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Pillar 1

Affordable and Reliable VRE

Factsheet P1-01

Renewable systems for enhancing stability and efficiency

Effective system stability assessments and feasible enhancement technologies are critical for the long-term stability and sustainable development of renewable energy (RE) in power systems. Grid-forming inverters and converters for photovoltaic (PV) and wind power plants will provide stability to power systems. Additionally, compared to alternating current (AC) systems, direct current (DC) systems are more efficient and cost-effective for integrating RE into grid and/or interconnecting them. Additionally, AI-assisted solutions also offer significant potential in RE applications. Demonstration projects of RE systems based on the above innovative solutions are showcased in this factsheet.

GPFM Innovation Priorities in scope:

- **IP 1.1.3** - Reliability evaluation of PV modules and systems
- **IP 1.3.2** - Large-scale IRE generation for improving system reliability and stability
- **IP 1.6.3** - MVDC / LVDC-based renewables systems for enhancing stability and efficiency

6 Case studies reported in the factsheet

10 Projects covering these IPs are reported in the GPFM National Pilots report

For further details on **GPFM Innovation Priorities (IPs):**

GPFM Roadmap **Action Plan 2022-2024** **National Pilots Report**

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Case studies

Case Study #1 PV MVDC power generation grid connection system

With the rapid development of renewable energy generation worldwide, photovoltaic power generation systems are evolving towards multi-scenario and high-efficiency directions. The photovoltaic medium-voltage direct current (MVDC) power generation system is a new type of system that efficiently collects power over a large area. It offers advantages such as fewer conversion stages, lower line losses, and easier integration with various energy sources or loads. This case study introduces briefly the key technologies of photovoltaic MVDC power generation systems. It also summarizes practical and industrial verification cases for photovoltaic MVDC systems.

Link to case study's detailed description

China

Case Study #2 AI-based algorithms for PV plant failure detection and diagnosis

New machine learning techniques can be adopted to develop diagnostic tools powered by Artificial Intelligence algorithms for PV Failure Detection and Diagnosis (FDD). When multiple faults or malfunctions that have similar consequences on the PV plant performances occur simultaneously, FDD algorithms have difficulties to correctly identify them. This case study focuses on studying the effect of a combination of different faults or malfunctions on the PV plant parameters to develop a model for their detection. The focus was on the overlapping effects of short circuit bypass diode and the increase of series resistance due to cell degradation, since data shows that this was the failure combination leading to the higher level of uncertainty.

Link to case study's detailed description

Italy

Annual RE power capacity additions from 2023 to 2050 under the 1.5°C scenario

1066 GW/yr

Share of RE in electricity generation by 2050 under the 1.5°C scenario

91%

Source: *IRENA*

Case Study #4 Online stability assessment and optimization of HVREPS

The high-proportion variable renewable energy power system (HVREPS) exhibits low inertia and significant random fluctuations, leading to the degradation of system stability. To address these challenges, an online stability evaluation and flexible active support control technology for HVREPS has been developed. Firstly, a multi-timescale renewable energy probabilistic prediction method was proposed to provide essential state parameters for stability evaluation. Then, a rapid online stability evaluation model based on machine learning was proposed. Finally, the "generator-station-grid" active support control technology and related device systems were developed to enhance the stability of HVREPS.

Link to case study's detailed description

China

Case Study #5 VisynC: Development of a hybrid energy storage system

This project aims to develop and validate a full-scale hybrid storage system combining lithium-ion batteries and ultracapacitors, managed by a control system to operate in synchronous grid-forming mode and provide the same services as a Synchronous Compensator. The new storage system will connect to the high voltage transmission grid in the Lanzarote-Fuerteventura electricity system, at Mácher 66 kV substation, and will operate as an integrated grid asset, offering various services to ensure the safe operation of the electricity system and increased integration of renewable energies. The system has a capacity of 16 MW, contributing to grid stability and renewable energy integration.

Link to case study's detailed description

Spain

Key metrics

To remain on a 1.5°C pathway by 2030, RE efficiency improvements must double and be driven by efficient technologies.

1. **More energy efficient technologies to reduce energy intensity, complemented by structural and behavioral changes.**
2. **A holistic approach, backed by systemic innovation to transform existing structures and systems built for the fossil fuel era**

https://www.irena.org/Digital-Report/World-Energy-Transitions-Outlook-2023

Case Study #3 800MW Offshore Wind Power Flexible HVDC Transmission Demo Project

The 800MW offshore wind power project of China Three Gorges Renewables (Group) Co., Ltd is located in the Huangsha Ocean area of Rudong County, Jiangsu Province. The total installed capacity is 800 MW, with a total of two hundred 4 MW wind turbines installed. The project has proposed a flexible high-voltage direct current (HVDC) transmission system to efficiently transmit the offshore wind power to shore. The system's overvoltage and insulation coordination design improved the safe and stable operating margin of the system under complex working conditions. The compact, lightweight equipment body design and interface coordination scheme also further reduced the size and weight of the offshore converter station.

Link to case study's detailed description

China

Case Study #6 RE empowering European and Indian communities (RE-EMPOWERED)

The "RE-EMPOWERED" project aims to develop and demonstrate novel tools for complete energy solutions for islanded/isolated communities. The tools include ecoPlanning Microgrids, Advanced Energy Management, ecoDR optimization, ecoCommunity engagement, ecoResilience for PV/wind, and ecoVehicle for e-mobility. All of these tools and solutions will be demonstrated in four demo sites with weak or non-existing grid, two in Europe (Denmark and Greece), and two in India (Ghoramara Island and Keonjhor). Additionally, hardware solutions will be upgraded and demonstrated, including dedicated converters, EVs and boats, cyclone-resistant PV and locally manufactured wind turbines, etc.

Link to case study's detailed description

India

Key findings

The case studies reported in this factsheet illustrate several novel tools for innovative energy solutions for enhancing the stability and efficiency of renewable energy systems. On the power generation side, photovoltaic medium-voltage direct current (MVDC) power generation systems offer advantages such as fewer conversion stages, reduced line losses, and greater stability. Lithium-ion battery and ultracapacitor hybrid storage systems could operate as an integrated grid asset by operating in synchronous grid-forming mode. Furthermore, several projects have highlighted the significant benefits of renewable energy in weak end-use grids. On the power system side, online assessment and optimization has been developed for stability evaluation of renewable energy systems, which shows the enormous potential of AI-assisted analysis applications. AI techniques can also be adopted to develop diagnostic tools for failure detection and diagnosis of PV plants, which is crucial for ensuring the long-term stability and reliability of the system. In terms of transmission, connecting the mainland to offshore stations using flexible high voltage direct current (HVDC) systems is a key factor in enhancing system efficiency.

- MVDC collection and grid integration technology provides a simpler, more efficient, and stable solution for large scale PV power stations
- Grid-forming hybrid energy storage system can provide various services to ensure the safe operation of electricity system and integration of renewable energies
- AI enables efficient stability analysis and control optimization of power system with high proportion renewable energy

About GPFM

The Green Powered Future Mission (GPFM), launched within the second phase of the global initiative Mission Innovation (MI2.0), is a public-private partnership with members from MI countries, private sector companies and international organisations. It aims to demonstrate that by 2030, power systems in different geographies and climates can effectively integrate up to 100% variable renewable energies, like wind and solar, in their generation mix, and maintain a cost-efficient, secure and resilient system.

https://explore.mission-innovation.net/mission/green-powered-future/

GPFM Coalition