Electricity transmission
Strengths and limitations of the European network

Jacques Percebois, economist, University of Montpellier

Until the end of the 1990s, electricity was generated, transmitted and delivered to European countries by so-called "integrated" public or private companies. In some countries, such as Germany, there were several regional companies; in others there was a single national company with a monopoly, such as EDF in France. The European Directive of 1996 put an end to monopolies in the generation and supply of electricity. Transmission and distribution networks, which functioned as "natural monopolies", became "essential infrastructure" open to all producers and suppliers, with access tariffs set by an independent regulatory commission. These networks are at the heart of current debate because they are needing to absorb a growing share of renewable energies and cope with increasing home energy generation.

Electricity is a product that cannot be stored, at least economically on a large scale. The quantity supplied upstream of the network must therefore be equal at all times to the quantity withdrawn downstream, adjusting for line losses due to the Joule effect. In principle, water can be stored in dams or pumping stations at off-peak times to use at peak times, but there are technical limits to pumping water from dams, especially for multi-purpose dams (power generation and irrigation). Although the introduction of increasingly efficient batteries on the market makes it possible to store a little electricity over short periods, and great progress is being made, particularly in reducing the cost, this is not currently profitable on the scale of a national network. This may soon change thanks to electric vehicle batteries[a].

The main problem is seasonal storage. The European electricity network is a highly interconnected grid, which is a safety feature and a means of building a single electricity market. However, the differences between the electricity mixes observed between European countries, sometimes make it difficult to achieve electricity price convergence for consumers. Some countries, such as France, have an electricity mix largely dominated by nuclear power; others, such as Germany, have a mix that relies heavily on coal or lignite power plants. The development of renewable energies, such as solar or wind farms, requires local network reinforcements to absorb this production on the distribution grid and sometimes feed it back into the transmission grid: injection points are not necessarily located close to the network, which complicates the task of grid operators and can increase the cost to the consumer.

A Europe-wide grid

The electricity network is now highly interconnected, but this was not always the case. In France, it is the local authorities, particularly the municipalities, which have been at the heart of creating small networks. This explains why these municipalities still own the distribution

networks today, even if Enedis (ex ERDF, Electricité Réseau de Distribution France) is the operator, except when Local Distribution Companies (municipal boards or mixed economic companies) remain [1]. It was between the two wars that the State intervened to encourage or force local networks to interconnect, both to supply regions with little electricity and to guarantee greater security of supply. It should be noted that the linking of the network makes it possible to take advantage of an "expansion" effect, as the installed capacity on a national scale can then be much lower than the sum of the installed capacities of all consumers. After the Second World War, and well before the signing of the Treaty of Rome in 1957, European electricity companies understood the need to develop transnational networks, mainly for mutual assistance. Thus "electric Europe" preceded economic Europe.

The liberalization of the electricity sector, which began with the adoption of the First European Directive in 1996, obliges member states to open up electricity production and supply to competition. The public company EDF, which had achieved a virtual monopoly on the generation, distribution and marketing of electricity and a total monopoly on transmission since the nationalization law of 1946, is no longer the only producer or supplier in France.

The networks are still "natural monopolies" due to the existence of high fixed costs, but they must be "regulated" by law, and the tariff for the use of public electricity networks is an important component of the price of electricity (about one third of the price including tax for a domestic consumer) [2]. In mainland France, the Electricity Transmission Network (Réseau de Transport de l'Électricité, RTE) is responsible for power transmission, i.e. the high-voltage public network, above 50,000 volts. Enedis manages distribution, i.e. medium and low-voltage lines below 50,000 volts, to end users. These two companies are still subsidiaries of EDF, 50% for RTE and 100% for Enedis, but they must act as independent network managers and not favor the original operator EDF. In other European countries, these network managers are mostly private companies that have cut all links with their parent company. To enable the creation of a genuine European electricity market, the European Commission is encouraging member states to develop transnational interconnections, this time not only for security reasons, but to facilitate electricity trade and allow relative convergence of kWh prices for consumers.

Investments in networks are costly and there are still some bottlenecks in Europe; this is particularly the case between France and Italy and between France and Spain, for both historical and geographical reasons (mountains make the construction of high-voltage lines expensive). Interconnections with Germany are better, which explains why electricity prices on the wholesale markets (where the kWh produced are traded) are often the same in France, Germany and Belgium. It should be noted that the connection with England, which is a submarine high-voltage power line, is a direct current line

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and not an alternating current line. Alternating current must be transformed into direct current at the French border and the reverse must be done at the entrance to England. This means that the British grid and the continental grid are not synchronized[(b)].

Diverging electrical mixes

Every country is free to choose its electrical mix and the means to produce it. As a result, the make-up of the electric mixes is very different from one European country to another, for reasons that have to do with both geography and history. In Germany, the structure of electricity production in 2015 was as follows: 42% coal- and lignite-based, 34% renewables (solar, wind, biomass, hydro), 14% nuclear, 9% natural gas and 1% oil-based. In France, in the same year, the composition was as follows: 76% nuclear, 17% renewables, 3% natural gas, 3% coal and 1% oil-based.

This explains why the price paid by the consumer can be very different from one country to another, because the cost of these energies is different [3]. Since renewables are heavily subsidized through guaranteed purchase prices and the extra cost of renewables compared to wholesale market prices is financed through taxes borne by the end-user, the German price per kWh including taxes paid by a domestic consumer is almost twice as high as the French one, as the share of renewables is much higher in Germany and the guaranteed purchase prices are higher [4]. However, with the falling production costs of renewables, subsidies are tending to fall sharply.

It should be recalled that the price of the domestic kWh, including tax, breaks down as follows in France: 36% for the generating and marketing cost of the kWh, 30% for transmission and distribution and 34% for taxes (which notably include the additional cost linked to the subsidies granted to renewables). It should also be noted that European interconnections sometimes lead the French grid to prioritize importing German renewable electricity, to the detriment of domestic production which may be nuclear. Trade-offs are made on the European wholesale market according to the increasing fringe costs of energy. Nuclear power is thus being squeezed out by surplus renewable electricity, supplied at virtually zero cost but with a very high level of subsidy.

Networking doesn't solve everything

The priority given to nuclear energy in France at the time of the oil crises (the 1974 Messmer Plan) explains why the heating of buildings relies heavily on electricity, making the demand for electricity highly temperature-dependent. Almost 50% of the increase in electricity demand in Europe during periods of extreme cold is from France. One degree Celsius less in winter means 2,400 MW more power is required on the French network. If the availability of nuclear power is momentarily lower, which was the case at the end of 2016 or early 2017 at the request of the Nuclear Safety Authority for technical reasons, operators fear load shedding, and the price of electricity on the wholesale market soars. Networks then become saturated, they are unable to stop this surge, and French and German prices may diverge. The available interconnexion capacity between France and Germany is around 5 GW, and 4 GW between France and Belgium, for a peak demand which is around 90 GW on average in France (it even reached a peak of 102 GW in 2012).

The development of intermittent renewable energies (solar and wind) would not resolve the issue, as these energies are not necessarily available at peak times (in the morning around 9 a.m. or in the evening around 7 p.m., particularly in winter). It is therefore necessary to plan reserve power plants or consider large-scale storage, via water electrolysis for example[(b)]. The development of renewables also means that the network has to be upgraded to absorb this electricity, which is sometimes produced far from the grids, and this reinforcement is costly. This also places a strain on the equilibrium of the network, since the injection of renewables is not modular: this is particularly true for wind power, whose injection is more random than that of solar power. Connecting a number of small sites is also more expensive than connecting large power plants, especially since the French network is now largely paid for; creating a new line is much more expensive than reinforcing an existing line.

Coexistence and coordination

Grid networks remain at the heart of the European electricity market, both for back-up and economic reasons. In the future, we will increasingly have to rely on the coexistence of two types of networks: on the one hand, large networks interconnected at the European level; and on the other hand, small networks developed at the level of a shopping center, a housing estate, a group of buildings or a new district if self-generation increases, in particular cooperative self-generation which is encouraged by law. It is the coordination of these two models that is an issue for network grid managers. The policy to encourage solar home energy-production off-grid is a way to alleviate these pressures, since the producer will theoretically no longer need to inject and withdraw electricity from the existing distribution network. But this does not solve everything, as the producer-consumer will sometimes want to remain connected to the national interconnected grid to cope with the failure of his installation when there is neither wind nor sun, at least until individual, low-cost and efficient means of storage are developed. ▮

References

1. C. Bouneau *et al.*, *Les réseaux électriques au cœur de la civilisation industrielle*, Timée Éditions (2007).
2. J.-P. Hansen *et al.*, *Énergie : économie et politiques*, Éditions de Boeck (2015).
3. J. Percebois *et al.*, « Cout complet lié à l'injection d'électricité renouvelable intermittente. Approche modélisée sur le marché français *day-ahead* », *Revue de l'Énergie*, **632** (2016) 287-306.
4. J.-P. Hansen *et al.*, *Transition(s) électrique(s) ; ce que l'Europe et les marchés n'ont pas su vous dire*, Éditions Odile Jacob, (2017).

a. (Editor's note) On the consequences of the proliferation of electric vehicles, see « Voiture électrique, une aubaine pour la Chine », Le Monde Diplomatique, n°773 (August 2018).

b. See on this issue the article of N. Maïzi et F. Briens (p. 49).

c. Using electricity, we can obtain hydrogen that can be combined with CO_2 to obtain methane, which can be stored for later use during peak periods.