# PV as an ancillary service provider

## Laboratory and field experiences from different IEA PVPS countries

Editor: Markus Kraiczy, Fraunhofer IEE

August 2021

Technology Collaboration Programme
by iea

# PV Grid Integration Challenges

## Stage 1: Low PV/ VRE penetration

**Main challenge: Get the grid PV/ VRE ready**

**Regional challenges, i.e.:**

- Potential over-voltage issues (especially in rural grids)
- Potential over-loading issues (especially in rural grids)

**System-wide challenges:**

- Usually none

**Inverter functionalities in focus:**

- Usually "get out of the way" approach. PV disconnects in case of a grid disturbance (**not recommended**).

Barrier: Advanced regulatory frameworks recommended*

## Stage 2: Regional PV/ VRE hotspots

**Main challenge: Increase regional grid hosting capacity**

**Regional challenges, i.e.:**

- Significant over-voltage and over-loading issues
- Reverse power flows and reco-ordination of protection settings

**System-wide challenges, i.e.:**

- Relevance of PV for system stability usually reached
- Adaption of unit-commitment conventional generation

**Inverter functionalities in focus:**

- Autonomous grid support functions, i.e. Volt-var, frequency-Watt
- Ride through and remain connected functions

Barrier: Advanced regulatory frameworks recommended*

## Stage 3: PV/ VRE significantly affect system-wide operation

**Main challenge: Increase flexibility in grid operation**

**Regional and system-wide challenges, i.e.:**

- See Stage 2
- High need for active and reactive power flexibility
- Coordination of regional and system-wide services
- Smart Grid concepts increasingly necessary at distribution level
- Potential reliability and stability issues (i. e. declining inertia)

**Inverter functionalities in focus:**

- See Stage 2
- Remote control functions, i.e. request P and Q, remote P curtailment increasingly also for distributed PV/VRE

Barrier: Advanced regulatory frameworks recommended*

## Stage 4: PV/VRE dominated power system

**Main challenge: Ensure system-wide stability**

**Regional and system-wide challenges, i.e.:**

- See Stage 2 & 3
- Potential reliability and stability issues in inverter dominated power systems (i.e. declining inertia, black-start, grid forming)
- PV/ VRE and PV/ VRE hybrids have to provide a major share of ancillary services

**Inverter functionalities in focus:**

- See Stage 2 & 3
- Active grid control functions, i.e. synthetic inertia, black start capability, grid forming capability

*Revision and update of regulatory frameworks, such as grid codes, selected standards and eventually ancillary service procurement procedures, before entering next stage highly recommended

**PV/ VRE Penetration level (regional / system-wide)**

| Stage 1 | Stage 2 | Stage 3 | Stage 4 |
|---|---|---|---|
| Low to Medium / Low | Medium to High / Low to Medium | High / Medium to High | High / High |

PVPS

# PV Inverter Functionalities

Levels and inter-relations between advanced inverter functionalities

**Active grid control**
- Fast frequency response (i.e. synthetic inertia)
- Black start capability
- Grid forming control

**Communication**
- Remote control: i.e. connect/ disconnect, adjust maximum generation, adjust reactive power
- Parameter adoption

**Autonomous grid support**
- Voltage control: i.e. Q(U) control
- Frequency control: frequency-watt P(f)
- Fast reactive current

**Interface protection**
- Compatible with ride-throughs
- Avoid inadvertent tripping
- Islanding not inflicting power quality

**Ride-Through and remain connected**
- Voltage ride-through
- Frequency ride-through
- RoCoF immunity

**Operational ranges**
- Active power-frequency range
- Voltage range
- Reactive power range

# Overview of Practice Examples in Report

| Service | Topic | Country/ Area |
|---|---|---|
| PV voltage control services | PV local reactive power compensation | Switzerland |
| | Remote PV reactive power control for voltage support at the Transmission – Distribution interface | Germany |
| PV frequency control services | Distributed PV response to a major separation event and resulting frequency excursions in the Australian National Electricity Market, August 2018 | Australia |
| | Frequency control services by Wind and PV power plants | Germany |
| PV curtailment | Dynamic PV power curtailment | Switzerland |
| | Remote curtailment of residential PV systems via Smart Meter Gateway | Germany |
| PV hybrids in insular power systems | PV storage hybrid system for 100% solar power on the remote island of St. Eustatius | St. Eustatius |
| | One hour with 100% renewable power - islanding operation test of the German community of Bordesholm | Germany |
| | PV hybrids in the island power system of El Hierro | Spain |
| Further | Minimization of harmonic current emissions of a PV plant | Germany |
| | PV inverter in hybrid (DC,AC) microgrids | Italy |