PV integration in the building: drivers, status and challenges

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Outline

- Introduction
- Physical integration into buildings
- Electrical integration into smart buildings
What is CSEM?

- Contract R&D and technology transfer organisation
- Public/private partnership
- Headquarters in Neuchâtel (Switzerland)
- 440 employees
- 160 customers worldwide
Energy systems at CSEM

- Energy management: control, automation
- PV-Center created in January 2013
- Covers value chain from basic **manufacturing processes** to **system integration** through to **cells** and **modules**
- Special relationship with EPFL / PV-Lab
- Unique CSEM advantage: combination of ICT and clean energy expertise

Measured aggregated load

Extracted power consumption by fridge (97% precision)
Rationale and challenges

- **Rationale**
  - Aesthetics
  - Cost (replacement of construction materials)
  - Available space
  - Regulation (higher subsidies in e.g., France, Switzerland)

- **Challenges:**
  - Aesthetics
  - Building design process:
    - PV taken too late into account
    - Lack of integration in materials libraries and design tools
  - Installation complexity
  - Compliance with standards and building codes
  - Manufacturing: diversity of designs and features vs. production costs
Status and trends

• Commercial status
  • Widely available: roof tile-like integration of standard modules
  • High-end products: double-skin façade, semi-transparent elements
  • Scarcely available: products for curved surfaces, flat roofs

• Under development
  • Advanced mounting structures for façades
  • Palette of textures and colours
  • Multi-functional elements (e.g., PV + insulation)
Market potential

Driver 1: impact of PV on power networks

- PV provides about **3% of total electricity demand** in Europe
- Ratio between PV power production and power demand peaks at **up to 77%** (Greece)

Driver 1: impact of PV on power networks

• Economics:
  • Zero marginal cost
  • Grid used as back-up: appropriate fee structure?

• Technology:
  • Intermittent and seasonal
  • Reverse power flows
  • Voltage variations

• Issues of intermittence and seasonality decrease by aggregation

• Demand-side management (incl. storage) further reduce variability

*Connecting the Sun: Solar Photovoltaics on the Road to Large-Scale Grid Integration (full Report).*
Driver 1: local issues and approaches

- Infrastructure cost:
  - Peak unchanged
  - Average decreased
  - Approach: capping, load management

- Voltage variations
  - Approach: reactive power injection, load management, on-load tap changers...

- Reverse power flows at transformer
  - Protection issue
  - Approach: storage, load management...

V. Musolino et al., to be published

E. Tognon, “Grid Integration” (Innovating photovoltaics: the way ahead, Milan, 7th May 2013)
Driver 2: end-user’s economic benefit

- LCOE < feed-in tariff < retail price e.g., Germany
  - LCOE \approx 0.10 \text{€/kWh} - 0.12 \text{€/kWh}
  - FiT = 0.1328 \text{€/kWh} (<10 \text{kW}_p)
  - Retail price = 0.1489 \text{€/kWh} (households, excl. taxes)
  - Retail price = 0.2921 \text{€/kWh} (households, incl. taxes and levies)

- Support scheme in favour of self-consumption:
  - UK: generation tariff + nominal export tariff
  - Switzerland: one-off investment grant + self-consumption up to 30 \text{kW}_p
Is storage the solution?

- Storage in the power system required
- Energy storage at generation point:
  - Specific operation strategy required
  - Fixed feed-in limitation implemented
  - > 3 kWh (battery) per kW$_p$ (PV) required to avoid transformer and voltage issues*
  - Typical commercial system today: 1 kWh/kW$_p$ to 2 kWh/kW$_p$
  - Additional energy cost > 0.19 €/kWh → not competitive + regulatory risk
- (Semi-)centralised storage: broader technology range, economies of scale

* Schmidt and Tröster, “Evaluating the Benefits of Storage in Low Voltage Distribution Systems with High PV Penetration.”

Weniger, Tjaden, and Quaschning, “Grid Integration of PV Battery Systems with Forecast-Based Operation Strategies.”
Management strategies

- Static boundary conditions e.g., capping of feed-in power
- Direct intervention by DSO
- Market-driven mechanisms:
  - Dynamic / time-of-use tariffs
  - Aggregation platform + local management for trading on wholesale market
- Example control architecture: Commelec protocol for micro-grids (J.-Y. Le Boudec & M. Paolone, EPFL)
  - Explicit set points
  - Grid agents (logical) interfacing resource agents (physical)
  - Fractal structure
Management strategies: challenges

- Acceptability, user engagement
- Stability and security
- Protocols and standards
- Market and regulatory design
Smart PV components: modules?

- Requirements for “smartness”
  - Bidirectional communication
  - Measurements
  - Data processing
  - Actionability
- “Smart modules”: module-level power electronics
  - Monitoring
  - Module-level optimisation
  - Possible actions:
    - Impedance adjustment
    - Disconnection (fire safety)
Smart PV components: inverters and managers

- **Inverters**
  - Physical interface between PV system and grid
  - Can accommodate storage on DC side
  - Now integrate active grid support functions

- **Energy manager**: existing features
  - Load analysis
  - Battery control
  - Heat pump control

- **Trends and challenges**
  - Load disaggregation
  - **Forecasting** of generation and load
  - Control of white goods: standardisation (several consortia e.g., Energy@Home)
  - Integration of energy manager to inverter or battery system
Self-consumption by design

- Better static matching between generation and load: new criterion for system optimisation
- Daily profile: azimuth angles
- Annual profile: tilt angles e.g., roof vs. façade
- Technology choice
- Safest option for customer

Match between generation and consumption for school building
Summary

- Potential steady-state BIPV market more than double current total PV market in most countries

- Local self-consumption of PV electricity driven by:
  - System benefits
  - Economic interests of end-users: PV costs below retail prices

- Local self-consumption can be maximised by:
  - Local storage: costly
  - Active demand management
  - Specific system design and integration in the building envelope

Thank you for your attention!