



112年太陽光電發電系統維運技術與O&M標章制度座談會

國外太陽光電發電系統維運 制度與O&M標章介紹

工研院量測中心綠能檢測認證組

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112年5月31日

大綱

- 一、太陽光電發電系統的挑戰與問題
- 二、NERL太陽能與儲能維運最佳實踐
- 三、JET 太陽光電系統維運驗證方案
- 四、歐洲太陽能O&M最佳實踐指南與標章
- 五、IEA不同氣候下PV電站運維指南
- 六、綜合討論與問卷調查

太陽光電發電系統的挑戰與問題

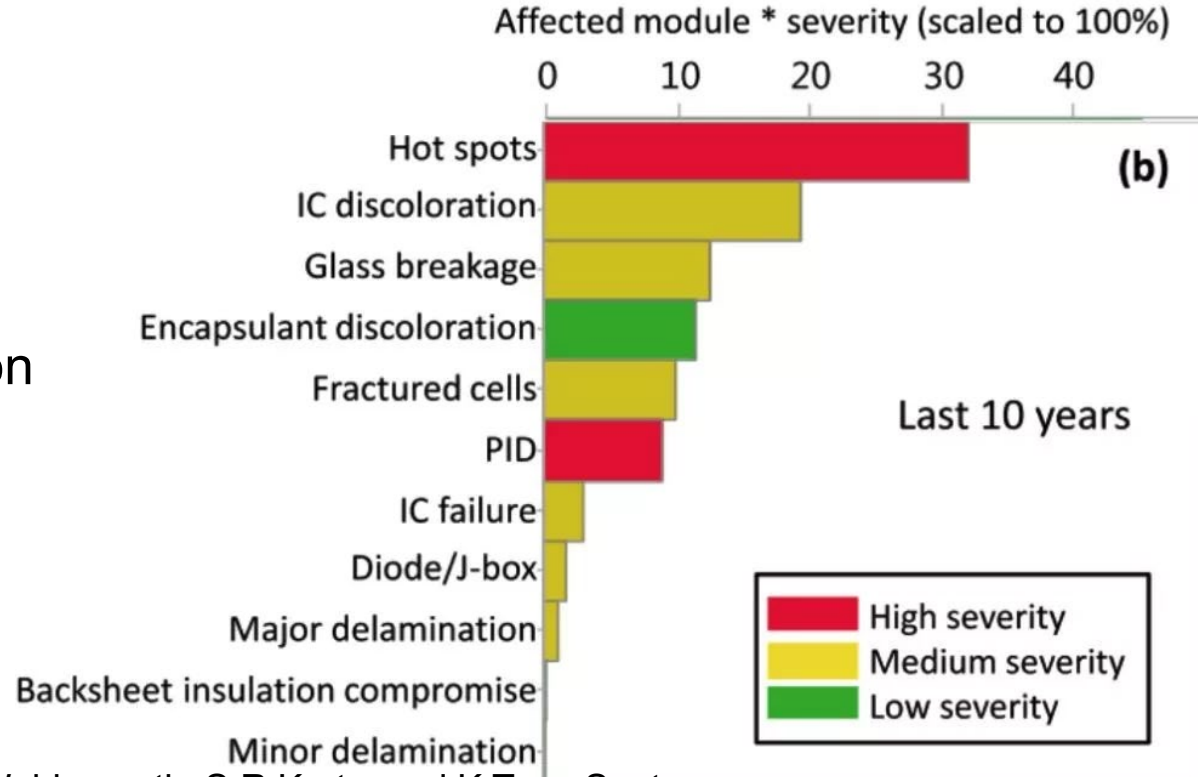
- 受新材料與氣候環境、外力影響，系統要能穩定營運20~25年，挑戰不小。
- PV O&M 運維不僅是割草、清潔和安全等工作，還需負責維持電廠的效率和能源傳輸，同時減少電廠的損失、延長壽命。



The rapid growth of the solar industry makes it important to ensure that industry best practices are harmonised

Top 10 Modern Solar Panel Failures

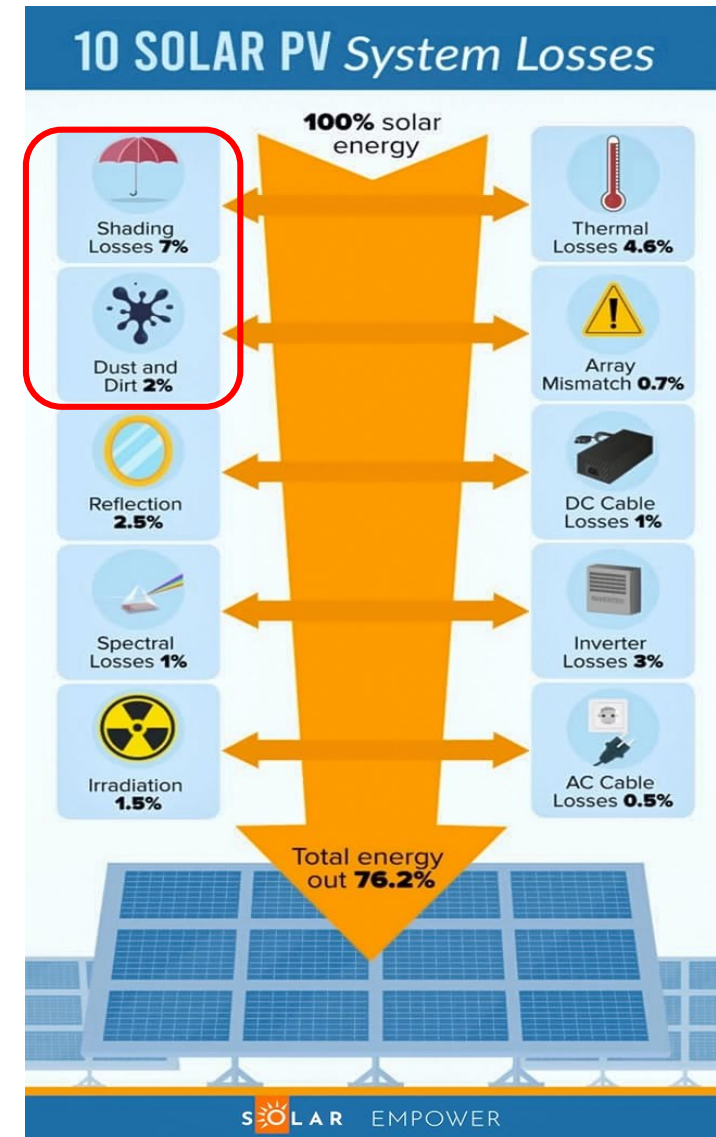
1. **Hot Spots**
2. Interconnection discoloration
3. Glass Breakage
4. Fractured Cells
5. **PID**
6. IC Failures
7. Diode / J-box
8. Major Delamination
9. Back sheet Insulation Compromise
10. Minor Delamination



Source: D Jordan, T J Silverman, J H Wohlgemuth, S R Kurtz, and K T vanSant
“Photovoltaic failure and degradation modes”, PIP, 2017

10 Solar PV System Losses

Cause of Energy Loss	Percentage Loss	Design or Maintenance	Total Losses
Shading	7%	Both	23.8% lost
Dust and Dirt	2%	Maintenance	
Reflection	2.5%	Design	23.8% lost
Spectral Losses	1%	Design	
Irradiation	1.5%	Design	
Thermal Losses	4.6%	Design	
Array Mismatch	0.7%	Design	
DC Cable Losses	1%	Design	
Inverter Losses	3%	Design	
AC Cable Losses	0.5%	Design	



Source: <https://www.solarempower.com/blog/> , 2023.1.26。

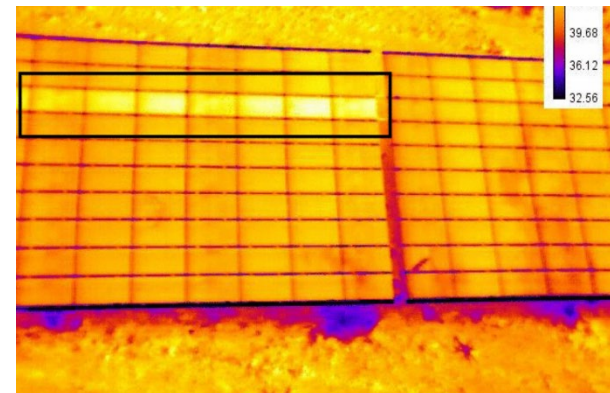
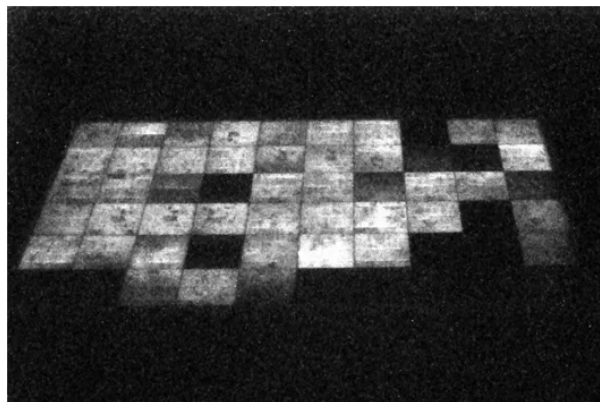
Component Failures 組件故障

Activity Description	Mean Time to Failure (years)	%
Insulated gate bipolar transistors matrix in inverter	1.9	10
Inverter fan motor	2.2	25
Inverter reboot to clear unknown error	1.6	40
Broken modules	2.3	20
Damaged racking	1.5	33.5
Tracker motor controller	1.1	76
Tracker bearing(s)	1.7	77

- The NREL report also summarizes failure patterns observed for specific PV components and local environmental conditions observed in Sandia's PV Reliability, Operations & Maintenance (PVRM) database, a collection of field records across 800+ systems in the U.S.
(Source: SANDIA REPORT , 2020/09 . <https://www.osti.gov/servlets/purl/1660804>)
- The age of the plants within PVRM is generally low-between 2-6 years, reflecting the general pattern of young plants within the industry (Jordan et al., 2020).

10 Practices to avoid for Solar O&M

1. Improper maintenance of pyranometer 日照計維護不當
2. Ignoring safety measures on-site 忽視現場安全措施
3. Lack of proactive testing 缺乏主動測試
4. Improper handling of cables 電纜裸露不當
5. Improper Labeling of cables 電纜標籤不當
6. Improper cleaning frequency and methodology 清潔頻率、方法不當
7. Improper module handling 模塊處理不當
8. Improper collection of plant data 電站資料收集不當
9. Inadequate inventory availability 零件庫存可用性不足
10. Preventive maintenance not based on proper root cause analysis




NREL Solar System O&M Analysis

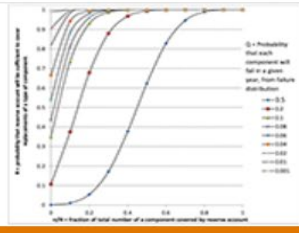
NREL透過收集數據、模擬性能和成本，優化 PV 系統的運營和維護 (O&M)，並提供產業專業知識。其方法如下：


1. 分析大量 PV 系統的性能數據
2. 收集一致的氣候數據
3. 建立運維成本模型
4. 模擬性能比和可用性對系統生命週期成本和平均能源成本的影响
5. 與可靠性、性能和財務相關的特殊主題，提供深入的專業知識
6. 利用機器學習來分析數據

Featured Publications




Best Practices in Operation and Maintenance of PV Systems and Energy Storage Systems, Third Edition , NREL Technical Report (2019)



Model of Operation-and-Maintenance (O&M) Costs for Photovoltaic Systems , NREL Technical Report (2020)



Best Practices at the End of the Photovoltaic System Performance Period , NREL Technical Report (2021)



NREL 太陽能與儲能維運最佳實踐

- O&M 為影響電站投報率的重要關鍵
- 因美國各地的 O&M 實踐和成本差異很大，使投資者難以預測這些變量。
- NREL為解決PV持續投資的障礙，PV運維工作組制定了PV運維最佳實踐指南，從2015年至2018年為第三版。



Solar Access to Public Capital (SAPC)
Working Group

Best Practices in PV System Installation

Version 1.0, March 2015



NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

Best Practices for Operation and Maintenance of Photovoltaic and Energy Storage Systems; 3rd Edition

National Renewable Energy Laboratory,
Sandia National Laboratory, SunSpec Alliance,
and the SunShot National Laboratory Multiyear Partnership
(SuNLaMP) PV O&M Best Practices Working Group

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy
Laboratory (NREL) at www.nrel.gov/publications.

Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-7A40-73822
December 2018



NREL 太陽能與儲能維運最佳實踐

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NREL 太陽能與儲能維運最佳實踐

5. PV系統類型、地點和環境條件

5.1 電氣系統

5.2 中央、組串、直流優化或微型變流器配置

5.3 與PV系統相關的屋頂維護

5.4 降載系統

5.5 地面安裝

5.6 追蹤支架

5.7 環境

5.8 站點訪問

5.9 PV Plus 光儲系統的依賴關係

5.10 系統和站點注意事項清單

6. 系統性能和運維計劃

6.1 系統性能規劃

6.2 PV運維計劃

6.3 運維計劃的使用

6.4 文件管理和記錄保存

6.5 PV電站運營

6.6 預防性/定期維護

6.7 糾正性維護

6.8 PV組件退化率、儲能容量退化

6.9 工作陳述示例

6.10 營運結束期

6.11 運維計劃評估

6.3.1.1 O&M Plan Considerations for Residential and Small Commercial

2015 第一版

	System should be installed according to SAPC PV System Installation Best Practices Guide (http://www.nrel.gov/docs/fy15osti/63234.pdf).
	Small commercial and residential onsite inspections are the responsibility of the contract offtaker (small commercial) or homeowner (residential). Often the small size precludes the use of automated monitoring (although developments, such as micro-inverter or power optimizer communications, are making automated and remote monitoring more feasible).
	Any inspection of fleets of small systems is usually on a representative sample rather than every system.
	Performance guarantees should consider typical amounts of malfunction (e.g., one string fuse) and soiling to ensure insignificant corrections can be deferred and module cleaning and snow removal (by turbofan) is not provided. Treat extreme soiling situations as corrective maintenance.
	A manual should be provided to the homeowner with contact information and description of operational indicators and procedures he/she can do, including clear documentation that states the customer is responsible for maintaining original insolation/shade study results by completing routine bush and shrub trimming.

6.3.3 O&M Plan Considerations for Commercial and Industrial

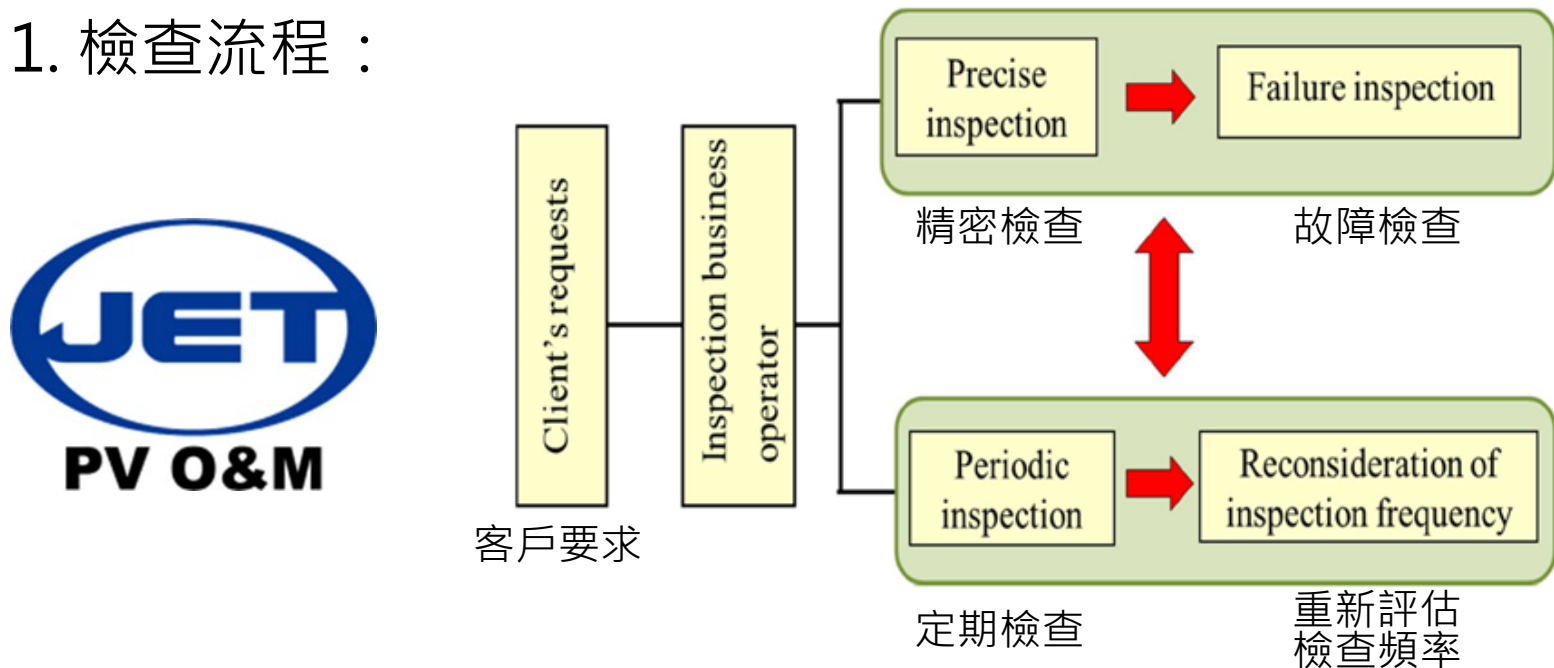
Key considerations for an O&M plan for systems larger than 500 kW include the following.

	Automated monitoring with diagnostics to push error alerts triggering corrective maintenance
	Continually analyzing performance information to optimize condition-based O&M, such as cleaning, and long-term issues, such as reliability trends
	Providing offtaker with manuals containing contact information and descriptions of their participation and responsibilities, self-inspection of the system, and what conditions necessitate the O&M provider to be notified of problems
	Providing offtaker with a shelter onsite for workers to meet and look at plans if size warrants

JET 太陽光電系統維運驗證方案

JET依「太陽光電發電系統定期檢查和故障檢查報告指南」，從第三方對PV系統運維公司和工程師進行註冊，並對報告進行驗證證。本方案自2016年8月1日開始實施。

1. 檢查流程：



2. 檢查種類：分為定期檢查、故障檢查和精密檢查。



JET PV O&M certification

1.定期檢查

要 求	對 象	檢 查 內 容	檢 查 頻 率
一般的	① 設計文件	確認 (是否被儲存)	僅限第一次。然後確認它被保留
	② 產生的能量	綜合發電	每小時 ~ 每年 (PR 值、PR+溫度校正)
環境	③ 安裝環境調查 (地面柵欄、植物、陰影等)	目視檢查	每次
配置	④ PV陣列、支撐結構、基礎	目視檢查	每次
	⑤ 接地工作要點	測量 (接地電阻)	每次
	⑥ 陣列接線盒	發電機接線盒	每次目視檢查和操作 每次測量 (絕緣電阻)
	⑦ PCS	外觀檢查和測量 (絕緣電阻	每次
	⑧ PCS與接線盒接合處	IR成像測量	每次
	⑨ 串列	IV曲線測量/開路電壓測量	每次
	⑩ 模組 (含接線盒)	目視檢查、IR成像測量	每次
		IV測量、EL測量、電池線路檢查	如有必要

JET PV O&M certification

2. 故障檢查

對發生故障的部分進行檢查稱為故障檢查。從以下①或②中選擇，或將①與②組合進行：

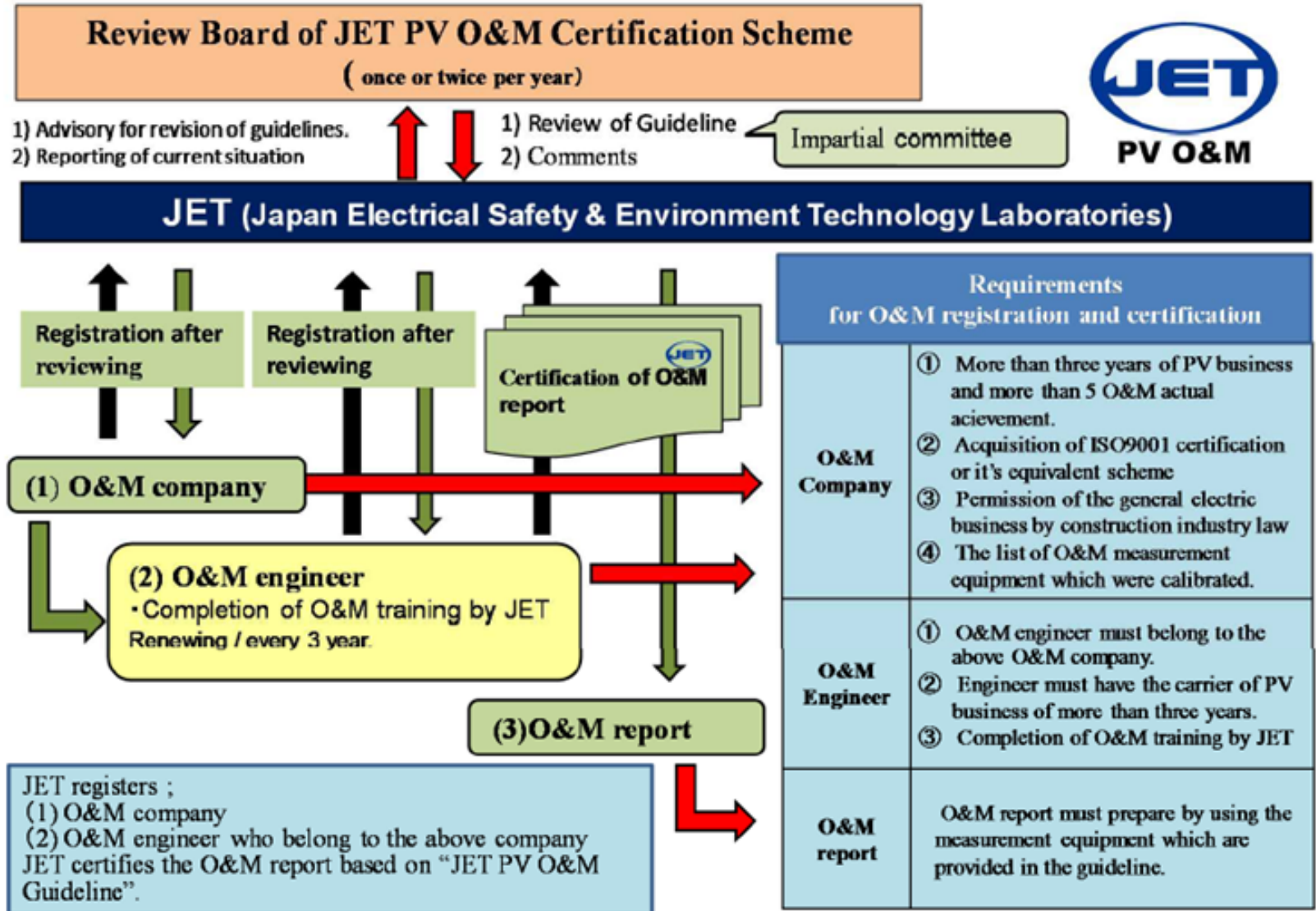
- ① 與發電、模組、PCS等故障相關的檢查。
- ② 根據定期檢查結果對PV發電系統的特定零組件等進行檢查。

3. 精密檢測

系統擁有者根據定期檢查和故障檢查結果，應要求進行的檢查稱為精密檢查。可從以下①②③④中選擇或組合進行。

- ① PV組件、PV陣列精密檢測外觀檢測、IV曲線、IR成像、EL成像、絕緣電阻等測量
- ② PV組件接線盒
- ③ 確認旁路線路是否完好，電路接線有無斷線等。
- ④ 配線、斷線 確認PV組件內電路是否斷開，旁路線路是否完好，檢查組件間連接器導通不良部位等。
- ⑤ 其他：根據要求確定。

JET O&M 維運驗證方案



公司

工程師

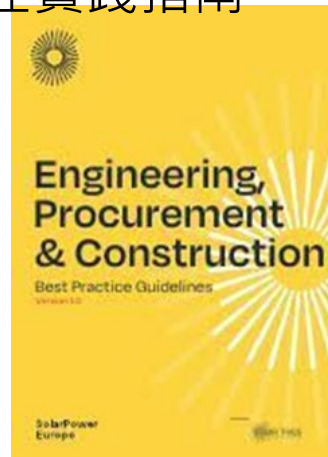
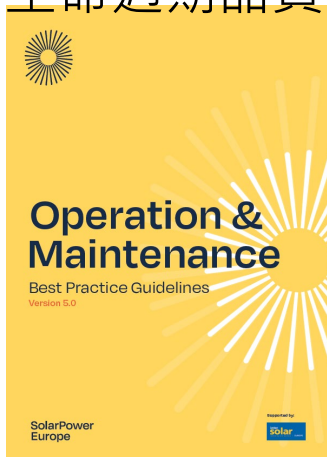
報告



SolarPower Europe

Best Practice Guidelines 最佳實踐指南

- ✓ 歐洲太陽能業者組織（ SolarPower Europe ）開發太陽光電最佳實踐工具，包含一系列指南、清單，還有最佳實踐標誌
- ✓ 太陽能最佳實踐指南是一套手冊，依據最高標準提供不同太陽能服務建議。
- ✓ 目的為提高行業的服務品質和標準化，其指南包括：
 1. O&M 最佳實踐指南
 2. EPC 最佳實踐指南
 3. 資產管理最佳實踐指南
 4. 生命週期品質最佳實踐指南



The O&M Best Practice Guidelines 5.0

- 新修訂的版本在健康、安全、安保和環境章節中，採用更加綜合的方法來處理**職業健康與安全**。
- 創新和趨勢章節已更新，包括創新現場檢查技術，例如基於**無人機的紫外線光螢光成像**。
- **商業和工業以及住宅屋頂PV裝置的日益普及**，對屋頂太陽能章節的 O&M 進行了全面改革，以將這兩個部分分開並提供更專業的建議。

The significance of O&M for the solar sector

In the lifetime of a PV plant, O&M is the longest activity



Source:

<https://www.solarpowereurope.org/insights/thematic-reports/o-and-m-best-practice-guidelines-version-5-0> , 2021/12。



The O&M Best Practice Guidelines 5.0

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The O&M Best Practice Guidelines 5.0

5. 電廠操作

5.1. 文件管理系統(DMS)

5.1.1. 資訊類型和詳細程度/竣工文件

5.1.2. 管理與控制

5.1.3. 紀錄控制

5.2. 電廠性能監測和監督

5.3. O&M優化

5.4. 電廠控制

5.5. 發電預測

5.6. 符合電網規範

5.7. 變革管理

5.8. 電廠安全

5.9. 報告和技術資產管理

6. 電廠維護

6.1. 預防性維護

6.2. 糾正性維護

6.3. 預測型維護

6.4. 特別維護

6.5. 額外服務

6.5.1. 模組清潔

6.5.2. 先進的航空熱影像

6.5.3. 植被管理

6.5.4. 減少損害

包含在所有O&M合約中的維運種類

預防性維護

- 預防性維護是PV電站維護服務的核心要素，包括定期目視和物理檢查，以及驗證太陽能發電廠的所有關鍵部件是否處於良好的工作狀態。
- 維護依據OEM和O&M的手冊定期進行，並包含在「年度維護計劃」中。

修復性維修

- 糾正性維護指將PV電站系統、設備或組件恢復到正常運行狀態而執行的任何活動，發生在遠端監控故障檢測之後或現場檢查期間。
- 糾正性維護包括故障診斷、臨時維修和修復，可分為3個級別的干預：無需替代的干預、需要替代的干預和需要對設備軟件進行干預。

預測性維護

- 預測性維護是一種基於條件的干預，依項目退化的重要參數的分析和評估得出的預測進行。
- 現場必須有「智能」設備和合適的監控軟件系統，讓營運團隊對PV電站的主要設備（變壓器、逆變器、匯流箱和/或直流電）進行定期監控、監督、預測和性能數據分析大批）。

The O&M Best Practice Guidelines 5.0

9. 數據&監控的要求

9.1. 數據紀錄儀

9.2. 數據品質和管理

9.3. 監控(網路) 門戶

9.4. 數據格式

9.5. 配置

9.6. 互操作性

9.7. 互聯網連接和局域網

9.8. 數據所有權和隱私

9.9. 網路安全

9.10. 通過監控系統收集的數據類型

9.10.1. 輻照度測量

9.10.2. 模塊溫度測量

9.10.3. 當地氣象數據

9.10.4. 串併測量

9.10.5. 逆變器測量

9.10.6. 電能表

9.10.7. 控制設置

9.10.8. 警報

9.10.9. 交流電路/保護繼電器

9.11. 太陽光電組件現場檢查收集數據

9.11.1. 紅外熱成像(IR)

9.11.2. 現場I-V曲線追蹤

9.11.3. 現場電致發光 (EL) 圖像

9.11.4. 電磁聚焦成像 (MFI)

9.11.5. 污染測量

如何獲得標章 Mark

Get the mark

1

Fill in the Checklist

First, and before registering, download [the free Checklist](#) to do a first self-evaluation to see if you pass the Mark's stringent requirements that are based on the O&M Best Practices Guidelines.

2

Compile your Technical Dossier

Second (still before registering), put together your Technical Dossier. The Technical Dossier is a set of documents to substantiate your Checklist. The required documents are listed in [the Checklist](#).

3

Register Below

Once you have passed the requirements, filled in the Checklist and put together the Technical Dossier, the third step is to sign up by filling in the registration form below.

4

Update your documents annually

Each year the Checklists are updated and new versions of the logo are issued containing the reference year. You will be informed when a new versions of the Mark and the Checklists are available.

啟用 Windows
移至 [設定] 以啟用 Windows

- 最佳實踐標章基於自我驗證，公司應自行負責確保核對清單和技術檔案的完整性，**SolarPower Europe** 不會對其進行驗證。
- 註冊後公司將出現在公司名錄中，而公司的清單和技術檔案不會在網站上發布，也不會與 SolarPower Europe 共享。
- 公司根據要求存儲、維護和資訊分享，**SolarPower Europe** 僅提供平台和工具。

Source: <https://solarbestpractices.com/get-the-mark>



Solar Best Practices checklists

- 使用太陽能最佳實踐清單進行標章註冊前自我評估
- Checklist 是一個 Excel 工具，可以計算分數，並判斷是否符合要求。
- 如果試算結果沒有通過，可透過實施優化措施來提高分數。



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Best practice checklist
2023 edition



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SOLAR AERIAL THERMOGRAPHY

Solar Aerial Thermography

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SOLAR ASSET MANAGEMENT

Solar Asset Management

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2023 edition



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註冊流程與費用

1 Choose your plan

2 Company information

3 Personal information

4 Payment details



What marks are you interested in?

Welcome to the registration page for the Best Practices Mark. For non-SolarPower Europe members, the cost of one mark is €1000, other marks purchased within three months of the first cost €800.

Solar Monitoring Best Practices Mark

Best Practices Mark

select

Solar O&M Best Practices Mark

Best Practices Mark

select

Solar Aerial Thermography Best Practices Mark

Best Practices Mark

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Solar Asset Management Best Practices Mark

Best Practices Mark

select

標章註冊費用 1000歐元/個

三個月內申請第二個 800歐元/個

已獲得標章公司清單

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Sinovoltaics

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Girasol Renewable Energy provides expert Solar Aerial Thermography using Sitemark analytics platform.

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IEA不同氣候下PV電站運維指南

- 因不同氣候帶和條件下，顯示溫度、濕度、暴露於紫外線、雨水和風等壓力因素，可能導致組件故障的發生。
- 國際能源署太陽光電發電系統計劃 (IEA-PVPS) 2022年在「不同氣候下光伏電站運維指南」報告中，針對七個不同氣候帶的定制一系列運維服務方案。
- 前四種適用於世界大部分地區普遍存在的條件（溫和、乾熱、濕熱、高海拔沙漠），而後三種適用於極端條件（洪水多發地區、颶風地區、多雪地區）。

Technology Collaboration Programme
by IEA



International Energy Agency
Photovoltaic Power Systems Programme



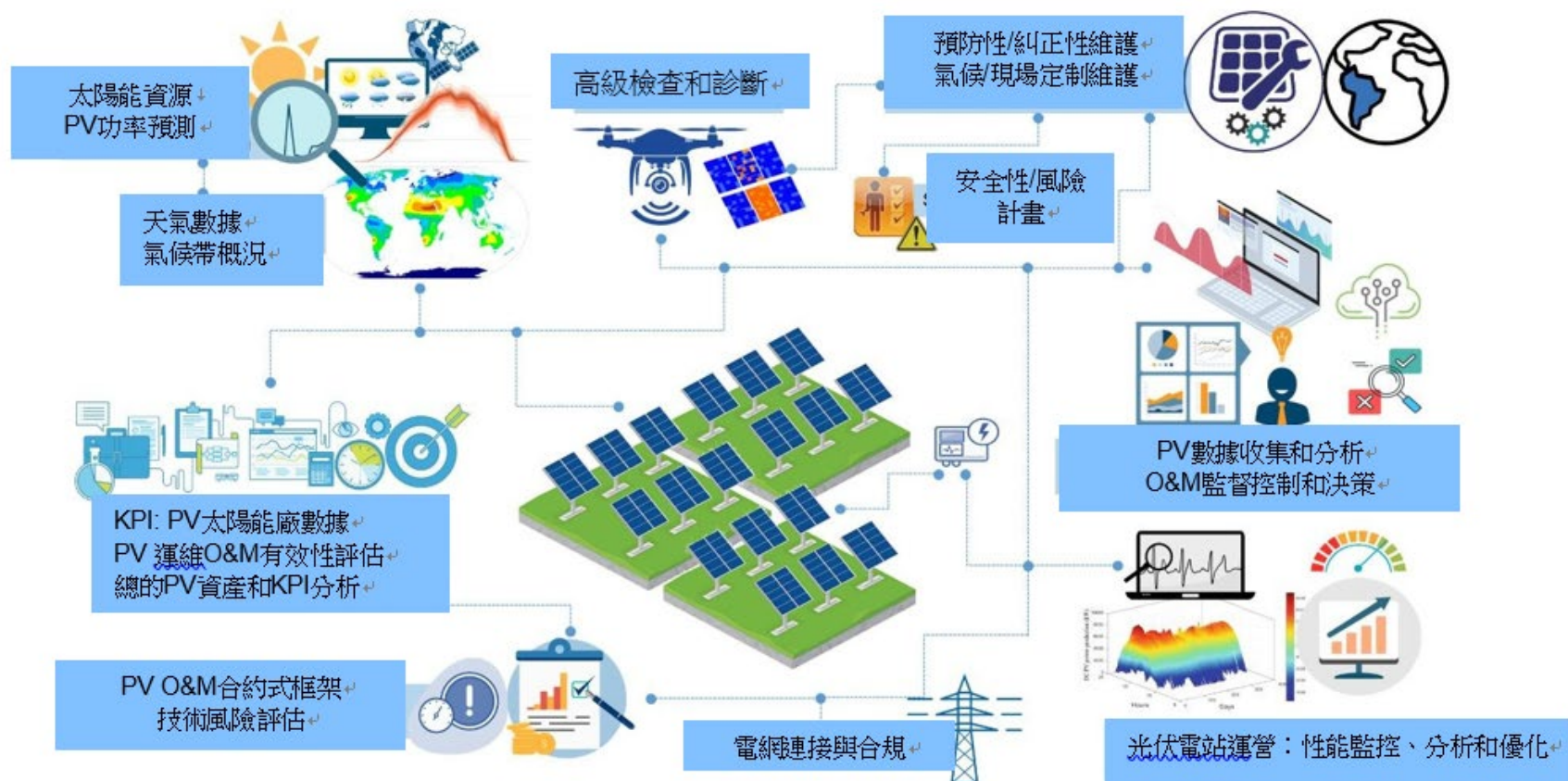
Task 13 Reliability and Performance of Photovoltaic Systems

SPVPS

Guidelines for Operation
and Maintenance of
Photovoltaic
Power Plants in
Different Climates
2022

Report IEA-PVPS T13-25:2022

- 報告主題包含維運性能指標和標準維運服務，PV電站性能和安全的監測、預測和分析指南，不同類型的維護服務和進階檢查，最後是特定氣候對O&M的影響建議，以及可靠性、性能和安全性的現場經驗。
- 由於運維服務是相互關聯的，包括PV電站的監控/檢查、數據分析、維護和優化。下圖顯示了整個PV電站技術生命週期的運維概念。



IEA不同氣候下PV電站運維指南

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Plant Performance Monitoring Guidelines

電廠性能監測指南

依IEC61724- 1 監控系統分類和建議應用

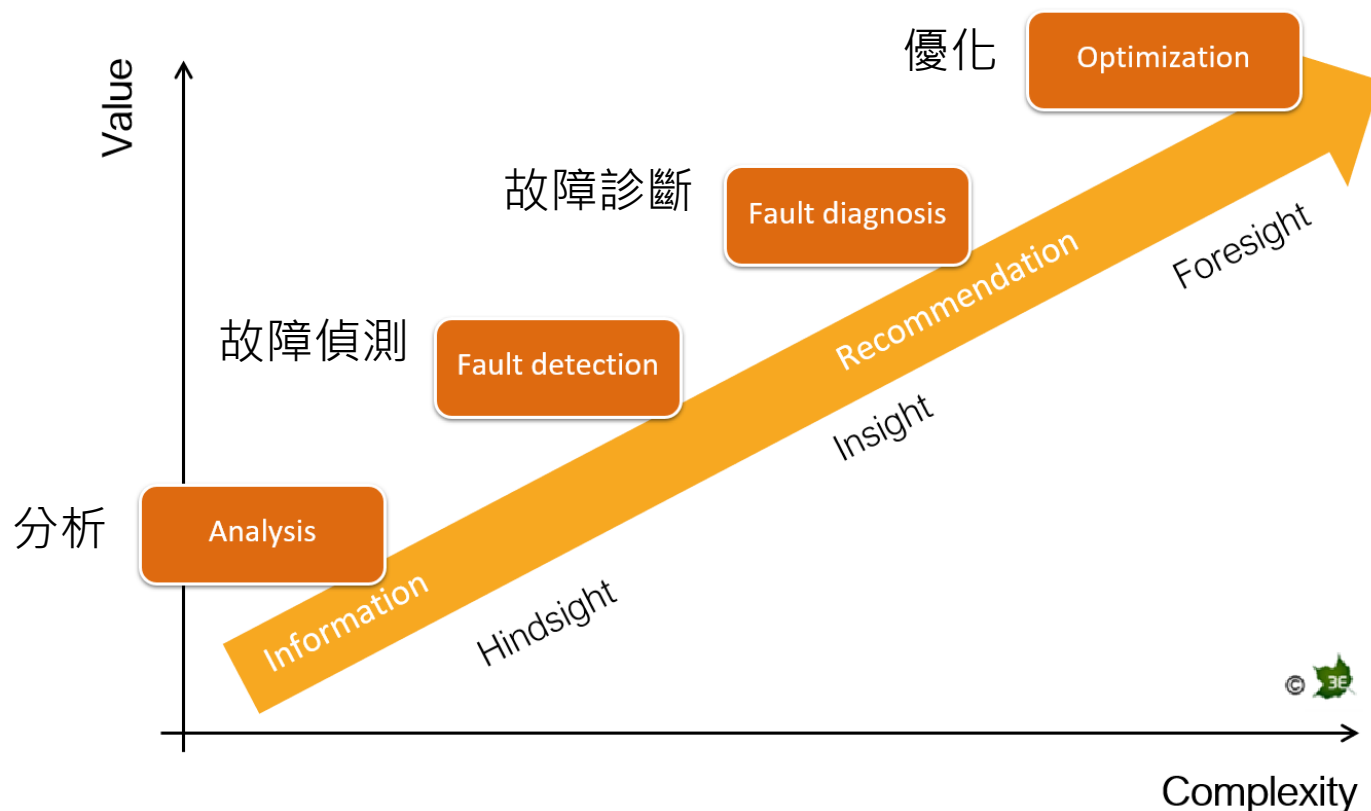
典型應用	A類 高準確率	B類 中準確率	C類 基本準確率
基本系統性能評估	X	X	X
性能保證文件	X	X	
系統損失分析	X	X	
電網互動評估	X		
故障定位	X		
PV技術評估	X		
精確的PV系統老化測量	X		

- ✓ IEA報告中 [3.1.2 Best Practice Guidelines](#) 反映當前監控和PV電站性能評估的最新技術，其研究結果亦參考” SolarPower Europe Operation & Maintenance Best Practice Guidelines” 。

Performance Analysis and Optimization

性能分析與優化

- PV智能性能監控系統優於簡單分析和警報系統，除提供故障檢測和診斷功能，為運營商和資產管理者提供可操作的建議。



大數據分析 - 不同操作和維護目標的價值和複雜性

Preventive Maintenance

預防性維護

- 預防性（或主動）維護 (PM) 代表了應用於PV電站的 O&M 計劃的基礎，包括範圍廣泛的「按計劃」活動和電站組件的維護服務。
- PM 方法是 O&M 中有效的標準實踐，特別是它們在降低PV系統意外停機風險的效果。
- 最常見的 PM 動作包括：
 1. 在模塊級對單個電氣 (I-V) 測量進行定期「採樣」
 2. PV 模塊或組串的定期檢查：主要是紅外和/或（輔助）EL 成像
 3. 清潔組件（包括除污和/或除雪）
 4. 場地維護，包括植被管理、清除鬆散物體
 5. BOS 維護（檢查、變流器維修、跟踪器維護）
 6. 維護 SCADA/監控系統（包括氣象站、數據採集單元、傳感器）
 7. 與場地管理相關的其他行動（排水、與野生動物隔離、圍欄/道路維修、環境合規和安全）

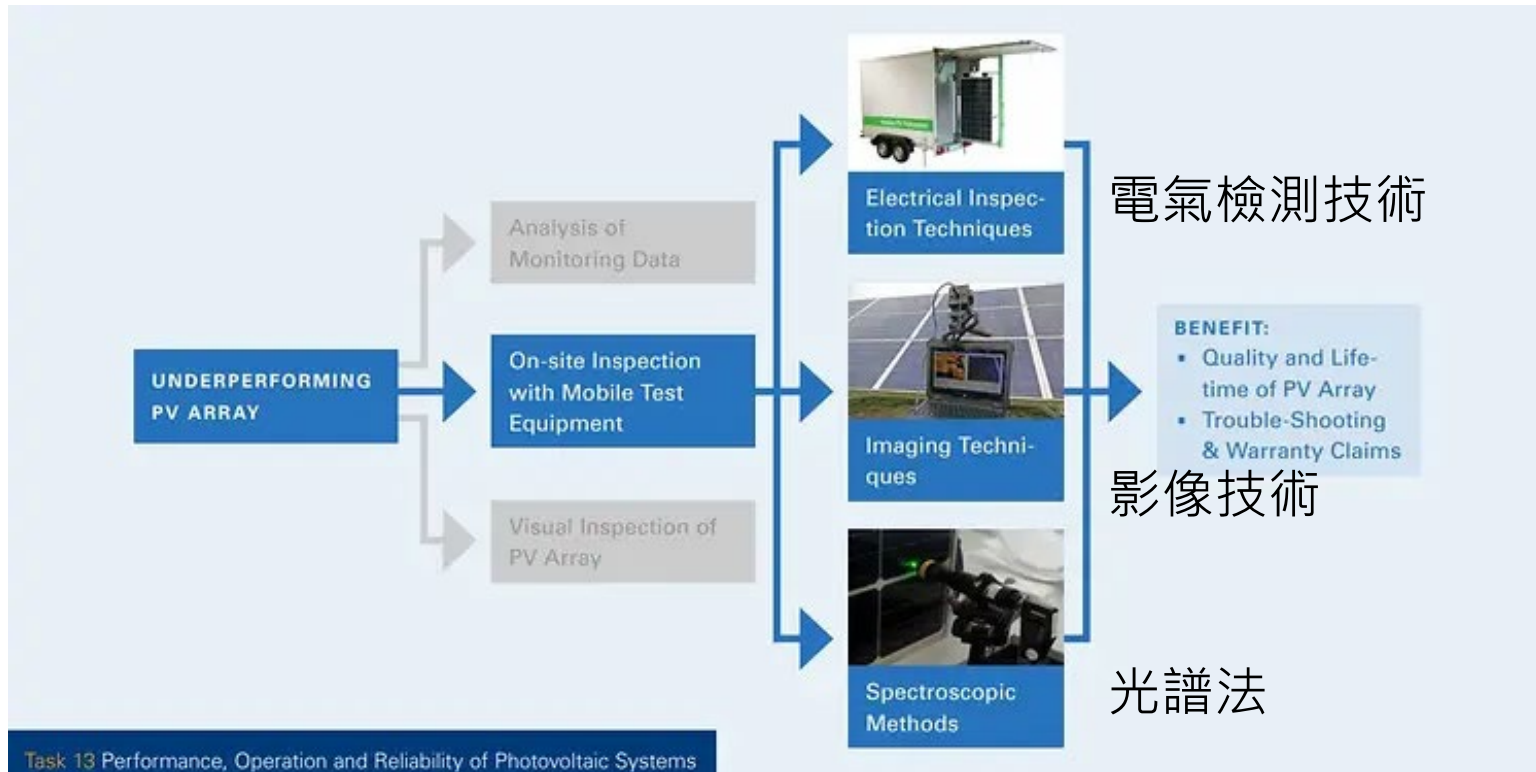
維運相關國際標準和技術規範

Table 6: O&M related international standards and technical specifications.

Standard / Technical Specification	Title	Highlights
IEC TS 63049	Terrestrial photovoltaic (PV) systems - Guidelines for effective quality assurance in PV systems installation, operation, and maintenance	Good practices for O&M management and development
IEC 62446-1:2016	Photovoltaic (PV) systems - Requirements for testing, documentation, and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection	Verifications, test procedures (I-V curve, IR inspection, etc.), results interpretation
IEC 62446-2:2020	Requirements for testing, documentation, and maintenance - Part 2: Grid connected systems - Maintenance of PV systems	Maintenance protocols, verifications tasks, safety procedures
IEC TS 62446-3:2017	Photovoltaic (PV) systems - Requirements for testing, documentation, and maintenance - Part 3: Photovoltaic modules and plants - Outdoor infrared thermography	Equipment requirements, inspection procedure, evaluation

On-site inspection methods 現場檢查方法

- 其優勢在於無需拆卸 PV 模塊並將它們運送到測試實驗室即可執行測試。
- 避免運輸風險和長時間的PV系統停機時間。



綜合討論與問卷調查

- 如何提高國內PV維運服務品質與透明度
- 如何降低PV系統維運成本與減少故障發生
- 台灣是否應建立PV最佳維運指南或相關工具？
- 確保人員接受 O&M 操作培訓和裝備來降低風險
- 透過 PV 預測性維護來減少可能的停機時間
- 維運業者問卷與意見調查 <https://reurl.cc/OvXVrr>





感謝聆聽 敬請指教
Thank you