New Energy Paradigms: Challenges and Options

Interesting observations in the July/August 2015 issue of IEEE Power & Energy

The July/August 2015 issue of IEEE Power & Energy includes an overall survey of the electricity landscape and articles with focus on Germany, Spain, California, Australia, and Great Britain.

From the editor's preface: *As a result, there is a crying need for innovation to create logical, workable electricity markets directed towards specific needs and requirements*.

Creative Destruction

In a short retrospect, Randell Johnson characterizes the continuous replacements of products and technologies as *creative destruction*. From 1882, the *Pearl Street Station* supplied electricity for incandescent lamps, which replaced kerosene lamps. The new way of lighting was cleaner and more cost effective. Since then a steady innovation has created improved technologies and products that are still more competitive.

Randell Johnson continues: *Today, the world is evolving away from coal and incandescent lighting technologies towards renewables and even more efficient lighting technologies. Prospects and opportunities for further creative destruction are vibrant from supply, transport, and demand impacting revenues affecting utility business models and structures of wholesale markets.*

Solar and wind power were successfully developed to industrial scale. The introduction of significant shares of solar and wind power was boosted by subsidies. Solar and wind power plants rely on energy market revenue from production as well, and decreasing subsidies were expected as the result of large scale production. However, both wind and solar have a tendency to lower short-run power prices. Therefore, the subsidies are rather increasing than decreasing.

The decreasing short-run power prices cause faster closure of thermal power plants than anticipated. The replacement of thermal power plants by solar and wind was a purpose of the transformation, but a fast closure of thermal power plants can erode the capacity reserves and bring security of supply at risk when the production from solar and wind is low.

The retirement of coal plants means not only loss of peak power capacity, but also the loss of energy storage because coal plants usually have coal for months on site.

Several countries realizing the risk are considering new market arrangements for reserve capacity.

Distributed Resilient Networks

Power shortages and attacks by extremists are potential threats requiring increasing attention. Therefore, the resiliency of local grids needs new considerations.

Several concepts are in the melting pot, often referred to as Smart Grids.

Flexible demand looks like a promising option if passive electricity consumers can be transformed into active consumers (prosumers). Rooftop solar cells (PV) and electric cars (EV) are expected to be important elements in the transformation. The demand response is controlled by local price signals.

The transformation will challenge the traditional business models for distribution companies in several ways. The increased use of electricity may require investments in local grid reinforcements or advanced (smart) load control arrangements. In the latter case, control signals must combine system power demand with local grid congestion control. Net metering for rooftop PV systems uses the grid as an electricity storage and reduces the revenue for the distribution company. Demand flexibility implies that prosumers opting for partial self-supply can practice arbitrage against utility rates. The prosumer expects the utility to maintain its obligation to serve during self-supply shortages, but to the distribution companies maintaining normal services will become increasingly difficult with shrinking revenues. It may become necessary to develop new rate structures reflecting new demands and services.

Evolution of the Planning Processes

Grid planning was for decades based on heuristic methods with focus on annual peak loads. Predictable load patterns were essential preconditions. Long-term breakdowns of power plants and interconnections were less predictable and required some modifications to the method. Gradually, better computers and stochastic methods improved the planning of grid development.

The increasing interdependence between different energy systems together with stronger computational tools paves the way for integrated energy transport planning. In a first step, the planning of the electric grids and natural gas networks could be coordinated. Later the planning of liquid natural gas (LNG), oil pipelines, coal and water could be added. From a Danish point of view, we would find it natural to include district heating.

Power Market Structures

Power markets have been developed in many countries during the last 25 years. Largely they have been successful in making short-run electricity prices transparent and bringing competition to supply. Many short-term products have been developed alongside the day ahead spot prices such as real time market, reserves, congestion products, derivatives, forwards and futures.

However, the combination with intermittent renewable generation with very low marginal costs seem to deflate the spot prices. Due to the decreasing spot prices, the renewable energy electricity sources still needs subsidies. The competitive power markets have helped handling the large number of new producers but they have fallen short of levelling the economic playing field of co-optimizing transmission investments and other resources.

There has been a change in the generation fleet in many markets with the retirement of older coal- and oil-fired generators in favour of natural gas. The decrease of fuel diversity can have an impact on security of supply. History has shown the risk of high dependence of one source of imported fuel.

Most power markets have yet to accomplish placing all options on a level playing field and producing market signals for different types of options such as transmission instead of local resources or vice versa.

How Renewable sources are Changing EU Electricity Prices

An article by four Spanish authors analyses the green transition with special focus on Spain and Germany. The article brings several charts and tables on the development of electricity from renewable sources.

From the beginning, both Spain and Germany used feed-in-tariffs (FiT) in order to encourage private investments in wind and solar and to reduce the market risk for the owners. When the cost of wind turbines and solar panels dropped FiT gave an overcompensation, and renewable investments boomed beyond policy targets and support budgets. The surges of renewable power created operational problems because the necessary grid reinforcements were missing and because there were no incentives for operators of renewable power to consider the system demand for electricity.

Both countries have gradually moved to feed-in-premium (FiP). The basic idea is to sell renewable electricity in the market in competition with traditional production but with a premium on the top of the market prices. FiP is planned to give more balanced incentives for investments in and operation of renewable power.

The economic trends are characterized by decreasing wholesale prices of electricity and increasing consumer prices. Figure 1 was extracted from figure 3 and 4 in the article.[1]

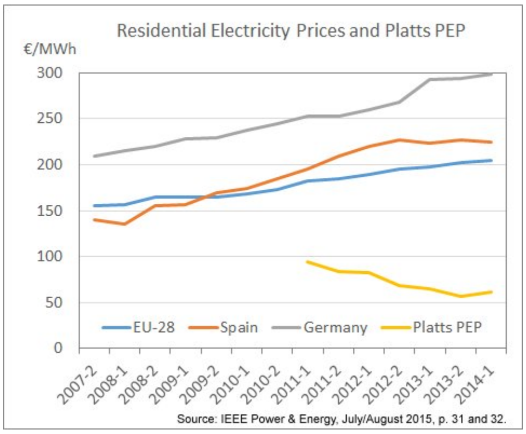

Figure 1. Consumer and wholesale prices of electricity in Europe. PEP: Platts European Power Index.

The increasing decoupling between wholesale prices and consumer prices may lead to weaker incentives for demand response by residential consumers.

Scenarios for 50% Renewable Electricity in California in 2030

The current Californian target for renewable electricity in 2030 is 33%, known as *33% renewable portfolio standard* (RPS). Now Governor Jerry Brown has set a new goal of deriving 50% of electricity from renewable resources by 2030. A recent study[2] commissioned by the four largest utilities has analysed if a 50% renewable grid is achievable with wind and solar as the primary resources.

The article mentions Germany, Spain and Denmark as world leaders in renewable goals, but degrades the Danish achievement due to the small size of the country and the use of interconnections for balancing.

The four scenarios:

- Large solar: Utility scale photovoltaic (PV) resources.
- Small solar: Distributed ground-mounted solar PV systems (1-20 MW) located close to load centres.

[1] The consumer prices include taxes. According to a Eurelectric source, taxes are increasing more than the net cost of producing and delivering electricity.
[2] Energy and Environmental Economics: Investigating a Higher Renewables Portfolio Standard in California, January 2014

- Rooftop solar: Distributed residential and commercial rooftop solar PV installations.
- Diverse: Utility scale resources including solar thermal resources with energy storage, in-state wind, and out-of-state wind, in addition to some in-state solar.

The operational challenges are illustrated by the CAISO duck chart (figure 2), which shows the residual load during a day. Increasing solar electricity will deflate the residual load during the daylight hours.

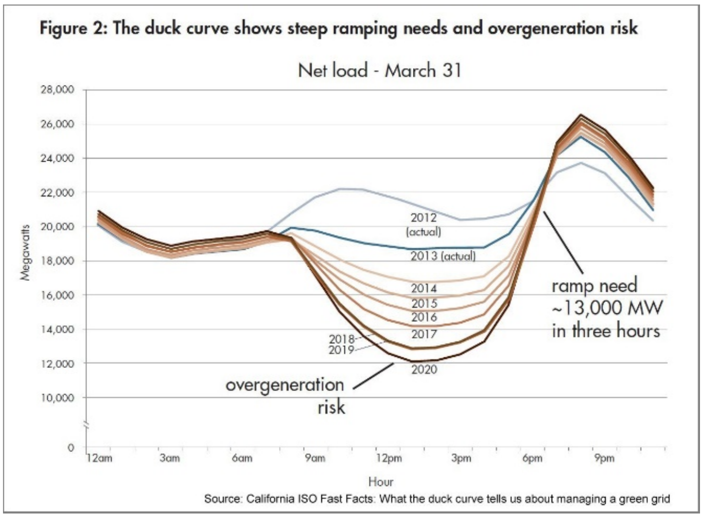

Figure 2. The famous CAISO duck chart

During the hours after noon, there will be a risk of overgeneration. One option would be closing down some of the thermal power plants running at minimum load, but this action might leave too little dispatchable capacity for ramping up to the peak load in the evening. The result would be load curtailment. The alternative would be curtailment of a part of the renewable production.

The value of lost load could be between US$5,000 and US$50,000 per MWh. The value of curtailed renewable output might range from US$50 to US$250 per MWh.

The study considers a number of potential solutions to the integration problems:

- Enhanced coordination with neighbours in the Western Interconnection.
- Conventional demand response (DR) such as peak shaving.
- Advanced DR moving load from peak hours to hours with overgeneration.
- Energy storage.
- Portfolio diversity (in the “Diverse” scenario).

For 50% RPS in 2030 the results show that the number of overgeneration hours range from 1,200 hours to 2,000 hours. The corresponding energy is between 4,700 GWh (3.4% of available RPS energy) and 12,000 GWh (8.9%).

The calculated average electric rates for 33% RPS in 2030 are between 20 US¢/kWh and 24 US¢/kWh. The calculated relative changes from 33% RPS to 50% RPS are:

- 23% for the rooftop scenario,
- 16% for the small solar scenario,
- 14% for the large solar scenario, and
- 9% for the diverse scenario.

It is not surprising that the diverse scenario is the most cost effective.

The carbon emission decreases from 64 MMt[3] for 33% RPS to about 49 MMt for all 50% RPS scenarios.

[3] MMt: million metric tons

PV Threatening the Centrally Dispatched Model in Australia

Australia had a rapid expansion of rooftop PV systems since 2010. The driving forces are:

- Rising electricity prices,
- Capital subsidies (certificate schemes), and
- Production subsidies (FiT)

The installed cost of PV on household roofs declined from around AU$12 per watt in 2008 to less than AU$2 per watt in 2014. From 1 January 2010 to 31 December 2014, 1.36 million households invested AU$11 billion in rooftop PV systems. The expected internal rate of return (IRR) for this investment is 8.9%. The IRR varies depending on many factors and ranges from 11.5% in South Australia to 5.5% in Tasmania.

It has been argued that declining demand for grid-supplied electricity leading to higher prices leading to declining demand is a “death spiral” for the established centrally dispatched electricity model. At least it can be concluded that the traditional industry model is facing a serious competitive threat. The incumbent utilities with vast sunk costs in network and generation will probably need to reconsider their business models.

Transmission Pricing in Great Britain

An article (“It’s all about grids”) discusses the complicated interrelation between transmission pricing, transmission planning, generation development and electricity prices.

In Great Britain, the electric transmission system has a main flow from north to south. Generators pay a charge in £/kW/year. The charge depends on location and vary from £25/kW/year in Northern Scotland to £-5/kW/year in South West England.

However, with fluctuating renewables and offshore production the grid planning must consider other situations than the annual peak demand. The article compares a uniform charging model (one common charge in £/kW/year) with different locational charging models.

The advanced tool (dynamic transmission investment model, DTIM) was also used for identifying candidate corridors for new offshore transmission.

Figure 3 demonstrates the importance of the Konti-Skan interconnection to Sweden (1965) and the Skagerrak interconnection to Norway (1976) for Denmark’s role as an electric hub in Northern Europe, even in a future with offshore to offshore links.

An interesting statement says that Great Britain is moving toward the introduction of an independent system operator (ISO), which will plan and operate but not own the transmission network infrastructure.

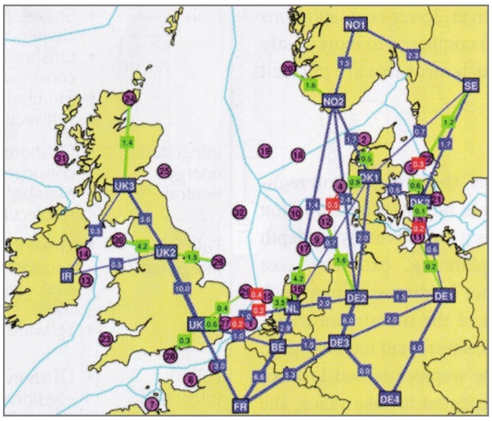

Figure 3. Extract of figure 12 in "It's all about grids". The red signatures are potential offshore to offshore links.

The article concludes that transmission arrangements have significant effects on consumer bills, and that inefficient transmission pricing can lead to significant increases in the cost of electricity. It is important that new technologies such as demand-side management, storage, protection schemes, and other smart grid solutions have the right incentives including facing realistic system costs.

Distribution Pricing

From a prosumers point of view, even distribution pricing is important for the incentives to contribute to absorbing fluctuations from renewable power.

The last article in this issue of IEEE Power & Energy concludes that major advances have already been made in reforming distributing pricing and tariff structures to meet low carbon requirements. The advances include:

- Locational use-of-system charges to encourage appropriate location of new generation and demand.
- Better alignment between transmission and distribution networks.
- Performance based revenue control, ensuring that customers pay a fair price for rewiring a smart distribution system.

Special Danish Challenges

Denmark has two challenges, which have not been discussed in the comprehensive examination of challenges and options:

- Denmark has decided an expensive conversion of overhead lines into underground cables for all voltage levels. This is in contrast to Germany where very large transmission projects are under construction.
- The combined heat and power concept (CHP) has a long tradition in Denmark. CHP saves energy and it has covered about half the Danish demand for space heating. This means significant constraints for the operations of the power system. The CHP concept will face new challenges from the transition into non-fossil electricity production and the share of CHP in heat supply is currently decreasing.

It remains to be seen if these challenges will gain ground internationally, or if Denmark must reconsider its targets.