Inverter Technology enabling high penetration PV

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IEA-PVPS Task 14

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PV is becoming relevant for electricity supply and grid operation

- Today
  - 17% of electricity generation capacity in EU added in 2009 was PV
  - 2% of electricity supply (kWh) in Germany from PV
  - In certain distribution grid areas, PV generation exceeds local demand → reverse power flow

- Impressive targets
  - EPIA: 12 % PV in Europe until 2020 – 390 GWp

➔ High PV penetration is becoming reality
➔ A number of previously irrelevant challenges arise
➔ PV is turning more and more into a Troublemaker.

The PV inverter as gateway to PV grid integration

- PV inverters
  - play a key role as interface between primary generation and electricity grid
  - Integrate protection and grid monitoring
  - System monitoring and control
  - Modern power electronics offer multifunctional characteristics
  - Interface between grid and local storage

The inverter as interface between PV generation and the grid

- Situation today
  - Sole conversion of DC to AC at unity power factor
    → maximizing conversion efficiency
  - Limitation of additional disturbances
  - ➔ Challenges:
    Maintain voltage quality in the distribution grid
    Accommodate increasing amounts of PV capacity

- In future high penetration PV scenarios
  - Capable to provide reactive power on demand
    Q or PF set points, time schedule
    depending on the voltage at the point of coupling "voltage control"
  - Remote controllability of active and reactive power injection
  - ➔ Provide voltage support in the distribution grid
  - ➔ Increase usable grid capacity ("hosting capacity")

The inverter as interface between PV generation and the grid

- Situation Today
  - Voltage/frequency monitoring
  - Additional passive or active anti-islanding schemes
  - "Disconnection at the first sign of trouble" practice
  - ➔ Threat: Simultaneous loss of a large number/capacity of PV systems due to remote faults in transmission system
  - ➔ Problem: Undefined behavior of PV systems during abnormal grid conditions

- In future high-penetration scenarios
  - Dynamic grid support by PV inverters (Fault-Ride-Through)
  - Behavior of the PV inverters adapted to the requirements of the system operation
  - ➔ PV support fault management in the grid
  - ➔ Grid operators will be able to "rely" on PV during critical situations.

System monitoring and control

- Situation today
  - PV inverters monitor a broad range of PV and grid parameters – but they are solely used for PV system monitoring
  - No standardized communication interfaces/protocols
  - No link to the grid operation
  - ➔ PV generation not visible to the grid operator

- In future, high penetration scenarios
  - PV inverter as hub and center for data acquisition, communication and control
  - Standardized communication interfaces and control protocols for easy interconnection
  - ➔ PV fully integrated into the EMS of the grid operator
  - ➔ Optimized direct utilization of PV electricity (grid parity!)

Multifunctional characteristics

- Situation today
  - PV inverters only provide active power to the grid
  - ➔ Opportunities of modern power electronics are not fully utilized

- In future high-penetration scenarios
  - PV inverter will become a key component in smart grids
  - Active improvement of quality of supply by filtering/compensation of Harmonics, Phase balancing
  - Virtual inertia
  - ➔ Provision of ancillary services to the grid can offer additional value to plant operation

The PV inverter as interface between local storage and the grid

- Situation today
  - Limited to local applications (UPS, backup supply,…)
  - ➔ Storage only used for local services
  - ➔ No link to grid operation

- In future, high penetration scenarios
  - Integration of local storage into grid management
  - Power-on-demand
  - Peak shaving/shifting
  - ➔ Increased security of supply and provision of ancillary services to the grid
  - ➔ Increase hosting capacity of the grid

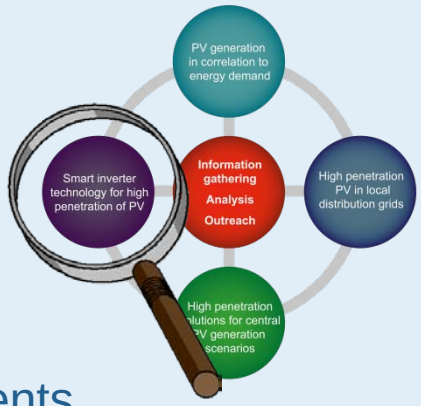
The PV inverter as part of the grid management

- Situation today
  - PV systems commonly not included in grid management
  - ➔ Challenge: Potential problems during critical situations in the grid
  - ➔ Negative perception of PV by grid operators

- In future high penetration PV scenarios
  - PV inverter integrated into the grid management
  - Temporary short term power curtailment during critical situation on demand of grid operator (by remote control)
  - Reduction of active power at increasing system frequency
  - ➔ Perception of PV is changing from being a troublemaker into becoming a part of the solution

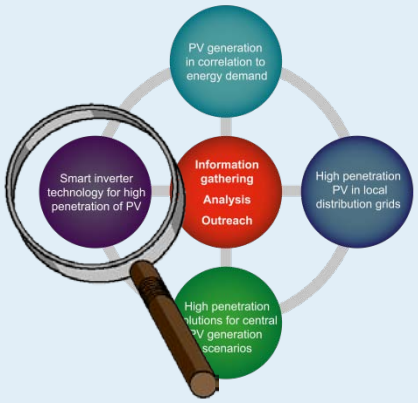
IEA-PVPS Task 14 Subtask 4
Smart inverters for high penetration PV

- Objective:
  Define inverter technology requirements for successful integration of a high penetration of PV in the electricity grids
  - Inverter technology requirements
    Design and topology related issues
  - Technical requirements, limits, capabilities
    What functionality can / needs to be added at certain levels of PV penetration?
  - Communication and control related requirements
    Interfaces, standards and protocols
  - The role of the PV inverter as interface between local storage and the grid



IEA-PVPS Task 14 Subtask 4
Smart inverters for high penetration PV

- Opportunities for Smart PV inverters in High-PV penetration scenarios
  - Review of functional, protection, control, safety and other requirements
  - Analysis of the impact of different applications (residential vs. utility scale), connection levels (LV, MV) and grid topologies
  - Elaboration of requirements to performance, operating ranges and utility compatibility with high penetration PV
- Technical capabilities and Inverter Topologies
  - Review of the suitability of different hardware and control topologies
  - Investigation of the impact of additional functionalities on design, dimensioning and performance of PV inverters
  - Improvement of available inverter simulation models
- Remote control and communication for Smart Inverters
  - Review of remote control practices (interfaces, communication technologies, protocols…)
  - Review of currently available communication standards suitable for Smart Inverters
  - Assessment of the suitability of current standards/practices for high penetration scenarios



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Summary & conclusions

- Growing PV penetration requires the active integration of the installations into grid operation
- PV inverters are the key elements to enable electricity grids for more PV
- New requirements will lead to a big step in technology innovation in the field of PV inverters

- PV inverters with new features
  - Provide system services
  - Contribute to grid support
  - Integrated into grid management
  - ➔ Help to significantly increase the share of PV generation in the electricity grids

Summary & conclusions

- Critical issues
  - Growing complexity and diversity of requirements may create an increasing barrier to effectively apply the potential of new inverter functionalities in practice
  - Important: International exchange of experiences and harmonized standards

- PVPS Task 14 will
  - act as a collaboration platform for international experts on the subject of high penetration PV
  - Use the worldwide PVPS network to disseminate information on high penetration PV and best practice models.

Thank you very much for your attention!

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