ICT IN A SMART GRID BASED ENERGY SERVICES DEVELOPMENT

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ABSTRACT

Smart Grids herald a revolution in the power sector. The centralised and passive power grid model known for over a century is before our very eyes assuming a completely brand new shape: of an active and dynamic network with an increasingly significant role of active consumers – prosumers, who are offered brand new products and services.

In terms of the market approach, these new products and services will complement the advanced technology and will allow prosumers to take full advantage of the functionality and benefits introduced by the modern smart power grid infrastructure, especially in the areas of demand response, efficiency programs and microgeneration.

Information and communications technology is an indispensable foundation, enabling the creation of new market shape, with a broad range of all-new possibilities for energy market participants.

However, it should be noted that fast paced ICT systems implementation in the power sector pose a risk of setting up inefficient, failing and overly difficult to maintain data and process links between the systems of involved energy market players. This risk should be mitigated by development and implementation of technical standards, methods, best practices and principles of good cooperation between the concerned parties. As a consequence, effective, standardised and interoperable Smart Grid systems will provide conditions for dynamic development of new roles and mechanisms on the energy market.

INTRODUCTION

Development of Smart Power Grids that combine power systems with state of the art ICT (Information and Communication Technology) systems is a development opportunity for the entire energy market and for materialisation of the prosumer concept in particular. A prosumer is a special type of consumer, which by generating energy in microsources, effectively managing its energy consumption, or actively participating in demand response processes, becomes an energy market player. Additionally, through aggregation services, the prosumers may even become co-providers of ancillary network services.

SMART POWER GRIDS: SYNERGY OF POWER INFRASTRUCTURE AND STATE OF THE ART ICT TECHNOLOGY

The conventional operating model of companies in the power sector, and especially of distribution grid operators, based on a simple, ‘two sides of the coin’ paradigm: energy supplier (distribution system operator and seller) - energy consumer, shall be subject to significant transformation in the nearest future. One of the main change drivers is the development of IT and information exchange technologies – jointly referred to as an Information and Communication Technology and its application in the energy sector.

Already now the operation of basic power system components without ICT involvement is hardly imaginable, not to mention the its importance for further evolution towards Smart Grids and the fulfilment of EU Member States' obligations to reduce CO2 emission, as referenced in numerous documents, such as the report of the European Commission's Ad Hoc Advisory Group “ICT for Energy Efficiency", published on 24 October 2008.

POTENTIAL BASED ON INTERACTION AND COMMON STANDARDS

Provision of new services to end consumers will require cooperation between DSOs and electricity sellers to a much greater extent than has been the case so far. An example of such co-operation may be a transfer of electricity consumption profiles from AMI systems implemented in the DSO structures to electricity sellers, or companies providing energy outsourcing services, in order to enable consumers' use of advanced management services, and not for billing purposes only. Enabling consumers' use of this type of services is one of many B2B class processes requiring direct communication, relevant data quality and high security standards of IT systems of concerned market players.

Smart Grids development will also enable provision of ancillary services to the TSO by "active consumers" with sufficient potential of electricity consumption reduction or production, by special entities dedicated to these tasks, such as for example the aggregators, as well as - in specific cases – by consumers themselves. Also in this area standardisation will be required with regard to interaction of the existing and developed ICT systems to enable effective actions aiming at assurance of the National Power Grid's

stability and sharing with end consumers the potential resulting from implementation of AMI and Smart Grids.
The growing number of active consumers, i.e. such customers, who knowingly want to and can shape their electricity consumption profiles, and increasingly - as prosumers - can generate electricity from microsources, requires implementation of new system solutions that provide a power grid with the "smartness" necessary to ensure the power grid stability, proper power supply quality, as well as safety for the DSO's technical services personnel. The necessary solutions involved are in fact advanced ICT systems made up of the hardware, teletransmission, and software layers. The advent of the new and smart solutions will enable the extension of the existing, centrally dispatched (in regard to generation sources) power grid operating model by the aforementioned active consumers and prosumers as market players of growing potential and relevance.
One of the major problems in the development of IT system software is the proper definition of interfaces, i.e. the piece of software which is responsible for data exchange with other systems.
The service interfaces of Smart Grid applications will have the key role in building a well-functioning ecosystem of services for all participants of the electricity market. Given the national market model: a single TSO – a number of DSOs - multiple sellers, and the required possibility of interaction between all the aforementioned groups, standardisation is a necessity in the area of B2B and B2C processes. Consistent actions of the market participants within the implemented standards allow for their efficient co-operation. Moreover with the advent of Smart Grids this operating formula will be extended both horizontally and vertically. New services for electricity consumers will be practically entirely based on consistent and business-oriented cooperation of the market players: the TSO, DSOs, electricity sellers, aggregators and last but not least – consumers and prosumers (Fig. 1). The most crucial standardisation enabling this cooperation development should be achieved first and foremost in agreeing upon a common language to be used in communication between the market participants. Besides the language, it will be also necessary to develop and secure appropriate communication channels. Despite the rapid development of Smart Grids and definition of many standards – a process which advances in parallel to implementation of solutions based on these standards - it's possible to employ well established information exchange and information definition standards. The information definition - as a language itself - must be based on clearly specified rules, comprehended by the communication parties, and it also must have a defined syntax. An example of such common language is the concept of CIM (Common Information Model), which enables the modelling in a standard way most of the data (objects) present in a power company, and determining a standard form of their representation. A detailed description of such approach is provided by a series of standards such as: IEC 61970 (Energy Management System Application Program Interface, EMS-API), IEC 62325 (including definitions, i.e.: Deregulated Energy Market Communication and Framework for Energy Market Communication), or typically operator activity oriented, such as IEC61968. Conversation channels, i.e. transfer and exchange of standardised CIM messages can be carried out within SOA (Software Oriented Architecture), which is utilised by major business applications in large companies and corporations. On the basis of SOA, large centralised ecosystems may be created, whereby information forwarded by market players is centrally collected and processed (like in the WIRE system - Energy Market Information Exchange in Poland), or alternatively decentralised and exchanged through peer-to-peer communication (like for example the global cooperation of mobile telephony operators using the TAP protocol that enables unrestricted exchange of roaming calls billing details).
It is advisable that the electricity market players on the supply and distribution side start implementing the standards listed above as soon as possible. Their implementation will pave the way for offering modern products to consumers. From the consumers' point of view these services will provide new opportunities, especially in the area of rationalisation of electricity consumption and improved efficiency of its use.

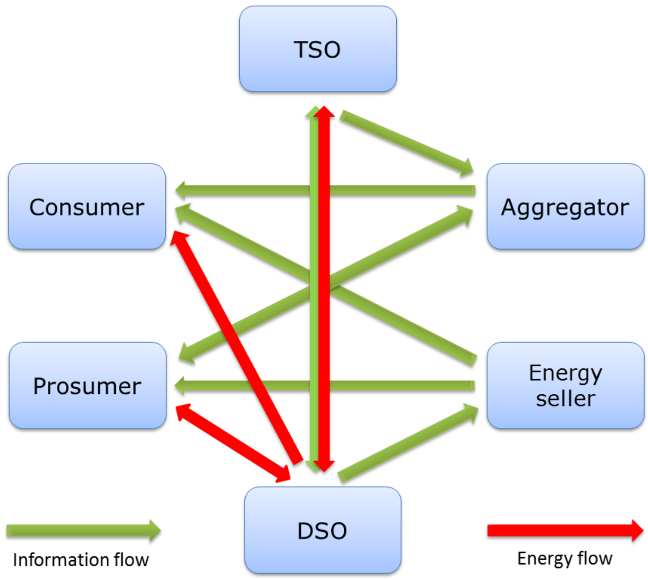

Fig. 1. Flow of information and energy between market players in Smart Grid networks

NEW ENERGY MARKET PLAYERS

Availability of the Smart Grid infrastructure and related ICT systems enabling the launch of new products to the electricity market will in turn stimulate the emergence of new specialised entities that will be able to offer modern services to customers, as well as perform brand new market roles. High growth rate is particularly evident in the areas of energy efficiency and energy demand aggregation.

ESCO companies

ESCO acronym (Energy Service Companies) is commonly used to denominate a power services provider that offers comprehensive expert services in the power sector, and warrants potential customers' energy savings and reduction of energy bills. ESCO companies provide comprehensive energy management services under executive contracts, and grant energy saving guarantees.
ESCO companies, on the basis of precise and available in real (or near real) time electricity consumption measurement data will be able to offer on a large scale to their customers - energy consumers - professionals services related to energy consumption and demand reduction. The fee for the services is typically covered by the customer's reduced energy bills. The scope of the services may include not only energy usage efficiency improving projects, but also equipment maintenance and repair, cogeneration of electricity and heat, and alternative electricity generation, provided the fee for these services originates from the accomplished savings.

Aggregators - demand management

In Smart Grid enabled networks the two-way electricity flow in grids is a paradigm. This means that electricity can flow not only from central sources to end consumers, but can also be generated by consumers and fed by them into power grids. The coexistence of the above trends is proven by the increased consumer activity on the energy market. An active consumer's actions may include informed consumption reduction, altering usage patterns in time and energy generation using microgeneration sources. The emergence of active consumers as well as the two-way electricity flow account for a new area, within which many technological solutions have been recently conceived. From the Smart Grid viewpoint the demand response and distributed generation management concept consists of two basic elements:

- controlled demand reduction (controllable loads aggregation),
- energy supply aggregation – materialising the Virtual Power Plant concept, whereby small sources play an important role - and support for their deployment is a commercially significant element of the demand response and distributed generation management.

SMART CONSUMER GRIDS – BENEFITS AND MODERN SERVICES

In order to accelerate the Smart Grid deployment and development, a number of activities have to be intensified in the area of value creation directly at consumers, as well as introducing an appropriate communication of potential benefits to all concerned parties.
On the electricity distribution side the Smart Grid deployment benefits for consumers will be primarily reflected in rarer occurrences and shorter durations of electricity supply interruptions. Owing to better observability of medium voltage grids, faults of which to a large extent affect SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) indices, faulty grid sections can be isolated in order to restore supplies to healthy grid sections. Another benefit from the Smart Grid deployment is the option to implement a system of public information on the electricity supply status and the other events in the power grid of relevance to the safety of local communities. Such a system, using a dedicated WWW website service, would present details of the current condition of a given grid area retrieved from the Smart Grid system. This way local residents, businesses, and authorities would acquire access to details of the current electricity supply status and problems, if there are any, related to its transient interruption.
On the consumer side, ICT utilisation within the Smart Grids is crucial for allowing the 'Smart Consumers' to achieve higher energy efficiency through online (and possible real time) enabled products and unprecedented demand side involvement potential, specifically through the following:

- **Providing useful knowledge and better understanding**: detailed energy consumption information in the form of report charts available online, particularly with the use of mobile devices allowing modification of energy consumption patterns through better consumer understanding.
- **Providing automated advisory and optimisation services:** with the detailed usage data the electricity sellers and potentially the ESCO companies will provide consumers with advisory on energy usage reduction through both behavioural and technical modifications and also will be able to provide wide scale tariff optimisation services within the mass market.
- **Smart Grid enabled PrePaid solutions:** based upon online connectivity and system interoperability between the electricity sellers, DSOs and the consumers – allowing near real time operations, remaining credit information and online top-up – all being a standard service in GSM networks nowadays – leading to an overall increase of customer satisfaction.
- **Introducing demand side involvement programmes:** for the first time, Smart Grid enabled technical cooperation between the key energy market players will allow to involve active mass market consumers and prosumers on a large scale.

- **Development of the Home Area Networks (HANs):** the new management centre for the house, energy efficiency, and ultimately a platform – state of the art springboard - for offering new value added services (e-Care, safety).
- **Microgeneration sources deployment and management**: enabling not only easier deployment of renewables but also very important in terms of effective management providing customers with current energy production data and potential benefits calculations (Feed-In-Tariff estimates). Smart Grids will also facilitate the widespread use of electric vehicles not only for transport, but also as elements of the demand management mechanisms or electricity storage (Vehicle-2-Grid concept).

In the context of the power sector's technical and operational conditions the aspect of demand management and potential programmes that may be offered to consumers seems to be particularly worthwhile. The implementation of such programmes may be beneficial not only for them, but also for electricity sellers, the TSO, and DSOs.
The demand management is typically divided into the following two basic areas:

Incentive programmes - enabling the reduction of the peak loads, when the ratio of energy price paid by consumer to purchase costs is high, usually resulting from events such as for instance energy supply shortage or increased overall demand. These may include:

- programmes whereby the energy seller initiates activities leading to energy consumption reduction,
- programmes that require the consumers' decision to reduce the consumption (or to shift it in time) based on appropriate financial incentives.

Pricing programmes - which require the consumers' decision to reduce the consumption (or to shift it in time) in specific times of the day, based on pricing incentives offered by energy supplier. The most popular groups of pricing programmes include:

- ToU (Time of Use) tariffs - electricity prices change in the daily, weekly, and seasonal (summer/winter) cycle. Price rates are set for longer periods. Such tariffs provide consumers with incentives to reduce the energy consumption at load peaks, and to use electricity when its prices are low (in a load valley).
- Real time tariffs RTP (Real Time Pricing) - provides for electricity price variability throughout a day. Electricity price rates vary similarly to wholesale market prices, while consumers are informed of projected energy prices in advance of one hour up to one day.
- CPP (Critical Peak Pricing) tariffs - a specific variety of ToU tariff, whereby rates are strictly tied up with the power system's current operating conditions. Some CPP tariff varieties introduce one or two additional very high rates for the system's peak loads, i.e. the periods when the wholesale market prices are the highest. Consumers are informed at short notice that the rates will apply, and their amount and validity period are set by the energy supplier.

The programmes presented above are only examples of demand management tools, the availability of which will be possible along with the Smart Grids and relevant ICT systems deployment, and which facilitate consumption reduction in peak periods or shift to non-peak periods.

SMART GRIDS FUTURE IN THE CONTEXT OF OFFERED SERVICES AND CONSUMER ROLE

The power system of the future will be based on the following two key pillars: Smart Grids and closely tied specialised energy management ICT systems. Smart Grids will provide an accessible and safe infrastructural platform and will be managed by DSOs and in some selected areas by the TSO as well. The energy management systems will belong to the sphere of competence of electricity sellers or specialised entities such as, for instance, aggregators.
In a longer run it may turn out that the strict interdependence of both systems will - in an evolutionary way - lead to the emergence of energy agents, i.e. autonomous entities continuously communicating with each other and implementing their own strategies in the context of the whole power system. The agent, as meant by the foregoing assumption, may be practically any receiver, device, or object connected to a power grid and provided with an appropriate controller with its own efficiency and optimisation algorithm with the option of unrestricted communication with other agents. In the system such agents will represent consumers, prosumers, energy sellers, large generators and grid operators at all levels. The agents' relations will be dynamic, and they will be automatically pursuing the maximisation of their own objective functions based on exchanged signals, for example: temporary and maximum allowable power grid operation parameters, prices of electricity from available sources, current and planned capacities of these sources, customers' tendency to consume a specific volume of energy at a specific price.
In the light of the currently conducted research and pioneering efforts undertaken in the area of providing the theoretical basis for operation of the energy agents model, Smart Grids and ICT systems as known today may be just a stopover in creating the power infrastructure of the future, which will ultimately shape consumers' behaviours and demand for the whole new set of energy market related services.