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SMART ENERGY

SMART GRID DEVELOPMENT: MULTINATIONAL DEMO PROJECT ANALYSIS

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This paper analyses demand side management (DSM) projects and stakeholders' experience with the aim to develop, promote and adapt smart grid tehnologies in Latvia. The research aims at identifying possible system service posibilites, including demand response (DR) and determining the appropriate market design for such type of services to be implemented at the Baltic power system level, with the cooperation of distribution system operator (DSO) and transmission system operator (TSO). This paper is prepared as an extract from the global smart grid best practices, smart solutions and business models.

Keywords: *demand side management, demand response, electricity market*

1. INTRODUCTION

According to Energy Efficiency Directive 2012/27/EU and its Article 15.4, all EU member states are required to "ensure the removal of those incentives in transmission and distribution tariffs that are detrimental to the overall efficiency (including energy efficiency) of the generation, transmission, distribution and supply of electricity or those that might hamper participation of demand response, in balancing markets and ancillary services procurement", whereas Art. 15.8 of the Directive states that "member states shall ensure that national regulatory authorities encourage demand side resources, such as demand response, to participate alongside supply in wholesale and retail markets." In addition, the European Commission "Winter Package" highlights that future electricity grid will integrate more renewable energy, especially wind and solar, including decentralised supplies. Thus, supply and demand must become more flexible through wider use of demand reduction, demand response mechanisms and energy storage. Currently, only several EU member states have regulatory and/or contractual measures that allow or promote different DR measures to be used for power system control [1].

Despite progress made over the years, corporations, municipalities and research institutions are still facing significant barriers to DEMO project implementation. Lack of executive or high-level regulatory support, staff/stakeholders expertise and funding are among such barriers.

This analysis is used as a preliminary study for DSM DEMO project planning in Latvia with the aim to identify possible flexibility of services, including DR, and determine the appropriate market design for such type of services to be implemented at the Baltic power system level, with the cooperation of DSO and TSO. Research was conducted in the Smart Grid Research Centre of IPE with the aim to facilitate national smart meter roll-out programme through knowledge transfer and support in smart grid technologies (SGTs), smart appliances and end-use device operational management to serve the consumer best needs [2].

2. DEMAND SIDE MANAGEMENT CONCEPTS AND ITS CONTRIBUTION TO POWER SYSTEM

2.1. General Concept and Terms

A number of EU and other national projects have demonstrated the utilisation of RES and DER flexibility within individual categories of grid connected devices, such as various types of domestic load, EV charging, storage with distributed generation [3]. The main challenges associated with smart grid operation are a coordinated approach and an optimal **energy management strategy** with respect to multiple objectives, where two main outcomes are:

- With a **new energy management solution (EMS)**, the wasteful use of energy will be decreased, and further **utilisation of RES** will be provided.
- With the developed EMS, a two-way digital communication between DSO and common household devices could enable smart energy system and advanced smart grid component management, **giving the prosumers a tool to improve their energy efficiency and actively participate in electricity market for lowering their costs of energy consumption.**

Another important part, before concept analysis consideration, is to consider the terminology used in the smart grid society and business case developers, for load management aggregation, over the world. Demand side management is understood as one of the key pillars of smart grids, where the role of load management takes the major place.

In respect to national case studies, the following two main definitions are used:

Demand Side Management (DSM) represents *a general category* of all end-user energy programmes that are often a set of dynamic tariffs or sustainable energy awareness strategies used to reduce consumption.

Demand Response (DR) is *a strategy* for energy consumption shaping, which aims at changing end-user consumption patterns according to system capacity and/or market requirements by altering the timing, the level of instantaneous demand or the total electricity consumption.

2.2. Price Responsive Demand

To research DSM specifics and investigate customer standpoint and behavioural barriers, the worldwide projects were analysed from the following countries: Austria, Canada, Denmark, France, Germany, Italy, Japan, Korea, South Africa, Sweden, the Netherlands and the USA [3]-[5].

Change of End-User Behaviour from Their Point of View

The two main lessons learned: 1) the need for the consumer personalised tool & services quality aiming towards maintaining the high level of the comfort, 2) smart network tariff should promote active consumers to participate in the system needs.

Finally, approaching the end consumers, the motivating factors should be carefully investigated and not be restricted to financial incentives. One of the positive ratings of the above-mentioned DEMO project analysis is that almost 80 % of involved consumers would like to continue DSM deployment.

Application of Smart Appliances and Home Automation System/Network (HAN)

SGT application for load management is mainly focused on the demonstration of the application of smart metering and developing monitoring and validation of concepts or the suggested approaches. Testing the role of information and communication technologies (ICT) in developing various concepts or security privacy issues is crucial in all DEMO projects. Therefore, the appropriate standardised instrument needs to be applied (Fig. 1).

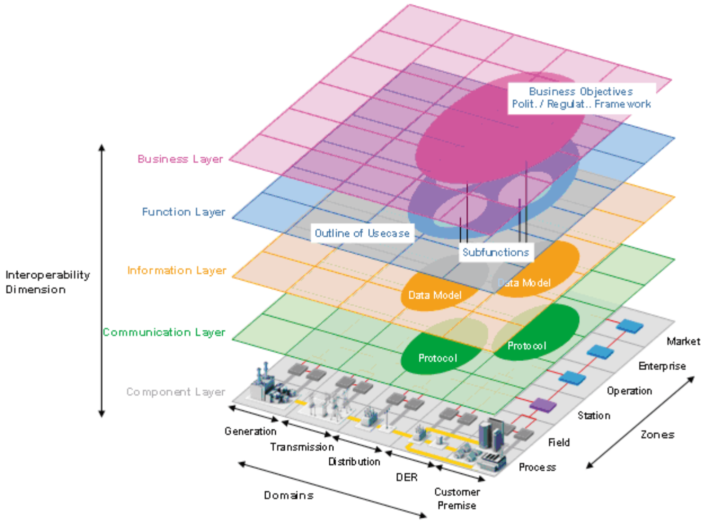

Fig. 1. SGAM (source: Smart Grid Coordination Group, “Smart Grid Reference Architecture”, CEN/CENELEC/ETSI, 2012).

The **potential of direct load control** and demand reduction (including heating solutions) have also been estimated and suggested in order to shift flexible load automatically.

The main lessons learned, after calculating the theoretical potential, are as follows: load shedding is up to 50 % of peak demand when all buildings are equipped with an electrical heating system. Practically the load shedding potential is about 10 % of the peak load in the parts of the grid with a high density of installed electric heating and about 1.5 % of the peak load is shiftable within the existing legal framework [2]-[5].

Home automation system/network based on the multi-energy agent principle application aims at demonstrating the application of smart metering and developing monitoring solutions/applications and validation of concepts. Here the role of ICT is of great importance in developing various concepts or security and privacy issues. In order to optimally integrate active buildings into the smart distribution grid not only the voltage should be kept within the regulated marginal values, but also the available renewable resources should be optimally exploited.

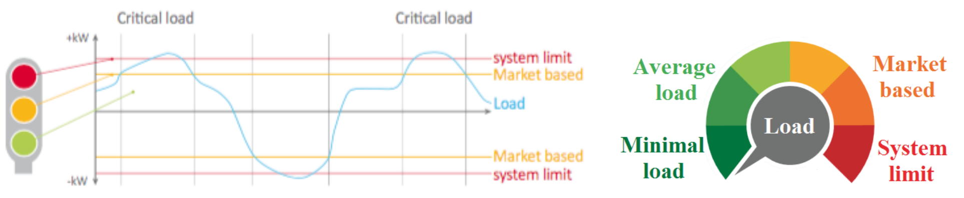

Fig. 2. Traffic-light model (source AIT and IPE).

In this regard the traffic-light model, for instance, can been suggested, in which active buildings react to the market signal as long as critical threshold values on the power grid are not reached (Fig. 2).

The **optimal energy management strategies** of smart metering & control, including deployment of the price responsive demand, aim at achieving the rational use of energy, demonstrating the first steps of implementation of home automation system with automated energy consumption scheduling units for load flexibility and controllable portion estimation.

Different DEMO projects have been carried out, which range from analysing the integration of renewables into distribution networks to assessing the impact of integration of electrical vehicles (EVs), residential consumers, buildings as well as commercial and industrial enterprises into the electricity grid. Therefore, **EV charging simulation** for an urban distribution network needs to be estimated at the DSO level, and symmetrical load distribution via three-phase charging should be adopted [6].

Purely market-oriented controlled charging, which leads to a high number of EV charging, at once should be avoided. In order to make the system as efficient as possible, a scheme or adaptive charging should be developed. Here, we can conclude that current **vehicle-to-grid delivery of electricity** is not feasible based on current market conditions, and the economic motivation for the EV participation in the electricity market needs to be developed in each particular DEMO project, taking into account regional tariff system and regulatory policy.

3. MARKET ESTABLISHMENT

All DEMOs were investigated taking into account the range of technologies under specific market rules. The target was to estimate if/how electricity markets provide the opportunities to realise value of (consumer) electricity to reduce the total demand.

Analysis of the above-mentioned DEMO projects shows that characteristic of every country and region should be investigated in order to identify the sources of flexibility and the nature of the market design in each case [3], [7]. The flexibility of the retail pricing schemes or the publication of sufficient balancing information is needed in order to trigger a reaction by the market actors or end-users through some examples of general guidelines.

Most DEMO projects have an objective of the proper integration of load from the residential sector and small industries in the balancing market. Besides, the investigated DEMOs take into account the fact that the capacity of the distribution grid can be a limiting factor in some cases due to security constrains:

- System change from a high level control of *small* number of large generation to *large* number of small/ medium distributed generation and flexible users.
- An extension of the market set-up is expected through the introduction of an ancillary services market.

The set-up of DSM ancillary services is also an important step in the further development of the existing electricity wholesale markets and balancing markets that create more favourable conditions for the integration of more renewable generation into the supply mix of energy resources.

Therefore, different electricity sub-markets and direct control mechanisms were investigated and the following market structure was proposed (Fig. 3) [7].

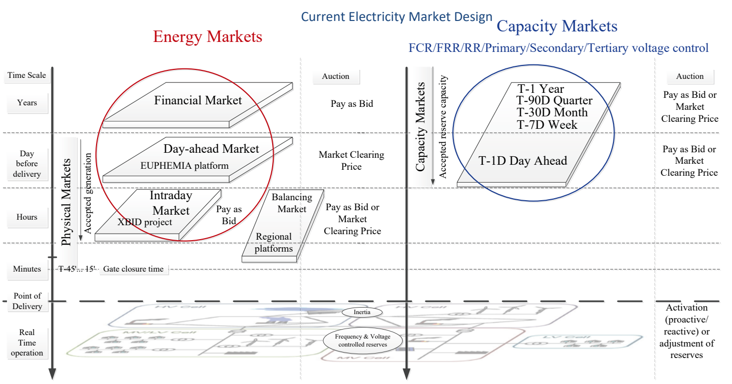

Fig. 3. The electricity sub-markets (source IPE).

To summarise DSM possible contribution to the existing electricity markets and further to balancing markets, the authors woud like to underline that the concept is to balance the power system by repeatedly issuing a price signal for flexible resources to respond. The price signal will be continuously updated in order to keep the power system balanced, by increasing the price when there is a power deficit in the system, and vice versa. In the demonstration, the TSO is not issuing the price, as it would be the case in the real world. The price is distributed by a "price mechanism" that computes an artificial price, which is sent directly to the customer equipment and aggregators.

Therefore, in the major projects a real-time price signal can be used to activate flexible consumption. There are the cases with a significant peak load reduction potential: the activation of flexible consumption with a five-minute real-time signal reduces the total peak load of the project participants by approximately 1.2 % of the peak load. Another things that need to be mentioned are as follows: 1) the flexible demand response can be forecasted – with some certainty – resulting in overall improved system efficiency; 2) households, possessing equipment that controlled their heating system to respond automatically to price signals, accounted for 87 % of the peak load reduction [5].

4. DSM APPROACH AND TECHNIQUE ANALYSIS

This chapter provides the analysis of the implemented DSM approaches and techniques based on real case analysis. There are three main approaches to demand side management:

- The feedback system, which consists in **informing the consumer** about the system constraints. It focuses solely on providing feedback on the electricity use. This approach represents the first setup towards DSM implementation;
- The **price-based approach**, which requires behaviour change on the customer side triggered by price signals;
- The **system capacity-based approach**, which does not rely on the price sensitivity of customers, but on other system forecasts. In this approach, the customers indicate their preferences to a third party player (aggregator or system operator) and consent to let this player take the control of smart appliances. For larger customers this can include contracts for load shedding.

Load management classification from the perspective of **active and passive DSM techniques –** DSM covers large scope of techniques ranging from passive to active ones:

1. Basic passive techniques. Little to no control.
2. Active techniques. The consumer can opt-in or opt-out at any time.
3. Technique combination.

In the case of applied technologies, more standardisation can be required. It is a condition for the development of DSM; therefore, the following conclusions can be made in this chapter:

- Smart grids and DSM technologies should address standardisation and interoperability in order to improve business cases and assure the diffusion of the implemented solutions (see Fig. 1).
- In order to make DSM sustainable, the automation for load management is an important step. Customer engagement is an important part of DEMO programme application. More cooperation between DSM actors/players is required to provide the adequate services.
- Active and passive techniques of DSM can be implemented according to the DEMO targets.
- There is the need to provide the personalised advice/"tool".
- Ensuring smart technologies & new services truly beneficial for consumers, new technologies (such as AMI and HAN) must meet the necessary functionalities & interoperability to enable consumers to participate in load management and contribute to the markets.
- Consumer participation and flexibility in their consumption need to be properly rewarded.

5. BIG DATA ANALYSIS MODEL

Efficient load management and DER coordination require advanced automation schemes, accurate distribution system element monitoring and modelling with advanced Volt/VAR optimisation. This can be implemented by exploiting the large amount of data from the advanced metering infrastructure (AMI) [8].

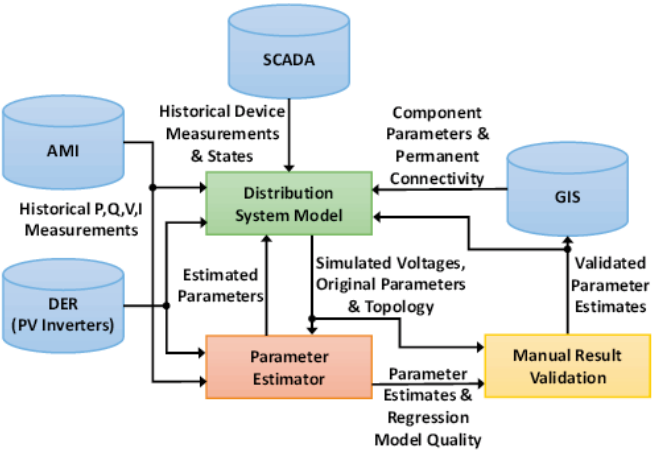

Fig. 4. BIG Data model for distribution system parameter estimation [8].

Therefore, with respect to the accuracy and quality, network topology and reliable control of all devices, implementation of the Big Data environment is of crucial importance. The practical estimation methods of computationally efficient distribution system parameters based on BIG Data model are used. The information flow is presented in Fig. 4:

- Current model components, parameters and permanent connectivity scheme will be imported from the GIS;
- SCADA will transmit the historical device measurement and states;
- AMI will provide load profiles;
- DER generation profiles as an input for the power flow simulation.

After passing manual validation, the estimated component parameters are passed to GIS and distribution system model. Such type of models plays an important role in validating and refining the existing DSO models, preparing them to the operational tasks for smart distribution systems.

6. CONCLUSIONS AND FURTHER RESEARCH

The tvelwe large-scale multinational demonstration projects have been investigated with the aim to study best practices of the stakeholders' experience, develop, promote and adapt smart grid tehnologies in Latvia and implement at the Baltic power system level, with the cooperation of distribution system operator (DSO) and transmission system operator (TSO). Several main conclusions and further research areas can be summarised as the *key findings*:

- As technologies have to be improved and system operators and companies have to become more strategic about how they direct spending, investments in energy efficiency result in significant decrease in greenhouse gases per dollar spent.
- Different approaches can be employed to recruit customers or the demonstrators depending on the expressed customer preferences and values as well as the current stage in the process of deploying DSM technologies in the country.
- Public trends and focus on the social values, and environmental aspects need to be included.
- Individual financial benefits and expectation affect DEMO challenges, and the contingency plan needs to be estimated.
- Consumer identification and lab validation selected use cases/ scenarios play an important and supporting role in the DEMO development.

Transfer of results, nature of intput need to be refined (technical specification requirement), and prelimenary stakeholder discussion is required with the aim to involve more partners from all cross sectors as parties of global smart grids.

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VIEDO TĪKLU ATTĪSTĪBA: MULTI-NACIONĀLO DEMO OBJEKTU ANALĪZE

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Kopsavilkums

Šodien enerģētikai tiek izvirzīti jauni mērķi: atjaunīgo energoresursu attīstība, kā no tehnoloģijas tā arī no tās pielietošanas viedokļa un vadības iespējām. Modernas, komplicētas sistēmas vadībai un attīstībai ir nepieciešamas jaunas viedās tehnoloģijas. Mainīga rakstura ģenerējošie avoti tiks savienoti ar tīkliem visos sprieguma līmeņos, un to vadībai ir nepieciešama radikāli jauna pieeja - ar reālā laika kontroli, augsto datu precizitāti un vadības iespējam.

Rakstā tiek apskatīta pieprasījuma vadības reakcijas (DSM) būtība, analizēta citu valstu pieredze pieprasījuma vadībā ar mērķi attīstīt, veicināt un piedāvāt tiem atbilstošu tirgus uzbūvi. Kā arī tiek piedāvāti iespējamie sistēmas pakalpojumu veidi, ko varētu īstenot Sadales Sistēmas Operatori un Pārvades Sistēmas Operatori Baltijas energosistēmas līmenī.

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