FINNISH SMART GRIDS – A MIGRATION FROM VERSION ONE TO THE NEXT GENERATION

Pertti JÄRVENTAUSTA
Tampere University of Technology – Finland
pertti.jarventausta@tut.fi

Pekka VERHO
Tampere University of Technology – Finland
pekka.verho@tut.fi

Jarmo PARTANEN
Lappeenranta University of Technology – Finland
jarmo.partanen@lut.fi

Dick KRONMAN
ABB Oy - Finland
dick.kronman@fi.abb.com

ABSTRACT

Smart Grid is a continuum from systems of today towards the visions of the next generation. In Finland, research and development work has been persistent within the electricity distribution domain and many new innovations have been installed by distribution companies in real use during the past decades forming the Finnish Smart Grids version 1.0. Level of automation and ICT systems in network operation is high and large-scale implementations of advanced AMR systems have opened up new possibilities to develop network management and the operation of electricity market.

INTRODUCTION

The energy markets are in transition and there are many drivers and needs for creating a new kind of power delivery system for the future, as follows [1]:

- The penetration of distributed generation (DG) will continue due to environmental reasons.
- The European and North American vision is to have common electricity market areas.
- Efficient use of energy at customer level and intelligent demand response have become essential issues.
- Regulation of network companies will tighten up while companies want to ensure the profitability of business.
- There is a need to increase the utilization rate of existing networks. At the same time many components of existing networks are reaching the end of their life cycles.
- Power quality (supply reliability and voltage quality) requirements will increase due to public and regulatory actions and at the same time failure rates are expected to increase due to the climate change.
- The risk of major disturbances is increasing, both the probability and the consequences.

There are many definitions and visions of smart grids worldwide including a vast amount of different characteristics. However, the role of the electricity distribution networks is of great significance for realising these visions. Electricity distribution networks create a market place for small-scale power producers (i.e. distributed generation) and for customers (i.e. users of electricity) in which the quality of service should be at a high level but with reasonable costs. In Finland, about a half of the total price of electricity for small customers and over 90 % of all interruptions are associated with the distribution networks. This emphasizes the importance of the distribution process as well as the societal expectations to develop it further.

Smart grid concept has different aspects as shown in Fig. 1. It includes novel solutions of infrastructure for future power distribution, e.g. use of power electronics and DC. Active resources (i.e. distributed generation, loads, storages and electricity vehicles) actually change the traditional passive distribution network into an active one. New network solutions and active resources call for novel ICT solutions for network operation and asset management providing intelligence to active networks. Smart grids enable active market participation of customers and also have effect on changes in the business environment. Smart grids are customer-driven marketplaces for DG and consumers.

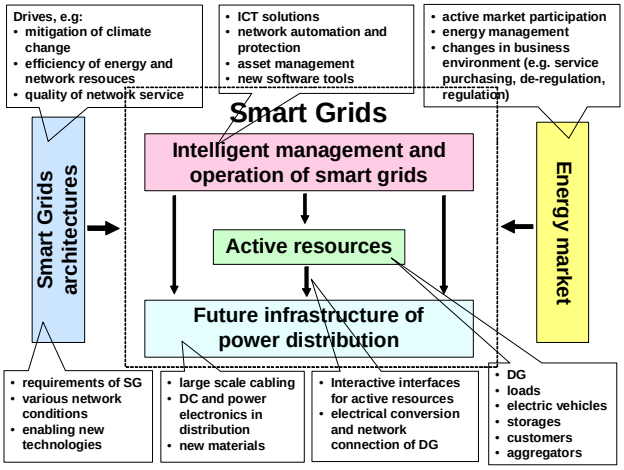

Fig. 1. Aspects of smart grids

Smart grid is not a brand-new concept to be ready 15 years hence, but rather a continuum from previous decades and the systems of today towards the visions of the next generation. The Smart grid vision has to be adjusted to meet the local special characteristics. In Finland, these include e.g. cold weather, long distances between cities, and a large amount of medium voltage overhead lines in the countryside. In Finland, research and development activities have been persistent within the distribution network domain and many novel innovations have been installed by distribution companies in real use during the past decades. There are a lot of applications and solutions which together form the Finnish Smart Grids version 1.0. The paper discusses the main achievements gained so far.

The end of 2009 saw the commencement of a large 5-year national research programme, Smart Grids and Energy Market (SGEM), whose goal is to create the vision as well as the practical solutions for the next generation smart grids.

FINNISH SMART GRIDS – VERSION 1.0

Distribution automation and network management

In Finnish distribution companies the level of automation and ICT systems in network operation is high. First SCADA systems at distribution level were already brought into use in the 70's and the first geographical network information systems (NIS) in the 80's. NIS includes applications for versatile network planning and calculation in addition to network documentation and map drawing. It is a common practice in Finland to have network data available at NIS also from low voltage (LV) network. All customers from the customer information system are connected to network data and the loads of the customers are modelled by hourly load curves in network calculation.

In Finland, the environmental and climate conditions for electricity distribution are challenging due to long distances, broad forests, harsh winter seasons and a large amount of overhead lines which have implied the need for advanced automation solutions for fast fault management and long term network planning. Novel intelligent automation solutions have been introduced already in the 80's in many distribution companies. Such automation applications have been e.g. remote controlled disconnector stations, microprosessor based protection relays at 110/20 kV main substations and real-time distribution management systems (DMS) including e.g. functions of automatic fault location, fault isolation and network restoration of MV-feeders.

In many utilities, the annual outage time of customers was decreased remarkably during a decade as shown in Fig. 2.

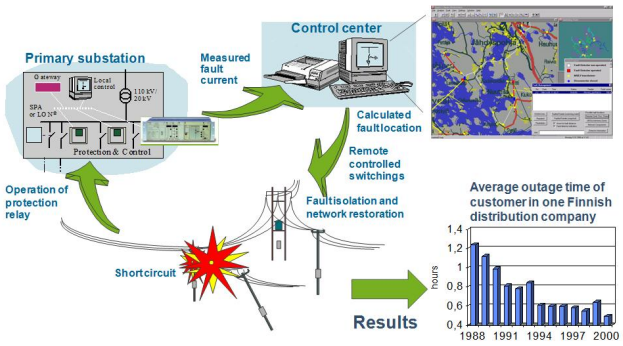

Fig. 2. Solutions for fault management in MW networks

Distribution automation has resulted in good level of quality of supply in rural network conditions with low investments.

During the past ten years many new solutions have been taken into use in distribution companies, such as light 110/20 kV primary substation solutions, pole mounted reclosers, 1000 V distribution system and advanced ICT solutions based e.g. on satellite communication as presented in Fig. 3.

Load and tariff control and remote meter reading through low-band PLC from HV/MV substation to LV customer were used extensively in many utilities already in the 80's.

Utilizing AMR systems in network management

The first generation of AMR systems was already introduced in the 90's. Implementations of advanced AMR systems during the past ten years have already changed the function of the basic energy meter to be a smart terminal unit and gateway that enables real time two-way communication between customers and utilities. In advanced meters e.g

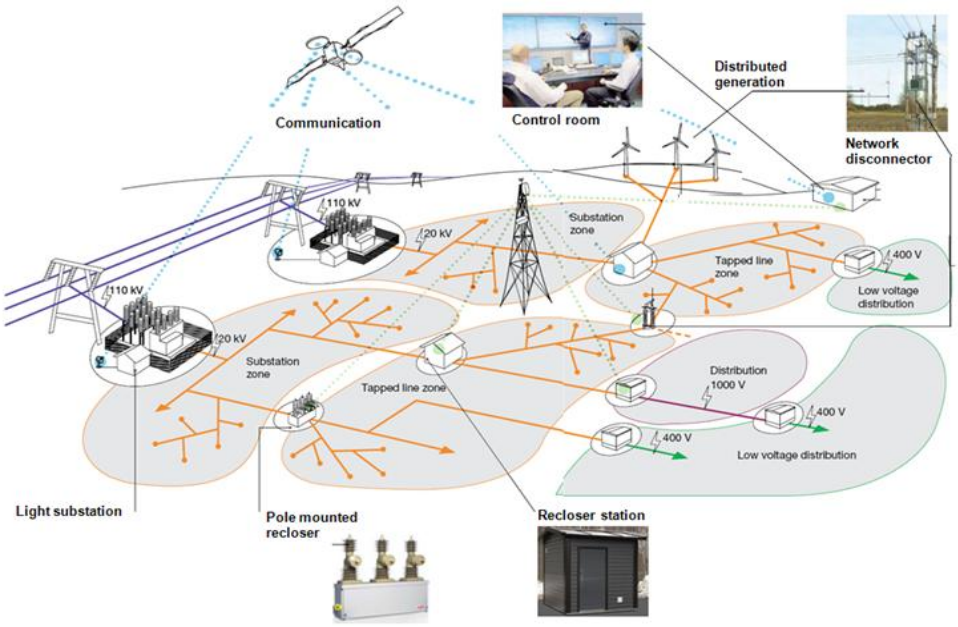

Fig. 3. Comprehensive distribution automation

alarms based on exceptional events (i.e. network faults and voltage violations) are enabled. The use and integration of an AMR system in network operation can be seen as an extension of SCADA (Supervisory Control And Data Acquisition) and distribution automation to the low-voltage level, as shown in Fig. 4. AMR system can be utilised in many functions of a distribution company, e.g. for supporting network operation (e.g automatic LV-fault indication, isolation and location, precise voltage and load data), network planning and asset management (e.g. exact load profiles for network calculations), power quality monitoring (e.g interruptions, voltage characteristics), customer service, and load control in addition to its traditional use in billing and load settlement [1].

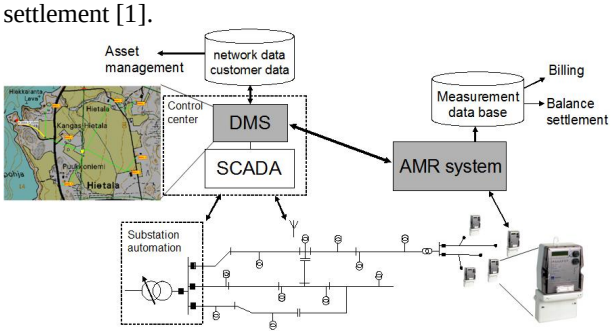

Fig. 4. Distribution network management by using AMR

This kind of comprehensive integrated information system entity based on the installation of an advanced AMR meter to all 350 000 customers is at present in real operation e.g. in Vattenfall Verkko Oy in Finland [2]. Also customer-specific hourly load information can be shown in the web e.g. for energy efficiency purposes.

Legislation requires that from 2013 on all Finnish customers are provided with an AMR meter that features hourly energy measurement as well as demand response functionality.

At present advanced network calculation applications of network information systems and DMS use hourly-load curves as load information. The AMR system offers a large amount of measurement data to determine more detailed load models for different purposes in network management and load prediction [3].

Novel network structures

New innovative network structures have been developed and taken into use in distribution companies during the 2000's, e.g. light 110/20 kV main substation to increase the number of infeed connections, weather proof network [4], 1000 V distribution systems, and low-voltage direct current distribution system (e.g. LVDC with ± 750 V and active voltage control). Fig. 5 illustrates the main principles of LVDC distribution system [5]. The main benefits of LVDC distribution system are a constant quality of customer voltage, lower network investment costs in many cases, better reliability of supply and efficient gateway for distributed small scale generation. The challenges for LVDC are energy efficiency of converters and filters and life time of power electronic components. One significant driver for LVDC is the price erosion of power electronic components. The practical implementation of LVDC distribution shown in figure 5 will be realized during the year 2011 in one Finnish distribution network company.

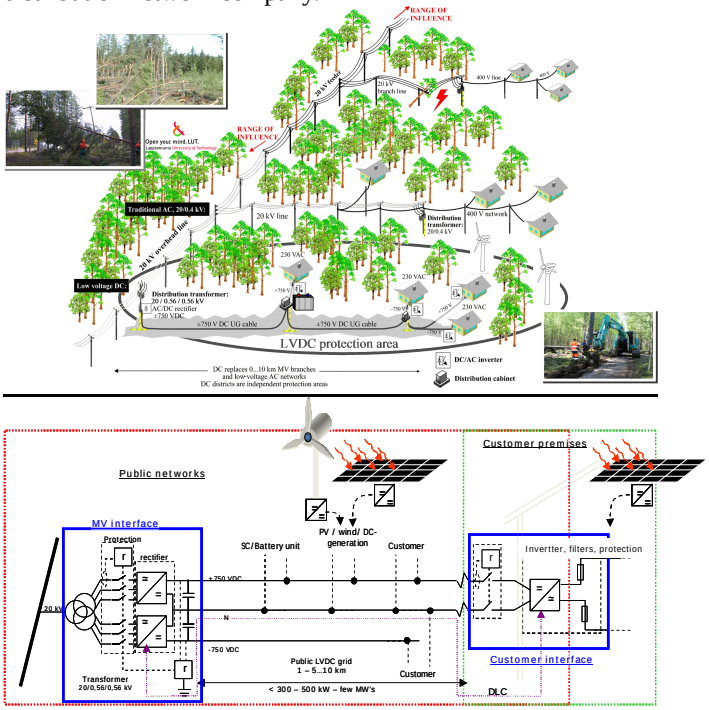

Fig. 5. LVDC distribution system

Nordic electricity market

The electricity market was opened in 1995 in Finland and it is a part of the Nordic electricity market interconnected since the late 90's. Nordic electricity exchange, Nord Pool, is one of the genuinely operating electricity exchanges providing the market price of electricity for various markets (i.e day-ahead, intra-day and regulating power).

Network business and regulation

The open market for service providers was started with network construction in the late 90's and nowadays service purchasing is a widely used and common practice for many functions of network companies. Service providers are private actors with an essential role in the whole network business.

Electricity Market Authority enforces network business. For example, outage costs of both long and short interruptions are part of economic regulation of network companies.

SMART GRID AND ENERGY MARKET (SGEM) RESEARCH PROGRAM

Finnish government has pushed for establishing new non-profit organizations for managing R&D, called Strategic Centers for Science, Technology and Innovations (CSTI). CSTI is a legal company whose shareholders are Finnish major private companies, universities and research institutes.

One CSTI, Cleen Oy, was established in 2008 for the energy and environment domain. In the end of 2009 Cleen Oy launched the first research programme, a large 5-year programme called Smart Grids and Energy Market (SGEM) in order to create the vision as well as the practical solutions for the next generation smart grids. The unique consortium consists of almost 20 private companies (e.g. DSOs, power technology and IT suppliers, telco companies and operators) and seven universities and research institutes. The annual volume of the SGEM is about 10 M€/a. The work is divided into several work packages such as drivers and vision, future infrastructure of power systems, active resources (i.e. active customer, customer interface, electrical vehicles, energy storages, distributed generation), management and operation of smart grids, and development of energy market and business potential. Real-life demonstrations are in essential role in the SGEM. Self-healing grids with market based solutions for managing the sustainable evolution of the electrical power system are in the focus of the SGEM.

SMART GRID VISION FOR THE NEXT GENERATION SOLUTIONS

The vision and path forward for the next generation smart grid solutions from customer, society, DSO, TSO and market point of view is defined and is being researched in the SGEM.

Smart Grid has two main functions:

- *enabler of energy-efficient and environmentally friendly energy market*, which means e.g. interactive customer interface, integration of active resources, demand response, common market models and comprehensive ICT solutions
- *critical infrastructure of society*, which includes e.g. fault management methods, major disturbance management, self-healing networks, island operation and microgrids

The concept of smart grids may be characterized by words like flexible, intelligent, integration and co-operation. Intelligence means here simply investments in protection, controllability and information and telecommunication technologies instead of pure passive lines, cables, transformers and switchgears. By making the customer connection point more flexible and interactive, the demand response functions are more achievable and the efficient use of the existing network and energy resources by market mechanisms can be improved. Interactive customer gateway opens up possibilities for network companies, energy traders and service providers to offer new kinds of added-value services to end customers. Fig. 6 proposes the concept of the interactive customer interface.

The development towards Smart Grids increases the importance of the LV network automation, which has traditionally been quite insignificant in electricity distribution. The role of the LV automation will be significant in Smart Grids due to advanced metering infrastructure, small scale DG, charging of EV, and concept of microgrids.

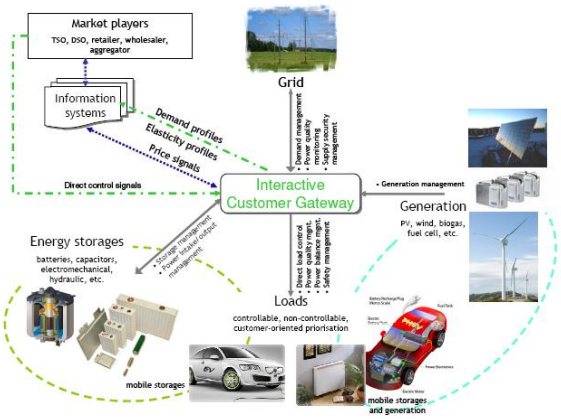

Fig. 6. Concept of the interactive customer interface

Achieving the Smart Grid vision requires development of traditional power engineering but even more importantly large-scale utilization of new communication interfaces and software applications. From ICT point of view, the most significant missing link in distribution networks has been the communication between utilities and end-customers. Implementation of advanced metering infrastructure (AMI) will remove this problem and fulfil one of the most important requirements of the Smart Grid. ICT with common interfaces and data models is an essential enabler of the Smart Grid. It is needed in all parts of the network to ensure reliable and efficient operation of the Smart Grid.

REFERENCES

[1] P. Järventausta, S. Repo, A. Rautiainen, J.Partanen, 2008,"Smart Grid Power System Control in Distributed Generation Environment", *Elsevier Annual Reviews in Control 34 (2010) p. 277-286*

[2] S. Antila, V. Maksimainen, J. Kuru, 2011, Integration of AMM functionality into operating systems of electricity distribution company for LV network fault management, *Proceedings of the 21th International Conference on Electricity Distribution*, Frankfurt, June 2011

[3] A. Mutanen, S. Repo, P. Järventausta, 2011, Customer Classification and Load Profiling based on AMR Measurements, *Proceedings of the 21th International Conference on Electricity Distribution*, Frankfurt, June 2011

[4] P. Verho, O. Bergius, P. Pakonen, J. Hämäläinen, S. Antila, K. Järvinen, 2011, Cabling of rural network – from vision to practice, *Proceedings of the 21th International Conference on Electricity Distribution*, Frankfurt, June 2011

[5] T. Kaipia, J., P. Salonen, J. Lassila, J. Partanen, "Possibilities of the Low Voltage DC Distribution Systems", *Proceedings of the NORDAC conference, 2006*