Data Management for
Photovoltaic Power Plants Operation and Maintenance

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Abstract

Main goal of this paper is to present our approach in terms of data management for operation and maintenance (O&M) activities of photovoltaic power (PV) systems that aims to decrease O&M costs and increase the availability and life cycle of the PV and profit of the business.

The O&M activities targets PV output maximization and cost minimization, improving performance and lifetime of the PV. Data management for PV O&M activities, proposed in this paper, contributes to the long-term performance and revenue capacity of PV.

1. Introduction regarding O&M of PV

Preventive maintenance is scheduled at predetermined time intervals or according with other prescribed criteria, aiming to reduce the probability of failure or damage to plant functioning. Maintenance of the PV includes the following types of procedures: administration area, wich ensures effective implementation, control, and documentation of maintenance services and results, including: securing funds for preventive and corrective maintenance; preventive maintenance: scheduling (frequency) of preventive maintenance operations is influenced by a number of factors, such as equipment type, environmental conditions (like: snow, pollen, dust, humidity, wild animals); scheduled maintenance operations are carried out at time intervals established according to manufacturer recommendations; corrective maintenance: required for repairs or replacement of failed equipments / components.

Generally, the operations in the photovoltaic power station are as follows:
- supervision and operation of low and high voltage. Supervision shall be carried out mainly using the command – control systems to ensure centralisation of information required.
- daily check of main elements of the installations within photovoltaic panel fields.

Maintenance of photovoltaic power plant consists of (NTE 005/06/00):
- electrical system maintenance:
  - periodic revisions and technical inspections for electrical installations, which shall be carried out in accordance with manufacturers instructions and regulations in force. On this occasion, minimum maintenance works are carried out, as well as inspections and tests necessary in determining the technical condition of electrical equipment. Any lack of conformity concerning measured parameters can lead to corrective maintenance operations.
  - corrective maintenance, by wich equipments and installations not in accordance with requirements shall be brought to operational parameters.
- photovoltaic panels maintenance consits mainly of:

- periodic revisions and inspections of photovoltaic panels, to identify any panel showing signs of malfunction.
- cleaning by periodic washing for removing dust, vegetation etc. Given the pollution and climatic characteristics of the area, it is estimated that panels washing with water should be carried out 2÷4 times per year.
- damaged panels replacement.
- other maintenance works:
  - removing vegetation that can cause shading to photovoltaic panels.
  - in the case of positioning systems with one degree of freedom, it is necessary to adjust periodically (four times a year, at the beginning of each season) the inclination angle of the photovoltaic panels.
  - maintenance of buildings, access routes, protection fence etc.

2. Literature review

Klise et. al. in Sandia Report a process where high quality data is collected and analysed using reliability engineering principles and statistical methods is presented. It consists in of PV plant components, and a failure reporting analysis corrective action system that shows continuous improvements through a feedback process that aims to reduce the likelihood of recurring failures.

In Best Practices in Photovoltaic System Operations and Maintenance (NREL), the authors proposed three aspects of best practices for system monitoring that consist in data presentation, quality of monitoring equipment and transparency of measurement protocols and procedures.

In Utility-Scale Solar Photovoltaic Power Plants, the authors proposed solar resource datasets and datasheet information for PV O&M data management.

Shiva Kumar and Sudhakar presented data monitoring system for performance evaluation of 10 MW grid connected solar photovoltaic power plant in India.

Papageorgas et. al. proposed a monitoring system of photovoltaic panels based on wired and wireless sensor networks that consists in distributed data acquisition. The presented architecture is scalable with the number of PV panels and promote an open-source platforms for web-publishing of characterization data at a low-cost.

An infrastructure for the management of large volumes of data via Big Data technologies to support the integration of solar energy is proposed by Escobedo et. al. It comprises an architecture for big data acquisition, processing, storage, management, analysis, monitoring and forecast.

3. Photovoltaic power plant components. Types of defects

Main component parts of a PV are shown in Figure 1.

Figure no. 1. PV connected to the grid

Source: http://k2solar.com.au/commercial-systems/]
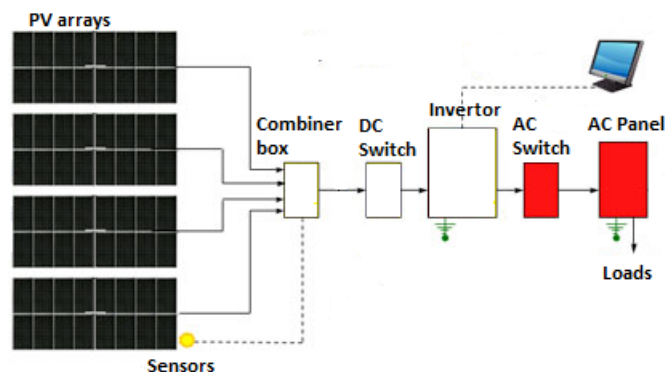
Establishment of maintenance procedures must take into account (Smith, C. O.):
- − photoelectric panels;
- − direct current circuits;
- − voltage regulators;
- − inverters;
- − alternating current (A.C.) circuits;
- − measuring, protection, control, signage and communication equipment;
- − equipment for plant safety.

Causes determining loss-performance

Usually, photoelectric panels requires the most important maintenance activities for limiting the causes leading to a reduction of solar irradiance (W/m²) wich reaches the level of photoelectric cells: dust, dirt buildup, changing the inclination angle of the panels from sun rays, shading due to trees or buildings in the area.

Limitation of photoelectric panels performance can be due to internal faults (short-circuits, diodes burning), increased resistance of electrical circuits (loose wiring connections), ground leakage through insulation faults, mechanical defects, defective electrical fuses on direct current circuits.

Inverter faults may result in a reduction of the power transmitted in the electrical grid, but usually this type of fault is normally identified by inverter control system.

The yield of the photoelectric cell (Planning & Installing Photovoltaic Systems) as in Table 1:
- electrical cells produce electricity and heat. During the summer, cells may reach 70 °C.
- the yield of a photoelectric cell depends on temperature: if the temperature is less, so the yield is greater (to increase by 1 degree of temperature, power generated decreases by 0,5 %).
- at 60°C resulting power is 20% less than at 20°C.

Table no. 1. PV Yield

Photoelectric cell type		Yield [%]	
		Present values	**Laboratory values**
Monocrystalline silicon cell		16···17	24
Polycrystalline silicon cells		12···13	17
Amorphous cells (thin film)	Silicon	6···7	12
	CIGS (copper-indium-gallium-diselenide)	12	19
	CdTe (cadmium telluride)	7···10	16

Source: Planning & Installing Photovoltaic Systems

Photoelectric system efficiency (Planning & Installing Photovoltaic Systems)
- Deviations from module nominal efficiency and radiation level
- Module soiling
- Module temperature
- Shading
- Direct current defects and losses
- Errors in MPP setting
- Inverter losses
- Alternating current losses

4. Solution for PV O&M

- removing impurities from the surface of the photovoltaic panels.
- verifying the performance of the PV system by comparing calculated data with measured data. If there are differences, it is necessary to analyze in detail the causes. It is recommended that, within the framework of maintenance operations, performance checking of the PV system shall be carried out in the presence of a reference pyranometer to record the actual data of solar irradiance.
- verifying the mechanical structure of photovoltaic system and removing the faults.
- verifying the electrical circuits (continuity, electrical resistance).
- verifying the insulation resistance of direct current circuits (the value should exceed 20 MΩ).
- verifying the surge voltage protection system.
- verifying the inverter functioning by power measurement for direct current and alternating current circuits (assessment of actual inverter efficiency and analysis of the causes that have led to changes from the values given by the manufacturer), according to manufacturer specifications.
- checking the voltages generated by each string of photovoltaic panels.
- verifying the operation of each photovoltaic module and of bypass diodes.
- verifying the security, control, signage systems.
- an useful information in assessing the modules proper functioning consists in the determination of the short-circuit current according to the measured irradiance level.
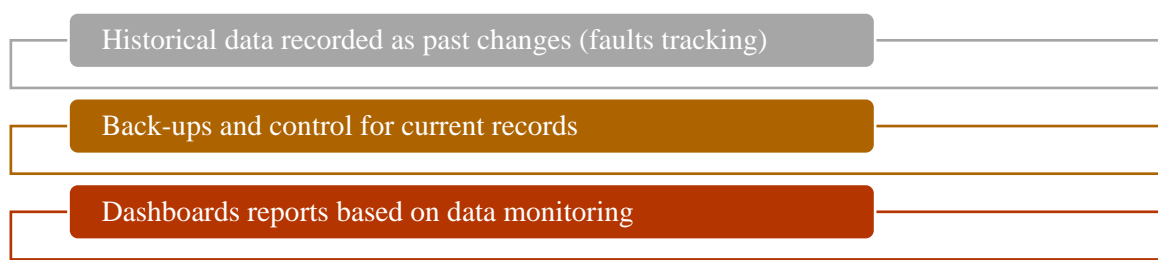
5. Data management

Recording of the following information is required (Best Practices in Photovoltaic System Operations and Maintenance):
- the physical condition of the PV plant, current contracts for services, data related to warranties;
- records of past changes carried out: corrective maintenance services and the results of each.

Before scheduling any maintenance service, it is necessary to know what type of equipment was initially installed and all changes that have been made since. Some problems are difficult to diagnose, so previous records are often essential for correcting the problem.
- a data management system provides change control and back-up for essential data as in Figure 2.

Figure no. 2. Data management hierarchy

Historical data recorded as past changes (faults tracking)

Back-ups and control for current records

Dashboards reports based on data monitoring

Source: Authors' contribution

- a structured document management system should include the following documents:
  - contact informations
  - list of all equipment (model, serial numbers, map of placement)
  - list of documents relating to property boundaries, electrical diagrams, specifications
  - operating manuals for inverters and any other equipments
  - reports from commissioning, re-commissioning, inspections

- data relating to past and current contracts with service providers (names, start/end date, scope of work, contract value, performance indicators, guarantees, contract clauses)
- preventive maintenance works and inspections records, data regarding corrective maintenance (date, status, causes, actions taken, confirmation that problem has been solved), work provider.
- inventory of spare parts, parts number, date of purchase
- list of all warranties (with all warranty documents), claims made (affected equipment, claim description, occurrence date, correspondence with manufacturer)
- documents relating to environmental conditions (meteorological data, temperature, wind speed)
- documents relating to production: PCC active and reactive power, houseload, c.c. power into inverter and other measurements as available.

Photovoltaic systems require monitoring for insulation faults tracking, permanent control of fault currents at the inverters, as well as for acting upon all determinante values in optimisation of PV operation in accordance with standards and for maximum efficiency (Best Practices in Photovoltaic System Operations and Maintenance).

The monitoring system depends on the size of the facility and its nature.

Monitoring can be performed directly from plant location or remote and can retrieve and process raw data from inverters or from measuring and checking instruments.

The monitoring systems can be used in two ways: only for surveillance or / and for other additional functions.

For monitoring systems specific protocols are used with data concerning inverters and other systems that records, assess and process various raw data, including data on weather, panels position etc.

Actions to be taken for optimization of plant functioning shall be decided after comparison with standard data.

Some systems may act via the Internet, with data received by satellite, providing an effective and permanent control of solar plants.

6. Conclusion and further research

In this paper we presented a couple of aspects regarding PV O&M activities that we studied in context the national research project OPTIM-PV. Data managemnt is essential to record events and track incidents during the lifetime of the PV systems. Thus, we proposed a list of documents, facts and events that schould be kept in order to improve the performance of the PV systems.

The large volume of data will require specific big data techniques that process the data flow in real time the heterogenous data gathered by various sensors.

7. Acknowledgement

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