Trends and Innovations in the Energy Sector

Martin Tackenberg, Siemens Energy Management | Regensburg, March 7, 2016
Agenda

Fact & Figures SIEMENS

Global Trends

Our Answers
Flat and market driven organization along the value chain will capture growth opportunities

Divisions (Global P&L)
- Power and Gas (PG)
- Wind Power and Renewables (WP)
- Energy Management (EM)
- Building Technologies (BT)
- Mobility (MO)
- Digital Factory (DF)
- Process Industries and Drives (PD)
- Healthcare (HC)
- Financial Services (SFS)

Managing Board
- Corporate Services
- Managing Board
- Corporate Core

* Commonwealth of Independent States
Siemens at a glance in FY14

€78.4bn Orders

€4.1bn R&D spending

343,000 Employees in more than 200 Countries

€71.9bn Revenue
Energy Management at a glance
We are where our customers are

~ €11 bn
Revenue

~ €350 m
Investment in R&D

~ 53,000
Employees

~ 100
Production locations
The Energy Management Business Units

**High Voltage Products**
- Circuit breakers
- Disconnectors and earthing switches
- Hybrid switchgear
- Instrument transformers
- Surge arresters
- Coils
- Bushings
- Gas-insulated switchgears (GIS systems)

**Transformers**
- Power transformers
- Distribution transformers
- Special purpose transformers
- Traction transformers
- Phase shifter transformers
- Transformer lifecycle management (TLM™)
- Transformer components

**Transmission Solutions**
- High-voltage direct-current transmission (HVDC)
- Reactive power compensation / FACTS
- Turnkey grid access solutions
- Solutions for gas- and air-insulated switchgear (GIS, AIS)
- Gas-insulated lines (GIL)

**Medium Voltage & Systems**
- Air- and gas-insulated medium-voltage switchgear
- Low-voltage switchgear and busbar-trunking systems
- Generator switchgear
- Storage & grid coupling
- Power supply solutions, E-houses
- Subsea prod. & systems

**Low Voltage & Products**
- Low-voltage protection, switching, measuring, and monitoring devices
- Low-voltage distribution boards/systems
- Medium-voltage vacuum circuit breakers, contactors, and interrupters

**Digital Grid**
- Consulting
- Grid automation & control centers
- Grid applications
- Communication devices
- Sensors
- Meter data management
- Data analytics
- Software solutions
- Integration services
- Asset services
Siemens Vision 2020 – leading position in Electrification, Automation, Digitalization

**Global trends**

**Digital transformation**
Networked world of complex and heterogeneous systems

**Globalization**
Global competition driving productivity and localization

**Urbanization**
Infrastructure investment needs of urban agglomerations

**Demographic change**
Decentralized demand of a growing and aging population

**Climate change**
Higher resource efficiency in an all-electric world

**Market development (illustrative)**

- **Electrification**
  - Today: 2–3% market growth
  - Mid term – 2020: 7–9% market growth

- **Digitalization**
  - Today: 4–6% market growth
  - Mid term – 2020: 7–9% market growth

- **Automation**
  - Today: 2–3% market growth
  - Mid term – 2020: 4–6% market growth

**Power**
- Generation

**Power transmission, distribution, and smart grid**

**Efficient energy application**

**Imaging and in-vitro diagnostics**
Digitalization changes everything
From record store ...
... to streaming
From bookstore ...
... to e-book
From taxi ...
... to ride sharing
From manual diagnostic based maintenance checks ...
From data-driven diagnostic-based maintenance checks...
Will this disruption stop in front of our business markets?
From centralized power plants ...
From centralized to decentralized & fluctuating power generation.
Energy Systems are changing fast
German Energiewende: Complexity is managed with increasing smartness throughout the grid

From centralized power and unidirectional grid …

… to Decentral and Distributed Energy Systems and bidirectional balancing

1. Changing generation mix
   higher volatility drives invest in stability / availability

2. Generation capacity
   additions generation capacity increase requires new connections

3. Distance from source to load
   natural resources and demand centers to be linked

4. Decentralization (public/private)
   small / distributed units drive invest in distr. automation/ IT

5. Refurbishment/ upgrades
   installed base is enhanced to cope with new challenges
Energiewende 2.0 – Worldwide challenges to the energy systems of the future

Past

Focus on:
- Efficiency
- Lifecycle cost reduction
- Availability/reliability/security

Traditional mix
- Fossil (coal, gas, oil)
- Nuclear
- Renewables (mainly hydro)

... 20+% 

System integration
- Fossil (coal, gas, oil)
- Renewables (wind, PV, hydro)

Focus on:
- Decreasing spot market prices
- Subsidized economy
- Increasing re-dispatch

Mid-term

Market integration
- Capacity markets, etc.

Focus on:
- Increase in Power2Heat and CHP
- Demand-side management
- Increase in storage solutions
- HVDC/AC overlay

Regional self-sustaining systems
- Topological power plants

Focus on:
- Increase in “autonomous” grids
- HVDC overlay and meshed AC/DC systems
- Power2Chem/CO2toValue
- System stability

Long-term

Decoupled generation and consumption
- All energy sources working together

Focus on:
- Complete integration of decentralized power generation
- Storage systems/Power2X
- Return to gas power plants?

Energiewende 2.0

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Martin Tackenberg / Energy Management
We are addressing all key elements of energy systems….

The core question of the optimal pathway from source to utilization is Energy at the **right Place**, on the **right Time**, in the **required Form** and **Quality**

... Conversion

... Transport

... Storage

... Utilization

Decrease of dispatchable (conventional) Power Generation

Increase of variable Power Generation (Wind, PV)

Source: TransnetBW
© Siemens AG 2016
Energiewende 2.0 – Future energy systems: Decoupling of generation and consumption

Past
Production follows consumption

Today
Consumption vs. production

Future
Production decoupled from consumption

- **2035+: Installed capacity** of renewable energy systems:
  - >220 GW
  - Electrical energy produced: 446 TWh
  - Electricity generation is occasionally 2.4 times higher than maximum consumption!

- **Excess energy** in northern states of Germany
  - More than 7,000 MW for over 3,000 hours per year

- **Grid stability** is the highest priority

Reducing uncertainties is a major challenge for research and development!

80% share of renewable energy in **2035+**
Renewable Production in Germany
Largely Depending on Seasonal Effects

Renewable Production
Germany
January 2015

Renewable Production
Germany
August 2015

Source: https://www.energy-charts.de/power.htm
Generation mix in 2030: Opportunities, Threats and Uncertainties

### Changing generation mix

**EU28 generation capacity until 2030 (TW)**

<table>
<thead>
<tr>
<th>Year</th>
<th>2015</th>
<th>Retirements</th>
<th>Additions</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil (incl. Engines, CHP)</td>
<td>1.1</td>
<td>0.3</td>
<td>0.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0.3</td>
<td>0.3</td>
<td>0.5</td>
<td>1.3</td>
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<tr>
<td>Wind</td>
<td>50%</td>
<td>33%</td>
<td>22%</td>
<td>21%</td>
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<td>Solar PV</td>
<td>9%</td>
<td>9%</td>
<td>22%</td>
<td>21%</td>
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<tr>
<td>Hydro</td>
<td>12%</td>
<td>12%</td>
<td>9%</td>
<td>9%</td>
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<tr>
<td>other Renewables</td>
<td>9%</td>
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</tbody>
</table>

- **2015**: 0.3 TW retirements, 0.5 TW additions, 1.1 TW capacities
- **2030**: 1.3 TW capacities

**Impact on Grid business**

- Connections for renewables
- Grid extensions required
- Stability challenges
- Power quality and security
- Automated operation and situational awareness
- New business models, solutions and customers
- New and growing players in the energy market, e.g. Google NEST, Viessmann
- Regulatory uncertainty and public acceptance
- Disruptive potential from cheap storage

**Source:** Siemens

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Content

Facts & Figures SIEMENS

Global Trends

Our Answers
Increasing role of Power Electronics and Digitalization in all voltage levels master the energy transition

| Changing generation mix | • Interconnectors  
|                         | • Network Control Systems  
|                         | • Synthetic Inertia |
| Generation capacity additions | • Transmission Grid Capacity additions  
|                                 | • Intelligent Distribution Grid  
|                                 | • Smart Substation |

| Distance from source to load | • High Voltage DC Systems (HVDC)  
|                               | • Flexible AC Transmission Systems (FACTS)  
|                               | • Supergrids |

| Decentralization (public / private) | • Active Network Mgmt., Microgrids, Nanogrids  
|                                    | • Distributed Energy Systems (DES)  
|                                    | • Energy Storage, Electrolyzers, Power-to-X |

| Refurbishment / upgrades | • Equipment with higher voltage ratings  
|                         | • Cyber Security Solutions  
|                         | • Resilience |
## Future challenges for utilities and solution implications

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Future challenges for utilities and Siemens portfolio implications

### Challenges

- Variable power generation
- Capacity constraints
- Frequency and voltage stability challenges
- Shorter market time intervals

### Solution

- Situational awareness and forecasting
- Fast reacting grid control, adaptive assets
- More interconnector capacity and grid stabilization
- Market integration of TSO, DSO, generators and retailers

### Portfolio

- Phasor Measurement Unit
- Advanced Control Center
- Dynamic Grid Control Center
- Digital substation
- Adaptive protection
- HVDC, FACTS
- Controllable Transformer
- Energy storage
- Virtual Power Plant
- Dynamic Load Management
- Central Information Hub
Ensuring stability and security of the system: Advanced control center for PJM Interconnection

Control centers
- Large scale energy management system
- Real time market pricing
- Dual-primary control center
- Capability to run the grid independently or as a single virtual control center

Benefits
- Increased security and reliability of the grid
- Practically uninterrupted power supply and grid control
Spectrum Power Active Network Management
Releasing hidden capacity by Active Network Management

1. Network state
2. Problem detection
3. Decision making
4. Set-point command

Active Network Management System

Energy storage
Voltage control device
Controllable generation
Controllable loads
Real time thermal rating
## Future challenges for utilities and Siemens portfolio implications

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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
Future challenges for utilities and Siemens portfolio implications

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| Frequency and voltage stability challenges | More interconnector capacity and grid stabilization                        | ▪ HVDC, FACTS  
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| Shorter market time intervals          | Market integration of TSO, DSO, generators and retailers                 | ▪ Virtual Power Plant  
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Wind offshore and the grid connection – Strong need for innovations
Offshore wind power connection: Example BorWin2 in the North Sea to supply 800,000 German households

Integrate 800 MW from 100 km offshore distance with highest efficiency
Offshore wind power connection:
Example BorWin2 in the North Sea to supply 800,000 German households

Customer: INELFE (Rte and REE)
Project Name: INELFE
Location: Baixas, France to Santa Llogaia, Spain
Power Rating: 2 x 1000 MW
Type of Plant: HVDC PLUS
Voltage Levels: ± 320 kV DC, 400 kV AC, 50 Hz
Semiconductors: IGBT
The innovation: Converter using intelligent control software
Area Voltage Control for Voltage Stability
Effects of the different Voltage Control Strategies

Voltage Regulation on MV
Primary and Line Volt. Transformer

Voltage Regulation on LV
Secondary Transformer
Voltage Control in low voltage grids: “FITformer REG”

Low-voltage load regulation range in three steps

• With well-proven electromechanical switching devices
• Switching under load
Frequency stability

- Frequency behaviour defined based on operational and statutory limits
- Power plants with synchronous generators participate in frequency control
- Two types of mandatory frequency response services
  - Primary (tens of seconds)
  - Secondary (up to minutes)
SVC PLUS Frequency Stabilizer
Layout of entire 50 MVA station

Converter (incl. building)
Cooling
Substation
Storage towers
Storage building
Power transformer
Reactors
Control room (incl. building)
Energy storage facilitates the integration of infrastructures and energy carriers

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<th>Application cases by location of storage</th>
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<td><strong>Central</strong></td>
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<td>Large Utilities</td>
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- **Pumped storage**
  - Electricity

- **H₂ / Chemicals**
  - Electricity
  - H₂ / Methane (gas grid)
  - H₂ Fuel for car

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

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

**Grid balancing and stability**

**Power-to-gas**

**Power-to-chemicals**
SIESTORAGE References
here: Network Stabilization and Blackstart applications

SIESTORAGE installation as standard container at the grid of ENEL, Italy for network stabilization with infeed of power from decentralized, renewable sources
Commissioning in 2012
1MVA/500 kWh

SIESTORAGE installation in existing modernized substation of VEO* Eisenhüttenstadt, Germany for black start in the steel and rolling mill of Arcelor Mittal GmbH (AMEH)
Commissioned in 2014
2.8 MVA/720 kWh

One-stop-shop:
- From planning and installation through to commissioning and services
- Possibility of integration into prefabricated standard container or existing building

* (Vulkan Energiewirtschaft Oderbrücke GmbH)

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Energiepark Mainz – Project scope and key facts

• Location: Mainz-Hechtsheim (DE)
• 3 high performance electrolysis systems, peak power of 2 MW el. each (6 MW peak)
• Highly dynamic operation over broad load range (ramp speed 10% per sec.)
• First Electrolyzer delivered mid of march
• Plant commissioning scheduled July 2015
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Virtual Power Plants: RWE, Stadtwerke München and Mark-E

Integration of distributed generation and load flexibility into power markets

Revenue improvement for distributed renewable generation

Improved cost efficiency of mixed generation fleet
Renewables can deliver a solid distributed supply and topological power.

Hybrid power plants expand conventional power plants by integrating renewables – and thus conserving fossil fuels.

Microgrid control systems manage distributed consumers and energy producers – and efficiently improve grid stability.
Microgrid
IREN2 research project in Wildpoldsried, Germany

Challenge:
Optimize regional use of local renewable generation

Solution:
Combining micro grid and VPP 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 independently of the supply grid
- Ancillary services from the distribution grid
Werner von Siemens hätte es damals Erfindergeist genannt.
Wir nennen es heute „Ingenuity for life“.
Thank you!

martin.tackenberg@siemens.com
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