Strategic Planning of Smart Grids

WP2: Future Infrastructure of Power Systems
Strategic Planning of Smart Grids

“Älyverkkojen strateginen suunnittelu”

Research Group of SGEM Task 2.1

Tero Kaipia / Jukka Lassila
Definition of Smart Grid

- “Electricity networks that can intelligently integrate the behaviour and actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies. A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies”
  - EC, Strategic Deployment Document for Europe’s Electricity Networks of the Future, 2010

- Electric power system that utilizes information exchange and control technologies, distributed computing and associated sensors and actuators, for purposes such as:
  - to integrate the behaviour and actions of the network users and other stakeholders,
  - to efficiently deliver sustainable, economic and secure electricity supplies
  - (1/2173/FDIS Amendment 1 to IEC 60050-617: International electrotechnical vocabulary - Part 617: Organization/market of electricity)

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Strategic planning:

- What are the impacts of changes in the operating environment on the distribution business and on the network development?
- How the objectives of Smart Grids can be integrated in the distribution networks and related business on most effective way?
Introduction to strategic planning

- Background
  - Electricity distribution business is in the middle of its most significant change since the beginning of electrification of the society
  - Even though the Smart Grids is mainly development of intelligent applications and related ICT, the biggest investments will be made to the primary electric infrastructure

- Strategic Planning
  - Strategic planning is a central part of power system asset management and required to be able to handle all existing and coming challenges in the long term, after all the distribution systems built today will still be in use in year 2040 and beyond

- Main concept
  - Strategic planning combines versatile information, both external and internal to distribution business, and produces inputs for long-term planning of distribution networks and business

- Key questions
  - What are the objectives set for the development of distribution systems and what are the effects of different development options, such as full-scale underground cabling, on the price of distributed electricity and the owner’s return on investment

- Motivation
  - Right methodologies, principles and business models enable development of primary network and integration of smart grid functionalities in optimal way
  - Capital-intensive nature of the distribution business emphasizes the significance of a well-planned strategy
Critical infrastructure and renovation needs

**ELECTRICITY** (375 000 km, need > 10 000 km/a)

**TELE**
(+ 40 000 km before 2015)

**SEWER NETWORK**
(50 000 km, need 900 km/a)

**WATER**
(100 000 km, need 1 000 km/a)

**DISTRICT HEATING**
(12 000 km +200-300 km/a)

**ROADS**
(78 000 km, need __ km/a)

**RAILWAYS**
(5 900 km, need __ km/a)
Electricity distribution business

Electric utility
- Generation
- Transmission
- Distribution
- Sale

- Generation
- Transmission
- Distribution
- Sale

Network ownership
- Financing arrangements
- Target setting
- Network management agreements

Asset management
- Setting principles of operation (= strategy)
- Management of service agreements

Service providers
- Equipment supplier
- System supplier
- Network operation
- Construction
- Measurement

35–40% of the total price of electricity for the end-users
Cost optimisation in distribution business

\[
C_{\text{total}} = \min \int_{0}^{T} \left( C_{\text{investment}}(t) + C_{\text{opex}}(t) + C_{\text{interruption}}(t) \right) dt
\]

Investment costs
- Construction
- Materials
- Capital costs
- Planning, research and development
- Storages, transportation (logistics)

Operational costs
- Network operation
- Network maintenance
- Network losses
- Fault repairing

Interruption costs
- Economic harm for end-user because of outage
- Loss of income
Role of strategic planning process

Strategic decision making

- Strategic planning
- Long-term network planning
- Detailed target planning
- Construction design

Network planning

- Investment program, General plans
- Target plans
- Construction plans

Quality of electricity
- Ageing infrastructure
- Energy policy
- Technical development
- Increase in electricity consumption

ELECTRICITY DISTRIBUTION BUSINESS

- Owners
- Economic regulation
- Climate change

Economic regulation

Owners

ELECTRICITY DISTRIBUTION BUSINESS
Strategic planning - Transition from the present network infrastructure to the smart grids

➢ Research questions
  - The most probable development scenarios for new energy solutions?
  - New challenges and opportunities that these solutions create for the grid business?
  - Technology alternatives to deal with the challenges and make use of the opportunities?
  - The best transition strategies for a grid company in each development scenario?
  - Reactive or proactive network development strategy?
  - Indicators and drivers to follow and critical values for them?
  - Development technologies which can and should be used now and in the future?
  - The way how the increasing amount of DG has to be taken into account?
  - The role of electric transportation (cars, busses) in the network development?

➢ Indicators and drivers from
  - Network calculations (power flow, fault current, losses)
  - Measurements (AMR data, voltage quality, interruptions)
  - Society: political decisions, trends and needs
  - Technology development (e.g. price of solar technology and energy storages)
  - Emergence of novel technical enablers (for instance “Internet of Energy”)
1. Operational environment survey
2. Definition of compelling drivers for network development
3. Determination of the owners objectives, expectations and financial contribution to the business
4. Survey of development alternatives and available technical solutions
5. Determination of the key calculation parameters for techno-economic analyses
6. Analysis of the reliability impacts of development alternatives
7. Analysis of the economical feasibility of development alternatives
8. Analysis of the technical feasibility of development alternatives
9. Definition of the application potential of technical development alternatives

Strategic analyses

- Potential use of technologies (%)
  - Transfer of overhead lines to roadsides (25 %)
  - Underground cabling (10 %)
  - Remote-controlled disconnector substations, circuit reclosers (1 pcs/feeder)
  - 1000 V technology (30 %)

- Cost effects of the technologies
  - Transfer of overhead lines to roadsides (50 km/a, 1 M€/a)
  - Underground cabling (5 km/a, 250 k€/a)
  - Remote-controlled disconnector substations, circuit reclosers (20 pcs/a = 250 k€/a)
  - 1000 V technology (50 km/a, 1 M€/a)

- Reliability effects of the technologies
  - Transfer of overhead lines to roadsides
  - Underground cabling
  - Remote-controlled disconnector substations, circuit reclosers
  - 1000 V technology

- Owners’ objectives
  - Reduction in SAIDI 20–40 %
  - Increase in the present value of the network from 45 to 50 %

Strategic decisions

- Main technologies
- Owners’ perspectives (amount and schedule of investments)

Implementation of strategic decisions

- How a single development technology e.g. underground cabling is implemented in practice?
- What are the effects of different development methods?
- Costs, reliability, distribution fee, allowed return

Long-term plan

A long-term plan for the example area and the whole distribution company taking into account the strategic decisions made in the process.
Simulation of impacts of strategic decisions

**Society:** political decisions, trends and needs

**Technology development**
(e.g. solar technology and energy storages)

**Network calculations**
(power flow, fault current...)

**Measurements**
(AMR data, interruptions,..)

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**DRIVERS**

**RESULTS**

The best transition strategies?

Technology alternatives to deal with?

**Effects:**
- Reliability?
- Age and condition?
- Distribution fee?
- Public relations?
- Return?
Development of electric load behaviour

Electricity markets

Supplier

Interactive customer interface

Price signals

Power signals

DSO

Grid

Active customer gateway

Active customer

Other information: customer classification; Local weather forecast: outside temperature, day light duration...

Loads

Electric heating, lightning, ...

Heat pumps

Electric vehicles (G2V)

Data: hourly use of electric heating and home appliances; heat pump penetration rate, coefficient schedule, properties of batteries, charging powers

Storages

Electric vehicles (V2G)

Battery

Data: number of EVs, driving devices; heat pump penetration rate, coefficient schedule, properties of batteries, charging powers

Generation

Wind power

Solar power

Data: number of EVs and batteries, driving schedule, properties of batteries, discharging (V2G) powers

Data: feeder load curve, peak powers, load forecast, distribution fee

Data: Wind speed, turbines, production

Data: radiation, panel properties, production
Strategic role of novel technologies

Environment
- Climate change
- Landscape issues
- Land-use issues
- Impregnants
- Electric and magnetic fields

Energy policies
- Legislation
- Energy efficiency objectives
- Reduction of emissions and oil dependency
  - Renewables, DG and EVs
  - Demand response

Society and socio-economics
- Safe use of electricity
- Reasonable pricing
- Supply security
- Energy efficiency actions
- Functional markets

Network infrastructure and assets
- Aging infrastructure
- Allowed profit regulation
- Revenue expectations of owners
- Supply quality expectations
- Major disturbance vulnerability
- Increasing prices of conventional network components
- Decreasing prices of emerging technologies

Customers
- Customer expectations on
  - Quality of supply
  - Pricing
  - Functional markets
- Changes in energy usage patterns
  - Energy efficiency actions
  - Dynamic loads
  - EVs and DG
- Equality
  - Pricing
  - Service quality

Power Quality
- Security of supply
- EMI and EMC, distortion
- Sensitivity of system and load appliances

Regulation of network business
- Allowed profit regulation
- Quality of supply
- Cost efficiency
- Energy efficiency

Recourses and competences
- Human resources
- Outsourcing
- Tools and methods to aid decision making

Technical development
- Automation and communication techniques
- DG and energy storages
- Building automation
- Underground cabling
- Power electronics
- Distributed intelligence
- Preventive maintenance techniques
- Software development

Role of power electronics in future electricity distribution infrastructure

Utility stake holders
- Profit expectations
- Predictable rules
- Company image
- Consolidation

Smart Grid visions
- Self healing and proactive power system
- Market and grid oriented system control
- No market limitations
Selection of development strategies

Initial Data:
Network Information System

Processing:
Network Analysing Tool

Results:

Drivers in the case area distribution company

- Climate change
- Reliability
- Ageing infrastructure
- Technical development

Development technologies which do not fulfill requirements and targets in the case company
Major blackouts and large scale cabling

Strategic analyses
• Comparison of technologies
• Reliability evaluation
• The goals of network development
• Evaluation of the state of present network
• Assessment of parameters

Assessment of the underground cabling process (Cabling concept)
• Locating of suitable targets
• Evaluation of the timing
• Priority of the targets in the renovation
• etc

Network structure is changing towards underground cabling

Strategic decisions

Routes of major storms in summer 2010

Required amount of underground cabling to survive the events without long supply interruptions for an example network

A) B) C)
Priorisation of investments

**Age**
- > 40 years
- 30 – 39 years
- 20 – 29 years
- 10 – 19 years
- < 10 years

**Reliability**
- > 8 points
- 7 – 8 points
- 5 – 6 points
- 3 – 4 points
- < 3 points

**Load and line layout**

**Mechanical condition**

**Transmission capacity**

INVESTMENT ORDER

Tero Kaipia / Jukka Lassila
Lappeenranta University of Technology 19.11.2012
Impact of selected strategy on supply security with different investment programs

Drivers
- Standard compensations
- Roads as infrastructure
- Climate change
- Ageing infrastructure
- Reliability criteria
- Interruption costs
- Economic regulation
- PR, Media
  - Owners
  - Media
  - Politics

Strategic decisions affecting reliability of distribution

Network analyses

- Cabling
- Technology and operation
- Human resources
- Roadsides
- Covered conductors
- Network automation

- Network analyses
Impact of electric transportation

Defining of technical (MW) and economical (€) effects in electricity distribution networks
- Determination of scenarios for use of electric transportation
- Considering applicability of V2G and availability of DR and local DG
- Defining charging behavior for different electric transportation
- Determination of coincidence with other electric loads and generation
- Determining probable scenarios for power flow calculations
- Defining impacts on network development needs
- Defining impacts on distribution business
### Strategic planning in SGEM – Key interests

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Effect to the strategy work, strategic questions</th>
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<tbody>
<tr>
<td><strong>Large scale cabling</strong></td>
<td>Renovation schedule, order, technology, role of</td>
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<tr>
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<td>automation, optimal topologies and role of OH</td>
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<td>networks?</td>
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<td><strong>Load development</strong></td>
<td>Critical need for real time information,</td>
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<tr>
<td>- Electric vehicles</td>
<td>measurements, load forecasts, short-term</td>
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<td>- Demand response</td>
<td>weather forecasts, understanding of customer</td>
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<td>- Distributed generation</td>
<td>behavior, analyses economic incentives,</td>
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<td>- Energy storages</td>
<td>development of battery technology (lifetime,</td>
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<td>prices)</td>
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<td><strong>Reliability</strong></td>
<td>Role of medium voltage networks in the future;</td>
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<tr>
<td>- Interruption costs (system</td>
<td>reliability and quality can be guaranteed in</td>
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<td>level incentives)</td>
<td>customer supply point?</td>
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<td>- Supply security criteria</td>
<td>How number of customers exceeding reliability</td>
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<td>(individual customer perspective)</td>
<td>criteria varies in different network strategies?</td>
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<tr>
<td>- Interruption time limits (6/</td>
<td>Impact of regulation in strategic planning; rapid</td>
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<td>24/36 hour limit)</td>
<td>changes in regulation policy,</td>
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<td><strong>Regulation</strong></td>
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