ROADMAP TOWARDS THE VISION OF THE FUTURE POWER SYSTEM AND ELECTRICITY MARKET

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ABSTRACT

This paper reports the results of the Finnish national project "Roadmap 2025" which had two main objectives. The first one was to clarify the long term vision (up to 2035) of the power system and electricity market, and the second one was to create a roadmap, a development path towards the vision. The project was partially an update of the project "Vision of the Power System 2030", reported at CIRED 2007. However, instead of focusing only on technological issues, the project also included electricity market and service market perspectives and emphasized the necessary actions needed in changing the present system into the system of the future. The main results can be summarized as follows: Challenges of the future flexible power system which will be achieved by strong transmission network, cross-border grid connections, automation, undergrounding of MV and LV networks, microgrids, controllable loads, energy storages and renewable energy.

INTRODUCTION

During 2005-2007 two closely linked national projects were carried out aiming at long term technology vision of the power system and a slightly wider development roadmap for ten years [1]. The results of these projects were effectively utilized in the coordination of R&D in Finland, and they created a solid basis for the development of a national multi-year research program, Smart Grids and Energy Markets (2009-2014), having over 50 M€ budget. The changes in the operating environment, satisfaction with the results of the former "Vision and Roadmap" entity, and the ending of the Roadmap 2015 period encouraged to initiate a new project with the main goals to create a vision for 2035 and roadmap for 2025.

The backbone of the project consisted of four workshops (Figure 1), organised by the participating universities. In these open workshops, dozens of representatives of various stakeholders discussed the present challenges and upcoming changes of the power system, electricity market and the operating environment, including both international and national aspects. The overall goal was to create a vision and a roadmap serving all stakeholders: customers, society, network companies, electricity market actors, manufacturing industry, and service providers.

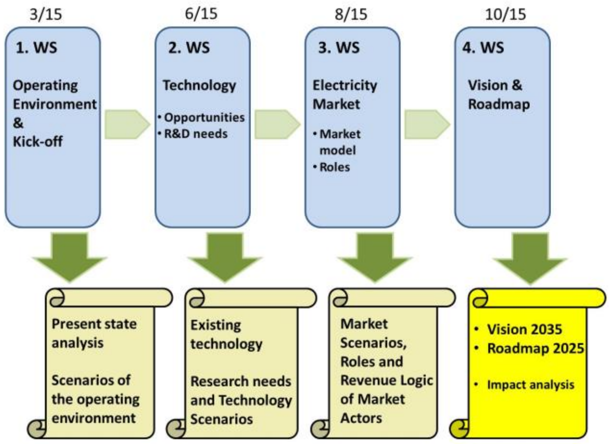

Figure 1. The basic structure of the project.

PRESENT CHALLENGES AND FORESEEN CHANGES

Present challenges

There is a significant change going on in power systems. Several major drivers change system thinking, technology and business models. Since the drivers are strongly linked to each other, it is challenging to predict the future.

One of the main findings of the former projects was that the reliability of the MV network should be increased. This has led to wide scale implementation of e.g. feeder automation and undergrounding. The Electricity Market Act (2013) has boosted this development by setting legal limits to the duration of outages (6 h urban/ 36 h rural), with a transfer period up to 2028. Another topical issue is the national self-sufficiency of electricity, especially the generation capacity during peak consumption.

Energy systems have a major role in mitigating the climate change. Political decisions have guided the development and supported the competitiveness of clean electricity generation. The present technology in wind and solar power does not provide e.g. the inertia that the power system requires, and most of the clean generation is weather dependent and non-controllable, which causes challenges to the management of the power balance. Moreover, the subsidised power generation with low operational costs has stopped practically all investments in controllable generation, and several power plants have been closed down for business reasons. This in turn escalates the generation capacity problem.

At present, almost all customers have AMR meters capable of producing time-stamped register values, in some cases also power quality and fault location related data. This enables new versatile tariff structures and demand response, but so far these are not fully utilised.

Foreseen changes

There are significant changes going on in electricity consumption and generation. These will influence in the transferred energy through distribution networks, peak power of the network, energy sold by retailers, and load profiles. There will also be changes in the predictability and controllability of the loads, caused by e.g. electric vehicles, heat pumps, renewable energy production and energy storages.

There are also several clearly identified trends in the operation environment, and development of technology:

- Dependence on electricity
- Digitalisation, IoT
- Environmental values, communality, locality
- Energy efficiency requirements
- Energy self-sufficiency intentions at local level, security of supply at national level
- Urbanisation, ageing population

However, the revolution of the power system will be mainly caused by the increase of weather dependent power generation with low operational costs and decreasing costs of energy storages. The driving forces are discussed more in detail in the following chapter.

DRIVING FORCES OF THE CHANGE

Uncontrollable generation

Mass production based weather-dependent generation technology with low operational costs is one the key driving forces of the change. It influences on the three main pillars of EU's strategic priorities, including impacts on both the technical aspects as well as on electricity market:

- Sustainability – This is self-evident and desirable.
- Competitiveness – The energy price on the market will be lower, and the capacity costs or costs of flexibility enabled by DR/DER will have a major role. Higher price volatility is to be expected, and new market models will be needed.
- Security of supply – The intermittent generation, lack of inertia, and bi-directional power flow cause technical challenges. Moreover, deficit of generation capacity is possible due to business reasons.

Energy Storage

The price of energy storage technology, including e.g. batteries, heat storage, and in the future also power-to-gas techniques, is coming down. Storages are expected to be competitive within a few years. They can benefit both end customers (by lowering energy and capacity costs), network companies (by lowering capacity related costs) and also retailers. Energy storages also decrease capacity needs in generation and may offer reserves for TSO.

Energy storages are an additional component in the power system, but they provide solutions to the challenges caused by intermittent generation. At present the national regulation does not permit network operators to own energy storages. However, from the whole system efficiency point of view this would be justified.

Electric Vehicles

The need to reduce emissions and oil dependency, and the development of biofuels and batteries are changing transportation sector. The spreading of electric vehicles includes challenges to the capacity of the networks, and an interesting potential of acting as energy storage.

Demand Response

At present, Demand Response is mainly applied in control of large energy users. Wide scale implementation including also small customers requires development of business models, understanding of customer behaviour, and development of technology. However, the Finnish power system provides very good environment for DR, including widespread electric space and water heating in combination with AMR meter penetration close to 100 %. Implementation of home energy management systems and second generation smart meters will pave the way to DR and related products.

The role of technology in the change of the power system

Technological development has a major importance in the development of the system. New technology is an enabler, and on the other hand there are technological development needs. Figure 2 illustrates the role of technology as one of the drivers of the profound change of the power system.

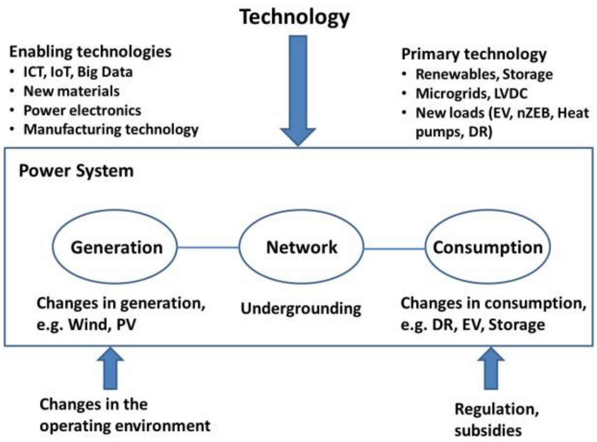

Figure 2. Drivers of the change of the power system.

The ongoing development of rural networks towards the required reliability level includes increase of network automation as well as wide scale undergrounding. The increase of cabling brings new challenges to network design, protection and operation. E.g. earth-fault analysis, fault management and online monitoring of cables require improved methods.

Microgrids and off-grid solutions may have potential as an alternative to grid based security of supply, especially when it is difficult to find cost efficient weather-proof solutions. This requires, however, development of energy storage technology.

Low voltage DC distribution (LVDC) provides a simple interface to energy storage (batteries) and distributed generation. The inverter technology in LVDC includes tools for voltage control and demand response functionalities, and intentional island mode (microgrid) is also easier by DC technology. Several pilot installations have already been built. It has been estimated that this technology will have its breakthrough within 5–10 years.

The rapidly developing ICT enables wider network monitoring and control. It also creates new business opportunities utilizing e.g. IoT and Big Data. However, since power systems are one of the most critical infrastructures of modern society, development should always ensure cyber security. Digitalisation brings so many opportunities and threats that a research program focusing on digitalisation in power systems may be justified.

Development of Electricity Market and the roles of different stakeholders

Within the EU there is a target of the Energy Union. At present this target seems to be distant. However, after the long established Nordic and Baltic wholesale electricity market, common Nordic retail market could be the next step in opening the market.

During the Roadmap 2025 project, a number of electricity market related development needs were recognized, including the following:

- Pricing models
    - Capacity based models and Demand Response
    - How capacity based models can be implemented?
- Regulation
    - How regulation can respond to fast developing needs in the operating environment?
    - Roles of energy storages and micrognids
    - Roles of stakeholders, e.g. TSO/DSO
    - Ownership and operation of energy storages
- Consumption data
    - Availability to all stakeholders
    - Business logic and rules of data mining
    - Who owns the data? Cyber security and privacy?
    - Open standardised interfaces and data structures
- Energy Services
    - Service processes and business logic

New services on the electricity market

The need of new services on the electricity market was examined by using a matrix structured survey. The survey revealed the expected hot spots of the service market. Consumer sector, including private consumers and enterprises, and services related to sales or aggregation of electricity stand out as the most potential areas. The relation between DSO and consumer is mutually important, and the role of aggregators in different interfaces between customers, market actors and network companies is one essential issue.

One interesting finding is the importance of internal services in the energy provider sector. Although the producers provide services to various actors they also acquire services from other energy providers. The reason for this is the need to buy capacity (generation or storage) to balance the variation of the own generation. This confirms the importance of markets for flexible resources.

VISION OF THE POWER SYSTEM 2035

The vision of the future power system was formulated after the four workshops, and it was refined by the steering group of the project. The vision is a flexible, reliable and competitive power system, serving electricity market and sustainable development, and it includes active customers. The increase of renewable energy requires flexibility that will be achieved by intelligent control and flexible resources. This will be enabled by ubiquitous ICT, well-functioning regulation and new business models. The reliability of the primary system will be improved also by developing the technology of the primary networks. Active customer, utilizing automated control of load and providing flexible resources to the market, is a new player in the system. The vision is visualized in Figure 3.

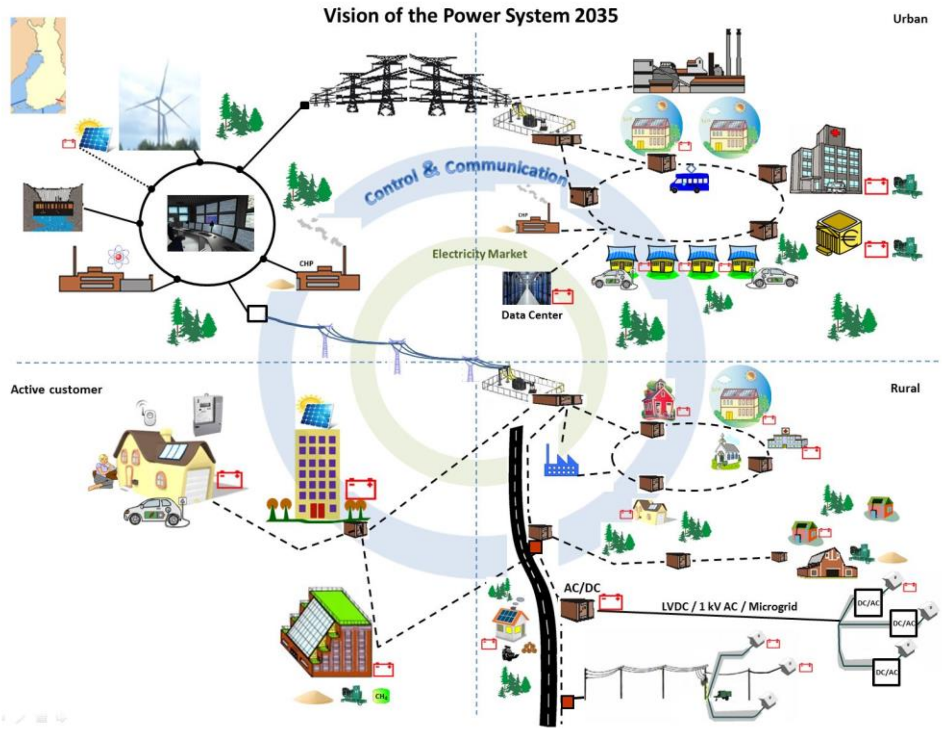

Figure 3. Vision of the future power system.

CORNERSTONES OF THE ROADMAP 2025

To able concrete actions towards the vision, a 10 year development path was sketched. Figure 4 illustrates the key enablers of the Vision, and Figure 5 presents the cornerstones of the Roadmap. Moreover, a number of research ideas and preliminary development project plans have been sketched.

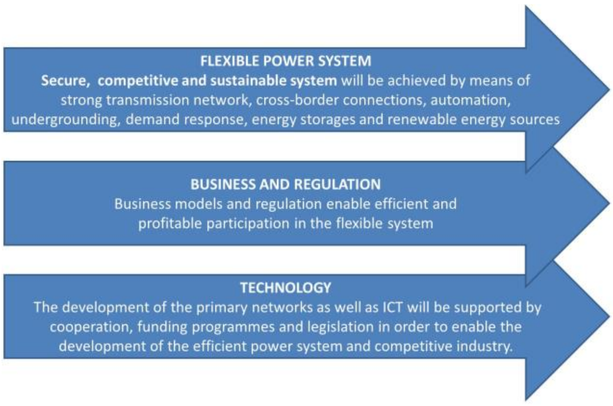

Figure 4. Key enablers of the Vision 2035.

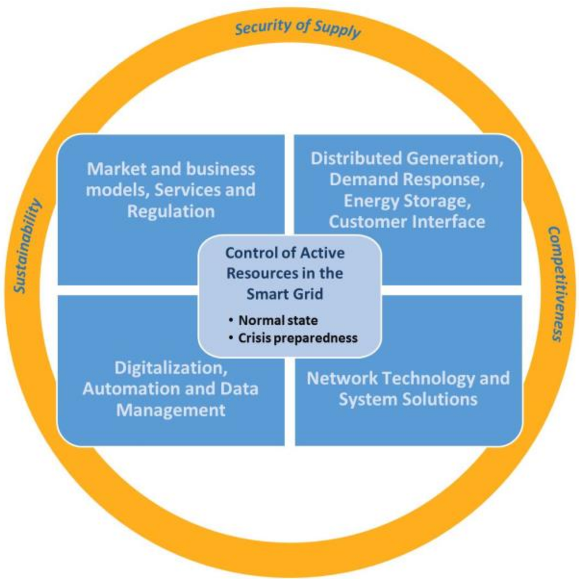

Figure 5. Cornerstones of the Roadmap 2025.

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[1] L. Kumpulainen, R. Komulainen, K. Kauhaniemi, M. Lehtonen, J. Partanen, P. Verho, 2007, "Vision of the Power System – Distribution System 2030", *Proceedings CIRED 2007*, 1–4.