The transformation of electricity distribution networks

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New challenges for the electric power systems

In 1882, Thomas Edison launched, in the United States, the operation of an electric power distribution system. He constructed on Pearl Street a production unit that supplied 59 customers in upper Manhattan with a 110 volt direct current. This was the first, basic electric power distribution system on which electric power systems are principally based to this day, more than one hundred years later. At that time, electric power systems relied on aggregation: the transmission, to industrial and residential consumers, of electricity generated in large production units was possible through high-voltage transmission lines and medium and low-voltage distribution lines. This system was successful because it used the “economies of scale” concept: it utilized primary energy resources, such as carbon and large rivers, to generate power through a centralized structure.

It is true that this traditional system covered society's power supply needs extremely well for many years. But the picture has since then changed. Today, there is:

- An imperative to tackle climate change by reducing carbon dioxide emissions linked with thermal energy generation activities.
- An increasing demand from industrial and residential customers for reliable and high-quality electricity tailored to the needs of “digital” economy.
- An imperative to reinforce and restore outdated production, transmission and distribution electricity infrastructure - a costly venture.
- New distributed electricity generation, information and telecommunication technology that offers new opportunities for reduced costs and the radical transformation of power systems.

At the same time, the basic concept of centralized production systems with long transmission lines is currently challenged by the economies of scale. The spread of distributed generation, mainly through renewable energy sources, that can cover large geographical areas with inexhaustible energy resources (wind, sun etc.) and the customers’ potential to choose “cleaner” and more flexible energy solutions are both part of an alternative attitude towards the development and the operation of present-day electric power systems. This new concept needs to be examined more carefully in order to assess its affordability, efficiency and capacity to meet our energy demands.

Active consumers

The construction and operation of distributed generation units was initially driven by the alluring economic incentives (feed-in tariffs, tax incentives etc.) offered in most European countries. After the initial penetration in several countries, these incentives have been rationalized or gradually replaced by other measures, such as net-metering, which encourages self-consumption of the electricity generated by local production units, and the injection into the grid of the non-consumed surplus electricity generated locally. However, thanks to the rapid fall of the capital cost for distributed generation systems, particularly for photovoltaic systems, distributed generation is expected to continue despite the lack of subsidies and incentives. The local storage of electricity generated from renewable sources, a trend which is expected to spread considering the gradual drop in battery costs and the wider adoption of electric vehicles, offers another technological solution which can bring more advantages to the operation of distribution networks. These technologies enable industrial and residential customers to behave as both consumers and producers (also known as “prosumers”). With smart meters, prosumers have immediate access to electricity usage figures and, given certain incentives, they are actively participating in the improvement of network efficiency, operation cost reductions and the adoption of an environmentally friendly attitude. A good example is Zero-Net-Energy Buildings, whereby, in the long run, the total amount of energy used by the building is roughly equal to the amount of energy generated locally on the site. This concept is currently widely accepted and there is great interest for a broader application, as demonstrated by the construction specifications across different countries for the erection of new buildings.

These developments are clearly illustrated in the new proposals issued by the European Commission for revised electricity market regulations (known as “Clean Energy for All” or “Winter Package”).

According to these, during the next decade, the electricity market: i) will be marked by flexible decentralized electricity generation, ii) will enable electricity consumers to reduce their electricity bills through participation in the electricity market (e.g. demand-side management), electricity self-production and self-consumption, and the storage of this energy.

Energy Communities

Special mention shall be made of the Winter Package of energy communities. These are cooperatives and other local-community initiatives which aim to promote the production and consumption of energy mainly from renewable sources, with a view to saving energy. Local-community initiatives on the use of renewable energy sources are not a new phenomenon in Europe: community wind projects are running since the 1980s in the Netherlands and for more than one century in Germany, while Denmark has been developing district heating systems and wind turbine

cooperatives since the 1970s (during the oil crisis). However, recent years have witnessed a remarkable growth of similar initiatives.

More specifically:

- In the Netherlands, apart from the traditional wind turbine cooperatives, citizens are currently running more than 200 local-scale initiatives on renewable energy sources, including a total of 55 registered energy cooperatives.
- Germany has developed more than 650 “Stadtwerke” (heat and electricity municipal utilities) with own power stations that support public building rooftop PV as well as biomass heating systems. Many of these initiatives provide model for active citizen participation and the collaboration between citizens and the local authorities.
- In Denmark, hundreds of energy cooperatives operate local heating systems along with electricity generation for both agricultural and urban areas. What is more, the country has developed around 100 active wind turbine cooperatives (three quarters of the country's wind turbines belong to local-scale units).

Despite the considerable differences amongst these cooperatives (concerning their financial incentives, their relationship with the state and the local communities, their targets and priorities), they all prioritize environmental protection, energy self-efficiency and active participation for citizens, and the enhancement of energy autonomy. Generally, all cooperatives acknowledge their capacity to reduce energy costs and utilize distributed energy sources (including supporting the overall system) as well as the higher reliability of these supply services thanks to the establishment of many smaller providers that represent groups of customers (also known as aggregators).

Another development is the Peer to Peer (P2P) electricity which enables consumers to directly list and purchase products and services. For example, the Dutch company Vandebron (“from the source”) launched a platform that enables customers to buy electricity from local producers who sell the surplus energy they have generated through PV systems or other power stations (such as biogas). Customers can navigate through the website and browse a long list of producers, photos and brief descriptions of their facilities as well as available rates and prices. Another example is Mosaic, a company based in California. Through its platform, the company offers to individual investors P2P rental opportunities for funding RES projects, such as school rooftop PV systems. Investors can share the profits generated from the production of electricity and offset these sums with electricity bill charges. These decentralized markets, with products coming from distributed energy sources, provide new models, economic growth opportunities and a vast potential for the establishment of a large platform based on participatory economics.

The new role of Electricity Distribution Operators

Net-metering, Zero Energy Buildings and energy communities are indeed instrumental in minimizing infrastructure that supports the transmission and the distribution of energy. However, when generated energy is insufficient, as well as for the export of the excess energy generated on-site, they all rely for covering their electricity needs on the existing networks. Local production from distributed energy sources is likely to balance out the respective consumption of electricity on an annual basis. However, this is not applicable for shorter periods of time, such as hours, days or weeks during which the renewable energy production is deficient or insufficient, requiring thus absorption from the network itself. We should not forget after all, that these networks have been designed and constructed to safely meet large-scale energy demand, over and over again. Distribution networks are thus indispensable, and their role in the transition of electric power systems to a new decentralized model is instrumental. For the realization of this new model for the efficient utilization of distributed energy sources, investment is necessary in order to convert distribution networks into smart grids. These investments in the "intelligent" management of the network are highly rewarding: the expansion/upgrade of network infrastructure ensures energy saving and guarantees better performance, higher reliability and better customer services.

In this constantly changing environment, the role of Distribution Operators is also changing. Today, Operators play a key role in the market, by interacting with retail customers, energy providers and the Transmission System Operator. Along with these conventional responsibilities, operators are now asked to efficiently incorporate into their network a plethora of distributed energy sources, active consumers, aggregators and new types of load, such as electric cars, local storage units etc. They have to manage a vast plethora of data generated from millions of smart meters and thousands of sensors installed in the network. Distribution Operators are gradually turning into providers and operators of distribution platforms, whereby distributed energy sources are utilized for designing and operating the distribution system, offering a large pool of new energy products and services that aim to improve overall performance and customer support. These concepts are far from being unrealistic: progress has already been made in the United States (e.g. New York) and Europe (e.g. The Netherlands). Alliander, a Dutch operator whose grid covers one third of the country, has recently launched an energy trading platform providing Realtime Energy eXchange (REX). The platform relies on specialized software which connects industrial and residential customers with existing energy trading markets. This means that they can buy and sell energy whenever it suits them best. This practice is linked with utility cost reduction and consistency of rates, since customers can take advantage of the flexibility provided in consumption. For example, a company can use the REX platform in order to turn on the heating system in its offices during off-peak times instead of using electricity during standard working hours when rates are higher. This is the first big step towards the transition to future distribution systems. These platform-operators provide vast potential for building new markets with products and services that bring benefits to the users, value to the system and opportunities for growth.