FACT SHEETS ABOUT PHOTOVOLTAICS

European Technology & Innovation Platform PV

PV generation is fit for modern, active power networks

PV makes a significant and growing part of power generation capacity

Global PV capacity is on an exponential trend, with more new capacity being added every year than the year before. Over 2016, global installed capacity **grew by 33% to reach 307 GW**. In Germany, PV now represents about 21% of the power generation capacity.

PV systems generated **1.5% of the world's electricity consumption** in 2016 and 4% of the EU's. In Italy the fraction of electrical energy demand covered by PV was above 9%.

PV challenges the old wisdom in power networks

Legacy power networks were designed based on generation by thermal power plants (nuclear, coal, natural gas, oil) and hydropower plants. PV generation is fundamentally different from these conventional generators (Table 1). In addition, conventional utilities own only 1% of PV capacity in Europe.

Conventional	PV
Synchronous	Current-switched
High inertia	Low inertia
Centralised	Distributed
Scheduled	Randomly variable

Table 1: Technical differences between conventional and PV power generation

The challenges of integrating solar PV generation in such networks are first felt at the local, low-voltage distribution level. These local challenges can be: overvoltage, reverse power flows, overloading of lines or transformers, phase unbalance, rapid voltage fluctuations, harmonic distortions, and unintentional islanding. Voltage issues appear because voltage and power injection are linked (Equation 1). Using this relation, they can be mitigated with injection or absorption of reactive power. Modern power networks, where distributed generation and prosumers play a major role, will be built around bidirectional flows of both energy and information. PV inverters are the most natural interface for these flows.

$$V_R - V_S \approx \frac{RP + XQ}{V_R}$$

V_R is the voltage at the point of connection of the PV system, V_S is the voltage at the feeder start, R and X are respectively the resistance and the reactance of the line, and P and Q are the active and reactive power injected by the PV system, respectively.

Equation 1

High penetration levels have already been achieved and managed in distribution networks

The medium- and low-voltage grid of the Seebach area in Bayern has one of the highest densities of PV systems in Germany. It hosts a **PV capacity 3.3 times as high as its winter peak load** (41 MW vs. 12.5 MVA). Resultant grid reinforcements could be reduced from 16 km to 1 km by implementing automated voltage management through the control of active and reactive power injection. In the distribution network of Ulm (Germany), the **installed PV capacity is above the rated power of the transformer** in several low-voltage branches.

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Solutions are under development for future system-wide challenges

With the share of PV in power generation further increasing, more and more system support functions will be expected from PV systems in terms of dispatchability, predictability, inertia emulation, and fault and recovery support. Integration with storage is progressing more rapidly than the system needs. European companies and research organisations are developing and implementing techniques to estimate and forecast PV production from the single plant to the national level. They combine meteorological methods with advanced machine learning algorithms.

Inverters have a central role and are a European strength

The active, controllable power conversion capabilities of the inverter open many possibilities for PV generators to support the electricity system (Figure 1).

VOLTAGE SUPPORT	FREQUENCY SUPPORT	GRID MANAGEMENT	DYNAMIC GRID SUPPORT
▸ Based on request, schedule, or set characteristics ▸ Control of reactive power based on active power injection or local voltage	▸ Over frequency: gradual reduction in active power ▸ Under frequency: active-power feed-in	▸ On request by grid operator in case of grid congestion ▸ Temporary limitation of active power injection	▸ Low-voltage ride through ▸ Contribution to short-circuit current

Figure 1: System-support functions available from PV inverters

The inverter therefore represents a crucial part of PV systems. It accounts, on average, for 5% of the investment in PV generation. Thanks to Europe's leading role so far in integrating PV in power systems, four of the top ten inverter suppliers are based in the continent and command a combined market share of more than 18%.

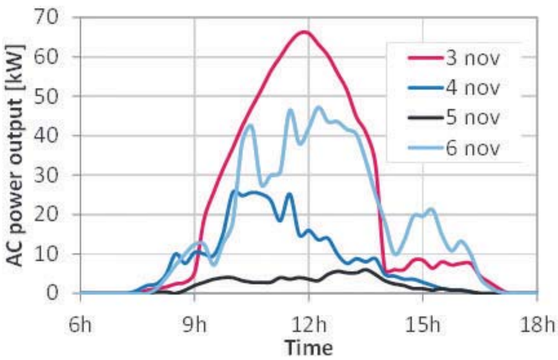

Figure 2: Intra-day and day-to-day fluctuations in output of PV plants are challenges for system management. Source: CSEM.

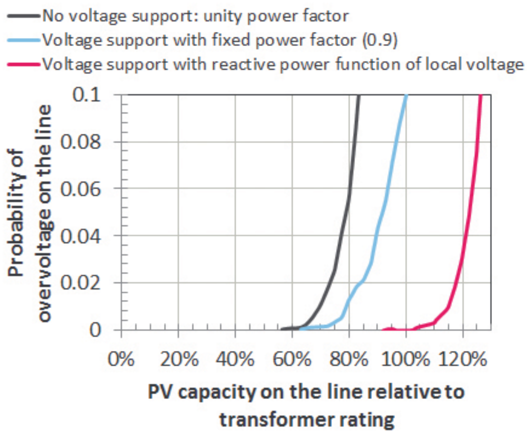

Figure 3: Reactive power management can prevent local overvoltage. Source: M. Kolenc et. al., MetaPV 2015.

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