Asset and Data Management Plan for Large Scale Solar PV Farm

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Abstract

Solar energy is one of the most important components in energy industry, its development and management appear to be particularly vital. This paper is focusing on how to develop a better data management and implementation strategy for large scale solar PV farm. In order to improve asset management system in this new area, this report will investigate the challenges and research gaps of solar plant asset management based on ISO55001, ISO14224 and asset management principals, it will also establish a comprehensive data management system to analyse the process of function of the solar PV farms.

Keywords

Asset management, ISO55001, ISO14224, solar PV farm.

1. Introduction

With a variety of factors impacting the bottom line of a PV system, solar asset management is essential in minimizing operation and maintenance expenses and maximizing lifetime energy yield. Management of large scale PV power plants has become a challenging issue mainly due to a lack of structured strategic asset management framework. In this essay, literature review of asset management and acquisition of data will be illustrated first, and then a case study of a PV solar farm will be analysed which will be followed by an improvement plan based on the understanding of ISO 55000 and ISO14224 standards. And recommendations are also put forward in the final part.

2. Research Questions and Methodology

2.1 Research Question

What are the rationale behind Asset management and asset management information system?

What are the challenges, management problems and issues of current large PV farms have?

Are the existing asset management frameworks and their elements sufficient for capturing existing and emerging management problems and issues of large scale PV power plants?

2.2 Research Objectives

To evaluate the rationale behind Asset management and asset management information system.

To evaluate the research gap of the current large scale solar PV farms.

To explore the current asset management method, the main elements and components of asset and information management.

To generate asset and information management improving plan for large scale PV power plants.

2.3 Methodology

Define the research questions that should be answered in this project.

Identification of literature that is relevant to the study.

Assessing study quality and conducting a case study of large scale PV plant.

Summarize the important information which gained from literature review.

Interpreting the findings

Create a strategic asset management framework for large scale PV power plants and identify key elements of this framework.

2.4 Data Collection Method

The research was based on a broad literature review which mainly about the present challenges and difficulties in current large scale solar plant as well as principles of asset management and asset information management. The information resources include journals, news, financial report, government publications and websites. The workloads have been evenly distributed to every group members, which ensures there will be enough information to be used for generating an solar plant asset management and information management plan.

3. 3 Analysis

3.1 Rationale Behind Asset Management

In current project or organization management, the asset management including physical and intangible assets plays an important role in different process which aims to hence the management efficiency and effect, such as the project planning, acquisition, operation, maintenance and disposal. To some extent, an effective asset management contributes to meet the anticipated goal or standard.

The rationale behind AM could be understood from macro and micro aspects. On macro aspect, AM contains a series of activities including: identifying what kind of assets are needed according to the project plan; the asset acquisition financial plan; asset acquisition section and operation monitoring; maintenance; disposal or renewing. While on micro aspect, AM could be separated into many specific items according to ISO 55000 or ISO 55001. [1] In ISO asset management system, a list of related AM knowledge items will be demonstrated, the definition and the standard requirements will be explained which provide the managers specific and practical instructions or references in AM application.

3.2 Rationale Behind Asset Management Information System

Asset management information system generally means an information system (such as an ERP software system applied in organization) integrated with different assets information and related management methods or other items in order to provide the managers an effective and efficient way to understand and manage the assets. In most cases, AM information system includes enterprise asset management, computerized maintenance management system, process control system and condition monitoring system. Different kinds of industries or companies will focus on different points in AM information system according to their attributes and operation goals. Totally, AM information system collects and links the AM information to generate a logical and operable network which provide important management platforms to managers.

3.3 Challenges and Research Gaps of Solar Plant Asset Management

What are the problems of current solar plant asset management system, what are the possible solution we could use to solve these problems. How important is to improve the asset management system in solar industry.

Asset management in solar plant has become increasingly important in recent years especially when the solar power industry is experiencing a fast development. The European and American experience shows that O&M (Operations and Maintenance) and Asset Management are to be recognized as essential components of any PV plant and portfolio in every maturing solar market. Besides, all the stakeholders, including the asset owners, the investors, the operation and maintenance contractors, hope to control any potential risks of the solar plant assets to obtain their expected returns. However, there are several challenges in this young industry.

3.3.1 Rapid Development of Solar Power Industry

The solar power industry has been increasingly developed worldwide, especially in Europe, the United states and Asia. In Asia, Japan is the leading country in developing the PV solar industry, Japan installed a 14 MW solar power plant, and now is expected to reach the ambitious target of 20 GW within 2020. Picture 1 shows the Japanese growth of PV capacity since 1992.

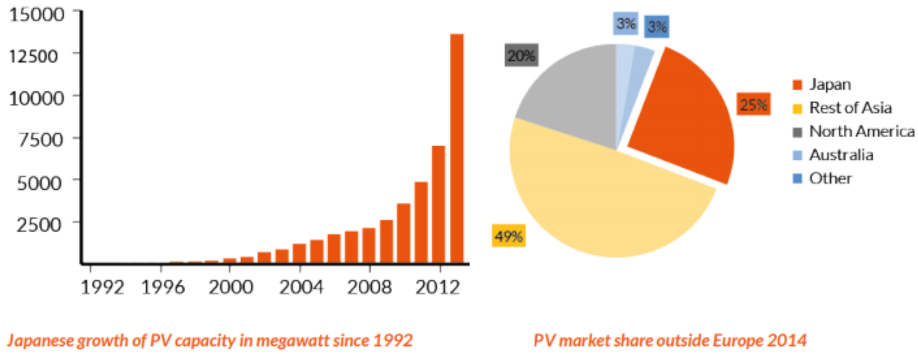


Figure 1. Japanese growth of PV capacity since 1992 and the market share outside Europe in 2014

3.3.2 Technical Asset Management and Financial Management

The technical asset management of solar plant includes the plant or asset performance supervision, asset performance reporting, management of Q&M provider and warranty administration. The financial management of solar plant contains billing, collection, payments, accounting and financial reporting, tax preparation, debt financial management, insurance administration, interface with banks, investors, regulators, local authorities, etc. therefore, a solar plant asset manager should have a good command of both technical and financial management skills to ensure the success of the operation of the solar plant.

3.3.3 Standards

In the operation and maintenance part, traditionally there are specific requirements for each solar plant asset management, but the asset owners and lenders are often confused for lack of clarity of the minimum requirements, the existing standards do not cover this blank. Even though there are many existing international standards in the operation field, more standards are needed to better manage the solar plant assets. Another difficulty lies in tracking and managing a physical solar plant asset. The management of a solar plant should go through the operation stages of the asset lifecycle. Solar asset management should collect all the data, documents and life events of the solar plant asset. For instance, a solar asset is expected to have minimum 20 years of life expectancy. So professional lifecycle management of the solar plant asset will help it to more effectively and efficiently work throughout its life period.

4. Improvement Plan

4.1 Asset Management Issues for Solar PV Farm

4.1.1 Environment, Health & Safety

Environment

The owner of the asset has a definitive lawful and moral responsibility to guarantee the health and safety of individuals in and around the solar plant and for the protection of environment around it.

As the renewable energy generating process has low environmental impact, the environmental issues are avoidable through proper solar plant maintenance and design. The environmental damage which may cause legal or penalties can be avoid as well.

Furthermore, several things need to be managed including recycling of electric waste and broken panels, minimizing the water used for module cleaning. In many circumstances, solar based plants offer an open door where overseen thoughtfully, to give a significant common living space to plans and creatures close by the basic role of generation of electricity. A well thoroughly considered ecological administration design can help advance the development of natural habitat. It can guarantee the fulfilment of any lawful prerequisites to ensure or keep up the habitat of the plant.

Health and Safety

The primary concern of the asset manager is the risk to the health and safety of the individuals from the solar plant. Large scale solar park are power generating stations and have noteworthy risks which can cause permanent injury or death. Through legitimate danger distinguishing, careful arranging of works, preparation of procedures to be followed, archived and standard examination and support, dangers are lessened.

The date plan of hazards is very important for asset management, which allows the asset manager to manage the staff and provide third party stakeholders with proper information. It is essential to keeps irrelevant people away from the solar plant area. This will be discussed in the security part.

A safety management system needs to be planed and management by the asset management team which should include the site rules and the works in relation to health and perceived hazards and safety. The asset management team should ensure that all of the workers follow the health and safety legislation.

Before the starting of any construction activity a risk assessment and method statements should be prepared by the relative party. The Asset management team should make a list of personnel training certifications. During the construction stage, the health and safety of every site should be supervised and documented.

4.1.2 Ambient Condition Effect Improvement

On account of improving the stability and preventing the failure probability, a comprehensive understanding of the possible failure occasions should be analysed and the cause-effect tree is developed to determine the failure reasons effectively (Harb, Kedia, Zhang &Balog, 2013). Therefore, the sub-units of ambient environment effect have been reviewed and the fishbone graph is plotted to help to find the corrective reasons.

(1). Packaging material degradation

The degradation of packaging materials in the operation phases mounted in the outside incorporates cracking of back sheet and delamination, breaking of glass, browning of encapsulant etc.

(2). Loss of adhesion

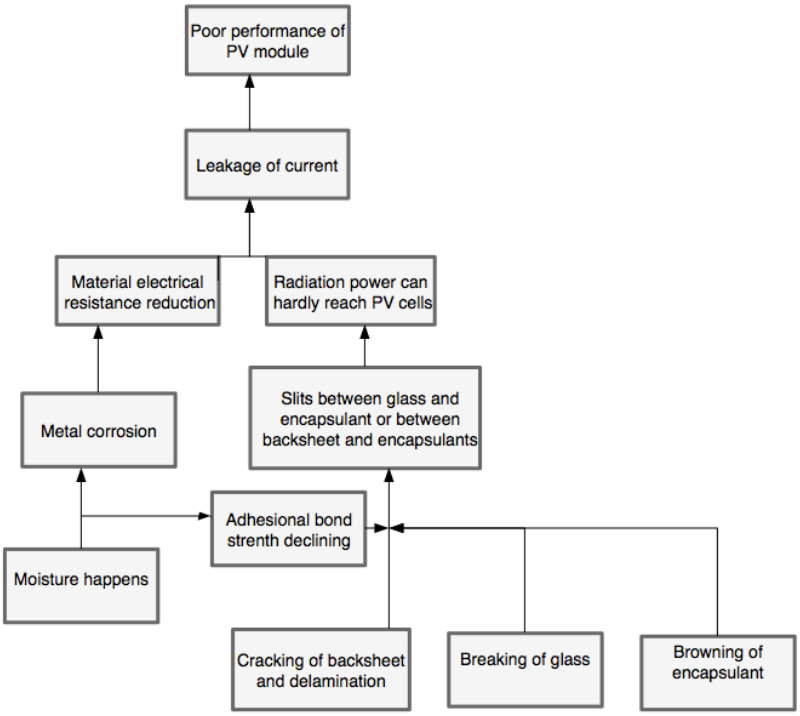
Solar cells in a PV module are encapsulated with a cover to protect the cells from ambient impact. Silts and breaking of bonds between glass and encapsulant or between encapsulant and back sheet can result in delamination which can lead to solar radiation barely reaching to cells.

(3). Moisture intrusion

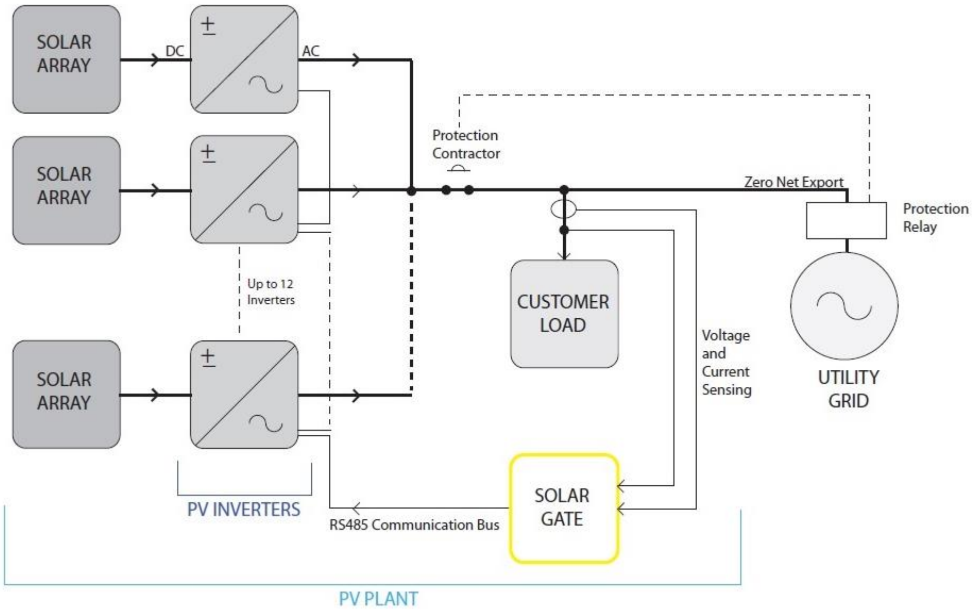
Moisture can permeate into PV modules from laminated edges, accounting for the leakage of currents and metal corrosion. Corrosions can lead to contact defect between grid and cells. Additionally, emergence of moisture in a module could also ascend the loss of current as a result of reducing material’s electrical resistance. Moisture can decrease the adhesiveness between various components layers of the module as well.

4.1.3 Data Acquisition

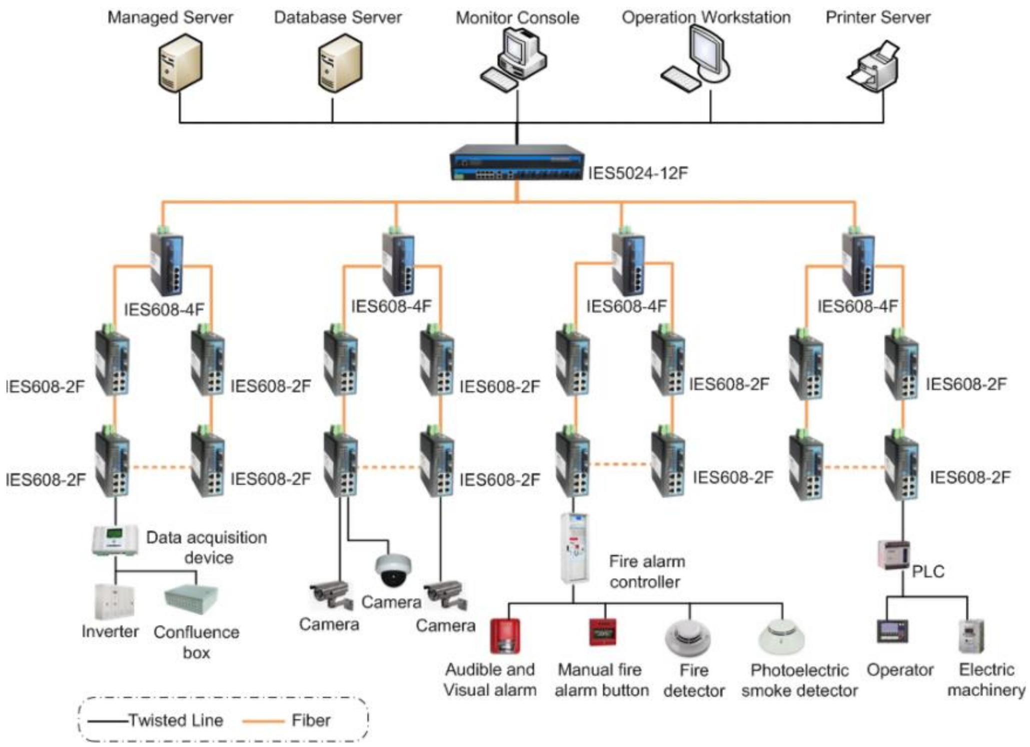
In each PV grid-connected inverter with current sensors and voltage sensors, real-time measurement of solar cell square peak voltage and peak current, AC output voltage and AC output current. SBC for the data acquisition controller, always read each inverter measurement data (Vpv, Ipv, Ppv, Vac, Iac, Ppv), SBC can simultaneously monitor 50 different power levels of the inverter, while monitoring each Inverter SBC through the calculation can be obtained by the entire PV grid system cumulative power generation, the cumulative power generation and the entire system instantaneous power. SBC through the RS485 converter, read the sensor box to collect a variety of analog data. These analog data include solar radiation intensity, solar cell square temperature, the ambient temperature and wind speed.



Cause and effect chart of ambient impact



There is a probabilistic error in the production data collected through the monitoring and data acquisition (SCADA) system. For maintenance contractors, in terms of overall equipment production efficiency, it is important to ensure that parameters are usually based on safety assumptions and that accurate technical assessments are required to avoid overall performance degradation.



The evaluation of the contractor's objectives is basically based on the measurement of the measurement station. This is a key factor in judging the actual situation, and therefore requires the staff to regularly calibrate and certify the instrument. Not only that, it is necessary to clean the irradiance sensor with the dust cover on the solar panel to ensure the consistency of the parameters. It is also possible to retain the additional sensor more frequently as a reference for the optimum value of the irradiance. The cleaning progress can then be optimized based on the difference between the irradiance measured in the two sets of sensors. As a final confirmation of the data, successive correlations between various sources of the same data (such as different stations at the site) can also provide early warning of problems in the data acquisition system.

4.1.4 Security

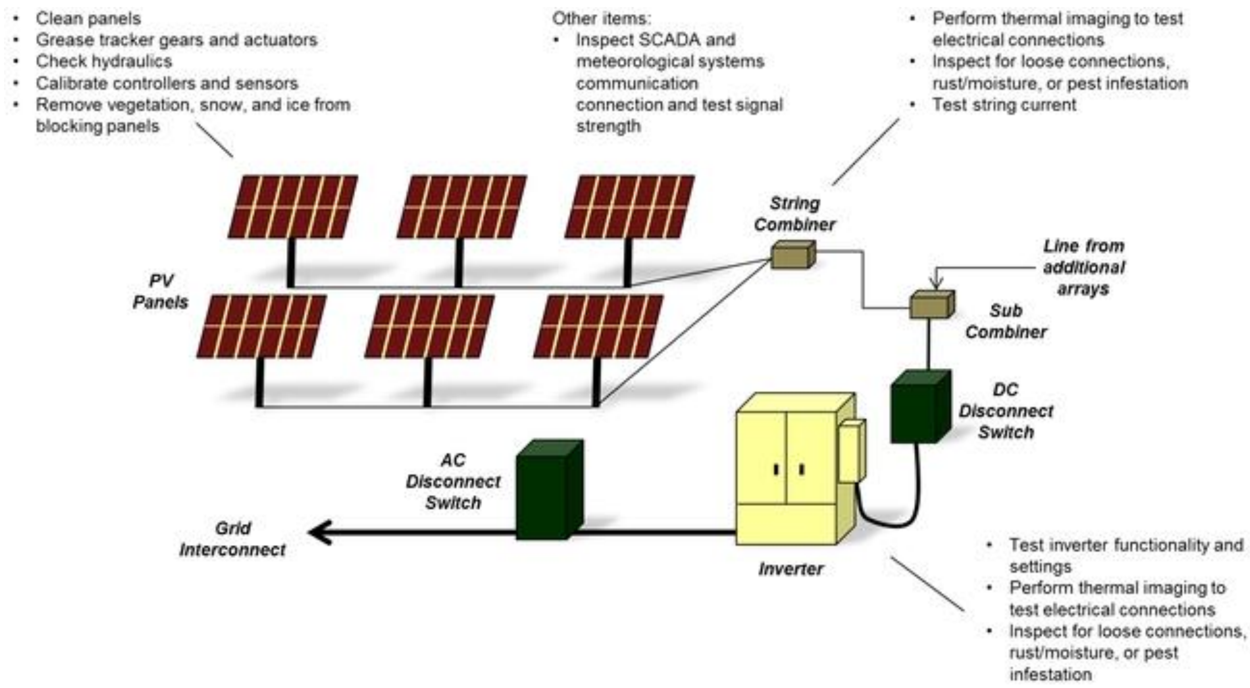
Whether it is a distributed small power station or a centralized large - scale ground power station, it has a certain risk.

Investigate the existing information, photovoltaic power plants are mainly faced with security issues are divided into two parts of the components and the inverter.

The safety of components mainly comes from junction boxes and hot spot effects. Poor connectors due to internal roughness, less contact points, so that the resistance is too high to ignite the junction box, and then burn the components backplane components caused by fragmentation. Under certain conditions, a shielded solar cell assembly in a series of branches will be treated as a load to consume the energy generated by other sunny solar modules. The shielded solar cell assembly will heat now, which is the hot spot effect. This effect can seriously damage the solar cell. Hot spot effect in addition to the component life has a serious impact, but also may burn components or even cause a fire.

The inverter is also a significant security risk. The traditional power station uses fuse design to increase the DC node, even if the use of fuses, cannot effectively protect the components; and in the case of overload current, the fuse will be due to slow melting, high fever, causing fire risk. Almost all the traditional power plants are suffering from high failure rate of fuse, part of the power station annual failure rate of> 7%, especially in the summer, a 30MW of solar plant average number of fuse failures per day up to 5-6.

Therefore, in our proposal, it is necessary to regularly maintain and troubleshoot important heat-generating components, combined with the asset management system to ensure the safety of the plant's sustainable level.



4.2 Data Management Improvement Plan

4.2.1 Data Collection and Exchange

Even though the plant investors have improved the availability of stability of the components of the facilities and equipment, the results and feedbacks of failure data and maintenance figures can be stored into database to support a database for better decision making and corrective maintenance measures (Turner, pp.30-31, 2014). International requirement standard IOS 20815:2008 demand a performance data tracking and analysis system, so a thorough strategy has been developed for the PV solar plant.

All the new improvement of equipment reliability should be founded up by the existing data from previous implementing phases and the data will be shared with the equipment manufacturers and designers, so the repairing and maintaining actions can be more effective.

In order to establish a complete database, including information of failure modes, failure frequency and corresponding solutions, the useful information should be collected and stored alignment to the following systematic flowchart as Fig. 2.

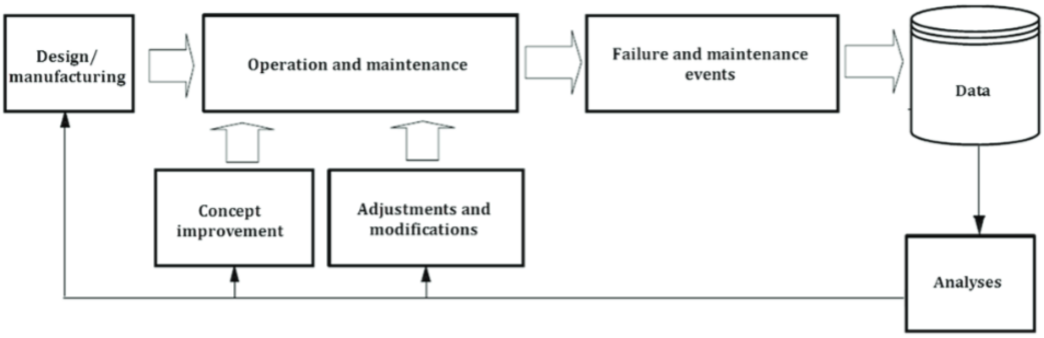


Fig.2-Data and feedback collection and implementation structure

4.2.2 Timeline Issues

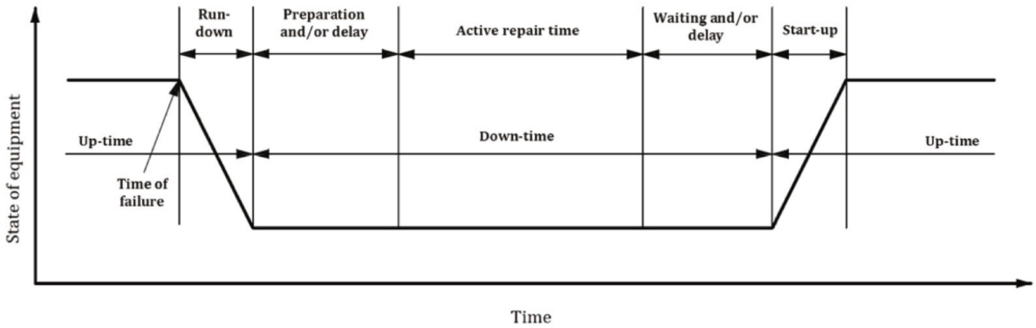
As asset has its operation states in different period based on the whole lifetime, it is necessary to make clear about the asset operation timeline of different function situation. According to the document of current British Standard Institution (BSI), timeline issues could be represented on the following three aspects [1] ISO 14224:2016

Surveillance period and operation period

Surveillance period can be treated as a whole duration of asset usage from beginning to the end, such as the Mean Time to Fail (MTTF). Generally, this period covers many different time periods, such as the operation period and maintenance period are two main parts in surveillance period. Operation period also means the normal operating state from the immediate usage time to the end. The following chart gives some specific definitions of asset timeline.

Data collection duration

Data will be collected during the asset lifecycle or a short period. As most assets tend to follow the “bathtub” curve research result, in most cases, the data collection should be conducted during steady operation state to the burn-in state, also we can get the failure rate of the asset operation by data collection duration.



Maintenance period

Table 4 — Timeline definitions

Total time [h]													
Down time								Up time					
Planned down time				Unplanned down time				Operating time				Non-operating time	
Preventive maintenance		Other planned outages		Corrective maintenance			Other unplanned outages						
Preparation and/or delay	Active preventive maintenance (item being worked on) [f]	Reserve [a]	“Modification [b]	Undetected faults [g]	Preparation and/or delay	Repair (item being worked on) [c]	Shut-down, operational problems/ restrictions etc. [d]	Run-down	Start-up	Running [e]	Hot stand-by	Idle	Cold stand-by

a Means that item is available for operation, but not required for some time. Does not include items considered as “spare parts” or items taken out of service on a more permanent basis.

b Modification can change the reliability characteristics of an item and can, therefore, require that the collection of reliability data for the surveillance period be terminated before the modification and be re-started with a new surveillance period after the modification.

c Includes fault diagnosis, repair action and testing (as required).

d Shutdown of machinery (trip and manual shutdown), see definition of trip (3.93) and also C.1.8.

e Running is the active operational period for equipment in oil & gas production systems. For drilling and workover systems, this is not sufficient since there are many different operational phases. The operational phases for drilling could include: Running, drilling, tripping, set casing; and, the phases for workover could include: well equipment removal, replace completion string, replace casing string, and various workover activities.

f Includes testing

g It is difficult to determine downtime associated with undetected faults. These faults are eventually revealed by test or demand.

h See also ISO/TR 12489:2013, Figures 5, 6, and 7.

Maintenance period can be treated as the down time of the asset. As the following figure shows, down time is divided into three parts, among them the active repair time is the main part. In most cases, the maintenance period is following the failure time with little time interval, so the operation time (up time) and maintenance time almost decide the asset operation quality.

Solar plants asset timeline management

As the PV and PV control system are the main assets of the solar plants' asset, the timeline management should focus on PV panels and other related components. The following steps are recommended as the timeline management

Identifying and classifying the timeline management assets

The data collection of different assets timeline elements

Record the asset data during the operation and maintenance

Evaluate the failure time rate and asset quality

Try to find the problems according to the operation results and solutions to improve the asset quality

4.2.3 Taxonomy for Solar Industry

A taxonomy is a systematic arrangement of things into nonexclusive gatherings. The general taxonomy hierarchy for solar PV farm is generated based on ISO14224:2016 show in the graph X below.

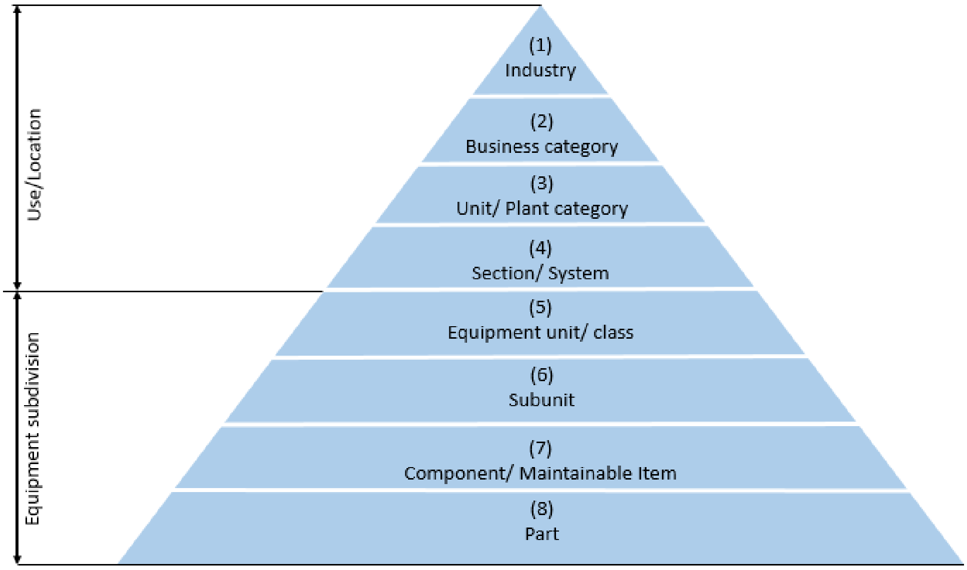


Figure 3. General taxonomy hierarchy

Table X demonstrates a case of Taxonomy hierarchy for solar PV farms. The first four levels are connected with ventures and plant application without considering of the gear units included. Level 5 to 8 are identified with the stock with the subdivision in bring down arrangement levels comparing to a parent-child relationship. Advance breakdown still need instrument. It is important that the reliability and maintenance information be identified with the specific level inside the chain of command to be comparable and meaningful.

Table 1 Taxonomy example

Main Category	Taxonomic level	Taxonomy hierarchy	Definition	Example
Use/Location data	1	Solar PV plant	Type of main industry	Solar PV plant
	2	Business category	Type of business	Solar farm, solar through, solar tower, hybrid
	3	Unit/Plant category	Type of plant/unit	Land based solar panel, roof top PV farm, floating PV farm, etc.
	4	Section/ System	Main section/ system of the plant	Solar Module, tracking system, etc
Equipment subdivision	5	Equipment class/unit	Class of similar equipment units.	Solar PV array, inverters and transformers, electrical connections, fencing and

				landscaping, operations and maintenance building, access road.
	6	Subunit	A subsystem necessary for the equipment unit to function.	Cooling subunit, control and monitoring, Lubrication subunit.
	7	Component/Maintainable item	The group of parts of the equipment unit that are commonly maintained as a whole	PV cell, tracking motor, electric circuit, temperature sensor
	8	Part	A single piece of equipment	Tube, electrical cables, steel driven pile, rails

4.2.4 Equipment Data

Normally, equipment data consists of two parts:

Common classes.

Equipment specific classes.

Equipment data common to all equipment classes

Data category	Data	Taxonomic level
Use/ Location attributes	Industry	1
	Business classification	2
	Installation classification	3
	Installation model/code #	3
	Proprietor code/name	4
	Geographic position	3
	Equipment /unit category #	4
	Equipment /unit code or name #	4
	Section/system #	5
	manipulation classification	5
Equipment attributes	Equipment class #	6
	Equipment Type #	6
	Equipment identification/location[1] #	6
	Equipment description (nomenclature)	6
	Picturesque equipment identification number[1]	6
	Manufacturer's name[2] #	6
	Manufacturer's model name	6
	Design data of subunit/component	6-8
Operation	Normal working state/mode #	6
	Original equipment debugging time	6
	Initial time of current service #	6
	Surveillance time #	6
	Operational time[3]	6
	Number of cyclical test requires during the surveillance period #	6-8
	Number of working requires during the surveillance period #	6-8
	Total wells drilled during surveillance period[4] #	4
	Process parameters of each equipment class	6
Additional	Additional information in	6

information	free text as applicable	
	Source of data,	6

1. each equipment has an 'unique equipment identification number', and this number can be needed documenting potential change-out at the equipment level. The unique identification number normally can be found at each equipment.
2. Manufacturer may be relevant for lower hierarchical levels.
3. The equipment may be affected by different operation stages.
4. This applies only to drilling related equipment categories.

# indicates the minimum data that should be collected.

4.2.5 Failures Data

A series of definition of system failures and various failure modes in appropriate method are significant foundation to organize data from different sources in the reliability management database.

A thorough framework is given as the following table shows, to collect and report failure data sourced from all equipment and operation components. For instance, inverter temperature, electricity generation are relatively important.

Data classification	Data to be collected	Description
Identification	Failure record #	Individual failure mode identification
	Equipment distribution/ location #	Equipment ID (different locations)
Failure data	Failure time #	(time/date/year)
	Failure mode #	At AC level and DC level/sub-unit level
	Failure effect on farm safety (stuff, fixed equipment, surrounding environment)	Quantitative and qualitative classification of the failure impact
	Failure impact on system operation	Quantitative and qualitative classification of failure classification (test, interruption and generation)
	Failure occurs in equipment implementation #	Impact on equipment-level operation (initial, degraded, severe failures)[1]
	Failure mechanism	The causes in physic or chemical systematic reasons[2]
	Subunit failures	ID and name of the failed subunit
	Failed component or maintaining items	ID and name of the specific failed component
	Monitoring method	How the parameters of failures can be detected[2]
	Working phases at failure #	Start-up, cold/hot standby, running, commissioning, end-up stages
	SIS failure mode category[3]	Classify the failure into assigned events (SU, SD, DU, DD)[4]
Critiques	Additional information	Show detailed causes and effects of failure

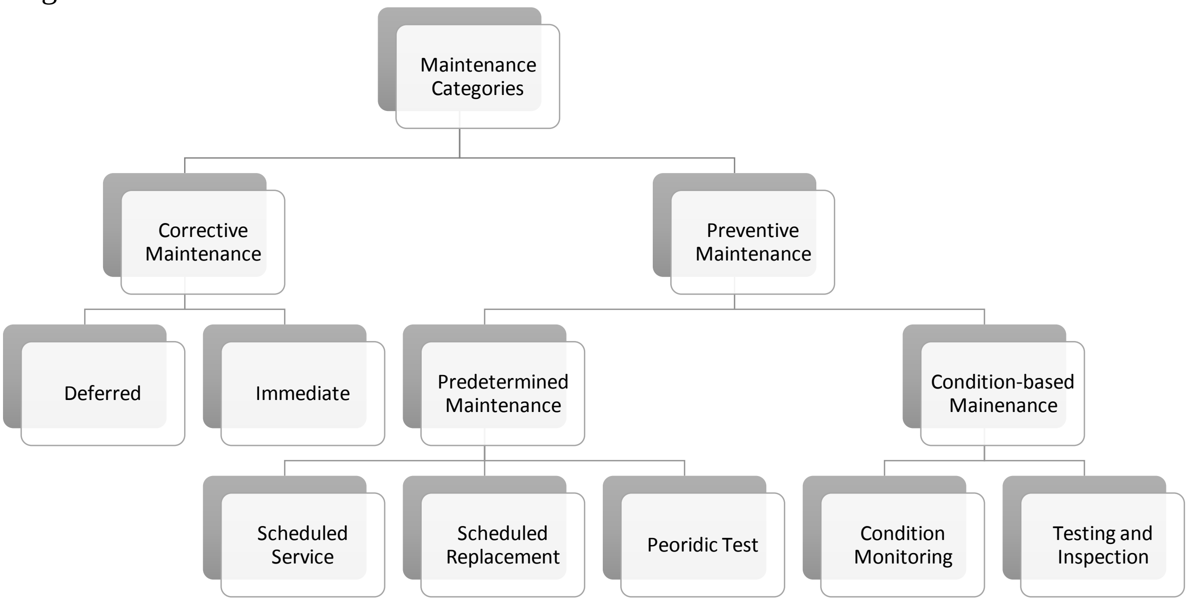
1. Regarding to equipment classification, it could be enough to collect critical and non-critical (initial and degraded) failure.

2. Sometimes the root causes of the failure can uneasily to be detected, so the analysis form or hierarchy should be constructed particularly in occasions of high frequency, high cost, long repairing time issues.
3. The data collection and monitoring detectors should be installed at important spots. And for large-scaled plant, all equipment should be monitored with temperature and insulation data detectors.
4. The classification indicates the category, DU (dangerous undetected), DD (dangerous detected), SU (safe undetected), SD (safe detected).

#. Demonstrate the lowest allowance for data to be collected.

4.2.6 Maintenance Data

(1). Categories



(2). Maintenance activity

Activity	Description	Examples
Replace	Replacement of the item by a new or refurbished item of the same type and make	Protector burns out
Repair	Manual maintenance action performed to restore an item to its original appearance or state	Inverter short-circuit
Modify	Replace, renew or change the item, or a part of it, with an item/part of a different type, make, material or design	PV panel components ageing
Adjust	Bring any out-of-tolerance condition into tolerance	Wrong connecting
Refit	Minor repair/servicing activity to bring back an item to an acceptable appearance, internal and external	PV panel angle tilt
Check	The cause of the failure is investigated, but no maintenance action performed, or action is deferred. Able to regain function by simple actions, e.g. restart or resetting	Voltage, current of inverter
Service	Periodic service tasks: Normally no dismantling of the item	Dust cleaning to avoid Static electricity
Test	Periodic test of function or performance	Overload test

Inspection	Periodic inspection/check: a careful scrutiny of an item carried out with or without dismantling, normally by use of sense	Line and equipment aging inspection.
Overhaul	Major overhaul	Investigation/update with broad dismantling and substitution of things as determined or require
Combination	Several of the above activities are included	In the event that one movement commands, this may on the other hand be recorded
Other	Maintenance activity other than specified above	Protection activities.
C: used typically in corrective maintenance; P: used typically in preventive maintenance		

(3). Maintenance Data

Date to be record	Details
Date of Maintenance	(Date when maintenance action was undertaken or planned)
Maintenance category	(corrective, preventive)
Maintenance priority	(High, medium or low priority)
Interval (planned)	(Calendar or operating interval)
Maintenance activity	(Description of maintenance activity)
Maintenance impact on plant operations	(Zero, partial or total)
Subunit maintained	(Name of subunit maintained)
Component/maintainable item(s) maintained	(Specify the component/maintainable item(s) that were maintained)
Spare part location	(Availability of spares)

5. Conclusions and Recommendations

The objectives of this report are finalized via using asset management principals, ISO55000 and ISO14224 standards to establish a well-rounded data management by analysing the process of the function of the solar PV farms and highly understanding of the rational of these specifications.

The literature review of the components of a solar PV module and the working processes of a solar farm as well as a case study have been examined. In addition, a rigorous realization of a database construction and implementation in terms of ISO asset management and industrial specification have been introduced and validated.

Database set up with a software encompassing a series of data categories has been built and a continuous data reflection and corresponding maintenance respond scheme is applied. From outside environment to interior PV module components, a thoroughly systematic data flows can be collected and stored to support making better decisions for the managers or the board.

Furthermore, ISO standard associated with data quality, data classification, data acquisition and better reliability to maintain facilities is suitably fit for the solar PV industry. However, if this project and the method can be realized in the real domain, more detailed monitoring system and the commissioning phase should be completed. Also, the different hierarchy of the data management system should be designed and operated by different teams and all these groups are in charged by the leader panel to build a comprehensive system.

Acknowledgements

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