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Distribution System Operators in a Changing Environment

1.1. Energy policies promoting the energy transition

During the last three decades, strong economic growth and expanding populations have lead to a significant increase in global energy demand. For the next three decades, many forecasts unanimously predict that this increase will continue at this pace. Also, because of the economic growth of China and India, the rate is accelerated in non-OECD (organization for economic co-operation and development) economies.

To support the energy demand, global net electricity generation has increased quickly from 1990 to 2010 and will supply an increasing share of the total demand from 2010 to 2040 as shown in Figure 1.1.

Electricity consumption by end-users is expected to grow faster than the use of other energy sources due to the increase in the standard of living and a higher demand for home appliances and electronic devices. This is also true with the expansion of professional sector's needs such as hospitals, office buildings, commercial services, shopping malls, etc.

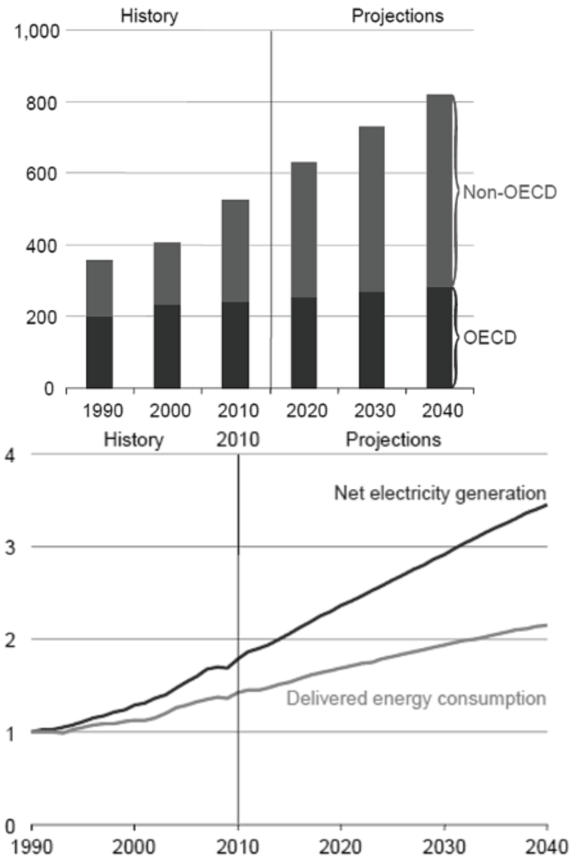

Figure 1.1. *World total energy consumption 1990–2040 (quadrillion btu)*[1] *and world electricity generation (index, 1990 = 1)*[2]*. For a color version of the figure, see www.iste.co.uk/boillot/smartgrids.zip*

Combinations of primary energy sources to produce electricity will be evolving in a significant way over the next three decades:

1 Source EIA – International Energy Outlook 2013.
2 Source EIA – International Energy Outlook 2013.

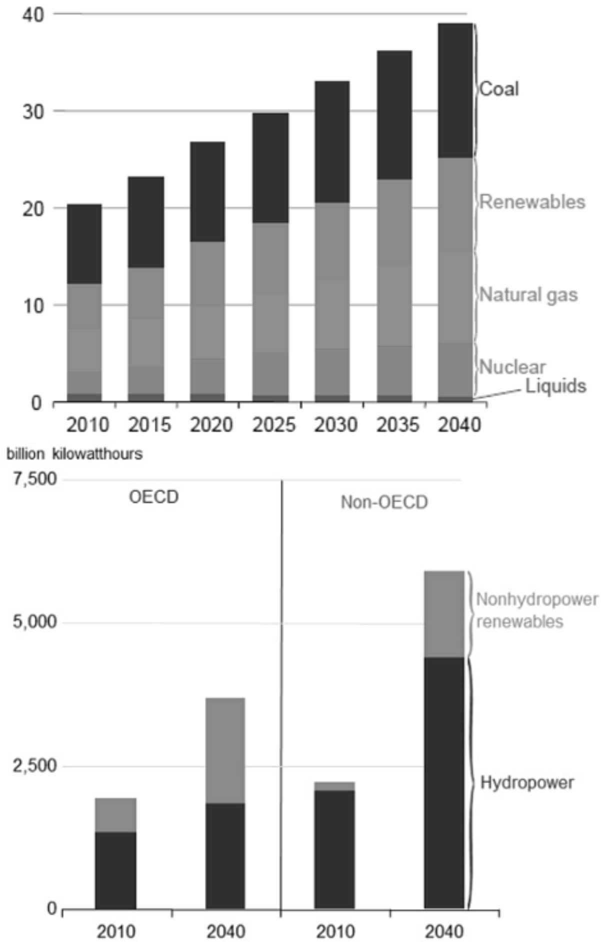

Figure 1.2. *World electricity generation by fuel 2010–2040 (trillion kWh) and world electricity generation from renewable energy sources 2010 and 2040*[3]*. For a color version of the figure, see www.iste.co.uk/boillot/smartgrids.zip*

In particular, according to US Department of Energy/Energy Information Administration (DOE/EIA)

3 Source: US Energy Information Administration (DEO/EIA) – International Energy Outlook 2013.

Reference Case projections, the renewable share of these combinations will increase from 21 to 25% – the world fastest growing source of electric power. Worldwide hydropower will account for 52% of the total increment and wind generation for 28%, with large differences between regions and countries:

– most renewable energy in OECD countries is expected to come from non-hydroelectric energy, because all resources have already been developed (except Canada and Turkey);

– in non-OECD countries, hydroelectric power is expected to be a dominant source of growth (in particular Brazil, China and India). Nevertheless, growth rates for wind power electricity will also be high. Particularly in China, where wind generated electricity should go from 6% in 2010 to 26% in 2040 (45–637 TWh of expected generated energy respectively).

Facing the challenge of a growing demand of energy, many regions of the world are engaged in a dymanic phase of energy transition. The production of electricity from renewable sources and, particularly, intermittent sources, is increasing in many regions. By 2012, more than 280 GW of wind farms and 100 GW solar photovoltaic (PV) are installed worldwide. The International Energy Agency (IEA) forecasts on a shorter term basis that the evolution will continue with the installation of +230 GW of wind power and +210 GW of solar PV by 2017.

Many governmental organizations encourage the development of sustainable transportation facilities (train, buses, tramway, etc.), and car manufacturers are now offering a wide range of plug-in hybrids and other electric vehicles (in December 2012, around 180,000 plug-in electric vehicles (EVs) were already on the road[4]).

4 Source IEA – Global EV Outlook 2013.

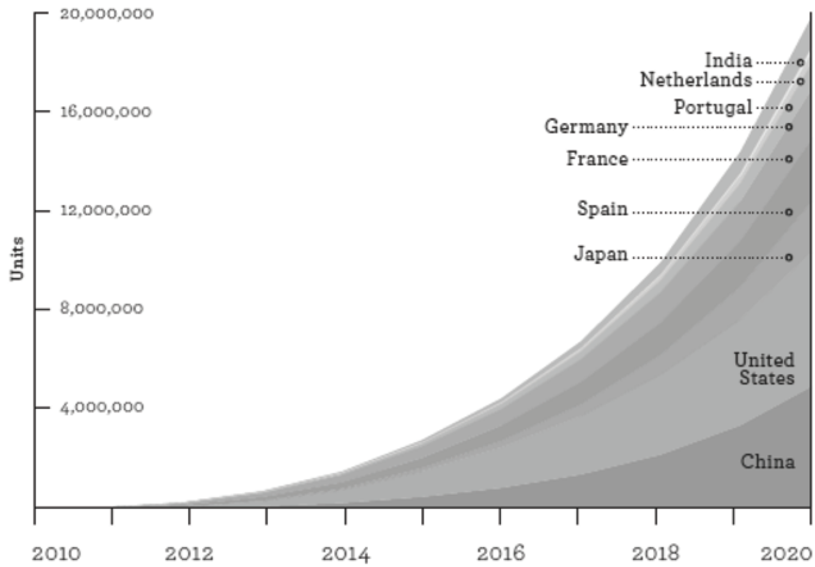

Figure 1.3. *Project of the evolution of EV throughout the world (plug-in and hybrid plug-in). Source: IEA – Global EV Outlook 2013. For a color version of the figure, see www.iste.co.uk/boillot/smartgrids.zip*

Last but not least, consumers are changing their attitude toward energy savings. The massive roll-out of electric smart meters will permit the development of energy conservation services. More than 80 million smart meters were already deployed worldwide by December 2013 including 46 million in the USA[5]. This number is expected to reach 100 million meters by the end of 2014 according to IHS Inc[6], and 1 billion meters by the end of 2020 according to Pike Research[7].

5 http://www.edisonfoundation.net.
6 http://www.cepro.com/article/100_million_smart_meters_to_be_installed_worldwide_in_2014.
7 http://www.navigantresearch.com/newsroom/the-installed-base-of-smart-meters-will-surpass-1-billion-by-2022.

The changes in generation means and consumption trends will impact energy systems worldwide:

– *Producers* will have to alter their business models in order to make their investments in existing generation facilities profitable, as well as to optimize operational management of energy combinations that increasingly integrate intermittent renewable energy sources (RES);

– *Transmission system operators (TSOs)* will have to anticipate the risks of an unbalanced supply-demand ratio that may lead to a decrease in frequency and potential blackouts; they must also develop interconnections;

– *Distribution system operators (DSOs)* will have to connect massively decentralized RES generation, electric vehicle recharge stations, modernize the networks and deploy smart grid technologies including metering systems;

– *Energy suppliers* will have to reevaluate their offers and services in response to consumers' expectations in the context of an increasingly competitive environment (progressive market opening, with the end of regulated tariffs).

The energy transition makes a major impact for DSOs, insofar as intermittent RES generation installations are predominantly connected to distribution networks. For instance, in France, at the end of 2013, 94% of RESs installations, around 300,000, were connected to the distribution network and represented a total of 11.4 GW[8].

To keep up with current energy volume, the total capacity of RES installations must be nearly five times greater than the capacity of current centralized thermal or nuclear generation sites. Indeed, the average running times for wind and solar power stations are around 2,000 and 1,000 h per year, respectively (average in France), while baseline generation times for a thermal or nuclear station can reach

8 ERDF Source – key figures 2013.

7,000–8,000 h per year. It is important to remind that wind and solar PV generation is not guaranteed and that the correlation with demand is generally low, depending on geographical location and types of usage.

EU DSOs landscape

The electricity distribution business in Europe includes more than 2,400 companies, which serve around 260 million connected customers supplying move than 500 million people, operating 10 million km of power line, distributing around 3,000 TWh a year and directly employing more than 240,000 people[9].

In most European countries, intermittent energy generation is developing very fast, leading to a total installed capacity of 106 GW of wind and 70 GW of PV by the end of 2012[10]. The vast majority of these plants are connected to distribution grids. Together with the development of active demand and electric vehicles, *this will lead to a pivotal transformation of the role of the DSOs.*

A real challenge for electric systems – a paradigm shift for distribution networks. In yesterday's market, the distribution networks were often designed to be operated radially in order to distribute electricity from HV/MV substations connected to transmission level, down to the end-user consumers. With the energy transition, tomorrow's electricity distribution network operation and management will change. The distribution networks will have to manage more complex interlinked networks mixing generation and demand with much higher variations and reverse flows from distribution to transmission networks. Also, new market players are developing, such as load curtailers, virtual power plant operators and aggregators, etc.

9 Article IEEE P&E magazine – Future of Power Distribution, European perspectives.
10 Source: Observ'Er : Etat des energies renouvelables en Europe – 2013.

At the same time, the basic principles of electric systems have not changed. Electricity must be generated at the same time it is consumed, whereas only small amounts can be stored. Also, voltage and frequency levels must be kept within prescribed limits to ensure the security and stability of electricity supply.

Smart grids are not an option, they are a necessity. To tackle the challenges of energy transition, electricity networks will need to be more reactive and flexible to ensure the security and stability of the system, and also enhance interactions between market players. Smart grids will contribute to those objectives by combining advanced electricity network technologies with information and communication technologies.

The main principles of smart grids are:

1) *collect data* on networks due to sensors and remote controlled devices (e.g. smart meters);

2) *analyze* the status of the network on a short-time basis;

3) *maintain or improve* the quality of supply by developing advanced tools and strategies to handle various disturbances and faulty situation (from predictive maintenance to self-healing grid);

4) *anticipate* local generation from RES; simulate the constraints on the network (short-, medium- and long-term approaches) and find solutions to manage safely the flows of electricity;

5) *manage optimally* the interaction grid-plug-in hybrid electric vehicle (PHEV);

6) *enable the development* of energy conservation services: by giving information on electricity consumption and permitting to manage electricity uses;

7) *manage peak situations* and interact intelligently with the end-user (consum'actor).

The DSOs play a central role in the deployment of smart grids. In charge of reliable operations of the distribution grid, DSOs should act as enablers and facilitators of the market in order to:

– ensure uniformed and harmonized deployment of smart grids;

– enable the deployment of new services;

– contribute to the operation and control of new flexibilities (storage, peak shaving programs, management of capacities (production and demand), dynamic tariffs, etc.);

– provide data to the customers, suppliers and other market players and ensure its security and usability.

1.2. A new era of technological revolution

For over 120 years, the electric power distribution sector successfully resolved technical and financial challenges brought by the increasing demand accompanying economic and demographic growth.

Until recently, electric power distribution was essentially a capacity network, simple and robust, featuring a minimum of complex systems; its functions were limited to transferring energy from the upstream (high-voltage transmission network) to the downstream (customers). This robustness was partly due to the large amount of equipment whose reliability was easy to guarantee, often owing to its fundamental simplicity. It was also ensured by the need for operational safety, which inherently led to taking special precautions while introducing new information and telecomunication technologies (ICTs), because of the disruptive nature of the electromagnetic environment surrounding medium-voltage installations.

Nevertheless, new functions were added progressively: remote control for network breakers and switches, automation devices for limiting supply interruption to the customers during incidents and remote monitoring systems to lower operational costs. France, in particular, favored deploying digital controlled primary substations (DCPSs) since the beginning of 2000.

These developments transformed the simple electric power distribution grid into a system composed of three highly synergized levels: a power network, a communication network between key points of the power network and a centralized control and command system, and finally, an information processing and monitoring system. Every level is confronted with its own major difficulties:

– *the electric network does not undergo technical revolutions, however, its oldest equipment suffers from age*. Optimizing renewal is a major challenge. It is essential to operate installations as close as possible to their limit and to be aware of their lifetime expectancy. This shows the importance of real-time monitoring systems based on decentralized sensors;

– *the communication network is the key point to modernizing the electric power network*. Today, it may be based on various technologies: dedicated lines, power line carrier (that is using the electrical current as support for the signal), shortwave radio, microwave transmission, optical fiber, etc. This will allow connecting various sensors to a single central monitoring point;

– *the information and monitoring system must maintain its performance* despite the important volume of incoming data and find an equilibrium between centralized and decentralized intelligence.

To resolve these challenges, the DSOs will be able to take advantage of a series of new technologies that will need to be integrated with current or future technologies. McKinsey Global Institute recently published a study[11] identifying 12 technologies with the greatest breakthrough potential on the 2025 horizon. Some examples include energy-storage, Internet of Things and *big data*.

At the heart of DSOs core business, most notable breakthroughs will likely occur with microelectromagnetic systems (MEMS)-based sensors), nanotechnologies and power electronics.

Thus, advanced smart grids will utilize a combination of different technologies throughout integrated and interoperable solutions. Certain technologies are already accessible (smart meters and network automation), others may be here in less than 10 years (energy storage and smart household communicating devices).

11 May 2013 – Disruptive Technologies: Advances that will transform life business, and the global economy.