

Operation & Maintenance

Best Practices Guidelines / **Version 2.0**

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FOREWORD

Welcome to the second edition of SolarPower Europe's Operation and Maintenance (O&M) Best Practices Guidelines. Building on the successful first edition published in June 2016, the second version incorporates even more industry experience, delivering a mature document and a forward-looking vision for the O&M market.

Europe is the continent with the largest and oldest fleet of solar PV plants, which made stakeholders realise that they needed proper "health care" for the assets to meet performance expectations. Today, O&M has become a standalone segment in the solar value chain with many companies specialising exclusively in solar O&M. Yet according to a survey conducted by SolarPower Europe, two out of three solar professionals say that there are 'very large' or 'significant' discrepancies between the quality of services provided by different O&M contractors. Reasons mentioned by the respondents were increasing price pressure, lack of standardisation and minimum requirements, poorly qualified and non-specialist staff and insufficient use of digital data analytics.

To address these challenges, SolarPower Europe launched the O&M Task Force in 2015, which, led by First Solar, developed the first edition of the industry-led O&M Best Practices Guidelines, published in June 2016. Alectris took over the Task Force's leadership in January 2017 with three core objectives: First, to further enhance the Best Practices Guidelines. Second, to work on a global O&M template contract under the Global Solar Energy Standardisation Initiative – jointly led by the Terrawatt Initiative (TWI) and the International Renewable Energy Agency (IRENA) and supported by SolarPower Europe and the Global Solar Council. Third, to work on a dissemination strategy for the Task Force's results. The Task Force is doing this with the involvement of more than 60 experts from more than 30 companies, including nearly 30 new experts and 15 companies who have joined the O&M Task Force since January 2017.

The present second edition of the O&M Best Practices Guidelines wishes to take the success of the first edition even further. The new Guidelines incorporate extended industry experience and expert input, not only O&M service providers but also other related stakeholders such as Asset Owners, Asset Managers and monitoring solutions providers, covering a significant share of the EU O&M market. SolarPower Europe has also collaborated with other European task forces including the Solar Trade Association's O&M working group who have made a specific contribution on Health & Safety. Over the course of the past twelve months, existing chapters of the first version have been extensively discussed, enhanced and refined in the O&M Task Force. This new edition features a dedicated chapter on technical asset management and covers new topics such as cybersecurity. The chapter on 'Key Performance Indicators' (KPIs) has adopted a new terminology to better differentiate between different types of KPIs and contractual obligations. The chapter on 'Contractual Framework' has been aligned with the global O&M template contract developed by SolarPower Europe, together with IRENA and Terrawatt Initiative, as part of the Global Solar Energy Standardisation Initiative.

The new Version 2.0 of the O&M Best Practices Guidelines proposes a mature and forward-looking vision for the O&M market, and SolarPower Europe will strive to bring best practices and standardisation even further for solar O&M.

If you want to be part of this endeavour, join our O&M Task Force!

Enjoy reading this report!



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Project Information: The SolarPower Europe O&M Task Force officially started its work in April 2015 and continues with frequent exchanges and meetings. The first version of the O&M Best Practices Guidelines was published in June 2016 and the second updated version was published in December 2017. The SolarPower Europe O&M Best Practices Guidelines reflect the experience and views of a considerable share of the European O&M industry today. There has been no external funding or sponsoring for this project.

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Please note that this Version 2.0 may be subject to future changes, updates and improvements.

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AC	Alternating Current
AMP	Annual Maintenance Plan
AMR	Automatic meter reading
AMS	Annual Maintenance Schedule
API	Application Programming Interface
CCTV	Closed Circuit Television
CMMS	Computerised maintenance management system
COD	Commercial Operation Date
CSMS	Cybersecurity management system
DC	Direct Current
DMS	Document management system
DOR	Division of responsibility
DSCR	Debt Service Coverage Ratio
DSL	Digital Subscriber Line
EH&S	Environment, Health and Safety
EPC	Engineering, procurement, construction
EPI	Energy Performance Index
FAC	Final Acceptance Certificate
FIT	Feed-in tariff
FTP	File Transfer Protocol
GPRS	General Packet Radio Service
H&S	Health and Safety
HV	High Voltage
IGBT	Insulated-Gate Bipolar Transistors
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
KPI	Key Performance Indicator
kW	kilowatt
kWh	kilowatt-hour
kWp	kilowatt-peak
LAN	Local Area Network
LCOE	Levelised Cost Of Electricity
LV	Low Voltage
MAE	Mean absolute error
MIT	Minimum Irradiance Threshold
MPPT	Maximum Power Point Tracking
MV	Medium Voltage
MW	Megawatt
O&M	Operation and Maintenance
OEM	Original equipment manufacturer
OS	Operating system
PAC	Provisional acceptance certificate
POA	Plane of array
PPA	Power purchase agreement
PPE	Personal protective equipment
PR	Performance Ratio
PV	Photovoltaic
RMSE	Root mean square error
ROI	Return on investment
RPAS	Remotely Piloted Aircraft System (drone)
SCADA	Supervisory Control And Data Acquisition
SLA	Service-level agreement
SPV	Special Purpose Vehicle
STC	Standard Test Conditions (1000 W/m², 25°C)
TF	Task force

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EXECUTIVE SUMMARY

Operation and Maintenance (O&M) has become a standalone segment within the solar industry and it is it is widely acknowledged by all stakeholders that high-quality O&M services mitigate potential risks, improve the Levelised Cost of Electricity (LCOE) and Power Purchase Agreement (PPA) prices, and positively impact the return on investment (ROI). Responding to the discrepancies that exist in today's solar O&M market, the SolarPower Europe O&M Best Practices Guidelines make it possible for all to benefit from the experience of leading experts in the sector and increase the level of quality and consistency in O&M. These Guidelines are meant for O&M Contractors as well as investors, financiers, Asset Owners, Asset Managers, monitoring tool providers, technical consultants and all interested stakeholders in Europe and beyond.

This document begins by contextualising O&M by explaining the roles and responsibilities of various stakeholders such as the Asset Manager, the Operation service provider and the Maintenance provider and by providing an overview of technical and contractual terms to achieve a common understanding of the subject. It then walks the reader through the different components of O&M, classifying requirements into "minimum requirements", "best practices" and "recommendations".

Environment, Health & Safety

Environmental problems are normally avoidable through proper plant design and maintenance, but where issues do occur the O&M Contractor must detect them and respond promptly. In many situations, solar plants offer an opportunity to provide opportunities for agriculture and a valuable natural habitat for plants and animals alongside the primary purpose of generation of electricity. Solar plants are electricity generating power stations and have significant hazards present which can result in injury or death. Risks should be reduced through proper hazard identification, careful planning of works, briefing of procedures to be followed, documented and regular inspection and maintenance.

Personnel & training

It is important that all O&M personnel have the relevant qualifications to perform the works in a safe, responsible and accountable manner. These Guidelines contain a skills' matrix template that helps to record skills and identify gaps.

Technical Asset Management

In many cases, the O&M Contractor assumes some Technical Asset Management tasks such as reporting on Key Performance Indicators (KPIs) to the Asset Owner. However, in cases where the Technical Asset Manager and the O&M Contractor are separate entities, a close coordination and information sharing between the two entities is indispensable. The periodic reports sent to the Asset Owner should include information on raw data measurements (such as energy produced), PV power plant KPIs (such as Performance Ratio or Availability), O&M Contractor KPIs (such as the Response Time), Equipment KPIs and Incidents. Technical Asset Management also includes ensuring that the operation of the PV plant complies with national and local regulations and contracts.

Power plant operation

Operations is about remote monitoring, supervision and control of the PV power plant. It also involves liaising with or coordination of maintenance activities. A proper PV plant documentation management system is crucial for Operations. A list of documents that should be included in the as-built documentation set accompanying the solar PV plant (such as PV modules' datasheets), as well as a list of examples of input records that should be included in the record control (such as alarms descriptions) can be found in the Annex of these Guidelines. Based on the data and analyses gained through monitoring and supervision, the O&M Contractor should always strive to improve PV power plant performance. As in most countries there are strict legal requirements for security services, PV power plant security should be ensured by specialised security service providers.

Power plant maintenance

Maintenance is usually carried out on-site by specialised technicians or subcontractors, according to the Operations team's analyses. A core element of maintenance services, Preventive Maintenance involves regular visual and physical inspections, as well as verification activities necessary to comply with the operating manuals. The Annual Maintenance Plan (*see an example in the Annex*) includes a list of inspections that should be performed regularly. Corrective Maintenance covers activities aimed at restoring a faulty PV plant, equipment or component to a status where it can perform the required function. Extraordinary Maintenance actions, usually not covered by the O&M fixed fee, can be necessary after major unpredictable events in the plant site that require substantial repair works. Additional maintenance services include tasks such as module cleaning and vegetation control.

Spare Parts Management

Spare Parts Management is an inherent and substantial part of O&M aimed at ensuring that spare parts are available in a timely manner for Corrective Maintenance in order to minimise the downtime of a solar PV plant. The spare parts should be owned by the Asset Owner while normally maintenance, storage and replenishment should be the responsibility of the O&M Contractor. It is considered a best practice not to include the cost of replenishment of spare parts in the O&M fixed fee. These Guidelines also include a minimum list of spare parts that are considered essential.

Data and monitoring requirements

The purpose of the monitoring system is to allow supervision of the energy flow in a PV power plant. Requirements for an effective monitoring include dataloggers capable of collecting data (such as energy generated, irradiance, module temperature etc) of all relevant components (such as inverters, energy meters, pyranometers, temperature sensors) and storing at least one month of data with a recording granularity of up to 15 minutes; as well as a reliable Monitoring Portal (interface) for the visualisation of the collected data and the calculation of KPIs. As best practice, the monitoring system should ensure open data accessibility, in order to enable easy transition between monitoring platforms. As remotely monitored and controlled systems, PV plants have exposure to cybersecurity risks, it is therefore vital that installations undertake a cyber security analysis and implement a cybersecurity management system.

Key Performance Indicators

Important KPIs include PV power plant KPIs, directly reflecting the performance of the PV power plant, and O&M Contractor KPIs, assessing the performance of the O&M service provided. PV power plant KPIs include important indicators such as the Performance Ratio (PR), which is the energy generated divided by the energy obtainable under ideal conditions expressed as a percentage; and Uptime/Availability, parameters that represent, as a percentage, the time during which the plant is operating over the total possible time it is able to operate. While Uptime reflects all downtimes regardless of cause, Availability involves certain exclusion factors to account for downtimes not attributable to the O&M Contractor (such as force majeure), a difference important for contractual purposes. O&M Contractor KPIs include Acknowledgement Time (the time between the alarm and the acknowledgement), Intervention Time (the time between acknowledgement and reaching the plant by a technician) and Resolution Time (the time to resolve the fault starting from the moment of reaching the PV plant). Acknowledgement Time plus Intervention Time are called Response Time, an indicator used for contractual guarantees.

Contractual framework

Although some O&M Contractors still provide Performance Ratio guarantees in some cases, recent developments including the recommendations of the Global Solar Energy Standardisation Initiative show that only using Availability and Response Time guarantees has several advantages. A best practice is a minimum guaranteed Availability of 98% over a year, with Availability guarantees translated into Bonus Schemes and Liquidated Damages. When setting Response Time guarantees, it is recommended to differentiate between hours and periods with high and low irradiance levels as well as fault classes, i.e. the (potential) power loss. As a best practice, we recommend using the O&M template contract developed as part of the Global Solar Energy Standardisation Initiative (SESI), a joint initiative of the Terrawatt Initiative, the International Renewable Energy Agency, SolarPower Europe and the Global Solar Council. The SESI contract template is set to be launched in 2018.



1 INTRODUCTION

1.1. Rationale, aim and scope

A professional Operation & Maintenance (O&M) service package ensures that the photovoltaic system will maintain high levels of technical and consequently economic performance over its lifetime. Currently, it is widely acknowledged by all stakeholders that high quality O&M services mitigate the potential risks, improve the levelised cost of electricity (LCOE) and Power Purchase Agreement (PPA) prices and positively impact the return on investment (ROI). This can be highlighted if one considers the lifecycle of a PV project which can be broken down into the 4 phases below. The O&M phase is by far the longest phase.

- Development (typically 1-3 years)
- Construction (a few months)
- **Operation & Maintenance (typically 20-35 years)**
- Dismantling or repowering (a few months)

Therefore, increasing the quality of O&M services is important and, in contrast, neglecting O&M is risky. The PV industry – a "young" industry that evolves also in the services segment – offers a wide range of practices and approaches. Although this is partly logical, reflecting the specificities of each system, topologies, installation sites and country requirements, there is a confusion or lack of clarity and knowledge of many Asset Owners and funding authorities (investors or/and banks) of what the minimum requirements should be. In cases, especially in the past where feed-in tariffs were very high and favourable, there was an obvious lack of risk perception in combination with an underestimated performance metrics definition which hindered the proof of value of a professional and high-quality service provision.

Existing standardisation still does not fill in the gaps, or clarify the requirements and their implementation. Although in Maintenance, there are a number of technical international standards that can be followed, in Operations, which also covers planning, scheduling and administrative related tasks, there are many shortcomings. Therefore, it is crucial to develop and disseminate best practices to optimise the Operations and thus energy production, power plant management and resulting benefits. Best practices that set the quality bar high will enhance investors' understanding and thus confidence.

With Version 2.0 O&M Best Practices Guidelines, SolarPower Europe makes the next step towards this objective. The value proposition of this report is that it is industry-led, containing the knowledge and the experience of well-established and leading companies in the field of O&M service provision, project development and construction (EPC), asset management, utilities, manufacturers and monitoring tool providers.

The scope of the current work includes the utility scale segment and more specifically, systems above 1MW. The geographical focus is Europe. It provides the high-level requirements that can be applied in all countries around Europe (and beyond). Specific national considerations such as legal requirements are not included and should therefore be considered separately if these Guidelines are to be used in specific countries.

The content covers technical and non-technical requirements, classifying them when possible into:

1. minimum requirements, below which the O&M service is considered as poor or insufficient, and which form a minimum quality threshold for a professional and bankable service provider;
2. best practices, which are methods considered state-of-the-art, producing optimal results by balancing the technical as well as the economic side;
3. recommendations, which can add to the quality of the service, but whose implementation depends on the considerations of the Asset Owner or Asset Manager, such as the available budget.

As for the terminology used in this document to differentiate between these three categories, verbs such as "*should*" indicate minimum requirements, unless specified explicitly otherwise, like in: "*should, as a best practice*".

1.2. How to benefit from this document

This report includes the main and important considerations for a successful and professional O&M service provision. Although it has not been tailored for each stakeholder, its use is similar for all: understand the mandatory requirements and the necessity of professional O&M and incorporate the recommendations accordingly into the service package. Any of the directly relevant stakeholders (*see the following section*) can benefit from this work, tailor it to their needs without lowering the bar and know what to ask for, offer or expect.

Although the focus is European, most of the content can be used in other regions around the world. The requirements described in the maintenance part apply without changes in regions with conditions similar to Europe and a moderate climate and additional requirements or modifications can easily be made for other regions with unique characteristics. With regards to the operations and technical asset management part, the requirements apply to PV assets regardless of their location.

1.3. Stakeholders and roles

Usually multiple stakeholders interact in the O&M phase and therefore it is important to clarify as much as possible the different roles and responsibilities. These can be abstracted to the following basic roles:

Asset Owner. The stakeholder who contributes to financing of construction and operation of the PV power plant is normally the investor (or a group of investors), who can be classified as private individuals, financing investors or investment funds and Independent Power Producers (IPPs) or Utilities. Assets are generally owned by "Special Purpose Vehicles" (SPV), i.e. limited liability companies, specifically incorporated for building, owning and operating one or more PV plants.

Lender. The lender or debt provider (financing bank) is not considered as an "Asset Owner" even if the loans are backed up by securities (collateral). In principal, the interests and performance expectations are different between the investor (equity provider) and the lender who normally measures the risk based on the debt service coverage ratio (DSCR). The role of the lender is becoming more and more "smart" and less passive, with enhanced considerations and involvement regarding the requirements for the debt provision.

Asset Manager. Asset management aims at ensuring optimal profitability of the PV power plant (or a portfolio of plants) by supervising energy sales, energy production, and O&M activities. It also ensures the fulfilment of all the administrative, fiscal, insurance and financial obligations of the SPVs. Therefore, this role has a financial and technical aspect. Asset Managers report to Asset Owners. In some cases, in particular where SPVs belong to large Asset owners such as utilities or large IPPs, the Asset management activity is done in-house. Today most O&M Contractors assume some (technical) Asset Management responsibilities such as performance reporting to the Asset Owner.

O&M Contractor. The entity that is in charge of O&M activities as defined in the O&M contract. In some cases, this role can be subdivided into:

- Technical Asset Manager, serving as an interface between the remaining O&M activities and the Asset Owner and in charge of high-level services such as performance reporting to the Asset Owner, contracts management, invoicing and warranty management.

- **Operations service provider** in charge of monitoring, supervision and control of the PV power plant, coordination of maintenance activities.
- **Maintenance service** provider carrying out maintenance activities.

The three roles are often assumed by a single entity through a full-service O&M contract. A comprehensive set of O&M activities (technical and non-technical) is presented in this report.

Technical Advisors / Engineers. These are individuals or teams of experts that provide specialised services (e.g. detailed information, advice, technical consulting etc). Their role is rather important since they ensure that procedures and practices are robust and of high quality – according to standards and best practices – to maintain high performance levels of the PV plant. Technical advisors can represent different stakeholders (e.g. investors and lenders).

Specialised suppliers. Such suppliers could be of specialised services (e.g. technical consulting) or hardware (e.g. electricity generating components, security system etc).

Authorities. These can be local (e.g. the municipality), regional (e.g. the provincial or regional authorities supervising environmental constraints), national (e.g. the national grid operator), or international (e.g. the authors of a European grid code).

Off-taker. The entity who pays for the produced electricity. This role is still evolving and is often subdivided according to national renewable power support schemes:

- The state or national grid operator / electricity seller(s), or specific authorities for renewable energy (such as GSE in Italy) in a feed-in tariff (FIT) scheme.
- Energy traders or direct sellers in a direct marketing scheme.
- End customers in schemes that underline autonomy in energy supply.

The aforementioned stakeholders and roles should support the provision of the necessary services and transfer the guidelines of this report to real life situations. For example, in cases where either one stakeholder/party may take over several roles and responsibilities or one role might be represented by several parties:

- An investor may take asset management responsibilities
- An Asset Manager may take over a more active role and intervene in operations
- An Asset Manager may even take over full O&M
- An O&M Contractor's role may be subdivided or may also include some asset management activities such as specified below (e.g. reporting, electricity sale, insurance, fiscal registrations, etc)
- The end customer (or electricity buyer) may at the same time be the Asset Owner, Asset Manager, and O&M Contractor (e.g. a PV power plant on an industrial site to cover its own energy needs)

Figure 1 on the following page attempts to classify and distribute the responsibilities among the different stakeholders and, in particular, among the Asset Manager (Asset management), the O&M Contractor (Operation & Maintenance) and the EPC Contractor (Engineering, Procurement, Construction). This figure is redesigned and based on a figure of GTM (2013).

In general, the O&M Contractor will have a more technical role (energy output optimisation) and the Asset Manager will undertake more commercial and administrative responsibilities (financial optimisation). The technical aspects of Asset Management are called Technical Asset Management, a role that is often assumed by the O&M Contractor. As opposed to the first version of the Best Practices Guidelines, this version handles Technical Asset Management as part of the core roles that can be provided by the O&M Contractor and thus dedicates a standalone Chapter to Technical Asset Management.

FIGURE 1 ROLES AND RESPONSIBILITIES BY DIFFERENT STAKEHOLDERS IN THE FIELD OF O&M



NOTE: THE RESPONSIBILITIES OF THE ASSET MANAGER AND THE O&M CONTRACTOR OVERLAP SOMETIMES, AND TECHNICAL ASSET MANAGEMENT CAN BE ASSUMEDBY EITHER THE O&M CONTRACTOR OR THE ASSET MANAGER.

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This grey zone of responsibilities makes it difficult to standardise properly the responsibilities of each stakeholder. With this perspective, it is important that contracts define as precisely as possible scope, rights and obligations of each party and the general work order management.

However, all stakeholders should have a good understanding of both technical and financial aspects in order to ensure a successful and impactful implementation of services. That will require Asset Managers to have technical skills in-house for a meaningful supervision and proper assessment of the technical solutions, and O&M Contractors to have the ability to cost-assess and prioritise their operational decisions and maintenance services.



2 DEFINITIONS

This section introduces a basic set of definitions of important terms that are widely used in the O&M field (contracts) and is necessary for all different stakeholders to have a common understanding. In general, there are standards in place that explain some of these terms, however, it is still difficult in practice to agree on the boundaries of those terms and what exactly is expected under these terms or services (e.g. the different types of maintenances or operational tasks).

Indeed, it is more challenging for terms in the Operational field since those are less technical and not standardised as in the case for Maintenance. The chapter provides a short list (alphabetically ordered) which is not exhaustive, but reflects the different sections of this document. For the definitions relating to Maintenance the standard EN 13306 (“Maintenance terminology”) was used as a basis.

Additional Services	Actions and/or works performed, managed or overseen by the O&M Contractor, which are not (but can be if agreed) part of the regular services and normally charged “as-you-go”, e.g. ground maintenance, module cleaning, security services etc. Some of the Additional Services can be found as a part of the Preventive Maintenance, depending on the contractual agreement.
Contract management	Activities related to the proper fulfilment of O&M contract obligations such as reporting, billing, contract amendments, regulator interaction etc.
Contractual Framework	An agreement with specific terms between the Asset Owner and the O&M Contractor. This agreement defines in detail the O&M services, both remote operations services and local maintenance activities, the management and interfaces of those services, as well as the responsibilities of each party. Liquidated damages and bonus schemes are also part of the contractual commitments.
Control Room Services/Operations Centre Services	Comprehensive actions like PV plant monitoring, supervision, remote controls, management of maintenance activities, interaction with grid operators, regulators, Asset Managers and Asset Owners, and the preparation and provision of regular reporting performed by experienced and qualified staff in a control room during operational hours for 365 days/year.

Corrective maintenance	Actions and/or techniques (immediate or deferred) taken to correct failures, breakdowns, malfunctions, anomalies or damages detected during inspections, or through monitoring, alarming, or reporting or any other source. The actions are desired to restore the PV system back into regular and required operation mode.
Data & monitoring requirements	Hardware and software, technical and functional specifications to collect, transmit and store production, performance and environmental data for plant management.
Documentation management system	A management system that records, manages and stores documents required for O&M, such as technical plant and equipment documentation and drawings, maintenance manuals, photos and reports, including the various versions that are being created by different users, reviews and approvals. Documentation management system also defines a proper format and use (information exchange).
Environment, Health & Safety (EH&S)	Environment, Health and Safety indicates the activities performed to ensure environmental protection, occupational health and safety at work and on site, applicable to staff and visitors according to the national applicable laws and regulations.
Extraordinary Maintenance	Actions and/or works performed in case of major unpredictable faults, such as serial defects, force majeure events etc, that are generally considered outside of the ordinary course of business.
Grid code compliance requirements	Equipment, procedures, actions and activities required by the respective grid operator(s) in order to comply with grid safety, power quality and operating specifications.
Insurance claims	Customer's activities required to claim a reimbursement based on specific insurance policy terms
Key Performance Indicator (KPI)	A technical parameter that helps the stakeholders to evaluate the successful operation of a PV plant and/or the success of the O&M Contractor's activities.
Management of change	Management of change defines the way to handle necessary adjustments of the design of a PV power plant after the Commercial Operation Date. Changes require a close cooperation between the plant owner and the O&M Contractor.
Performance analysis & improvement	Measurements, calculations, trending, comparisons, inspections etc performed in order to evaluate the PV plant, segments and/or single component performance, site conditions, equipment behaviour etc, and to provide reports and assessment studies to interested parties (customer, public authority, etc).
Personnel & training	Operators, technicians, engineers and managers employed for the execution of the O&M activities and training plans/programmes to train them on relevant PV plant related aspects and to keep them continuously updated on their respective roles.
Power plant controls	Actions required by the grid operator, for controlling active and/or reactive power being fed into the grid, other power quality factors that are subject to adjustments and/or (emergency) shut down (if applicable).
Power plant monitoring	Overall monitoring of the functioning, energy generation and reference data of the PV plant and its components, which is performed through real-time (web based) monitoring software. The monitoring operates 24h/365d and is fed by in-plant data-logging systems that collect data from different plants as well as by irradiation and temperature measurements from particular sensors and other sources such as meteorological information (data acquisition 24h/365d).

Power plant supervision	The activity to supervise and analyse data provided by the monitoring system which is performed by experienced human resources during daylight hours and managed by one or more control rooms (365 days/year). The reception and qualification of the alarms from the monitoring tool is also considered to be part of the supervision.
Predictive Maintenance	Actions and/or techniques that are performed to help assess the condition of a PV system and its components, predict/forecast and recommend when maintenance actions should be performed. The prediction is derived from the analysis and evaluation of significant parameters of the component (e.g. parameters related to degradation). Monitoring systems and expert knowledge are used to identify the appropriate actions based on a cost benefit analysis.
Preventive Maintenance	Actions and/or testing and/or measurements to ensure optimal operating conditions of equipment and of the entire PV plant and to prevent defects and failures. Those take place periodically and according to a specific maintenance-plan and maintenance schedules.
Power Generation Forecasting	Adoption of forecasting tools calculating expected power production for a certain timeframe from weather forecasts in order to supply the expected power production to owner, grid operator, energy traders or others. This is normally country and plant dependent.
Regulatory compliance	Compliance to any law, statute, directive, bylaw, regulation, rule, order, delegated legislation or subordinate legislation directly applicable in the country where the service is provided, as well as to any mandatory guidelines and measures issued by a utility and any other competent public authority.
Reporting & other deliverables	Deliverables produced periodically, according to requirements detailed in the O&M agreement or following best market practices, including PV plant performance, Key Performance Indicators, maintenance activities and work orders performed, alarm handling, equipment status, warranty handling activities and spare parts tracking and any other analysis performed in compliance with the O&M contract requirements.
Security	Actions, procedures, equipment and/or techniques that are adopted on site and remotely in order to protect the plant from theft, vandalism, fire and unauthorised entry. Security services are to be provided be specialised security service providers.
Spare Parts Management	Activities that ensure availability of the right amount and type of components, equipment, parts etc, either on site or in warehouses or in manufacturers' consignment stocks, for prompt replacement in case of failure and/or to meet guarantees under O&M contracts.
Warranty management	Warranty management usually aggregates activities of a diverse nature which are linked to areas such as supply of equipment and services, and project construction. All these responsibilities (warranties) are usually materialised with the issue of the Provisional Acceptance Certificate (PAC) by the EPC. Warranty Management is the activity that manages these warranties with the objective of reducing the costs and response times after warranty claims for repair or replacement of certain PV system components (under the warranty of the EPC and/or the components manufacturer).



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3

ENVIRONMENT, HEALTH & SAFETY

The Asset Owner has the ultimate legal and moral responsibility to ensure the health and safety of people in and around the solar plant and for the protection of the environment around it. The practical implementation is normally subcontracted to the O&M Contractor.

Environment. Renewable energies are popular because of their low environmental impact and it is important that solar plants are operated and maintained to minimise any adverse effects. Environmental problems can normally be avoided through proper plant design and maintenance – for example, bunds and regular inspection of HV transformers will reduce the chances of significant oil leaks – but where issues do occur the O&M Contractor must detect them and respond promptly. Beyond the environmental damage there may be financial or legal penalties for the owner of the plant.

Other aspects that need to be taken into account, as best practice, are recycling of broken panels and electric waste so that glass, aluminium and semiconductor materials can be recovered and reused. In areas with water scarcity, water use for module cleaning should be minimised.

In many situations, solar plants offer an opportunity, where managed sympathetically, to provide opportunities for agriculture and a valuable natural habitat for plants and animals alongside the primary purpose of generation of electricity. A well thought out environmental management plan can help promote the development of natural habitat, as well as reduce the overall maintenance costs of managing the grounds of the plant. It can also ensure the satisfaction of any legal requirements to protect or maintain the habitat of the site.

Health and Safety. Managing the risks posed by the solar plant to the health and safety of people, both on and around the plant, is a primary concern of all stakeholders. Solar plants are electricity generating power stations and have significant hazards present which can result in permanent injury or death. Risks can be reduced through proper hazard identification, careful planning of works, briefing of procedures to be followed regular and well documented inspection and maintenance (see also section *6.10. Power plant security*).

The dangers of electricity are well known and can be effectively managed through properly controlled access and supervision by the O&M Contractor.

Any person coming on to a solar farm should expect some form of induction to ensure they are briefed on any hazards and risks. Staff working on electrical equipment must be appropriately trained, experienced and supervised, but it is also key that others working around the equipment - for example panel cleaners - are equally aware of the potential risks and have safe methods of working around HV and LV electricity.

Hazardous areas and equipment should carry appropriate markings to warn personnel of possible hazards and wiring sequence. Such markings should be clear and evident to all personnel and third parties (and intruders) entering the plant premises.

As well as the inherent dangers of a typical solar plant, every site will have its own set of individual hazards which must be considered when working on the plant. An up-to-date plan of hazards is important for the O&M Contractor to use to manage his own staff and to provide third party contractors with adequate information. It is usually the case that the O&M Contractor holds the authority and responsibility to review and, where necessary, reject works taking place on the plant. Failure to carry this out properly has important consequences to general safety.

Besides workers on the solar plant, it is not unusual for other parties to require access to it. This may be the Asset Owner, or their representative, the landlord of the land, or in some situations members of the public. It is important that the plant access control and security system keeps people away from areas of danger and that they are appropriately supervised and inducted as necessary.

The Asset Owner is ultimately responsible for the compliance of H&S regulations within the site/plant. The Asset Owner must make sure that, at all times, the installation and all equipment meet the relevant legislations of the country and also, that all contractors, workers and visitors respect the H&S Legislation by strictly following the established procedures, including the use of established personal protective equipment (PPE).

At the same time, the O&M Contractor should prepare and operate its own safety management systems to be agreed with the Asset Owner taking into account site rules and the Works in relation to health and safety and perceived hazards. The O&M Contractor should ensure that it complies, and that all subcontractors comply with the H&S legislation.

The Asset Owner will have to require from the O&M Contractor to represent, warrant and undertake to the Owner that it has the competence and that it will allocate adequate resources to perform the duties of the principal contractor pursuant to specific national regulations for health and safety.

Before starting any activity on site the Asset Owner will deliver risk assessment and method statements to the O&M Contractor who will provide a complete list of personnel Training Certifications and appoint a H&S coordinator. During the whole duration of the contract the O&M Contractor will keep the H&S file of each site updated.

The O&M Contractor must have his personnel trained in full accordance with respective national legal and professional requirements, that generally result in specific certification to be obtained, for example in order to be allowed to work in MV and/or HV electrical plants. Within Europe, referral to European Standards is not sufficient (examples of standards used today are ISO 14001, OHSAS 18001 etc).

In order to achieve a safe working environment, all work must be planned in advance, normally written plans are required.

Risk assessments need to be produced which detail all of the hazards present and the steps to be taken to mitigate them.

The following dangers are likely to exist on most solar plants and must be considered when listing hazards in order to identify risks. The severity of any injuries caused are commonly exacerbated by the terrain and remoteness often found on solar plants.

1. **Medical problems**. It is critical that all personnel engaged in work on solar farms have considered and communicated any pre-existing medical problems and any additional measures that may be required to deal with them.
2. **Slips, trips and falls**. The terrain, obstacles and equipment installed on a solar farm provide plenty of opportunities for slips, trips and falls both at ground level and whilst on structures or ladders.

3. **Collisions.** Collisions can occur between personnel, machinery/vehicles and structures. The large areas covered by solar farms often necessitate the use of vehicles and machinery which when combined with the generally quiet nature of an operational solar farm can lead to a lack of attention. General risks such as difficult terrain, reversing without a banksman and walking into the structure supporting the solar panels require special attention.
4. **Strains and sprains**. Lifting heavy equipment, often in awkward spaces or from uneven ground, presents increased risk of simple strains or longer term skeletal injuries.
5. **Electrocution.** Operational solar farms whether energised or not present a significant risk of electrocution to personnel. This risk is exacerbated by the nature and voltage of the electricity on site and the impossibility of total isolation. Staff engaged in electrical work obviously suffer the greatest risk but everybody on site is at risk from step potential and other forms of electrocution in the event of a fault. Specific training needs to be given to all those entering a solar farm as to how to safely deal with the effects of electrocution.
6. **Fire.** Several sources of combustion exist on a solar farm, the most common being electrical fire others including combustible materials, flammable liquids, and grass fires. Safe exit routes need to be identified and procedures fully communicated. All personnel need to be fully aware of what to do to both avoid the risk of fire and what to do in the event of a fire.
7. **Mud and water.** Many solar farms have water travelling through them such as streams and rivers, some have standing water, and some are floating arrays. Mud is a very common risk particularly in winter as low-grade farmland is often used for solar farms. Mud and water present problems for access as well as electrical danger.
8. **Mechanical injury.** Hand-tools, power tools, machinery as well as such mechanisms as unsecured doors can present a risk of mechanical injury on site.
9. **Weather**. The weather presents a variety of hazards, the most significant of which is the risk of lightning strike during an electrical storm. Due to the metal structures installed on a solar farm an electrical storm is more likely to strike the solar array than surrounding countryside. A solar farm MUST be vacated for the duration of any electrical storm. Working in cold and rainy weather can cause fatigue and injury just as working in hot sunny weather presents the risk of dehydration, sunburn, and sun stroke.
10. **Wildlife and livestock.** The renewable energy industry is proud to provide habitats for wildlife and livestock alongside the generation of electricity. Some wildlife however presents dangers. There are plants in different regions which can present significant risk, some only when cut during vegetation management. Animals such as rodents, snakes and other wildlife as well as livestock can present significant risks. The nature of these risks will vary from place to place and personnel need to be aware of what to do in the event of bites or stings.

Everyone entering a solar farm, for whatever reason, should have been trained in the dangers present on solar farms and be trained for the individual task that they will be performed. They should have all of the PPE and tools necessary to carry out the work in the safest way possible. The work should be planned in advance and everyone concerned should have a common understanding of all aspects related to the safe execution of their task. Different countries will mandate written and hard copy paperwork to meet legislation, but best practice is to exceed the minimum requirements and to embrace the spirit of all relevant legislation.

Best practice in H&S sees the ongoing delivery of training and sharing of lessons learned and work methods. By increasing the skills of persons involved in the industry, we can make the industry both safer and more productive.



4 PERSONNEL & TRAINING

It is of critical importance that all Operation and Maintenance Personnel have the relevant qualifications to perform the works in a safe, responsible and accountable manner. It is difficult to define exactly and in general not advisable to be rigid with the profile of the employees suitable to carry out the work and meet the necessary requirements. Indeed, the necessary knowledge and experience can be gained through different career developments and by different engagements.

The solar industry benefits from a wide range of skills and experience. Team members with a range of electrical, mechanical, financial, business and communications skills are required to handle different tasks and all of them strengthen the positive impact of the service provision.

Everyone who enters a solar plant needs to be trained in the dangers present in addition to their individual skills and experience required for the tasks that they normally perform. Awareness of the necessary health and safety regulations is a must.

As the solar industry globally is a growth industry, it follows that skills will need to be taught in order to create a suitable workforce. It is therefore incumbent on all employers in the industry to create a training scheme both internally and externally which creates opportunities for qualifications and development. Whilst it is inevitable that some staff will choose to leave, it is unrealistic to imagine that any company can always employ already skilled and qualified staff.

The creation of a training matrix such as shown the proposed skills matrix in the Annex enables a company to record skills, both formal and informal, to identify gaps and to provide training to fill the gaps.

As the industry grows, there is a rapid rate of technological change as well as emergent best practices, which require a programme of continuous personal development to which both individuals and companies need to be committed.

The matrix goes beyond any educational background and focuses on the skills required by the O&M company in a specific country. Therefore, many of the skills/requirements are adjustable due to different practices and regulations across Europe.



5 TECHNICAL ASSET MANAGEMENT

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It is not easy to draw a sharp line between the high-level tasks of the Operations team and the more technical responsibilities of the Asset Manager. In many cases, the O&M Contractor assumes some tasks related to Technical Asset Management such as KPI reporting. The below tasks can be regarded as Technical Asset Management and can by performed by the O&M Contractor or the Asset Manager. Thus "Technical Asset Manager" in the below sections can mean either the O&M Contractor or the Asset Manager. In cases where the Technical Asset Manager and the O&M Contractor are separate entities, a close coordination and information sharing between the two entities is indispensable.

5.1. Reporting

The Technical Asset Manager is responsible for preparing and providing regular reporting to the Asset Owner and further recipients defined in the agreement between the Asset Owner and the Technical Asset Manager.

The frequency of the reporting can be set daily, weekly, monthly, quarterly or annually (with monthly being the most common), with specifically defined content for each of these reports. Generating a report for any specific time range in the past can also be possible.

Table 1 includes some proposed quantitative and qualitative indicators which should be in reports as a minimum requirement, a best practice or a recommendation. For more details on the individual indicators, see *10. Key Performance Indicators*.

A new trend in the industry is to extend the reporting beyond the pure PV plant indicators and to incorporate reporting on the actual activities. This means that the O&M Contractor can have a CMMS (Computerised Maintenance Management System) in order to measure various O&M KPIs (e.g. Acknowledgement Time, Intervention Time, Reaction Time, Resolution Time) and equipment performance (e.g. Mean Time Between Failures). The Technical Asset Manager should also report on Spare Parts Management and in particular on spare parts stock levels, spare parts consumption, in particular PV modules on hand, spare parts under repair. With the emergence of Predictive Maintenance, the Technical Asset Manager can also report on the state of each individual equipment. Furthermore, the periodic reporting can include information on the status of the security and surveillance system. In this case, the security service provider is responsible for providing the relevant input to the Technical Asset Manager.

On top of the periodical standard reports (monthly, quarterly or yearly) where operations activities are reported by the Technical Asset Manager to the Asset Owner, it is a best practice for the O&M Contractor to provide an intermediate operation report when a fault is generating a major loss. A loss due to a fault is considered major when PR and availability are affected by more than a certain threshold throughout the ongoing monitoring (or reporting) period. A best practice is to set this threshold to 1 % of Availability

TABLE 1 PROPOSED INDICATORS/VALUES REQUIRED FOR THE REPORTING

TYPE OF DATA	PROPOSED INDICATOR	TYPE OF REQUIREMENT
Raw data measurements	Irradiation	Minimum Requirement
	Active Energy Produced	Minimum Requirement
	Active Energy Consumed	Best Practice
Raw data measurements	Reference Yield	Recommendation
	Specific Yield	Recommendation
	Performance Ratio	Minimum Requirement
	Temperature-corrected Performance Ratio	Best Practice
	Energy Performance Index	Best Practice
	Uptime	Best Practice
	Availability	Minimum Requirement
	Energy-based Availability	Recommendation
	Acknowledgement time	Minimum Requirement
O&M Contractor KPIs	Intervention time	Minimum Requirement
	Response time	Minimum Requirement
	Resolution time	Minimum Requirement
	Mean Time Between Failures (MTBF)	Recommendation
Equipment KPIs	Inverter Specific Energy Losses	Recommendation
	Inverter Specific Efficiency	Recommendation
	Module Soiling Losses	Recommendation
	Main incidents and impact on production	Minimum Requirement
Incident Reporting	Warranty issues	Best Practice
	EH&S issues	Best Practice
	Spare parts stock levels and status	Best Practice
	Preventive Maintenance tasks performed	Best Practice

or 1% PR within a reporting period of one month. The report should be sent as soon as the fault is acknowledged or solved and should contain all the relevant details related to the fault together with recommendations for Extraordinary Maintenance when the necessary operations are not included in the maintenance contract.

- Typically, this maintenance report should contain: Relevant activity tracks (alarm timestamp, acknowledge time, comments, intervention time, operations on site description, pictures etc).
- The estimated production losses at the moment of writing the report.
- The estimated production losses for the total duration of the period, counting on the estimated resolution time if the issue is not solved yet.
- The device model, type and Serial Number when the fault is affecting a device.
- The peak power of the strings connected to the device(s).
- The alarm and status log as provided by the device.
- The resolution planning and suggestions. Eventual replacement needed.
- Spare parts available.
- Estimated cost for the extra-ordinary maintenance.

5.2. Regulatory compliance

The Technical Asset Manager is responsible for ensuring that the operation of the PV plant is in compliance with the regulations. Several levels of regulation have to be considered:

- Many countries have a governing law for the operation of energy generating assets or renewable energy and PV plants in particular. This is something the O&M Contractor should be aware of in any case, even if the O&M Contractor and the Technical Asset Manager are separate entities.
- Power Purchase Agreements (PPA) and Interconnection Agreements must also to be known and respected by the Technical Asset Manager.
- Power generation license agreements need to be made available by the Asset Owner to the Technical Asset Manager so that the Technical Asset Manager can ensure compliance with the regulations of these licenses.
- Specific regulation for the site such as building permits, environmental permits and regulations can involve certain requirements and the need to cooperate with the local administration. Examples include restrictions to the vegetation management and the disposal of green waste imposed by the environmental administration body, or building permits restricting working time on site or storage of utilities.
- It is the O&M Contractor's responsibility to ensure grid code compliance. See *6.8. Grid code compliance*.

As a minimum requirement the agreement between the Technical Asset Manager/O&M Contractor and the Asset Owner should list all the relevant permits and regulations and specify that the Asset Owner makes relevant documents available to the Technical Asset Manager or O&M Contractor.

As a best practice, all regulations, permits and stipulations should be managed within the electronic document management system (See section *6.1. Document Management System (DMS)*). This allows the Technical Asset Manager to track reporting and maintenance requirements automatically and report back to the Asset Owner or the administration bodies.

5.3. Warranty management

The Technical Asset Manager can act as the Asset Owner's representative for any warranty claims vis-à-vis the OEM manufacturers of PV plant components. The agreement between the Asset Owner and the Technical Asset Manager should specify warranty management responsibilities of the Technical Asset Manager and the Asset Owner and set thresholds under which the Technical Asset Manager can act directly or seek the Asset Owner's consent. The Technical Asset Manager or the Operations team will then inform the Maintenance team to perform warranty related works on site. Usually the warranty management scope is limited by Endemic Failures (*see definition below in this section*). Execution of warranty is often separately billable.

For any warranty claims the formal procedure provided by the warranty provider should be followed. All communications and reports should be archived for compliance and traceability reasons.

Objectives of Warranty Management:

- Improve the efficiency in complaining processes
- Help to reduce the warranty period costs
- Receive and collect all the warranty complaints
- Support the complaint process
- Negotiate with manufacturers more efficient complaint procedures
- Study the behaviour of the installed equipment
- Analyse the costs incurred during the warranty period

Types of warranties on a PV Plant:

- Warranty of Good Execution of Works
- Warranty of Equipment (Product Warranty)
- Performance Warranty

Warranty of good execution of works and equipment warranties

During the warranty period, anomalies can occur in the facility, which the EPC provider is liable for. The anomalies must be resolved according to their nature and classification, in accordance to what is described in the following chapters.

The anomalies or malfunctions that might occur within the facility warranty period might be classified the following way:

- Pending Works, in accordance to the List of Pending Works (or Punch List) agreed with the client during EPC phase;
- Insufficiencies, these being understood as any pathology in the facility resulting from supplies or construction, that although done according to the project execution approved by the client, has proven to be inadequate, unsatisfactory or insufficient;
- Defects, these being understood as any pathology resulting from supplies or construction executed in a different way from the one foreseen and specified in the project execution approved by the client;
- Failure or malfunction of equipment, being understood as any malfunction or pathology found in the equipment of the photovoltaic facility – Modules, Inverters, Power transformers or other equipment.

Anomalies Handling. During the Warranty Period, all the Anomaly processing should, as best practice, be centralised by the Technical Asset Manager/O&M Contractor, who is responsible for the first acknowledgment of the problem and its framework according to its type, and is the main point of contact between the internal organisational structure and the client in accordance to the criteria defined below.

Pending Works, Insufficiencies and Defects. In the case of anomalies of the type "Pending Works", "Insufficiencies" or "Defects", the Technical Asset Manager must communicate the occurrence to the EPC provider, who shall be responsible to assess the framework of the complaint in the scope of the EPC contract, determining the action to be taken.

Resolution of failures in the case of anomalies of the type "Failures". The Technical Asset Manager should present the claim to the equipment supplier and follow the claims process.

Endemic Failures. Endemic failures are product failures at or above the expected failure rates resulting from defects in material, workmanship, manufacturing process and/or design deficiencies attributable to the manufacturer. Endemic failure is limited to product failures attributable to the same root cause.

Performance Warranty

EPC Contractors usually provide a 2-year performance warranty period after COD. During the warranty period, it is the responsibility of the Technical Asset Manager to monitor, calculate, report and follow-up the values of Performance Ratio and other KPIs guaranteed by the EPC Contractor.

Within this scope, it is the responsibility of the Technical Asset Manager to:

- Manage the interventions done within the scope of the warranty in order to safeguard the performance commitments undertaken under the contract;
- Periodically inform the Asset Owner about the condition of the contracted performance indicators;
- Immediately alert the Asset Owner whenever the levels of the indicators have values or tendencies that could indicate a risk of failure.

5.4. Insurance claims

The Technical Asset Manager can act as the Asset Owner's representative for any insurance claims vis-à-vis the insurance provider.

The Agreement between the Technical Asset Manager and the Asset Owner should specify insurance management responsibilities of the Asset Owner and the Technical Asset Manager. The Technical Asset Manager will at least be responsible for the coordination of site visits by an insurance provider's representative or technical or financial advisors in connection with the information collection and damage qualification, as well as for the drafting of technical notes to support the reimbursement procedure.

For any insurance claims the formal procedure provided by the insurance provider should be followed. All communications and reports should be archived for compliance and traceability reasons.

5.5. Contract management

The Technical Asset Manager is also in charge of overseeing various contractual parameters, responsibilities and obligations of the Asset Owner linked to the respective PV plant. Contract management responsibilities depend largely on factors such as geographic location, project size, construction and off-taker arrangements.

As a minimum requirement, the initial step in this process is a comprehensive analysis of the contracts followed by a well-defined Division of Responsibility ("DOR") matrix that clearly delineates which entity is responsible for commercial, operational and maintenance actions on both short and long term. Upon mutual agreement between the parties, the DOR can serve as the driving and tracking tool for term of life contractual oversight.

As a form of best practice, the Contract Manager's responsibilities often also extend to functioning as the initial contact for all external questions. This allows for optimal access by the Asset Owner to all areas of the service provider's organisation, and adherence to the contractual responsibilities. The Contract Manager also assumes the responsibility for invoicing of the O&M fees to the Asset Owner.

For reasons of quality, the Technical Asset Manager should also track their own compliance with the respective contract, either O&M contract or Asset Management contract, and report to the Asset Owner in full transparency.

Upon agreement, the Technical Asset Manager can also handle the management of contracts between the Asset Owner and component suppliers. As an additional service, this can be considered best practice.



Central control room. © BayWa r.e.

6 POWER PLANT OPERATION

Operations is about remote monitoring, supervision and control of the PV power plant. It also involves liaising with or coordination of maintenance activities. The below sections give an overview of Operations tasks and requirements.

6.1. Documentation Management System (DMS)

Solar PV plant documentation is crucial for an in-depth understanding of the design, configuration and technical details thereof. It is the Asset Owner's responsibility to provide those documents and if not available, they should, as best practice, be recreated at the Asset Owner's cost.

Before assuming any maintenance and/or operational activities, it is important to understand in-depth the technical characteristics of the asset. There are two important aspects related to the management of this information:

- Information type and depth of detail / as-built documentation
- Management and control

Moreover, for quality / risk management and effective operations management a good and clear documentation of contract information, plant information, maintenance activities and asset management are needed over the lifetime of the plant. This is what is called here:

- Record control (or records management)

Nowadays, there are different DMSs available and described by a series of standards (ISO) that can be implemented. This is an important requirement that would allow any relevant party to trace any changes during the lifetime of the plant's operation and follow up accordingly (e.g. when the O&M Contractor changes, or the teams change, or the plant is sold etc).

Information type and depth of detail / as-built documentation

The documentation set accompanying the solar PV plant should, as a best practice, contain the documents described in the Annex. The IEC 62446 standard can also be considered to cover the minimum requirements for as-built documentation.

In general, for optimum service provision and as a best practice, the O&M Contractor should have access to all possible documents (from the EPC phase). The Site Operating Plan is the comprehensive document prepared and provided by the plant EPC, which lays out a complete overview of the plant location, layout, electrical diagrams, components in use and reference to their operating manuals, EH&S rules for the site and certain further topics. All detailed drawings from the EPC need to be handed over to the O&M Contractor and being stored safely for immediate access in case of PV plant issues or questions and clarifications with regards to permits and regulation.

Management and control

Regarding the document control, the following guidelines should be followed:

- Documents should be stored either electronically or physically (depending on permits/regulations) in a location with controlled access. An electronic copy of all documents should be available for all documents.
- Only authorised people should be able to view or modify the documentation. A logbook of all the modifications should be kept. As a best practice, such a logbook should contain minimally the following information:
  - Name of person, who modified the document
  - Date of modification
  - Reason of modification and further information, e.g. link to the work orders and service activities
- Versioning control should be implemented as a best practice. Involved people should be able to review past versions and be able to follow through the whole history of the document.

Record control

A key point is that necessary data and documentation are available for all parties in a shared environment and that alarms and maintenance can be documented in a seamless way. Critical to the Operations team is that the maintenance tasks are documented back to and linked with the alarms which might have triggered the respective maintenance activity (work order management system log). Photographs from on-site should complement the documentation (when applicable) – photo documentation. Tickets (ticket interventions) should be stored electronically and made available to all partners. The Asset Owner should also maintain ownership of those records for future references.

To learn from the past and ongoing operation and maintenance and to then be able to improve performance via for example Predictive Maintenance in the following years, it is crucial that all data is stored and that all workflows and alarms are stored to create automatic logbooks of operation and maintenance and alarms. Such data collection together with those acquired by the monitoring tool can be used for further analysis and future recommendations to the client. Such analysis and the respective outcomes should also be recorded.

Last but not least, there should be a proper documentation for the curtailment periods as well as the repairing periods when the plant is fully or partly unavailable. This will all be recorded by the monitoring system to be able to measure lost energy during maintenance activities. For this, having the correct reference values at hand is crucial. For important examples of input records that should be included in the record control, see *Annex c*.

As in the case of the as-built documentation, all records, data and configuration of the monitoring tool and any sort of documentation and log that might be useful for a proper service provision must be backed up and available when required. This is also important when the O&M Contractor changes.

6.2. Plant performance monitoring and supervision

The Operations team of the O&M Contractor is responsible for continuous monitoring and supervision of the PV power plant conditions and its performance. This service is done remotely through the use of monitoring software system and/or plant operations centres. The O&M Contractor should have full access to all data collected from the site in order to perform data analysis and provide direction to the Maintenance service provider/team.

Besides the data from the site, if a CCTV system is available on site, the O&M Contractor should, as a best practice, be able to access it for visual supervision and also have access to local weather information.

The O&M Contractor is responsible for being the main interface between the plant owner, the grid operator and the regulator (if applicable) over the lifetime of the O&M contract regarding production data. The Operations team should be staffed to provide services and be reachable by the Asset Owner via a hotline during daytime, when the system is expected to generate electricity. The Operations team is also responsible to coordinate accordingly with the Maintenance service provider/team.

For more information on monitoring requirements, see *9. Data and monitoring requirements*.

6.3. Performance analysis and improvement

The O&M Contractor makes sure that the performance monitoring is correct.

In general, the data should be analysed down to the following levels:

1. Portfolio level (group of plants) under control of the O&M Contractor (minimum requirement).
2. Plant level (minimum requirement).
3. Inverter level (minimum requirement).
4. String level (as a recommendation).

The analysis should furthermore show the required data on the specific levels listed above and for different time aggregation periods from the actual recording interval up to monthly and quarterly levels.

The analysis should also include the option for having custom alarms based on client specific thresholds such as for example business plan data or real-time deviations between inverters on site.

In particular, the agreed KPIs should be computed and reported (see *10. Key Performance Indicators*). Special attention should be paid to the fact that such KPI calculations should take into consideration the contractual parameters between O&M Contractor and Asset Owner, in order to provide an accurate and useful calculation for evaluation and eventually liquidated damages or bonuses.

6.4. Optimisation of O&M

An essential part of Operations is the analysis of all the information generated throughout O&M, such as Response Time, and how this correlates to the various classification of events and root causes. Another vital part of Operations is the analysis of costs incurred for various interventions, categorised into materials and labour. Having such information helps to further optimise the asset by reducing production losses and the cost of O&M itself.

6.5. Predictive Maintenance

Predictive Maintenance is a special service provided by O&M Contractors who follow best practices principles. It is defined as a condition based maintenance carried out following a forecast derived from the analysis and evaluation of the significant parameters of the degradation of the item (according to EN 13306). A prerequisite for a good Predictive Maintenance is that the devices on site can provide information about their state, in such a way that the O&M contractor can evaluate trends or events that signal deteriorations of the device. As a best practice, the device manufacturer should provide the complete list of status and error codes produced by the device together with the detailed description of their meaning and possible impact on the function of the device. Additionally, a standardisation of status and error codes through inverters and dataloggers within a same brand should be followed and, in the future, this standardisation should be common to all manufacturers.

The Asset Owner or interested party that wants to benefit from Predictive Maintenance should, as a best practice, select "intelligent" equipment set with sufficient sensors, and opt for an appropriate monitoring software system which should be able to provide basic trending and comparison (timewise or between components and even between PV sites) functionality (minimum requirement).

The Operations team of the O&M Contractor does Predictive Maintenance thorough continuous or regular monitoring, supervision, forecast and performance data analysis (e.g. historical performance and anomalies) of the PV plant (at the DC array, transformer, inverter, combiner box or/and string level). This can identify subtle trends that would otherwise go unnoticed until the next circuit testing or thermal imaging inspection and that indicate upcoming component or system failures or underperformance (e.g. at PV modules, inverters, combiner boxes, trackers etc level).

Before deciding which Predictive Maintenance actions to recommend, the Operations team should implement and develop procedures to effectively analyse historical data and faster identify behaviour changes that might jeopardise systems performance. These changes of behaviour are usually related to the pre-determined or unpredicted equipment degradation process. For this reason, it is important to define and to monitor all significant parameters of wear-out status, based on the sensors installed, algorithms implemented into the supervision system and other techniques.

Following such analysis, the Maintenance team can implement Predictive Maintenance activities to prevent any possible failures which can cause safety issues and energy generation loss.

For an efficient Predictive Maintenance, a certain level of maturity and experience is required, which is at best a combination of knowledge of the respective system's performance, related equipment design, operation behaviour and relevant accumulated experience and track record from the service provider. Normally it is a process that starts after the implementation of an appropriate monitoring system and the recreation of a baseline. Such baseline will then represent the entire PV system operation as well as how equipment interact with each other and how this system reacts to "environmental" changes.

Predictive Maintenance has several advantages, including:

- Optimising the safety management of equipment and systems during their entire lifetime;
- Anticipate maintenance activities (both corrective and preventive);
- Delay, eliminate and optimise some maintenance activities;
- Reduce time to repair and optimise maintenance and Spare Parts Management costs;
- Reduce spare parts replacement costs and
- Increase availability, energy production and performance of equipment and systems;
- Reduce emergency and non-planned work;
- Improve predictabilit.

The following three specific examples show how Predictive Maintenance might be implemented.

Example 1 – An O&M Contractor signs a new contract for a PV plant equipped with central inverters. Analysing its back-log of maintenance, the O&M Contractor knows that these inverters showed several times in the past signs of power loss due to overheating. This might be related to problems in the air flow, filter obstructions, fans or environmental changes (high temperature during summer). It was decided to monitor the temperature of IGBTs (Insulated-Gate Bipolar Transistors). Before any emergency action might be needed, in case these components have some variations in their behaviour, an "air flow inspection" is performed to detect if this change is related to the air flow. This type of activity is a condition based inspection performed after the detection of a change in a significant parameter. It is also considered as a type of Predictive Maintenance. The final purpose is to identify if, for example, the ventilation systems will need some upgrade, replacement or if there is any type of air flow obstruction or even if it is required to anticipate replacing or cleaning the filters.

Example 2 – The Operations team detects a possible underperformance of one of the sections inside the PV plant. This could be the power transformer, the inverter or some particular PV generator area that presents a lower performance when compared with others in the same conditions (or past behaviours evidence of loss of

production). After the anomaly detection or recognition, an incident is created and immediately sent to the Maintenance team. Before anything happens that might jeopardise contractual guarantees and might need urgent interventions, the O&M Contractor decides to do a "General Infrared Inspection" in the PV field taking general pictures with RPAS (Remotely Piloted Aircraft Systems), also known as drones. The main purpose of this inspection is to identify possible problems related to PV modules that might justify the loss of performance. This is considered as a type of Predictive Maintenance.

Example 3 – The Operations team or the inverter provider monitors all critical parameters of the inverter and can provide information related to the health and performance of each individual inverter as an absolute value or as a relative comparison of different inverters at one PV site, or compare batch of inverters between different PV sites. This type of information can help O&M Contractors to operate PV sites more cost effectively without compromising the equipment health. On the other side, Asset Manager (or Owner) can also compare how inverters are aging at various sites managed by different O&M companies and evaluate how well their investment is being managed. For instance, one O&M Contractor perceived as more expensive might be providing more regular care to the inverters compared to another; as a result, the inverters are operating in better condition and are not ageing as fast, resulting in less stress and lower expected failure.

6.6. Power plant controls

If applicable, the Operations team is the responsible contact for the grid operator for plant controls. The Operations team will control the plant remotely (if applicable) or instruct the qualified maintenance personnel to operate breakers/controls on site. The O&M Contractor is responsible for the remote plant controls or emergency shut-down of the plant, if applicable and in accordance with the respective grid operator requirements and regulations (see also *6.8. Grid code compliance*). The plant control function varies from country to country and in some cases from region to region. The respective document refers to details in PV plant control regulation which are issued by the respective grid operator and (energy market) regulator.

The Power Plant Controller itself is a control system that can manage several parameters such as active and reactive power and ramp control of PV plants. The set points can normally be commanded either remotely or locally from the SCADA. Moreover, the system should be password protected and log all the executed commands. Any executed commands should release real-time notifications to the Operations team.

The following list shows typically controlled parameters in a PV plant:

- Absolute Active Power Control
- Power Factor Control
- Ramp Control (Active and Reactive Power if needed)
- Frequency Control
- Reactive Power Control
- Voltage Control

6.7. Power Generation Forecasting

If the Asset Owner requires Power Generation Forecasts, the O&M Contractor may supply such forecasts (usually for large scale plants). Forecasting services for PV power generation are generally offered by operators of PV monitoring services, however external services can also provide this function. For the state of the art of PV power forecasting, the paper of (Pelland et al. 2013) can be used as a reference. When the Asset Owner requires Power Generation Forecasting from the O&M Contractor, they could choose a service level agreement with the forecast provider. This kind of activities may have an influence on the contract agreement for electricity dispatching between the Asset Owner and a trading service provider.

The requirements for such forecasts may differ from country to country and also depends on the contract agreement for electricity dispatching between the Asset Owner and a trading service provider. Forecast requirements are characterised by the forecast horizon, the time resolution, and the update frequency, all depending on the purpose. For power system or power market related purposes, forecast horizons are typically below 48 hours and the time resolution is 15 minutes to one hour, in line with the programme time unit of the power system or the market. Common products are day-ahead forecasts, intra-day forecasts and combined forecasts. Day-ahead forecasts are typically delivered in the morning for the next day from 0 to 24 and updated once or twice during that day. Intraday forecasts are delivered and updated several times per day for the rest of the day and should be delivered automatically by the forecast provider.

For long-term planning of unit commitment and maintenance decisions, forecasts with longer time horizons are used, typically one week or more.

PV Power Generation Forecasts rely on numerical weather predictions, satellite data and/or statistical forecasting and filtering methods. Most products combine several of these techniques. Good practice requires numerical weather predictions for day-ahead forecasting and a combination with satellite data for intra-day forecasts. In all cases, good practice requires statistical filtering which in turn requires a near-real-time data feed from the monitoring system to the forecast provider. For best practice, the forecast provider should also be informed about scheduled outages and the expected duration of forced outages.

The most common KPIs for forecast quality are the Root Mean Square Error (RMSE) and the Mean Absolute Error (MAE). They are normalised to peak power and not to energy yield.

6.8. Grid code compliance

The O&M Contractor, and in particular the Operations team is responsible to operate the PV plant in accordance with the respective national grid code. The operator of the grid, to which the PV plant is connected (either low voltage grid or medium voltage grid or high voltage grid) provides the requirements for power quality, voltage regulation and management of active and reactive power. In some countries (and/or regions) specific grid codes for renewable energy generators and consequently solar PV plants have been issued.

Depending on the voltage level of the grid the plant is connected to, the specificities and quality requirements for the PV plant change. A higher level of the grid usually has more specific and higher quality requirements.

Most of the utility scale PV plants in Europe connected to a grid are required to be controllable to meet the grid operator requirements. Such plant controls allow the grid operator to adjust the power output from the PV plant according to the grid capacity and power frequency requirements.

It is expected, that the O&M Contractor is familiar with all the details of the grid code and grid operator requirements. Depending on the regulations, either the grid operator himself is steering the PV plant controller (with remote signals) or the Operations team is managing the plant controller per direction of the grid operator.

6.9. Management of change

In the event that the design of a PV power plant needs to be adjusted after the Commercial Operation Date, the O&M Contractor should, as a best practice, be involved by the Asset Owner and the EPC Contractor and can be a main contributor if not the leader of this change process. Reasons for such changes can be motivated by non-compliance of the PV power plant with the capacity predicted by the EPC, by regulation (introduction of new PV power plant controls regulations), by the unavailability of spare parts or components, or by an interest to upgrade the PV power plant. These events would cause some new design works for the PV power plant, procurement and installation of equipment and will lead to adjustment of operation and maintenance procedures and/or documentation. It may also impact certain performance commitments or warranties provided by the O&M Contractor, which need to be adjusted.

In any such case, the O&M Contractor should to be involved in such changes to the PV power plant from the beginning. Concepts, design works and execution need to be coordinated with ongoing O&M activities. Implementation to the plant SCADA and monitoring system is required. For data continuity and long-term analysis, the monitoring system should be able to trace all changes of electrical devices. This should include documentation of inverter replacement date, manufacturer and type, and serial number in a structured way for further analysis (e. g. spare part management, Predictive Maintenance analysis). The monitoring of replaced devices will also facilitate the O&M Contractor to verify that the new component is correctly configured and is sending data of good quality. Adjustments to the Site Operating Plan, the Annual Maintenance Plan and the Annual Maintenance Schedule need to be applied and the O&M Contractor needs to familiarise the O&M staff with the operating manuals of the new equipment. Such change will have a definite impact on Spare Parts Management and inventory (replacement). Depending on the significance of such changes, the O&M annual fee might need to be adjusted.

It is advisable that the O&M Contractor takes the lead in the process of such change. The O&M Contractor is the trusted partner of the Asset Owner and should advise the owner in the decision making of such change processes. In the case of major changes the owner should also consider to inform lenders in the decision process and provide concepts, proposals and calculations.

The fixed O&M fee does not usually cover such services. The Asset Owner and the O&M Contractor should manage changes in a rather formalistic way. This procedure might include the following steps: description of proposed change (including time plan, costs, consequences, and alternatives), authorisation of the change by the Asset Owner, realisation of the change, documentation by the O&M Contractor and acceptance.

6.10. Power plant security

It is important that the solar PV plant, or key areas of it, are protected from unauthorised access. This serves the dual purpose of protecting the equipment of the plant and also keeping members of the public safe. Unauthorised access may be accidental, people wandering into the plant without realising the dangers, or it may be deliberate for the purposes of theft or vandalism.

Together with the O&M Contractor and the security service provider, the Asset Owner will put in place a Security Protocol in case an intrusion is detected.

In most countries there are strict legal requirements for security service providers. Therefore, PV power plant security should be ensured by specialised security service providers subcontracted by the O&M Contractor. The security service provider will be responsible for the correct functioning of all the security equipment including intrusion and surveillance systems as well as processing alarms arriving from the security system by following the Security Protocol and the use of the surveillance systems installed on site. The security system provider will be also responsible for any site patrolling or other relevant services. The security service provider should also assume liability for the security services provided. The O&M Contractor will coordinate with the security service provider and can optionally act as an interface between the Asset Owner and the security service provider.

A security system may be formed of simple fencing or barriers but may also include alarm detection and alerting systems and remote closed-circuit television (CCTV) video monitoring. An access protocol would be required if solar plants have CCTV when reactive and planned works are carried out. This will ensure that authorised access is always maintained. This can be done by way of phone with passwords or security pad codes, both of which should be changed periodically.

For additional security and in high-risk areas it is advised that there is a backup communication line installed (the first thing that gets damaged in case of vandalism is the communication with the surveillance station) as well as an infrastructure for monitoring connectivity and communication with the security system. As well as any remote monitoring, it is likely that provision for onsite attendance is required when significant events occur. Processes for liaison with local emergency services, e.g. police, should be considered.

Within the solar plant, there may also be additional areas with restricted access, for example locations containing High Voltage equipment. When authorising access to the parks it is important that all workers or visitors are appropriately informed of the specific access and security arrangements and where they should or should not be. Warning signs and notices can form an important part of this and may be mandated depending on local regulations.

As well as the general security of the site over the lifetime of the park, particular attention should be made to periods of construction or maintenance when usual access arrangements may be different. It is important that security is maintained at all times particularly when there are activities that may be of more interest to members of the public, children or thieves.

The Asset Owner will likely have insurance policies in place directly or indirectly and these will be dependent on certain levels of security and response being maintained. Failure to meet these may have important consequences in the case of an accident or crime.

6.11. Reporting and Technical Asset Management

The Operations team is responsible for providing periodic reporting to the Asset Manager or directly to the Asset Owner. In many cases, the Operations team also assumes further Technical Asset Management responsibilities. For more details on reporting and other Technical Asset Management tasks, see *5. Technical Asset Management*.



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7 POWER PLANT MAINTENANCE

This chapter is about the various responsibilities and tasks related to Maintenance. Maintenance is usually carried out on-site by specialised technicians or subcontractors, in close coordination with the Operations team's analyses.

7.1. Preventive Maintenance

Preventive Maintenance activities are the core element of the maintenance services to a PV plant. It comprises regular visual and physical inspections, as well as verification activities conducted with specific frequencies of all key components which are necessary to comply with the operating manuals and recommendations issued by the Original Equipment Manufacturers (OEMs). It must also maintain the equipment and component warranties in place and reduce the probability of failure or degradation. The activities should also comply with respective legal issues e.g. national standards for periodic inspection of certain electrical components. Technical experience and relevant track records will optimise the activities further. The O&M contract should include this scope of services and each task frequency.

This maintenance is carried out at predetermined intervals or according to prescribed OEM and O&M manuals. These are included in a detailed Annual Maintenance Plan which provides an established time schedule with a specific number of iterations for carrying out the maintenance.

It is under the responsibility of the O&M Contractor to prepare the task plan until the end of the contract, following the periodicities or frequencies contracted. These activities should be reported to the Client (Asset Owner or Asset Manager). The reporting of this activity is important to follow up the plan.

The **"Annual Maintenance Plan"** (see *Annex or download it from www.solarpowereurope.org*) developed as an attachment of this report includes a list of regular inspections per equipment (e.g. module, inverter etc) and per unit of equipment (e.g. sensors, fuses etc).

Examples of Preventive Maintenance can also be ad-hoc replacement of parts of inverters or sensors (Predictive Maintenance). In general, outside of the equipment warranty terms or after its expiration it is important to follow detailed Preventive Maintenance procedures, which are agreed upon in the Annual Maintenance Plan.

In cases where downtime is necessary to perform Preventive Maintenance, the execution of Preventive Maintenance activities during the night would be considered best practice as the overall power generation is not affected.

7.2. Corrective Maintenance

Corrective Maintenance covers the activities performed by the Maintenance team in order to restore a PV plant system, equipment or component to a status where it can perform the required function. The Corrective Maintenance takes place after a failure detection either by remote monitoring and supervision or during regular inspections and specific measurement activities (see also the *"Annual Maintenance Plan" attachment*).

Corrective Maintenance includes three activities:

1. Fault Diagnosis also called troubleshooting to identify fault cause and localisation;
2. Temporary Repair, to restore the required function of a faulty item for a limited time, until a Repair is carried out;
3. Repair, to restore the required function permanently.

In cases where the PV plant or segments need to be taken offline, the execution of scheduled Corrective Maintenance during night or low irradiation hours would be considered best practice as the overall power generation is not affected.

Corrective Maintenance can be divided into three levels of intervention:

1st level: Intervention to restore the functionality of a device without the need for substituting a component. In general, this kind of Corrective Maintenance includes only labour activity carried out by a specialised technician (that could belong to the O&M maintenance team or be subcontracted). This activity could be included in the O&M agreement or billed separately on hourly rates on top of the O&M contract, depending on the specific scope of work agreed between the parties. By way of an example it could consist of repairing a device that stopped due to a failure.

2nd level: Intervention to restore the functionality of a device that requires substitution of a component. In general, this kind of Corrective Maintenance involves labour activity carried out by a specialised technician (that could belong to the O&M maintenance team or be subcontracted) plus the physical intervention on the device in order to substitute a part of it. An example would be an inverter fan failure where the maintenance team intervenes to substitute the fan in order to restore inverter functionality.

3rd level: Intervention to restore device functionality with a necessity to intervene on the software of the device. In general, this kind of Corrective Maintenance includes both labour activity carried out by specialised technician (that could belong to the O&M maintenance team or be subcontracted) and, often, also an intervention on behalf of the device manufacturer's maintenance team or of other external companies that have been licensed by the device manufacturer to intervene and restore device functionality. This activity could be included in the O&M agreement or billed separately to it, depending on the specific scope of work agreed between the parties. Generally however, this intervention is excluded by the contractual scope of work especially when the device manufacturers' maintenance team or third party licensed company needs to intervene. By way of an example a 3rd level Corrective Maintenance could involve a device fault without apparent reason or specific broken component that could be restored only through reconfiguration or software update by the manufacturer.

The scope of Corrective Maintenance activities and its "border" or definition with respect to Preventive Maintenance requires specific attention and it should be properly defined in the Maintenance contract. For an easier comprehension, an example is presented below:

- A cable termination tightening activity using a torque device for the correct fixation should be under the Preventive Maintenance scope of works, but depending on the quantity and/or frequency, it could be considered a Corrective Maintenance activity.

Usually the Corrective Maintenance is contractually obliged to comply with contractually agreed minimum Response Times (see *10.2.3. Response Time* and *10.3.2. Response Time guarantee*).

Contractual agreements can foresee that the included Corrective Maintenance will be capped on a per year basis. Depending on the type of the Asset Owner being a pure financial investor or an energy producer (e.g. utility or IPP) the requirements for coverage under the Corrective Maintenance will vary.

Interventions for reconditioning, renewal and technical updating, save for the cases where those actions are directly included in the scope of the contract, should be excluded from Corrective Maintenance and included in the Extraordinary Maintenance (see *7.3. Extraordinary Maintenance*).

7.3. Extraordinary Maintenance

Extraordinary Maintenance actions are necessary when major unpredictable events take place in the plant site that require substantial activities and works to restore the previous plant conditions or any maintenance activity generally not covered or excluded from the O&M Contract.

Generally, these activities are billed separately in the O&M contract and are managed under a separate order. It is advisable that the O&M contract includes the rules agreed among the parties to prepare the quotation and to execute the works. Both a "lump sum turn-key" or a "cost-plus" method can be used for such purposes.

Extraordinary Maintenance interventions are required for:

- damages that are a consequence of a Force Majeure event;
- damages as a consequence of a theft or fire;
- serial defects or endemic failures[1] on equipment, occurring suddenly and after months or years from plant start-up;
- modifications required by regulatory changes.

In case the O&M Contractor was not the EPC of the plant, it is to be considered that also the following occurrence is an Extraordinary Maintenance:

- major issues of which O&M Contractor becomes aware during its ordinary activity i.e. defects or other problems that are not a consequence of equipment wear or deterioration and that are not of the O&M Contractor's responsibility because they can be reasonably considered to have been caused by design mistakes (e.g. "hidden" defects that require re-engineering).

Although not necessarily maintenance interventions, also the following can be included in the Extraordinary Maintenance list, or at least managed with same rules:

- improvement and revamping (restoring and optimisation) activities etc.

After the approval by the Asset Owner of the O&M Contractor's proposal, activities may commence, subject to availability of the required equipment and special machinery (if required).

The potential loss of energy between the event occurrence and full repair generally cannot be considered in the SPV financial model, but it has to be considered that many of the above events are reimbursed to the Asset Owner by the insurance company under any "All Risk Insurance" coverage that is in place.

Best Practices of O&M agreements regarding Extraordinary Maintenance activities include:

- general rules to quantify price and schedule to perform repair activities, and the right of the Asset Owner to ask for third party quotations to compare to the quotation of the O&M Contractor; in this case a "right-to-match" option should be granted to the O&M Contractor;
- the obligation for the Asset Owner to have in place a consistent "All Risk Property" Insurance including loss of profit.

7.4. Additional services

The O&M agreement can foresee services other than those pertaining to electrical and mechanical plant maintenance as per the above sections. Some of these additional services are generally included in the scope of work and the O&M annual fixed fee and some are not.

Additional services not included in the O&M contract scope of work can be requested on demand and can either be priced per service action or based on hourly rates applicable to the level of qualification of staff required to perform the works. These hourly rates usually escalate at the same rate as the O&M Service fee. In some cases, a binding price list for the delivery of some of these additional services can be included in the O&M contract as well.

Table 2 presents a non-exhaustive list of Additional services. For more information on general market trends as regards to whether these additional services are generally included in the O&M agreement or not, see *11.1. Scope of the O&M contract*.

1 For a definition of endemic failures and its repercussions in terms of warranty, see *5.3. Warranty management*.

TABLE 2 EXAMPLES FOR ADDITIONAL MAINTENANCE SERVICES

	ADDITIONAL SERVICES
PV site maintenance	Module cleaning
	Vegetation management
	Snow or sand removal
General site maintenance	Pest control
	Waste disposal
	Road management
	Perimeter fencing repair
	Maintenance of buildings
	Maintenance of Security Equipment
On-site measurement	Weekly/monthly meter readings
	Data entry on fiscal registers or in authority web portals for FIT tariff or other support scheme assessment (where applicable)
	String measurements – to the extent exceeding the agreed level of Preventive Maintenance
	Thermal inspections – to the extent exceeding the agreed level of Preventive Maintenance

Note that some of these items can be considered as a part of the Preventive Maintenance. This depends on the agreement between the Asset Owner and the O&M Contractor.



8 SPARE PARTS MANAGEMENT

It is important to differentiate between Consumables and Spare Parts.

"**Consumables**" are items which may be depleted or worn out by use and become incorporated into other items and lose their identity upon such incorporation and cannot be used for their intended purpose without extinguishing or transforming their substance, necessary to the regular operation of the PV Plant, to the extent that those are not a part of the Spare Parts. O&M Contractors should always have consumables on stock and maintenance crews should carry consumables with them, together with the relevant tools.

"Spare Parts" are all the items (materials and equipment such as modules inverters) listed on the "Spare Parts List", not in use or incorporated in the PV plant, intended to replace similar items in the PV plant.

Spare Parts Management is an inherent and substantial part of O&M that should ensure that spare parts are available in a timely manner for Corrective Maintenance in order to minimise the downtime of (a part of) a solar PV plant. As regards to Spare Parts Management, the following considerations have to be made:

- Ownership and responsibility of insurance
- Stocking level
- Location of storage
  - Proximity to the plant
  - Security
  - Environmental conditions

Ownership of spares is with the Asset Owner while normally maintenance, storage and replenishment is the responsibility of the O&M Contractor. Besides ownership matters, it is very important to make sure, upon mutual agreement, that one of the parties undertakes the responsibility of insuring the spares: as a recommendation spare parts stored on-site should be insured by the Asset Owner and spare parts stored off-site should be insured by the O&M Contractor.

For a new PV plant, the initial spare parts for two years from COD are procured by the Asset Owner or the EPC on behalf of the Asset Owner. However, it is best practice for the EPC and O&M Contractor to have agreed upon the list. The O&M Contractor should, as a best practice, recommend additional spares that they deem necessary to meet the contractual obligations (e.g. availability guarantees).

Generally, it is not economically feasible to stock spare parts for every possible failure in the plant. Therefore, the O&M Contractor together with the Asset Owner should define the stocking level of specific spare parts that make economic sense (Cost-Benefit Analysis). For example, if a specific part in a

solar PV plant has a frequency of failure at least of once every year or more and the loss of revenues due to such failure is greater than the spare part cost, it is important to have such a spare part available.

Regarding the stocking level, due to the very different configurations and sizes of solar PV plants, it is very difficult to define a hard number for stocking specific spare parts. Furthermore, the regional portfolio of the O&M Contractor might also influence this and as it was mentioned above, the determination of spare items and quantity is also driven by the O&M Contractor's contractual commitments and guarantees. In an attempt to define the stocking levels of Spare Parts and Consumables, the following parameters should be taken into consideration:

- Frequency of failure
- Impact of failure
- Cost of Spare Part
- Degradation over time
- Possibility of consignment stock with the manufacturer
- Equipment reliability

However, for any given utility scale solar PV system (big or small) there are certain spare parts that could be considered as essential to have – no matter the cost which is normally system size dependent.

Table 3 below summarises a minimum list. This list is not exhaustive and system requirements and technology developments can lead to this list being updated.

Regarding the storage and warehousing, this should be done in locations where the spare parts cannot be damaged (e.g. from humidity or high temperature variations) and are easily identifiable as being owned by the Asset Owner. Additionally, the storage sites should have appropriate security measures.

The decision for having either onsite or an offsite warehouse facility or just an agreement with the suppliers to provide the spare parts depends on many factors, including the kind of part, the commercial agreement, and the facilitation of the service provision. If the spare parts owned by the Asset Owner are stored off-site, such spares should be stored separately and be clearly identified as the property of the Asset Owner.

While proximity to the plant is a parameter that needs to be evaluated on a case by case basis, security and environmental conditions are very important as they could lead to a loss of property either through thefts or damage.

TABLE 3 MINIMUM LIST OF SPARE PARTS (NON-EXHAUSTIVE)

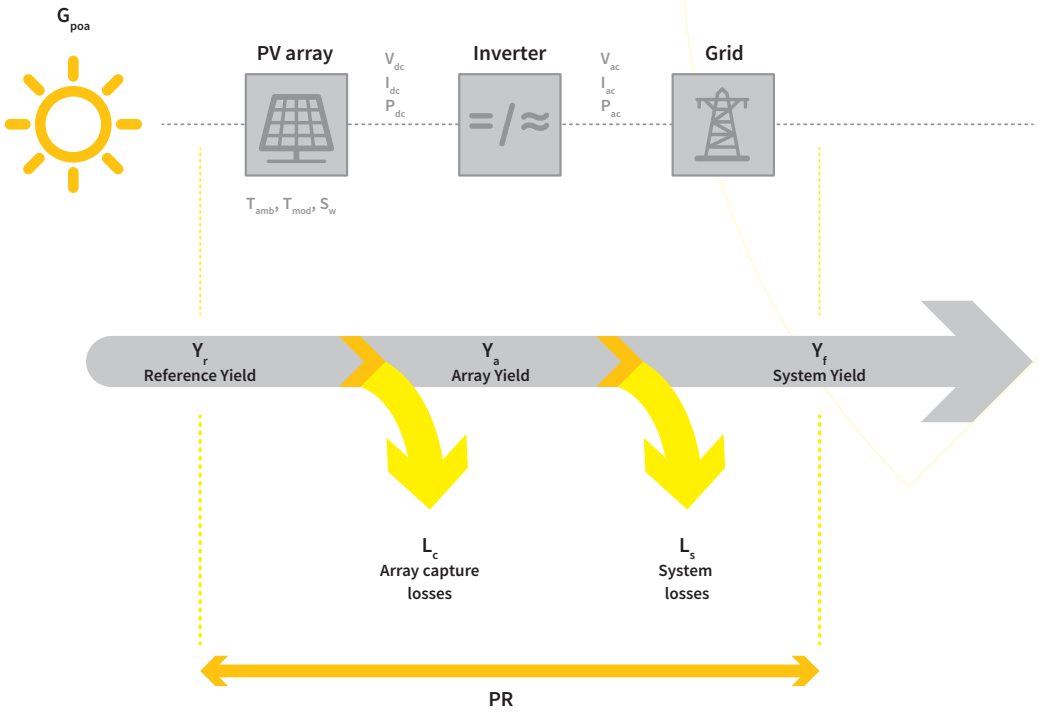
NO.	SPARE PART
1	Fuses for all equipment (e.g. inverters, combiner boxes etc) and fuse kits
2	Modules
3	Inverter spares (e.g. power stacks, circuit breakers, contactor, switches, controller board etc)
4	Uninterruptible Power Supply (UPS)
5	Voltage terminations (MV)
6	Power Plant controller spares
7	SCADA and data communication spares
8	Transformer and switchgear spares
9	Weather station sensors
10	Motors and gearboxes for trackers
11	Harnesses and cables
12	Screws and other supplies and tools
13	Security equipment (e.g. cameras)



9 DATA & MONITORING REQUIREMENTS

In general, the monitoring system should allow follow-up on the energy flows within a photovoltaic system. In principle it reports on the parameters that determine the energy conversion chain. These parameters, along with the most important energy measures in terms of yields and losses are illustrated in Figure 2. These yields and losses are always normalised to installed PV power at standard test conditions in kilowatt-peak for ease of performance comparison.

FIGURE 2 ENERGY FLOW IN A GRID-CONNECTED PHOTOVOLTAIC SYSTEM WITH PARAMETERS, YIELDS AND LOSSES[2]



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2 The figure is redesigned and based on a figure produced by 3E and published in (Woyte et al. 2014)

9.1. Data loggers

The main purposes of a datalogger are:

- Collecting data of relevant components (inverters, meteo data, energy meter, string combiners, status signals) with every device registered separately.
- Basic alarm functionality (e.g. Field Communication issues, time critical events like AC Off).
- Provide a temporary data backup (in case of missing internet connection during commissioning or general internet-related communication issues).
- Support the technicians during commissioning (e.g. checking whether all inverters work and feed-in).

In addition to this, some dataloggers can also provide the following functions:

- Power Plant Controller (Monitoring & Control should be managed by one instance to avoid communication issues regarding concurrent access). The Power Plant Controller can be integrated in the datalogger or can be a separate device using the communication channel of the datalogger.
- Solar Energy Trading Interface (control the active power by a third-party instance like energy trader)

The recording interval (also called granularity) of the datalogging should range from 1 minute to 15 minutes. Within one monitoring environment granularity should be uniform for all the different data collected.

As a minimum requirement, data loggers should store at least one month of data. Historical data should be backed up constantly by sending it to external servers and, after every communication failure, the data logger should automatically send all pending information. Moreover, data transmission should be secure and encrypted (see *9.9. Cybersecurity*). There should also be a logbook to track configuration changes (especially relevant when acting as Power Plant Controller).

As a best practice, the data logger should store a minimum of three months of data locally and a full data backup in the cloud. Moreover, the operation of the data logger itself should be monitored. Such monitoring should be done out of an independent server remotely and should ideally deliver information on the status of operation of the data loggers on Operating System (OS) and hardware level and also provide alerts to the Operations room in case of failures and communication loss.

Best practice is to have dataloggers and routers constantly monitored by a watchdog device (response to ping pos./neg.) on site. In case of no response to the control unit, the power supply will be interrupted by the watchdog unit performing a hard reset on the stopped equipment. In cases where it is not possible to have an external watchdog it can be useful to have an automatic reboot function.

The entire monitoring installation should be protected by an uninterruptable power supply (UPS). This includes data loggers, network switches, internet modems/routers, measurement devices and signal converters.

For more information, see also *IEC 61724-1 Photovoltaic system performance – Part 1: Monitoring*.

9.2. Monitoring (web) portal

The main purposes of the monitoring portal are:

- Long-term archive for the monitoring data
- Visualisation of data in standard and specific diagrams
- Visualisation of Key Performance Indicators and plant status on dashboard views
- Validation of data quality (e.g. through calculation of data availability)
- Detection of malfunctions as well as long term degradations with customisable alarms
- Handling of alerts from field devices like dataloggers or inverters
- Calculate typical Key Performance Indicators (such as Performance Ratio and Availability) with the possibility to adapt parameters
- Creation of reports for single plants as well as for portfolios
- Making data available via a standardised API for use in other systems

The monitoring portal should fulfil the following minimum requirements:

- Accessibility level of at least 99% across the year
- Responsible Interface and/or apps dedicated to use cases (on-site service, investor etc)
- Different user Access Level
- Graphs of irradiation, energy production, performance and yield

- Downloadable tables with all the registered figures
- Alarms register

As best practice, the following features will also be included in the Monitoring Portal:

- Configurable User Interface to adjust the views depending on the target group (e.g. O&M Manager, EPC, Investor, Asset Manager)
- User configurable alarms
- User configurable reports
- Ticket system to handle alarm messages
- Plant specific KPIs
- Integrate Third Party Data (e.g. Solar power forecast, Weather data, Satellite data for irradiance)
- Frequency of data should be adaptable for downloads of figures and tables

The above lists are not exhaustive.

9.3. Data format

The data format of the recorded data files must respect standards such as IEC 61724 and has to be clearly documented. Data loggers should collect all inverter alarms in accordance with original manufacturers format so that all available information is obtained.

9.4. Configuration

The configuration of the monitoring systems and data loggers needs to be checked in order to avoid mistakes. This is normally done at commissioning phase or at plant takeover by a new O&M Contractor (recommissioning of the monitoring system).

During commissioning each single equipment monitored should be checked to make sure it is properly labelled in the Monitoring System, this can be done by temporarily covering insolation sensors or switching off others such as string boxes or inverters.

The best practice is to have a Monitoring System capable to read and record all IDs from all sensors and equipment monitored, which will reduce the possibility of mislabelling elements and to trace equipment and sensor replacement along the life of the facility. Some Monitoring Systems have even an auto-configuration feature (plug-and-play) that reduces start-up time and potential mistakes. This it is done by capturing automatically the device ID and configuration information. This also allows for automatic inverter or sensor replacement detection.

9.5. Interoperability

As best practice, the system should ensure open data accessibility, in order to enable easy transition between monitoring platforms. Table 4 below shows some examples of data integration options. Because of the lack of unifying standards this is normally not the case and every Monitoring System provider has its own method to store and retrieve data. Best practice systems have the possibility to retrieve data by using open APIs such as RESTful, providing interoperability between different systems.

TABLE 4 EXAMPLES OF DATA INTEGRATION OPTIONS

METHOD	ADVANTAGES	DISADVANTAGES
FTP Push	Easy to implement No need for additional hardware	Not secure Limited control of data flow to the FTP server
Modbus/TCP (with additional logger on site)	Reliable and secure Best control of data flow	Additional cost for additional hardware More time-consuming implementation Relies on the existing monitoring system hardware, hence two hardware vendors involved
API (or similar) in the cloud	Fast and easy to implement No need for additional hardware Reliable	Small time lag from data collection to final destination Relies on the existing monitoring system vendor, double fees for monitoring.

9.6. Internet connection

The Asset Owner should make sure to provide the best possible network connectivity to the O&M Contractor with bandwidth that is sufficient for the installed monitoring system.

Whenever a DSL connection is available within the PV-site area, this should be the preferred way to connect to the internet, with industrial routers considered as standard. In case a DSL connection is not available, satellite communication is preferred. An additional back-up system can be seen as best practice. Any subscription should allow for the data quantity required and should foresee the amount of data (e.g. Closed-Circuit Television (CCTV) or not) and the granularity of data.

9.7. Local Area Network

For PV plants > 1MW it is advised to have a LAN connection and as an alternative an industrial router that allows for GPRS or satellite communication back-up in case the LAN connection fails. A router with an auto-reset capability in case of loss of internet connection is recommended. A direct connection to a monitoring server with a service-level agreement (SLA) guarantees continuous data access. If data passes via alternative monitoring servers without SLA, (e.g. monitoring portal of the inverter manufacturer), this SLA can no longer be guaranteed. The automatic firmware updates of the data logger should be disabled. Firmware updates are subject to acceptance procedure with the monitoring service.

All communication cables must be shielded. Physical distances between (DC or AC) power cables and communication cables should be ensured, as well as the protection of communication cables from direct sunlight. Furthermore, cables with different polarities must be clearly distinguishable (label or colour) for avoiding polarity connection errors.

9.8. Data ownership and privacy

The data from the monitoring system and data loggers, even if hosted in the cloud, should always be owned by and accessible to the Asset Owner (or SPV). Stakeholders such as the O&M Contractor, the Asset Manager or auditors during due diligence phases that need the data to perform their duties should be granted access. It is also important to have at least two access levels (read-only, full access).

The monitoring system hardware can be provided (and owned) by the O&M Contractor or a third-party monitoring service provider (in this case the monitoring system hardware is the property of the Asset Owner as part of the installation):

- If the O&M Contractor is the monitoring service provider, the O&M Contractor has full responsibility for protecting and maintaining the data and the proper functioning of the monitoring system.
- In case of a third-party monitoring service provider, the responsibility for protecting and maintaining the data resides with the third-party monitoring service provider. The O&M Contractor should use their best endeavours to make sure the performance monitoring is correct, to the extent possible. The O&M Contractor's ability to properly maintain and use the monitoring system should be evaluated. If necessary, the O&M Contractor should be appropriately trained to use the monitoring system. Data use by third party monitoring providers should be extremely limited, i.e. for the sole purpose of correcting bugs and developing additional functions to their systems.

9.9. Cybersecurity

Since PV plants will at least include inverters and power plant controllers (and monitoring systems) and these are expected to be accessible from (i.e. connected to the) internet to enable surveillance and remote instructions by operators, they have significant exposure to cybersecurity risks. It is therefore vital that installations undertake a cyber security analysis, starting from a risk assessment (including analysis at the level of the system architecture) and implement a cybersecurity management system (CSMS) that incorporates a plan-do-check-act cycle. The CSMS should start from a cybersecurity policy, and definition of formal cybersecurity roles and responsibilities, and proceed to map this onto the system architecture in terms of detailed countermeasures applied at identified points (e.g. via analysis of the system in terms of zones and conduits). These detailed countermeasures will include the use of technical countermeasures such as firewalls, encrypted interfaces, authorisation and access controls, and audit/detection tools. But they will also include physical and procedural controls, for example to restrict access to system components and to maintain awareness of new vulnerabilities affecting the system components.

As minimum requirements, loggers should not be accessible directly from the internet or at least be protected via a firewall. Secure and restrictive connection to the data server is also important.

As a best practice, dataloggers installed should be selected following a selection process by the operating party. For example, an EPC Contractor will choose and install the first data logger used to monitor the site. This datalogger should be selected:

- for its compatibility with the inverters and auxiliary equipment present on site
- for any command functionality that may be needed (this is site type and country specific)
- for its connectivity strength to the internet
- for its robustness (longevity of life and durability for the environmental conditions it will be kept in)
- for its, and the cloud server it is connected to, cyber security measures

The manufacturer of the datalogger and the monitoring platform (because these do not have to be one and the same) should provide information on penetration tests for their servers, any command protocol activation channels and security audits for their products. Command functions should be sent using at a minimum, a secure VPN connection to the control device. Best practice would entail double authentication. Further security measures are advisable.

For further information, beyond the scope for this document, please look at the European Parliament's study "Cyber Security Strategy for the Energy Sector" (EP 2016).

9.10. Types of collected data

9.10.1. Irradiance measurements

Irradiance Sensors. Solar irradiance in the plane of the PV array (POA) is measured on site by means of at least one irradiance measurement device according to Secondary Standard or First Class quality classification and ISO 9060:1990 (ISO 9060 1990). The higher the quality of the pyranometer, the lower the uncertainty will be. Best practice is to apply at least two pyranometers in the plane of the PV array. In case of different array orientations within the plant, at least one pyranometer is required for each orientation. It should be ensured that the pyranometers are properly assigned to the different arrays for the calculation of the Performance Ratio (PR) and Expected Yield.

Pyranometers are preferred over silicon reference cells because they allow a direct comparison of the measured performance of the PV plant with the performance figures estimated in the energy yield assessment. For plants in Central and Western Europe, measuring irradiance with silicon cells yields approximately 2 to 4% higher long-term PR than with a thermopile pyranometer (N. Reich et al. 2012).

Irradiance sensors must be placed at the least shaded location. They must be mounted and wired in accordance with manufacturers' guidelines. Preventive Maintenance and calibration of the sensors must follow the manufacturers' guidelines.

The irradiance should be recorded with a granularity of up to 15 minutes (minimum requirement).

Satellite-based Irradiance Measurements. In addition to the irradiance sensors, irradiance data from a high-quality satellite-based data service as a complement can be acquired after certain period to perform comparisons with data from ground-based sensors. This is especially useful in case of data loss or when there is low confidence on the data measured onsite by the Monitoring System and it can be considered as best practice. The longer the period considered the lower the error will be for satellite-based irradiation data. For daily irradiation values, the error is relatively high, with root-mean-square error (RMSE) values of 8 to 14% in Western Europe. For monthly and annual values it decreased below 5 and 3%, respectively, which is in line with an on-site sensor (Richter et al. 2015).

When satellite-based irradiance data is used, hourly granularity or less (15 minutes if possible) is recommended. The data must be retrieved once per day at least.

9.10.2. Module temperature measurements

To have a complete monitoring system, direct measurement of the module temperature is required.

The accuracy of the temperature sensor, including signal conditioning and acquisition done by the monitoring system hardware, should be < ±1 °C.

The temperature sensor should be stuck with appropriate and stable thermally conductive glue to the middle of the backside of the module in the middle of the array table, positioned in the centre of a cell, away from the junction box of the module (Woyte et al. 2013). The installation should be in accordance with manufacturer guidelines (e.g. respecting cabling instructions towards the datalogger).

PV module temperature is not supposed to be identical for all modules in a plant mainly due to different wind exposure. Therefore, in large plants more sensors will be required across the site because module

temperature should be measured at different representative positions, e.g. for modules in the centre of the plant and for modules at edge locations where temperature variation is expected.

9.10.3. Local meteorological data

It is best practice to measure ambient temperature and wind speed with the installation of a local meteorological station in accordance with the manufacturers' guidelines. Ambient temperature is measured with a shielded thermometer, e.g. of the PT100 type. The shield protects the sensor from radiative heat transfer. Wind speed is measured with an anemometer, at 10 m height above ground level.

Wind and ambient temperature data are normally not required for calculating PR unless this is a contractual requirement/agreement (e.g. according to specific recommendations such as from NREL). However, they are required when the PV plant is to be modelled in operation or in retrospect.

For plants >10 MW_p, it is recommended to have automated data collection of independent hourly meteo data (ambient temperature, wind speed, snow coverage) from an independent meteo source. The reason for this is that on-site meteorological stations are subject to local phenomena and installation-specific results. Data from an independent meteo-station is less subject to this while being also more stable and robust with respect to long-term drift.

Therefore, for both performance assessment and detailed analysis purposes, it is recommended to enable automated data collection from a nearby independent meteo reference. However, for performance assessment the most important measurement remains the in-plane irradiation (see *10. Key Performance Indicators*).

9.10.4. Soiling measurements

The operational efficiency of modules is affected by soiling accumulation. Soiling limits the effective irradiance and, therefore, the output of the PV module. It is recommended to measure soiling in order to optimise cleaning schedules and thus revenues. Several methodologies exist for soiling monitoring, the most basic being human inspections. A widely used soiling measurement method is using ground-based soiling reference modules consisting of a module that remains soiled, a washed reference cell, an automatic washing station and measurement electronics. Upcoming digital solutions for soiling monitoring include the analysis of satellite imagery with remote sensing techniques, machine intelligence algorithms and statistical methods.

9.10.5. String measurements

PV arrays that are not subject to DC input current monitoring at inverter level can have current measurements monitored at string level. Depending on module technology used in the plant, strings can be combined (in harnesses) which can help reducing operation costs.

In order to detect problems quickly and to increase the plant uptime, it is good to install string monitoring equipment (as a recommendation). This will constantly measure current and voltage of every string and register those measurements every up to 15 minutes. To reduce costs, the current sensor can potentially measure more than one string, but it is not recommended to parallel more than two of them.

9.10.6. Inverter measurements

Inverters have a big amount of values that are constantly measured by its hardware that can be interrogated from the monitoring system and registered. The data sent from the inverter to the monitoring system should, as a recommendation, be cumulative values to allow the following of the overall electricity generation of the inverter even in case of outages of the monitoring system.

Recommended variables to be monitored are:

- Cumulative Energy generated (kWh)
- Instant Active Power injected (kW)
- Instant Reactive Power injected (kVAr)
- Instant Apparent Power injected (kVA)
- AC Voltage per each phase (V)
- AC Current per each phase (A)
- Power Factor / Cos Phi
- Frequency for each phase (Hz)
- Instant DC Power absorbed for each MPPT (kW)
- Instant DC Current absorbed for each MPPT (A)
- Instant DC Voltage absolved for each MPPT (V)
- Total instant DC Power absorbed for all MPPTs (kW)
- Total instant DC Current absorbed for all MPPTs (A)
- Average instant DC Voltage absolved for all MPPTs (V)
- Internal temperature (ºC)
- Conversion components temperature (ºC)

It should be noted that the precision of inverter-integrated measurements is not always documented by the manufacturers and can be imprecise. For example,

energy or AC power measurements taken by inverters may differ substantially from the values recorded by the energy meter. Monitoring systems and reporting should specify and be transparent about the devices used to acquire each measurement.

It is also very useful to have the Monitoring System collecting all inverter alarms as they are a valuable source of information for fault detection. Also, low importance alarms or warnings can be used for the organisation of maintenance activities and even setting up Preventive Maintenance actions.

In certain cases, the grid connection has limits that must be always respected, such as the maximum AC power that can be injected. For these cases there are two possibilities, one is to set limits using inverter parameters, the second one is to install Power Plant Controller that will change inverter parameters dynamically. In both cases it could be useful to monitor inverter parameters and to program alarms so that the O&M Contractor is notified when there is a parameter that has been changed wrongly and does not respect certain limit.

Best practice for the measurement of inverter based variables is a <1min sampling and a granularity of up to 15 minutes. For ad-hoc performance analysis purposes e.g. to allow the analysis of PV array performance, root cause analysis or possible MPP-tracking problems, the input DC voltage and current need to be measured and stored separately.

In general, and as best practice, any parameter from an inverter that can be measured should be logged by the data loggers, since there are a lot of additional important parameters such as internal temperature, isolation level etc that could be useful for O&M services.

Inverters should detect overheating of its conversion components to protect themselves under extreme or abnormal operating conditions. Therefore, it is advisable to record the temperature as provided by the inverter so that ventilation performance can be assessed.

9.10.7. Energy meter

One of the most important features of a Monitoring System is the automated collection of energy meter data with a granularity of up to 15 minutes. Gathering energy meter data is required for invoicing purposes but it is also the best reference for measuring energy and calculating plant PR and Yield, and is much more accurate than using inverter data.

A high accuracy energy meter to measure energy produced and consumed by the plant is normally required by the utility. When this is not the case it is a best practice to install a meter with a maximum uncertainty of ± 0.5%, especially for plants > 100 kWp.

To allow data acquisition via the Monitoring System, it is recommended to have a meter with two communication bus ports as well as Automatic Meter Reading (AMR) service from the Utility or Meter Operator.

For meters that can store historical data it is a best practice to have a Monitoring System capable of retrieving the historical data to avoid any production data loss in case of Monitoring System outages.

9.10.8. Control settings

It is important to monitor all control settings of the plant at inverter level as well as grid injection level if available. Many plants apply control settings for local grid regulation (injection management) or optimisation of the market value of the PV generation portfolio (remote control). These settings need to be monitored for reasons of contractual reporting or performance assessment.

9.10.9. Alarms

As a minimum requirement, the monitoring system will have the following alarms sent by email:

- Loss of communication
- Plant stop
- Inverter stop
- Plant with Low Performance
- Inverter with Low Performance (e.g. due to overheating)

As best practice, the following alarms will also be sent by the monitoring system:

- String without current
- Plant under UPS operationi
- Discretion Alarm (or Alarm Aggregation)

As a best practice, the following alarms should also be followed by the O&M Contractor, but these alarms are sent by separate systems other than the monitoring system:

- Intrusion detection
- Fire alarm detection

The above lists are not exhaustive.

9.10.10. AC circuit / Protection relay

It is recommended to monitor the position of all AC switches through digital inputs. Whenever possible, it can also be useful to read and register the alarms generated by the protection relay control unit via communication bus.



10 KEY PERFORMANCE INDICATORS

This section deals with Key Performance Indicators (KPIs), which provide the Asset Owner with a quick reference on the performance of the PV power plant. The KPIs are divided into the following categories:

- **PV plant KPIs**, which directly reflect the performance of the PV power plant. PV plant KPIs are quantitative indicators.
- **O&M Contractor KPIs**, which reflect the performance of the service provided by the O&M Contractor. O&M Contractor KPIs are both quantitative and qualitative indicators.

The O&M Contractor (or the Technical Asset Manager) is generally responsible for the calculation of the KPIs and reporting to the Asset Owner, see *5.1. Reporting*.

It is important to underline that the O&M Contractor cannot, and is thus not responsible for providing contractual guarantees for all the KPIs listed in this chapter. For more information on suggested contractually guaranteed KPIs, see *11.3. Contractual guarantees*.

10.1 PV power plant data

PV power plant data can be split into two groups:

1. Raw data measurements: data obtained directly from the PV plant and used for performance calculation.
2. PV power plant KPIs use the raw data from the PV plant to give a more balanced overview of the operation of the PV plant.

10.1.1. Raw data measurements for performance calculation

The following is a list of raw data measurements that can be used to calculate KPIs:

- AC Power produced (kW)
- AC Energy produced (kWh)
- AC Energy metered (kWh)
- Reactive power (kVAR)
- Irradiation (reference for the plant or the sub-plants) (W/m^2)

- Air and module temperature (Celsius degrees)
- Alarm and status code and duration
- Outages, unavailability events

This is a basic list and is non-exhaustive.

10.1.2. PV power plant KPIs

Calculated KPIs give a more balanced view of the operation of a PV plant as they take into account the different operating conditions for each plant. Suggestions for calculated KPIs along with relevant formula can be found below. These KPIs can be calculated over different time periods, but often they are computed on an annual basis. When comparing different KPIs or different PV power plants' KPIs, it is important to keep consistency in the time period used in computation.

10.1.2.1. Reference Yield

The Reference Yield represents the energy obtainable under ideal conditions, with no losses, over a certain period of time. It is useful to compare the Reference Yield with the final system yield (see *10.1.2.3. Performance Ratio*).

The Reference Yield is defined as:

$$Y_{r(i)} = \frac{H_{POA}}{G_{STC}}$$

Where:
$Y_{r(i)}$ = Reference Yield for the time period *i* expressed in peak sun hours (h) or (kWh/kW)
$H_{POA(i)}$ = The plane of array irradiation for the time period *i* (kWh/m²)
G_{STC} = The reference irradiance at standard test conditions (STC) (1000 W/m²).

10.1.2.2. Specific Yield

Specific Yield is the measure of the total energy generated per kW_p installed over a certain period of time.

This measure is generally calculated both at plant DC energy produced or at plant AC energy metered. In both cases it indicates the number of full equivalent hours a plant produced during a specific time frame.

Specific Yield is calculated as follows:

$$Y_i = \frac{E_i}{P_0}$$

Where:
Y_i = Plant Specific Yield for the time period *i*, expressed in (kWh/kW_p) or peak sun hours (h)
E_i = Plant energy production or Plant energy metered for the time period *i* (kWh)
P_0 = Plant Peak DC power (nominal power) (kW_p)

This measurement normalises plant output over a chosen time frame and thus allows the comparison of the production of plants with different nominal power or even different technologies (e.g. PV, wind, biomass etc). For example, the Specific Yield of a PV Plant can be compared against the Specific Yield of a wind plant for investment decision taking or the Specific Yield of a 5 MW_p ground mounted PV plant can be compared directly to a 1 MW_p double tracker PV plant's Specific Yield.

Calculating Specific Yield on the inverter level also allows a direct comparison between inverters that may have different AC/DC conversion rates or different nominal powers. Moreover, by checking inverter level Reference Yield within a plant, it is possible to detect whether an inverter is performing better than others.

10.1.2.3. Performance Ratio

The Performance Ratio (PR) is a quality indicator of the PV plant. As the ratio between the actual Specific Yield and the theoretically possible Reference Yield, PR captures the overall effect of losses of the PV system when converting from nameplate DC rating to AC output. Typically, losses result from factors such as module degradation, temperature, soiling, inverter losses, transformer losses, and system and network downtime. The higher the PR is, the more energy efficient the plant is.

PR, as defined in this section, is usually used to report on longer periods of time, such as a year. Based on PR, the O&M Contractor can provide recommendations to the plant owners on possible investments or interventions.

Performance Ratio is defined as:

$$PR = \frac{Y_f}{Y_r} \times 100$$

Where:
PR = Performance Ratio over a year (%)
Y_f = Specific Yield over a year (also called final yield) expressed in (kWh/kW_p) or peak sun hours (h)
Y_r = Reference Yield over a year expressed in (kWh/kW_p) or peak sun hours (h)

These definitions are based on (Woyte et al. 2014) in line with the IEC 61724-1:2017 and are common practice.

PR is measured for available times (see *10.1.2.8 Availability*) at the inverter level.

Note that special attention is needed when assessing the PR of overrated plants, where the output of the plant is limited by the inverter maximum AC output. In such situations and for the period that overrating takes place, PR will calculate lower than normal although there is no technical problem with the plant. Stakeholders should be careful assessing PR values for overrated plants, although the amount of overrating is normally statistically constant or with negligible differences on a yearly basis.

10.1.2.4. Temperature-corrected Performance Ratio

In some situations, such as a commissioning test or PV power plant handover from one O&M Contractor to another, PR needs to be measured over a shorter time period, such as two weeks or a month (referred to as time period *i* below). In such situations, it is recommended to use a PR formula corrected with temperature factor in order to neutralise short-term PR fluctuation due to temperature variations from STC (25°C). As a best practice, temperature should be registered with a granularity of up to 15 minutes (referred to as time period *j* below) and the average temperature for the time period *i* should be weighted according to Specific Yield.

Temperature-corrected PR can be defined as follows:

$$PR_{T0(i)} = \frac{Y_i}{Y_{r(i)} \times \left[\left(1 - \frac{\beta}{100} \times (T_{MOD(i)} - 25°C)\right)\right]} \times 100$$

Where:
$PR_{T0(i)}$ = Temperature-corrected Performance Ratio for the time period *i* (%)
Y_i = Plant Specific Yield for the time period *i*, expressed in (kWh/kW_p) or peak sun hours (h)
$Y_{r(i)}$ = Reference Yield for the time period *i*, expressed in (kWh/kW_p) or peak sun hours (h)
β =Temperature coefficient for P_o that corresponds to the installed modules (%/°C).
$T_{MOD(i)}$ =Average module temperature for the period *i*, weighted according to Specific Yield Y_j (°C)

$$T_{MOD(i)} = \frac{\sum_{j=1}^{i} Y_j \times T_{MOD_{MEAS(j)}}}{\sum_{j=1}^{i} (Y_j)}$$

Where:
Y_j = Plant Specific Yield for the time period *j* (*j* ≤ 15 minutes), expressed in (kWh/kW_p) or peak sun hours (h)
$T_{AMB_{MEAS(j)}}$ = Average measured module temperature for the time period *j* (*j* ≤ 1 hour) (°C)

10.1.2.5. Expected Yield

Expected Yield $Y_{exp(i)}$ is the Reference Yield $Y_{r(i)}$ multiplied by the expected PR and thus expresses what should have been produced over a certain period of time *i*.

Expected Yield can be defined as:

$$Y_{exp(i)} = PR_{exp(i)} \times Y_{r(i)}$$

Where:
$Y_{exp(i)}$ = Expected Yield for the time period *i*, expressed in (kWh/kW_p) or peak sun hours (h)
$PR_{exp(i)}$ = Average Expected Performance Ratio of the plant over the period *i*, based on simulation with given actual temperature and irradiation and plant characteristics. (PR_{exp} simulation is beyond the scope of the present document but for more information on this, see Brabandere et al (2014), Klise and Stein (2009), NREL (2017), PVsyst (2017) and SANDIA (2017).)
$Y_{r(i)}$ = Reference Yield for the time period *i* (based on past irradiation data) expressed in (kWh/kW_p) or peak sun hours (h)

Note that Expected Yield is based on past values of irradiation data. Predicted Yield is based on forecasted data, from day ahead and hour ahead weather reports.

10.1.2.6. Energy Performance Index

The Energy Performance Index (EPI) is defined as the ratio between the Specific Yield Y_i and the Expected Yield Y_{exp} as determined by a PV model. The EPI is regularly recalculated for the respective assessment period (typically day/month/year) using the actual weather data as input to the model each time it is calculated. This concept was proposed, e.g. in (Honda et al. 2012).

The Energy Performance Index (EPI) is defined as:

$$EPI_i = \frac{Y_i}{Y_{exp(i)}}$$

Where:
EPI_i = Energy Performance Index for the time period *i* (%)
Y_i = Specific Yield for the time period *i* (kWh/kW$_p$) or (h)
$Y_{exp(i)}$ = Expected Yield for the time period *i* (kWh/kW$_p$) or (h)

The advantage of using the EPI is that its expected value is 100% at project start-up and is independent of climate or weather. This indicator relies on the accuracy of the expected model. Unfortunately, there are more than one established models for the Expected Yield of PV systems in operation and not all of them are transparent. Therefore, the use of EPIs is recommended mainly for the identification of performance flaws and comparison of plants.

10.1.2.7. Uptime

The following three KPIs – Uptime, Availability and Energy-based Availability – are three closely related indicators to measure whether or not the PV power plant is generating electricity. In these Guidelines, the term "Uptime" is used to avoid any confusion with "Availability", however, these terms are sometimes used interchangeably.

Uptime is the parameter that represents the time during which the plant is operating over the total possible time it is able to operate, *without taking any exclusion factors into account*. The total possible time is considered the time when the plant is exposed to irradiation levels above the generator's Minimum Irradiance Threshold (MIT).

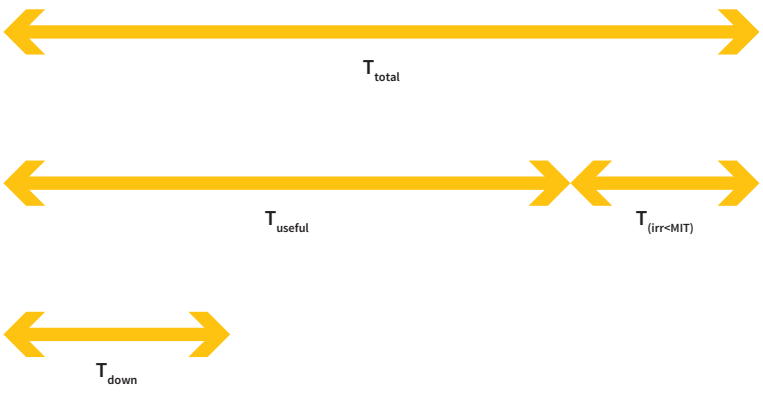
Uptime is then defined as:

$$U = \frac{T_{useful} - T_{down}}{T_{useful}} \times 100$$

Where:
U = Uptime (%)
T_{useful} = period of time with in plane irradiation above MIT (h)
T_{down} = period of T_{useful} when the system is down (no production) (h)

The figure below illustrates the various periods in time mentioned above.

FIGURE 3 VARIOUS PERIODS OF TIME FOR THE CALCULATION OF UPTIME



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Normally, only the time where irradiance is above the MIT is considered and this is noted above as T_{useful}, where $T_{useful} = T_{total} - T_{(irr<MIT)}$. Typical MIT values are 50 or 70 W/m². MIT should be defined according to site and plant characteristics (e.g. type of inverter, DC/AC ratio etc).

Uptime should be measured at inverter level. Individual inverters' Uptimes U_k should be weighted according to their respective installed DC power P_k. In this case, the Uptime of the total PV power plant U_{total} with an installed total DC power of P_0 can be defined as follows:

Uptime weighted by individual inverters' installed DC power:

$$U_{total} = 100 \times \sum (U_k \times \frac{P_k}{P_0})$$

Where:
U_{total} = Uptime of the plant (%)
U_k = Uptime of the inverter *k*
P_k = Installed DC power of the inverter *k*
P_0 = Plant Peak DC power (nominal power) (kW_p)

For the calculation of Uptime, typically up to 15 minutes of irradiation and power production data should be taken as basis, if granularity of components remains at the level of inverter or higher. Anything below the level of inverter is then captured with the Performance Ratio calculation presented below.

10.1.2.8. Availability

Availability is Uptime with certain contractually agreed exclusion factors (*see below*) applied in the calculation used as a basis for Availability guarantees provided by the O&M Contractor to the Asset Owner. A best practice is a Minimum Guaranteed Availability of 98% over a year. (For more details on Availability guarantee provided by the O&M Contractor, see *11.3.1. Availability guarantee*.

Availability is thus the parameter that represents the time in which the plant is operating over the total possible time it is able to operate, taking into account the number of hours the plant is not operating for reasons contractually not attributable to the O&M Contractor (listed below in the same section).

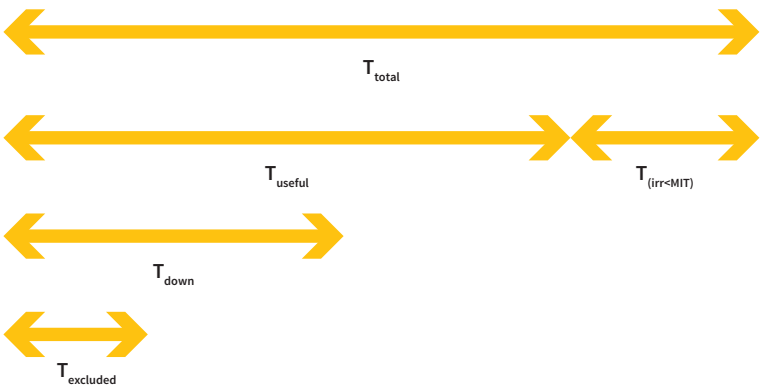
Availability is therefore defined and calculated as:

$$A = \frac{T_{useful} - T_{down} + T_{excluded}}{T_{useful}} \times 100$$

Where:
A = Availability (%)
T_{useful} = period of time with in plane irradiation above MIT (h)
T_{down} = period of T_{useful} when the system is down (no production) (h)
$T_{excluded}$ = part of T_{down} to be excluded because of presence of an exclusion factor (*see below*) (h)

The figure below illustrates the various periods in time mentioned above.

FIGURE 4 VARIOUS PERIODS OF TIME FOR THE CALCULATION OF AVAILABILITY



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3 The T_{down} represents the whole downtime, before the exclusions are applied. Therefore, $T_{excluded}$ is a part of T_{down} in the diagram. In practice you often first see that a plant is down (= measurement of T_{down}) and only in the course of troubleshooting one gets the information whether you can exclude part of the downtime.

Like Uptime, Availability is also calculated for irradiance levels above the MIT and measured at inverter level. Individual inverters' Availabilities A_k should be weighted according to their respective installed DC power P_k. In this case the Availability of the total PV power plant A_{total} with an installed total DC power of P_0 can be defined as follows:

Availability weighted by individual inverters' installed DC power:

$$A_{total} = 100 \times \sum (A_k \times \frac{P_k}{P_0})$$

Where:
A_{total} = Availability of the plant (%)
A_k = Availability of the inverter *k*
P_k = Installed DC power of the inverter *k*
P_0 = Plant Peak DC power (nominal power) (kW_P)

For the calculation of Availability, typically up to 15 minutes of irradiation and power production data should be taken as basis, if granularity of components remains at the level of inverter or higher. Anything below the level of inverter is then captured with the Performance Ratio calculation presented below.

As Availability is used for contractual purposes, any failure time should only begin to run when the O&M Contractor receives the error message. If the data connection to the site was not available, failure time should only begin after reestablishment of the link.

The Asset Owner and the O&M Contractor should agree on certain failure situations that are not taken into account (exclusion factors) in the calculation of Availability. Some good examples for exclusion factors are:

- Force majeure;
- Snow and ice on the PV modules;
- Damage to the PV plant (including the cables up to the feed-in point) by the customer or third parties who are not sub-contractors of O&M Contractor, including but not limited to vandalism;
- Disconnection or reduction of energy generation by the customer or as a result of an order issued to the customer by a court or public authority;
- Operational disruption by grid disconnections or disruptions in the grid of the grid operator;
- Disconnections or power regulation by the grid operator or his control devices;
- Downtimes resulting from failures of the inverter or MV voltage components (for example, transformer, switchgear), if this requires
  - Technical support of the manufacturer and/or
  - Logistical support (for example supply of spare parts) by the manufacturer;
- Outages of the communication system. Any failure time only begins to run when the O&M Contractor receives the error message. If the data connection to the site was not available, failure time shall only begin after reestablishment of the link.
- Delays of approval by the customer to conduct necessary works;
- Downtimes for implementation of measures to improve the PV plant, if this is agreed between the parties;
- Downtimes caused by the fact that the customer has commissioned third parties with the implementation of technical work on the PV plant.

10.1.2.9. Energy-based Availability

Energy-based Availability takes into consideration that an hour in a period with high irradiance is more valuable than in a period with low irradiance. Therefore, its calculation uses not time but energy (and lost energy) for its basis:

Energy-based Availability is defined as:

$$EA_i = \frac{E_i}{E_i + E_{loss(i)}} \times 100$$

Where:
EA_i = Energy-based Availability for the time period *i* (%)
$E_{loss(i)}$ = Calculated lost energy in the period *i* (kWh)
E_i = Plant energy production or Plant energy metered in the time period *i* (kWh)

Note that the exclusion factors defined for Availability apply for Energy-based Availability too.

10.2. O&M Contractor KPIs

As opposed to power plant KPIs, which provide the Asset Owner with information about the performance of their asset, O&M Contractor KPIs assess the performance of the O&M service.

The following time KPIs are illustrated in Figure 5.

10.2.1. Acknowledgement Time

The Acknowledgement Time (also called Reaction Time) is the time between detecting the problem (receipt of the alarm or noticing a fault) and the acknowledgement of the fault by the O&M Contractor by dispatching a technician. The Acknowledgement Time reflects the O&M Contractor's operational ability.

10.2.2. Intervention Time

The Intervention Time is the time to reach the plant by a service technician or a subcontractor from the moment of acknowledgement and whenever when visit by the O&M Contractor is contractually necessary (in certain cases remote repair is possible or the O&M Contractor is not able to repair the fault and third-party involvement is necessary). Intervention Time assesses the capacity of the O&M Contractor how fast they can mobilise and be on site.

10.2.3. Response Time

The Response Time is the Acknowledgement Time plus the Intervention time. Used for contractual purposes, minimum Response Times are guaranteed on the basis of fault classes, i.e. the (potential) loss of energy generation capacity. For recommendations for Response Time guarantees, see *11.3.2. Response Time guarantee*.

10.2.4. Resolution Time

Resolution Time (or Repair Time) is the time to resolve the fault starting from the moment of reaching the PV plant. Resolution Time is not guaranteed, because resolution often does not depend totally on the O&M Contractor.

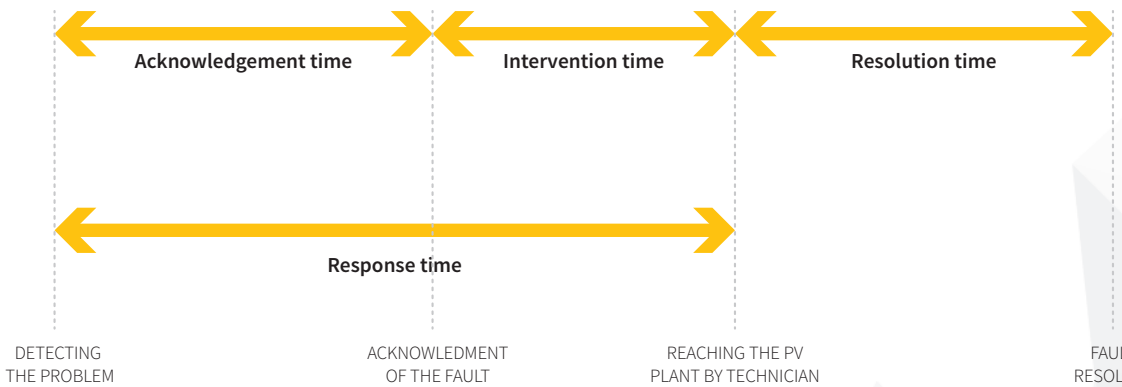
10.2.5. Reporting

It is very important for the O&M Contractor to comply with reporting requirements and reporting timelines. Content and timing of the reporting is generally agreed by the parties in the Contract agreement. Content of the reporting should be expected to be consistent and any change in content or format needs to be explained by the O&M Contractor. Delivery of reports per the agreed upon timeline is an important indicator for reliability and process adherence within the O&M Contractors organisation. See also *5.1. Reporting*.

10.2.6. O&M Contractor experience

Experience of the O&M Contractor with PV power plants in the particular country, region, grid environment and/or with PV power plants equipped with certain technology or size can play an important role. This is quite relevant for the selection of the O&M Contractor and can be tracked by the owner over time (track record).

FIGURE 5 ACKNOWLEDGEMENT TIME, INTERVENTION TIME, RESPONSE TIME, RESOLUTION TIME



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11 CONTRACTUAL FRAMEWORK

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This section contains a set of considerations for the contractual framework of O&M services for the utility scale segment, and more specifically, systems above 1 MW_p. A complement to the technical specifications detailed in the previous chapters, the contractual framework described in this chapter are considered as a best practice.

As a best practice, we recommend using the O&M template contract developed as part of the Global Solar Energy Standardisation Initiative (SESI), a joint initiative of the Terrawatt Initiative, the International Renewable Energy Agency, supported by SolarPower Europe and the Global Solar Council. The O&M template is set to be launched together with the six other document templates – as these seven contractual document templates form a package of this Initiative. The whole package will be launched in 2018 after a thorough review.

11.1. Scope of the O&M contract

Services to be provided by the O&M Contractor include:

Technical Asset Management. (Most of these services can be performed by either the O&M Contractor or the Asset Manager.)

- Reporting to Asset Owner
  - Reporting on PV plant performance
  - Reporting on O&M performance
  - Reporting on incidents
- Ensuring regulatory compliance
  - Legal requirements for PV plant operation
  - Power Purchase Agreements and Interconnection Agreements
  - Power generation licence agreements
  - Building permits and environmental permits
- Warranty management
- Insurance claims
- Contract management

Power Plant Operation

- Plant documentation management
- Plant supervision
  - Performance monitoring and documentation
  - Performance analysis and improvement
  - Issue detection/diagnostics
  - Service dispatch/supervision
  - Security monitoring interface (*optional*)
- Plant operation
  - Plant controls
  - Power Generation Forecasting (*optional*)
  - Grid operator interface, grid code compliance
  - Maintenance scheduling

- Management of change (*optional*)
- Reporting to Technical Asset Manager (in case O&M Contractor is not the Technical Asset Manager)

Power Plant Maintenance

- PV Plant Maintenance
  - Preventive Maintenance
  - Corrective Maintenance in accordance with agreed Response Time guarantees (some types of maintenance activities may be beyond the scope of the contract, for more information, see *7.2. Corrective Maintenance*)
  - Extraordinary Maintenance (generally not included in the O&M fixed fee but it is advisable that the O&M contract includes the rules to prepare the quotation and to execute Extraordinary Maintenance works)
  - PV plant includes: modules, racks/trackers, wires and conduits, combiners, inverters, monitoring systems incl. weather station, transformers, switchgear, substation
- Additional maintenance services (optional, see *7.4. Additional services*)

Here below is a non-exhaustive list of Additional services and general market trends with regards to whether these Additional services are generally included in the O&M agreement or not.

TABLE 5 EXAMPLES FOR ADDITIONAL MAINTENANCE SERVICES AND GENERAL MARKET TRENDS WITH REGARDS TO WHETHER THESE ADDITIONAL SERVICES ARE GENERALLY INCLUDED IN THE O&M AGREEMENT OR NOT

	ADDITIONAL SERVICES	**GENERAL BEHAVIOUR**
PV site maintenance	Module cleaning	Generally included
	Vegetation management	Generally included, but need to specify perimetral vegetation management and management on possible environmental compensation measures
	Snow or sand removal	Generally not included and also generally not easy to provide
General site maintenance	Pest control	Generally not included
	Waste disposal	Generally included with reference to waste generated during O&M activities
	Road management	Generally not included
	Perimeter fencing repair	Generally not included and often caused by force majeure (i.e.: theft)
	Maintenance of buildings	Generally not included
	Maintenance of Security Equipment	Generally not included, these activities are performed by a separate surveillance and security provider in order to have clearly defined responsibilities (see *6.10. Power plant security*)
On-site measurement	Meter weekly/monthly readings	Generally included since it feed the periodical performance reporting to the Asset Owner
	Data entry on fiscal registers or in authority web portals for FIT tariff assessment (where applicable)	Generally this activity is deemed to the Asset Manager. Can be however included in O&M scope of work
	String measurements – to the extent exceeding the agreed level of Preventive Maintenance	Generally not included but a price could be agreed in advance in the O&M contract
	Thermal inspections – to the extent exceeding the agreed level of Preventive Maintenance	Generally not included but a price could be agreed in advance in the O&M contract

All the services not included in the scope and in the fixed fee such as *7.3. Extraordinary Maintenance* and *7.4. Additional services* should be regulated within the contract. A dedicated clause should indicate the procedure that should include: (i) a proposal by the O&M Contractor within a fixed time frame, (ii) a fixed period for the Asset Owner to accept it or request modification, (iii) a final approval. Pre-agreed tariffs for manpower, machinery renting etc could be agreed and a specific table could be attached as Contract Annex.

Spare Parts Management. (See also *11.8. Spare Parts Management*)

- Spare parts maintenance
- Spare parts replenishment
- Spare parts storage (optional)

For more information on the specific items in the above list, please view the respective sections and chapters of the present Guidelines.

11.2. O&M contract fee

As a best practice, O&M services should be provided on a fixed fee plus escalation basis.

11.3. Contractual guarantees

The present Version 2.0 O&M Best Practice Guidelines adopts a more progressive stance regarding the contractual framework as compared to the first edition. Although some O&M Contractors still provide Performance Ratio (PR) guarantees in some cases, recent developments including the recommendations of the Global Solar Energy Standardisation Initiative show that eliminating PR guarantee and only using Availability and Response Time guarantees has several advantages.

PR is to a large extent a result of equipment choice, design and construction, which the O&M Contractor has little influence on beyond vegetation control and module cleaning. Moreover, removing PR as an O&M Contractor KPI makes power plant handover from EPC to O&M Contractor or from O&M Contractor to O&M Contractor simpler.

Eliminating the PR guarantee and using the Availability and Response Time guarantees instead is a more progressive approach that protects the Asset Owner from poor performing O&M Contractors. Availability is the KPI that best reflects O&M Contractor's service. Thanks to the Response Time guarantee, in case of events affecting the performance of the plant that are not covered by the Availability guarantee, the contractor has to intervene in a pre-agreed timeframe depending on the impact of the fault. Since there are specific points that can influence the PR originating from the contractors, these can be easily identified and addressed in the contract. Moreover, the O&M Contractor is also obliged to intervene in case of incidents not affecting the performance, referring to good industry practices in general. A further upside of eliminating the PR guarantee is that it makes the transition to a new contractor is much smoother and hence allows Lenders and Owners to pick a contractor of their choice and with the sole criterium of quality of services. Excluding PR guarantee eliminates the heavy change management process due to the necessity of recalculating the guaranteed PR in case of power plant handover, which is an obstacle in the market.

11.3.1. Availability guarantee

A best practice is a Minimum Guaranteed Availability of 98% over a year. For contractual KPI reasons, Availability should be calculated at inverter level, on an annual basis. For more information on this, see *10.1.2.8. Availability*.

The Availability achieved by the O&M Contractor is translated into Bonus Schemes and Liquidated Damages. For more information on this, see *11.4. Bonus Schemes and Liquidated Damages*.

11.3.2. Response Time guarantee

The O&M Contractor should guarantee to react on alarms received from the plant through the monitoring and supervision system within a certain period of time, 7 days a week. This translates in a minimum guaranteed Response Time. For a definition of Response Time, see *10.2.3. Response Time*.

When setting Response Time guarantees, it is recommended to differentiate between hours and periods with high and low irradiance levels as well as fault classes, i.e. the (potential) loss of energy generation capacity.

Following is an example for Response Time guarantees according to fault classes:

TABLE 6 EXAMPLES FOR FAULT CLASSES AND CORRESPONDING MINIMUM RESPONSE TIMES

NOTE: FAULT CLASSES AND THE CORRESPONDING RESPONSE TIME GUARANTEES APPLY EVEN IF THE DURATION OF THE RESPECTIVE POWER LOSS IS LESS THAN THE CORRESPONDING RESPONSE TIME GUARANTEE, PROVIDED THAT THE POWER LOSS MAY OCCUR AGAIN.

FAULT CLASS	FAULT CLASS DEFINITION	RESPONSE TIME GUARANTEE
Fault class 1	The entire plant is off, 100% power loss.	4 daytime hours
Fault class 2	More than 30% power loss or more than 300kWp down.	24 hours
Fault class 3	0%-30% power loss	36 hours

In case the replacement of an equipment is needed, the O&M Contractor should commit to make it available to the plant's site and replace the equipment within 8 business hours from the end of the Response Time if the spare part is included in the portfolio of minimum spare parts list. If the spare part is not included in the minimum spare parts list, the O&M Contractor should commit to order the spare part within 8 business hours from the end of the Response Time and to replace it on the plant area in the fastest possible way after receiving the related spare part from the equipment supplier.

In case the fault cannot be fixed by the O&M Contractor and the equipment supplier's intervention is required, the following actions are necessary:

- if the intervention requires spare parts up to the limit under the O&M cost responsibility (see *11.8. Spare Parts Management)*, the O&M Contractor may proceed without separate approval (insurance aspects to be taken into account);
- if the costs exceed the above budget limit, the Contractor should communicate the issue in writing to the Asset Owner within 8 business hours from the end of the Response Time.

Force Majeure events are excluded from Response Time obligations.

Resolution time is not guaranteed, because resolution depends on the extent of the malfunction or damage.

11.4. Bonus Schemes and Liquidated Damages

The Availability guarantees provided by the O&M Contractor can be translated into Bonus Schemes and Liquidated Damages. These ensure that the Asset Owner is compensated for losses due to lower-than-guaranteed Availability and that the O&M Contractor is motivated to improve their service in order to achieve higher Availability. Higher Availability usually leads to higher power generation and an increase of revenues for the benefit of the plant owner. Hence the Bonus Scheme agreements lead to a win-win situation for both parties and ensures that the O&M Contractor is highly motivated.

Since the O&M Contractor's responsibility is focused on the O&M works for the PV asset, other influencing factors like force majeure events, grid operator activities to reduce the plant output, grid instability or offline periods should be exempted from the O&M Contractor's responsibility and therefore from any Liquidated Damages. (See *exclusion factors in 10.1.2.8. Availability*.)

An example for Availability Bonus Schemes and Liquidated Damages can be found below:

- Bonus Schemes: if the Minimum Guaranteed Availability is overachieved, the additional revenue based on the base case scenario expected annual revenue will be equally divided (50/50) between the Asset Owner and the O&M Contractor.
- Liquidated Damages: if the Minimum Guaranteed Availability is underachieved, 100% of the lost revenue due to the Availability shortfall from the Minimum Guaranteed Availability based on the base case scenario expected annual revenue will be compensated by the O&M Contractor. This is usually translated into a reduction of the O&M annual fee.
- Bonuses can be offset against Liquidated Damages and vice versa.
- The amount of Liquidated Damages is capped at 100% of the O&M annual fee on a period of 12 months. Reaching this cap usually results in termination rights for the Asset Owner and the O&M Contractor.

11.5. Service standards

O&M Contractor is to provide the services in accordance with all laws, good industry practice, planning consents, manufacturer's warranties and operating manuals.

The Asset Owner should be entitled to instruct a third-party operator to provide the services at the O&M Contractor's cost, where the O&M Contractor fails to provide the services and fails to follow a remedy cure programme.

11.6. O&M contractors' qualification

The O&M Contractor, has the means, skills and capabilities to operate and maintain the plant in accordance with the contractual obligations. Experience and availability of a professional organisation, skilled teams and access to spare parts are criteria for the selection of the O&M Contractor. As O&M services are a combination of remote operations services and local maintenance activities, the Asset Owner should make sure that both components are well managed and interfaces between operations services and maintenance services are well defined, especially when subcontracted to different entities by the O&M Contractor where each entity is responsible and can be held accountable for the overall O&M performance.

11.7. Responsibility and accountability

The responsibility of the O&M Contractor is usually defined in the Scope of Works, which forms a part of the O&M contract. A detailed description of the O&M scope items ensure clarity of what the O&M Contractor will do during the term of the contract. In addition to the Scope of Works, the Annual Maintenance Plan (AMP) and Annual Maintenance Schedule (AMS) (please refer to attachment "Annual Maintenance Plan") outline the granularity and frequency of (predominantly) Preventive Maintenance works. The execution of the activities is being reported to the Asset Owner through the regular reporting – this forms the minimum guidelines. Best practices can be seen if the regular reporting compares the executed activities with the AMP and AMS, and outlines deviations and reasoning.

Corrective Maintenance activities, which will be performed in case of any component failure or energy generation shortfall are controlled by performance commitments signed by the O&M Contractor.

Moreover, Availability and Response Time Guarantees explained in 11.3. Contractual Guarantees of the present chapter also represent a level of accountability of the O&M Contractor.

In most countries there are strict legal requirements for security service providers. Therefore, PV power plant security should be ensured by specialised security service providers subcontracted by the O&M Contractor. The security service provider should also assume liability for the security services provided. For more information on this, see *6.10. Power plant security*.

11.8. Spare Parts Management

As explained in the *chapter 8. Spare Parts Management*, it is important to differentiate between Consumables and Spare Parts. While the former should be included in the O&M fixed fee, there are specific contractual specifications on the latter.

It is considered a best practice not to include the cost of replenishment of spare parts in the O&M fixed fee. Nevertheless, there can be exceptions to this clause, such as equipment whose unit value is below 500 EUR/MW_p, or where multiple units are aggregated up to a maximum annual amount of 2000 EUR/MW_p (numbers are given as indications), as well as situations in which spares are required due to the O&M Contractor's act or default.

Ownership of spares is with the Asset Owner while normally maintenance, storage and replenishment is the responsibility of the O&M Contractor. Besides ownership matters, it is very important to make sure, upon mutual agreement, that one of the parties undertakes the responsibility of insuring the spares: as a recommendation spare parts stored on-site should be insured by the Asset Owner and spare parts stored off-site should be insured by the O&M Contractor.

There should be a components, materials and spare parts defects warranty for 12 months from the date of installation, which should continue to apply even after expiry or termination of the O&M contract.

For more information on Spare Parts Management, see *chapter 8. Spare Parts Management*.

11.9 Power plant remote monitoring

The O&M Contractor should operate and maintain the metering system according to local regulations or norms. In some countries there are two metering systems: one that measures power injection in the grid, owned and operated by the grid operator, and one that measures power production, owned by the Asset Owner as part of the installation and operated by the O&M Contractor.

The O&M Contractor will also make sure that performance monitoring and reporting is operated and maintained according to the monitoring specifications and best practices (see *9. Data and monitoring requirements*).

The Asset Owner has the right to carry out the verification of the metering system to evaluate and control the exactitude of the measured data.

11.10. Reporting

Reporting should be done periodically, as contractually agreed between the O&M Contractor (the Technical Asset Manager) and the Asset Owner. The Asset Owner should have the right to debate the report within a certain timeframe.

For more information on industry best practices regarding Reporting, see *5.1. Reporting*.

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A ANNEX

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

		First name	Surname	Function	Data & Comms	Trainee Electrician	Trainee Electrician	Trainee Electrician	Trainee Electrician	Electrician/ supervisor	Electrician/ supervisor	Electrician/ supervisor	Electrician/ supervisor	Electrician/ supervisor	Administration	Administration	Administration	Managerial	Managerial	Managerial	Managerial
Health & Safety	Company's Services induction																				
	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 certificate etc.)																				
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 tool)																				
PV Modules	Basic knowlege about the installed product (e.g. handling, general sefety guidlines, 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																				

Planned

Not required

Required

Update required

B ANNEX

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

INFORMATION TYPE AND DEPTH OF DETAIL / AS-BUILT DOCUMENTS

NO.	MINIMUM REQUIREMENT	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	PV Modules	• Datasheets • Flash list with 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	

C ANNEX

C. 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/El ement 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 PV 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	PV Plant Energy Production; PR; Expected vs Real	

RECORD CONTROL

NO.	ACTIVITY TYPE	INFORMATION TYPE	INPUT RECORD	REFERENCES/ COMMENTS
15	Preventive Maintenance	Maintenance Plan	Preventive Maintenance Plan	
16	Preventive Maintenance	Intervention equipment/ Element name	Affected Power and Affected Production, Equipment Code / Name, Intervention Start and End Date	
17	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	
18	PV 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
19	PV Plant Documentation	Operation and maintenance	Equipment Manuals, PV 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
20	PV 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
21	Warranty Management	Claims registration	Affected Equipment, Claim Description, Occurrence Date; Communications between O&M, client and manufacturer/supplier	

D ANNEX

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

SUB GROUP	EQUIPMENT	SUB UNIT	TASK	FREQUENCY	IMPORTANCE	O&M DECISION ON FREQUENCY (BY TECHNICAL MANAGER)	W1 - W52 (REPORTING EVERY WEEK OF THE YEAR)
Documentation	as -built	AC-System	Complete and correct of documentation AC-System	initial/	necessary		
Documentation	as -built	Auxiliary Systems	Complete and correct documentation of all auxiliary systems (security, monitoring, ICT, energy	initial/	necessary		
Documentation	as -built	DC-System	Complete and correct of documentation DC-System	initial/	necessary		
Documentation	as -built	System Documentation (IEC 62443)	System Data, Wiring diagram, mechanical design, O&M information (e.g. Operation and maintenance information shall be provided and shall include, at a minimum, the following items: a) Procedures for verifying correct system operation. b) A checklist of what to do in case of a system failure. c) Emergency shutdown and isolation procedures. d) Maintenance and cleaning recommendations (if any), Test results and commissioning data,	initial/ ongoing	necessary		
Documentation	as -built	System Verification	Inspection, Testing. 1)Test continuity of equipment grounding conductors and system grounding conductors (if applicable). 2) Test polarity of all dc cables and check for correct cable identification and connection. 3) Test open-circuit voltage [Voc] for each PV source circuit. 4) Test short-circuit current [Isc] for each PV source circuit. 5) Test functionality of major system components (switchgear, controls, inverters), including inverter anti-islanding. 6) Test the insulation resistance of the dc circuit conductors	initial/ ongoing	necessary		
Documentation	O&M-Duration	Plant Audit	Audit of a power plant at take-over by O&M contractor, checking O&M reports, faults, repairs,	initial +	necessary		
Documentation	O&M-Duration	Log Book	Checking and keeping records for tickets, faults, inspection results, or other events into one log book, as well as feed back and ensuing work plan for internal purpose, client, insurance, etc.	daily	necessary		
Documentation	O&M-Duration	Maintenance	Creation of a maintenance protocole (about maintenance done according to manufacturer requirements or at least to mandatory national regulatory regulations)		necessary		
Documentation	O&M-Duration	Inspection	Creation of an inspection protocole		necessary		
Documentation	O&M-Duration	Work Plan	Action Plan following Audit, Maintenance Protocole, and Inspection Protocole, in order to	ongoing	necessary		
Documentation	O&M-Duration	Report	Ongoing reporting as specified in O&M Contract to inform client about issues, diagnosis, and repairs, as well as plant performance (Summary of failures, losses, KPIs, human activity on site)	monthly/ quarterly/ annually	necessary		
Documentation	O&M-Duration		Variance analysis	ongoing	necessary		
Power Generation	Modules		Integrity inspection	Annual	necessary		
Power Generation	Modules		Cables visual inspection	Annual	necessary		
Power Generation	Modules		Thermography inspection	Monthly	necessary		
Power Generation	Modules		Measurements inspection	Annual	necessary		
Power Generation	Modules		Retightening	Monthly	necessary		
Power Generation	Modules		Modules cleaning	Annual	necessary		
Power Generation	Modules		On-Site degradation measurement (with most accurate and available technology) with pre-defined reference modules and strings. NB: accurate module and string selection necessary + stable+high irradiation	Annual	optional/according to client		
Power Generation	LV	Array/String Junction	Integrity inspection	Semi-annual	necessary		
Power Generation	LV	Array/String Junction	Documents inspection	Semi-annual	necessary		
Power Generation	LV	Array/String Junction	Cables visual inspection	Semi-annual	necessary		
Power Generation	LV	Array/String Junction	Labelling and identification	Semi-annual	necessary		
Power Generation	LV	Array/String Junction	Electrical protections visual inspection	Semi-annual	necessary		
Power Generation	LV	Array/String Junction	Thermography inspection	Semi-annual	necessary		
Power Generation	LV Switchboard	Array/String Junction Box	Sensors functional verification	Annual	necessary		

SUB GROUP	EQUIPMENT	SUB UNIT	TASK	FREQUENCY	IMPORTANCE	O&M DECISION ON FREQUENCY (BY TECHNICAL MANAGER)	W1 - W52 (REPORTING EVERY WEEK OF THE YEAR)
Power Generation	LV Switchboard	Generator Junction Box	Measurements inspection	Annual	necessary		
Power Generation	LV Switchboard	Generator Junction Box	Electrical protection correct operation	Monthly	necessary		
Power Generation	LV Switchboard	Generator Junction Box	Check fuse status	Annual	necessary		
Power Generation	LV Switchboard	Generator Junction Box	Monitoring operation test	Semi-annual	necessary		
Power Generation	LV Switchboard	Generator Junction Box	Check cables terminals	Annual	necessary		
Power Generation	LV Switchboard	Generator Junction Box	General cleaning	Annual	necessary		
Power Generation	LV Switchboard	AC Combiner Switchboard	Integrity inspection	Semi-annual	necessary		
Power Generation	LV Switchboard	AC Combiner Switchboard	Documents inspection	Semi-annual	necessary		
Power Generation	LV Switchboard	AC Combiner Switchboard	Cables visual inspection	Annual	necessary		
Power Generation	LV Switchboard	AC Combiner Switchboard	Labelling and identification	Annual	necessary		
Power Generation	LV Switchboard	AC Combiner Switchboard	Electrical protections visual inspection	Semi-annual	necessary		
Power Generation	LV Switchboard	AC Combiner Switchboard	Thermography inspection	Semi-annual	necessary		
Power Generation	LV Switchboard	AC Combiner Switchboard	Sensors functional verification	Annual	necessary		
Power Generation	LV Switchboard	AC Combiner Switchboard	Measurements inspection	Semi-annual	necessary		
Power Generation	LV Switchboard	AC Combiner Switchboard	Check correct operation	Annual	necessary		
Power Generation	LV Switchboard	AC Combiner Switchboard	Electrical protection correct operation	Annual	necessary		
Power Generation	LV Switchboard	AC Combiner Switchboard	Check fuse status	Annual	necessary		
Power Generation	LV Switchboard	AC Combiner Switchboard	Check cables terminals	Monthly	necessary		
Power Generation	LV Switchboard	AC Combiner Switchboard	General cleaning	Annual	necessary		
Power Generation	LV Switchboard	AUX Switchboard	Integrity inspection	Semi-annual	necessary		
Power Generation	LV Switchboard	AUX Switchboard	Documents inspection	Semi-annual	necessary		
Power Generation	LV Switchboard	AUX Switchboard	Cables visual inspection	Semi-annual	necessary		
Power Generation	LV Switchboard	AUX Switchboard	Labelling and identification	Semi-annual	necessary		
Power Generation	LV Switchboard	AUX Switchboard	Electrical protections visual inspection	Semi-annual	necessary		
Power Generation	LV Switchboard	AUX Switchboard	Thermography inspection	Semi-annual	necessary		
Power Generation	LV Switchboard	AUX Switchboard	Measurements inspection	Semi-annual	necessary		
Power Generation	LV Switchboard	AUX Switchboard	Electrical protection correct operation	Semi-annual	necessary		
Power Generation	LV Switchboard	AUX Switchboard	Check fuse status	Semi-annual	necessary		
Power Generation	LV Switchboard	AUX Switchboard	Check cables terminals	Semi-annual	necessary		
Power Generation	LV Switchboard	AUX Switchboard	General cleaning	Semi-annual	necessary		
Power Generation	Cables	DC Cables	Integrity inspection	Semi-annual	necessary		
Power Generation	Cables	DC Cables	Cables visual inspection	Annual	necessary		
Power Generation	Cables	DC Cables	Labelling and identification	Annual	necessary		
Power Generation	Cables	AC Cables	Cables visual inspection	Semi-annual	necessary		
Power Generation	Cables	AC Cables	Labelling and identification	Annual	necessary		
Power Generation	Cables	AC Cables	Measurements inspection	Semi-annual	necessary		
Power Generation	Inverters	Central Inverters	Safety equipment inspection	Annual	necessary		
Power Generation	Inverters	Central Inverters	Integrity inspection	Semi-annual	necessary		
Power Generation	Inverters	Central Inverters	Documents inspection	Semi-annual	necessary		

SUB GROUP	EQUIPMENT	SUB UNIT	TASK	FREQUENCY	IMPORTANCE	O&M DECISION ON FREQUENCY (BY TECHNICAL MANAGER)	W1 - W52 (REPORTING EVERY WEEK OF THE YEAR)
Power Generation	Inverters	Central Inverters	Cables visual inspection	Annual	necessary		
Power Generation	Inverters	Central Inverters	Labelling and identification	Annual	necessary		
Power Generation	Inverters	Central Inverters	Electrical protections visual inspection	Semi-annual	necessary		
Power Generation	Inverters	Central Inverters	Thermography inspection	Annual	necessary		
Power Generation	Inverters	Central Inverters	Sensors functional verification	Annual	necessary		
Power Generation	Inverters	Central Inverters	Measurements inspection	Annual	necessary		
Power Generation	Inverters	Central Inverters	Parameters check	Semi-annual	necessary		
Power Generation	Inverters	Central Inverters	Electrical protection correct operation	Semi-annual	necessary		
Power Generation	Inverters	Central Inverters	Check ventilation system operation	Annual	necessary		
Power Generation	Inverters	Central Inverters	Check fuse status	Annual	necessary		
Power Generation	Inverters	Central Inverters	Check cables terminals	Semi-annual	necessary		
Power Generation	Inverters	Central Inverters	Battery replacement	Every five years	According to manufacturers recomendations		
Power Generation	Inverters	Central Inverters	Fans replacement	Every five years	According to manufacturers recomendations		
Power Generation	Inverters	Central Inverters	General cleaning	Semi-annual	necessary		
Power Generation	Inverters	Central Inverters	Ventilation cleaning	Annual	necessary		
Power Generation	Inverters	String Inverters	Safety equipment inspection	Semi-annual	necessary		
Power Generation	Inverters	String Inverters	Integrity inspection	Semi-annual	necessary		
Power Generation	Inverters	String Inverters	Cables visual inspection	Annual	necessary		
Power Generation	Inverters	String Inverters	Labelling and identification	Semi-annual	necessary		
Power Generation	Inverters	String Inverters	Electrical protections visual inspection	Semi-annual	necessary		
Power Generation	Inverters	String Inverters	Thermography inspection	Annual	necessary		
Power Generation	Inverters	String Inverters	Measurements inspection	Semi-annual	necessary		
Power Generation	Inverters	String Inverters	Parameters check	Annual	necessary		
Power Generation	Inverters	String Inverters	Electrical protection correct operation	Annual	necessary		
Power Generation	Inverters	String Inverters	Check ventilation system operation	Semi-annual	necessary		
Power Generation	Inverters	String Inverters	Check cables terminals	Annual	necessary		
Power Generation	Inverters	String Inverters	Battery replacement	Every five years	According to manufacturers recomendations		
Power Generation	Inverters	String Inverters	Fans replacement	Every five years	According to manufacturers recomendations		
Power Generation	Inverters	String Inverters	General cleaning	Annual	necessary		
Power Generation	Inverters	String Inverters	Ventilation cleaning	Semi-annual	necessary		
HV Systems	Cables	HV Cables	Cables visual inspection	Semi-annual	necessary		
HV Systems	Cables	HV Cables	Labelling and identification	Semi-annual	necessary		
HV Systems	Power Transformer		Integrity inspection	Semi-annual	necessary		
HV Systems	Power Transformer		Cables visual inspection	Annual	necessary		
HV Systems	Power Transformer		Mechanical visual inspection	Annual	necessary		
HV Systems	Power Transformer		Labelling and identification	Annual	necessary		
HV Systems	Power Transformer		Thermography inspection	Semi-annual	necessary		

SUB GROUP	EQUIPMENT	SUB UNIT	TASK	FREQUENCY	IMPORTANCE	O&M DECISION ON FREQUENCY (BY TECHNICAL MANAGER)	W1 - W52 (REPORTING EVERY WEEK OF THE YEAR)
HV Systems	Power Transformer		Sensors functional verification	Semi-annual	necessary		
HV Systems	Power Transformer		Measurements inspection	Semi-annual	necessary		
HV Systems	Power Transformer		Parameters check	Annual	necessary		
HV Systems	Power Transformer		Check correct operation	Semi-annual	necessary		
HV Systems	Power Transformer		Check cables terminals	Semi-annual	necessary		
HV Systems	Power Transformer		Power transformer cleaning	Semi-annual	necessary		
HV Systems	HV Switchgear		Integrity inspection	Annual	necessary		
HV Systems	HV Switchgear		Cables visual inspection	Annual	necessary		
HV Systems	HV Switchgear		Mechanical visual inspection	Semi-annual	necessary		
HV Systems	HV Switchgear		Labelling and identification	Annual	necessary		
HV Systems	HV Switchgear		Electrical protections visual inspection	Semi-annual	necessary		
HV Systems	HV Switchgear		Thermography inspection	Semi-annual	necessary		
HV Systems	HV Switchgear		Sensors functional verification	Annual	necessary		
HV Systems	HV Switchgear		Measurements inspection	Annual	necessary		
HV Systems	HV Switchgear		Check correct operation	Annual	necessary		
HV Systems	HV Switchgear		Check fuse status	Annual	necessary		
HV Systems	HV Switchgear		Check cables terminals	Semi-annual	necessary		
HV Systems	HV Switchgear		General cleaning	Annual	necessary		
HV Systems	HV Switchgear		Mechanical lubrication	Semi-annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Integrity inspection	Annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Documents inspection	Annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Cables visual inspection	Annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Labelling and identification	Annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Electrical protections visual inspection	Annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Thermography inspection	Annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Sensors functional verification	Semi-annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Measurements inspection	Semi-annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Parameters check	Annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Check correct operation	Semi-annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Electrical protection correct operation	Annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Check fuse status	Annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Software maintenance	Annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Monitoring operation test	Annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Check cables terminals	Annual	necessary		
HV Systems	Main Switchboard	Main AUX Switchboard	Battery replacement	Every five years	According to manufacturers recomendations		
HV Systems	Main Switchboard	Main AUX Switchboard	General cleaning	Annual	necessary		
HV Systems	Main Switchboard	Main AC Switchboard	Integrity inspection	Annual	necessary		
HV Systems	Main Switchboard	Main AC Switchboard	Documents inspection	Semi-annual	necessary		
HV Systems	Main Switchboard	Main AC Switchboard	Cables visual inspection	Annual	necessary		

SUB GROUP	EQUIPMENT	SUB UNIT	TASK	FREQUENCY	IMPORTANCE	O&M DECISION ON FREQUENCY (BY TECHNICAL MANAGER)	W1 - W52 (REPORTING EVERY WEEK OF THE YEAR)
HV Systems	Main Switchboard	Main AC Switchboard	Labelling and identification	Annual	necessary		
HV Systems	Main Switchboard	Main AC Switchboard	Electrical protections visual inspection	Annual	necessary		
HV Systems	Main Switchboard	Main AC Switchboard	Thermography inspection	Semi-annual	necessary		
HV Systems	Main Switchboard	Main AC Switchboard	Sensors functional verification	Annual	necessary		
HV Systems	Main Switchboard	Main AC Switchboard	Measurements inspection	Annual	necessary		
HV Systems	Main Switchboard	Main AC Switchboard	Check correct operation	Annual	necessary		
HV Systems	Main Switchboard	Main AC Switchboard	Electrical protection correct operation	Annual	necessary		
HV Systems	Main Switchboard	Main AC Switchboard	Check fuse status	Annual	necessary		
HV Systems	Main Switchboard	Main AC Switchboard	Check cables terminals	Semi-annual	necessary		
HV Systems	Main Switchboard	Main AC Switchboard	General cleaning	Annual	necessary		
HV Systems	Power Monitoring	Power Analyser	Battery replacement	Every five years	According to manufacturers recomendations		
HV Systems	Power Monitoring	Power Analyser	Cables visual inspection	Annual	necessary		
HV Systems	Power Monitoring	Power Analyser	Labelling and identification	Annual	necessary		
HV Systems	Power Monitoring	Power Analyser	Measurements inspection	Annual	necessary		
HV Systems	Power Monitoring	Power Analyser	Integrity inspection	Annual	necessary		
HV Systems	Power Monitoring	Power Analyser	Software maintenance	Annual	necessary		
HV Systems	Power Monitoring	Power Analyser	Monitoring operation test	Semi-annual	necessary		
HV Systems	Power Monitoring	Power Analyser	Parameters check	Semi-annual	necessary		
HV Systems	Power Monitoring	Power Analyser	General cleaning	Semi-annual	necessary		
HV Systems	Power Monitoring	Energy Meter	General cleaning	Annual	necessary		
HV Systems	Power Monitoring	Energy Meter	Cables visual inspection	Annual	necessary		
HV Systems	Power Monitoring	Energy Meter	Labelling and identification	Annual	necessary		
HV Systems	Power Monitoring	Energy Meter	Measurements inspection	Annual	necessary		
HV Systems	Power Monitoring	Energy Meter	Integrity inspection	Annual	necessary		
HV Systems	Power Monitoring	Energy Meter	Monitoring operation test	Annual	necessary		
HV Systems	Power Monitoring	Energy Meter	Parameters check	Annual	necessary		
HV Systems	Power Monitoring	Energy Meter	Check cables terminals	Annual	necessary		
HV Systems	Power Monitoring	Multifunctional HV Protection	Battery replacement	Every five years	According to manufacturers recomendations		
HV Systems	Power Monitoring	Multifunctional HV	Parameters check	Annual	necessary		
HV Systems	Power Monitoring	Multifunctional HV	Cables visual inspection	Annual	necessary		
HV Systems	Power Monitoring	Multifunctional HV	Labelling and identification	Annual	necessary		
HV Systems	Power Monitoring	Multifunctional HV	Integrity inspection	Annual	necessary		
HV Systems	Power Monitoring	Multifunctional HV	Software maintenance	Annual	necessary		
HV Systems	Power Monitoring	Multifunctional HV	Monitoring operation test	Annual	necessary		
HV Systems	Power Monitoring	Multifunctional HV	General cleaning	Annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	Battery replacement	Every five years	According to manufacturers recomendations		

SUB GROUP	EQUIPMENT	SUB UNIT	TASK	FREQUENCY	IMPORTANCE	O&M DECISION ON FREQUENCY (BY TECHNICAL MANAGER)	W1 - W52 (REPORTING EVERY WEEK OF THE YEAR)
HV Systems	Power Monitoring	Power Control Unit	Electrical protection correct operation	Semi-annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	Battery inspection	Annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	Cables visual inspection	Semi-annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	Labelling and identification	Semi-annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	Sensors functional verification	Semi-annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	Integrity inspection	Semi-annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	Check correct operation	Semi-annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	Software maintenance	Semi-annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	Electrical protections visual inspection	Semi-annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	Monitoring operation test	Semi-annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	Check cables terminals	Semi-annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	Parameters check	Semi-annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	Measurements inspection	Annual	necessary		
HV Systems	Power Monitoring	Power Control Unit	General cleaning	Annual	necessary		
General Utilities	Backup Power Supply	UPS	Integrity inspection	Annual	necessary		
General Utilities	Backup Power Supply	UPS	Cables visual inspection	Annual	necessary		
General Utilities	Backup Power Supply	UPS	Thermography inspection	Annual	necessary		
General Utilities	Backup Power Supply	UPS	Electrical protection correct operation	Annual	necessary		
General Utilities	Backup Power Supply	UPS	Battery inspection	Annual	necessary		
General Utilities	Backup Power Supply	UPS	Check ventilation system operation	Annual	necessary		
General Utilities	Backup Power Supply	UPS	Check cables terminals	Annual	necessary		
General Utilities	Backup Power Supply	UPS	General cleaning	Semi-annual	necessary		
General Utilities	Backup Power Supply	Emergency Generator	Integrity inspection	Semi-annual	necessary		
General Utilities	Backup Power Supply	Emergency Generator	Mechanical visual inspection	Annual	necessary		
General Utilities	Backup Power Supply	Emergency Generator	Measurements inspection	Annual	necessary		
General Utilities	Backup Power Supply	Emergency Generator	Parameters check	Annual	necessary		
General Utilities	Backup Power Supply	Emergency Generator	Check correct operation	Annual	necessary		
General Utilities	Backup Power Supply	Emergency Generator	Electrical protection correct operation	Semi-annual	necessary		
General Utilities	Backup Power Supply	Emergency Generator	Battery inspection	Semi-annual	necessary		
General Utilities	Backup Power Supply	Emergency Generator	Mechanical verification	Semi-annual	necessary		
General Utilities	Backup Power Supply	Emergency Generator	Retightening	Annual	necessary		
General Utilities	Backup Power Supply	Emergency Generator	Filters replacement	Every five years	According to manufacturers recomendations		
General Utilities	General Utilities Switchboard		Integrity inspection	Semi-annual	necessary		
General Utilities	General Utilities Switchboard		Documents inspection	Semi-annual	necessary		
General Utilities	General Utilities Switchboard		Cables visual inspection	Semi-annual	necessary		
General Utilities	General Utilities Switchboard		Labelling and identification	Semi-annual	necessary		
General Utilities	General Utilities Switchboard		Thermography inspection	Annual	necessary		
General Utilities	General Utilities Switchboard		Measurements inspection	Semi-annual	necessary		

SUB GROUP	EQUIPMENT	SUB UNIT	TASK	FREQUENCY	IMPORTANCE	O&M DECISION ON FREQUENCY (BY TECHNICAL MANAGER)	W1 - W52 (REPORTING EVERY WEEK OF THE YEAR)
General Utilities	General Utilities Switchboard		Electrical protection correct operation	Semi-annual	necessary		
General Utilities	General Utilities Switchboard		Check cables terminals	Annual	necessary		
General Utilities	General Utilities Switchboard		General cleaning	Semi-annual	necessary		
General Utilities	Auxiliary System	Lights and Electric Sockets	Integrity inspection	Annual	necessary		
General Utilities	Auxiliary System	Lights and Electric Sockets	Cables visual inspection	Annual	necessary		
General Utilities	Auxiliary System	Lights and Electric Sockets	Measurements inspection	Semi-annual	necessary		
General Utilities	Auxiliary System	Lights and Electric Sockets	Check correct operation	Annual	necessary		
General Utilities	Auxiliary System	Lights and Electric Sockets	General cleaning	Semi-annual	necessary		
General Utilities	Auxiliary System	HVAC	Air conditioning visual inspection	Semi-annual	necessary		
General Utilities	Auxiliary System	HVAC	Heater visual inspection	Semi-annual	necessary		
General Utilities	Auxiliary System	HVAC	Ventilation visual inspection	Semi-annual	necessary		
General Utilities	Auxiliary System	HVAC	Sensors functional verification	Semi-annual	necessary		
General Utilities	Auxiliary System	HVAC	Measurements inspection	Semi-annual	necessary		
General Utilities	Auxiliary System	HVAC	Check correct operation	Semi-annual	necessary		
General Utilities	Auxiliary System	HVAC	Check ventilation system operation	Semi-annual	necessary		
General Utilities	Auxiliary System	HVAC	Air conditioning cleaning	Semi-annual	necessary		
General Utilities	Auxiliary System	HVAC	Ventilation cleaning	Semi-annual	necessary		
General Utilities	Auxiliary System	HVAC	Heater cleaning	Semi-annual	necessary		
General Utilities	Water Supply System		Integrity inspection	Annual	necessary		
General Utilities	Fire Detection Central		Sensors functional verification	Semi-annual	necessary		
General Utilities	Fire Detection Central		Check correct operation	Semi-annual	necessary		
General Utilities	Fire Detection Central		Electrical protection correct operation	Semi-annual	necessary		
General Utilities	Fire Detection Central		Battery inspection	Semi-annual	necessary		
General Utilities	Fire Detection Central		General cleaning	Annual	necessary		
General Utilities	Fire Detection Central		Cameras & Sensors cleaning	Semi-annual	necessary		
General Utilities	Lightning Protection		Integrity inspection	Annual	necessary		
General Utilities	Low Voltage Power Transformer		Integrity inspection	Semi-annual	necessary		
General Utilities	Low Voltage Power Transformer		Cables visual inspection	Semi-annual	necessary		
General Utilities	Low Voltage Power Transformer		Mechanical visual inspection	Semi-annual	necessary		
General Utilities	Low Voltage Power Transformer		Labelling and identification	Annual	necessary		
General Utilities	Low Voltage Power Transformer		Thermography inspection	Annual	necessary		
General Utilities	Low Voltage Power Transformer		Sensors functional verification	Semi-annual	necessary		
General Utilities	Low Voltage Power Transformer		Measurements inspection	Semi-annual	necessary		
General Utilities	Low Voltage Power Transformer		Parameters check	Semi-annual	necessary		
General Utilities	Low Voltage Power Transformer		Check correct operation	Semi-annual	necessary		
General Utilities	Low Voltage Power Transformer		Check cables terminals	Semi-annual	necessary		
General Utilities	Low Voltage Power Transformer		Power transformer cleaning	Semi-annual	necessary		
Infrastructure	Field	Fence	Integrity inspection	Annual	necessary		
Infrastructure	Field	Fence	Mechanical lubrication	Annual	necessary		

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Infrastructure	Field	Vegetation	Vegetation clearing	Semi-annual	necessary		
Infrastructure	Field	Paths	Integrity inspection	Semi-annual	necessary		
Infrastructure	Field	Paths	Vegetation clearing	Semi-annual	necessary		
Infrastructure	Field	Drainage System	General cleaning	Annual	necessary		
Infrastructure	Field	Manholes	Integrity inspection	Semi-annual	necessary		
Infrastructure	Buildings		Integrity inspection	Annual	necessary		
Infrastructure	Buildings		Documents inspection	Annual	necessary		
Infrastructure	Buildings		General cleaning	Annual	necessary		
Infrastructure	Safety		Safety equipment inspection	Annual	necessary		
Infrastructure	Safety		Check correct operation	Semi-annual	necessary		
Infrastructure	PV Support Structure	Fixed Structure	Integrity inspection	Semi-annual	necessary		
Infrastructure	PV Support Structure	Fixed Structure	Retightening	Semi-annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Integrity inspection	Annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Cables visual inspection	Semi-annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Mechanical visual inspection	Semi-annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Labelling and identification	Annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Thermography inspection	Annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Measurements inspection	Semi-annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Parameters check	Semi-annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Check correct operation	Annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Electrical protection correct operation	Semi-annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Monitoring operation test	Annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Check cables terminals	Semi-annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Retightening	Semi-annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Battery replacement	Every five years	According to manufacturers recomendations		
Infrastructure	PV Support Structure	Solar Tracker	General cleaning	Semi-annual	necessary		
Infrastructure	PV Support Structure	Solar Tracker	Mechanical lubrication	Annual	necessary		
Monitoring System	Weather Station		Integrity inspection	Annual	necessary		
Monitoring System	Weather Station		Cables visual inspection	Annual	necessary		
Monitoring System	Weather Station		Sensors functional verification	Annual	necessary		
Monitoring System	Weather Station		Measurements inspection	Annual	necessary		
Monitoring System	Weather Station		Check correct operation	Semi-annual	necessary		
Monitoring System	Weather Station		Electrical protection correct operation	Annual	necessary		
Monitoring System	Weather Station		Battery inspection	Annual	necessary		
Monitoring System	Weather Station		Monitoring operation test	Semi-annual	necessary		
Monitoring System	Weather Station		General cleaning	Annual	necessary		
Monitoring System	Weather Station		Cameras & Sensors cleaning	Annual	necessary		
Monitoring System	Weather Station	Irradiation Sensors	Integrity inspection	Annual	necessary		
Monitoring System	Weather Station	Irradiation Sensors	Cables visual inspection	Semi-annual	necessary		

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Monitoring System	Weather Station	Irradiation Sensors	Sensors functional verification	Semi-annual	necessary		
Monitoring System	Weather Station	Irradiation Sensors	Sensors calibration	Annual	necessary		
Monitoring System	Weather Station	Irradiation Sensors	Cameras & Sensors cleaning	Annual	necessary		
Monitoring System	Monitoring System Cabling		Cables visual inspection	Semi-annual	necessary		
Monitoring System	Monitoring System Cabling		Labelling and identification	Semi-annual	necessary		
Monitoring System	Monitoring System Cabling		Monitoring operation test	Semi-annual	necessary		
Monitoring System	Communication Board		Integrity inspection	Annual	necessary		
Monitoring System	Communication Board		Documents inspection	Annual	necessary		
Monitoring System	Communication Board		Cables visual inspection	Annual	necessary		
Monitoring System	Communication Board		Electrical protection correct operation	Annual	necessary		
Monitoring System	Communication Board		Battery inspection	Annual	necessary		
Monitoring System	Communication Board		Check ventilation system operation	Annual	necessary		
Monitoring System	Communication Board		Monitoring operation test	Annual	necessary		
Monitoring System	Communication Board		Check cables terminals	Annual	necessary		
Monitoring System	Communication Board		General cleaning	Annual	necessary		
Monitoring System	Communication Board		Ventilation cleaning	Annual	necessary		
Monitoring System	Monitoring System Software		Measurements inspection	Annual	necessary		
Monitoring System	Monitoring System Software		Software maintenance	Monthly	necessary		
Monitoring System	Monitoring System Software		Monitoring operation test	Annual	necessary		
Monitoring System	Data Logger		Integrity inspection	Semi-annual	necessary		
Monitoring System	Data Logger		Check correct operation	Semi-annual	necessary		
Monitoring System	Data Logger		Monitoring operation test	Semi-annual	necessary		
Security System	Security System Central		Parameters check	Semi-annual	necessary		
Security System	Security System Central		Check correct operation	Semi-annual	necessary		
Security System	Security System Central		Battery inspection	Annual	necessary		
Security System	Security System Central		Check ventilation system operation	Semi-annual	necessary		
Security System	Security System Central		General cleaning	Annual	necessary		
Security System	System CCTV		Integrity inspection	Annual	necessary		
Security System	System CCTV		Sensors functional verification	Annual	necessary		
Security System	System CCTV		Cameras & Sensors cleaning	Annual	necessary		
Security System	Intrusion Systems		Integrity inspection	Annual	necessary		
Security System	Intrusion Systems		Sensors functional verification	Semi-annual	necessary		
Security System	Intrusion Systems		Cameras & Sensors cleaning	Annual	necessary		
Security System	Security System Cabling		Cables visual inspection	Semi-annual	necessary		
Security System	Security System Cabling		Labelling and identification	Semi-annual	necessary		
Security System	Security System Board		Integrity inspection	Annual	necessary		
Security System	Security System Board		Documents inspection	Semi-annual	necessary		
Security System	Security System Board		Cables visual inspection	Semi-annual	necessary		

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Security System	Security System Board		Electrical protection correct operation	Semi-annual	necessary		
Security System	Security System Board		Battery inspection	Semi-annual	necessary		
Security System	Security System Board		Monitoring operation test	Annual	necessary		
Security System	Security System Board		Check cables terminals	Semi-annual	necessary		
Security System	Security System Board		General cleaning	Annual	necessary		
Security System	Security System Board		Ventilation cleaning	Annual	necessary		
Spare parts			Inventory of stock	Annual	necessary	e.g. Monthly	
Spare parts			Visual inspection of stock conditions	Quarterly	necessary		
Spare parts			Stock replenishment	Ongoing	necessary		
Spare parts			Review failure rates and adjust stock keeping	Annual	necessary	e.g. Monthly	



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