Best Practice Checklist for O&M

☑/☒	Technical aspect & what to look for in the O&M contract
A	**Definitions, interpretation**
☐	1. Is there a set of definitions of important terms provided and are those clear and understood by all stakeholders?
B	**Purpose and responsibilities**
☐	2. Is the fundamental purpose (goals) of the contract clearly defined?
☐	3. Are the roles and responsibilities (and boundary conditions) of the multiple stakeholders within the contract clear and understood?
C	**Scope of works – environmental, health and safety** Note: 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.
☐	4. Environment • Regular inspection of transformers and bunds for leaks (according to the annual maintenance plan) • Recycling of broken panels and electric waste • Sensible water usage for module cleaning • Proper environmental management plan in place
☐	5. Health and safety (H&S) • Properly controlled access and supervision in the solar plant – necessary boundaries and site restrictions • Proper induction to ensure awareness of risks and hazards • Proper training and certification on the specifics of a PV plant and voltage level • Hazard identification/marking • Wiring sequence marking • H&S legislation available • Established personal protective equipment (PPE) (not exhaustive list): safety shoes, high visibility clothing, helmet, gloves (and/or insulated gloves), slash masks and glasses (depending on the site), fire retardant and/or arc flash rated PPE where necessary • Calibrated and certified equipment (full documentation available)
D	**Scope of works – operations**
☐	6. Documentation Management System (DSM) • As-built documentation / IEC62446 (see “Best Practice Checklist for As-Build Documents – Type and Details”) ○ Site information ○ Project drawings ○ Project studies ○ Studies according to national regulation requirements ○ PV modules ○ Inverters

	○ Medium voltage / inverter cabin ○ MV/LV transformer ○ HV switchgear ○ UPS and batteries ○ Mounting • Management and control ○ Define type of storage (physical or/and electronical) ○ Ensure electronic copy of all documents ○ Ensure controlled access to documents ○ Ensure authorization for modifications – keep a logbook on name of person who modified the document, date of modification, reason for modification and further information e.g. link to the work orders and service activities ○ Ensure history of the documents (versioning) • Record control (see “Best Practice Checklist for Record Control”)
☐	7. [Best practice] Predictive maintenance • Define scope of this cluster, the type of performance analysis, the level (portfolio level, plant level, inverter level, string level) • Define the monitoring requirements needed to perform predictive maintenance, provide basic trending and comparison functionality
☐	8. Power generation forecasting • Ensure a service level agreement with the forecast provider • Define the purpose and consequently the requirements for power forecasting (e.g. time horizon, time resolution, update frequency)
☐	9. Reporting (see “Best Practice Checklist for Reporting Indicators”)
☐	10. Regulatory compliance • Grid code compliance: plant controls (e.g. ability for emergency shut-downs or curtailment according to grid regulations) • PPA compliance • Building permits (if applicable) • Environmental permits • Specific regulation for the site (e.g. vegetation management, disposal of green waste)
☐	11. Management of change: define responsibilities and involvement when PV plant needs to be adjusted after the Commercial Operation Date: e.g. spare parts, site operation plan, annual maintenance plan etc.
☐	12. Warranty management • Warranty of Good Execution of Works • Warranty of Equipment • Performance Warranty: agree on reporting period • Classification of anomalies and malfunctions: Pending Works, Insufficiencies, Defects, Failure or malfunction of equipment
☐	13. Insurance claims management
E	**Scope of works – maintenance**

☐	14. Inclusion of an adequate Preventive Maintenance Plan
☐	15. The minimum requirements for preventative tasks and their frequency follow the manufacturer's guidelines when applicable
☐	16. The minimum requirements for preventative tasks and their frequency should respect relevant national standards
☐	17. Corrective maintenance (CM) • Fault diagnosis (troubleshooting) • Repair and temporary repairs • Agreed response times and/or minimum repair times • Clear definition of "boarders" and "limitations" of CM tasks, especially with preventative maintenance and extraordinary maintenance. Definition of yearly cap of CM works (when applicable)
☐	18. Extraordinary maintenance • Define what is included in this cluster ○ Damages that are a consequence of a Force Majeure event ○ Damages as a consequence of a theft or a fire ○ Serial defects on equipment, occurring suddenly and after months or years from plant start-up ○ Modifications required by regulatory changes ○ Agreed interventions for reconditioning, renewal and technological updating • Define the rules on how to execute tasks and prepare quotations – ways of payment
☐	19. Additional services: define what is included in this cluster and how this service is paid (non-exhaustive list) • Module cleaning • Vegetation management • Road maintenance • Snow removal • Pest control • Waste disposal • Maintenance of buildings • Perimeter fencing and repairs • Maintenance of security equipment • String measurements – to the extent exceeding the agreed level of preventative maintenance • Thermal inspections – to the extent exceeding the agreed level of preventative maintenance • Meter weekly/monthly readings and data entry on fiscal registers or in authority web portals for FiT tariff assessment (where applicable)
F	**Scope of works – data and monitoring**
☐	20. Irradiance measurements • Measurement in the POA according to the Secondary Standard or First Class quality classification (ISO9060:1990) • Minimum requirement: one measurement device (pyranometer of high quality) • [Best practice] At least 2 pyranometers

- If different array orientations, one pyranometer per orientation – careful assignment for proper calculation of PR and yield
- Sensors placed at the least shaded location
- Sensors installed according to manufacturer's guidelines
- Preventative maintenance and calibration according to manufacturer's guidelines
- Set irradiance to be recorded with averages of 15 min (minimum requirement) or 1 min and less (best practice)
- High quality satellite-based data to complement terrestrial measurements [best practice] – mainly for monthly and annual values and not daily since the RMSE is high (8-14%)
- Minimum requirements for satellite data: hourly granularity or 15 min. Set data to be retrieved once per day at least

☐ 21. Module temperature measurements

- Temperature sensor properly installed according to manufacturer's guidelines
- Use of stable thermally conductive glue to the middle of the backside of the module in the middle of the array, in the center of the cell away from junction box
- Accuracy should be <±1 C including signal conditioning
- For large systems, different representative positions for installing the sensor should be considered: module at the center of the array and at the edge of this module where temperature variations are expected

☐ 22. Local meteorological data

- [Best practice] Ambient temperature and wind speed with sensors installed according to manufacturer's guidelines
- Ambient temp with shielded thermometer e.g. PT100
- Wind speed with anemometer at 10 m height above ground level
- For large plants >10 MW automated data from an independent nearby meteo source to smooth local phenomena and installation specific results

☐ 23. String measurements

- If not DC input current monitoring at inverter level, then current monitoring at string level is recommended – depending on module technology, combined strings (harnesses) can help reducing operating costs
- [Best practice] Increase up-time for timely detection of faults: 1 sec sampling and 1 min averaging at data logger, maximum two strings current measurement in parallel

☐ 24. Inverter measurement

- AC level: energy and power data should be collected
- Energy data should be cumulative values over the lifetime of the inverter
- Collect all inverter alarms – important to plan your maintenance activities (corrective and preventative)
- Monitor and manage control settings at the inverter level and the grid injection level
- DC input measurements <1s sampling and <1min averaging
- DC voltage to be measured and stored separately for allowing MPP-tracking and array performance problems
- [Best practice] measure all parameter from the inverters including internal temperature, isolation level etc.

☐ 25. Configuration

	• In cases of change of O&M contractor (or recommissioning of the monitoring system), the configuration of the monitoring system and the data loggers should be checked • [Best practice] if technically available, auto-configuration is recommended – e.g. automatic collection of inverter and sensor IDs and labels • Back up of the configuration should be in place
☐	26. Energy meter • Collection of energy meter data by the monitoring system in daily basis and with 15 min granularity • High accuracy energy meter is required – uncertainty of ±0.5% for plants >100 kWp • The above point can be considered as best practice for plants smaller than 100 kWp
☐	27. AC circuit / protection relay • [Best practice] Monitor the AC switch position for (sub) plants. Read the alarms from the protection relay via communication bus if possible
☐	28. Data loggers • Sufficient memory to store at least one month of data • Historical data should be backed up • After communication failure, the data logger should resend all pending information • The entire installation (monitoring system, signal converters, data loggers, measurement devices) should be protected by a UPS • [Best practices] Memory to store at least six months of data and full data backup in the cloud. Separate remote server to monitor the status of the data loggers and inform the operations. The system should be an open protocol to allow transition between monitoring platforms. If possible, reboot itself once per day (during night time) to increase reliability

☐	29. Alarms
	• Minimum requirement: alarms sent by email (non-exhaustive list)
	  ○ Loss of communication
	  ○ Plant stop
	  ○ Inverter stop
	  ○ Plant with low performance
	  ○ Inverter with low performance (e.g. due to overheating)
	• [Best practice] (non-exhaustive list)
	  ○ String without current
	  ○ Plant under UPS operation
	  ○ Intrusion detection
	  ○ Fire alarm detection
	  ○ Discretion alarm (or alarm aggregation)

☐	30. Dashboard / web portal
	• Minimum requirements for features of the monitoring system (non-exhaustive list)
	  ○ Web portal accessible 24h/365d
	  ○ Graphs of irradiation, energy production, performance and yield
	  ○ Downloadable tables with all the registered figures
	  ○ Alarms register
	• [Best practices] (non-exhaustive list)

	○ User configurable dashboard ○ User configurable alarms ○ User configurable reports ○ Ticket management
☐	31. Data format • Data format of recorded files according to IEC61724 – clearly documented • Data loggers should collect alarms according to manufacturer's format
☐	32. Communication from the site to the monitoring servers • Best network connectivity with sufficient bandwidth according to the available monitoring system • DSL connection preferred if available at the PV site – industrial routers recommended • [Best practice] GPRS-connection as back up • For sites >1 MW 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 • Data security should be ensured: 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 • Communication cables must be shielded and protected by direct sunlight • Physical distance between DC or AC power cables and communication cables should be ensured • Cables with different polarities must be clearly distinguishable (label or color) for avoiding polarity connection errors
G	**Scope of works – spare parts management**
☐	33. Definition of ownership and responsibility of insurance
☐	34. Define separate list of consumables if applicable (e.g. tools and fuses)
☐	35. Stocking level: consider initial EPC list and the following parameters • Frequency of failure • Impact of failure • Cost of spare part • Degradation over time • Possibility of consignment stock with the manufacturer
☐	36. Location of storage/warehouse • Proximity to the plant • Security • Environmental conditions
☐	37. List of minimum spare parts (non-exhaustive list) • Fuses for all equipment (e.g. inverter, combiner boxes etc.) and fuse kits • Modules • Inverter spares (e.g. power stacks, circuit breakers, contactor, switches, controller board) • UPS

	• Voltage terminations • Power plant control spares • Transformer and switchgear spares • Weather station sensors • Motors and gearboxes for trackers • Harnesses and cables • Screws and other supply tools • Security equipment (e.g. cameras)
H	**Scope of works – plant security**
☐	38. Define protective measures for the plant • Security protocol in place • Video monitoring • Alerting system • Fencing or barriers • Warning signs and notices • Security pad codes and passwords • Back up communication in case of vandalism
I	**Key performance indicators (KPIs)**
☐	39. Plant KPIs • Availability • Energy-based availability • Performance Ratio • Energy Performance Index
☐	40. O&M contractor KPIs • Reaction time • Reporting • O&M contractor experience • Maintenance effectiveness and maintenance support efficiency
☐	41. Security and surveillance of PV plant • On-site or remote • Around the clock coverage (24h/365d) • On-site patrol, security camera • On-site intervention time upon alarm etc.
J	**Contractual commitments**
☐	42. Qualification of parties involved: Owner's Engineer, O&M contractor, monitoring, security firm
☐	43. Responsibility and accountability
☐	44. Bonus schemes and liquidated damages