1 Characteristics of the Norwegian power system and electricity use

In Norway historically, hydro power has been the main energy source for electricity generation. Thus, today 98-99% of the total electricity generation in Norway is hydro power based. Due to this fact, it is not on the Norwegian smart grid agenda to convert fossils based electricity generation to renewable generation. But as Norway is committed to fulfill the so-called European Renewables Directive [15], 67% of the total energy use in Norway should be based on renewable energy by 2020 which requires an increase in renewable electricity generation to substitute the use of fossils based energy in industry (on-shore and off-shore) and in transport. Incentive schemes in terms of a common green certificate market with Sweden thus motivates for more renewable electricity generation which in part will be based on intermittent energy sources like wind, PV and small hydro power plants without any reservoir capacity.

The Norwegian power system and electricity use has several characteristics different from most countries giving specific challenges and opportunities within the Smart Grid context:

- Large part of electricity in the domestic sector used for space and water heating offers much flexibility for demand response and demand side management schemes.
- Large availability of hydropower plants with reservoirs which are fast and easy to control. These offer low-cost balancing services. (Most new production is small scale distributed generation without storage.)
- Quickly growing use of purely battery based electric vehicles due to very good incentives (tax exempt, free parking, free use of toll roads and bus lanes etc.)
- Significant part of the LV distribution system is of type 230 Volt IT system (230 V line voltage) different from the 400 Volt line voltage systems in most of Europe.
- Weak grids with approx. 40% of the supply terminals weaker than the standardized EMC reference impedance give more severe voltage quality problems when connecting EVs, PVs etc. than many countries.
- Well-developed broadband communication to homes and increased use of fiber-to-home communication provided by power utilities.
- Well-developed power markets. There are multi-national wholesale markets with significant volumes for day-ahead and intra-day and also inter-TSO balancing markets with participation of producers and consumers.

In total, Norway’s power system and -markets are well positioned for a future smarter and more renewable power and energy system, but some barriers such as weak grids in parts of the LV system needs to find their cost efficient and smart solutions.

Full scale demonstration projects connected to real power systems are necessary to properly develop, test and verify Smart Grids solutions. Immature and high-risk solutions are best studied and tested in laboratories while the more mature cases and cases which include the behaviour or human response of customers need to be tested in demonstration projects that are linked to real power systems with real customers.
2 Overview of Demo Norway for Smart Grids

One of the goals of the Norwegian Smart Grid Center – [www.smartgrids.no](http://www.smartgrids.no) – is to establish national demos and laboratories for the purpose of developing, testing and verifying Smart Grid technology and services. Demo Norway is the result of coordinated development of complementary demos at individual sites (“Living Labs”) with modern off-grid laboratory facilities at the research institutions NTNU/SINTEF. The Fig. below is an overview of the Demo and Lab activities in Norway for smart grids:

The living labs (blue color in the fig. above) are planned to be connected to the National Smart Grid Laboratory (red color in the fig above) via remote access. Connection between the demos and the off-grid laboratories will be established for exchange of data and to be able to run research projects in a relevant setting. The demos are designed in a way to be useful also for the supply industry both for component and services and in this way they are also incubators for research and business development.

3 Demo Steinkjer

The Demo Steinkjer involves 4500 network customers, including domestic as well as business customers. The main driver for this pilot has been the deployment of smart meters and 800 smart meters are running within the Demo-area. AMS meters recording energy consumption every hour have been installed in the participants’ households. As part of the project, the time-based values are
uploaded once a day to a cloud-based storage service/database specially adapted for time series. The data are anonymised and individual customers can not be traced.

One of the key features of the pilot is to use and test IP-communication via fiber optics that have been installed to most domestic customers. Foreseen challenges to be addressed include interoperability and scaling of back office IT systems to cope with the large increase in data to be exchanges. Smart metering deployments logistics, customer education and data security are also issues addressed.

Demo Steinkjer has developed a REST API (representational state transfer application programming interface) from which these data are made available to “system clients” – that is, clients who wish to carry out system tests and need machine-readable consumption data. The objective is to give researchers and developers access to authentic time series that they can use when developing their systems and products. This is a new way for the energy industry to make this type of data and information accessible to other partners. In general, the use of cloud-based services in the energy industry has been sparse – even internationally. The methods of gathering and storing data have been using proprietary standards.

The exiting thing about the API is that all data made available are following the CIM standard, more precisely the IEC 61968-9 compliant CIM-format. Today the energy consumption data variable (ActivePlus and ReActivePlus) from all the smart meters in the demo area is available through the API, but in near future also other types of time series data from the smart meters will be included. For example voltage, amper and earth fault measurements like earth current. Voltage and amper are actually included from approximate 10 high frequent AMS meters (1 minute resolution). All CIM compliant.

Another main driver has been local DSO’s proactive Smartgrid interest. The main objective so far has been testing domestic customers ‘willingness to use new market products subjecting them to market price volatility.
Flexibility of end users and value added services for the distribution companies will especially be developed and tested in this project. Dynamic tariffs are one of the incentive schemes being tested. Both the technologies involved and the customer response are addressed. A high-level identification of information security threats of the AMI pilot in Demo Steinkjer have been investigated primarily concerning the smart meter and its communication with the main system of the Distribution System Operator (DSO). A number of information security threats have been identified, and will be further analyzed in a complete risk analysis to prioritize risks and possible measures.

Demo Steinkjer will be developed further in the short term especially on the following aspects:
- Monitoring and control of secondary substations
- Communication systems for secondary substations
- Distribution management system (DMS) functionality and visualization

4 Demo Smart Energy Hvaler

Demo Smart Energy Hvaler is located on islands in southern Norway. The area consists of four main islands and several smaller ones. Customers on area are mainly summer cottages. Main project driver has been the requirement to change electricity meters on the island according to regulations based on the EU MID-directive. Further objective has been testing smart metering and associated infrastructure for enhanced monitoring of MV and LV distribution networks for more efficient distribution system asset management and more rapid fault detection and restoration. Customer demand response as well as micro generation and charging of EVs and PHEVs are also addressed.

- Four «main islands» and 16 small ones
- 6,800 load points with AMS
- 4,300 cottages
- 50 kV radial supply
- 1 primary substation, 30 MW
- 18 kV HV network (110 km OHls)
- 206 secondary substations (MV/LV)

Use cases for smart operation and planning of the distribution system have been developed. The availability of new smart meter data has already given improved information on end user load profiles and thus changed the decision base for network planning. The old load profiles have often given a conservative peak load estimate. Bringing the new data into the planning process have thus reduced the needs for grid reinforcements and saved money.

Specific use cases demonstrated during 4smartLV are planned to include
- Utilizing information from Smart meters in outage management
• Power quality integrated with smart metering
• Detection and localization of faults in the distribution grid
• Detecting incipient/early faults in the distribution grid

Further Demo case studies in the short term will focus on combining/sharing measurements from smart meters with sensor data from other instrumentation to provide a complete picture of the state of the distribution grid. To achieve this, methods such as "sensor fusion" and "data fusion" is essential. To do this, not only based on historical data but in the operational context, there is a need for a data communication solution that can link information sources together in near real-time.

Demo Hvaler has plans to implement a communication infrastructure based on both public and private IP communications systems. In previous test set-ups, the communications systems have had a major impact on the perceived quality of the Smart metering systems. Establishing and maintaining communications channels with necessary quality from the Smart meter to the central systems are also believed to have major impact on total system costs. Within the 4smartLV project a public LTE service will be used, together with a licenced private radio system, such as WiMax. Both systems will cover smart meter concentrators and a relevant set of other instrumentation in the demonstration area. The project will focus on achieving an in-depth understanding of requirements for the communication channels, such as security, IP connectivity, capacity, delays and service / support requirements. Development will also be done in existing distribution management system (DMS), meter data management systems (MDMS) and advanced metering interfaces (AMI). The development will focus on capacity, utilizing standards and security in the vertical from customers to data concentrators to the back office systems for planning and operations including the SCADA and DMS functionality for both MV and LV grid.

5 Demo Skarpnes: Plus houses

Demo Skarpnes is investigating the impact on the local grid of a residential area consisting of plus (zero) houses in southern Norway. The area consists of 19 detached houses, 20 apartments and 8 semi-detached houses. All the buildings are equipped with PV panels, CSP and energy wells, and they are self-supplied with energy over the timespan of a year.

The main objectives of the demo include monitoring and analyzing the variation in need for power of the single and the aggregation of buildings during different seasons and understanding better the energy use of
In a short term, Demo Skarpnes seeks to extend the demonstration site by setting up a full scale aggregator on the area. The aggregator is planned for full market participation. Demand response will be applied as one of the aggregator tools, implemented separately or in combination with the AMI system.
6 Demo Lyse: Services based on a platform of smart house automation

Lyse energy will install 160 000 smart meters together with a gateway unit facilitating additional services. The information of this unit may be displayed on for example an iPad for the customers and the information will be embedded in the control systems of Lyse. In addition, Lyse energy will offer to their customers at a certain price, smart lighting control (four wireless switches and four control units for light sources) and smart heating control (3 thermostats for rooms or floors, and the control of 3 heat sources like electrical radiators or underfloor heating).

Within Demo Lyse one of the subprograms is called "Smart power" where 40 network customers have been recruited to test solutions for energy efficiency and energy control utilizing a smart house control concept. In this concept a fiber communication based AMI infrastructure is used for controllable household devices interaction.

The 40 houses are equipped with broad band connection, Smart House Controller and AMS. The demo setup enables smart control of 3 heating zones, and 7 lighting sources, including scheduling and remote control enabled by smart devices as iPads, Smart Phones, PC etc. It also features physical push buttons and "scenario" buttons for day/night and home/away presets. Demo has also been applied for developing smart house controls for future welfare/health care services and security.

Demo has been developed for testing use cases for different kinds of services, for evaluating business models and for developing smart power/demand response systems for the network operator.

In a short run, Demo Lyse will be developed especially on following aspects:
• End customer services and involvement, prosumer aspects
• Smart houses and potential of energy storage
• EV charging
• LV micro grid operation
• LV voltage quality monitoring and management
In addition, Demo Lyse will be developed further in the short term a large scale pilot on
• Monitoring and control of secondary substations
• Communication systems for secondary substations
• Distribution management system (DMS) functionality and visualization

7 Demo Statnett: Pilot North Norway (TSO)

The Demo Statnett encompasses the development and testing of principles and procedures which contribute to the secure and cost effective planning and operation of the power system from a system operator’s (TSO) point of view. Statnett is the Norwegian Transmission System Operator (TSO). In this demo different solutions related to close to real time reliability and risk assessment are tested and verified. Wide area monitoring systems including phasor measurement units (PMUs) for state estimation and stability monitoring are important elements in the demo. The demo also addresses TSO load management for system balancing purposes by playing on the DSO loads in the northern region of the Norwegian power system. A short description of this project is provided below.

BACKGROUND:
The power grid in the North of Norway has a number of challenges that require effective operational tools to ensure cost efficient operation and acceptable security of supply. Planned investment and grid reinforcements do not resolve all these challenges, and therefore various smart solutions shall be tested through R&D projects to evaluate how current operational practice can be developed to meet the remaining challenges.

In addition, Statnett wishes to prepare for the implementation of Network Code for Load Frequency Control and Reserves (LFCR), which requires load and production to be treated equally in terms of provision of control reserves. The Demand Connection Code (DC) specifies technically how load can be utilized as reserves. LFCR and DC will become law in EU from 2016.

The European Commission has political ambitions to include flexible load (including aggregation thereof) to manage the challenges from renewable energy sources aimed to reduce the EU carbon footprint by 2020.

GOAL and RESULTS:
The main goal is to validate efficient usage of flexible load in planning and operation of the power system during challenging operational situations. The solutions are currently (Nov 2014) in the implementation phase for test and evaluation in the Northern Regional Control Center in Alta.

The project will demonstrate technical proof of concept and validate usage of flexible load as an additional tool for power system management through usage of existing and new technical solutions (AMI technology, Aggregator solutions and development of LFC solution from large industry). The first test was recently conducted, and showed that it took less than a minute to disconnect a substantial amount of load as planned.

CONTENT of STUDY:
The content builds on the pre-study work covering description and analysis of available load in the target region, conducted in Jun-Oct 2013. Through three sub-projects, the study will cover the following:

1. Conceptual design, communication architecture and technical specification
2. Analysis of Load Characteristics for DR product definitions
In the area of Smart Grids, several research laboratories have been operating in Norway in a rather uncoordinated manner for several years. Each of them could offer a limited range of services and testing capabilities with limited access. The concept of a National Smart Grid Laboratory did not exist until the Norwegian Research Council decided to open a dedicated call for applying for funding to build National Infrastructures in the year 2012.

A brand new Smart Grid National Laboratory was granted by the Norwegian Research Council to a consortium composed by NTNU, SINTEF, Narvik University College (NUC), and NCE SMART under the leadership of NTNU. This consortium has the mandate to establish in the period 2014-2018 a one-site Smart Grid laboratory facility equipped with advanced infra- and control structures with high modularity to simulate in as realistic setting as possible occurring scenarios in real life. One of the objectives of this laboratory is the testing of new equipment, functions and control strategies to gain insight on their operation before they are implemented in a real application. Although the central laboratory facility will be located in Trondheim, there exist several other connected facilities and demonstration sites that will be linked to the central laboratory by a high speed communication system by which remote access to the facilities and databases will be given. Lay-out of the laboratory facility with planned extension and upgrade: