Operational and Economic Impacts of Extreme Weather on PV Power Plants
极端天气对光伏电站运行与经济性影响

IEA PVPS has published a new Task 13 report examining the operational and economic impacts of extreme weather on photovoltaic power plants. As extreme weather events become more frequent and severe, and global PV capacity continues to grow rapidly, understanding and addressing weather-related risks is increasingly important.
国际能源署光伏系统项目（IEA PVPS）发布了一项新的 Task13 工作组报告，探讨极端天气对光伏电站运行性能与经济性的影响。随着极端天气事件日趋频繁剧烈、全球光伏装机容量持续快速增长，理解并应对天气相关风险愈发重要。
The report provides a comprehensive overview of extreme weather events that are most relevant for PV systems, including tropical cyclones, convective storms and hail, snowfalls, dust and sandstorms, heatwaves, floods and wildfires. It assesses both catastrophic damage, such as the destruction of modules or mounting structures, and sub-catastrophic damage that may not be immediately visible but can lead to accelerated performance degradation over time.
该报告全面梳理了与光伏系统最相关的极端天气事件，包括热带气旋、对流风暴与冰雹、降雪、沙尘暴、热浪、洪水及野火。报告既评估了组件或支架结构损毁等灾难性破坏，也分析了可能不会立即显现、但会随时间推移导致性能加速衰退的次生损害。

Key Takeaways:
核心要点：

1. Most PV plants can survive most extreme weather events, if appropriately sited, designed and maintained.
选址、设计与运维得当：多数光伏电站在适当选址、设计和维护的前提下，能够经受住大部分极端天气事件

2. This report considers weather events that 1) have short-term impacts and occur sporadically, e.g., tropical cyclones, convective storms (including hail) and 2) those that have longer-term impacts and tend to be repetitive, e.g., snow, dust storms, heatwaves, and wildfires. From an impact perspective, two types of damage can be identified in PV systems: acute and chronic. Risk assessment for PV plants in the

first category is a critical first step, whereas design optimization for plants in the second is the priority. From a resilience and mitigation standpoint, site planning is essential. Risk assessment based on a review of historical weather data and the probability of future extreme weather events for each location is crucial and must be addressed in the design phase. Once the threat landscape has been properly assessed, project developers, and owners must make informed design and procurement choices. All materials and structural components must be code-compliant; module architecture also matters, as in, modules specifically designed for hail resilience. In addition, review of the racking/tracking design, including hardware, by an independent engineer is strongly encouraged. In addition, architects should pay close attention to the terrain and geological conditions at the proposed site. For example, when installing a PV system on sloped ground, the foundation should include features to prevent landslides triggered by tropical cyclones or flooding.

风险分类与应对策略：本报告涉及的天气事件可分为两类：1）具有短期影响且偶发的事件，如台风、对流风暴（含冰雹）；2）具有长期影响且往往重复发生的事件，如积雪、沙尘暴、高温和野火。从影响角度看，光伏系统损害可分为急性与慢性两类。对第一类事件的风险评估是首要关键步骤，而对第二类事件的设计优化则是优先事项。从抗灾与缓解角度，场址规划至关重要。基于历史天气数据及各地未来极端天气发生概率的风险评估至关重要，必须在设计阶段予以解决。在准确评估威胁态势后，项目开发商与业主需做出明智的设计与采购选择。所有材料与结构部件必须符合规范标准；组件架构亦很重要，例如专为抗冰雹设计的组件。此外，强烈建议由独立工程师对支架/跟踪系统设计（包括硬件）进行审核。同时，设计方需密切关注选址地形与地质条件。例如，在坡地安装光伏系统时，基础结构应包含防止热带气旋或洪水引发滑坡的措施。

3. Site owners and operators should keep relevant commissioning documents, particularly those related to energy production in order to have a baseline against which future performance can be compared. Similarly, any electroluminescent (EL) and infrared (IR) images, along with records of visual inspections and I-V measurements, should be preserved.

文档保存：电站业主与运营商应保存相关调试文件，特别是与发电量相关的记录，以便建立未来性能比较的基准。同理，任何电致发光（EL）与红外（IR）图像，以及目视检测和 I-V 测量记录均应妥善保管。

4. Electrical performance data are essential for evaluating the effects of extreme weather events and any resulting acceleration in system degradation. When combined with weather data-such as temperature, solar irradiation, and wind speed-this information forms time-series data that can help detect weather-related damage. Awareness among site owners and maintenance teams needs to increase regarding the importance of collecting and preserving these data.
数据监测价值：电气性能数据对评估极端天气事件影响及由此导致的系统加速衰退至关重要。结合温度、太阳辐照度及风速等气象数据，可形成时间序列数据，有助于识别天气相关损害。需提升电站业主与维护团队对收集并保存此类数据重要性的认识。

5. Robust operation and maintenance (O&M) protocols are essential. Defects left unresolved after storm exposure may worsen over time when exposed to additional environmental stressors like heat, wind, and moisture. Continuous monitoring of power output from restored PV systems is therefore critical to ensure their performance and reliability. If a significant drop in power generation is detected, the collected data will help the owner make informed decisions about further actions, such as system refurbishment.
强化运维规程：严格的运维规程必不可少。风暴过后未修复的缺陷，在后续暴露于高温、大风和潮湿等环境压力时可能持续恶化。因此，对修复后光伏系统的发电输出进行持续监测至关重要，以确保其性能与可靠性。若检测到发电量显著下降，所收集的数据将帮助业主就后续行动（如系统翻新）做出明智决策。

6. Proactive maintenance is equally important and should be tailored to the probability of risk. Before a tropical cyclone, for example, tasks such as checking the t tightness of fasteners and clearing debris, which could become airborne-should be carried out in advance.
预防性维护：预防性维护同等重要，且应根据风险概率进行针对性安排。例如，在台风来临前，应提前完成检查紧固件松紧度、清理可能被卷起的杂物等任务。

7. If damage from extreme weather does occur, corrective maintenance should be implemented as soon as possible. Immediate steps include 1) ensuring the safety of the site by disconnecting it from the grid and opening all breakers; and 2) conducting electrical and mechanical inspections of the affected PV system. Damaged equipment should be left in situ, pending insurance or other

claim-related inspections but all damaged PV modules and electrical components must be replaced prior to re-energization.
灾后修复：若极端天气确实造成损害，应尽快实施纠正性维护。措施包括：1）通过断开电网连接并打开所有断路器确保现场安全；2）对受影响光伏系统进行电气与机械检查。受损设备应在保险或相关索赔检查前保持原位，但所有损坏的光伏组件及电气部件必须在重新通电前予以更换。

By consolidating international experience and best practices, the report supports PV developers, owners and operators in improving the resilience and long-term reliability of PV power plants under increasingly challenging climatic conditions.
该报告通过整合国际经验与最佳实践，支持光伏开发商、业主和运营商在日益严峻的气候条件下，提升光伏电站的抗灾能力与长期可靠性。