REDESIGNING NETWORK REGULATION FOR RENEWABLE GENERATION

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Summary

Electricity markets around the world were designed with the aim of lowering energy supply costs. Such markets have demonstrated to work. Simply put, monopoly infrastructure was separated from competitive functions. The network is accessible at equals terms to every player. At each point in time, the competitive power market selects the set of power plants that satisfies system demand with the lowest marginal costs[1].

However, our most important renewable power sources (solar and wind) have no fuel costs and very low marginal costs. Also, their production pattern depends on the weather and is, almost by definition, not in balance with demand. So, the transition to renewable energy sources brings up the question: is the current market design still adequate?

The answer is: no. The current electricity market design provides no meaningful signals that can direct the location and operation of renewable power plants. This is an issue for the electricity system as a whole including the network infrastructure. The electricity system needs adequate pricing information for investment and dispatch decisions in production and in transportation.

This article suggests that a new system design is needed in which price signals are based much more on the availability of network capacity (kW) than on the costs of energy (kWh). In a (future) renewable power generation system the energy is abundant but cannot be dispatched at will at all times. The transport capacity that links the renewable resources with demand is the scarce resource that should be managed through a market mechanism.

Background

Around the year 1900, electricity started to become available on an industrial scale in large parts of the world. Governments saw this new form of energy as essential for the development of the national economy. Therefore, many countries introduced some form of regional monopoly. The main reasons for establishing such a monopoly were:

- To ensure that all users are connected, whether or not commercially attractive on an individual basis,
- To ensure that there would be sufficient (low risk) revenues so that the vast investment in infrastructure could be financed.

This led to the industry-model of vertically integrated utilities serving a specific region. These utilities would own (1) a transmission system designed to serve all customers in the network region and (2) the power plants that could serve the regional (peak) demand. The model

[1] Fuel costs, balancing costs, variable transport and system costs, variable OPEX.

worked well for decades. It ensured that all users in the region were connected and served. Transactions between regions and countries long remained rare and were generally scheduled well in advance.

Over time, the downsides of a monopolistic industry structure started to become apparent: high costs, limited efficiency and stalling innovation. As a reaction, electricity markets were designed and implemented with a view to increase innovation and reduce over-all system costs. A key step for electricity markets occurred in the 1990s when the UK government and several US states introduced independent system operators (ISOs) and regional transmission organizations (RTOs) to facilitate competitive supply. European Directives guided a gradual but similar opening of the market. For the largest customers this started in 1998.

Underlying concepts

In the different market introduction processes many of the underlying concepts were the same. These concepts are:

1. separate the potentially competitive functions of generation and retail from the natural monopoly functions of transmission and distribution;
2. establish a wholesale electricity market over an as large as possible area for maximum market liquidity and depth;
3. accommodate a retail electricity market for competitive delivery to end customers.

Clearly, if the transport infrastructure is managed or occupied by the major (monopolistic) supplier an impartial access regime cannot be expected. Therefore, regulation was put in place that guarantees network access to each market player at exactly the same terms. Every player must be able to access the power infrastructure on a 24/7 basis at identical terms. How this sits with increasing renewable generation will be discussed further down in this article.

The main objective under 2. was to create reliable pricing signals. The role of the wholesale market is to allow trading between generators, retailers and other (financial) intermediaries both for short-term delivery of electricity (spot market) and for future delivery periods (forward market). The quality of market pricing increases with market depth and liquidity. To get that, an as large as possible single network is the obvious way to go. Again, how this sits with increasing renewable generation will be discussed further down in this article.

The main objective under 3. was to provide customers with a choice of suppliers that all compete at equal terms. Preferable, a choice on a comparable basis. Therefore, the access rules were standardized across customer groups. Especially so, for the residential market in which the customer is assumed to be non-professional and in need of a level of customer protection. And again, how this sits with increasing renewable generation will be discussed further down in this article.

Renewables as game changer

Worldwide, renewables (wind and solar) are the biggest contributor to new-built generation capacity. There is an increasing number of days in spring and summer on which e.g. Germany or California are completely supplied by solar and wind. And the UK National Grid's Future Energy Scenarios 2020 (National Grid, 2020) forecast that 'zero marginal cost generation' will provide up to 71% of generation output in 2030, and up to 80% in 2050.This profound change in the generation mix puts into question whether the current electricity market design is still adequate (see figure 2). Sources of power become weather dependent and much more local.

Electrification and decentralisation lead to more efficiency

Electrification across all energy sectors is inevitable (see Figure KF-1) and is more resource efficient than the current system. Electricity generation in 2050 will exceed four to five times that of 2015, primarily due to high electrification rates of the transport and heat sectors. Final energy fuel consumption is reduced by more than 2/3 (68%) from 2015 numbers, as fossil fuels are phased out completely and remaining fuels are either electricity-based or biofuels. Electricity will constitute for more than 90% of the primary energy demand in 2050. This electrification results in massive energy efficiency gains when compared to a low electrification trajectory (see KF-1). Almost all of the renewable energy supply will come from local and regional generation.

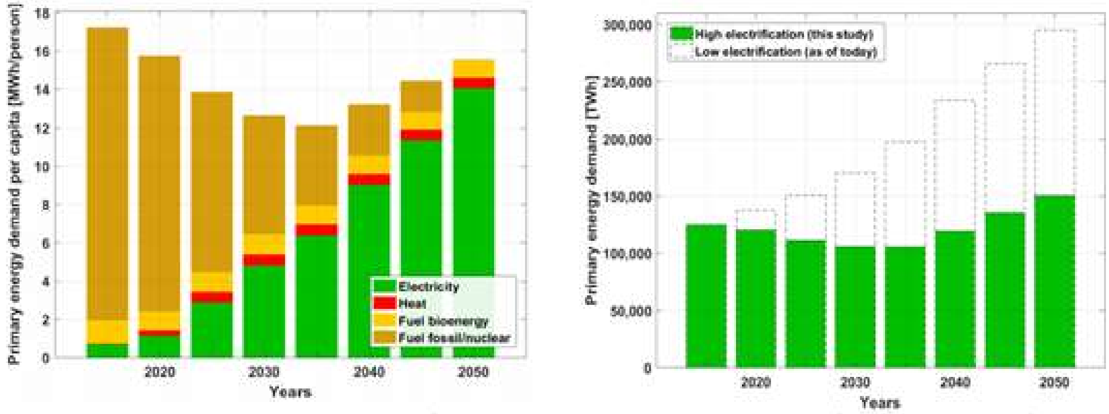

Figure 2. Primary energy demand per capita (left) and primary energy demand with high and low electrification through transition (Ram e.a., 2019).

As we saw, the current electricity market design is built on three main concepts. The impact on the network is:

- market players should always be able to access the market at equal and fixed terms
- that markets should be large and that therefore location (in the power network) should matter as little as possible ('copper plate' concept).
- that the functions of supply and demand are separate with players being either supplier or customer.

However, the two dominant sources of renewable power (wind and solar) do not easily fit these concepts.

The planning and construction of power networks takes much longer than planning and construction of (especially) solar PV assets. Solar- and wind-power are available at the same moment as a function of weather conditions. Network access at equal terms and at all times then becomes an illusion. Depending on the mix of renewable production assets, up to 20 times more production capacity is needed to make the same amount of kWh's as in the case of fossil production assets. For The Netherlands, installed generation peak capacity is estimated to grow by around 75% to 2030. Some 15% is related to demand growth and 60% to production capacity growth. It seems to make no sense to design the power network so that it can serve the maximum production peak. This peak is far higher than maximum demand so the peak electricity simply has nowhere to go.

Meteorological circumstances fully determine the potential output of both wind and solar plants. All generators in a certain area will produce at the same moment. Consequently, prices will be lower and lower when there is sun and wind. The more renewable sources there are, the stronger this effect will be. And although the marginal costs of solar and wind may be low, these sources are not at all for free. Without a realistic perspective of sufficiently high prices and of access to a market the necessary investments will not be made. If kWh prices get too low and do not represent value then new pricing signals are needed that can drive investment and dispatch.

Solar and wind power enable a far more distributed energy production system. Solar is the example ‘par excellence’ of a scalable technology. Permitting and construction times of wind plants may be less favourable but still far below conventional fossil plants or nuclear. This difference in scale means that generation capacity is added throughout the system in a much higher and less predictable tempo than what we were used to.

The distributed character and small minimal scale also mean that customers can easily choose to produce part of their demand themselves. The classical boundaries between supplier and customers disappear.

Transport capacity as new commodity

Because CAPEX are so dominant in renewable generation, the financial risk is very ‘front-loaded’. This investment risk will therefore have to be allocated up-front. But no investor will put her/his money in a market where long-term prices trend to zero and in which it is uncertain that the product can even be brought to market. So, somehow, a (fixed) price for the generation capacity will have to be agreed between stakeholders before the investment is made. In the market we now see that PPA’s between large consumers and producers of renewable electricity can take over the role of subsidies. Large tech-companies like Microsoft and Apple have bought the output of entire windfarms to off-set their global power consumption. In such agreements the buyer gives some form of revenue stability to the producer. This can for example be done through a fixed price but also through price caps and floors.

If the energy price is set in the way described above, then what has to be steered (through price signals) is the real scarce resource: the transport capacity that links supply and demand. In other words, capacity to transport, store and deliver between points in the grid. These resources are much more scarce than the energy when there is such an enormous peaksupply/peakdemand imbalance (ReThinkX, 2020). And that in turn means that an instrument to optimize capacity use will have to be developed. Given the positive experience with energy markets this can be a network capacity market.

What is meant here is not the capacity market that is often advocated by power producers. The issue here is not about back-up. What is meant here is the mainly short term pricing of capacity between points (nodes) on the grid. This makes transparent where there is a scarcity of capacity and what is the value of linking supply to demand.

If we can put such a system in place then all market players can contribute to the rational solution to transport bottle-necks. These players can be the owners of storage facilities, consumers with demand management options or even the owners of the renewable production sources themselves. “In a world where we want to quickly replace dispatchable fossil power plants with renewable assets, using all the enablers of the vast flexibility portfolio of resources is the best way to lower the overall transition cost and to make greater use of renewable generation capacities” [9].

With renewable production assets, transport capacity will become the scarce resource. Its use needs to steer production. This price signal is needed to direct the production of power in time and place. Transport capacity costs can be that price signal as follows for two typical situations.

Demand is lower than (peak) renewable production: The energy for end-use has been pre-purchased. Suppliers will satisfy this demand from the (abundant) sources. The energy surplus will look for a sink. Such a sink is preferably close to production as this avoids transport costs when demand for transport is high

Demand is higher than (low) renewable production. The energy for end-use has been pre-purchased. Suppliers will deliver from production assets and from additional sources like storage. Transport costs are a function of demand so delivery from storage is possible and valuable.

The transport pricing information will give investors visibility on the value of power in particular point on a network.

Outline of a network capacity market

The idea of the transport capacity market is to provide price signals for the availability of transport capacity from point A to point B in a power network. Today in most markets consumers pay the network costs as if the system were a single ‘copper plate’. Their tariff depends on their tension level in the network. This tariff is mostly fixed and for firm guaranteed capacity.

The capacity market proposed here would work exactly opposite. Here producers pay for availability of network capacity. The price will depend on two factors mainly:

- where in the network is the production asset located and connected?
- where is the point of transfer of this power to a customer or a market party?

In such a market the price for capacity will be high in times of high capacity demand i.e. at moments of peak production or peak demand. In periods of low production/use the demand for capacity will be low and hence the price of capacity will be low. Such capacity pricing will stimulate producers and users to:

- choose smart locations in the grid,
- consider to shed energy production or store energy production for release in periods when capacity prices are low,
- to transport energy at moments that the demand for capacity is low.

The assumption for such a market would be that customers (demand side) can choose for different contract forms with a varying level of delivery certainty. This would allow suppliers to compete in balancing supply and demand with different levels of supply certainty. In this way the competition would focus on the best use of the single sparse ‘commodity’: network capacity.

The pricing structure for the end customer in the system would then be a fixed payment for the chosen minimum service level plus a payment for the more variable or uncertain part of the delivery. This is not a fiction as, for example, most of the mobile telephony markets work on such a basis. These are subscriptions with different service levels for different prices. In energy, the fixed payment would probably largely depend on the capital costs of the assets that produce the energy. The suppliers thus compete on:

- reducing capex for the production assets;
- optimizing network capacity usage.

In networks with ample capacity the competition would largely focus on low capex for the renewable assets. Asset locations can then move to locations with e.g. low prices for sites thus driving down CAPEX. The power may need to be transported over longer distances but if sufficient capacity is available this would not be a burden on the network.

In networks with scarce capacity the competition would focus less on CAPEX of the production assets but much more on limiting the costs of network usage. Asset locations would move to e.g. rooftops close to demand thus driving down network costs. The power will need to be transported over short distances only and would relieve the scarce network capacity.

A case study

The Dutch island Goeree-Overflakkee houses some 55.000 inhabitants and 25.000 homes. Traditionally there has been limited industrial activity. Agriculture and its related activities are the main source of income.

The island is connected via two power cables of 150 kV and 50 kV. On the island there are three transformer stations (medium and intermediate tension).

Under current projections there may already be bottlenecks at all transformer stations before 2030. All these bottlenecks are caused by the supply of electricity from solar and wind. None are caused by high electricity demand.

According to the network vision of the network operator solutions are projected that will solve all bottlenecks around 2050.

A simulation was carried out to study the effect of 'non-network' measures that players on the power system could implement when properly incentivized:

1. More energy consumption savings through: Further insulation of homes (towards A++) and utilities (A+), maximum behavioural change, most efficient appliances, more short and medium distant transport through e-bicycles (3x compared to current level),
2. a 25MW electrolyzer,
3. flexible 'superpower' users (in total about 70 MW). These users use energy when it is in abundance,
4. Curtailment of all solar parks to 50% of peak capacity and battery systems at all solar parks.

The effects on the transformer capacity are strong. Only one bottle-neck in 2050 and of a manageable size (32 MW).

Further study is needed as to the level of incentives needed to make market players implement all these measures. However, under current regulation the measures 1 and 4 will already be implemented prior to 2030. Therefore, the scenario does offer a true alternative and a view of the feasibility of an alternative approach. Dutch network operator Liander (Liander, 2022) also concluded that changes in this direction are needed rather than adding network capacity.

How to get there?

With this vision of the new architecture of power network management we can ask the final question of how to get there. It is hard to see how this can happen spontaneously. Already one can see that there would be some winners and some losers if such a capacity market were to be introduced. Owners of (large) generation assets in markets/countries with limited network capacity would suffer. Power traders would have to master a new trade. Network operators have to play with new rules and regulations but would get a powerful new instrument for managing their system.

Against this background of varied interests it is unlikely that change will be spontaneous. The potential winners need the vision and will of politicians to get this of the ground.

Schweppe c.s. said about market liberalisation that: “There is a need for fundamental changes in the ways society views electric energy. Electric energy must be treated as a commodity which can be bought, sold, and traded….

The time has come to give this vision a new object. There is a need for fundamental changes in the ways society views electric energy and network capacity. Electric energy must be treated as an abundant resource and network capacity as a scarce commodity which can be bought, sold, and traded.

In this vision the capex exposure of renewable electrical generation capacity is shared up-front between players in the industry. This drives capacity costs down.

The value of such capacity will depend on its location in the network relative to demand. Traders and users of capacity will optimize between them.

Politicians and regulators must show the courage to move into this new direction.

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