Energy Delta Institute
Energy Business School

Algemene informatie – electricity

Deze artikelen zijn door EDI geschreven in het kader van het EDIAAL programma

The value of distributed generation

Key concepts

Renewable energy – especially solar and small-scale wind – is often a ‘distributed’ generation asset, feeding electricity in at the distribution level instead of the transport level. The economics of any kind of distributed generation is partly dependent on how power delivered to the grid is valued, and the valuation of distributed generation is a topic of much debate.

Retail pricing

In different European countries consumers may compensate consumed electricity with electricity they produce and deliver back to the grid for part of the retail price or the full retail price (net metering). However, retail prices are a very poor guide of the value of produced power, because they include significant fixed cost recovery (e.g., the fixed costs of local distribution networks) and taxes and they reflect little or none of the locational (or time) variation in wholesale power purchase or production cost. At one extreme, it is argued that customers should not only be able to reduce their power bills to zero by generating as much power over a billing period as they consume, they should be paid the retail rate by the utility for any net power they contribute to the system. At the other extreme, it is argued that intermittent distributed generation not only doesn’t reduce local distribution costs to a significant extent – and so should be compensated no more than the wholesale price of power – as the intermittent nature of power production and the reverse flow from customers increases the stress on distribution transformers and increases the frequency of repairs. At the heart of this conflict is an internal inconsistency in the utility revenue model: local electricity distribution service is a regulated, largely fixed-cost, business, but costs are recovered primarily through charges that vary with the quantity of electricity consumed.

Residential solar power

Residential solar photovoltaic generation has been at the centre of this debate. Residential solar does offer greater value than suggested by its high levelized cost – because it produces disproportionately at times of higher demand and avoids the small percentage of power that is dissipated as heat when it is sent through the transmission and distribution lines from a distant generator(1). Nonetheless, retail rates don’t accurately reflect the social value of distributed solar generation. With distributed generation, a significant share of the savings customers see in their electricity bills would have gone to pay the utility’s fixed costs. These costs change very little, even in the long run, when customers generate some of their own power.

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Nuclear power generation

Definition
Nuclear power plants convert the energy released from the nucleus of an atom via nuclear fission that takes place in a nuclear reactor.

Key concepts

A nuclear power plant produces and controls the release of energy from splitting the atoms of elements such as uranium and plutonium. In a nuclear power plant, the energy released from continuous fission of the atoms in the fuel as heat is used to make steam. The steam is used to drive the turbines which produce electricity as in most fossil fuel plants, but without the combustion of fossil fuels and greenhouse gas emissions.

In 2010, nuclear power supplied 13,5% of the world-wide electricity demand with the US and France being the major producers (1).

There are several components common to most types of reactors:

- Fuel: Usually pellets of uranium oxide (UO2) arranged in tubes to form fuel rods. The rods are arranged into fuel assemblies in the reactor core.
- Moderator: This is material which slows down the neutrons released from fission so that they cause more fission. It is usually water, but may be heavy water or graphite.
- Control rods: These are made with neutron-absorbing material such as cadmium, hafnium or boron, and are inserted or withdrawn from the core to control the rate of reaction, or to halt it.
- Coolant: A liquid or gas circulating through the core so as to transfer the heat from it. In light water reactors the moderator functions also as coolant.
- Pressure vessel or pressure tubes: Usually a robust steel vessel containing the reactor core and moderator/coolant, but it may be a series of tubes holding the fuel and conveying the coolant through the moderator.
- Steam generator: Part of the cooling system where the heat from the reactor is used to make steam for the turbine.
- Containment: The structure around the reactor core which is designed to protect it from outside intrusion and to protect those outside from the effects of radiation in case of any major malfunction inside. It is typically a metre-thick concrete and steel structure.

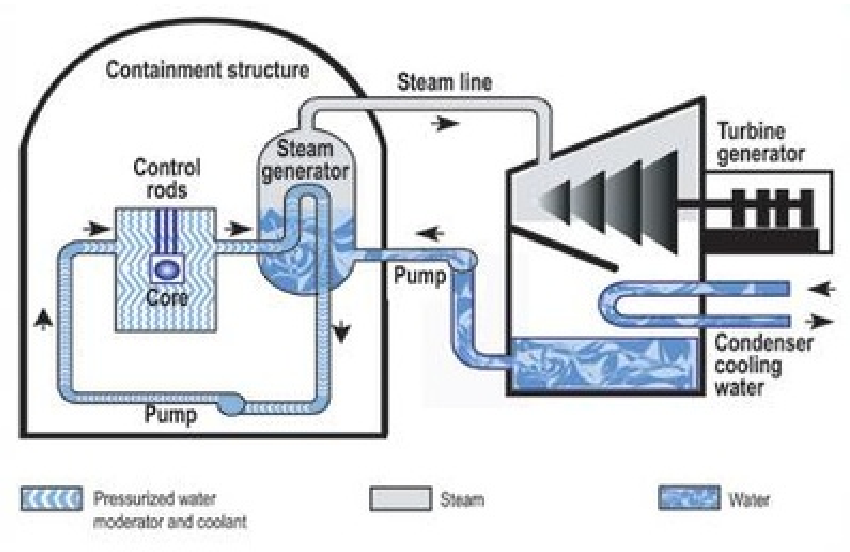

Figure 1: General nuclear power plant layout (2)

Design Generations

Several generations of reactors are commonly distinguished. Generation I reactors were developed in 1950-60s and very few are still running today. They mostly used natural uranium fuel and used graphite as moderator. Generation II reactors are typified by the present US fleet and most in operation elsewhere. They typically use enriched uranium fuel and are mostly cooled and moderated by water. Generation III are the Advanced Reactors, the first few of which are in operation in Japan and others are under construction and ready to be ordered. They are developments of the second generation with enhanced safety.

Generation IV designs are still on the drawing board and will not be operational before 2020 at the earliest, probably later. They will tend to have closed fuel cycles and burn the long-lived actinides now forming part of spent fuel, so that fission products are the only high-level waste. Many will be fast neutron reactors (3).

The greatest difference between second-generation and third-generation designs is that many third-generation designs incorporate passive or inherent safety features which require no active controls or operational intervention to avoid accidents in the event of malfunction. Another difference is that some third-generation designs will be designed for load-following, where normally nuclear power plants are built to supply base-load power. While most French reactors today are operated in load-following mode to some extent, the third-generation designs have better capabilities. It will potentially be able to change its output from 25% to 100% in less than 30 minutes, though this may be at some expense of wear and tear (4).

Nuclear waste

Disposal of nuclear waste is often said to be the Achilles' heel of the industry. Presently, waste is mainly stored at individual reactor sites and there are over 430 locations around the world. Reprocessing can potentially recover up to 95% of the remaining uranium and plutonium in spent nuclear fuel, putting it into new mixed oxide fuel. This produces a reduction in long term radioactivity within the remaining waste, since this is largely short-lived fission products, and reduces its volume by over 90%. Reprocessing of civilian fuel from power reactors is currently done on large scale in Britain, France and (formerly) Russia, soon will be done in China and perhaps India, and is being done on an expanding scale in Japan. The full potential of reprocessing has not been achieved because it requires breeder reactors, which are not yet commercially available (5).

Nuclear fusion

Nuclear fusion will use abundant sources of fuel, they will not leak radiation above normal background levels and they will produce less radioactive waste than current nuclear fission reactors. Fusion reactors are now in experimental stages at several laboratories in the United States and around the world (6). A consortium from the United States, Russia, Europe and Japan are currently building a fusion reactor called the International Thermonuclear Experimental Reactor (ITER) in Cadarache, France, to demonstrate the feasibility of using sustained fusion reactions for making electricity (7).

Extensions

Technology Roadmaps - Nuclear Energy

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Future price developments

Definition

Future price development describes the possible development of electricity prices in markets with high shares or renewable energy

Key concepts

Future price development is highly dependent on whether capacity markets will be introduced in (part of) the Northwest European market. If no capacity measures are implemented, the mix off generation capacity will be purely based on the economics of the sale of electricity. Changes in conventional capacity needed to balance the system and provide sufficient security of supply will have an upward effect on electricity prices as more expensive generation capacity will be needed earlier in the merit order. The intermittent nature of renewable electricity production means an increase in the level and volatility of peak prices, combined with an increase in the number of hours in which residual demand is so low (relative to the output from "must-run" plants) that some of these must be constrained off the system and prices become negative(1). Especially at moments of peak demand, the limited availability of capacity can cause high price peaks. These price spikes are necessary to provide for the economic viability of peaking plants and serve an important role in the system in the absence of capacity markets.

Capacity markets

If capacity markets are implemented it is likely that more peak capacity will be available, meaning that price peaks will be less frequent and less extreme. Price peaks would no longer be necessary as peaking power plants would receive steady income from capacity payments and price peaks as a mechanism to ensure adequate supply would then be redundant. This does not necessarily imply lower consumer prices, as a surcharge would be required to fund capacity payments. Whether the capacity market has a positive or negative effect on consumer prices is mostly dependent on the adequacy of the scheme and a correct capacity valuation by the regulator.

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Future investment decisions

Definition

Future investment decisions describes the future investments decisions in markets with high shares or renewable energy

Key concepts

Because of an expected growing demand for electricity and retirement of old power plants driven by economics, technical issues or regulation, there will be a need to invest in new capacity. From a system's point of view this new capacity should be flexible so that the varying supply of renewable electricity can be balanced and grid stability and security of supply ensured(1). It is also of importance that enough new capacity is built to prevent blackouts when peak demand coincides with low renewable energy production.

Changing power plant portfolio

This mix of conventional capacity with higher levels of renewable generation is likely to be different from the mix which would be required without investment in renewable energy. In particular, a higher proportion of conventional plants can be expected to operate at relatively low load factors, since these will be only needed to meet demand at times when renewable energy production is below average. Plants with relatively low capital costs will therefore be favoured over those with low operating costs, compared to a mix associated with low levels of renewables output(2).

New investments

Decisions to invest (or not) in new capacity are not made based on the technical needs of the system (adequate backup) but on the long-term economic viability of the new power plant and it is not evident that investments necessary to reach an optimal generation stack will materialize without support measures. Investment decisions are plagued with uncertainty due to high but uncertain potential price spikes, depressed average prices because of the merit order effect and uncertain future regulation. Especially in the case of 'super peaking' plants, where the financial feasibility is based on a few short price spikes to cover all costs, it will be difficult to provide a good business case for future investments. These plants will also suffer from load factor risks, as it is possible that their services might not be required at all during a 'high wind' year(3). If the current 'energy only' market is maintained (with no mechanism to account for capacity) this might result in extreme price peaks, which are necessary to make peaking plants profitable.

Capacity markets

To prevent such price peaks, capacity markets or similar measures to guarantee available capacity can be introduced to provide incentives for power producers to invest in new capacity or keep old capacity online. However, they may harm proper functioning of the market and there is ongoing debate whether such measures are necessary and desirable.

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Merit order effect

Definition

The merit order effect describes the short-term effect of adding large amounts of renewable energy capacity to a competitive market. This effect partially compensates the costs of renewable energy support policies for consumers, at least in the short term.

Key concepts

Renewable energy production may have a large effect on spot prices for electricity, especially at moments of high renewable energy production. When renewable energy is produced, it takes precedence in the market both because of regulation and its near-zero marginal costs and has the effect of a reduction in residual demand. As electricity demand is almost inelastic in the short-term perspective of a day-ahead market, this shifts the merit order in such a way that a cheaper power plant becomes the price setter and the wholesale power price is reduced. Since this effect shifts market prices along the merit order of power plants this effect is called the merit order effect.

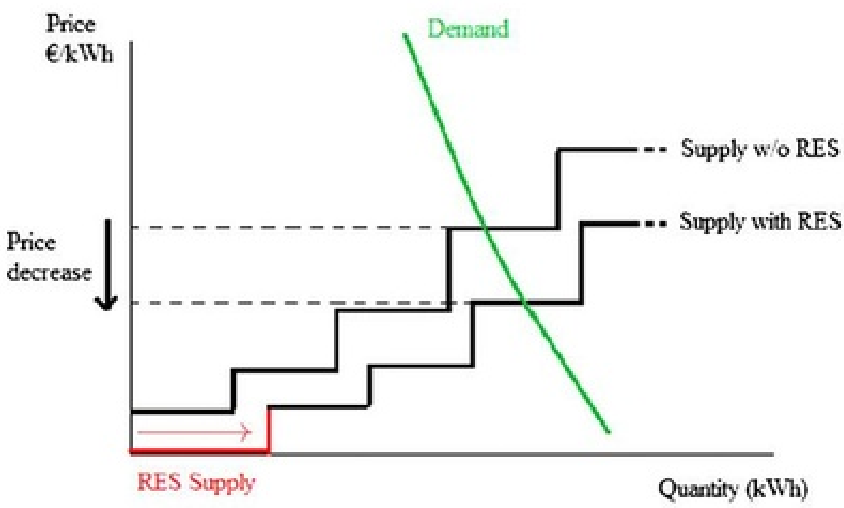

Figure 1: The merit order effect on wholesale market prices(1)

Quantified effects

This price suppression effect of renewables has been proven from both theoretical evidence and simulation studies(2) while different studies have attempted to quantify the effect for specific markets. For instance, results for the German market indicate a reduction of the average market price by 7.83 €/MWh in 2006, resulting in a merit order effect of about 4.98 billion euro, offsetting most of the costs from financing FiT-schemes that year(3). A similar study performed in Spain comparing the simulated merit order effect due to wind with its financial support calculated savings for consumers of more than two billion Euros between 2005 and 2007(4). Another study examining Spanish prices between 2005 and 2009 reported a marginal increase of 1 GWh of renewable electricity production yielding a 4% decline in electricity prices(5).

Future investments

The merit order effect also has a downside, in this case for the power producer. Due to lower average power prices, power producers receive a lower price for their product and run their plants at lower capacity factors. As a result, the profits of the majority of the utilities diminish(6) and these trends will obviously impact future investment decisions.

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