KAHRAMAA
كهرماء
المؤسسة العامة القطرية للكهرباء والماء
Qatar General Electricity & Water Corporation

EP-EPP-P7-G2

Guidelines for Information in Basic and Final Design

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1 Purpose

The purpose of this guidelines is to help the Consultant/Contractor to prepare the information and technical documents required for designing a PV System.

2 Scope

During the Connection Process, the Consultant/Contractor of the Customer should deliver to Kahramaa a set of documents, reports and information required during the Connection Process steps. This document contains specific guidelines

DISCLAIMER

This document is a guideline for the information that the designer of a PV System (Consultant or Contractor) has to deliver to Kahramaa via the integrated system with Baladiya.

This document is not a guideline for designing a PV System, which is the responsibility of the Approved Consultant/Contractor.

The document lists a minimum set of requirements for delivering the information for obtaining the approvals for connecting a PV System to Kahramaa network. The Consultant/Contractor should consider the following guideline and checklists as a starting point.

3 Abbreviations, Definitions of Terms & Key References

Abbreviations

AC	:	Alternating Current	AFCI	:	Arc Fault Circuit Interrupter
ASTM	:	American Society for Testing and Materials	BAPV	:	Building-Attached Photovoltaic Modules
BIPV	:	Building-Integrated Photovoltaic modules	$\cos \varphi$	:	Power factor
DC	:	Direct Current	GHI	:	Global horizontal irradiance
IEC	:	International Electrotechnical Commission	IP	:	Interface Protection
IR	:	Infrared	ISO	:	International Organization for Standardisation
ITP	:	Inspection and Test Plan	LOM	:	Loss of Mains
LV	:	Low Voltage (namely 220/127 V or 380/220 V or 400/230 V)	LVRT	:	Low Voltage Ride Through
MV	:	Medium Voltage (namely 13.8kV or 33 kV)	MS	:	Method Statement
NEC	:	National Electrical Code	NFPA	:	National Fire Protection Association
P	:	Active power	P_{ELV}	:	Protected Extra Low Voltage
P_{nom}	:	Nominal active power of the equipment	POA	:	Plane of Array
PPE	:	Personal protective equipment	PR	:	Performance Ratio

PV	:	(Solar) Photovoltaic	Q	:	Reactive Power
RCD	:	Residual Current Device	ROCOF	:	Rate of Change of Frequency expressed in Hz/s.
S/S_n	:	Apparent Power	SELV	:	Safety extra-low voltage
SPD	:	Surge Protection Device	SR	:	Soiling Ratio
STC	:	Standard Test Condition	UL	:	Underwriters Laboratories
UV	:	Ultraviolet	V_{nom}	:	Nominal Voltage
WMO	:	World Meteorological Organization	EP	:	Electricity Planning Dept

Term	Description
AC Module	PV module with an integrated inverter in which the electrical terminals are AC only
Active Power	Active Power is the real component of the apparent power, expressed in watts or multiples thereof, e.g. kilowatts (kW) or megawatts (MW). In the text, this will be generically referred as *P* or P_{nom} in case of the nominal active power of equipment
Apparent Power	The product of voltage and current at the fundamental frequency, and the square root of three in the case of three-phase systems, usually expressed in kilovolt-amperes (kVA) or megavolt-amperes (MVA). It consists of a real component (Active Power) and the reactive component (Reactive Power). This will be generically referred to *S* or S_n in case of the rated apparent power of equipment
Apparent power of an Inverter	The rated apparent power of an Inverter is the product of the rms voltage and current and is expressed in kVA or MVA.
Auxiliary Supply Power	Electricity supply for supporting auxiliary systems and services such as Interface Protection or circuit breaker and contactor opening coils.
Building-Attached Photovoltaic Modules (BAPV modules)	Photovoltaic modules are considered to be building-attached if the PV modules are mounted on a building envelope. The integrity of the building functionality is independent of the existence of a building-attached photovoltaic module.
Building Attached Photovoltaic system (BAPV system)	Photovoltaic systems are considered to be building attached if the PV modules they utilise do not fulfil the criteria for BIPV modules.
Building-Integrated Photovoltaic modules (BIPV modules)	Photovoltaic modules are considered to be building-integrated if the PV modules form a construction product providing a function. Thus, the BIPV module is a prerequisite for the integrity of the building's functionality. If the integrated PV module is dismounted (in the case of structurally bonded modules, dismounting includes the adjacent construction product), the PV module would have to be replaced by an appropriate construction product. The building's functions in the context of BIPV are one or more of the following: • mechanical rigidity or structural integrity • primary weather impact protection: rain, snow, wind, hail • energy economy, such as shading, daylighting, thermal insulation • fire protection • noise protection • separation between indoor and outdoor environments

Term	Description
	• security, shelter or safety Inherent electro-technical properties of PV, such as antenna function, power generation and electromagnetic shielding etc., alone do not qualify PV modules to be building-integrated.
Building-Integrated Photovoltaic system (BIPV system)	Photovoltaic systems are considered to be building-integrated if the used PV modules fulfil the criteria for BIPV modules.
Circuit Breaker (CB)	As per the Kahramaa Electricity and Wiring Code definition
Connection Point	Also referred to as *Point of Connection*, is the interface point at which a PV System of the Customer is connected.
Consultant	A qualified consultant for the design of grid-connected solar PV Systems.
Customer	Any Person supplied with electricity services for his own consumption. In this context, this term will also be used to refer to a User owning a solar PV System.
Contractor	A certified contractor for the installation of grid-connected solar PV Systems.
Delay time (of a protection relay)	Indicates the minimum duration of a fault detected by the protection relay before the output of the protection relay is triggered.
Delivery Point	The interface point at which electrical energy is delivered by Kahramaa to a Demand Facility or Generating Unit or by a Demand Facility or Generating Unit to Kahramaa.
Distribution System / Distribution Network	Qatar electrical infrastructure (lines, cables, substations, etc.) at 33 kV and below, operated by Kahramaa. The Distribution network can be either a Medium or Low Voltage system for the scope of the present document and in accordance with international standards: • A Low Voltage (LV) Distribution System is a network with a nominal voltage lower than 1 kV AC or 1.5 kV DC. The LV network in the State of Qatar is 240/415 V ± 6%, 3 Phase, 4 Wire. • A Medium Voltage (MV) Distribution System is a network with nominal voltage included in the range from 1 kV AC up to 33 kV. The MV Distribution System nominal voltages in Qatar are 11, 22 and 33 kV. • Electrical network voltages equal to or higher than 33 kV are not considered in this document. According to the Transmission Grid Code, the 33 kV is considered a sub-transmission network. To avoid doubt, the term Distribution Network will be preferred in this document in place of Distribution System.
Electricity Transmission Network (ETN)	Qatar electrical infrastructure (lines, cables, substations, etc.) from above 33 kV up to 400 kV operated by Kahramaa.
Global horizontal irradiance (GHI)	Direct and diffuse irradiance incident on a horizontal surface expressed in W/m^2.
In-plane irradiance (Gi or POA)	The sum of direct, diffuse, and ground-reflected irradiance incidents upon an inclined surface parallel to the plane of the modules in the PV array, also known as plane-of-array (POA) irradiance. It is expressed in W/m^2
$I_{MOD\_MAX\_OCPR}$	PV module maximum overcurrent protection rating determined by IEC 61730-2 (Note: This is often specified by module manufacturers as the maximum series fuse rating).

Term	Description
Inspection	Examination of an electrical installation in order to ascertain correct selection, design and proper erection of electrical equipment.
Interface protection (IP)	Electrical protection part of the solar PV System that ensures the PV System is disconnected from the network in case of an event that compromises the integrity of Kahramaa's distribution network.
Inverter	Electric energy converter that changes direct electric current to single-phase or polyphase alternating current.
Irradiance (G)	Incident flux of radiant power per unit area expressed in W/m^2.
Irradiation (H)	Irradiance integrated over a given time interval and measured in energy units (e.g. $kWh/m^2/day$).
Islanding	Situation where a portion of the distribution network containing generating plants becomes physically disconnected from the rest of the distribution network. One or more generating plants maintain electricity supply to such isolated parts of the distribution network.
Load Flow	It is a numerical analysis of the electric power flow in a transmission and/or distribution systems. A power-flow study usually uses simplified notations such as a one-line diagram and per-unit system, and focuses on various parameters, such as voltages, voltage angles, real power and reactive power. It analyses the power systems in normal steady-state operation.
Loss Of Mains (LOM)	Represents an operating condition in which a distribution network, or part of it, is separated from the main power system (on purpose or in case of a fault) with the final aim of de-energisation. The protection that detects this condition is known as anti-islanding protection.
Main Meter	It is the bidirectional smart meter installed at the Connection Point which measures the amount of electric energy actually exchanged (import or export) by the Customer with the distribution network.
Maximum Available Active Power Output	This is the Active Power Output based on the primary resource (for example, sun irradiance) and the maximum steady-state efficiency of the Solar PV System for this operating point.
Maximum Capacity (P_{max})	It is the maximum continuous active power which a Generating Unit can produce, less any auxiliary consumption associated used to facilitate the operation of that Generating Unit. The Maximum Capacity shall not be fed into the distribution network as specified in the *Connection Agreement*. In this document, this term is also referred to as Maximum Connected Capacity.
Module Integrated Electronics	Any electronic device fitted to a PV module that provides control, monitoring or power conversion functions (Note: Module integrated electronics may be factory fitted or assembled on-site).
National Control Centre (NCC)	Main Kahramaa's facility used to operate and control/maintain the Electric Power System.
Peak Power (Wp)	The output power achieved by a Photovoltaic Module under Standard Test Conditions (STC). It is measured in W_p (W peak). The sum of the peak power of the photovoltaic modules of either a string or an array determines the peak power of the string and the array, respectively (usually measured in kW_p). The peak power of a photovoltaic array at STC is conventionally assumed as the rated power of the array.
Photovoltaic (PV) cell	The most elementary device that exhibits the photovoltaic effect, i.e. the direct non-thermal conversion of radiant energy into electrical energy.
Power Factor	It is the ratio of Active Power to Apparent Power.

Term	Description
Power Park Module (PPM)	A unit or ensemble of units generating electricity, which is either non-synchronously connected to the network or connected through power electronics, and that also has a single Connection Point to the ETN.
PV Array	Assembly of electrically interconnected PV modules, PV strings or PV sub-arrays. For the purposes of these Technical Standards, a PV Array comprises all components up to the DC input terminals of the Inverter.
PV Module	PV modules are electrically connected PV cells packaged to protect them from the environment and protect the users from electrical shock.
PV String	A set of series-connected PV modules.
PV String Combiner Box	A box where PV strings are connected, which may also include circuit breaker, monitoring equipment, and electrical protection devices.
Rated Active Power	Represents the sum of the nominal active power of all the Solar PV Units which compose the Solar PV System; it is generally referred to as *Pnom* of the Solar PV System.
Reactive Power	Represents a component of the apparent power at the fundamental frequency, usually expressed in kilovar (kVAr) or Megavar (MVAr).
Reactive Power Capability	Defines the reserves of inductive/capacitive reactive power which can be provided by a generating system/unit. The reactive power capability usually varies with the active power and the voltage of the generating system/unit.
Residual Current Device (RCD)	A sensitive switch that disconnects a circuit when the residual current exceeds the operating value of the circuit, referred as RCD in this document.
Soiling ratio (SR)	A ratio of the actual power output of the PV array under given soiling conditions to the power that would be expected if the PV array were clean and free of soiling.
Solar PV System	This term also has the same meaning as Power Plant or User's System or Grid User, defined in the Transmission Grid Code. It is a solar PV installation of not more than 25 MW and not less than 1 kW capacity installed in one Premise and connected in parallel to Kahramaa's Distribution Network. This document aims to be considered a power plant with one or more Solar PV Units. Besides, circuits and auxiliary services are also part of a solar PV System. To avoid doubt, in this document, the generic term Solar PV System is considered equivalent to solar PV System. This PV System includes the PV array, controllers, inverters, batteries (if used), wiring, junction boxes, circuit breakers, and electrical safety equipment.
Solar PV System Meter	It is the smart metering installed at the output point of the solar PV System and measures the total energy produced from the Solar PV Units.
Solar PV Unit	A group of devices that collects the sun's irradiance in a Solar PV System, together with all plant and apparatus and any step-up transformer which relates exclusively to the operation of that part of the same Solar PV System. Only units that are Inverter based (i.e., Asynchronously connected to the Distribution Network through power electronics devices) are considered in this document. For these Technical Standards, this definition will be equivalent to that of the Power Park Module as given in the Transmission Code. For the avoidance of doubt, in this document, the generic term Solar PV Unit will be considered equivalent to a solar PV Unit.
Standard test conditions (STC)	Reference values of in-plane irradiance (1 000 W/m2), PV cell junction temperature (25 °C), and the reference spectral irradiance defined in IEC 60904-3.
Switch	As per the Kahramaa Electricity and Wiring Code definition.

Term	Description
Testing	Implementing measures in an electrical installation to prove its effectiveness (Note: It includes ascertaining values using appropriate measuring instruments, said values not being detectable by inspection).
Time Current Curve (TCC)	The time current curve plots the interrupting time of an overcurrent device based on a given current level. These curves are used for the protection coordination and are provided by the manufacturers of electrical overcurrent interrupting devices such as fuses and circuit breakers.
THD (Total Harmonic Distortion)	Concerning an alternating quantity, it represents the ratio of the r.m.s. value of the harmonic content to the r.m.s. value of the fundamental component or the reference fundamental component.

Key References

[1] The Qatar Transmission Grid Code – Issue ES-M4 – Revision 0.0 – March 2020 and amendments in force until 02/2022 (in this document referred to as "Transmission Code")
[2] CS-CSI-P1/C1 Kahramaa's Low Voltage Electricity Wiring Code 2016
[3] Qatar Construction Specifications, Latest edition
[4] Safety Rules for the Control, Operation and Maintenance of Electricity Transmission & Distribution System of Qatar General Electricity & Water Corporation.
[5] Inspection and Testing Checklists
[6] System Operation Memorandum (SOM).
[7] Kahramaa interlocking document, (Qatar Power Transmission System Expansion – Latest phase – Substations).
[8] ET-P26-G1 Guidelines for Protection Requirements.
[9] ES–EST-P1-G1 Guidelines for System Control Requirements for Power Supply to Bulk Consumers.
[10] ET-P20-S1 Transmission Protection Standards for TA and ET Projects.
[11] ES-M2 Qatar Power System Restoration Plan; and
[12] ES-M3 System Emergency, Categorization, Communication & Restoration Responsibility.
[13] QCDD (Qatar Civil Defence Department) regulations
[14] CS-CSI-P2 E_W – Infrastructure Preparation for Service Connection Purpose v3
[15] CS-CSI-P3 E_W – Services Inspection v5
[16] CS-CSI-P4 – Low Voltage Electrical Contractor Licensing v3
[17] CS-CSI-P5 – Handling of Contractors Violations Procedure v2
[18] CS-JCU-P1– Illegal Connections Reconnections v3
[19] CS-CSM-P2 E_W – Supply Connection and Disconnection
[20] -CS-AMI-P1 – AMI operations
[21] CS-MAS-P2 E_W – Meter Installation v4
[22] CS-MAS-P3 – Maintenance of Electricity and Water Meter v2
[23] CS-MAS-P5 – Materials Submittal Review _ Approval Procedure v2
[24] Energy and Water Conservation Code 2016
[25] EP-EPD-P1 – Electricity Supply Approval
[26] EP-EPD-P4 – Processing Service Notes
[27] EP-EPD-P6 - 11kV – Load Flow Study
[28] EP-EPM-P4 – Material Specification Standards
[29] EP-EPM-P6 – Tech Evaluation of Materials for KM Elect Dist. Tenders and External Submittal

[30] EP-EPM-P7 – Prequalification of Materials and Related Manufacturers and Factories for KM Elect Dist. Net
[31] EP-EPP-C1 – Electricity Planning Regulations for Supply
[32] EP-EPP-P3 – Early Arrangement for Supply Connection
[33] EP-EPP-P5 – Electricity Supply Application
[34] EP-EPT-P2 – Basic Concept Report-Direct Connection Notification
[35] EP-EPT-P3 – Peak Demand Forecast
[36] EP-EPT-P4 – Power System Studies and Five Years Development Plan
[37] ES-ESN-P3 – Dispatching Procedure v2
[38] ES-ESN-P4 – Bulk Industrial Consumers Energy Meter Readings Collection v2
[39] ES-ESP-P1 – Creating Operational Load Forecast v2
[40] ES-ESP-P2 – Long Term Operation Planning v2
[41] ES-ESP-P3 – Develop Monitor Energy Purchase Schedules and Allocation Plans v2
[42] ES-ESP-P4 – Operation Studies v2
[43] ES-ESP-P7 – Develop Surplus Available Capacity Plan for Marketing v2
[44] ES-M4 – Qatar Transmission Grid Code 2020
[45] ET-P26 ETD – Responsibilities for Bulk Consumer's Request for Supply of Electricity
[46] -CS-CSB-P1 – Bulk Supply of Electricity and Water
[47] PW-PWP-P1 E_W – Demand Forecasting
[48] PW-PWP-P2 – Additional Capacity Planning
[49] PW-PWP-PL1 – Planning _ Procurement Policy
[50] PW-PWR-P2 – Renewable Energy Standards Development
[51] IEC 60364-6 – Low voltage electrical installations. Part 6: Verifications
[52] IEC 61010 – Safety requirements for electrical equipment for measurement, control and laboratory use
[53] IEC 61557 – Electrical safety in low voltage distribution systems up to 1000 V AC and 1500 V DC
[54] IEC 61724-1 – Photovoltaic system performance. Part 1: Monitoring
[55] IEC 61724-2 – Photovoltaic system performance. Part 2: Capacity evaluation method
[56] IEC 61724-3 – Photovoltaic system performance. Part 3: Energy evaluation method
[57] IEC 61730-2 – Photovoltaic (PV module safety qualification. Part 2: Requirements for testing
[58] IEC 62446-1 – Photovoltaic (PV) systems. Requirements for testing, documentation and maintenance. Part 1: Grid connection systems. Documentation, commissioning, tests and inspection
[59] IEC TS 62446-3:2017- Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 3: Photovoltaic modules and plants - Outdoor infrared thermography
[60] IEC 61829:2015 Photovoltaic (PV) array - On-site measurement of current-voltage characteristics
[61] IEC 62548 – Photovoltaic (PV) arrays. Design requirements

Companion Documents

The documents listed hereinafter have to be considered a compendium of the current document. Therefore, they should be carefully read in addition to this.

a) EP-EPP-P7 Electricity Supply Approval for REG connection

b) EP-EPP-P7-S1 Technical Specifications for the Connection of PV Systems to the Network
c) CS-CSI-P3-G2 Inspection and Testing Guidelines for Solar PV Systems Connected to LV and MV Network, last revision
d) EP-EPM-G2 Guidelines for the Eligibility of Manufacturers' Equipment, last revision
e) PW-PWR-G2 Safety related to the installation of Solar PV Systems, last revision
f) KM-PW-PL01-Kahramaa policy for Renewable Energy systems connected to the distribution network

4 Introduction

4.1 Responsibilities in the Design

During the implementation of a PV System, there are two stages, each one with a different design level of a PV System:

1) Basic Design
2) Final Design

The Basic Design shall contain minimum information to demonstrate:

a) The maximum capacity allowed as an Eligible Customer.
b) Enough roof and/or ground space is available for this capacity.
c) Energy Production data kWh/year
d) Type of building and intended implementation to verify if there are architectural, environmental, or other restrictions.
e) The location of the Customer for network purposes analysis.
f) The basic diagram of the PV System.
g) The basic characteristics required to run a power flow and standard analysis and verify if the PV System affect (or not) the Kahramaa network and other Customers in the grid.

The final design shall contain the full design of the PV System that includes the previous lists, plus the manufacturer's equipment technical specification, the technical documentation, rationale of the design, interface protection proposed settings and several additional details explained in Chapter 0 of this document.

The designer is responsible for preparing this Basic Design and the Final Design, i.e., the Kahramaa approved Consultant/Contractor selected by the Customer who signs the design presented.

Figure 1 summarises the timeline of the verification process and other related activities according to the different roles:

- The Consultant/Contractor is in charge of the Basic Design and Final Design.
- Kahramaa is in charge of carrying out the evaluation only of those parameters that may affect the Kahramaa Distribution Network. Kahramaa does not evaluate the design itself of the PV System but its impact on the Distribution Network.

The diagrams in Figure 1 and Figure 2 do not consider the information flow, the documents produced in the process and the checks between actions.

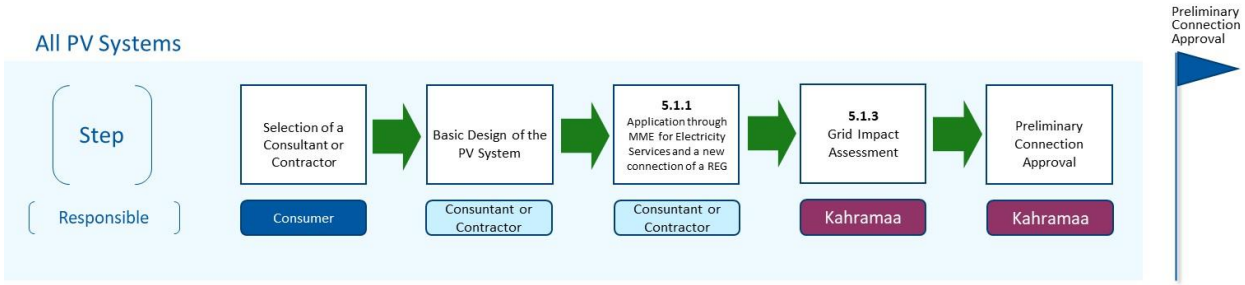

Figure 1 –Responsible for the Basic Design of a PV System1

[1] The number in the steps boxes correspond to the step in the internal process of Kahramaa

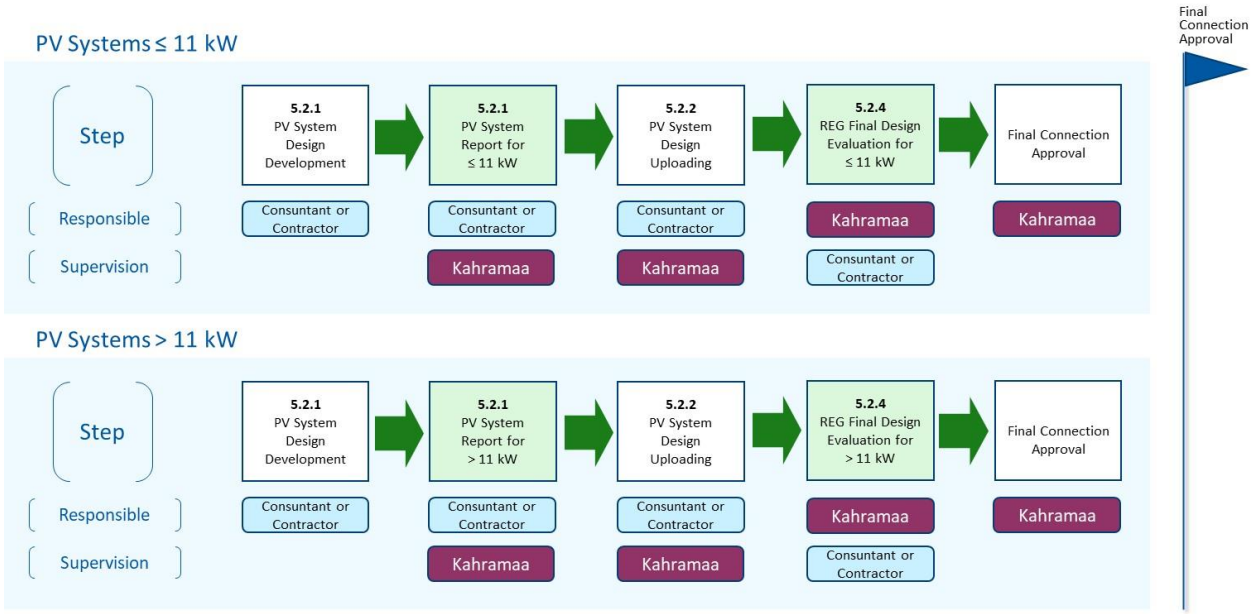

Figure 2 –Responsible for the Final Design of a PV System1

As shown in Figure 2, there is a division in the evaluation process according to the PV System size. PV Systems that are up to 11 kW have a lower evaluation level than PV Systems with nominal power above 11 kW.

The difference is in the Final Design evaluation and not the *Basic Design*. The Report for PV Systems above 11 kW is more difficult with the required information and data, and this is detailed in Chapter 0 of this document.

It is not the responsibility of Kahramaa to check nor to approve the mechanical design of the PV systems, the mechanical and fire safety of the building without or with the PV systems, as well as any issues that regard the compatibility of the PV Systems with the aesthetic rules or regulations in force, shall be the role of the MME deputed to manage the above-mentioned duties and responsibilities.

4.2 Connection Process Overview

The Connection process for connecting a solar PV System will follow three main stages, as depicted in Figure 3.

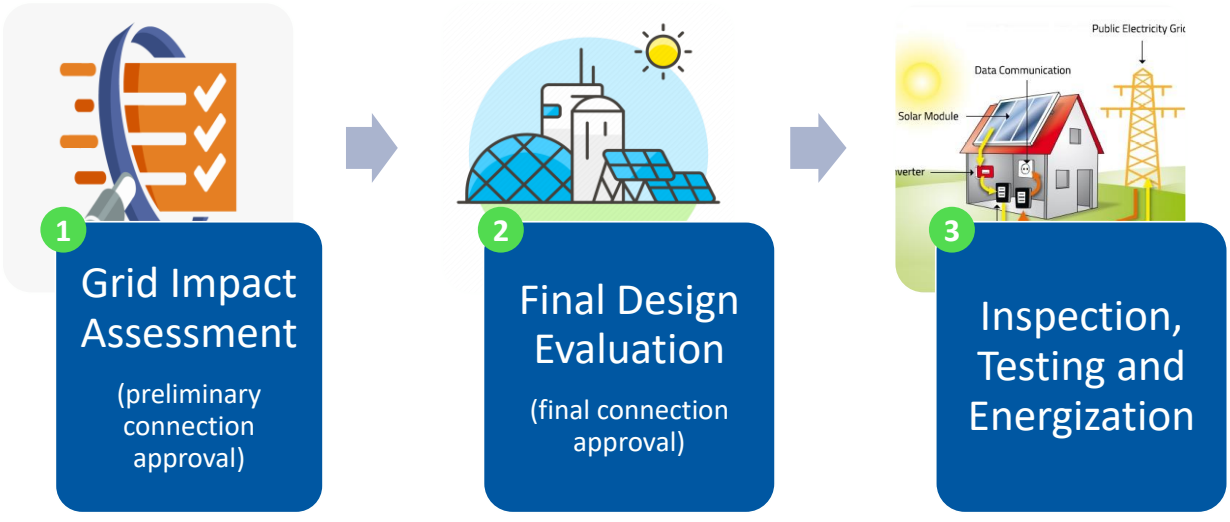

Figure 3 – Main Stages in the Connection Process

These three high-level stages also consider some activities inside each Stage. Each Stage has a main outcome that enables the Consultant/Contractor to move to the next Stage.

The main outcome of the first Stage is the approval of the *Preliminary Connection Approval* to be issued by Kahramaa based on the ***Basic Design***, some additional information required and network analysis.

The main outcome of Stage 2 is the approval of the *Final Connection Approval* to be issued by Kahramaa based on the ***Final Design*** and some additional information required.

This document **focuses** on Stage 1 and Stage 2 regarding the information that the Consultant/Contractor has to prepare and deliver to Kahramaa (via the integrated system with Baladiya) for obtaining the respective approvals in each Stage (1 and 2).

4.2.1 Stage 1: Preliminary Connection Approval

In this Stage, there are two key activities to be performed: your Consultant's ***Basic Design*** and the verification of Kahramaa if the solar PV System can be connected to Kahramaa network without jeopardising the network and other Customers.

The Consultant/Contractor has to perform the application and request via the Municipality integrated system (Baladiya) and the Customer perform the *Application Fee* payment required for this Stage. Kahramaa may decide to not charge in this Stage according to the type of Customer and location.

The *Basic Design* should contain the capacity of your system, how many solar panels are required, the size of the roof and if you will require a modification of the structure of your roof or premises for installing your PV System. For example, have to be checked if your roof can support the weight of the solar panels or if the panels may affect the urban landscape or may not be permitted because of the historical architecture. For these reasons, the Consultant/Contractor should enter the request via the Municipality and obtain, at the same time, the Build Permit.

When Kahramaa receives the application and the payment, it can evaluate the basic design. First, verify if there is complete documentation, if it is correct, and if it is technically feasible to install a REG on the feeder of the distribution network and in the specific Point of Connection (POC) indicated. This is called *Grid Impact Assessment*. During this high-level assessment, Kahramaa may require some clarifications from your side.

After a predefined deadline (respecting the quality of service to Customers), Kahramaa should issue his ***Preliminary Connection Approval*** or rejection based on his high-level assessment. In case of rejection, Kahramaa should explain the reasons to your Consultant or Contractor.

Together with the *Preliminary Connection Approval*, Kahramaa will perform the feeder reservation, i.e., once the connection is preliminary approved, there will be reserved capacity on that specific feeder for the connection of the PV System, with precedents to other connection requirements that may come later.

4.2.2 Stage 2: Final Connection Approval

If the *Preliminary Connection Approval* was obtained in the previous Stage, the Consultant or Contractor can go ahead and develop a full design of your PV System, fully compliant with the "*EP-EPP-P7-S1" Technical Specifications for the Connection of PV Systems to the Network*" document issued by Kahramaa and the National Codes and regulations.

The Consultant or Contractor has to deliver a set of reports and documents in the process part of the Final Design. Kahramaa will evaluate based on the documentation and the checklist in this document if the PV System Final Design contains all required documents and data. Kahramaa will also evaluate if all the main data are consistent with those delivered in the previous Stage and if they are consistent with the specific PV technology.

After reviewing the check-listed topics of the final design, Kahramaa may observe the design. After Kahramaa verifies that the designed conditions and characteristics of the PV System do not affect the distribution network and other Customers, it will issue a *Final Connection Approval*. Therefore, the Customer should perform the payment of the *Connection Fee* for connecting the PV System.

4.3 Ownership Boundaries

The boundary between Customer and Kahramaa is regulated as follows:

- The boundary between Kahramaa and the Customer is the Connection Point as indicated in the connection schemes of the "*EP-EPP-P7-S1" Technical Specifications for the Connection of PV Systems to the Network*" document.
- The respective ownership of PV System or equipment shall be recorded in the *Connection Agreement* between Kahramaa and the Customer in a diagram.

4.4 Notice to Users of these Guidelines

This document is for use by employees of Kahramaa, Consultants, and Contractors. The checklists included in this document are for the common use of Kahramaa and the approved Consultants/Contractors.

Users of this document should consult all applicable laws, regulations and standards. Users are responsible for observing or referring to the applicable regulatory requirements. Kahramaa does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Users should be aware that this document may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. All users should ensure that they obtained this document's latest edition uploaded on the Kahramaa website.

Finally, unless otherwise specified, the User shall refer to all applicable Kahramaa Standards, Qatar Standards, or International Standards mentioned in this document.

5 Design of a PV System

5.1 Overview

The *Basic Design* is a key part of Stage 1 of the Connection Process, and it is connected with the activities under 5.1.1 of the General Connection Process.

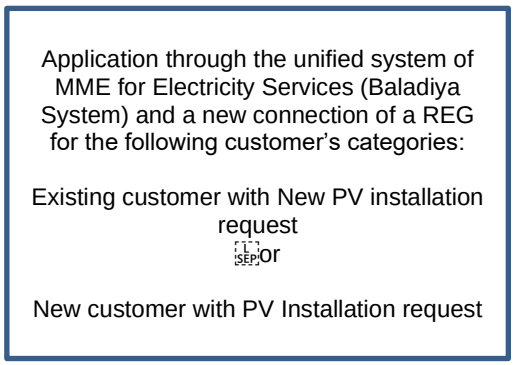

Figure 4 – Connection Process steps related to submitting the Basic Design2

The "*Application through the unified system of MME for Electricity Services and a new connection of a REG*" (5.1.1) is the Consultant or Contractor's responsibility and shall be performed in case of a PV System application.

This chapter aims to list the data required to have a minimum set of information that a Consultant/Contractor (representing the Customer) needs to present to Kahramaa.

5.2 Basic Design: Electric Single Line Diagram

The single line diagram (SLD) shall be part of the documentation of the Basic Design submitted by the Consultant/Contractor in the application. The SLD document shall contain the basic drawing of the PV System and should be in PDF, DWG, DXF format. Depending on the size of the project, there can be several SLDs.

Table 1 of Form EP-EPP-P7-G2-F1 summarises the information submitted.

5.3 Basic Design: Site Plan

The site plan shall be part of the documentation of the Basic Design submitted by the Consultant/Contractor in the application. The site plan document shall contain the basic drawing of the PV System and should be in PDF, DWG, DXF format. Depending on the size of the project, there can be one or several drawings.

Table 2 of Form EP-EPP-P7-G2-F1 summarises the information required from Site Plans.

5.4 Basic Design: Basic Design Report

Together with some requirements of the *Basic Design*, a technical *Basic Design Report* shall be part of the documentation submitted in the application. The document shall

[2] The number in the steps boxes correspond to the step in the internal process of Kahramaa

contain the main characteristics of the PV System and the rationale for the basic choices. The document shall be prepared and submitted by the Consultant/Contractor and should be in PDF format. According on the size of the project, there can be several documents for the main report and the Annexes.

Table 3 of Form EP-EPP-P7-G2-F1 summarises the information required in the Basic Design Report.

5.5 Checklist for Kahramaa Basic Design Evaluation

Kahramaa will receive the *Basic Design* information as requested in the previous sections of this chapter and then will verify if this information is complete and if they contain the required level and basic details for conducting its analysis of the network with the proposed PV System (*Grid Impact Assessment*).

The digital data and information that the Consultant/Contractor should provide are the following:

a) Information on the location where pretends to install a REG
b) Basic information regarding the PV System foresee to install
c) Basic Design of the PV system
d) Project implementation schedule
e) Environmental Impact Assessment (EIA) – if needed
f) Information of the Consultant/Contractor
g) Other documents that Kahramaa may require to the Consultant.

Below is a minimum information verification checklist for Kahramaa in order to verify the completeness and adequacy of the data delivered.

Table 4 of Form in EP-EPP-P7-G2-F1 contains the Checklist for Kahramaa's verification of the information delivered for Basic Design.

A positive final result requires that that the information send it are accepted and the Grid Impact Assessment will be performed by Kahramaa.

6 PV System Final Design

6.1 Overview

Once Kahramaa approves the *Basic Design* and issues the *Preliminary Connection Approval*, the Consultant/Contractor (representative of the Customer) can start the final design of the PV System.

The *Final Design* is a key part of Stage 2 of the connection Process, and it is connected with the activities under 5.2 of the General Connection Process.

Some activities shall be performed by the Consultant/Contractor, such as design, upload and reporting (see Figure 5) and other activities performed by Kahramaa, such as the evaluation (see Figure 6).

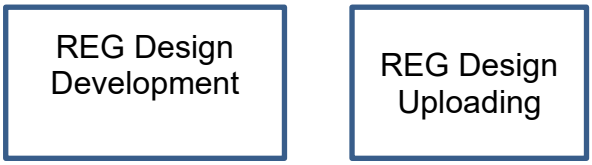

Figure 5 – Connection Process steps related to performing and submitting the Final Design by the Consultant/Contractor[3]

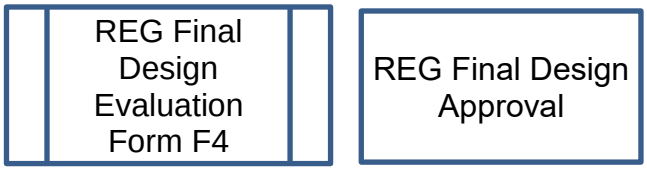

Figure 6 – Connection Process steps related to the evaluation of the Final Design by Kahramaa[4]

The objective of this chapter is to list the information, data and reports required to have a minimum set of information that a Consultant/Contractor needs to present to Kahramaa for the evaluation of the *Final Design* in the steps presented in Figure 6.

6.2 Final Design Documentation

This section summarises the key documentation required for the Final Design Evaluation. This section aims to inform the documents that the Consultant/Contractors require to prepare for submitting to Kahramaa for their evaluation.

The following sections present the list of documentation to be prepared by the Consultants/Contractors.

6.2.1 Final Design Documentation: Electric Single Line Diagram

The single line diagram (SLD) shall be part of the documentation of the Final Design submitted by the Consultant/Contractor. The SLD document shall contain the complete drawings of the PV System and should be in PDF, DWG, DXF format. Depending on the size of the project, there can be several SLDs.

Table 1 of Form EP-EPP-P7-G2-F2 summarises the information submitted.

6.2.2 Final Design Documentation: Layout of the PV System

The PV System layout shall be part of the documentation of the Final Design submitted by the Consultant/Contractor. The layout shall contain the drawings of the PV System and should be in PDF, DWG, DXF format. Depending on the size of the project, there can be one or several drawings.

Table 2 of Form EP-EPP-P7-G2-F2 summarises the information and any update required from Site Plans.

6.2.3 Final Design Documentation: Supporting Structures

The PV System layout shall be part of the documentation of the Final Design submitted by the Consultant/Contractor. The layout shall contain the drawings of the PV System

[3] The number in the steps boxes correspond to the step in the internal process of Kahramaa

and should be in PDF, DWG, DXF format. Depending on the size of the project, there can be one or several drawings.

Table 3 of Form EP-EPP-P7-G2-F2 summarises the information required to verify the supporting structures.

6.2.4 Final Design Documentation: Design Report

Together with the requirements of the *Final Design*, a *PV System Design Report* shall be part of the documentation submitted in the application. The document shall contain the main characteristics of the PV System and the rationale for the choices and design. This report is the responsibility of the Consultant/Contractor and should be submitted in PDF format. Depending on the size of the project, there can be several documents for the main report and the Annexes.

Table 4 of Form EP-EPP-P7-G2-F2 summarises the information required in the Final Design Report.

6.2.5 Final Design Documentation: Quality Assurance Documents

Together with the information in this stage, the Method Statement (MS) and the Inspection and Test Plan (ITP) should be submitted for Kahramaa approval. The generic templates to be used are in Form EP-EPP-P7-G2-F3.

6.3 Design Report for PV Systems ≤ 11 kW

Here below, the structure of the *Design Report* is described, along with a list of the minimum information to be included. Further information might be required, depending on the type and size of the PV system, and the document might be organised differently. For example, in the case of MV connection, a further section dedicated to MV shall be included.

Although the organisation of the *Design Report* as described below is recommended, it might be possible to adopt a different structure, provided the general criteria be fulfilled (e.g. separation of the input data from the information elaborated during the design), and no information is missing.

As a minimum, the following basic system information shall be provided. This “nameplate” information preferably shall be presented on the cover page of the system documentation pack:

a) Project identification reference or name
b) Rated (nameplate) system power (kW DC and kVA AC)
c) PV modules and inverters – manufacturer, model and quantity
d) Installation date
e) Commissioning date
f) Customer name
g) Site address

6.3.1 Wiring Diagram

As a minimum, a single line wiring diagram in a suitable and readable format shall be provided.

In general, it is expected that this information will be presented as annotations to the single line wiring diagram. In some circumstances, typically for larger systems where space on the diagram may be limited, this information may be presented in table form.

6.3.1.1 Array – General specifications

The wiring diagram or system specification shall include the following information of the array design:

a) PV module type(s).
b) Total number of PV modules.
c) Number of strings.
d) Number of PV modules per string.
e) Identify which strings connect to which Inverter.

Where an array is split into sub-arrays, the wiring diagram shall show the array – sub-array design and include all of the above information for each sub-array.

6.3.1.2 PV string information

The wiring diagram or system specification shall include the following PV string information.

a) String cable specifications – size and type.
b) String overcurrent protective device specifications (where fitted) – type and voltage/current ratings.
c) Blocking diode type (if relevant).

6.3.1.3 PV array electrical details

The wiring diagram or system specification shall include the following information about the array (where fitted).

a) Array main cable specifications: Size, type, manufacturer and model.
b) Array junction boxes / combiner boxes: Locations, manufacturer, model and internal electric diagram.
c) DC switch disconnector: Location and rating (voltage/current), manufacturer and model.
d) Array overcurrent protective devices: Type, location, rating (voltage/current), manufacturer and model.
e) Other arrays electronic protective circuitry (such as arc fault detection), if applicable: Type, location, rating, manufacturers and models.

6.3.1.4 AC system

The wiring diagram or system specification shall include the following AC system information.

a) AC isolator location: Type, rating, manufacturer and model.
b) AC overcurrent protective device: Location, type, rating, manufacturer and model.
c) Residual current (where fitted): Device location, type and rating.
d) Interface protection: Type, manufacturing and model
e) Interface switch (and backup switch if applicable): Location, type, rating, manufacturer and model.

6.3.1.5 Earthing and overvoltage protection

The wiring diagram or system specification shall include the following earthing and overvoltage protection information:

a) Details of all earth / bonding conductors – size and type. Including details of array frame equipotential bonding cable, where fitted.
b) Details of any connections to an existing Lightning Protection System (LPS).
c) Details of any surge protection device installed (both on AC and DC lines) to include location, type and rating.

6.3.2 Planimetry and String layout

Planimetry of the PV array has to include information about the tilt and orientation. Possible sources of shading shall be clearly indicated.

A layout drawing of the PV system showing how the array is split and connected into strings shall be provided for systems with three or more strings.

This is particularly useful for finding faults in larger systems and on building-mounted arrays where access to the rear of the modules is difficult.

6.3.3 Datasheets

As a minimum, datasheets shall be provided for the following system components:

a) PV module datasheet for all types of modules used in the PV System
b) Inverter datasheet for all types of inverters used in the PV System.
c) Interface protection datasheet

The provision of datasheets for other significant system components should also be considered.

6.3.4 Mechanical design information

A data sheet for the array mounting system shall be provided. If the mounting structure was custom-engineered, include the relevant documentation.

6.3.5 Emergency systems

Documentation of any emergency systems associated with the PV system (fire alarms, smoke alarms, etc.). This information shall include both operation and design details.

6.3.6 Estimation of the yearly energy production

An estimate of the yearly energy production shall be calculated using solar energy simulation software like PVsyst or SAM.

6.4 Design Report for PV Systems > 11 kW

6.4.1 Design Report Content

Here below, the structure of the *Design Report* is described, along with a list of the minimum information to be included. Further information might be required, depending on

the type and size of the PV system, and the document might be organised differently. For example, in the case of MV connection, a further section dedicated to MV shall be included.

Although the organisation of the *Design Report* as described below is recommended, it might be possible to adopt a different structure, provided the general criteria be fulfilled (e.g. separation of the input data from the information elaborated during the design), and no information is missing.

As a minimum, the following basic system information shall be provided. This “nameplate” information preferably shall be presented on the cover page of the system documentation pack:

h) Project identification reference or name
i) Rated (nameplate) system power (kW DC and kVA AC)
j) PV modules and inverters – manufacturer, model and quantity
k) Installation date
l) Commissioning date
m) Customer name
n) Site address

6.4.1.1 Chapter 1 – Foreword (or Introductory section, or Preface, etc.)

As a minimum, the following information shall be provided:

- Type of solar system (rooftop, ground-mounted, façade, etc.), integration if relevant (BAPV, BIPV, etc.), fixed mounting or tracking, technology (monocrystalline, polycrystalline, thin-film, etc.)
- A short description of the project's purpose, also referring to the benefits for the client, for the environment, for the electric system, for the Nation, etc.
- System designer information for all bodies responsible for the design of the system. Where more than one company has responsibility for the system's design, the following information should be provided for all companies, together with a description of their role in the project.
    a. System designer, company.
    b. System designer, contact person.
    c. System designer, postal address, telephone number and e-mail address.
- System installer information for all bodies responsible for the installation of the system. Where more than one company has responsibility for the installation of the system, the following information should be provided for all companies, together with a description of their role in the project.
    a. System installer, company.
    b. System installer, contact person.
    c. System installer, postal address, telephone number and e-mail address.

6.4.1.2 Chapter 2 – Input data

It is important to dedicate a chapter to the input data used for the design (environment, local laws and rules, constraints, relevant grid characteristics, etc.) listed below. In contrast, the information elaborated at the design stage will be detailed in the upcoming paragraphs.

As a minimum, the following input data and information shall be provided:

- Definitions (recommended)

- Laws and standards applicable (the most relevant ones)
- Solar and environmental data on the site (monthly averages of direct and diffuse solar radiation, wind speed, average and maximum temperatures, etc.)
- Geological and environmental constraints (if any) as the type of soil, inclination, the need of stabilisation or other treatment, shading, presence of vegetation, animals, etc.)
- Characteristics of the distribution network at POC: voltage, frequency, No. of phases, type of earthing system (TT, TN, IT, etc.), short circuit current, and any further available information on the power supply.

6.4.1.3 Chapter 3 – Characteristics of the main devices and equipment

As a minimum, the following information shall be provided:

- PV modules (Manufacturer, model, technology, type of PV cells, P_N, V_m, I_m, V_{oc}, I_{sc}, Temperature coefficients, NOCT, dimensions and weight, certifications, etc.)
- Inverters (manufacturer, model, Pn, Max input current, Max input voltage, MPPT range, output voltage and frequency range, Max temperature, IP enclosure, dimensions, weight, certifications, etc.)
- DC combiner boxes – if present – (Manufacturer, model, No. of inputs, protection on inputs, switch/disconnector, PV string monitoring if any, IP enclosure, dimensions, weight, certifications, etc.)
- Interface protection – if external to the inverters – (Manufacturer, model, functions, standards compliance, certifications, etc.)
- Monitoring system – if present – (manufacturer, model, solar and meteorological inputs, DC inputs, AC inputs, data line exchange, storage, data display, certifications, etc.

6.4.1.4 Chapter 4 – System architecture and dimensioning

As a minimum, the following information shall be provided:

- DC and AC capacity and how it is obtained from PV modules and inverters
- The system's general architecture from PV modules to the POC (this should include a very simple block diagram with PV modules, inverters, main switches and protections, meters, POC, energy flows, etc.)
- Characteristics of the PV strings and PV array(s) (V_m, I_m, V_{oc}, I_{sc}, inclination(s), orientation(s))
- Verification of compliance for PV strings/array(s) and inverters (MPPT range, maximum voltages, maximum currents, etc.)
- Description of the distribution network connection and power delivery (protection, grid services, capability, etc.)

6.4.1.5 Chapter 5 – DC section

As a minimum, the following information shall be provided:

- Verification of compliance for DC cables (current, voltage drops)
- Measures to prevent overcurrent in parallel PV strings

6.4.1.6 Chapter 6 – AC section

As a minimum, the following information shall be provided:

- Measures to prevent electric shocks from direct contacts (class II insulations, tubes and channels, etc.)
- Measures to prevent electric shocks from indirect contacts (earthing, RCDs, etc.)
- Characteristics of the main AC devices (Manufacturer, model, type of device, No. of poles, aux contacts, nominal current, short-circuit current, protection characteristics, etc.)
- AC calculations (verification of compliance for AC devices and cables)

6.4.1.7 Chapter 7 – Civil and mechanical installation

As a minimum, the following information shall be provided:

- Description of the mounting structures
- Design philosophy
- Structural calculations and analysis
- Civil drawings

6.4.1.8 Chapter 8 – Performance calculation

As a minimum, the following information shall be provided:

- Calculation of the solar radiation on the PV system
- Energy Yield (monthly and yearly)
- CO_2 saved

6.4.2 Wiring Diagram

As a minimum, multiple line wiring diagrams in a suitable and readable format shall be provided. If necessary, the diagram may be distributed in more than one sheet.

In addition, a single line diagram, which contains the most relevant information and gives an overview of the PV system, is recommended, especially in the case of large systems.

The information listed below is also required. In general, it is expected that this information will be presented as annotations to the single line wiring diagram. In some circumstances, typically for larger systems where space on the diagram may be limited, this information may be presented in table form.

6.4.2.1 Array – General specifications

The wiring diagram or system specification shall include the following information of the array design:

a) PV module type(s).
b) Total number of PV modules.
c) Number of strings.
d) Number of PV modules per string.
e) Identify which strings connect to which Inverter.

Where an array is split into sub-arrays, the wiring diagram shall show the array – sub-array design and include all of the above information for each sub-array.

6.4.2.2 PV string information

The wiring diagram or system specification shall include the following PV string information.

a) String cable specifications – size and type.
b) String overcurrent protective device specifications (where fitted) – type and voltage/current ratings.
c) Blocking diode type (if relevant).

6.4.2.3 PV array electrical details

The wiring diagram or system specification shall include the following electrical information of the array (where fitted).

a) Array main cable specifications: Size, type, manufacturer and model.
b) Array junction boxes / combiner boxes: Locations, manufacturer, model and internal electric diagram.
c) DC switch disconnector: Location and rating (voltage / current), manufacturer and model.
d) Array overcurrent protective devices: Type, location, rating (voltage / current), manufacturer and model.
e) Other arrays with electronic protective circuitry (such as arc fault detection), if applicable: Type, location, rating, manufacturers and models.

6.4.2.4 AC system

The wiring diagram or system specification shall include the following AC system information.

a) AC isolator location: Type, rating, manufacturer and model.
b) AC overcurrent protective device: Location, type, rating, manufacturer and model.
c) Residual current (where fitted): Device location, type and rating.
d) Interface protection: Type, manufacturing and model
e) Interface switch (and backup switch if applicable): Location, type, rating, manufacturer and model.

6.4.2.5 Earthing and overvoltage protection

The wiring diagram or system specification shall include the following earthing and overvoltage protection information:

a) Details of all earth / bonding conductors – size and type. Including details of array frame equipotential bonding cable, where fitted.
b) Details of any connections to an existing Lightning Protection System (LPS).
c) Details of any surge protection device installed (both on AC and DC lines) to include location, type and rating.

6.4.3 Planimetry and String layout

Planimetry of the PV array must include information about the tilt and orientation. Possible sources of shading shall be clearly indicated.

For systems with three or more strings, a layout drawing of the PV system showing how the array is split and connected into strings shall be provided.

This is particularly useful for finding faults in larger systems and on building-mounted arrays where access to the rear of the modules is difficult.

6.4.4 Datasheets

As a minimum, datasheets shall be provided for the following system components:

a) PV module datasheet for all types of modules used in the PV System
b) Inverter datasheet for all types of inverters used in the PV System.
c) Interface protection datasheet

The provision of datasheets for other significant system components should also be considered.

6.4.5 Mechanical design information

A data sheet for the array mounting system shall be provided. If the mounting structure was custom-engineered, the relevant documentation should be included.

6.4.6 Emergency systems

Documentation of any emergency systems associated with the PV system (fire alarms, smoke alarms, etc.). This information shall include both operation and design details.

6.5 Checklists for Kahramaa Final Design Evaluation

The following checklist is a guide for the Consultant/Contractor to consider the information required to deliver to Kahramaa and be part of his evaluation. Also, it is a guideline for Kahramaa to verify the detailed design presented by the Consultant/Contractor of the Customer.

Kahramaa will receive the *Final Design* information as requested in the previous sections of this chapter and then verify if this information is complete and if they contain the required level details for conducting its evaluation (see Figure 6).

The digital data and information that should be provided by the Consultant/Contractor are the following:

a) Customer Information
b) Completeness of the documentation
c) Evaluation of the documentation
d) Verification of the completeness of the *Design Report* – Foreword
e) Verification of the completeness of the *Design Report* – Main devices and equipment
f) Verification of the completeness of the *Design Report* – System architecture and Dimensioning
g) Verification of the completeness of the *Design Report* – DC Section
h) Verification of the completeness of the *Design Report* – AC Section
i) Verification of the completeness of the *Design Report* – Civil and mechanical installation
j) Certifications required

Table 5 of Form EP-EPP-P7-G2-F2 contains the minimum information verification checklist for Kahramaa in order to verify the completeness and adequacy of the documentation delivered.

Additionally, of the documentation verification, Kahramaa shall evaluate the aspects of interest of the Final Design itself. These are evaluated aiming to protect the Kahramaa network.

In the case of minor projects, the list of evaluated requirements is lower than bigger plants. Considering these categories, there are two (2) checklists for evaluating the Final Design. One for PV Systems with $P_N \leq 11$ kW and one for PV Systems with P_N higher than 11 kW.

6.5.1 Checklist for Final Design Evaluation of PV Systems ≤ 11 kW

Table 6 of Form in EP-EPP-P7-G2-F2 contains the Checklist for the Final Design Evaluation of PV Systems ≤ 11 kW

6.5.2 Checklist for Final Design Evaluation of PV Systems > 11 kW

Table 7 of Form in EP-EPP-P7-G2-F2 contains the Checklist for the Final Design Evaluation of PV Systems > 11 kW