SCENARIOS DESCRIBING SMART GRID TECHNOLOGIES APPLIED TO ELECTRICITY DISTRIBUTION SYSTEMS

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ABSTRACT

This paper describes a set of future scenarios, reflecting the views and visions regarding smart grid of Norwegian distribution network companies, ICT (Information and communication technology) companies, manufacturing industry, and research and educational institutions. The scenarios are based on a series of workshops held in a national project, the DeVID project (Demonstration and Verification of Intelligent Distribution networks), aimed at demonstrating new smart grid technologies and methods for distribution networks. The DeVID project has performed the scenario process to establish a future outlook, and to pinpoint major challenges and opportunities related to the smart grids development and deployment. The results from the study provide a common understanding and knowledge platform for further research, testing and verification in the project.

INTRODUCTION

Smart grid is an all-encompassing term describing various aspects of the future electrical energy system; hence it covers a very wide topical area. In order to make the meaning of the term more understandable and possible to relate to, a Norwegian multilateral project, DeVID, launched a scenario process to outline potential futures within the area of smart grid.

Utilities all over the world are in the process of establishing their smart grids, through installation of advanced meters, increased monitoring of critical components and integration of new networks user (distributed generation (DG), electrical vehicles (EVs), etc.). The opportunities enabled through widespread ICT solutions seem endless, and it is a challenge for distribution companies to visualise the potential directions for the development of their distribution networks.

This paper contains a brief description of the scenario process, but most importantly reports on the results from the process. The results are four scenarios for distribution networks towards 2030 and challenges, opportunities and recommendations for different actors identified on the basis of analyses of the four scenarios. The recommendations are related to future application of smart grids technologies applied to electricity distribution systems. More information can be found in [1].

BACKGROUND – THE SCENARIO PROCESS

The process consisted of four workshops with participants from the different partners of the DeVID project. The work was conducted in four groups with the same participants each time. The aim was to develop scenarios describing possible "futures" for the application and spreading of smart technology in the distribution network toward 2030. The slogan for the process was "Focus on the imaginable, not the probable", hence the aim was to create a sample space for imaginable futures for distribution networks and not to evaluate the probability of the scenarios nor any of the elements included in the scenarios. The four workshops of the scenario process are briefly described below.

Workshop 1

The participants identified numerous factors and actors that are likely to be setting the agenda for the development of smart distribution networks towards 2030. A few examples are given in Table 1.

Table 1: Examples of factors and actors

Factors	**Comments/examples**
Security and protection of privacy	IT-security, hacking, security of supply.
Politics and governance	Laws and regulations from Norwegian authorities and EU. Climate policies, income cap regime.
Actors	**Comments/examples**
Consumers	"Active" and "passive" household consumers, health sector, prosumers.
Manufacturers of equipment	Smart meters, cars, smart house technology, sensors, software.

Workshop 2

The identified factors and actors of workshop 1 were used as a basis for the development of 68 mini-scenarios. A mini-scenario is an imaginable incident, development or action which is significant for the development of smart distribution networks toward 2030. It is a small "story" including a title and a small description. The mini-scenarios were related to one (or more) of the factors or actors identified in workshop 1. An example of a mini-scenario is provided below.

Factor: Security and protection of privacy.
Title: The straw that broke the camel's back.
Description: Smart metering technologies (or other critical components in the smart grid) get "infested" by bad software and an unfriendly organisation or group gain control over the network or parts of it. Their aim may be disconnection of customers, data manipulation, extortion, theft or getting information to commit other types of crimes. This situation can create a domino effect – if the smart grid falls, other critical infrastructures and the internet of things might also fall, as these are interconnected.

Workshop 3

The four groups developed one scenario each using the identified factors, actors and mini-scenarios as inspiration. In addition, some guidelines for each of the four scenarios were made by the administrators of scenario process in order to aid the scenario development in the groups and make sure that the scenarios covered different aspects of outcomes. These guidelines were meant to be an aid and not rules for the scenario making.

Workshop 4

In the last workshop the scenarios were analysed and each group analysed at least three scenarios, including their own scenario. The analyses resulted in identification of challenges and opportunities for different actors regarding the development of smart distribution networks and also recommendations for actors concerning the need for development of new knowledge, methods, products, processes and so on. The recommendation were intended to aid the development of smart distribution networks and shed light on the further work that needs to be done.

SCENARIOS

Four scenarios were written and these are briefly summarised below.

Services Sans Frontiers

In 2030, electrical energy is still a low interest product in Norway, but the electrical energy consumption is flexible through automatic management and coordination schemes. Demand response is important for the power system and all customers are "active" in the sense that there are possibilities in all households for consumption, production and storage of electrical energy. All overhead lines have been replaced by underground cables in the distribution network and unplanned interruptions are non-exiting for the customers. All homes have an electrical car which participates as an active resource in the power system. A broker offers different service packages and the customer can choose package depending on their own wishes and needs. Available options are "The environmentally friendly package", "The luxury package", "The practical package", "The busy package", "The care package", and so on.

Total control in a time of crisis

In 2030, both weather conditions and crimes have become more extreme. These two factors have lead to a large interest in the ability of the network to handle extreme weather and computer crimes like hacking. The use of fossil fuels is prohibited; hence there is a large interest in all other energy recourses. This situation imposes new challenges for the network to handle power flow in all directions to all hours of the day and year. The network companies have been restructured into large companies with advanced system competence due to the complexity of smart grid. Locally, the network companies have special expertise in handling critical network situations and ICT-competence for emergency preparedness (islanding, local delta teams which can interpret and act based on information/alarms from different systems simultaneously). Non-critical functions have been outsourced.

Well equipped toolbox and unlimited access to data

In 2030, the weather has become more extreme, but the chosen solution for the network companies in order to ensure good security of supply is new practices for redundancy with widespread use of microgrids. These microgrids provide local supply whenever the central supply experiences an interruption. The customers demand a network with high reliability and use integrated service solutions (energy, communication, entertainment and welfare). The electricity network is a complex infrastructure with online condition monitoring and online monitoring for network operation purposes. This makes rapid fault localisation and recovery possible. In addition, the condition of critical network components is closely monitored and the lifetime of the components are maximised. In 2030, Norway has an excellent interdisciplinary smart grid competence due to a large focus on education and research.

It was fun while it lasted

Disappointment and despair characterises the network companies in 2030. The introduction of smart metering did not go as planned and the result was damaged reputation and high costs due to insufficient technology and solutions for ICT-security. Data from smart meters are solely used for invoicing of customers and nothing else. The smart meters were popular the first years after the introduction. But then the negative publicity, in the form of stories of poor personal information protection, reached the surface, coincident with low electrical energy prices. The incentives

and motivation to make adjustments in the use of electrical energy disappeared. The network companies are struggling with large challenges in the distribution network caused by new consumption patterns and domestic appliances. In addition, the network companies are not able to recruit people with the needed competence and therefore have to rely on expensive external resources.

CHALLENGES, OPPORTUNITIES AND RECOMMENDATIONS

Some of the most important challenges, opportunities and recommendations identified by analyses of the four scenarios are given below.

Challenges

Reliability and demand for information

Climate change will increase the stress on the distribution network and increase the risk of interruptions in the supply for large regions in Norway. There will be a demand for updated information during interruptions in a society which both require high reliability of electricity networks and have become accustomed to easy access to information, as described in [2]. This increased risk for interruptions and demand for reliability and information is a challenge for, among others:

- The network companies when performing their risk assessments and emergency preparedness planning. Choices concerning tree trimming, redundancy and availability of manpower and material during critical situations.
- Cooperation between infrastructure owners, public authorities and population.
- Information activity and customer service of the network companies.

Customer relations

Smart metering provides an opportunity to communicate directly with customers e.g. through home displays. A challenge in relation to this is providing incentives and information to customers about moving/reducing consumption of electrical energy in order to realise the potential of demand response, for instance reduction of peak power. Handling of high customer expectations concerning smart grid might also prove to be a challenge.

Customer services

If customer service packages should become the standard (electricity, water, district heating, health services and so on), one of the challenges will be to create market players to offer such service packages to the customers. Such service packages will demand extensive cooperation and coordination between different actors, among other things for distribution of responsibility. Conflicting interests may also be a challenge; an example can be that a customer has an agreement for buying electrical energy and at the same time has an agreement with another actor for disconnection of consumption.

Demand response

The customer will change in the future due to the possibilities for reducing energy consumption (passive houses), increasing peak load (electrical vehicles, instant water heating, induction tops etc.) and the available options for distributed electricity production (prosumers). This will be challenging for network companies in many areas, for instance planning of energy and power demand [3], reduced potential for demand response since loads with thermal storage capacity is reduced (the traditional water heater is replaced by instant water heating) and also might generate a need for some sort of coordination/control of power intensive loads at customer level.

Information security

Information security will be a significant challenge with the introduction of smart grid; an example is hackers entering the network operation system, gaining control over the network and starts to disconnect loads, as described for instance in the EU Viking project [4].

Selection of technology

A robust smart grid demands new technology for measurement, management and communication. It will be challenging to make the right choices for technology. It is also a challenge to exploit the possibilities that lie in smart metering and other types of measurements and create useful information from all the data received from measurements.

Condition monitoring

Condition monitoring is an important part of smart grid, see for instance [5]. It is not possible or desirable to monitor all components in the network; hence a challenge for smart condition monitoring is a cost/benefit evaluation and selection of which components in the network to monitor.

Competence

It will be a challenge for network companies to have the right competence for handling the transition phase and the operation of the smart grid. ICT and handling of critical situations are two examples of areas where specialised competence will be needed.

Opportunities

Smart grid bring about great opportunities for manufacturers to develop and sell new products and solutions, for instance for electrical energy storage, sensor technology and smart metering data management.

Smart grid technology makes it possible for network companies to improve security of supply through increased monitoring of the network and new and more widespread use of components and solutions to provide redundancy, like microgrids. In addition, smart grid technology offers opportunities for the network companies to improve their control over the network; loads, voltages, condition of assets, finding faults fast and so on.

Widespread use of new components in the network, like sensors, provides opportunities for new replacement strategies in the form of modular prefabricated solutions

which are easily replaceable without causing an interruption of the power supply. Use of redundancy solutions in the network makes new solutions possible for network maintenance, as more components can stay in the network until failure. This can reduce the need for condition monitoring. Smart condition monitoring and redundancy solutions will have to be coordinated.

Recommendations

Important recommendations from the scenario process are listed below in non-prioritised order:

- Develop and use more extreme weatherproof components.
- Perform risk based evaluation of what measures to implement, i.e. replace overhead lines with underground cables, extent of tree trimming, use of redundancy options, monitoring of components and so on.
- Establish a common security regime for the entire network business sector.
- Avoid burning all bridges to manual systems and also have the possibility to go back to an older version of the software if new versions prove to be unsatisfactory.
- Initiate projects were commercial processes are developed to handle and use the large masses of data from smart metering and sensors.
- Use real-time monitoring of the network for automated network operation, for instance automatic fault localisation and management.
- Demand response is dependent on involvement of customers; hence market mechanisms and incentives which stimulate desired behaviour must be established. In addition, producers of domestic appliances must be involved in smart grid projects, to ensure that control systems are integrated into washing machines, water heaters and so on.
- There is a need for more research on the future customers with passive houses, electrical vehicle, instant water heating and induction tops. What will the consequences of this development be for demand response and the development of the distribution network?
- The network companies must make strategic decisions concerning the smart grid competence they wish to have in-house and which functions/services they want to outsource. In-house competence might be specialised on specific areas of smart grid or a broader approach with some knowledge on all areas of smart grid. The competence can be centralised in expert networks/centres in the companies or distributed within the companies.
- Smart grid must be used to recruit new employees to the network companies and make this business sector more attractive.
- Competence must be built on the social-economic potential (cost/benefit) of many smart grid elements, like dynamic tariffs and load management. This can disclose the benefits of tariffs and load management as alternatives to network investments [6].

Further research

The main idea of the DeVID project is to provide a novel and better knowledge basis for decision makers who shall purchase, deploy and/or develop smart grid technologies. Development and demonstration of technologies and decision support methods is central in the work. The DeVID project will continue in 2013 and 2014 and the results from the scenario process will be used to generate new ideas and prioritise research tasks within the project.

Acknowledgments

This paper was written as part of the reporting from the DeVID project (Demonstration and Verification of Intelligent Distribution networks) http://www.sintef.no/Projectweb/DeVID/. The DeVID project has more than 30 national participants, including distribution network operators, ICT companies, manufacturing industry/vendors, country authorities, interest organisations and research institutions.

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