

A. Applicable international standards for solar O&M

Generic for O&M	
IEC 62446-1:2016	Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection
IEC 62446-2	Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 2: Grid connected (PV) systems - Maintenance of solar PV systems
IEC TS 63049:2017	Terrestrial photovoltaic (PV) systems - Guidelines for effective quality assurance in solar PV systems installation, operation and maintenance
IEC 60364-7-712:2017	Low voltage electrical installations - Part 7-712: Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems
System Performance and Monitoring	
IEC 61724-1:2017	Photovoltaic system performance - Part 1: Monitoring
IEC TS 61724-2:2016	Photovoltaic system performance - Part 2: Capacity evaluation method
IEC TS 61724-3:2016	Photovoltaic system performance - Part 3: Energy evaluation method
IEC TS 61724-4	Photovoltaic system performance - Part 4: Degradation rate evaluation method (not yet published as of October 2019)
IEC TS 63019:2019	Photovoltaic power systems (PVPS) - Information model for availability
ISO 9847:1992	Calibrating field pyranometers by comparison to a reference pyranometer
Specialised Technical Inspections	
IEC TS 62446-3:2017	Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 3: Photovoltaic modules and plants - Outdoor infrared thermography
IEC 61829:2015	Photovoltaic (PV) array - On-site measurement of current-voltage characteristics
IEC TS 60904-13:2018	Photovoltaic devices - Part 13: Electroluminescence of photovoltaic modules
Other supporting documents	
IEC TS 62738:2018	Ground-mounted photovoltaic power plants - Design guidelines and recommendations
IEC TR 63149:2018	Land usage of photovoltaic (PV) farms - Mathematical models and calculation examples
IEC 60891:2009	Photovoltaic devices - Procedures for temperature and irradiance corrections to measured I-V characteristics
IEC 61853-1:2011	Photovoltaic (PV) module performance testing and energy rating - Part 1: Irradiance and temperature performance measurements and power rating
IEC 61853-2:2016	Photovoltaic (PV) module performance testing and energy rating - Part 2: Spectral responsivity, incidence angle and module operating temperature measurements
IEC 61853-3:2018	Photovoltaic (PV) module performance testing and energy rating - Part 3: Energy rating of solar PV modules
IEC 61853-4:2018	Photovoltaic (PV) module performance testing and energy rating - Part 4: Standard reference climatic profiles
IEC 60904-5:2011	Photovoltaic devices - Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method

B. Proposed skill matrix for O&M personnel. (Download it from www.solarpowereurope.org)

First name	Surname	Function												
			Health & Safety											
			Company's Services introduction											
			Health & Safety assessment test											
			Manual Handling											
			Display Screen Equipment											
			Risk Assessment											
			Occupational Health & Safety training course											
			Training to handle Health & Safety in a team											
			Certification of Occupational Health & Safety											
			First Aid at Work											
			HV Substation Access											
			Managing Contractors											
			Other task, company or country relevant requirements (e.g., working at height, asbestos awareness, use of specific equipment, construction/installation)											
			Environmental											
			Certificate of Environmental Management and Assessment											
			Other relevant training course and/or certificate of Environmental Management											
			Monitoring & Metering											
			Certain Monitoring tool training											
			Meter accreditation and calibration											
			Other relevant skills (e.g., data handling)											
			PV Modules											
			Basic knowledge about the installed product (e.g., handling, general safety guidelines, installation etc.; see also recommendations by module manufacturer/installation manual)											
			Basic measurement skills (e.g., thermography, power measurements)											
			Inverter											
			Power Electronics											
			Learning Tools Interoperability (LTI)											
			Other skills (e.g., experience with specific product and type of inverter)											
			Electrical											
			Certification of Electrical Qualification											
			Other relevant skills (e.g., Specific Inspection & Test training, relevant accredited courses etc.)											
			Data & Comms											
			Termination of specific communication cabling											
			Installation of the monitoring system											
			Installation and connection of meters											
			Installation of satellite broadband system											
			Other skills											

C. Documentation set accompanying the solar PV power plant . (Download it from www.solarpowereurope.org)

INFORMATION TYPE AND DEPTH OF DETAIL / AS-BUILT DOCUMENTS			
NO.	MINIMUM REQUIREMENTS	DESCRIPTION	COMMENTS
1	Site Information	- Location / Map / GPS Coordinates - Plant Access / Keys - Access Roads - O&M Building - Spare Parts Storage / Warehouse - Site Security Information - Stakeholder list and contact information (for example, owner of the site, administration contacts, firefighters, subcontractors / service providers, ...)	
2	Project Drawings	- Plant Layout and General Arrangement - Cable routing drawings - Cable list - Cable schedule/ cable interconnection document - Single Line Diagram - Configuration of strings (string numbers, in order to identify where the strings are in relation to each connection box and inverter) - Earthing/Grounding System layout drawing - Lightning Protection System layout drawing - Lighting System layout drawing (optional) - Topographic drawing	"Lightning Protection System layout drawing" can be considered as optional
3	Project studies	- Shading study/simulation - Energy yield study/simulation - Inverter sizing study	
4	Studies according to national regulation requirements	- Voltage drop calculations - Protection coordination study - Short circuit study - Grounding study - Cable sizing calculations - Lightning protection study	
5	Solar PV Modules	- Datasheets - Flash list with solar PV modules positioning on the field (reference to string numbers and positioning in the string) - Warranties & Certificates	
6	Inverters	- O&M Manual - Commissioning Report - Warranties & Certificates - Factory Acceptance Test - Inverter settings - Dimensional drawings	
7	Medium Voltage/ Inverter Cabin	- Medium Voltage/Inverter Cabin layout and general arrangement drawing - Medium Voltage/Inverter Cabin foundation drawing - Erection procedure - Internal Normal/Emergency Lighting Layout Drawing - Fire Detection and Fire Fighting System Layout Drawing (if required) - HVAC system Layout Drawing - HVAC system Installation & O&M Manual - HVAC Study (according to national regulations) - Earthing system layout drawing - Cable list	
8	MV/LV Transformer	- O&M Manual - Commissioning Report - Factory Acceptance Test Report - Type Test Reports - Routine Test Reports - Warranties & Certificates - Dimensional drawing with parts list	

NO.	MINIMUM REQUIREMENT	DESCRIPTION	COMMENTS
9	Cables	- Datasheets - Type & Routine test reports	
10	LV & MV Switchgear	- Single Line Diagram - Switchgear wiring diagrams - Equipment datasheets and manuals - Factory Acceptance Test report - Type Test Reports - Routine Test Reports - Dimensional drawings - Warranties & Certificates - Protection relays settings - Switching procedure (according to national regulations)	"Protection relays settings" and "Switching procedure" are considerations for the MV Switchgear
11	HV Switchgear	- Single Line Diagram - Steel structures assembly drawings - HV Switchyard general arrangement drawing - HV Equipment Datasheets and Manuals (CTs, VTs, Circuit Breakers, Disconnectors, Surge Arresters, Post Insulators) - Protection & Metering Single Line Diagram - HV Equipment Type & Routine Test Reports - Interlock study - Switching procedure (according to national regulations) - Warranties & Certificates	
12	UPS & Batteries	- Installation & O&M Manual - Commissioning report - Warranties & Certificates - Datasheets - Dimensional Drawings	
13	Mounting Structure	- Mechanical Assembly Drawings - Warranties & Certificates	
14	Trackers	- Mechanical Assembly Drawings - Electrical Schematic Diagrams - Block diagram - Equipment Certificates, Manuals and Datasheets (Motors, Encoders) - PLC list of inputs and outputs (I/O) by type (Digital, Analog or Bus) - Commissioning reports - Warranties & Certificates	
15	Security, Anti-intrusion and Alarm System	- Security system layout/general arrangement drawing - Security system block diagram - Alarm system schematic diagram - Equipment manuals and datasheets - Access to security credentials (e.g., passwords, instructions, keys etc) - Warranties & Certificates	
16	Monitoring/ SCADA system	- Installation & O&M manual - List of inputs by type (Digital, Analog or Bus) - Electrical Schematic diagram - Block diagram (including network addresses) - Equipment datasheets	I/O list includes e.g., sensor readings that are collected by data loggers.
17	Plant Controls	- Power Plant Control System description - Control Room (if applicable) - Plant Controls instructions - Breaker Control functionality (remote / on-site) and instructions - List of inputs and outputs	
18	Communication system	- Installation and O&M manual - System internal communication - External Communication to monitoring system or Operations Centre - IP network plan - Bus network plans	

D. Important examples of input records in the record control. (Download it from www.solarpowereurope.org)

RECORD CONTROL				
NO.	ACTIVITY TYPE	INFORMATION TYPE	INPUT RECORD	REFERENCES/ COMMENTS
1	Alarms / Operation Incidents	Alarms description	Date and Time, Affected Power, Equipment Code / Name, Error messages / Codes, Severity Classification, Curtailment Period, External Visits/Inspections from third parties	
2	Contract Management	Contract general description	Project Name / Code, Client Name, Peak Power (kWp)	
3	Contract Management	Asset description	Structure Type, Installation Type	
4	Contract Management	Contract period	Contract Start and End Date	
5	Contract Management	Contractual clauses	Contract Value, Availability (%), PR (%), Materials / Spare parts, Corrective Work Labour	
6	Corrective Maintenance	Activity description	Detailed Failure Typification, Failure, Fault Status, Problem Resolution Description, Problem Cause	EN 13306 - Maintenance. Maintenance terminology
7	Corrective Maintenance	Corrective Maintenance event	Associated Alarms (with date), Event Status	EN 13306 - Maintenance. Maintenance terminology
8	Corrective Maintenance	Corrective Maintenance event log	Date and Time of Corrective Maintenance Creation (or Work Order), Date and Time status change (pending, open, recovered, close), End date and time of the intervention, Start date and time of the intervention, Technicians and Responsible Names and Function	EN 13306 - Maintenance. Maintenance terminology
9	Corrective Maintenance	Intervention equipment/ Element name	Affected Power and Affected Production, Equipment Code / Name	
10	Inventory Management	Warehouse management	Inventory Stock Count and Movement, Equipment Code / Name	
11	Monitoring & Supervision	Equipment status	Date, Status log (protection devices, inverters, monitoring systems, surveillance systems)	
12	Monitoring & Supervision	Meteo data	Irradiation, Module temperature, Other meteo variables (ambient temperature, air humidity, wind velocity and direction, ...)	IEC 61724 - Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis
13	Monitoring & Supervision	Production / consumption data	AC active and reactive power at solar PV power plant Injection Point and other subsystems or equipment, Consumption from auxiliary systems, Other variables (DC/AC voltages and currents, frequency), Power from DC field	IEC 61724 - Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis
14	Monitoring & Supervision	Performance data	Solar PV power plant Energy Production; PR; Expected vs Real	

RECORD CONTROL				
NO.	ACTIVITY TYPE	INFORMATION TYPE	INPUT RECORD	REFERENCES/ COMMENTS
15	Preventive Maintenance	Intervention equipment/ Element name	Affected Power and Affected Production, Equipment Code / Name, Intervention Start and End Date	
16	Preventive Maintenance	Maintenance description	Measurements, Preventive Maintenance Tasks Performed, Problems not solved during activity and its Classification and Typification, Technicians and Responsible Names and Function	
17	Solar PV power plant Documentation	Commissioning	Commissioning Documentation and Tests Results	IEC 62446 - Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection
18	Solar PV power plant Documentation	Operation and maintenance	Equipment Manuals, solar PV power plant O&M Manual	IEC 62446 - Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection
19	Solar PV power plant Documentation	System Documentation	As built documentation (Datasheets, wiring diagrams, system data)	IEC 62446 - Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection
20	Warranty Management	Claims registration	Affected Equipment, Claim Description, Occurrence Date; Communications between O&M service provider, client and manufacturer/supplier	

E. Annual Maintenance Plan. (Download it from www.solarpowereurope.org)

The utility maintenance plan is conceived for a 3-5 MW site (land-locked site far from seashore). The distributed maintenance plan is conceived for a 50 kW to 1 MW fixed mount rooftop installation with secure access. The maintenance plan applies for both utility and distributed solar plants. For distributed, please take into account the following legend.

a: distributed: only if required; b: distributed: recommendation; c: distributed: not applicable; d: distributed: best practice

The abbreviations describe the importance and frequency of the maintenance tasks related to each component of the solar plant:

D: Daily; M: Monthly; Q: Quarterly; SA: semi-annual; Y: yearly; nYr: every n years; T: Total installation; S: Defined subset; R: random subset.

EQUIPMENT	TASK	IMPORTANCE	FREQUENCY	EXTENT
Modules	Integrity inspection & replacement	Minimum requirement	Y	T
	Thermography inspection	Recommendation	Y	T
	Measurements inspection	if required	Y	S
	Check tightening of clamps	Minimum requirement	Y	R
	Modules cleaning	According to local conditions	(Y)	T
Electrical cabinets and switchboards - Array/string junction box - Generator junction box - AC switchboards - AUX switchboard - General utilities switchboard - Weather station's cabinet - Monitoring system cabinet - Communication cabinet - Security system board - Other cabinets	Sample internal inspection of junction boxes (if possible)	Recommendation	Y	T
	Integrity check & cleaning	Minimum requirement	Y	T
	Documents inspection	if required	Y	T
	Check labelling and identification	Minimum requirement	Y	R
	Electrical protections visual inspection & functional test	Minimum requirement	Y	T
	Check fuse status	Minimum requirement	Y	T
	Check surge protection status (if applicable)	Minimum requirement	Y	T
	Check integrity of cables & state of terminals	Minimum requirement ^a	Y	T
	Sensor functional verification (if applicable)	Recommendation ^a	Y	T
	Measurements inspection	Best practice ^a	Y	T
	Thermographical inspection	Recommendation ^a	Y	T
	Check tightening	Minimum requirement ^a	Y	T
	Lubrication of locks	Minimum requirement ^a	Y	T
	Monitoring operation test (if applicable)	Recommendation ^a	Y	T
	Integrity inspection	Minimum requirement	Y	R
	Check labelling and identification	Minimum requirement	Y	R
	Check cable terminals	Minimum requirement	Y	R
Cables - DC / AC cables - Cables in switchboards, cabinets, inverters	Measurements inspection	Recommendation	Y	R
	Integrity check & cleaning	Minimum requirement	Y	T
	Documents inspection	Best practice	Y	T
	Check labelling and identification	Minimum requirement	Y	R
	Electrical protections visual inspection check correct operations	Minimum requirement	Y	T
	Check fuses	Minimum requirement	Y	T
	Check surge protections	Minimum requirement	Y	T
	Thermographical inspection	Best practice ^b	Y	T
	Sensors functional verification	Minimum requirement	Y	R
Inverters - Central inverters - String inverters				

EQUIPMENT	TASK	IMPORTANCE	FREQUENCY	EXTENT
Inverters - Central inverters - String inverters	Measurements inspection	Minimum requirement	Y	T
	Check parameters	Minimum requirement	Y	T
	Functional test of ventilation system	Minimum requirement	SA	T
	Check batteries	According to manufacturer's recommendations	(Y)	T
	Replace batteries		(3yr)	T
	Replace fans		(5yr)	T
Transformer ^c - Power transformer - AUX transformer	Safety equipment inspection	Minimum requirement	Y	T
	Clean filters	Minimum requirement	SA	T
	Replace filters	Minimum requirement	2yr	T
	Integrity check & cleaning	According to local conditions	(Y)	T
	Check labelling and identification	Minimum requirement	Y	R
	Thermographical inspection	Best practice	Y	T
MV switchgear incl. protection devices ^c	Functional verification of sensors & relays	Minimum requirement	Y	T
	Check parameters	Minimum requirement	Y	T
	Check oil level (if applicable) and max. temperature	Minimum requirement	Y	T
	Check of cooling system (fans) if applicable	Minimum requirement	Y	T
	Check of MV surge discharger devices (if applicable)	Minimum requirement	Y	T
	Integrity check & cleaning	According to local conditions	(Y)	T
	Safety equipment inspection	Minimum requirement	Y	T
	Check labelling and identification	Minimum requirement	Y	R
	Electrical protections visual inspection	Minimum requirement	Y	T
	Thermographical inspection, if possible	Recommendation	Y	T
	Sensors functional verification	Minimum requirement	Y	T
	Measurements inspection	Minimum requirement	Y	T
	Check correct operation	Minimum requirement	Y	T
	Check fuse status	Minimum requirement	Y	T
	Check cables terminals	Minimum requirement	Y	T
	Battery / UPS check	Minimum requirement	Y	
	Mechanical lubrication	According to manufacturer's recommendations and necessity	(5yr)	T
	Replace certain mechanical parts		(5yr)	T
	Battery / UPS replacement		(3yr)	T

EQUIPMENT	TASK	IMPORTANCE	FREQUENCY	EXTENT
MV switchgear incl. protection devices °	Check protection parameters	According to local grid code	(5yr)	T
	Functional check of protection devices		(5yr)	T
Power analyser °	Integrity check & cleaning	Minimum requirement	Y	T
	Check labelling and identification	Minimum requirement	Y	R
	Measurements inspection	Minimum requirement	Y	T
	Software maintenance	Recommendation	Y	T
	Monitoring operation test	Minimum requirement	Y	T
Energy meter	Check parameters	Minimum requirement	Y	T
	Integrity check & cleaning	Minimum requirement	Y	T
	Check labelling and identification	Minimum requirement	Y	R
	Check values and parameters	Recommendation	Y	T
	Check of communication devices (modem, converters) if applicable	Recommendation	Y	T
Power control unit °	Check batteries	According to manufacturer's recommendations	(Y)	T
	Replace batteries		(3yr)	T
	Functional verification		Y	T
	Integrity check & cleaning	Minimum requirement	Y	T
	Integrity check & cleaning	Minimum requirement	Y	T
UPS °	Check batteries	According to manufacturer's recommendations	(Y)	T
	Replace batteries		(3yr)	T
	Functional test of ventilation system (if applicable)	Best practice	Y	T
	Integrity check & cleaning	According to manufacturer's recommendations	(Y)	T
	General maintenance		(Y)	T
Emergency generator (if applicable) °	Check correct operation		(Y)	T
	Replacement of filters		(5yr)	T
	Integrity check & cleaning	Minimum requirement	Y	T
	Check correct operation	Minimum requirement	Y	T
	Check conformity to local security standards	Minimum requirement	3yr	T
Lights and electric sockets	Integrity check & cleaning	According to manufacturer's recommendations	(Y)	T
	Functional verification		(Y)	T
	Change of air filters		(Y)	T

EQUIPMENT	TASK	IMPORTANCE	FREQUENCY	EXTENT
Water supply system (if applicable)	Integrity inspection	If applicable	Y	T
Fire detection central (if applicable)	Integrity check & cleaning	According to manufacturer's recommendations and local requirements	(Y)	T
	Check correct operation		(Y)	T
	Battery inspection		(Y)	T
	Sensors functional verification		(Y)	T
Lightning protection (if applicable)	Cleaning of cameras & sensors	Minimum requirement	(Y)	T
	Integrity inspection		Y	R
	Integrity inspection		Y	T
Fences and gates	Lubrication of locks	Minimum requirement	SA	T
Vegetation	Vegetation clearing	According to local conditions	(Q)	T
Paths	Integrity inspection	Best practice	Y	T
Drainage System	Vegetation clearing	Recommendation	Y	T
	General cleaning	Minimum requirement	SA	T
Manholes	Integrity inspection	Best practice	Y	T
Buildings	Integrity check & cleaning	According to local requirements	(Y)	T
	Lubrication of locks	Minimum requirement	SA	T
	Documents inspection	According to local requirements	(Y)	T
	Check fire extinguishers		(Y)	T
Safety equipment	Check earthing		(3yr)	T
	Integrity check & cleaning	Minimum requirement	Y	T
	Check correct operation	Minimum requirement	Y	T
PV support structure	Integrity inspection	Minimum requirement	Y	R
	Check tightening	Minimum requirement	Y	R
	Check potential equalization	Minimum requirement	2yr	T
Tracker system °	Integrity check & cleaning	Minimum requirement	Y	T
	Check correct operation	According to manufacturer's recommendations	(Y)	T
	Check tightening		(Y)	R
	General maintenance		(Y)	T
	Mechanical lubrication		SA	T

EQUIPMENT	TASK	IMPORTANCE	FREQUENCY	EXTENT
Weather station ^d	Integrity check & cleaning	According to manufacturer's recommendations	(Y)	T
	Functional test of sensors		(Y)	T
	Check correct operation		(Y)	T
	Check batteries (if applicable)		(Y)	T
	Monitoring operation test		(Y)	T
Irradiation sensors	Integrity check & cleaning	According to manufacturer's recommendations and local requirements	Q	T
	Calibration		2yr	T
	Monitoring operational test		Y	T
Communication Board	Functional communications check	Minimum requirement	D	T
Intrusion detection and verification system ^e	Integrity check & cleaning	Minimum requirement	Y	T
	Functional verification of intrusion detection	According to manufacturer's recommendations	(Y)	T
	Functional verification of alarming		Y	T
	Functional verification of cameras		M	T
	Specific maintenance		Y	T
Stock of spare parts ^d	Inventory of stock	Minimum requirement	Y	T
	Visual inspection of stock conditions	Minimum requirement	Y	T
	Stock replenishment	Minimum requirement	M	T