ENERGY STORAGE

STORAGE AS A TOOL FOR SMART DISTRIBUTION

CEDEC POSITION PAPER

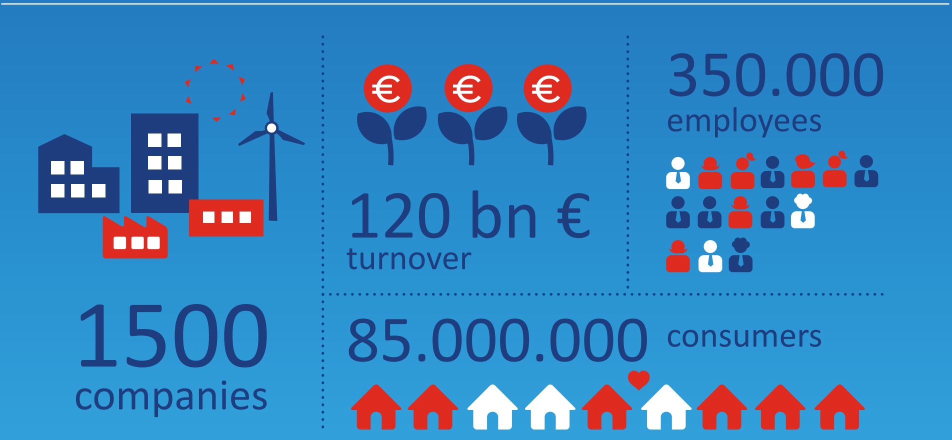
January 2016

CEDEC

CEDEC - Background information

CEDEC represents the interests of 1,500 local and regional energy companies with a total turnover of €120 billion, serving 85 million electricity and gas customers and connections, with more than 350,000 employees.

These predominantly medium-sized local and regional energy companies have developed activities as electricity and heat generators, electricity and gas distribution grid and metering operators and energy (services) suppliers.



The wide range of services provided by local utility companies is reliable, sustainable and close to the customer. Through their investments and local jobs, they make a significant contribution to local and regional economic development.

KEY POINTS

Ensure a reliable and affordable energy supply at all times

- It is vital that Distribution System Operators (DSOs), who are responsible for the cost effective distribution of energy, are able to select the best option available, to ensure that society is provided with a reliable and affordable energy supply at all times.
- The amount of variable renewable energy sources, such as solar-PV and wind, will continue to rise in the future. A large part of these variable renewable energy sources will be connected to the distribution grid. In some areas, the increase of local renewable energy generation may exceed the growth of additional installed grid capacity due to differences in installation time. The increase of highly variable and concentrated load is expected mostly during peak hours and in high density urban territories .
- This will raise challenges for the energy system, such as voltage, peak load and congestion, and confront DSOs with considerable investment challenges to increase the capacity of the grid.

Increase the robustness and resilience of smart distribution grids

- When the locally produced energy exceeds the local demand and distribution capacity, or in case highly concentrated and variable load exceeds the capacity of the grid, congestion occurs. This could ultimately result in a system overload, which triggers grid safety systems to switch off a specific area to prevent damage to the infrastructure, resulting in a power outage in that area.
- Energy storage is an option that can increase the robustness and resilience of distribution grids, since it peak-shifts the load and thereby allows DSOs to avoid the occurrence of congestion and power quality problems. It also maintains system stability and facilitates the increase in generation of renewable energy sources in the short and long term.

Act on local flexibility markets or own local storage facilities

- The use of energy storage allows the faster deployment of renewable energy, which is beneficial to reaching the EU's renewable energy target.
- Therefore DSOs must be able to use local storage capacity offered on local flexibility markets, when this is cost effective to manage short term unpredictable fluctuations to avoid congestion.
- When this short term capacity cannot be provided by market parties, DSOs must be able to use own energy storage facilities to provide the required flexibility to the system, in order to maintain security and quality of supply.
- The incremental capacity that energy storage provides to the DSOs can, in the long term, defer or reduce investments in additional grid capacity. These long term investments in storage capacity can be considered as a DSO responsibility similar to traditional grid investments such as cables.

Account for the energy flows caused by the use of storage

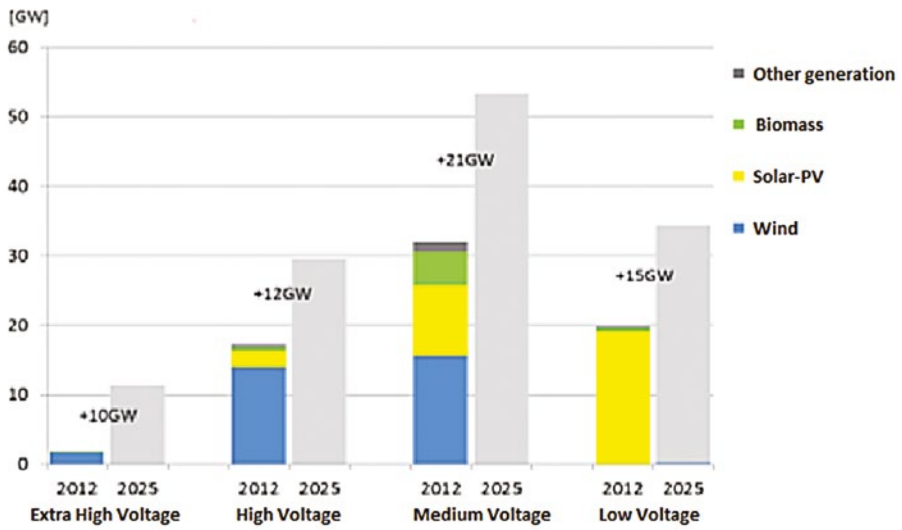
- DSOs must be able to invest, own and operate energy storage facilities as part of the grid when this provides the best available solution to ensure the long term distribution of energy.
- DSOs must ensure transparency and accountability about the use of the energy storage capacity.
- In order to account for the energy flows caused by the use of energy storage facilities, there are three options:
  - Re-dispatch by the DSO;
  - Administrative compensation of storage actions with the grid losses;
  - Storage as a grid connection.
- The operational decision to charge or discharge a storage facility in order to provide the required action to maintain security and quality of supply, must lay with the DSO. However, for the last two options, the reverse action (discharging or charging) can be taken within a certain time frame in coordination with BRP's.

STORAGE AS A TOOL FOR SMART DISTRIBUTION

The broader picture

Based on the EU energy and climate goals, the European Union and its member states are committed to increase the amount of renewable energy over the next years up to 20% of the final energy consumption in 2020, and to rise to an average of 27% in 2030 in the EU member states. A large part of this renewable energy, such as electricity from PV-panels and biogas from digesters, will be generated on a local scale. Therefore, the feed-in of different forms of renewable energy will continue to occur for a large part in the distribution grid, as can be seen in figure 1.

FIGURE 1 - Grid connected renewable energy generation capacity on transmission and distribution level and expected growth in Germany



(Source: EEG-Anlagenstammdaten and expectations VKU)

The continued increase of distributed renewable energy generation poses challenges for the energy system as a whole and for DSOs in particular, namely:

- Due to the variable character of renewable energy, such as solar-PV and wind, high fluctuations will occur in the system. This will be especially the case since the time and amount of generation will not often take place simultaneously with demand. The grid is not designed to transport these high peak loads and therefore congestion can occur, for example in summer time during a high peak load of solar-PV. This congestion could ultimately result in a system overload, which in turn triggers grid safety systems to switch off a specific area to prevent damage to the infrastructure, resulting in a power outage in that area.
- The variability of renewable energy requires additional balancing power. If balancing power and inertia from conventional power plants are insufficient or lacking, they will have to be replaced or completed by other solutions.
- Fast deployment of distributed renewable energy generation will most likely exceed the capacity to install additional grid reinforcements in some areas. This is caused by a difference in installation time between grid reinforcements and new renewable generation installations.
- The feed-in of especially solar-PV leads in some cases to power quality issues where the voltage level exceeds the required specifications, which could potentially lead to damaged consumer's equipment.

In addition, DSOs are facing a change in energy consumption patterns, with increasingly variable and concentrated load on the grid – heat pumps, electric vehicles, air conditioning systems – mostly in peak hours and in high density urban territories .

DSOs must ensure that the distribution grid is robust enough to guarantee the security and quality of supply, yet is agile enough to allow the speedy connection and successful integration of distributed generation. Currently DSOs tackle these challenges by reinforcing the grid with additional capacity where necessary.

The expected growth of renewable energy generation and change in electricity consumption patterns will require a huge investment in grid reinforcements and smartening: the European Commission calculated that up to 2020, distribution grids would require a total investment of €400 billion (Source: EC 2011). Next to grid expansions and reinforcements, other options for a DSO to manage congestion and voltage problems are:

- **Local flexibility market:** when congestion problems are foreseen, a local flexibility market could be developed. Local flexibility is then priced to reflect the scarcity of distribution capacity.
- **Curtailment**: the generation of energy or the consumption level is limited, based on the available distribution capacity.
- **Energy storage:** the excess amount of energy is buffered in the grid and released at a later time.

While all 3 options have their pros and cons, DSOs are responsible for the cost effective distribution of energy and must be able to select the best option which is available to them, within their specific regulatory framework.

Since energy storage can constitute an alternative solution for the challenges outlined above, the analysis will be further developed in this paper.

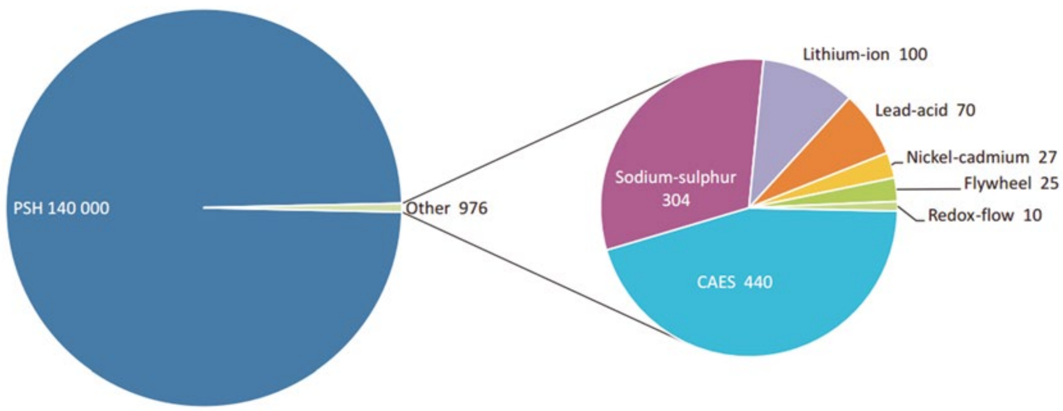
Energy storage: more than a battery

CEDEC considers any device or media used for storing energy, and which is able to store and release energy at a controlled moment in time, as energy storage. The release of energy could either occur in the same form of energy as it was absorbed, or in cross energy solutions such as power-to-gas or power-to-heat.

Energy storage is already widely used to store various energy forms, such as gas or heat, within the energy system. It provides flexibility to the system by buffering energy at a point where an excess of energy exists and that can be released and used at a later point in time. Energy storage is, for example, used for natural gas, which is often stored in depleted gas fields or salt caverns during summertime to guarantee the supply in winter. Hot water boilers are used, for example, to store thermal energy. In order to store electricity, it is necessary to convert it into another form of energy.

Pumped Storage Hydro (PSH) is the technology most often used to store electricity, as can be seen in figure 2. Electricity is stored by pumping water to a higher altitude (converted to potential energy) and releases this at a later time where a turbine is used to convert it back to electricity. Other forms of electricity storage are currently under development and increasing in capacity. Cross energy solutions such as power-to-gas or power-to-heat could also provide the same flexibility to the system as energy storage.

FIGURE 2 - Current capacity grid connected storage worldwide



(Source: IEA 2014)

From centralised to decentralised storage

Most forms of energy storage which are currently applied, such as Pumped Storage Hydro (PSH) occur on a large scale on specific locations and are used within the wholesale market. These locations are mainly determined by geographical and geological characteristics, such as the presence of difference in altitude and availability of water.

However, due to the increase of variable decentralised energy generation the need for local flexibility will increase. This flexibility could, amongst others, be provided by energy storage. Decentralised energy storage will become increasingly attractive in the coming years since the prices of different energy storage technologies are expected to decrease.

Energy storage could be used for different purposes and by different parties, such as storing self-generated electricity by prosumers, or trading by market parties. Each role and each purpose requires different characteristics of the storage technology. Some applications would require a high power capacity (kW), to charge a battery for example;while other situations require (also) high capacity (kWh). Although energy storage is a scalable technology, there may be occasions where this scalability is limited, due to space limitations on specific locations for example. Therefore, a case by case consideration must be made on which energy storage technology and which characteristics are suitable solutions for a specific situation.

Energy storage for smart grid operation

The flexibility that energy storage provides, can also be used by DSOs in the operation of the distribution grid. One can differentiate two types of solutions where energy storage can be beneficial for the operation of the grid, namely:

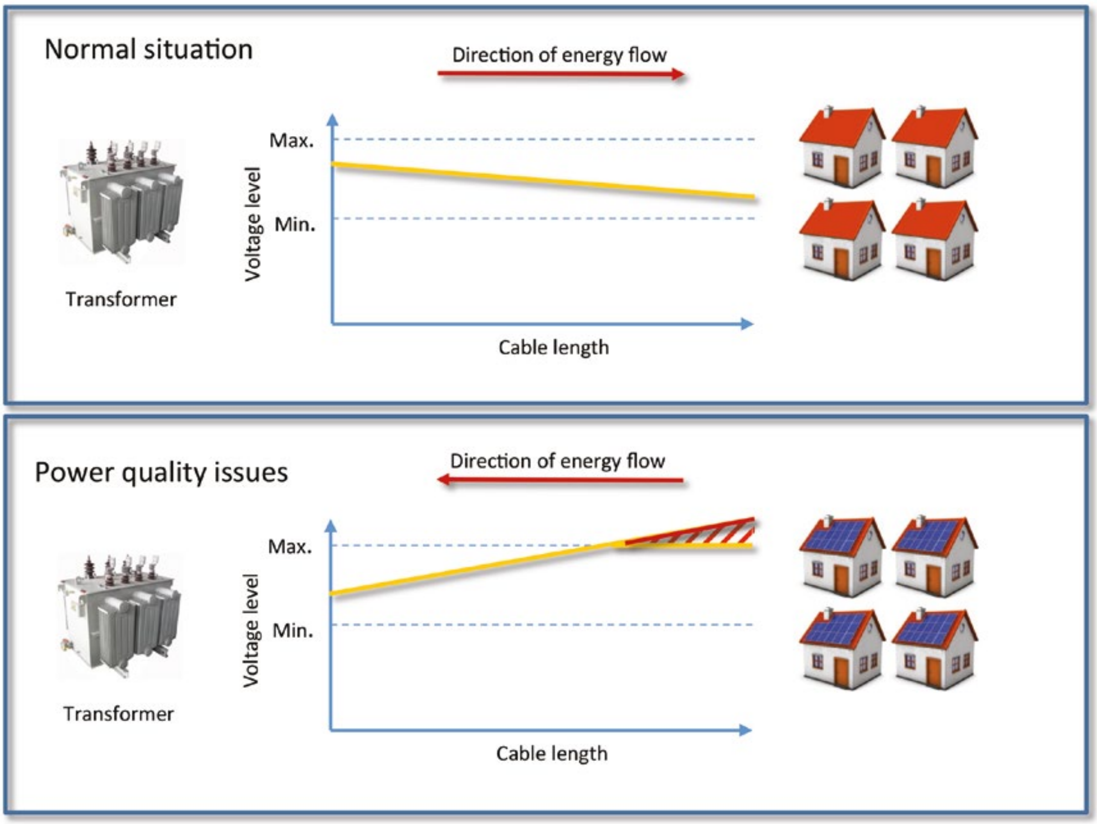
- Short-term system management solutions;
- Long-term system management solutions.

Short-term system management solutions

Energy storage can provide several benefits in the effective and safe operation of the grid:

- Energy storage can provide incremental capacity to the grid in case a short and high peak load causes congestion. This guarantees the uninterrupted supply of energy to the end-users and reduces the stress for the network.
- The instalment of energy storage can also allow the continuous feed-in and additional deployment of renewable energy. This would be beneficial to reach national and EU targets for renewable energy.
- Energy storage can also be used to avoid power quality issues, occurring mostly in rural areas. In these areas, the increase in cable length in combination with the feed-in of solar-PV has an effect on the voltage level: the required specifications cannot be met, as illustrated in figure 3. This could lead to damaged electrical equipment for end-users.

FIGURE 3 - Example of power quality issues, which could be resolved with energy storage



Normal situation (figure 3): In the 'normal' distribution situation, without any decentralised generation at the level of end-users, the voltage level will decrease with the (longer) distance from the transformer, because of the losses in the cable.

Power quality issues (figure 3): With a lot of decentralised generation which is not (completely) consumed at the end-users side, the electricity flow will reverse and may even inject into the higher voltage grid. This may cause locally higher voltages - even too high voltages which will cut off the decentralised generation. Local energy storage (see red-striped area in figure 3), in this case working as an additional load, can be used to lower the voltage level again and so to reduce power quality issues.

Energy storage can be used to solve these short term system management issues and so to increase the security and quality of supply. This can be done on a temporarily basis, until a structural solution like grid reinforcement will be in place, or on a structural basis.

These solutions are needed on a specific location to tackle a specific issue. This requires the energy storage facility on the specific location to have the necessary power capacity (kW) to (dis)charge at the right ramp speed. However, it also requires sufficient energy capacity (kWh) to store the energy for the required time until the required distribution grid capacity is available, or the power quality issues are solved.

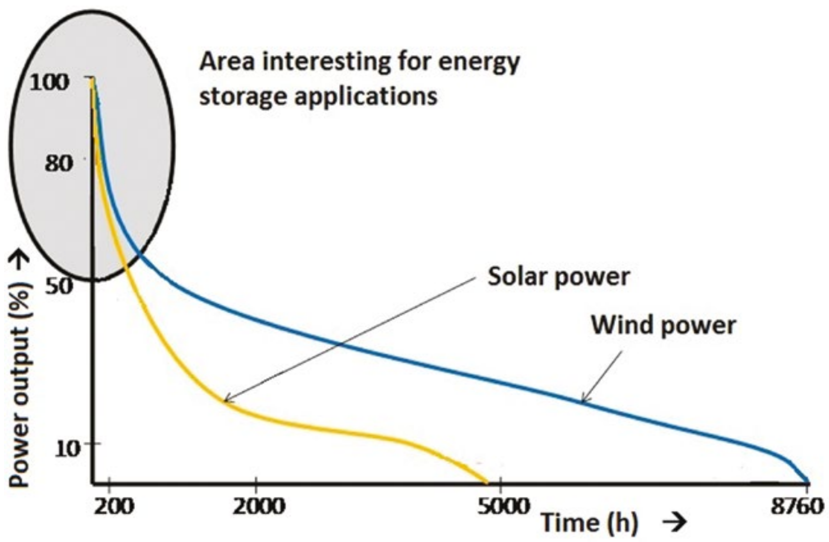
The availability of reactive power management is also important and could be taken into account when considering different solutions.

Long term system management solutions

DSOs, as regulated parties under strict control of a NRA, perform their operations as cost efficient as possible. Variable renewable energy generation, such as solar-PV and wind, seldom generate on their full capacity, as it is illustrated in figure 4.

The expected increase in variable renewable energy generation forces DSOs to invest in additional grid capacity. This is currently in most Member States the only option DSOs have. Consequently, this requires additional grid reinforcements to cover the full renewable generation capacity. Since in this case a significant part of the distribution capacity will not be optimally utilised, the investment in additional distribution capacity is suboptimal in terms of cost efficiency.

FIGURE 4 - Typical load duration curves for solar-PV and wind power

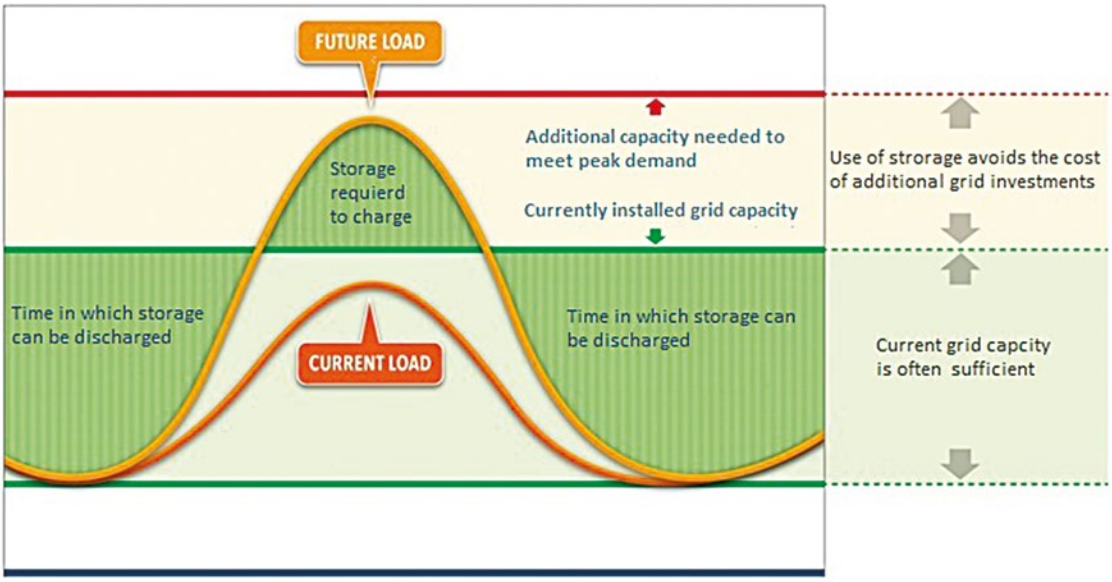


(Source: DNV GL)

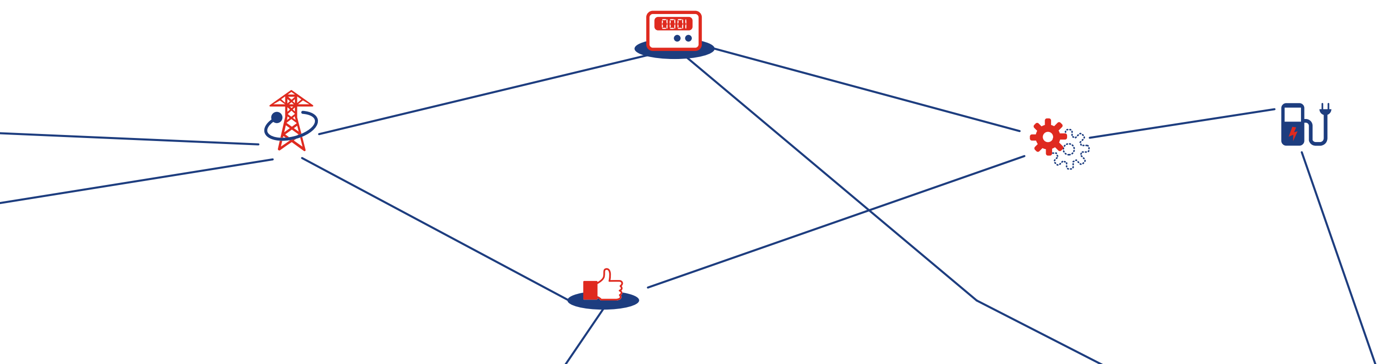
Energy storage provides incremental capacity to the grid and allows peak shifting . The peak of energy load is shifted from a time where no distribution capacity is available due to a high load, to a time where there is enough distribution capacity available. This allows a more (cost) efficient use of the grid, as investments in grid expansion can be avoided or deferred.

Figure 5 illustrates the effect of peak shifting by energy storage as a smart grid operation.

FIGURE 5 - effect of peak shifting by energy storage on the grid investments



(Source: NRSTOR)



DSO access to third party energy storage or own energy storage facilities

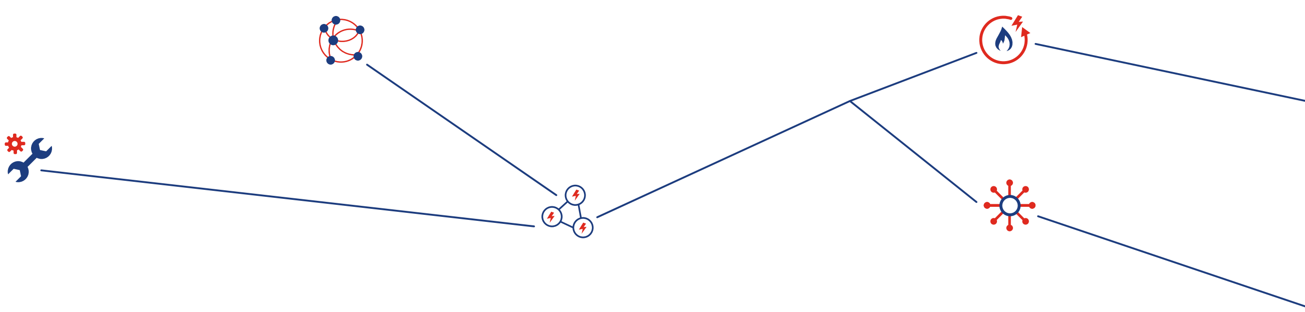
DSOs are responsible for the distribution of energy to end-users and for system quality in a cost effective way. Energy storage can provide long and short term benefits as grid assets, as pointed out above.

DSOs must also be able to make use of local storage capacity of third parties (like consumers or aggregators) when this is offered on a local flexibility market and when it is cost effective. This could then be used by DSOs to manage short term fluctuations, which are hard to predict and thereby avoid congestion in the short run. For DSOs it is important that the availability and reliability of this capacity can be guaranteed to them. The storage facility should furthermore have sufficient ramp speed and storage capacity to provide the required services.

Since a DSO will require the storage capacity at a specific point in the grid, it will be hard to reach a liquid market with no risk of market power abuse or gaming. This difficulty will most likely have a negative effect on the price of storage services for DSOs. When the needed short term capacity cannot be provided by market parties or cannot be provided by market parties at a reasonable price, DSOs must be allowed to (temporarily) use their own energy storage facilities. They will then provide the required flexibility to the system in order to maintain the expected security and quality of supply.

Where energy storage can provide a structural long term solution on a specific location in the grid, in case it is the most cost effective solution for the distribution system, it facilitates all parties to produce energy to the full extent, not hindered by a shortage in distribution capacity. This long term investment in storage capacity can be considered as a DSO responsibility similar to traditional grid investments. Therefore, DSO must be able to invest in, to own and to operate energy storage facilities as part of the grid when this provides the best available solution to ensure the long term distribution of energy.

The addition of energy storage as a grid asset requires a shift in the regulatory framework for most member states. Especially in these cases it is important that DSOs are transparent about the use of energy storage and accountable to the national regulatory authority.



Storage and shifting energy flows

In order to physically balance the energy system, it is key that supply and demand are matched at every point in time. Therefore each flow of energy must be accounted for in order to provide overall system balance. Whereas each Balance Responsible Party is responsible to balance his own portfolio, the balancing of the system is a task of the system operator, usually the TSO. BRPs will try to minimize the imbalance in their portfolio since imbalances lead to additional costs. BRPs are jointly responsible for all energy flows in the system.

The use of energy storage by a DSO is shifting energy flows in time. In order to account for these flows one can distinguish three options:

- Re-dispatch by the DSO;
- Administrative compensation of storage actions with grid losses;
- Storage as a grid connection.

Re-dispatch by the DSO

When energy is stored by the DSO in a storage facility owned by the DSO at a particular point in the grid in order to avoid congestion, a certain amount of energy is subtracted from the system. This amount of energy was fed into the grid and measured at one or more connection points, but has not been consumed at the same time by the system users. The physical balance is restored when the same amount of energy is fed back into the grid by the DSO at another location where sufficient distribution capacity is available.

Since the energy fed back into the grid is not from a particular BRP, no additional administrative measures are required. As long as the same amount of energy is fed back into the system, it does not matter on which exact location or on what voltage level.

When the storage facility which has been used to store the energy, is later discharging, the reverse process should be followed. Therefore, it makes sense to use two storage facilities to charge and discharge at the same time. This way the energy is “virtually” or “administratively” transported.

Administrative compensation of storage actions with grid losses

Grid losses usually consist of physical losses and administrative losses (mainly fraud). The grid losses are expressed as a certain value of energy (kWh) per 15, 30 or 60 minutes. Usually the profile of the grid losses is closely linked to the profile of the distributed energy. However, the grid losses are an estimation as - by nature - they cannot be measured. In many Member States the DSO is responsible for the grid losses at the distribution level.

The energy stored in a storage facility run by the DSO for congestion management purposes can be measured. The amount stored can be added to the estimated grid losses for the particular 15, 30 or 60 minutes energy value. When the storage facility is discharged, the grid losses are lowered with the amount of energy that is discharged and fed back into the grid. This way the administrative balance is maintained and all energy is accounted for.

The discharging of the storage facility should be driven by technical considerations, meaning when it is safe to discharge. Market prices should have no influence on the timing of charging or discharging. However, if the grid losses are bought from a BRP and it is profitable for the DSO, the timing of the discharging of the storage facility must be coordinated with the BRP. Of course within certain time frames and under certain conditions, to be agreed in a contract.

Storage as a grid connection

The storage facility of the DSO is connected to the grid. If this connection is measured and is considered as a normal grid connection, it must have a supplier and a BRP, comparable to a grid connection for an office of the DSO with PV panels on its roof.

It is possible that the DSO enters into a special contract with the supplier/BRP for a storage facility, keeping it exclusively available for the DSO during a certain period of the day, for example from 7am till 7pm when solar panels can be at their peak. During the evening and the night it is then up to the supplier/BRP to discharge the storage facility at the most profitable time.

These three options would ensure the neutral position of the DSO, while the market is not negatively influenced. DSOs should only use energy storage where it is required for the safe and efficient operation of the grid. Therefore, the operational decision to activate (charge/discharge) the storage facility in order to provide the required solutions to the system must lay with the DSO.

However, for the options where the shifts in energy flows are part of the grid losses or a storage facility is seen as a grid connection, the reverse action can be taken in coordination with BRPs, within certain time frames, and when this does not intervene with the operation of the grid. This would require a clear contractual agreement between DSO and BRP.

BEST PRACTICES

WEMAG STORAGE BATTERY AN EXAMPLE FROM GERMANY

In Schwerin the electricity supplier WEMAG AG runs a lithium-ion based energy storage to compensate rapid network variations. The energy capacity is 5 MWh and the electric power capacity 5 MW. It was brought online in September 2014. The lithium-ion based energy storage consists of 25,600 lithium manganese oxide cells and 5 medium-voltage transformers. It is connected to the regional distribution network as well as to the 380KV high voltage grid.

Name of storage project	WEMAG storage battery
Location	Schwerin Lankow / Germany
Technology	Lithium-Ionen
Capacity	5 MW
Brought online	Sept. 2014
Efficiency factor in % t	85%
Investment	6, 5 Mill. €

Source: WEMAG AG

USE OF PUMPED STORAGE HYDROPOWER IN SCANDINAVIA

Norway manages 50 % of the hydro storage capacity in Europe. More than 99 % of the energy is produced by hydro power. In Sweden it is around 40 %. PSH plants however are rare. Due to low energy prices, the PSH is not economical to run. The need for more balancing power on the European continent might open a new market if the connection between Scandinavia and the continent would expand .

Sweden's largest PSH, Juktan, was commissioned in 1978. In 1996 Juktan was converted into a standard hydropower plant. All the pumping functions remained and there are now plans to restore the PSH: this would allow to increase the supply of balancing power, in line with the continued expansion of wind power. Juktan is located close to the Blaiken wind farm with a capacity of 250 MW.
Juktan has a capacity of 26 MW as a conventional power plant, and 335 MW as a PSH plant.

Lake Kymmen is with its 57 MW capacity the second PSH in Sweden. Because of the water regulation directive, the power plant is not in use in summer time. In a recently posted article Fortum is pleading for a change in the water regulation directive to make better use of wind power during low load.

In Sweden PSH is used for daily storage , whereas in Norway PSH is used for seasonal storage.

THE "ENERGY STORAGE CLOUD"
EWE PROJECT GREEN2STORE

The goal of the green2store project is to ensure that a greater proportion of renewable energy generation can be integrated into the distribution networks. The project aims to develop a local storage system that contributes to increasing network intake capacity for renewable energies.

As there have been great obstacles up to now in relation to investing in storage technologies, the project's primary goal is to enable non-discriminatory access to all storage units from a technical point of view, and thereby to achieve more intensive use and greater economic efficiency.

As part of this project and in view of these specifications, a cluster is being designed, developed and researched that combines a local network storage unit, an area storage unit, a campus storage unit and nine household storage units into one overarching storage system with enhanced capabilities called "Energy Storage Cloud". This is being tested and demonstrated in a field trial and is being made available not just to the owner, but also to any other player (Multi Purpose Use).

In summary, the project aims to answer a central research question on the integrative usage of local storage units by various players in the energy industry: how can this usage both technically, and in terms of the energy industry, enable the intake of further renewable electricity generation by the distribution network, without increased network development, and thereby ensure a sustainable conservation of resources ?

The green2store project is funded by the Federal Ministry for Economic Affairs and Energy of Germany (BMWi). Members of green2store are EWE AG, EWE NETZ GmbH, Alcatel-Lucent Deutschland AG, BTC Business Technology AG, ABB AG Deutschland, Süwag Energie AG, OFFIS e. V., NEXT ENERGY, EWE-Forschungszentrum für Energietechnologie e. V., Institute for High-Voltage Technology and Electrical Power Plants at Brunswick Technical University.
The project started in November 2012 and is funded for four years, with a budget of 9 million Euros.

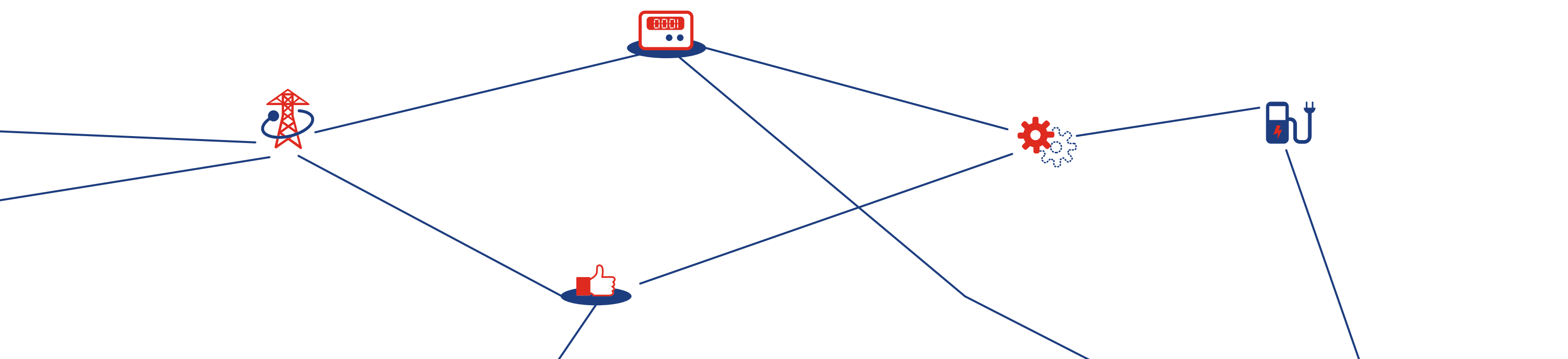
THE "NEIGHBOURHOOD BATTERY" LOCAL COMMUNITY BATTERY EXAMPLE FROM THE NETHERLANDS

The DSOs Enexis and Liander are testing a smart storage solution in a neighbourhood of the Dutch town Etten-Leur, with many houses with PV on the roof. In 2012 a 'neighbourhood battery' was installed to store the electricity that is generated by the household's PV panels. The battery prevents the electricity that is produced during day times to leave the neighbourhood and the Low Voltage part of the grid. The battery is usually filled during daytime hours and discharged during evening hours, when people arrive at their homes after work. An additional software solution defines optimisation of charging moments of electric vehicles in the neighbourhood. The households are using a smart phone based solution to define their parameters for charging their electric vehicle.

The pilot will be evaluated in 2017.

Some facts and figures:

- Total installed PV capacity in the neighbourhood: 180 kWp.
- Smart storage solution (to a large extent below surface): 4 lithium-ion batteries with a joint capacity of 232 kWh, equivalent capacity for an average household usage for two weeks.
- Smart storage unit: connected with a MV/LV transformation station (from Medium Voltage (10 kV) to Low Voltage (400/230 V)).
- 100kW-inverters: they assure AC/DC invertion to allow injection of PV generated electricity into the grid without major quality issues.



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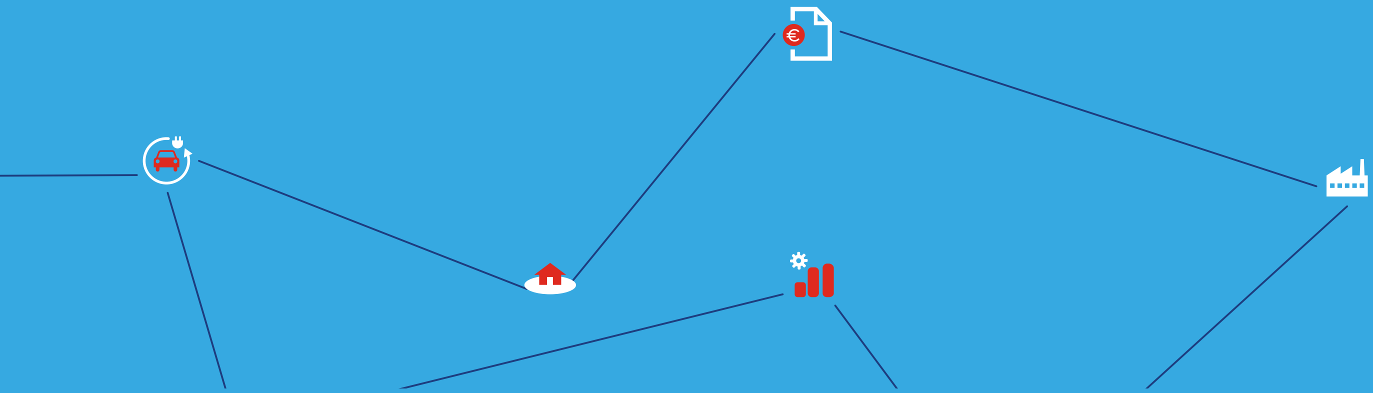

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