that may experience elevated temperatures, it's crucial to take precautions to prevent overheating. Failure to follow these precautions can result in a decrease in system efficiency, as the inverter will reduce its output capacity when it reaches its maximum operating temperature. This information shall be emphasized in the operation and user manual.

5.11.4 String Inverters with Multiple MPPT Inputs

String solar inverters with multiple MPPT inputs are designed to optimize the performance of PV systems by efficiently managing multiple strings of solar panels with varying characteristics. These inverters allow each string to operate at its optimal power point, making them ideal for installations with panels in different orientations or shading conditions.

String inverters shall incorporate essential protection features such as overvoltage and overcurrent protection to protect the inverter and connected equipment, reverse polarity protection, ground fault detection, temperature monitoring, and anti-islanding protection to enhance safety and prevent grid feedback during outages.

Whenever string inverters with multiple MPPT inputs are utilized, the overcurrent protection for the sub-array connected to these inputs shall consider the possibility of reverse currents.

5.11.5 AC Modules (Microinverters)

In cases where inverters are either directly mounted on or positioned adjacent to PV modules, compliance with IEC 60364 still necessitates the installation of a switch disconnector. However, there is a practical consideration that suggests a DC isolator may not always be obligatory if the system meets all the following criteria:

- It connects only one module per inverter.
- Does not require extending the PV module DC cables beyond the factory-fitted length.
- Operates within Extra-Low Voltage (ELV) limits (not exceeding 50 V AC or 120 V ripple-free DC between conductors or to earth).
- Employs a plug-and-socket type connector system for the DC cables.

Manufacturers' guidelines must be followed, particularly concerning the earthing of microinverters and to prevent excessive loads on AC wiring. Specifically, AC cables should meet appropriate voltage ratings, and unless they are adequately shielded, they should demonstrate resistance to elevated temperatures, UV exposure, and potential mechanical strains.

5.11.6 AC Cable Protection

Protection for the cable coming from the inverter(s) needs to be placed at the distribution board (which might be an AC Combiner Box in case of multiple inverters or a separate enclosure in case of single inverter). This protection shall be designated and set up in compliance with the guidelines specified in IEC 60364. The protection provided at the starting point of the circuit (the distribution board) eliminates the necessity for supplementary overcurrent protection to be positioned at the inverter end of the AC installation.

5.12 SURGE PROTECTION MEASURES

DC cables shall be installed with the goal of minimizing their length, and positive and negative cables from the same string or primary DC source shall be kept together to prevent loop formation within the system. This requirement also applies to any associated earth or bonding conductors. For longer cables, such as PV DC cables exceeding approximately 50 meters, they shall either be enclosed in earthed metal conduit or trunking or be shielded cables with armor.

It's important to note that these measures serve the dual purpose of both protecting the cables from inductive surges and, by increasing inductance, reducing the transmission of surges. Properly designed and installed vents shall be included in conduit or trunking to allow for the drainage of any accumulated water or condensation.

While most grid-connected inverters come with some built-in surge suppression, additional standalone surge protection devices may also be specified. It's worth noting that surge protection devices integrated into inverters can only be of type D, so an Approved Contractor might consider adding supplementary devices of type B or C on either the DC or AC sides. To protect the AC system, surge protection devices can be installed at the primary point of the AC supply (typically at the AC Combiner Box that combines multiple inverters into a single outgoing circuit). For DC system protection, surge protection devices can be placed at the inverter end of the DC cabling. In cases where specific equipment needs protection, surge protection devices shall be installed as close as practically feasible to that equipment.

5.13 METHOD OF STATEMENT FOR DSS INSTALLATION

A method of statement for the installation of a small-scale solar PV system shall provide clear, detailed instructions and considerations to ensure a safe and efficient installation process. Some recommendations and items to include in a method of statement for a solar PV system are:

1. Project Overview:

- Provide a brief description of the project, including its purpose, location, and scope.
- Identify key personnel involved in the installation and their roles.

2. Safety Precautions:

- Detail safety procedures and precautions for the installation, including personal protective equipment (PPE) requirements.

- Outline emergency response procedures in case of accidents or incidents.

3. Site Assessment:

- Describe the site assessment process to determine the suitability of the location for solar panel installation.
- Include any necessary environmental impact assessments and permits.

4. Material and Equipment Requirements:

- List all materials, tools, and equipment needed for the installation, ensuring they are of the appropriate quality and quantity.
- Include sourcing information for materials, if applicable.

5. Installation Procedure:

Provide step-by-step instructions for the installation process, including:

- Mounting and securing solar panels and racking systems.
- Connecting solar panels in series or parallel.
- Installing inverters.
- Wiring and cable management.
- Grounding and bonding.
- Electrical connections and junction boxes.
- Testing and commissioning procedures.
- Final inspection and quality control checks.

6. Electrical Safety:

- Describe procedures for working with electrical components, including isolation, lockout/tagout, and testing for voltage presence.
- Specify procedures for addressing electrical faults and emergencies.

7. Maintenance and Monitoring:

- Outline routine maintenance procedures and schedules.
- Explain how to monitor system performance, including checking for signs of wear, corrosion, or damage.

8. Documentation and Records:

- Specify the records to be maintained throughout the installation, including design documents, as-built drawings, inspection reports, and test results.

9. Quality Assurance:

- Describe quality control measures, including inspections and audits, to ensure the installation complies with industry standards and regulations.

10. Training and Certification:

- Ensure that personnel involved in the installation are appropriately trained and certified for their respective tasks.

11. Handover and Commissioning:

- Outline the process for handing over the completed system to the owner, including documentation and training.

12. Appendices:

- Include relevant documents such as system diagrams, drawings, and equipment specifications.

13. References:

- List applicable codes, standards, and guidelines that were followed during the installation.

14. Contact Information:

- Provide contact information for the project manager or supervisor for any inquiries or issues that may arise during or after the installation.

Remember that the method of statement shall be tailored to the specific requirements of the project and shall be prepared by the Approved Contractor executing the project.

5.14 SAFETY

This section provides a summary of the safety guidelines related to DSS. For the full safety guidelines refer to Safety Guidelines for Small-Scale Solar PV Systems [5].

5.14.1 General

All applicable established health and safety protocols and traditional electrical installation procedures shall be followed when installing a DSS.

The design shall consider the possible hazards during the installation, operation, and maintenance of the DSS. Additionally, it shall address the evaluation of installation limitations, including factors such as wind and structural loading.

5.14.2 PV Specific Hazards

When creating a method statement and risk assessment for the installation of a PV system, several PV-specific dangers must be accounted for. These should be considered alongside standard precautions like Personal Protective Equipment (PPE), working at heights, manual handling, and handling of glass.

PV modules generate electricity when exposed to daylight, and individual modules cannot be switched off. Consequently, unlike most other electrical installation work, PV system installation typically involves working on a live system.

As current-limiting devices, PV module string circuits cannot depend on fuse protection for automatic supply disconnection in fault conditions, as the short-circuit current is only slightly higher than the operating current. Once a fault occurs, it may persist as a hazard, possibly going unnoticed for an extended period.

Adhering to good wiring design and installation practices will protect both system installers and anyone who may subsequently interact with the system against electrical shock hazards (e.g., operators, owners, cleaners, service engineers).

Undetected fault currents can also evolve into a fire hazard. Without fuse protection to clear such faults, protection against this fire hazard necessitates both a well-designed DC system and a careful installation.

PV systems present a distinctive blend of hazards, comprising the risk of shock, falling, and simultaneous manual handling difficulties. While each of these risks is commonly encountered on construction sites individually, encountering them simultaneously is rare. Roofing professionals may be well-versed in minimizing fall and manual handling risks but might not be accustomed to handling electric shock risks. Conversely, electricians may be familiar with electrical shock hazards but may lack experience in handling large objects at heights.

5.14.3 Shock Hazard

It is crucial to emphasize that, despite all the precautions mentioned above, there remains the possibility of an installer or service engineer encountering an electric shock hazard. Therefore, always perform a voltage presence test on system components before making any contact with them.

Electric shock risks may arise from capacitive discharge, where a charge can accumulate in the PV system due to its inherent capacitance to the earth. Such situations are more common in specific types of modules and systems, particularly amorphous (thin film) modules with metal frames or steel backing. When encountering these conditions, it is essential to adopt suitable and safe live working practices.

One scenario where these hazards might be encountered is when an installer is positioned on an earthed metal roof while wiring a large PV array. In such cases, there is a potential risk of receiving an electric shock by touching the PV cabling. The electric shock voltage increases with the number of series-connected modules. To mitigate this hazard, the use of insulated tools and gloves, along with insulating matting for standing or sitting, can be effective.

Another source of electric shock risk is the development of an earth leakage path within the PV array. While good wiring practices, double insulation, and modules with double or reinforced insulation construction can help reduce this issue, it's important to recognize that leakage paths may still occur in installed systems.

Therefore, anyone working on a PV system must remain aware of this possibility and take the necessary precautions.

5.14.4 PV Array Mounting

Manufacturer's guidelines shall be always followed when creating a mounting structure for a PV array. It is essential to focus on the specific clamping areas outlined by each manufacturer, as these requirements can differ.

Proper measures into the PV module mounting system shall be considered to accommodate the maximum expansion and contraction of the modules as they operate within expected temperature ranges, following the manufacturer's guidance. Similar considerations shall also apply to other relevant metallic elements, such as mounting structures, conduits, and cable trays.

The support structures for the PV array must adhere to local standards, industry norms, and regulatory requirements regarding load characteristics.

The PV array mounting structure and the techniques employed to assemble it must be constructed from materials resistant to corrosion, and appropriate for the system's lifespan and operational demands, such as aluminum, galvanized steel, zinc-coated steel, etc.

Efforts shall be made to prevent electrochemical corrosion that can arise when different metals come into contact. This can happen between the supporting structures and the building, as well as between structures, fasteners, and PV modules.

To mitigate electrochemical corrosion between dissimilar metal surfaces, Stand-off materials like nylon washers and rubber insulators shall be employed. Additionally, it's essential to refer to the manufacturer's instructions and local regulations for guidance when designing mounting systems.

5.14.5 PV Roofing

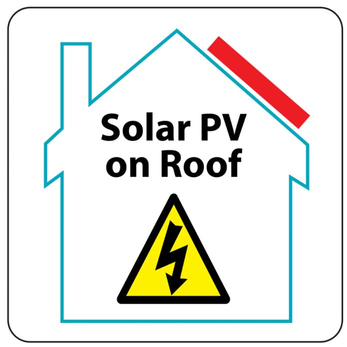
For solar rooftop systems, the mounting brackets used to secure the PV modules shall not compromise the roof's ability to remain weatherproof. The attachment methods must avoid placing additional loads on the roof coverings that could undermine their primary function of weather-tightness.

The routing of cables through the roof shall not compromise the roof's ability to remain weatherproof and shall be sealed effectively to withstand expected movement and temperature variations.

5.14.6 Labelling and Warning Signs for DSS Components

The designated location for PV modules and related equipment shall be clearly labeled with appropriate signage as depicted in Figure 5-10. These signs shall be also fixed on each access door to the PV plant. These signs shall have UV resistance and shall display the DC voltage of the PV array. All labels need to be easy to see and stay readable. Other required labels shall be utilized per Figure 5-5, Figure 5-8, and Figure 5-9 previously mentioned.

Figure 5-10 — DSS Warning Sign [14]



6. SAFETY GUIDELINES

6.9 PURPOSE

This section is designed to provide a guideline for ensuring the safety and development of rooftop Distributed Solar Systems (DSS) installations across the Northern Emirates.

The primary purpose is to

- Safeguard the well-being of workers, occupants, and the public, while also ensuring the long-term reliability and performance of the solar PV systems.
- Minimizing risks associated with rooftop solar PV installations reduces the potential for accidents, injuries, and property damage.

Regardless of whether the activities occur in a household or an industrial facility, individuals working with live electrical components must remain vigilant about associated hazards. It is crucial that they embrace and implement all safety measures designed to prevent and minimize these potential risks.

PV installation work is for qualified personnel only. All workers must be competent and understand the hazards involved with electrical work.

To prevent electric shocks during site work or maintenance involving PV modules, it is essential to implement various measures. While prioritizing prevention, it is crucial for individuals engaged in this work to possess sufficient knowledge of electricity and wiring. A higher level of awareness about potential hazards enables workers to effectively avoid risks. Before entering a site, whether a worker or engineer, it is imperative to thoroughly understand the project details of the specific PV system. Ensuring that potential hazards are well comprehended, all involved parties should be adequately informed and trained to adopt necessary precautionary steps and measures.

6.10 SCOPE OF APPLICATION

These guidelines apply to all rooftop DSS, regardless of scale or capacity, within the jurisdiction of Etihad Water and Electricity (“ETIHADWE”).

6.11 REGULATORY COMPLIANCE

Adherence to local and relevant laws, regulations, and codes governing the design, installation, and operation of solar PV systems is mandatory.

Key references include but are not limited to:

- UAE Fire & Life Safety Code of Practice
- National Standard for Occupational Safety and Health Management System
- Civil Defense (2018)
- International Building Code (IBC)
- National Fire Protection Association (NFPA) Codes
- American Society of Civil Engineers (ASCE) 7-16, Minimum Design Loads and Associated Criteria for Buildings and Other Structures

6.11.1 Permits and Approvals:

Obtaining all necessary permits, licenses, and approvals from relevant authorities is a prerequisite for any installation. This includes but is not limited to building permits, electrical permits, and necessary approvals.

6.11.2 Documentation and Record Keeping:

Documentation of all phases of the installation process, including design, permitting, inspections, and maintenance, must be maintained for auditing and compliance verification purposes.

6.12 STRUCTURAL HAZARDS

The installation of rooftop DSS introduces potential structural hazards that should be carefully considered to ensure the safety and integrity of the building.

- **Additional Roof Load:** Additional loads to the roof are added from the weight of solar panels, mounting structures, and associated equipment. This can lead to structural stress if the roof is not designed to accommodate the additional weight. Additionally, different types of roofs have varying load-bearing capacities.

- **Roof Penetrations:** Roof penetrations are typically required to secure mounting systems onto the roof. Penetrations that are poorly executed can potentially compromise the integrity of the roof and lead to the weakening of the structure and leaking.

- **Wind Loading:** Wind forces experienced by the solar panels can exert additional loads on the roof. Inadequate design and installation in areas prone to high winds may lead to structural issues.

- **Racking System Design:** The racking system that supports solar panels should be installed correctly to distribute loads evenly. Poor installation can lead to localized stress and compromise the roof structure.

- **Aging and Deterioration:** Assessing the condition of a roof is crucial as adding a DSS may exacerbate existing aging and deterioration issues.

- **Drainage:** Poor drainage can lead to water pooling and potential structural damage. Solar panels and their mounting systems should not impede proper water drainage on the roof.

6.4.1 STRUCTURAL ASSESSMENT

A thorough structural assessment of the rooftop is essential to ensure it can support the installation of the DSS components.

Considerations:

- **Engage a Structural Engineering company**: Employ an experienced structural engineering organization to conduct a comprehensive assessment of the rooftop's structural integrity.
- **Review Architectural Plans**: Obtain and review the original architectural plans of the building to understand its design specifications and load-bearing capacities.
- **Inspect Roof Condition**: Conduct a visual inspection of the roof's condition, looking for signs of deterioration, leaks, or structural damage.
- **Analyze Load-Bearing Capacity**: Utilize engineering calculations and software tools to assess the maximum load the roof can safely support.
- **Consider Dead and Live Loads**: Factor in both dead loads (permanent loads such as the weight of the solar panels and racking) and live loads (temporary loads like wind).
- **Evaluate Impact on Building Integrity**: Assess how the installation of solar PV components may affect the overall structural integrity of the building.

6.4.2 LOAD-BEARING CAPACITY

Determine the maximum load that the roof can safely support, including the weight of the solar panels, racking, and associated equipment.

Calculations:

- **Calculate Dead Loads**: Determine the weight of the solar panels, racking, inverters, and other fixed equipment to be installed.
- **Evaluate Live Loads**: Consider dynamic loads such as wind and snow, using regional data and established engineering formulas.

- **Factor in Safety Margins**: Apply appropriate safety factors to ensure that the assessed load is well within the roof's capacity.

6.4.3 WEATHER CONSIDERATIONS

Consider local weather conditions and their potential impact on the DSS and structural integrity in accordance with the International Building Code (IBC) - Chapter 16, Structural Design.

Factors to Consider:

- **Wind Speed and Direction**: Evaluate historical wind data and consider factors like prevailing wind direction and maximum gust speeds.
- **Seismic Activity**: Assess the risk of seismic events and implement measures to mitigate potential damage.

6.5 ELECTRICAL HAZARDS

DSS poses several electrical hazards that need to be considered during installation, operation, and maintenance.

Solar panels generate DC power. High-voltage DC is considerably more dangerous than AC. Solar panels do not have an on/off switch and are considered electrically energized when light falls on them. Besides the solar panels themselves, there are multiple conduit runs, grounding and bonding systems, junction boxes, disconnects, inverters, breakers, and meters that form part of the DSS system.

Installers and maintenance personnel should be aware of the specific electrical risks associated with rooftop PV systems and take appropriate precautions to minimize those risks.

- **Exposed Wiring:** Improperly installed or damaged wiring can expose conductors increasing the risk of electric shock.
- **Arcing:** Arc flashes can release a significant amount of energy and pose a risk of electric shock, burns, and injuries.
- **Equipment Malfunction:** Equipment when experiencing a fault or malfunction can lead to the presence of high-voltage and pose a risk of electric shock, burns, and injuries.
- **Isolation and Lockout/Tagout:** Failure to properly electrically isolate the equipment being worked on during commissioning and maintenance can lead to unexpected energization and the risk of electric shock.
- **Grounding:** Improper grounding can lead to equipment malfunction and electrical shock.
- **Overcurrent:** Lack of proper overcurrent protection can lead to excessive current flow, overheating, and fire hazards

6.5.1 ELECTRICAL CODE

Ensure that all electrical work associated with the DSS adheres to local electrical codes and standards.

Considerations:

- **Familiarize with Local Codes**: Familiarize all installers and contractors with the specific electrical codes and regulations applicable in the Northern Emirates.
- **Code Adherence Verification**: Verify that all installations and connections comply with the latest edition of the FEWA electricity wiring regulation book and any additional local requirements.
- **LOTO (Lock-out tag-out)"** procedures shall be put in place by the Approved Contractor, and described in the Operation and Maintenance manual for delivery to the DSS customer. The manual shall specify also the position of the manual call point. LOTO procedures shall be according to rules and regulations of the relevant authorities.
- **Professional Electrical Oversight**: Engage Approved electrical contractors /engineers to oversee the electrical aspects of the installation process. Ensure compliance to Lockout Tagout procedures listed in Chapter 17 of the UAE Code of Construction Safety Practice [**Error! Reference source not found.**]

6.5.2 GROUNDING AND BONDING

Approved Contractor to perform and ensure proper grounding and bonding to mitigate the risk of electrical shock and fire hazards.

Considerations:

- **Grounding System Design**: Design a grounding system that includes grounding rods, conductors, and connections in accordance with FEWA electricity wiring regulation book Section 13 requirements and Distributed Solar Systems Standards and Guidelines For Small-Scale Solar Systems.
- **Bonding of Metal Components**: Ensure all metal components, including racking, frames, and conduits, are properly bonded to prevent potential differences and reduce electrical hazards.

- **Periodic Grounding Inspections**: Approved Contractor to conduct routine inspections to verify the integrity and effectiveness of grounding systems during O&M inspections.

6.5.3 OVERCURRENT PROTECTION

Provide overcurrent protection devices to prevent overloading and short circuits within the solar PV system.

Considerations:

- **Sizing Overcurrent Protection**: Calculate the appropriate overcurrent protection device sizes for both DC and AC circuits based on the current-carrying capacities of the conductors.
- **Selection of Circuit Breakers or Fuses**: Choose suitable circuit breakers or fuses based on the calculated overcurrent protection requirements.
- **Labeling of Overcurrent Devices**: Clearly label all overcurrent protection devices to indicate their purpose and rated capacity.

Overcurrent Protection will follow requirements as per the FEWA electricity wiring regulation book.

6.5.4 AC AND DC WIRING

Ensure safe and compliant installation of AC and DC wiring systems.

Considerations:

- **Conduit and Raceway Installation**: Use appropriate conduits, raceways, and cable management systems to protect and route AC and DC wiring.
- **Proper Sizing and Ampacity**: Size conductors based on load calculations and ensure their ampacity meets or exceeds system requirements.
- **Wire Termination and Connection Quality**: Employ proper termination techniques and ensure high-quality connections to minimize electrical losses and risks of arcing.

Wiring to follow the requirements set in the FEWA electricity wiring regulation book.

6.5.5 DISCONNECTS AND EMERGENCY SHUTDOWN

Install accessible and clearly marked DC and AC disconnects, with emergency shutdown on the AC side for maintenance purposes.

Considerations:

- **Placement and Labeling**: Position disconnect switches in easily accessible locations and clearly label them for quick identification.
- **Emergency Shutdown Protocols**: Develop and communicate protocols for emergency shutdown procedures to all personnel involved in system operation and maintenance.

6.6 FIRE HAZARDS

Fire hazards associated with DSS can arise from various factors, including electrical issues, system malfunctions, or external causes.

- **Electrical Arcs and Faults**: Faulty, damaged, or poorly installed wiring can lead to electrical faults and arcs and the risk of fire.
- **Corrosion**: When electrical components corrode over time, heat can be generated from the additional resistance created and increase the risk of fire.
- **Inverter Failure:** Inverter malfunctions or failures can result in overheating and the risk of fire.
- **Hotspots**: DSS system components, such as connectors, may develop hotspots if not properly installed or damaged and increase the risk of fire.
- **Arcing:** Electrical arcs can occur in DSS systems, especially when damaged components are present or during maintenance that can ignite nearby materials.
- **Combustible Roofing Materials:** In the presence of combustible material on the roof, such as leaves or debris, a fire can originate and spread to the roof.
- **Lightning Strikes:** If DSS systems are directly hit by lightning or induced surges, damage may be caused to their electrical components possibly leading to a fire.
- **Improper Installation:** Not properly fastened solar panels or mounting structure issues can cause solar panels to get dislodged and potentially cause damage or fire.
- **Insufficient Ventilation:** Inadequate ventilation beneath solar panels can result in heat buildup, increasing the risk of fire, especially in hot climates like the UAE.

6.6.1 CLEARANCES AND SPACING

Maintain proper clearances and spacing to reduce the risk of fire hazards associated with the rooftop solar PV system.

Considerations:

- **Module-to-Module Spacing**: Maintain a minimum distance between solar modules as recommended by the module manufacturer. This allows for ventilation and reduces the potential for hotspots that could lead to fires.

- **Module-to-Edge Clearances**: Ensure that there is a specified clearance between the edges of the solar modules and any roof edges, parapets, or other obstructions. This prevents potential fire hazards due to overheating.

- **Inverter Ventilation:** Inverters produce heat and require adequate ventilation. It is important to adhere to the manufacturer's specified clearance distances, for example, to a heat sink. When selecting locations for inverters, such as plant or boiler rooms, or roof spaces susceptible to elevated temperatures, careful consideration is essential to prevent overheating.

- **Roof Penetrations and Clearances**: Maintain proper clearances around roof penetrations such as vents, chimneys, skylights, and other roof features. Avoid placing solar modules in close proximity to these elements to prevent potential shading or fire risks.

- **Clear Access Pathways**: Establish clear pathways for access to the rooftop and around the solar installation. This ensures that firefighters have unobstructed access in case of an emergency.

6.6.2 FIRE-RESISTANT ROOFING MATERIALS

Select and use fire-resistant roofing materials to mitigate the risk of fire propagation in the event of a system malfunction or fire incident according to International Building Code (IBC) - Chapter 15, Roof Assemblies and Rooftop Structures and UAE Fire and Life Safety Code of Practice [**Error! Reference source not found.**].

Considerations:

- **Class A Fire Rating**: Specify and use roofing materials with a Class A fire rating, indicating the highest level of fire resistance. These materials are highly effective in preventing the spread of fire.
- **Roof Material Compatibility**: Ensure that the selected roofing material is compatible with the rooftop solar PV system. Some roofing materials may be more susceptible to damage from the installation process, potentially compromising fire safety.
- **Roof Inspection and Maintenance**: Regularly inspect the roof for any signs of damage or wear that could affect its fire-resistant properties. Promptly repair or replace any compromised roofing materials.

6.6.3 FIRE EXTINGUISHING SYSTEMS

Implement fire extinguishing systems or devices to promptly suppress fires if they occur near or within the solar PV system.

Considerations:

- **Fire Extinguishers**: Install accessible and appropriately rated fire extinguishers in proximity to the solar PV installation. Ensure that all personnel involved are trained in their proper use.
- **Automatic Fire Suppression Systems**: Consider installing automatic fire suppression systems, such as sprinklers, where required by local fire codes. These systems can provide an additional layer of protection, especially in larger installations.
- **Emergency Response Plan**: Develop and communicate a clear emergency response plan that outlines procedures for fire containment and evacuation. Conduct regular drills to ensure that all personnel are familiar with the protocol.
- **Coordination with Civil Defense Department**: Establish a working relationship with the local civil defense / fire department and provide them with information about the solar installation, including system layout and shut-off procedures.

6.7 FALL HAZARDS

Working on rooftops, especially during the installation, maintenance, or inspection of DSS, presents fall hazards that need careful consideration to ensure the safety of workers.

At elevated heights, individuals engaged in construction or the utilization of PV systems on buildings face a high risk of falls, often resulting in severe injuries or fatalities. This hazard is particularly relevant for those working on structures under construction or using equipment like ladders, platforms, lifts, baskets, and various material handling systems.

Mitigating the risk of falls on construction sites involves the implementation of safety measures such as scaffolds, fencing, nets, and other Collective Protective Equipment (CPE). These protective measures are provisionally installed to safeguard workers.

In terms of fall prevention, Personal Protective Equipment (PPE) plays a crucial role. It is either used concurrently with CPE or serves as an alternative safety measure in situations where the installation of CPE is impractical. Specifically designed for working at heights, PPE includes harnesses securely anchored to one or more fixed points.

The main hazards to be considered when working on roofs are the following:

- **Roof Surface Conditions:** Accumulated roof debris and slippery roof conditions pose the risk of trips and falls.
- **Openings and Skylights:** Unprotected roof openings and skylights can be hazardous if inadvertently stepped on.
- **Guardrails and Edges:** Inadequate or absent guardrails and inadequate edge protection can increase the risk of falling.
- **Roof pitch:** Steep roofs can increase the risk of falling.
- **Ladder/Scaffold Safety:** Improper ladder/scaffold use, such as placing them on unstable surfaces, not properly securing them, or using damaged ladders/scaffolds can increase the risk of falls.
- **Equipment and Material Handling:** Tools, equipment, or materials may accidentally fall from the rooftop, posing a hazard to workers or the public below.

- **Wind:** Strong winds can create instability and increase the risk of falls.

6.7.1 FALL PROTECTION SYSTEMS

Provide adequate fall protection measures to ensure the safety of workers during installation and maintenance activities, according to NCEMA 6000, the National Standard for Occupational Safety and Health Management System ("OHSMS") and Code of Construction Safety Practice [**Error! Reference source not found.**].

Considerations:

- **Fall Arrest Systems**: Implement approved fall arrest systems, including harnesses, lifelines, and anchor points, where there is a risk of falling from heights.
- **Guardrails and Barriers**: Install temporary or permanent guardrails and barriers around roof edges, openings, and any other potential fall hazards.
- **Safety Nets**: Utilize safety nets to catch workers in case of a fall. Ensure they are properly installed and inspected for effectiveness.
- **Training and Certification**: Ensure that all workers are trained and certified in fall protection procedures and equipment usage.

6.7.2 SAFE ACCESS POINTS

Establish safe access points to and from the rooftop, ensuring that workers can move about the site securely.

Considerations:

- **Designated Access Points**: Clearly mark and designate safe access points to the rooftop, indicating routes free from hazards.
- **Ladders and Stairs**: Provide safe and secure ladders, stairways, or access platforms with appropriate handrails and anti-slip surfaces, in compliance with National Standard for Occupational Safety and Health Management System.

- **Roof Hatches and Doors**: Ensure that roof hatches and access doors are properly secured, equipped with fall protection measures, and meet local building codes.

- **Regular Inspection and Maintenance**: Routinely inspect access points to identify and address any potential hazards or maintenance needs.

6.7.3 GUARDRAILS AND EDGE PROTECTION

Install guardrails and edge protection systems to prevent accidental falls from the rooftop, according to the NCEMA 6000, the National Standard for OHSMS.

Considerations:

- **Guardrail Design and Installation**: Ensure that guardrails are installed around all exposed edges of the rooftop and are designed to meet or exceed relevant safety standards.

- **Height and Load Capacity**: Verify that guardrails meet height requirements and have the necessary load-bearing capacity to withstand potential impacts.

- **Regular Inspection and Maintenance**: Conduct regular inspections to confirm that guardrails remain secure, undamaged, and in compliance with safety regulations.

- **Warning Signage**: Install visible warning signs indicating the presence of guardrails and their purpose.

6.8 COMPONENT LABELING

Clearly label components of the rooftop solar PV system to provide important information for maintenance, operation, and emergency response.

Considerations:

- **Inverter Labeling**: Each inverter must be labeled with its capacity in kilowatts (kW), voltage ratings (DC and AC), maximum current, and manufacturer information. This ensures that maintenance personnel have crucial information readily available.

- **Module Labeling**: Every solar module should be labeled with its maximum power output in watts (W), voltage, current ratings, and manufacturer details. This information aids in troubleshooting and replacement efforts.

- **Serial Number Recording**: Record and cross-reference the serial numbers of modules and inverters for accurate tracking, especially in cases of warranty claims or replacements.

- **Wiring Diagrams**: Create and label clear wiring diagrams indicating the layout of modules, inverters, combiner boxes, and disconnects. This aids in troubleshooting and maintenance.

6.8.1 WARNING SIGNS AND LABELS

Install warning signs and labels to communicate potential hazards and provide safety instructions, in accordance with FEWA electricity wiring regulation book – Section 6.4.

Considerations:

- **High Voltage Warning**: Place highly visible warning signs indicating high voltage areas, such as near inverters and electrical panels. These signs should feature universally recognized high-voltage symbols.

- **Emergency Shutdown Instructions**: Provide clear and concise instructions on how to perform an emergency shutdown of the PV system in case of an electrical or fire emergency. Include step-by-step procedures and make sure they are easily accessible.

- **Arc Flash Hazard**: Label equipment and areas where arc flash hazards may exist, in compliance with NFPA 70E requirements. Use appropriate warning labels with standardized symbols.

- **Personal Protective Equipment (PPE)**: Affix labels indicating the necessary Personal Protective Equipment (PPE) for working on or near the solar PV system. Include icons representing required gear like gloves, safety glasses, and insulated tools.

6.8.2 EMERGENCY CONTACT INFORMATION

Display emergency contact information for quick access in case of accidents, incidents, or system malfunctions.

Considerations:

- **Local Emergency Numbers**: Clearly post local emergency contact numbers, including fire, police, and medical services, in multiple visible locations on the rooftop.

- **Utility Company Contacts**: Include contact information for the utility company and relevant grid operators for reporting grid-related incidents. This ensures timely response in case of emergencies related to grid connection.

- **Installer and Maintenance Contacts**: Provide contact details for the responsible installer or maintenance personnel for immediate assistance. Include names, phone numbers, and email addresses for rapid communication.

- **Evacuation Procedures**: Display evacuation procedures in case of a fire or other emergency. Use easily understandable graphics and concise instructions for quick action.

6.9 PRE-COMMISSIONING CHECKS

Ensure that all necessary preparations and checks are conducted before commissioning the rooftop solar PV system. Additionally, prior to commissioning, Approved Contractors will follow the Inspection and Testing Guidelines [1], Inspection and Testing Checklist Before Interconnection [2] and Inspection and Testing Checklist After Interconnection [3], the guidelines include but are not limited to the following.

Considerations:

- **Visual Inspection**: Conduct a thorough visual inspection of all components to verify that they are installed correctly and in good condition.
- **Electrical Continuity**: Test the electrical continuity of all wiring and connections to ensure there are no loose or faulty connections.
- **Voltage Checks**: Verify that voltages are within expected ranges at various points in the system, including at the modules, inverters, and at the point of interconnection.
- **Polarity Checks**: Confirm that the polarity of DC connections is correct to prevent potential issues with inverters or other components.
- **Grounding Verification**: Validate that the grounding system is properly installed and functional to ensure safety and system stability.

6.9.1 FUNCTIONAL TESTING

Test the functionality of the entire rooftop solar PV system to ensure it operates as designed.

Considerations:

- **Inverter Testing**: Verify that inverters are converting DC power to AC power efficiently and within specified parameters.
- **Module Performance Checks**: Measure the output of individual modules to ensure they are producing power according to their specifications.
- **String Testing**: Test the performance of strings of modules to ensure they are operating within expected ranges.

- **Grid Connection Tests**: Confirm that the system successfully synchronizes with the electrical grid and is feeding power as intended.
- **Emergency Shutdown Test**: Verify that the emergency shutdown system functions as expected.

6.9.2 INSPECTIONS AND DOCUMENTATION

Conduct final inspections and document all commissioning procedures and results.

Considerations:

- **Final Walkthrough**: Conduct a final walkthrough to ensure that all components are properly installed, labeled, and meet safety requirements.
- **Document Results**: Record all test results, including voltage readings, performance metrics, and any deviations from expected values.
- **Create Commissioning Report**: Generate a comprehensive commissioning report that includes system specifications, test results, and any recommended corrective actions.
- **Submission for Approval**: Submit the commissioning report to the relevant stakeholders for approval and compliance verification.

6.10 OPERTAION AND MAINTENANCE

Routine Inspections

Implement a schedule of regular inspections to identify and address any potential issues or safety hazards.

Considerations:

- **Visual Inspections**: Conduct visual inspections of the entire system, including modules, wiring, inverters, and structural components.
- **Electrical Checks**: Perform routine electrical checks to ensure there are no loose connections, corrosion, or other electrical issues.
- **Monitoring System Review**: Review data from monitoring systems (if installed) to identify any anomalies or underperformance.
- **Shadow Management**: Monitor and manage vegetation (plants/trees), and other obstacles around the solar array to prevent shading and ensure optimal performance.

6.10.1 PREVENTIVE MAINTENANCE

Implement preventive maintenance measures to extend the lifespan of the rooftop solar PV system and prevent potential failures.

Considerations:

- **Cleaning and Debris Removal**: Regularly clean modules to remove dirt, dust, and debris that may reduce energy production.
- **Tightening and Torquing**: Periodically check and tighten electrical connections and mounting hardware to prevent loosening over time.
- **Inverter Checks**: Inspect inverters for signs of wear or damage and address any issues promptly.
- **Cooling System Maintenance**: If applicable, ensure that any cooling systems associated with the inverters are functioning properly.

6.11 DECOMMISSIONING PROCEDURES

Establish procedures for safely decommissioning and removing the rooftop solar PV system.

Considerations:

- **Isolation and Disconnection**: Safely disconnect the system from the electrical grid and ensure all electrical connections are properly isolated.
- **Module Removal**: Carefully remove solar modules, ensuring they are handled and stored in a manner that prevents damage.
- **Inverter and Equipment Removal**: Dismantle and remove inverters and other equipment according to manufacturer and safety guidelines.
- **Structural Integrity Assessment**: Conduct a structural assessment to verify that the rooftop is left in a safe condition after system removal.

6.11.1 DISPOSAL AND RECYCLING

Ensure that all components of the decommissioned rooftop solar PV system are disposed of or recycled in an environmentally responsible manner.

Considerations:

- **Component Recycling**: Identify and separate components that can be recycled, such as modules, inverters, and mounting hardware.
- **Hazardous Material Handling**: Properly dispose of any hazardous materials, such as lead-acid batteries or chemicals, in compliance with local regulations.
- **E-Waste Recycling Facilities**: Coordinate with e-waste recycling facilities for the responsible disposal of electronic components.

6.12 EMERGENCY RESPONSE PLAN

Establish a comprehensive plan for responding to emergencies involving the rooftop DSS, In accordance with the UAE Fire and Life Safety Code of Practice Section 19. Emergency Action Plans and Evacuation Procedures.

Considerations:

- **Emergency Contact List**: Compile an up-to-date list of emergency contacts, including local authorities, fire department, medical services, and utility company contacts.

- **Roles and Responsibilities**: Define specific roles and responsibilities for personnel in case of emergencies, including evacuation coordinators and first responders.

- **Evacuation Procedures**: Develop clear and well-communicated evacuation procedures for all personnel involved in the rooftop solar PV program.

- **Emergency Equipment**: Ensure that necessary emergency equipment, such as fire extinguishers, first aid kits, and emergency lighting, are readily accessible.

Figure 0-1 Fire Safety flier

Figure 0-2 Emergency Contact details

6.12.1 INCIDENT REPORTING AND DOCUMENTATION

Establish procedures for reporting and documenting incidents or accidents related to the rooftop solar PV system.

Considerations:

- **Immediate Reporting**: Require immediate reporting of any incidents, accidents, or near-misses to the designated supervisor or safety officer.
- **Incident Documentation**: Document all pertinent details of the incident, including date, time, location, individuals involved, and a description of the incident.
- **Investigation and Analysis**: Conduct a thorough investigation and analysis of incidents to identify root causes and implement corrective actions.
- **Regulatory Reporting**: Comply with all regulatory requirements for reporting incidents to relevant authorities, if applicable.

6.13 TRINING AND EDUCATION

6.13.1 PERSONNEL TRAINING

Approved Contractor to provide comprehensive training to all personnel involved in the DSS program.

Considerations:

- **Safety Training**: Conduct regular safety training sessions covering topics such as fall protection, electrical safety, and emergency procedures.
- **Technical Training**: Provide specialized training on the installation, maintenance, and operation of rooftop solar PV systems.
- **Certification Requirements**: Ensure that all personnel meet any necessary certification or licensing requirements for their respective roles.

6.13.2 ONGOING EDUCATION AND UPDATES

Approved Contractor to maintain ongoing education and provide updates to personnel to keep them informed about industry best practices and safety standards.

Considerations:

- **Continuing Education**: Encourage and facilitate ongoing education and professional development for personnel involved in the rooftop solar PV program.
- **Safety Bulletins and Updates**: Disseminate safety bulletins and updates to all relevant personnel to keep them informed about any changes in safety regulations or procedures.
- **Annual Reviews**: Conduct annual reviews of safety protocols and provide refresher training as necessary.

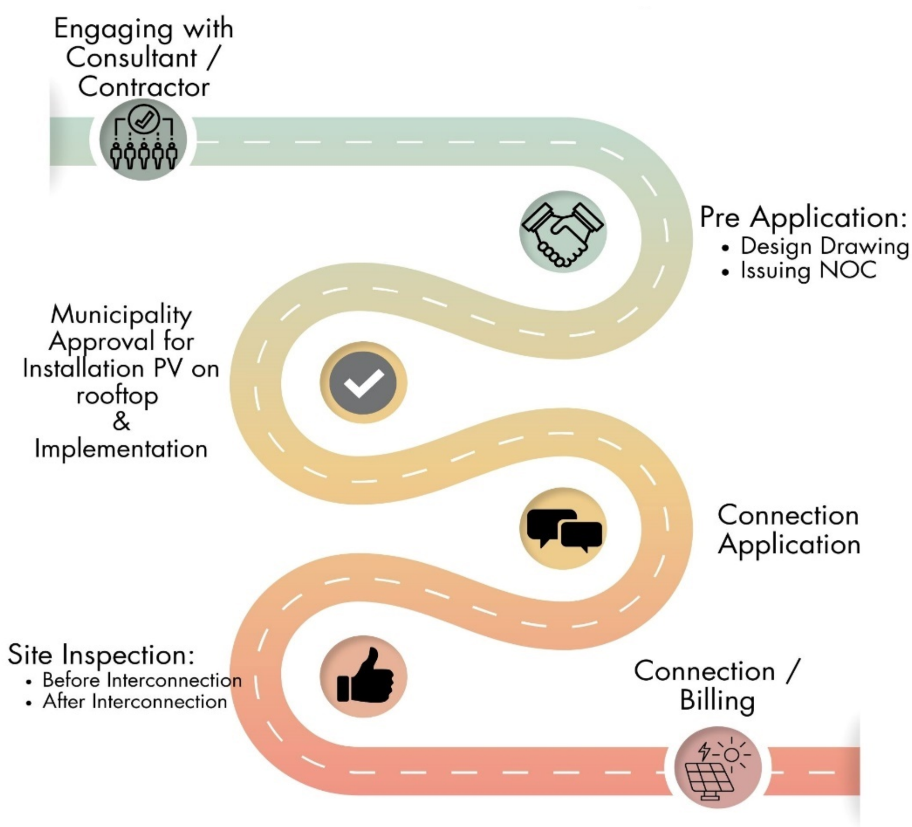
7 INTERCONNECTION APPLICATION PROCESS

7.1 INTERCONNECTION APPLICATION

The following describes the steps that an Approved Contractor engaged by a DSS Customer must complete in order to connect a DSS to the ETIHADWE's Distribution Network.

All Approved Contractors shall follow the process outlined in Figure **7-1**.

Figure 7-1 — DSS Interconnection Application Process



Steps Description

1. The Approved Contractor shall provide the customer with a full turnkey solution for the solar PV system including but not limited to site survey, design package preparation, obtaining relevant utilities' approvals, installation, testing, and commissioning.

2. The Approved Contractor shall submit a Pre-Application to ETIHADWE. The Approved Contractor shall submit the electrical design documents to ETIHADWE for electrical approval.
3. The Approved Contractor shall design the system based on the standards and guidelines in this document.
4. ETIHADWE will provide a Pre-Application Approval indicating whether there is available capacity at the proposed Point of Interconnection.
5. The Approved Contractor shall submit the structural design documents to the municipality for structural approval.
6. The municipality will review the Application based on the municipality's review process.
7. Upon Application approval from ETIHADWE and the municipality, the Approved Contractor can start the installation of the system based on the approved documentation.
8. The Approved Contractor shall inform the municipality once the system installation is complete to conduct the mechanical inspection.
9. The Approved Contractor shall apply new DSS connection application.
10. The Approved Contractor shall inform ETIHADWE and submit the Inspection and Testing Before Interconnection Checklist [3] per the Inspection & Testing Guidelines for Small-Scale Solar PV Systems [2].
11. An ETIHADWE inspector will inspect the installation to verify compliance with the Inspection and Testing Before Interconnection Checklist [3].

- ETIHADWE may choose to either observe the testing of the DSS conducted by the Approved Contractor or receive the test results.
- After obtaining approval from both ETIHADWE and the municipality following inspection and testing before interconnection, the Approved Contractor is eligible to request the supply and installation of smart meter(s) from ETIHADWE. This request is contingent upon the successful payment of connection fees.

12. Inspection and testing after interconnection per the Inspection and Testing After Interconnection Checklist [4] per the Inspection & Testing Guidelines for Small-Scale Solar PV Systems [2].

- Upon the installation of the smart meter(s), DSS can be energized and start temporary operation.
- The Approved Contractor shall submit the Inspection and Testing After Interconnection Checklist [4].
- ETIHADWE may choose to either observe the testing of the DSS conducted by the Approved Contractor or receive the test results.

13. Upon the satisfactory completion of the inspection and testing after interconnection, ETIHADWE will issue the DSS Customer a Permit to Operate (PTO). Once a PTO is granted, the Approved Contractor can energize the system and start operation.

Note: If any deviations from the approved design are identified during the inspection and testing, or if the system is unable to pass the required tests, it is the responsibility of the Approved Contractor to address and rectify these issues before obtaining the necessary Permit to Operate (PTO).

7.2 PRE-APPLICATION PROCESS

Once the DSS Customer has engaged with an Approved Contractor, the Approved Contractor, on behalf of the DSS Customer, shall submit a Pre-Application Form [**Error! Reference source not found.**] to ETIHADWE along with the required processing fees. The purpose of this is for the utility to provide initial feedback to the Approved Contractor as to whether there is available capacity at the proposed POI before they proceed with the complete system design. In case the proposed interconnection is likely to result in distribution equipment Overloads, the utility can inform the customer that he cannot proceed due to Distribution Network limitations or provide a budgetary estimate of the modifications required to accommodate the interconnection.

In requesting a Pre-Application Approval, the DSS Customer understands that:

a. The presence of 'available capacity' should not be misconstrued as an assurance that the interconnection process can be seamlessly completed, as it involves a comprehensive assessment of various variables as an integral part of the Application review process.
b. The Distribution Network is dynamic and subject to change.
c. Pre-Application Approval may become outdated and not useful at the time of submission of the complete Application. The Pre-Application Approval shall remain valid for a period of 6 months from the date of issuance.
d. If a budgetary estimate is provided, it is subject to change upon completion of the Application review process.

In the Pre-Application Form [**Error! Reference source not found.**], the Approved Contractor shall provide the following information:

a. Customer details.
b. Approved Contractor details.
c. DSS details.
d. Initial Design Drawing and POI
e. The list of required documents.

ETIHADWE based on a good faith estimate of whether there is available capacity at the selected POI will approve or reject the proposed interconnection.

7.3 APPLICATION PROCESSING

7.3.1 Submission of Complete Application

Upon receipt of the Pre-Application Approval, the Approved Contractor shall proceed with the detailed design of the DSS system. A complete Connection Application [Appendix C] shall be provided to ETIHADWE for approval. For the Application to be considered complete it shall include:

a. DSS customer account details.
b. DSS details.
c. Solar module details.
d. Inverter details.
e. The list of required documents.

All DSS main components (such as PV modules, inverters, cables, and interface protection) shall be selected from the List of Approved Equipment available on ETIHADWE's Solar Platform[4] and shall comply with the standards outlined in Section 2.2 - PV System Components where applicable.

7.3.2 Application Completeness Review

On receipt of a Connection Application [Appendix C] along with the processing fees, ETIHADWE will notify the Approved Contractor that the Application has been received. If the Application is incomplete ETIHADWE will provide the Approved Contractor with the deficiencies and inform the Approved Contractor that they must submit a complete Application. The Approved Contractor shall provide the requested information by the deficiency cure window or their Application will be deemed withdrawn.

7.3.3 Interconnection Queue

When ETIHADWE deems that a Connection Application [Appendix C] is complete, it will assign the Application a queue position. ETIHADWE will maintain a single interconnection queue.

7.3.4 Application Impact Review

ETIHADWE will prioritize the review of Applications in the queue and assess the potential impact of the proposed interconnection on the Distribution Network. Following the completion of the review, ETIHADWE will communicate to the Approved Contractor whether the proposed interconnection can be accommodated. If it cannot be accommodated, ETIHADWE will provide the Approved Contractor with the reasons for this

[4] To be determined.

decision and engage in a meeting with the Approved Contractor to discuss the results. During this meeting, any necessary modifications that could make the interconnection viable will be proposed and considered.

7.3.5 Modifications to an Application

When an Application is considered complete, including after receiving the review results, either the Approved Contractor or ETIHADWE has the opportunity to suggest changes to the planned DSS that could enhance their cost-effectiveness, reliability, and the utility's ability to facilitate the interconnection. The Approved Contractor is required to submit to ETIHADWE any proposed adjustments to the information presented in the Application.

If ETIHADWE determines that the proposed modification is a Material Modification, then ETIHADWE shall notify the Approved Contractor of the determination and the Approved Contractor may:

1. Withdraw the modification or
2. Proceed with a new Application (therefore going to the back of the queue).

If the proposed modification is determined not to be a Material Modification, then ETIHADWE shall notify the Approved Contractor of the determination that the modification has been accepted and that the Application shall retain its place in the interconnection queue.

8 REFERENCES

1. Distributed Solar Systems Standards and Guidelines for Small-Scale Solar PV Systems.

2. Inspection & Testing Guidelines for Small-Scale Solar PV Systems.

3. Inspection and Testing Before Interconnection Checklist for Small-Scale Solar PV Systems.

4. Inspection and Testing After Interconnection Checklist for Small-Scale Solar PV Systems.

5. Safety Guidelines for Small-Scale Solar PV Systems.

6. Grid-Connected Solar PV System", image, GharPedia, June 16, 2020, https://gharpedia.com/blog/rooftop-solar-pv-system-basic-guide/.

7. The European Commission, "General Requirements", COMMISSION REGULATION (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators, Article 14, Figure 3, Official Journal of the European Union, April 14, 2016.

8. "Schematic Diagram of the Inverter in Solar On Grid Power System", image, inverter, March 2, 2021, https://www.inverter.com/how-to-buy-a-solar-inverter-for-on-grid-system.

9. "Solar Panels in Parallel of Same Characteristics", image, alternative-energy-tutorials, https://www.alternative-energy-tutorials.com/solar-power/connecting-solar-panels-together.html.

10. "Solar Panels in Series of Same Characteristics", image, alternative-energy-tutorials, https://www.alternative-energy-tutorials.com/solar-power/connecting-solar-panels-together.html.

11. Kasim, Naseer. "Configuration of cell, module and array", image, researchgate, July, 2020, https://www.researchgate.net/figure/Figure-17-Configuration-of-cell-module-and-array34_fig5_342736081.

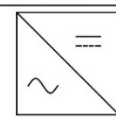
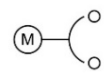
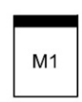
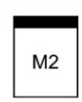
12. Microgeneration Certification Scheme ('MCS'), "String Cables", Guide to the Installation of Photovoltaic Systems, Section 2.1.5, Fig 5, MCS, 10 Fenchurch Street, London EC3M 3BE, 2012.

13. Microgeneration Certification Scheme ('MCS'), "d.c. Plug and Socket Connectors", Guide to the Installation of Photovoltaic Systems, Section 2.1.7, Fig 6a, MCS, 10 Fenchurch Street, London EC3M 3BE, 2012.

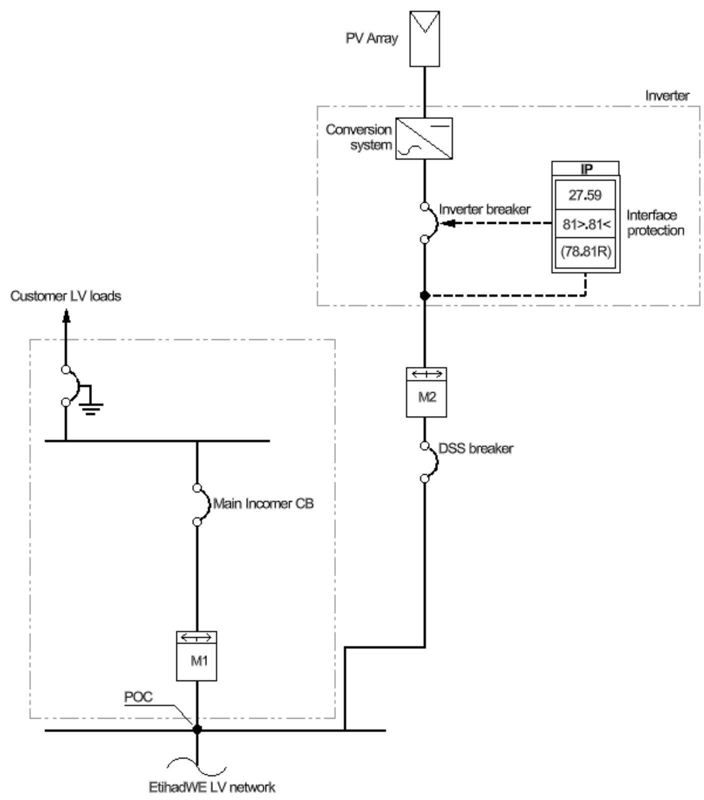
14. ” PV on roof Hazard warning Label sheet”, image, electric-solar, October 3, 2023, https://electric-solar.co.uk/products/pv-on-roof-hazard-warning-label-sheet

APPENDEX A - DSS CONNECTION SCHEMATICS

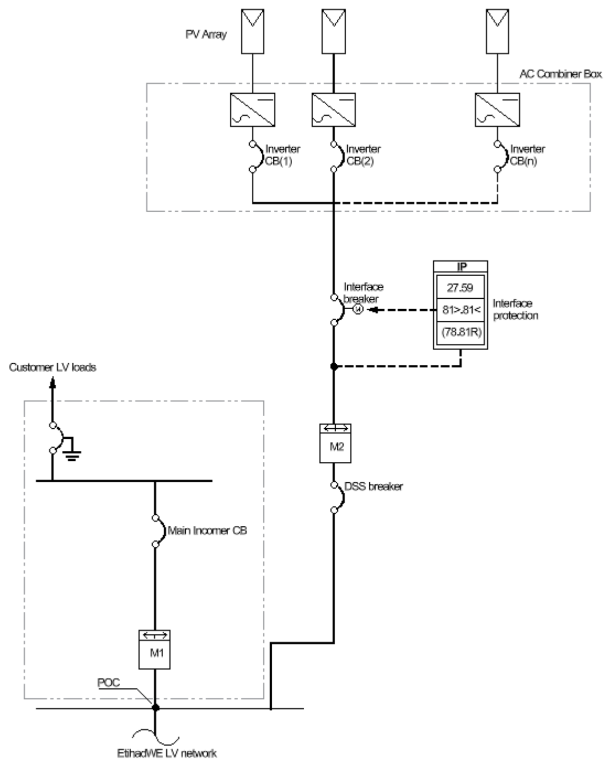
A.1 Legend

LEGEND	
PV MODULE	
INVERTER	
MOTORIZED LV CIRCUIT BREAKER	
DISCONNECT SWITCH	
CURRENT TRANSFORMER	
LV CIRCUIT BREAKER	
TRANSFORMER	
MV CIRCUIT BREAKER	
SMART METER – MAIN	
SMART METER – SOLAR	

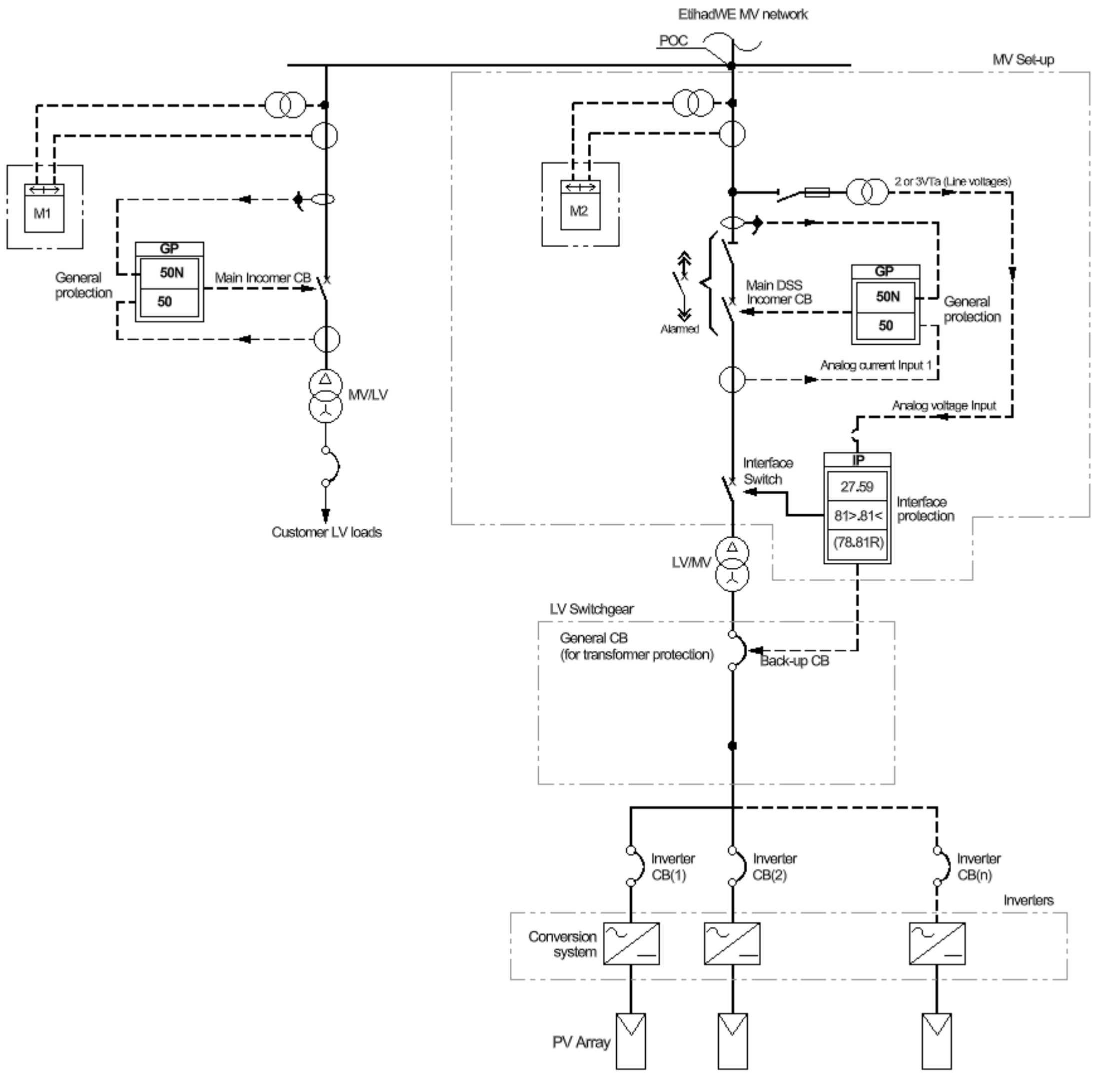
A2. DSS connection at LV network – One inverter



A2. DSS connection at LV network – Multiple inverters



A3. DSS connection at MV network



APPLIDEX B: INSPECTION CHECK LISTS

GNERAL INFORMATION

CUSTOMER AND EXISTING METER DETAILS

Customer Name	Address

ETIHADWE Account Number	Meter ID Number	Date

Type of Existing Meter (Direct / CT)	POI – Specify name and location of the electrical panel where DSS is connected

DSS DETAILS

DSS Size (kW_{dc} / kW_{ac})	Type of Roof (Flat / Inclined)

Date of Inspection	Name of Testing Engineer	ETIHADWE License Number

MECHANICAL INSPECTION CHECKLIST

General

Inspections and tests outlined in these checklists shall follow the guidelines detailed in [**Error! Reference source not found.**].

Municipality Approval

No.	Check Item	Result		
1	Municipality approval has been granted	N	Y	N/A

PV Array

No.	Check Item	Result		
1	Circuit conductors are properly supported and are not touching the roof surface.	N	Y	N/A
2	Circuit conductors are the same conductor type/size as on the approved documents.	N	Y	N/A
3	Solar module count aligns with the approved documents.	N	Y	N/A
4	Solar module manufacturer/model aligns with the approved documents.	N	Y	N/A
5	Solar modules are effectively grounded using lugs or a racking-integrated grounding method.	N	Y	N/A
6	Solar modules and racking are properly secured.	N	Y	N/A
7	Wire ties are UV-rated.	N	Y	N/A
8	All electrical connections are secured to ensure no arcing.	N	Y	N/A
9	Mounting structure is properly grounded (grounding conductor bonding the rails).	N	Y	N/A
10	Outdoor components have sufficient protection degree (IP rating) for outdoor installation.	N	Y	N/A
11	Top discharge AC units are not covered by the solar modules.	N	Y	N/A
12	Warning labels are fixed and meet the requirements of [**Error! Reference source not found.**].	N	Y	N/A

Mounting Structure

No.	Check Item	Result		
1	All roof penetrations are properly flashed and sealed.	N	Y	N/A
2	Connecting bolts are properly installed, not over torqued deforming the flashing.	N	Y	N/A
3	Torque marks on all connecting bolts	N	Y	N/A
3	Roof appears to be in good condition, with no signs of leaking or damage; Roof is free of debris.	N	Y	N/A
4	All racking splices are properly supported per manufacturer requirements (generally splices must be supported on both sides of the joint by a structural attachment).	N	Y	N/A

No.	Check Item	Result		
5	Solar modules are installed as per manufacturer recommendations and torque marked.	N	Y	N/A
6	Dissimilar metals are separated and will not cause a galvanic reaction.	N	Y	N/A

Inverter(s)

No.	Check Item	Result		
1	Inverter(s) model, rating, and quantity align with the approved documents.	N	Y	N/A
2	Inverter(s) location, elevation, and clearances from surrounding objects/walls align with the approved documents and meet the requirements of [**Error! Reference source not found.**].	N	Y	N/A
3	Inverter(s) is/are properly mounted per the manufacturer's recommendations and guidelines.	N	Y	N/A
4	The number of PV strings aligns with the approved documents.	N	Y	N/A
5	The conductors have sufficient ampacity for each string.	N	Y	N/A
6	Conduit penetrations are properly sealed between conditioned and unconditioned space.	N	Y	N/A
7	Conduit is properly supported.	N	Y	N/A
8	Conduit is not being used as conductor support.	N	Y	N/A
9	The enclosure is properly grounded.	N	Y	N/A
10	Grounding equipment is properly installed.	N	Y	N/A
11	Maximum string voltage below inverter maximum allowable input voltage.	N	Y	N/A
12	DC and AC disconnecting means are located within sight of or in each inverter.	N	Y	N/A
13	System is equipped with Rapid Shutdown.	N	Y	N/A
14	Rapid Shutdown label is present.	N	Y	N/A

AC Combiner Box or Solar SMDB

No.	Check Item	Result		
1	AC Combiner Box location, elevation, and clearances from surrounding objects/walls align with the approved documents and meet the requirements of [**Error! Reference source not found.**].	N	Y	N/A
2	The number of branch circuits aligns with the approved documents.	N	Y	N/A
3	The conductors have sufficient ampacity for each branch circuit.	N	Y	N/A
4	The conductors are properly terminated at the respective circuit breakers.	N	Y	N/A
5	The Overcurrent Protective Device (OCPD) for the conductors has a rating sufficient to protect them.	N	Y	N/A
6	Components have sufficient protection degree (IP rating) per installation condition.	N	Y	N/A
7	Conduit penetrations are properly sealed between conditioned and unconditioned space.	N	Y	N/A

No.	Check Item	Result		
8	Conduit is properly supported.	N	Y	N/A
9	Conduit is not being used as conductor support.	N	Y	N/A
10	The enclosure is properly grounded.	N	Y	N/A
11	Grounding equipment is properly installed.	N	Y	N/A
12	Enclosure is labeled as a solar AC Combiner Box or Solar SMDB.	N	Y	N/A
13	AC characteristics label is present (voltage and amperage).	N	Y	N/A
14	Interface protection relay is tested on-site through simulated tests of intervention where possible.	N	Y	N/A
15	Physical protection barriers inside the electrical panel are in place to prevent accidental touch.	N	Y	N/A

Earthing

No.	Check Item	Result		
1	The DSS's earthing system has been installed in accordance with the approved documents and requirements of [**Error! Reference source not found.**]. Verify the bonding connections and the connection to the terminals of the existing earthing grid/busbar.	N	Y	N/A
2	DSS earthing conductors are terminated at the earthing busbar located in the AC Combiner Box / Solar SMDB.	N	Y	N/A
3	Separate earth connection of main components to the earthing busbar.	N	Y	N/A
4	Earthing conductors of both the DC and AC sides of the DSS are terminated at the same earthing busbar.	N	Y	N/A
5	Confirm earthing termination points of major components such as mounting structures, combiner boxes and inverters comply with an n-1 redundancy concept.	N	Y	N/A

Work Quality

No.	Check Item	Result		
1	Work is done in a neat and workmanlike manner.	N	Y	N/A
2	Equipment is visibly damaged.	N	Y	N/A

TESTS BEFORE INTERCONNECTION

General

For DSS testing before interconnection, the following conditions and notes shall be met:

- DSS is shut down by switching off the inverter(s) from the DC and AC sides.
- Tests shall be performed at stable irradiance conditions of at least 400 W/m2 as measured in the plane of the array per IEC 62446-1 Section 7.2.3.
- The measured Voc variation between PV strings connected to the same inverter (for inverters with single MPPT) or to the same MPPT (for inverters with multiple MPPTs) shall not exceed 5% per IEC 62446-1 and shall be compared to the manufacturer's permitted tolerances.
- The measured short circuit currents of all PV strings involved are within approximately 10% of the average string current per IEC 62446-1.
- The DC cables insulation resistance for all PV strings shall have values of 1 MΩ or higher per IEC 62446-1.

Test Report

The table below shall be filled by the Approved Contractor and shall be submitted to ETIHADWE.

Inverter No.	PV String No.	Open-Circuit Voltage		Short-Circuit Current		Insulation Resistance	
		V_{OC} (V)	Deviation Percentage from Average V_{OC}	I_{sc} (A)	Deviation Percentage from Average I_{sc}	Value (MΩ)	Insulation Test Result (Pass/Fail)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

Inverter No.	PV String No.	Open-Circuit Voltage		Short-Circuit Current		Insulation Resistance	
		V_{OC} (V)	Deviation Percentage from Average V_{OC}	I_{sc} (A)	Deviation Percentage from Average I_{sc}	Value (MΩ)	Insulation Test Result (Pass/Fail)
13							
14							
15							
16							
17							
18							
19							
20							
Average V_{oc} (V)			**Average I_{sc} (A)**				
Testing instrument details		Make: Model: Serial Number: Calibration Date: Calibration Certificate Number:					
Remarks							

Safety Information

The Approved Contractor must complete the table below, detailing specific risks related to the site, prior to the site visit by ETIHADWE inspectors or the relevant authority for the DSS.

No.	Site-Specific Risks	Protective Measures and Required PPE
1	Chemical / Harmful materials	
2	Falling hazard	
3	Restricted access	
4	Slipping hazard	
Other Risks – please specify below		
5		
6		

TECHNICAL DOSSIER

It is crucial for the operation of any DSS, especially for maintenance technicians, to have access to as-built designs, documents, and equipment documentation (such as technical specifications, installation guides, user manuals, etc.).

Verify the availability of the following documentation:

No.	Document Description	Document Availability (Tick if available)	Document Reference No.	Remarks
1	**Copy of ETIHADWE design approval**			
2	**Site layout showing the locations of main equipment (PV modules, inverters, energy meters, electrical panels, and POI)**			
3	**Single Line Diagram (SLD)**			
4	**DC and AC wiring layouts**			
5	**Approved structural calculations and drawings**			
6	**Additional Documents/Reports**			

FUNCTIONAL INSPECTION CHECKLIST

General

Inspections and tests outlined in these checklists shall be performed upon ETIHADWE's approval on the inspection and testing before interconnection and upon supply and installation of the electricity meter(s) by

ETIHADWE at the site. These inspections and tests shall follow the guidelines detailed in “Inspection & Testing Guidelines for Small-Scale Solar PV Systems in ETIHADWE.” [**Error! Reference source not found.**]

DSS Startup

The following checks shall be done upon connection of the AC side of the DSS to the Distribution Network while keeping the DC side off by opening DC isolator switches.

No.	Check Item	Result		
1	All inverters are receiving power supply from the Distribution Network. This can be verified by visually checking the LED indicators status on the inverters.	N	Y	N/A
2	All auxiliary services within DSS are receiving power supply from the Distribution Network such as weather station, data loggers, interface protection relays within the AC Combiner Box or Solar Sub0main distribution board (SMDB).	N	Y	N/A
3	Interface protection relay settings are in accordance with the parameters and guidelines in [**Error! Reference source not found.**].	N	Y	N/A

DSS Operation

The following checks shall be done upon passing the checklist in the previous section 3.1.2. For these checks, both the DC and AC sides of the DSS shall be connected by closing isolator switches and breakers from both sides.

No.	Check Item	Result		
1	All inverters are operating properly with no failures or alarm messages detected.	N	Y	N/A
2	Input and output voltage and current of each inverter are either shown on the inverter display or can be measured and values are within expected levels.	N	Y	N/A
3	All circuit breakers are in close position and no tripping is detected for all protection equipment for a period of at least 15 minutes after DSS energization.	N	Y	N/A
4	Confirm that any local monitoring systems are operational.	N	Y	N/A

Energy Meter(s)

No.	Check Item	Result		
1	Verify that energy meter(s) wiring and connection to CT/VT (if applicable) as per the requirements of Reference **Error! Reference source not found.**, Section 8.	N	Y	N/A
2	Verify the rating of energy meter(s) and current transformers (CT) / voltage transformers (VT), if any.	N	Y	N/A
3	Verify energy meter(s) calibration certificate.	N	Y	N/A
4	Record the energy meter(s) initial readings and verify that DSS is generating energy by monitoring the movement of the meter reading.	N	Y	N/A

TESTS AFTER INTERCONNECTION – POWER QUALITY TEST

General

This test is only applicable to DSS with a Maximum Capacity (P_{ac}) of 100 kW or greater.

For the DSS power quality test, the following conditions and notes shall be met:

- The observation period for the test shall be at least one week.[5]
- The test shall be performed while DSS is operational during the whole observation period.
- Approved Contractors shall submit the raw measurement data to ETIHADWE as logged in the testing instrument.
- The testing instrument shall be capable of measuring 1-minute interval data for the following parameters:
    a. Voltage (V)
    b. Current (A)
    c. Power (W)
    d. Power Factor
    e. Voltage and current harmonics

Test Report

The table template below shall be filled by the Approved Contractor and shall be submitted to ETIHADWE. This template is made for one day out of seven days of the observation period for reference. Approved Contractor shall submit the data for the whole observation period of seven days using the same table outline.

Date	Time	Max/Min Voltage (V)	Hourly Average Real Power – P (W)	Hourly Average Reactive Power – Q (VAR)	Power Factor – $\cos(\tan^{-1}(Q/P))$
	00:00-01:00				

[5] Based on other utilities in the UAE. May be revised based on ETIHADWE Distribution Network planning requirements, if different.

Date	Time	Max/Min Voltage (V)	Hourly Average Real Power – P (W)	Hourly Average Reactive Power – Q (VAR)	Power Factor – $\cos(\tan^{-1}(Q/P))$
	1:00-2:00				
	…				
	23:00-00:00				
Testing instrument details	Make: Model: Serial Number: Calibration Date: Calibration Certificate Number:				
Remarks					

Note: In addition to the table above, the Approved Contractor shall submit voltage and current harmonics readings to the 50th order in an Excel sheet as well as the raw data file extracted from the testing instrument. Harmonic values shall be within acceptable limits per the requirements of Reference**Error! Reference source not found.**, Section 2.5.4.