
Trends and innovations in the digital energy world

Michael Weinhold, CTO Siemens Energy Management
Agenda

1. Trends
2. Innovations
3. Outlook
The Energy Revolution: Big Picture

From centralized power and unidirectional grid …

… to Decentral and Distributed Energy Systems and bidirectional balancing

1. Changing generation mix
2. Generation capacity additions
3. Distance from source to load
4. Decentralization (public/private)
5. Refurbishment/upgrades

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Global Generation Capacity additions of Wind and Photovoltaic Power Plants (note: overall installed global Power Generation capacity ca. 6500 GW)

Wind Power Global Capacity, 2004–2014


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Customer trends drive dramatic change in energy systems

Affordability
- Renewables and conventional
- Distributed energy
- HVDC / FACTS
- Energy Storage
- Power to X
- e-Mobility

Availability
- Agility in energy

Environment
- Automation
- Digitalization
- Forecasting
- Generation control
- Grid stability
- Security
- MDM
- Customer engagement

HVDC/FACTS = High Voltage Direct Current/Flexible AC Transmission Systems
MDM = Meter Data Management
Impact on Grid business

- Integration of Renewables
- Grid extensions
- Stability challenges (less inertia, towards “solid state grid”)
- Power quality and reliability of supply
- Cyber Security
- Automated operation and situational awareness
- New business models, solutions and customers
- Regulatory uncertainty and public acceptance
- Disruptive potential from cheap storage

Source: Siemens
Interconnectivity in Europe – ENTSO-E Ten Year Network Development Plan 2014


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ULTRANET, Germany, 2021
World’s first VSC HVDC with full-bridge converter

<table>
<thead>
<tr>
<th>Customer</th>
<th>Amprion / TransnetBW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Name</td>
<td>ULTRANET</td>
</tr>
<tr>
<td>Location</td>
<td>Osterath – Philippsburg, Germany</td>
</tr>
<tr>
<td>Power Rating</td>
<td>2000 MW, bipolar</td>
</tr>
<tr>
<td>Type of Plant</td>
<td>HVDC PLUS in full-bridge topology, 340 km</td>
</tr>
<tr>
<td>Voltage Levels</td>
<td>± 380 kV DC 400 kV AC, 50 Hz</td>
</tr>
<tr>
<td>Semiconductors</td>
<td>IGBT</td>
</tr>
</tbody>
</table>

![ULTRANET Project Map](image-url)
HVDC PLUS Power Electronics
Agile and 360° digital: standards-based end-to-end architecture and services from field level to software applications and analytics

PSS® grid planning and simulation: Digital Twin
Spectrum Power grid operations / control: central
Energy IP applications, analytics: distributed, “Internet of Things”

Smart communication + control

Substation:
Automation & protection
Field area networks:
Sensors, meters, controls, concentrators

Primary equipment:
High-voltage substations – flexible AC transmission systems (FACTS) – high-voltage direct current transmission systems (HVDC) – grid access solutions – power transmission lines – medium-voltage power supply solutions
Primary equipment:
Distributed energy systems, low-voltage products, building technology, smart home, industrial power supply, …

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End-to-End Cyber Security is a Must for All Areas of a Digital Grids

Enterprise IT

PSS® grid planning and simulation: Digital Twin

Spectrum Power grid operations / control: central

Energy IP applications, analytics: distributed, “Internet of Things”

Enterprise IT

OT&IT integration, consulting

Managed/cloud services

Grid cyber security

Central power
TSOs
DSOs/Municipalities
Distributed generation
Oil & Gas, heavy industries
Discrete Manufacturing
Infrastructure & Data Center
Construction/Buildings

PaaS option powered by Sinalytics

Substation:
Automation & protection

Field area networks:
Sensors, meters, controls, concentrators

Primary equipment:
High-voltage substations – flexible AC transmission systems (FACTS) – high-voltage direct current transmission systems (HVDC) – grid access solutions – power transmission lines – medium-voltage power supply solutions

Primary equipment:
Distributed energy systems, low-voltage products, building technology, smart home, industrial power supply, …

Electrification
Automation
Digitalization
Information technology
Energy IP applications, analytics: distributed, “Internet of Things”

Smart Grid analytical apps based on Siemens advanced analytics platform to address customer use cases

Customer access (utilities) | Service (e.g. asset service) | End-user access for consumer engagement apps

Web access to application UI, dashboards and reports

Customer / Grid / Market / AMI – Operations app


Device Lifecycle | Grid Data Vault | Meter Ops & Provisioning | Settlements | Exceptions & Event Mgr. | Power Quality | Asset Performance Mgmt. | Load Forecasting

Asset database | Time-series / sensor data | SQL data warehouse

EnergyIP Platform

Siemens systems
- e.g. Spectrum, EnergyIP, ISCM

Customer systems (utility)
- Utility
- MDM
- ADMS
- CIS
- AMI
- GIS

3rd-party data sources
- Weather data
- Social media
- Housing data
- Demographic
- Data historians

Secure environment

ISCM = Integrated Substation Condition Monitoring

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At the front edge of digital innovation:
Elhub: Market transaction management, Statnett, Norway

EnergyIP® 8
- Meter Data Management (MDM) application
- Market Transaction Management (MTM)

Benefits
- Peak avoidance
- Distributed optimization
- CO₂ and cost avoidance
- Allocation of grid losses and unaccounted energy

Digitalization optimizes investments of New Brunswick (NB) Power, Canada

- Decentralized generation and consumer load bundled on a virtual platform
- To be used as a flexible single power plant

Benefits:
- Optimization of investments
- New business model makes NB Power fit for the future
- CO₂ reduction

Dems: Decentralized Energy Management System  Drms: Demand Response Management System

Gas-fired Peaker Plant (underutilized)

Dems

Drms

Decentralized Generation

Onshore Wind

Grid control system

Energy exchange

Billing

Industrial

e-Mobility

Residential

Commercial

DEMS: Decentralized Energy Management System  DRMS: Demand Response Management System
Research project
Dynamic Grid Control Center

Challenge:
- Changing system dynamics
- More power electronics within the grid, less rotating mass

Target:
- Autopilot and Master Power Control operation
- Controllable grid dynamics
- Self healing capabilities

Partnering:
- 3 universities
- 4 TSOs
- 2 scientific institutes
Prosumers in the Distributed Energy System

Distribution grid

Microgrid / Nanogrid

- Industry
- Infrastructure
- Facilities
Active Network Management –
Grand Unified Scheme – Northern Power Grid (NPG), United Kingdom

Solution
- Integration of battery storage, enhanced voltage control, demand response, and real-time thermal rating in a closed loop
- Wide area communication

Benefits
- Efficient and stable grid operation
- Prosumers as active participants offering load flexibility
Energy storage applications and sector couplings

**Application cases by location of storage**

<table>
<thead>
<tr>
<th>Central</th>
<th>Distributed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Utilities</td>
<td>Small utilities, municipalities, industry – prosumer</td>
</tr>
</tbody>
</table>

- **Pumped storage**
  - Grid balancing and stability
  - Electricity

- **H2/Chemicals**
  - Power-to-gas
  - Power-to-chemicals
  - Electricity
  - $\text{H}_2$ / Methane (gas grid)
  - $\text{H}_2$ Fuel for car

- **Battery**
  - Grid stability, self-supply, electro-mobility
  - Electricity

- **Thermal**
  - Power-to-heat
  - Heat

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Holistic end-to-end energy management – example of an industrial facility

Distributed energy systems (DES)

- Distributed generation
- Storage solutions
- Electrical equipment and power electronics
- Energy automation & management, software

- Wind turbines
- eCar charging station
- Microgrid manager, energy management systems, etc.
- Photovoltaic system
- Battery storage, power to gas
- Combined heat and power
- Medium voltage, low voltage, circuit breakers, etc.
Holistic end-to-end energy management – example of an industrial facility

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Microgrid
IREN2 research project in Wildpoldsried, Germany

Solution
Combining micro grid and Virtual Power Plant to form a topological power plant, which can be operated in island mode

Benefits
- Stable and economically optimized grid operation
- Black start capability
- Profitable use of renewable resources
- Ancillary services from the distribution grid
Reference projects demonstrate the broad range of different prosumers in a distributed energy system

**Battery storage system safeguards power supply at VEO**
- Black start capability of power plant's gas turbine at any time and without feeding in power from the public grid
- This island network keeps the critical production processes at the steel mill operating

**Data analytics decision-making support for GESTAMP**
- Real-time monitoring via web portal
- Early detection of machinery failure and inefficient processes
- Customized reports
- Worldwide implementation possible

**Turnkey integrated power supply solution for Südzucker**
- Drawing power from the high-voltage grid, but also feeding electricity from the on-site power plants into the grid

**Intelligent microgrid for Savona University**
- Highly energy-efficient conventional and renewable sources are controlled in real-time
- The campus can generate enough electricity and heat to satisfy its needs autonomously
Distributed Energy System
Green Tower Freiburg (under construction)

Energy-/Power Management System
- Optimization of self-generated Energy

Building Automation
- Security
- Fire protection
- Building and Room Automation, Energy Monitoring and Controlling (EMC)

Power Supply
- AC loads e.g. typical household loads
- Internal DC loads e.g. for lifts, emergency lighting
- CHP or Engine
- Li-Battery (0.5 MWh)
- PV-System (400kWp)

Source:
http://www.freyarchitekten.com/projekte/549_smart-green-tower.html
Residential Nanogrids
example Sunverge: Battery Storage for Homes (up to 6 kW / 20 kWh)

Monitoring via Smart Phone

Battery Storage installations with PV in a townhouse development in Sacramento

Source: Sunverge
Sharing Economy – what impact will it have in the energy system?
“Brooklyn Microgrid“:
A Blockchain-based Platform for locally traded electricity

• “Small-scale, community microgrid
• local residents buy and sell rooftop solar
• direct energy trading
• Participants do not need to own solar panels

• Usage of Ethereum (public blockchain platform)
• Platform runs itself to high extent

• energy is automatically priced “based on things consumers care about” (e. g. preferences on savings, cheaper energy to lower income customers etc)

Source:
http://brooklynmicrogrid.com/
Vision of the future for discussion:
The three essential grids in context of an energy cell concept

Digital Grid

Energy cells can be
- Community, Campus
- Village
- Factory
- Power plant
- Dedicated storage facility

Energy cells may contain
- Power generation
- Thermal and gas grids
- Energy storage
- Sector couplings
- Power-to-X (-value)
- Dynamic load control
- ICT, self-organizing, self-healing intelligence
- Resiliency, microgridability
- Peer-to-peer trading
Future Market Regulation / Summary

1. Political Targets & Cost-efficiency lead to more Wind- and PV-Power Plants, Electrification, Distributed Energy Systems

2. Sector-couplings and Energy Storage are increasingly relevant

3. Digitalization is key enabler (simulation, operation, market integration)
Agile and 360° digital