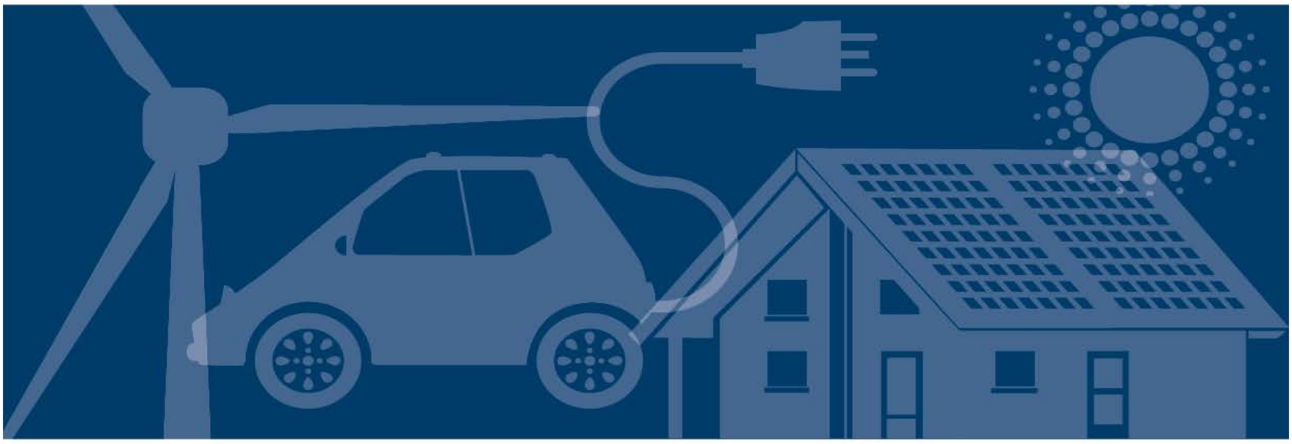
RDD for the promotion of power system efficiency

– Status and proposals for development initiatives in the Smart Grid area



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Summary and conclusions

The framework for the expansion of wind power capacity in Denmark is laid down in a political agreement concluded in spring 2012. The natural variations of wind power will present a challenge to power system operation. In order to help solve this problem, a new generation of intelligent automation systems is introduced in the power grids, ensuring two-way communication all the way to the users. One of the objectives is to be able to adapt electricity consumption to the current supply and to the local grid conditions. The new methods are known internationally as Smart Grid.

In Denmark, Smart Grid preparations have been underway for many years. In April 2013, the Danish Ministry for Climate, Energy and Building presented a Smart Grid strategy with a number of initiatives for implementation by the political system and the energy companies. The aim is to enable the wholesale and retail markets to handle flexible electricity consumption in the period up to 2020. The report specifies a total of 14 initiatives for the political system and six initiatives for the energy sector. The last of the initiatives to be implemented by the energy sector is as follows:

> "The energy research programmes are called on to arrange for an interdisciplinary assessment of which factors need to be developed and demonstrated in order to promote the optimal use of resources by introducing 50% wind power in the power system."

The energy research programmes have appointed a working group of evaluators to handle the task. The working group has based its assessments on available information on ongoing and completed Smart Grid research projects.

The working group has found that a number of ongoing research projects are expected to deliver operating results well before 2020, particularly as concerns the operation of the transmission system and the planning of the distribution systems.

On the other hand, the working group has found that significant recommendations from the Coordination Committee for the Power System of the Future from 2011[1] have only been followed up on to a limited extent, especially within the communication and market areas.

The working group has noted that the government's Smart Grid strategy[2] places special emphasis on making electricity consumption more flexible in order to accommodate more wind power. However, the working group would like to highlight the broader Smart Grid objectives described in chapters 4.2 and 4.3.

A flexible electricity consumption assumes varying (volatile) electricity prices. Other concurrent means of addressing the new challenges may, however, dampen the price fluctuations, and, by extension, the flexibility of electricity consumption. For example, there are special incentives for the installation of reserve capacity (capacity schemes) as well as electric boilers and large heat pumps to absorb surplus energy. It is therefore important to analyse the competition between all potential means and measures and their overall effect.

The possibility of compensating for the natural variations in wind and solar power by influencing electricity consumption is not expected to gain more than marginal significance until after 2020. The

[1] Analysis of the Danish electricity industry's Smart Grid RDD initiatives (*Kortlægning af den danske elbranches Smart Grid FUD-indsats*), Energinet.dk and the Danish Energy Association, 25 January 2011.

[2] Smart Grid strategy – the intelligent energy system of the future (*Smart Grid-strategi – fremtidens intelligente energisystem*). The Danish Ministry of Climate, Energy and Building. April 2013

wholesale model with the option of settling flexible electricity consumption will be launched towards the end of 2015, after which it will gradually be rolled out in the individual grid companies. It will then take some time before the industry and customers discover the new potential source of revenue. In 2020, other measures will therefore have to absorb most of the wind power variations.

'Smart Grid in Denmark' published in 2010[3] includes a cost-benefit analysis. Major changes have already been made to the key prerequisites for this analysis (see chapter 4.4.1). The working group therefore recommends that the calculations be updated, preferably divided into individual Smart Grid elements, including heat pumps, energy storage facilities, electric car charging stations and solar cells and preferably divided into businesses and private households.

The transformation of power generation from controllable power stations to weather-dependent wind power and solar cells presents various challenges to **the overall grid** and **the local grids**. It involves dilemmas, because there may be conflicting interests between securing overall system balance and eliminating local congestion, and making the most of end-user flexibility requires development of effective mechanisms to coordinate these interests.

The Smart Grid Research Network[4] defines five Smart Grid research areas, on which the working group should base its work. The working group also emphasises that research should be conducted into system properties across the five areas.

For each of the five areas, the working group has identified the following topics, where it may be advantageous to step up research in the period leading up to 2020:

- Power grid:
    - The distribution companies' future role should be examined thoroughly with a view to ensuring effective and consistent customer service.
    - An expansion strategy with related analysis tools should be developed to ensure acceptable quality of supply in the distribution networks (see 5.1.1).
    - A modernisation of the protection of local grids (up to 60 kV) should be examined with a view to making grids with a high share of wind power and solar cells more resilient during outages.
    - Planning of resources for the supply of reactive power is normally not considered a Smart Grid topic, but according to the descriptions in chapters 4.2 and 4.3, it might well be. Systematic automation (including PMU) and optimisation based on appropriate operational reliability could contribute positively to the efficiency of the power system. Grid rules, division of responsibilities, planning and management of reactive capacity may therefore be relevant to coordinated system-technical and socio-economic research.

- Energy markets:
    - The development of new market designs is key to ensuring more flexible electricity consumption. Dynamic price signals should lead to action, but only if prices are considered to be the most effective guide. We need projects which can clarify which services are suitable for price control and which are suitable for other types of control, which services can effectively be offered by the individual end-user and when an aggregator would be more appropriate. Furthermore, it should be clarified which consumption segments are expected to be most relevant to the different services, and to what extent the conditions for effective price formation are met for the services and segments in question (see chapter 4.5).

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[3] Danish Energy Association and Energinet.dk: Analysis of the Danish electricity industry's Smart Grid RDD initiatives, January 2011.

[4] Road map for Smart Grid research, development and demonstration up to 2020 (*Roadmap for forskning, udvikling og demonstration inden for Smart Grid frem mod 2020*), 22 January 2013.

- A particularly important area is business models for the implementation of demand response (flexible electricity consumption). This requires further research within areas such as possible product definitions, price roles and other signal factors, rules, market establishment and, of course, costs. This implies some unexplored dilemmas:
  - If congestion in local grids is to be countered by controlling private electricity consumption via electricity prices, electricity prices must be different on each side of the given congestion. Are we prepared to accept different electricity prices in different parts of a city?
  - Grid tariffs may interfere with or enhance price signals from the electricity market. How should the grid tariffs be designed so as to achieve the maximum impact on electricity consumption? And how do we ensure that grid tariffs are fair?
  - If congestion in local grids becomes commonplace, it should be considered how congestion rents at the grid companies should affect grid tariffs, and how we ensure that the grid companies carry out a proper assessment of whether the congestion should be removed through grid reinforcement or whether it should continue to be addressed by means of price differences.

- Components:
  - Generation
    - The ability of wind turbines and wind farms to stabilise the grid should be further analysed and demonstrated.
    - New power station types for periods without wind and for back-up and peak load times should be developed.
    - Large heat pumps suitable for installation in the district heating systems should be developed and demonstrated in combination with CHP plants.

  - Energy conversion
    - Processes and fuel types for energy conversion should be investigated further, emphasising thermodynamic efficiency, storage options and cost-effectiveness.
    - Upgrading of biogases and methanation of hydrogen for injection into the natural gas network should be optimised and demonstrated.

  - Distribution system
    - Standardisation of measuring equipment and communication for Smart Grid elements with special emphasis on elements, where active management is relevant.
    - Analysis of the real potential for consumption management and the profitability of the current methods.

  - Consumer side
    - Future building regulations should be adapted to accommodate automatic energy management, placing more emphasis on the capability of buildings to integrate dynamically with energy solutions.
    - The value of local electricity and heat storage facilities should be analysed.
    - The requirements of electric vehicles and hybrid vehicles for infrastructure and reusability of existing infrastructure should be identified.

- Consumers:
  - Knowledge of consumer behaviour
    - Knowledge should be gathered of how consumer behaviour can be incorporated in a Smart Grid system, both with and without focus on the financial benefits. This should

include knowledge of the needs and preferences of consumers which may lead to new forms of involvement and commitment to the Smart Grid of the future.
    - Impact assessments of consumer behaviour, contributions and involvement in various Smart Grid initiatives should be carried out.
    - The trend is for more and more private consumers to form partnerships and adjust consumption to the current market situation. It should be identified how behaviour within the partnership can be changed/adapted.

  - Adapting to new market functions
    - If the impact assessments show that it would be expedient to involve consumers in the long term, technological solutions should be developed for this purpose and followed up by a study of consumer reaction to the new solutions.
    - Knowledge of consumer practices, motivations and values for relevant products, services and markets should be gathered, as in future homes are expected to be intelligent and in many cases self-sufficient in heating and energy from small local plants.
    - Studies should be initiated to determine how consumers act under changed conditions at household level, neighbourhood level, housing level, workplace level and in terms of transport. The studies could be carried out as Living Labs.
    - Consumers need to be able to shift their consumption to times, which are advantageous to the energy system. At present, there is not sufficient knowledge of which solutions may be put to use, and to what extent they can contribute to a shorter or longer offset. There will be appliances, components or plants, where the offset can take place by giving the consumer a control signal, but by far most of the offset is estimated to be executed via the storage of energy. Knowledge should be gained of how the need is coupled with the size of the stock and the desired offset.

  - Company processes and indoor climate
    - Knowledge should be gained of the extent to which companies are willing to compromise production in terms of managing their processes. How flexible are they?
    - The trend is expected to be for higher temperatures as well as denser housing with more heat being generated by appliances and sunlight, leading to higher electricity consumption and lower heat consumption. Solutions should therefore be developed for intelligent control of energy-consuming technologies such as cooling systems and ventilation systems in relation to forecast heat radiation and outdoor temperatures, taking into account the orientation of the building and dynamic use of the building facades.

- Information and communications technology:
  - Sensors and measurement
    - Different methods should be tested. The added value of obtaining more and more frequent data should be examined. A need for frequent intervention also entails a need for frequent measurements, for example by using PMU technology. The need for sensors should be based on an evaluation of the necessary input signals from sensors, which should therefore be designed for the purpose.

  - Data presentation
    - Various options for displaying data to control room staff, on other people’s smart phones etc. should be tested to ensure a correct perception of the condition and correct actions. It is necessary to compress the information to identify what is important.

- Decision-making
  - Decisions may be made by people and/or computers. Multiple sensors may result in a huge volume of data. Decisions should be based on the best information available on the condition of the system and the implications of the decisions. Better tools for this purpose should be developed.

- Transmission of control signal
  - The performance of various methods should be compared. This includes human and/or electronic receipt of control signals, back-up system design if the first response fails, and the determination of whether a transmitted control signal resulted in the intended action.

- Financial assessment
  - The balance between the costs of more ICT and the value of having more ICT should be examined in more detail. This includes what should be measured and how often, data handling, data security, frequency of interventions, human/automatic decisions, control signal types etc.

- Personal integrity, cyber security and interoperability
  - There is not much research into this area. As early as 2011, several areas were identified by the Coordination Committee for the Power System of the Future, and there is a strong need for more projects within areas such as choice of data protocol, data security concept, communication system and communication system security architecture.

Some topics can be postponed until after 2020. The working group suggests the following:

- Components
  - Research basis for non-fossil fuels for power generation and heavy transport.
  - Analysis of energy storage options (heat storage facilities, batteries, gas storage facilities, synthetic fuels).
  - HVDC solutions for offshore wind turbines and Super Grid, and their significance for Denmark.
  - Infrastructure for high-power electric vehicle charging and non-fossil fuels for heavy transport.
  - Better forecasting tools, grouped by time and place, to ensure that control parameters are available for the individual branches.

It is the working group's view that energy research in Denmark should continue to be broad in scope, because of the considerable degree of uncertainty about the power system's development in Denmark and other European countries, also in the short term.

The uncertainty also means that energy research programmes should not have a strictly technical focus. The interaction between the technologies and people/society is of vital importance. The markets and energy supply institutions must be adapted to the technological and political development. Social sciences (economics, political science, sociology) should therefore play a natural role in energy research, including the identification of regulatory barriers.

Because of the working group's difficulty in gaining a complete picture of the results of Danish energy research, the working group recommends that the research programmes present a summary of the results. This could also provide a better basis for targeting future research activities.

Compared to other EU countries, Denmark has a relatively low share of projects involving demonstration and implementation of new methods[5]. The working group therefore recommends that more projects focusing on these areas be approved.

5 Reference to the JRC report.