Grid-scale flow batteries

EUDP Final Report

EUDP 2019-II 64019-0566

September, 2021

Contents

1. Project details

Project title	Store flow-batterier til elnettet Grid-scale flow-batteries
Project identification (program abbrev. and file)	EUDP 2019-II Projekt no. 64019-0566
Name of the programme which has funded the project	EUDP ENERGITEKNOLOGISK UDVIKLINGS- OG DEMONSTRATIONSPROGRAM
Project managing company/institution (name and address)	Nordisk Energirådgivning ApS Ved Skoven 6 DK-3070 Snekkersten
Project partners	Skanda A/S, CVR 14481834 Inter Terminals Denmark A/S, CVR 33757905 Dansk Energirådgivning A/S, CVR 32785905 HOFOR Vind A/S, CVR 33354304
CVR (central business register)	35242775
Date for submission	15 September 2021

2. Short description of project objective and results

UK

The need to establish major cost-effective energy storage systems in the public power system grows as we begin using more renewable energy. Therefore, the purpose of this project is to investigate the design-related and technical opportunities to install and integrate grid-scale flow batteries to the Danish power system.

This project has determined that a grid-scale battery for the Danish power system can benefit from being placed near existing power plants and major oil terminals. Data from the electricity market also show that one should establish a battery system that has a storage capacity of at least five hours and ideally longer. This will improve the economy of the battery system and make it easier to optimize the use of renewable energy in the power system.

On a technological level, the project group has concluded that all-iron batteries are expected to be the most suitable - both financially and technologically - when it comes to grid-scale energy storage systems. The project group therefore recommends that the goal should be to construct a pilot system with a capacity of 3 MW / 36 MWh with all-iron technology in order to test the technology in the Danish power system.

DK

Behovet for at etablere store, omkostningseffektive energilagre i det kollektive elnet stiger i takt med udbredelsen af vedvarende energi. Derfor har dette projekt til formål at undersøge de designmæssige og tekniske muligheder for at opføre og tilslutte store flow-batterier til det danske elnet.

Med projektet er vi kommet frem til, at et stort batteri til det danske el-system med fordel kan placeres i forbindelse med eksisterende kraftværker og store olieterminaler. Data fra el-markedet viser også, at man bør etablere et anlæg, der har en lagerkapacitet på minimum 5 timer og gerne længere. Dette vil forbedre anlæggets økonomi og vil forbedre muligheden for at optimere udnyttelsen af VE produktion i elnettet.

Teknologimæssigt er projektgruppen kommet frem til, at all-iron er den forventelige mest fordelagtige batteri-teknologi, både økonomisk og teknologisk, når det gælder store el-lagringsanlæg. Det er derfor projektgruppens anbefaling, at der sigtes efter at opbygge et pilot-anlæg på 3 MW / 36 MWh med all-iron som teknologi til afprøvningen af teknologien i det danske elnet.

3. Executive summary

The purpose of the project was to investigate and at length develop prototypes for grid scale flow batteries for the power system. The project work was based on reusing large steel tanks that had previously been used to store fossil fuel.

The flow batteries that are available today are mainly vanadium or zinc/bromide battery systems. These are based on small-scale household storage capacities, typically in the range of 5 kW and around 20 kWh. The technological opportunities for upscaling and testing the use of flow batteries in the MW range for the grid have to be investigated, if the technology is to be used to solve the pressing need to store electricity generated by renewable energy sources.

It is expected that in the long run there will be larger and cheaper flow battery modules on the market which will be more suited for large storage capacities connected to the electrical grid. Unfortunately, the pace of development is slow and the scaling up of battery storage systems intended for use in the public grid is today typically done by connecting hundreds of individual modules. With funds from EUDP, this project has investigated how a battery storage system can be designed and connected to the public grid for the purpose of storing the increasing amounts of fluctuating energy generated by renewable energy sources in the Danish power system.

Li-ion is currently the most used battery technology, but the technology is assessed as being a transitional technology in terms of storing large amounts of energy in stationary storage systems, as li-ion batteries are limited in terms of: price, due to the large demand from other industries (including the auto and consumer electronics industry), the fact that cells get depleted from frequent charging and discharging and due to fire safety issues.
The project group's investigation of other battery technologies has shown that using vanadium in flow batteries is not a good solution, mainly due to price and application issues. On the other hand, it is assessed that currently all-iron batteries are the most promising battery technology for scaling, particularly due to their power and price level. all-iron batteries are expected to be both cheaper and better than Li-ion and vanadium systems.

It is therefore the recommendation of the project group that work continues on a pilot plant on a scale of 3 MW / 36 MWh using the all-iron technology.

Price comparison between different storage technologies for a 3 MW unit:

Type:	Hours of full load operation	Power capacity [MW]	Storage capacity [MWh]	Specific price level [Index pr MWh]
Li-ion	1	3	3	Index 100
	5	3*	15	50
	12	3*	36	40
Vanadium	1	3	3	265
	5	3	15	80
	12	3	36	45
All-iron	1	3	3	315
	5	3	15	70
	12	3	36	38

**output reduced to 3 MW to reach the required duration of operation*

4. Project objectives

The project's primary objective was to develop a technical solution model and a budget for establishing grid-scaled flow batteries in the public power grid. The project has thus been aimed at optimizing the establishment costs for creating energy storage systems by investigating the possibilities of reusing existing large steel tanks originally used for oil storage as the container component of a flow battery.

The project's activities were divided into five work packages: Below, is a description of the objective for each work package, whether the development progressed as planned and whether the agreed upon milestones were reached in addition to what risks were associated with each work package.

Work package 1: Project management and administration	
Objective	The purpose of this work package was to ensure that the project consortium worked in the same direction and that the course of the project was planned in such a manner that the knowledge and results gained from each work package create synergies and act as input to other work packages.
Work package 2: Using steel tanks as containers in flow battery	
Objective	The objective of this work package was to ensure that the different types of flow batteries were investigated in terms of their suitability for storage in existing steel tanks.
Milestones	• Paper on types of flow batteries and their characteristics • Paper on environmental and health and safety conditions • Paper on the opportunity to reuse the tanks (if relevant, with a new coating) and associated pipes, valves and pumping units. • Report on technology recommendation for a certain type of battery
Development and unforeseen problems	After the mapping of technologies, at first vanadium was chosen as the best medium, as it is currently the most available and mature technology. However, the results showed vanadium systems for grid scaled storage systems is less suitable due to the price, and the coating applied to large steel tanks is not durable enough and is associated with major risks. As an alternative, the zinc-air and all-iron technology was examined, which is both cheaper and better suited for steel tanks.
Work package 3: Integration of the flow batteries into the Danish electricity market	
Objective	This work package examined the opportunities to connect the large-scale flow batteries to the Danish power system. The result was used to assess which commercial business models were best suited for grid-scale flow batteries.
Milestones	• Reports that examine market models, for example, the benefits in the grid compared to the possible financial revenue that can be achieved with the flow battery. • Paper on requirements for connecting the flow battery to the grid and the current regulation. • Evaluation of operational experiences and risks with current operating flow batteries.

Development and unfore-seen problems	The various services a flow battery can provide to the power grid were mapped, and the results showed that, besides functioning as a storage system for excess energy from renewable sources, flow batteries can also provide utility services to the electrical grid to achieve the optimal revenue. In the work package, the aim was to collected experiences from other major battery storage systems, but unfortunately, the project group had to downsize its activities due to COVID-19.
Work package 4: Designing grid-scale flow batteries	
Objective	The purpose of this work package was to find the best solution for developing grid-scale flow batteries in existing steel tanks and how they should be designed to become a cost-effective solution model.
Milestones	• Project proposal for completion of a pilot project • Design guide for flow batteries in existing steel tanks
Development and unfore-seen problems	Two design guides were developed, one using vanadium technology and the other using all-iron technology. The case study was based on a 3 MW / 36 MWh solution. The using og steel tanks as container components in the flow battery were deemed unfeasible due to the technology disadvantages found under work package 2.
Work package 5: Selection of pilot project	
Objective	Based on the most suitable solution found in work package 4, this work package was to select and design a suitable pilot project to test and demonstrate this technology in operational environment.
Milestones	• Project proposal for completion of a pilot project • Work with authority processing • Fire and health and safety assessments
Development and unfore-seen problems	Based on the work with the battery design in work package 4, the project group has worked on how a grid scaled pilot project could be prepared. However, current taxes and tariffs make it infeasible to establish grid-scale batteries in the power system. The project group has therefore looked at how a battery could be placed together with a renewable energy source together with an oil terminal. Partly to avoid double tariffs, and partly in relation to how the battery can provide utility to the power grid, to the oil terminal and to the wind or solar park.
Work package 6: Dissemination	
Objective	Work package 6 contains the dissemination of the project result and preparation of the final report.

Milestones	• Final report
	• Articles on the knowledge acquired from the establishment of grid-scale flow batteries via relevant magazines such as:
	  o Ingeniøren
	  o EnergySupply
	  o Dansk Energi
	  o Relevant social media, such as LinkedIn

	• Holding a theme day at the selected site
Development and unfore-seen problems	The project completed the following communication activities: Homepage, press releases, ect. Press releases and articles can be seen in the appendix. The theme day where cancelled due to covid-19.

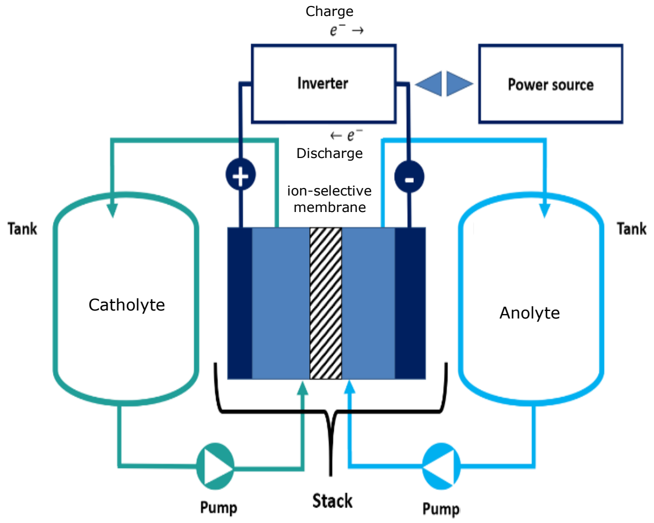
5. Project results and dissemination of results

5.1 Flow batteries in general

A redox flow battery is a battery in which the energy is stored electrochemically in a fluid. Generally, the batteries are charged with excess electricity generated by renewable sources such as solar or wind. The energy is stored in the electrolyte fluid in the redox flow battery until the energy is to be used, at which point it can be return in the form of electricity.

A redox flow battery consists of three main components:

1. Tanks used to store the electrolyte fluid. The size of the tanks determines the amount of energy that can be stored. The larger the tank, the more capacity. There needs to be used at least two tanks in a flow battery; one for the positive side (catholyte) and one for the negative side (anolyte).
2. The stack, which consists of ion-selective membranes that ensure that ions can wander between the anode and cathode sides during charging and discharging.
3. Pumps that pump the fluid from the tanks and through the stack and back to the tank again.



Characteristics of flow batteries:

- The storage capacity is scalable. It just requires larger tanks.
- Long life-expectancy and operationally reliable, and thus has relatively low lifetime costs
- The electrolytes that store the energy are non-flammable
- The chemistry of the electrolyte fluid is well-known and manageable
- The electrolyte fluids are poisonous to varying extents

5.2 Mapping of technologies

The project first mapped the various commercially available flow battery technologies currently on the market. The technologies needed to be examined in relation to suitability for grid-scale batteries and in terms of using existing steel tanks for storage. The study focused on:

- Composition of electrolytes
- Mass
- Toxicity
- Temperature intervals
- Lifetime
- Energy density

The following is an overview of the most commonly used technologies at present.

Flow battery type	Anode	Cathode	Density $\left[\frac{kg}{L}\right]$	Safety	Temperature interval [°C]	Lifetime	Energy density [Wh/L]
Vanadium	V(II)/ V(III)	V(IV)/ V(V)	1.324	Toxic to the aquatic environment in high concentrations	10-40	12,000-20,000 cycles	15-25
Zinc-Bromine	Zn/Zn^{2+}	2Br/$2Br^{-}$	1.5	Bromide is a very toxic gas	20-50	>2,000 cycles	16-39
Polysulfide-Bromine	Polysulfide	Br/Br^{-}	3.2	Bromide is a very toxic gas	20-40	>2,000 cycles	11-60
Iron-Chrome	Cr^{2+} /Cr^{3+}	$\frac{Fe^{2+}}{Fe^{3+}}$	-	-	40-60	750	11.5
ORBATS	$AQDS$ $(NH_4)_2$	NH_4I	1-1.3	-	-30-50	-	17
Copper battery	Cu^{+}/Cu	Cu^{+}/Cu^{2+}	> Vanadium	-	5-70	-	20
Zinc-air	Zn/Zn^{2+}	O_2 /OH^{-}	1.28	KOH is very alkaline	10-40	20 years	250-1,000
All-iron	Fe^{2+}/Fe^{+3}	Fe^{2+}/Fe^{+3}	-	-	10-50	25 years	15-25

5.3 Suitable technologies

Vanadium

Based on parameters such as availability, lifetime and usability, the project group first chose the vanadium technology (VRFB). The vanadium flow battery has the advantage that the same electrolyte is used on both the anode and cathode side, whereby cross-contamination is eliminated if a leak occurs between the two sides. This increases the lifetime of the battery considerably and the lifetime of a VRFB will typically be over 20 years. In addition, the electrolyte is completely reusable after 20 years and thus maintains its market value.

The anolyte must not come into contact with air, as the oxygen in the air will oxidize the electrolyte and this will reduce the battery's overall capacity. Therefore, the gas at the top of the storage tank must be an inert gas which isolates the electrolyte from the oxygen in the air. The vanadium electrolyte works in a temperature range of 10-40 °C. It is important to emphasise that the temperature around the battery can easily be outside of the temperature interval of 10-40 °C without damaging the battery - it is only the electrolyte that needs to be within this temperature range. The surrounding temperature could therefore in theory easily

be at -5 °C or 50 °C without damaging the battery as long as the temperature of the electrolyte is in the range of 10-40 °C.
Under normal conditions, there is neither generated hydrogen or oxygen gas during the charging and discharging processes.

Zinc-air
The zinc-air technology was examined as an alternative to the vanadium technology, and was selected due to being more economically feasible and having better opportunities for long-duration storage.

Zinc-air batteries are a promising battery technology due to their very high energy density (250-1,000 Wh/kg) and because the electrolytes they use are significantly less costly than those used by vanadium batteries. A zinc-air battery can be constructed with only a single tank used to store the electrolyte, as the electrolyte's density and viscosity change during the charging process and the charged and discharged electrolytes are thus separated even though they are in the same container. However, it is still recommended to use several tanks.

The chemistry that the zinc-air batteries are based on has been known for a long time (more than 50 years). The electrochemical reaction is based on zinc being used as an active and static anode material while air flows through the flow cell on the cathode side. The electrolyte that the zinc is immersed in is very alkaline (9-12M KOH). With an alkaline electrolyte, there is no problem using steel tanks for storage.

However, the zinc-air system is not commercially available yet.

All-iron
The all-iron technology was also examined as an alternative to the vanadium technology. This technology was selected due to being more economically feasible and having better opportunities for long-duration energy storage such as beyond the normal 4 hours. The technology is commercially available but with only one vendor.

5.3.1 Recommended technology

For the time being all-iron batteries are recommended as the storage technology for the Danish electricity market in the context of integrating flow batteries into the grid. The technology is one of the most promising battery technologies due to its relative low price (100 USD/kWh) compaired to >500 USD/kWh for a Vanadium system.

The all-iron solution has the following advantages compared to a vanadium solution:

1. much cheaper electrolyte
2. allows for larger and more flexible battery storage and thus long-duration storage, which is an advantage in terms of a better utilization of renewable energy compared to the current 4-hour vanadium solutions.

Type:	Hours of full load operation	Power capacity [MW]	Storage capacity [MWh]	Specific price level [Index pr MWh]
Li-ion	1	3	3	Index 100
	5	3*	15	50
	12	3*	36	40
Vanadium	1	3	3	265
	5	3	15	80
	12	3	36	45
All-iron	1	3	3	315
	5	3	15	70
	12	3	36	38

**output reduced to 3 MW to reach the required duration of operation*

5.4 Establishment of grid-scale flow batteries

5.4.1 Vanadium systems

The initial goal of the project was to investigate what kinds of treatment methods that were needed to use the electrolyte in existing steel tanks placed at oil terminals or power plants. The idea of reusing existing large oil tanks was to recycle them as they were phased out in connection with the green transition.

The vanadium electrolyte is strongly acidic with a pH 1 and if the solution is to be used in existing steel tanks, they will need to be coated. Any potential iron contact from the tank's interior construction would be a problem, as hydrogen is formed when iron comes into contact with the vanadium solution. Hydrogen gas is not recommended in areas where oil products are stored.

Several vendors have been asked whether there is a coating on the market that can withstand the vanadium solution. In principle, it is possible to coat the tanks for this purpose, but it only has a lifetime of 2-3 years and require annual inspections. In order to prevent iron leakage, there would need to be installed a covering or floating membrane. Existing oil pipeline systems at the oil plant cannot be used due to the sizes of the pipes – and it would be too expensive to coat them. It is therefore recommended that pipes be constructed from PE100 plastic.

Oil tanks at oil terminals and refineries are generally in the size range of 20-90,000 m^3 and will be able to contain a vanadium energy storage of up to 2 TWh. As the basis for this analysis is to be able to store 10 MWh (equivalent to two tanks of 250 m^3), the existing tanks will be far too large for this amount of energy.

The partial conclusion is therefore that existing steel tanks are not suited for the task of being used with vanadium, mainly due to the low durability with coating. In addition, several current tank storage facilities are built with embankments and soil floors - which are capable of handling Heavy Fuel Oil - but they are not suitable when it comes to containing a vanadium solution spillage.
It is therefore recommended that a vanadium solution is constructed from several double-walled plastic tanks of approximately 150 m^3 and that there should be established a tank storage facility with concrete flooring and walls that is large enough to contain the dimensions of the largest tank plus a safety margin.

With an tank and pipe facility constructed in PE100 plastic and based on a system with 2MW and 10MWh of energy storage, there is a need for 4x150 m³ tanks and a flow of electrolyte of 60-120 m³ per hour with at relatively low pressure over the stack (less than 1 bar). The operation temperature is between 10-40 degrees Celsius.

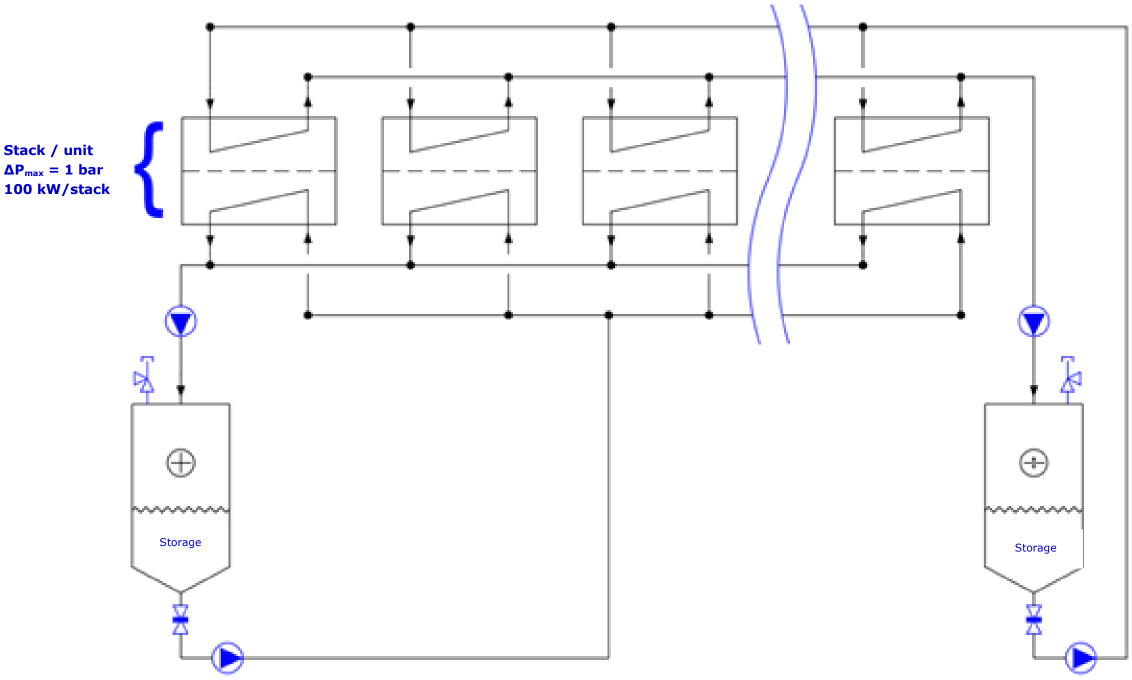


Diagram of a flow battery storage system based on vanadium

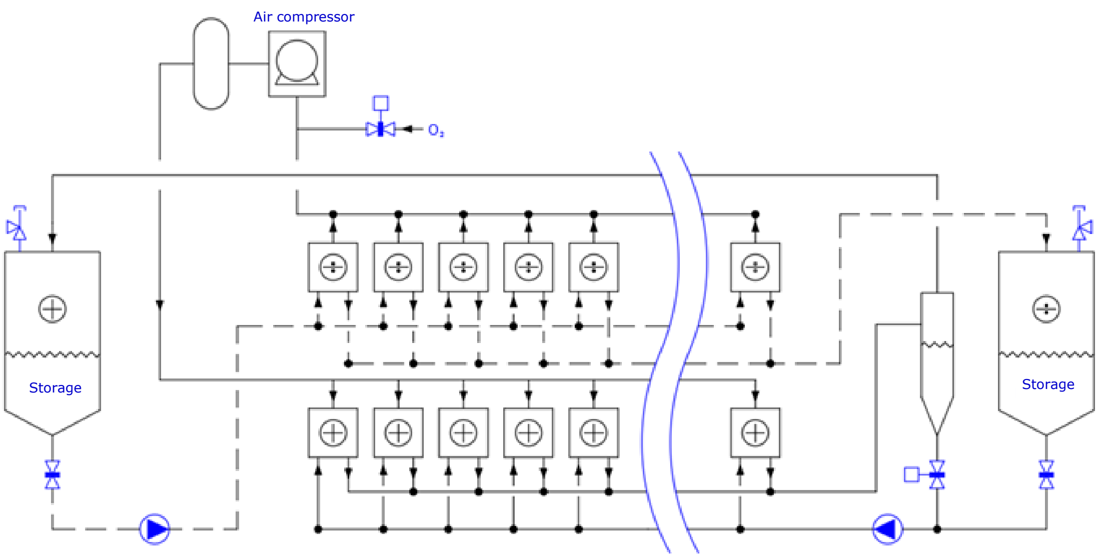
PE tanks can be purchased with a volume of approximately 150 m³ which can be transported by trucks (4 metre diameter, 12 metres high). This will therefore require 3-4 tanks to achieve the desired level of storage. PE pipes can be found up to PN16 (16 bars) in with the required diameters. Similarly, one pump with a plastic pump housing and magnetic coupling can manage up to 300 m³/hour at 5 bar and therefore easily meet the need for 200 m³/hour.

5.4.2 Zinc-air system

The all-iron flow battery has a number of advantages. Besides being a less expensive product, the energy density of the charged solution is approximately 50 times greater than the energy density of vanadium batteries (can hold approximately 1 kWh/litre). This results in small storage tanks of only 75 m³ (for example, 2.5 metre diameter x 2.5 metres high) each in order to be able to store 10 MWh. In addition, the zinc solution is alkaline (pH>13) and can be used in steel tanks without apparent issues.

In relation to the choice of materials, 1.4401/1.4571 (AISI316 / AISI316Ti) has been found to be suitable for the task. The plastic types EPDM (up to 90°C), PTFE, PVC and PP are also suitable choices. Tanks and pipe systems therefore do not need to be insulated for the process to work. As stainless steel is used, there are many opportunities for designing tanks and pipes - even with a density of 1.3 and a viscosity that will vary in the process. Concerning tank facilities, there needs to be established a tank holding area with robust floors/sides (concrete) that is large enough to contain the dimensions of the largest tank plus a safety margin.

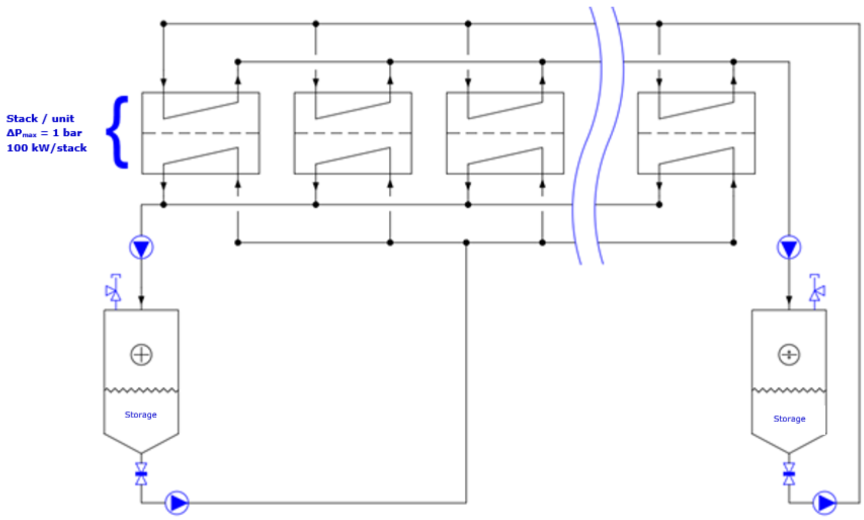
In a 3MW/36MWh setup, there will be needed 2 x 275 m³ tanks for storage and a flow between the stack/valve of up to around 100-200 m³/hour at relatively low pressure (<1 bar over stack). It operates at temperatures of between 10-40 degrees Celsius.



Unlike the vanadium solution where one uses the same stack to charge and discharge, the zinc-air model requires two different stacks for, respectively, charging and discharging.

5.4.3 All-iron system

The all-iron flow battery is in terms of system design a lot like the Vanadium system.



The all-iron electrolyte is strongly acidic with a pH 2 and if the solution is to be used in existing steel tanks, they will need to be coated.

In a 3MW/36MWh all-iron battery, there will be needed 2500 m^3 tanks for storage and a flow between the stack/valve of up to around 100-200 m^3/hour at relatively low pressure (<1 bar over stack). It operates at temperatures of between 10-50 degrees Celsius.

5.4.4 Connection to the power grid

An interconnection between the energy storage system and the public power grid must be established if the storage system is to participate in the electricity and utility service markets. Depending on the geographic location and the nominal power of the storage system, it will be connected at voltage levels specified by the power system operator.

The Danish power system is split into two categories, grids operating below 100 kV are classified as distribution systems, and above 100 kV are classified as transmission system. The process in Denmark is initiated by the distribution system operator (DSO) determining which voltage level will result in the lowest total cost of the interconnection. The main factor in deciding the voltage level is the nominal power of the plant.

Regardless of the voltage level, the storage system can be connected in two ways, either directly to the grid with a completely new interconnection, or by integrating in an existing installation.

By integrating in an existing installation, the owner would already have an established interconnection infrastructure, thus making the CAPEX of the plant significantly lower. Another advantage of having the storage system in an existing installation, is the ability to optimize the power consumption from the grid to minimize cost.

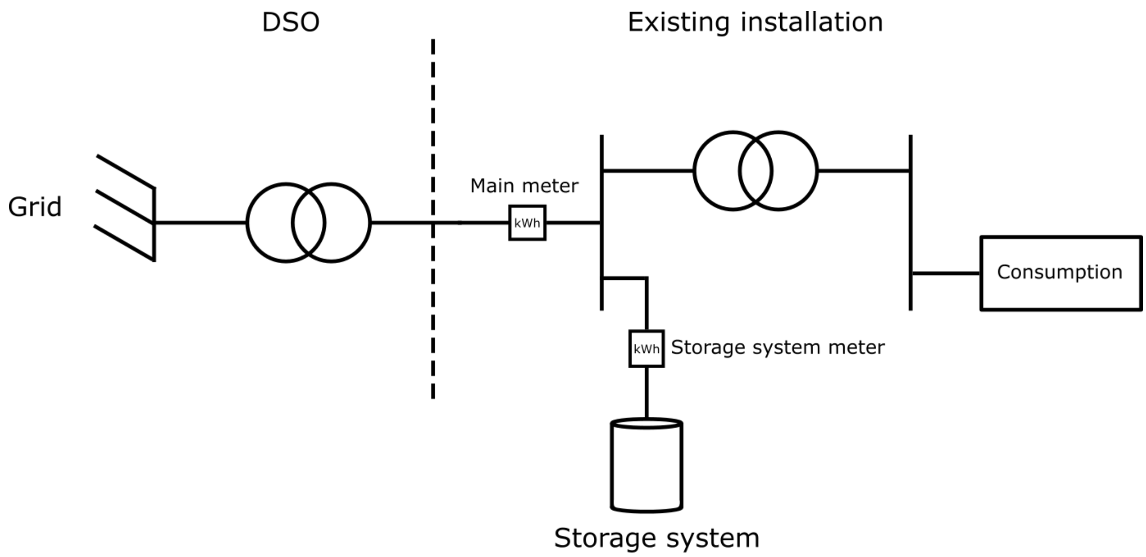


Figure 1 Example of a storage system connected to the grid via an existing installation

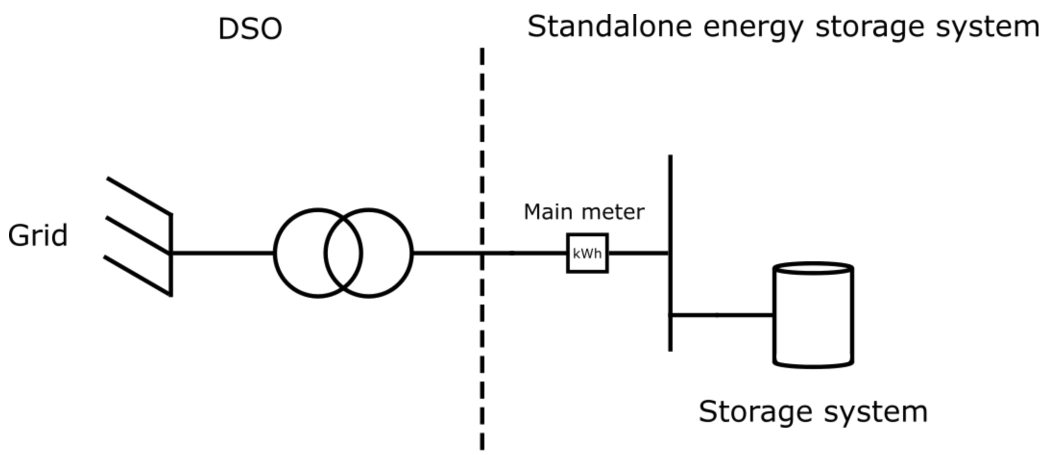


Figure 2 Example of a storage system connected to the grid via a dedicated interconnection

The costs when connecting to the public grid will be specified after a cost-sharing agreement between the developer and system operator. The cost-sharing agreement means that if the flow battery should be attached to an existing transformer station, the developer would need to pay all costs for upgrades required to the existing station. For example, this might be new areas, including busbars, separators, switches, earthing systems, transformers plus control and personal protection equipment for the impacted areas. The boundary for operation and maintenance will be in the grid connection point.

In order to be allowed to connect to the grid, the storage system must fulfill a set of technical requirements described in the "Technical Regulation 3.3.1", which specifies the technical and functional minimum requirements the battery plants must comply with in the Point of Connection in Installation. The regulation includes provisions for the properties which these plants must have throughout their service lives.

When the energy storage system is to be connected to the grid, there must be prepared documentation showing that all requirements described in TF 3.3.1 are met. This documentation must contain information on tolerance for voltage and frequency deviations, electrical quality parameters, control functions, protection functions and exchange of data as described in the various sections of the regulation.

5.4.5 Environment, safety and operation

For a grid-scale flow battery, it is important that the system is placed correctly in relation to existing infrastructure. The placement of the battery also depends on the acceptance of authorities and the local area.

Power plants and oil terminals are considered a good location for a large flow battery, as these companies have extensive experience in handling oil and thus have a highly specialised organisation for operations that meets society's requirements for safety and environmental considerations. Power plants and oil terminals have written procedures for all significant work tasks, so that both safety and quality are addressed while at the same time being located in industrial areas that are zoned for heavy industry. It is therefore assessed that there will be significant economies of scale advantages by operating flow battery systems alongside power plants and oil terminals. These companies often also have a strong electrical infrastructure that can be used for a flow battery.

In terms of environmental and safety issues for the two different solutions (vanadium and all-iron), in principle the same precautionary measures need to be taken.

Both types of flow batteries are not permitted to emit any dangerous gases during charging or discharging, and the temperature interval during the process must be in the 10-40 degrees Celsius range.
As neither vanadium or all-iron electrolyte is classified as a dangerous substance, cf. the Seveso Directive, then it seems that it will not be necessary to prepare a safety document and the company (the flow battery alone) will neither be a "kolonne 2" og "kolonne 3" company. As dangerous substances are being worked with in both cases (strongly acidic), there must be prepared a number of operational protocols and procedures that ensure the health and safety of personnel working with the battery systems.

In addition, in both cases it is recommended - and presumably also a requirement by the authorities - that there be two layers of security and sectioning of tank storage facilities in order to reduce the economy losses and reduce the size of acidic/alkaline leaks if an accident occurs.

5.5 Business models

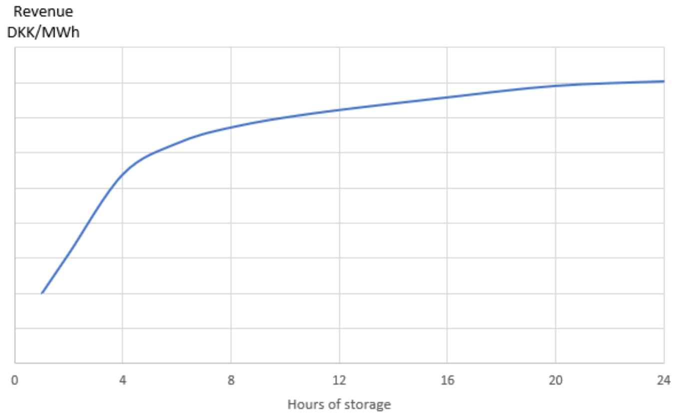
The project has investigated which commercial services a grid-scale energy storage system can offer to the Danish power system, i.e. how they can be part of the electricity market in terms of utility services and as a commercial battery on the day-ahead market.

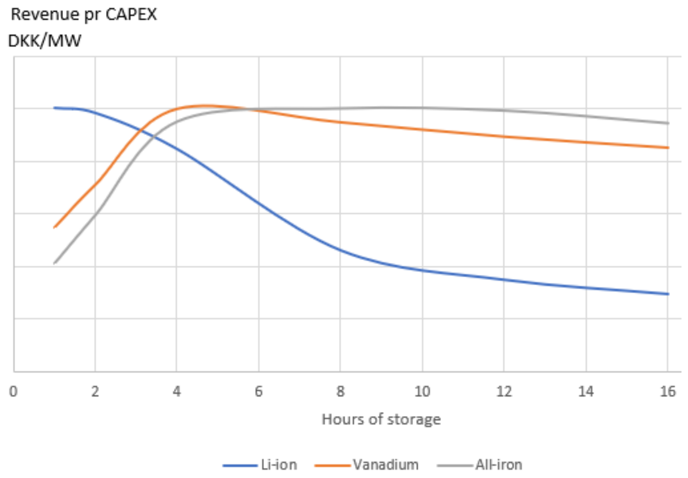
List of commercial services for a battery:

Service	Description	Requirements
Storage of energy from renewable energy sources	The battery is charged when there is a surplus of renewable energy in the grid (-> low electricity price) and discharged when there is a surplus of renewable energy (-> high electricity price).	Buying/selling and production of electricity will be handled by an actor in the electricity market.
Frequency containment reserve FCR	The battery is part of the utility services in the grid in terms of maintaining a stable frequency	FCR: Response time of 15-30 seconds. Activation is automatic when frequency deviations occur. Activation in 4-hour blocks. FCR-N: Response time of 150 seconds. Activation is automatic when frequency deviations of 50±0.1Hz occur. Activation for 3 or 6-hour blocks. FCR-D: Response time of 5 seconds, 50% and 25 seconds, 100%. Activation is automatic at frequencies <49.9Hz. Activation for 3 or 6-hour blocks.
Automatic frequency recovery reserve aFRR	Not currently possible.	Response time <15 minutes
Manual frequency recovery reserve mFRR	System service in relation to maintaining a balance on the electrical grid based on variations between expected and actual consumption and production.	Response time of 15 minutes
Utility services -Inertia -Short circuit power -Voltage reg.	The battery is included as a system-supporting function which is currently managed by the central power plants.	The requirement is expected to be a response time of 1.3 seconds.
Arbitrage	The battery is part of wind farms or solar parks as a storage system so that energy can be retained when energy prices are low and sent back to the grid when prices are high.	
Peak-shaving -in renewable energy facilities -in companies -in the electrical grid	The battery must remove the peak loads to/from the grid in order to prevent local overloads. For wind farms, this can also be used to optimise operations.	
Black start (Starting up from 0)	A large battery with an existing amount of energy in its storage can be used for a black start of the electrical grid.	The inverter must be able to supply energy to a dead grid and maintain the frequency. Must be connected to the 132/150 kV grid. 12-hour operations.

For the various services, the project group has investigated which requirements batteries should fulfill in terms of response times and how long the service must be supplied to the grid, to determine the requirements for the structure, size and management of a large-scale flow battery.
Besides earnings, the project group also has mapped how a flow battery in the electrical grid will be charged taxes and tariffs for the services it provides to the grid. Based on this work, a recommendation on power, storage capacity and reaction speeds has been made.

The recommendation for the duration of a battery in the Danish power grid is at least 5 hours of storage and optimally 12 hours for better integrating renewable energy source in the grid.





The response time for an idle battery with pumps running is 1 sec. so it can take part in utility services, peak-shaving and for Frequency containment reserve. For services as Storage of energy from renewable energy sources, Automatic and manually frequency recovery reserve and Black start an idle battery with pumps stopped should be up and running in maximum 15 min.

For the current taxation and tariffs problem in Denmark it is recommended to establish the battery in conjunction with wind farms or solar parks and local consumption to avoid this. However, the project group still find it possibly for the battery to do the above services even if it is places behind the meter.

The Danish energy tax/tariff system in the electricity sector has been and partially still is set up to treat energy as an instantaneous commodity which has to be consumed in the same moment that is it created. The introduction of storage conflicts with this method of taxing the use of electricity. For storage, this means that the owner will be taxed both when storing and when releasing energy from the storage system back into the grid.

As the amount of transported energy involves more taxes, the current taxation system does not support the integration of electricity storage systems in the electrical grid. Conversely, the integration of electricity storage capacity in the existing installation, where minimized use of the public grid can result in major financial advantages for the plant owner, mainly by optimizing taxes/tariffs.

This means in brief that the current taxation system primarily supports decentralised electricity generation systems where private producers/consumers produce and store electrical energy themselves. Therefore integration of electricity storage capacity in the electric grid will be driven by the need to maintain security of supply and electricity storage capacity in existing installation will be driven by optimization of the tax costs for the plant owner.

However, the Danish parliament is currently working on a new energy bill, which includes a reassessment of the Danish tariff and tax system in the electricity sector. This results in a great deal of uncertainty about how the electricity market will work in the future and whether the above conclusion will also apply after changes to the tariff/tax system.
Therefore, it is the recommendation of the project group that future energy storage systems should be able to carry out as many as possible of the current and expected future utility services listed in the table above in order to ensure the highest revenue.

5.6 Dissemination of results

The project’s results were communicated via a number of channels. Besides knowledge sharing via the project group’s network, the following channels have also been used to communicate about the project:

5.6.1 Homepage

At the start of the project, the www.nelt.dk homepage was set up. The project group has used the homepage as a shared online platform to share knowledge about the project and how it progresses.
There has been submitted press releases on an ongoing basis in addition to news and other relevant info on the homepage.

5.6.2 Press releases and articles

For the purpose of making the knowledge gained during the project available to relevant target groups, there has been submitted a number of press releases and articles about the project work and its results. The publications have, among other things, put the focus on flow battery technologies and their areas of application in terms of storing large amounts of renewable energy in the power grid and the challenges with the current tax system that may make it impossible to spread the use of the technology.
The press releases and articles have been redistributed by various media outlets, including Ingeniøren, Altinget, Energy Supply, Electronic Supply and TekniskFokus. In addition, the project group's participants have also contributed to sharing press releases and articles via company websites and LinkedIn.

6. Utilisation of project results

Utilisation: Nordisk Energirådgivning

Nordisk Energirådgivning has via its participation in the preliminary project stages gained knowledge and an overview of how large-scale flow batteries can and should be integrated into the Danish power grid. Based on that knowledge, Nordisk Energirådgivning will currently be capable of offering technical advice to those building or planning to build flow battery electricity storage systems.

Nordisk Energirådgivning has also worked together with the other participants of the project consortium to get market insights into what construction and delivery interfaces it would be necessary to define and specify between relevant suppliers of components and solution systems.

Likewise, Nordisk Energirådgivning has also identified the various financial and regulatory barriers that one would have to consider during a decision-making process.

Overall, with its participation in the preliminary project stages, Nordisk Energirådgivning has gained the required advisory capacity that will be needed when either developing, building and launching flow battery electricity storage systems.

Utilisation: Inter Terminals

Inter Terminals has used the project to gain insight into large-scale electricity storage systems, and as owners of tank terminals, in the long run the building and operation of flow battery systems, etc. may become a new business area for us - if the business case is sound.

Utilisation: HOFOR Vind

Throughout the project, HOFOR has gained knowledge about the maturity of the project and whether it could be a component in future renewable energy projects and contribute to the project economy and the general utilisation of renewable energy in the Danish electrical grid.
HOFOR has gained knowledge about the construction of systems and design considerations plus the operational opportunities in the current electricity market and under the current ruleset in addition to what opportunities there might be in a future market with a greater proportion of renewable energy and more focus on flexible services.
With this project, HOFOR has gained a better basis for decision making when it comes to future investment decisions involving battery technologies and also gained a better basis for evaluating a potential pilot project.

Utilisation: Skanda

As a specialist and entrepreneur in a relatively conservative business - the oil industry - this project has shown Skanda some future business opportunities. Storing energy in the way

this project does also touches parts of the industry specialisation that Skanda already possesses in the tank industry.
For the same reason, we have also had a commercial interest in the EUDP project as it might be a potential business area in the future.
Additionally, in its vision and business plan Skanda has a goal of making itself a more green and sustainable company. Participating in this project has been very constructive in terms of seeing green transition potentials.

Utilisation: Dansk Energirådgivning
Based on the project, Dansk Energirådgivning has gained insight into how large energy storage systems in the form of how flow batteries can be designed and integrated into the Danish electricity market in order to be able to store the increasing amount of renewable energy in the electrical grid.

Together with the companies in the project consortium, Dansk Energirådgivning has uncovered and assessed the current technological possibilities in the market and has, through plant visits and the exchange of experiences both nationally and internationally, gained new knowledge about flow batteries. In addition, Dansk Energirådgivning has been involved in analysing the economic and regulatory barriers to the integration of flow batteries in the Danish power grid.

Overall, the project process has resulted in Dansk Energirådgivning expecting to take part in a pilot project that can test and mature the flow battery technology for the Danish power grid and in the long term also foreign markets. Based on the project and the collaboration with the consortium, Dansk Energirådgivning will be able to function as a project developer and thereby contribute to the conceptualisation of a profitable energy storage facility project.

7. Project conclusion and perspective

The project has shown that there is potential in placing large energy storage facilities near power plants and oil terminals in order to use their infrastructure and operating organisation, as this provides an opportunity to optimise the costs of the systems.
However, the project has also shown that the possibility of reusing steel tanks by oil terminals is limited, as it has not been possible to find a suitable long-term type of coating for steel tanks when using acidic electrolytes. In addition, the solution requires that the tank storage facilities in general need to be rebuilt, as while they are suitable for oil products, they are not suitable for more volatile liquids such as electrolytes.

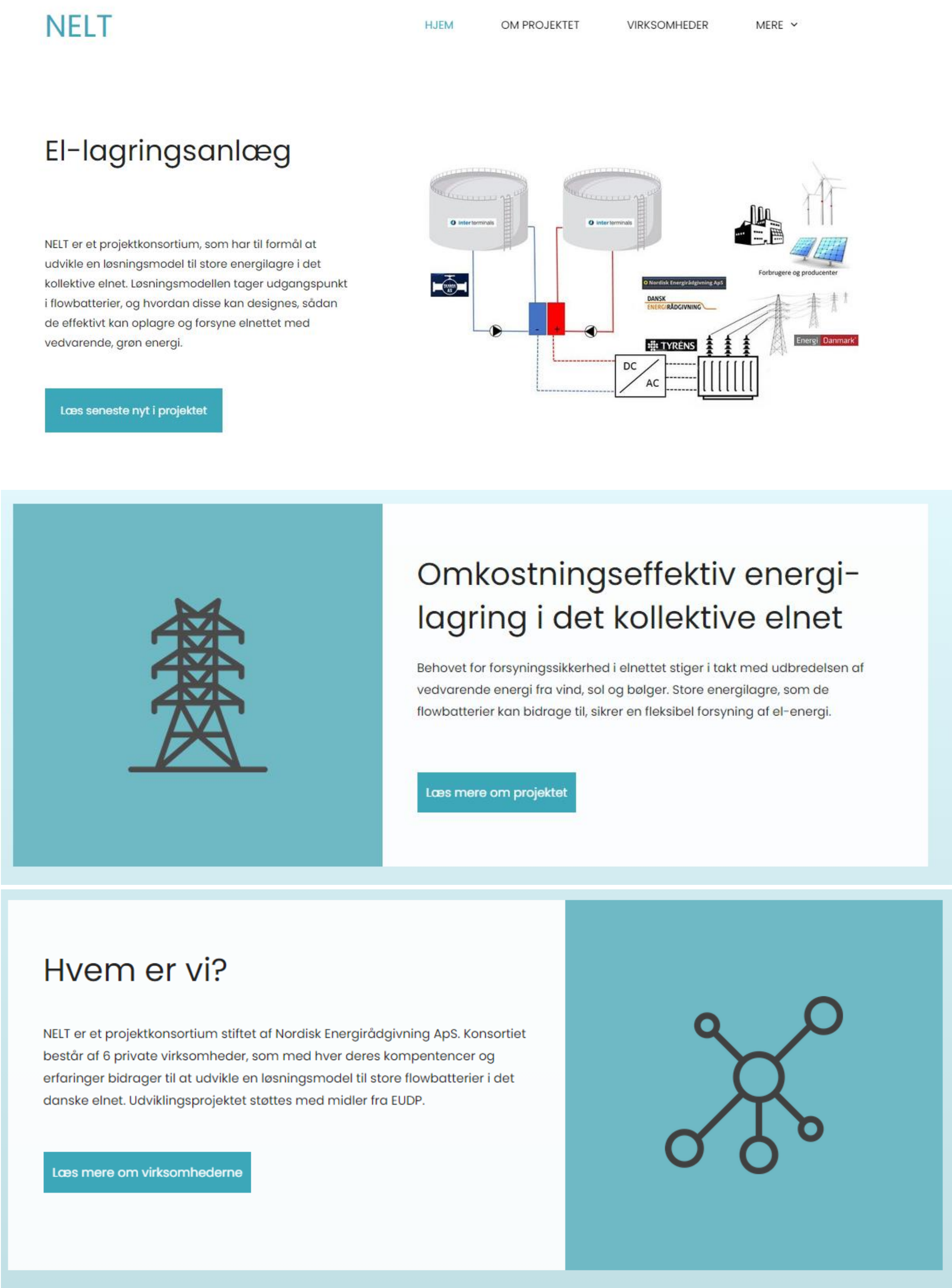
Based on the project group's study of various electrolytes and the associated economy, safety issues, energy density, etc. it is assessed that all-iron batteries are the most suitable solution at the present time. However, there are rapid developments going on with battery technologies, and this may mean that new and less well-developed technologies begin gaining ground on the market. The developments are taking place as the need for large-scale energy storage systems grows as renewable energy sources begin making up a greater proportion of the electricity in the power grid. Here, flow batteries are extremely competitive on a price basis for long-term storage of electricity (more than 5 hours) compared to other technologies, particularly li-ion batteries. Due to the current development stage of flow batteries, the establishment and operating costs for the technology remain high. However, these costs are expected to decrease significantly once the battery technology enters large-scale production.

In relation to the Danish power grid, on the basis of the project's investigations, it is recommended to aim for a solution that has 5-12 hours of storage capacity in the flow battery. However, at present the tax and tariff systems makes it impossible for large-scale battery systems to be integrated into the Danish electrical grid. It has not been the project's purpose to find a solution to this, but as the political parties working on a new energy legislation which aims at reassessing the Danish tariff and tax system in the electricity sector. It is the project group's recommendation that future battery storage facilities be built so that they can be connected to the power grid and perform as many utility services as possible. This ensures the best possible return on the large capital investment.

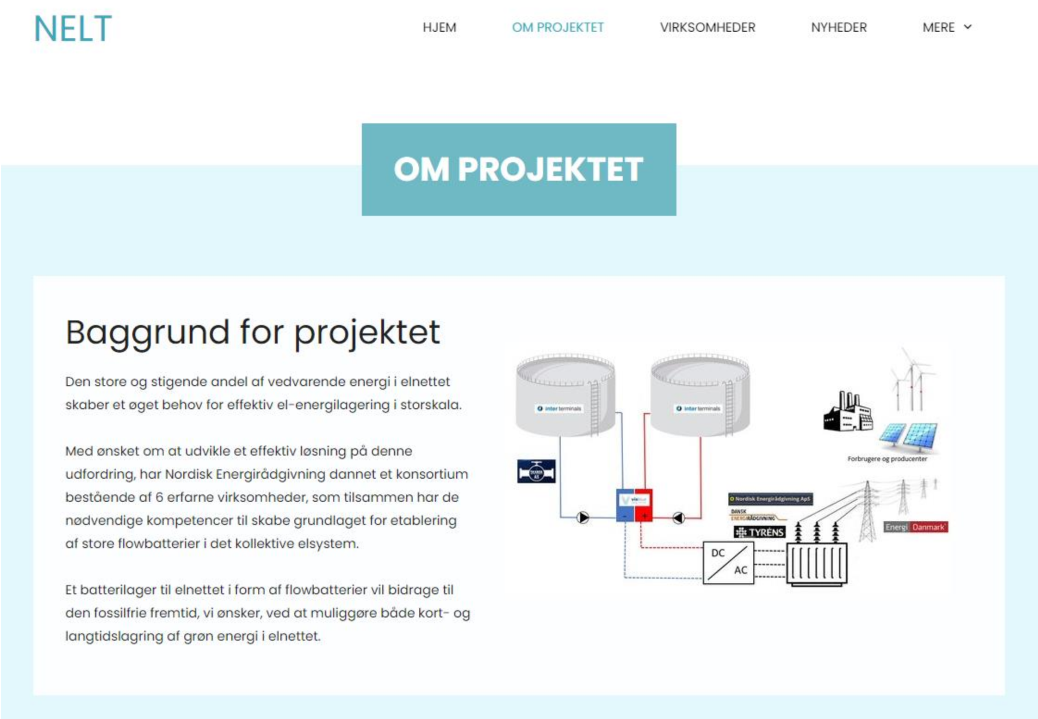
Flow battery technology is a promising solution for promoting renewable energy in Denmark, and if the current tariff and tax system in the electricity sector is changed, there is a possibility that flow battery technology can develop and Denmark can become a European leader in this space. In order to develop the technology, it requires that a pilot-plant is tested on a large scale so that the commercial, technological and regulatory opportunities are investigated in further detail.
At the same time, there is a need for clarification as to how batteries can avoid "double taxation", and this requires that there is a political focus on this problem. One possible solution would be to have a special dispensation from taxes for a large-scale pilot project.

8. Annex

The Project homepage: NELT.DK




The Future Of Energy Storage Beyond ...
Se senere
Del
CNBC
THE FUTURE
OF ENERGY
STORAGE
Se på YouTube
Bliv klogere på flowbatterier
Se CNBC's lærerige dokumentar om fremtidens energilagring.


NELT
HJEM
OM PROJEKTET
VIRKSOMHEDER
NYHEDER
MERE
OM PROJEKTET
Baggrund for projektet
Den store og stigende andel af vedvarende energi i elnettet skaber et øget behov for effektiv el-energilagering i storskala.
Med ønsket om at udvikle et effektiv løsning på denne udfordring, har Nordisk Energirådgivning dannet et konsortium bestående af 6 erfarne virksomheder, som tilsammen har de nødvendige kompetencer til skabe grundlaget for etablering af store flowbatterier i det kollektive elsystem.
Et batterilager til elnettet i form af flowbatterier vil bidrage til den fossilfrie fremtid, vi ønsker, ved at muliggøre både kort- og langtidslagring af grøn energi i elnettet.
Forbrugere og producenter
TYRENS
DC
AC

FLOWBATTERIER

Hvorfor fokusere på flowbatterier?

Et flowbatteri anses som værende en billig, energieffektiv, miljøvenlig, fleksibel og langtidsholdbar batteriløsning til lagring af vedvarende energi fra vind, sol og bølger.

I flowbatteriet bindes og opbevares energien elektrokemisk i en væske, hvor energien først omsættes og afleveres som elektricitet, når der igen er behov for den. Et batterilager tilsluttet elnettet muliggør dermed, at energien afleveres direkte tilbage til elnettet efter lagring, modsat andre lagringsteknologier der omhandler konvertering til mindre anvendelige energimedier, f.eks. varme.

Flowbatteri-teknologien er en velkendt teknologi. Der eksisterer allerede større anlæg i bl.a. Kina, Japan og USA, som gør brug af teknologien.

Hvordan kan flowbatterier integreres i elnettet?

Udviklingsarbejdet, som projektkonsortiet udfører, tager udgangspunkt i at anvende eksisterende energiinfrastruktur og tanklagringsanlæg, da dette vil omkostningseffektivisere etableringen af flowbatterier i elnettet.

Tankanlæggene er ofte placeret som en del af et eksisterende eller tidligere kraftværk og raffinaderi, hvilket gør, at en omfattende el-infrastruktur til batteriet er til stede, uanset hvordan man ønsker at koble anlæggene på elnettet.

Støtte fra EUDP

Projektet udføres som en del af det Det Energiteknologiske Udviklings- og Demonstrationsprogram (EUDP), hvor konsortiet til dels med egne midler arbejder på udvikling af bæredygtige, integrerede energilagringsløsninger.

EUDP er en offentlig tilskudsordning, som støtter ny teknologi på energiområdet, der kan bidrage til at indfri Danmarks målsætninger inden for energi og klima.

EUDP
Energiteknologisk udvikling og demonstration

NELT

HJEM | OM PROJEKTET | VIRKSOMHEDER | NYHEDER | MERE

VIRKSOMHEDER I KONSORTIET

Nordisk Energirådgivning ApS

Energirådgivning

Nordisk Energirådgivning

Nordisk Energirådgivning er teknisk bygherrerådgiver, som arbejder med et primært fokus på etablering af proces- og energianlæg hos primært industrivirksomheder.

Energirådgivning

Dansk Energirådgivning

Dansk Energirådgivning er et energirådgivningsvirksomhed, der bl.a. varetager alle aspekter ved større tankanlæg til biogasproduktion og drift af disse.

Tankterminaler

Inter Terminals

Inter Terminals er en virksomhed, der varetager drift og udlejning af tankterminaler. Virksomhedens arbejdsområde er primært indenfor opbevaring af heavyfuel og lettere drivmidler.

Udvikling, anlæg og drift af land-og havvindmøller

Hofor Vind

Hofor Vind har erfaringer med eje og drifte vindmølle-og solcelleparker samt andre energianlæg, herunder også batterianlægsintegration med vindmøller.

Totalleverandør af forsynings- og tankanlæg

Skanda

Skanda er totalleverandør og anlægsfirma, der anlægger og idriftsætter større forsynings- og tankanlæg.

NELT

HJEM OM PROJEKTET VIRKSOMHEDER NYHEDER MERE

NYHEDER

Læs seneste nyt i projektet.

18.05.21

Vil vi nå i mål med den grønne omstilling, skal vi kunne lagre energi fra sol og vind

Fremtidens elforsyning er uden tvivl grøn, men den er også ustabil og ineffektiv, hvis ikke vi får indbygget store energilagre i elnettet, som kan gemme den varierende vedvarende energi. Heldigvis findes teknologien til energilagring allerede, det er blot et spørgsmål om at få den opskaleret og implementeret.

I Danmark har vi en ambition om at være uafhængige af fossile brændsler i 2050. Midlet til at opnå målet virker meget lige til: vi skal have mere energi fra sol og vind i vores energisystem, således vi kan dække det stigende elforbrug med grøn energi. Udfordringen ved at omstille energiforsyningen fra fossile brændsler til grøn energi er dog, at energiproduktionen svinger, som solen skinner og vinden blæser.

Elnettet skal være i balance

I Danmark er der blevet investeret massivt i at udbygge den grønne energiproduktion med vindmøller og solceller. Det er en vigtig brik i den grønne omstilling, men ifølge Kristian Hegner, ingeniør og medejer i Nordisk Energirådgivning, er det afgørende, at vi indbygger lagerkapacitet i elnettet og ikke blot udbygger med mere vedvarende energi.

"Hvis vi ikke indtænker lagerkapacitet i elnettet, vil vedvarende energi aldrig kunne dække Danmarks samlede elforbrug hele året rundt. Vi kan bygge vindmøller nok til, at de i teorien kan dække 100 % af elforbruget. I praksis vil møllerne dog producere alt for meget, når det blæser godt, men stadigvæk ikke nok når der kun er lidt vind. Reelt set vil møllerne derfor kun kunne dække ca. 70 % af elforbruget, selvom de i teorien skulle kunne levere 100 %", siger Kristian Hegner.

Skal elnettet være i balance, er der altså brug for, at store energilagre bliver indtænkt i det fremtidige grønne energisystem. Disse lagre vil gøre det muligt, at vi i perioder med overproduktion kan lagre energien til perioder, hvor elforbruget overstiger den grønne elproduktion.

Flowbatterier er en del af løsningen

Energilagring har heldigvis fået mere opmærksomhed de seneste år, hvilket har resulteret i en udvikling af både eksisterende og nye teknologier i markedet. Nogle af disse teknologier viser et stort potentiale for at kunne implementeres i det danske elnet med henblik på at skabe stabilitet i den grønne elforsyning.

Det forklarer Kristian Hegner, der sammen med sin kompagnon i Nordisk Energirådgivning, Nicolaj Rotbøl, har samlet et projektkonsortium, som undersøger nogle af disse muligheder for el-lagring i storskala. Konsortiet består af virksomhederne Nordisk Energirådgivning, Dansk Energirådgivning, Inter Terminals, Hofor Vind og Skanda, der med støtte fra Det Energiteknologiske Udviklings- og Demonstrationsprogram (EUDP) har fundet frem til en effektiv el-lagringsløsning, som involverer flowbatterier.

Flowbatteri-teknologien går ud på, at energien fra sol og vind bindes og opbevares elektrokemisk i en væske. Når energien skal bruges igen, omsættes den og afleveres den tilbage i elnettet som elektricitet. I projektkonsortiet har man bl.a. kigget på flowbatteri-løsninger som zinc-air og all-iron, som på nuværende tidspunkter vurderes til at være nogle af de billigste og mest energieffektive teknologier til el-lagring.

Men hvorfor etablerer vi så ikke flowbatterier som energilagre i elnettet?

Det vil kræve store investeringer at få implementeret flowbatterier som lagerkapacitet i det danske elnet, men Thomas Kristiansen, ingeniør og medejer i Dansk Energirådgivning A/S, minder om, at sådan var det også med vindmøller og solceller:

"Vindmøllerne er i dag den billigste måde at producere grøn strøm på, men det er de blevet, fordi vi har videreudviklet teknologien og investeret massivt i den i mere end 40 år. Nu er næste skridt, at vi skal være villige til at investere teknologier, som kan skabe balance i det grønne elnet".

Desuden pointerer Thomas Kristiansen, at det samlet vil være billigere at indbygge lagerkapacitet i elnettet, fremfor udbygning af elnettet eller produktionsanlæg, der kun ville være behov for i spidsbelastningsperioder.

Flowbatterier kan blive det næste eksporteventyr – hvis lovgivningen tillader det

Der er andre lande, som er længere med at udvikle og teste forskellige flowbatterier, men teknologien er stadig et sted, hvor Danmark kan blive foregangsland, forklarer Thomas Kristiansen og uddyber:

"Gør vi plads til at flowbatteriteknologien kan modnes i Danmark, eksisterer der et kæmpe eksportpotentiale i at opskalere flowbatteriet og gøre det omkostningseffektivt."

På nuværende tidspunkt eksisterer der dog nogle lovgivningsmæssige barrierer, som sætter en stopper for flowbatterier i det danske elnet:

"Det en udfordring, at batterier i dag ikke er defineret som et separat produkt i elnettet. Det skelnes kun mellem forbruger og producent. Batterier betragtes som både forbruger og producent i elnettet, idet batteriet tager energi fra nettet og lagrer det, indtil det leveres tilbage i nettet igen. Det betyder, at batteriet bliver straffet med afgifter og tariffer ved både opladning og afladning, og denne dobbeltbeskatning gør det kommercielt umuligt at etablere et stort batterianlæg i det danske elnet", forklarer Thomas Kristiansen.

01.12.20 Leverandører af flowbatteri-løsninger

Leverandører af flowbatteri-løsninger

Læs mere om de forskellige leverandører inden for flowbatteri-teknologien.

ViZn Energy Systems, Inc.
Systemleverandør af flowbatterier designet til en elektrolyt baseret på zink og jern.
www.viznenergy.com

Somitomo Electrical Industries, Ltd.
Systemleverandør af flowbatter-iteknologi primært baseret på vanadium elektrolyt.
https://global-sei.com/products/redox/

J.Schmalz Gmbh
Veksler- og systemleverandør af flowbatteri-teknologi primært baseret på vanadium elektrolyt.
https://www.schmalz.com/

Zinc8 Energy Solutions Inc.
Systemleverandør af zink-luft batterisystemer baseret på zink luft elektrolyt.
https://www.zinc8energy.com/

Redflow
Systemleverandør af flowbatteriteknologi primært baseret på zink bromid elektrolyt.
https://redflow.com/

26.02.20 **Pressemeddelelse: Flowbatterier kan muliggøre effektiv el-energilagring i storskala. Læs her.**

NELT

HJEM | OM PROJEKTET | VIRKSOMHEDER | NYHEDER | MERE

KONTAKT OS

+45 50 55 01 50

info@nelt.dk

Har du spørgsmål til projektet?

Udfyld kontaktformularen.
Så vender vi hurtigst muligt tilbage med svar på dit spørgsmål.

Navn *

E-mail *

Besked *

Press releases

Energilagring i flowbatterier skal skaleres op og gøres omkostningseffektivt

Af **Maria Berg Badstue Pedersen**
Tip redaktionen om en historie
26. februar 2020 12:31

Et projektkonsortium bestående af seks private virksomheder vil med midler fra den offentlige tilskudspulje EUDP udvikle en løsningsmodel til omkostningseffektiv energilagring i det kollektive elnet.

Læs også: Skatteministeren vil ikke diskutere elbiler før til efteråret

Fokus vil være på anvendelsen af flowbatterier, da de anses som værende en billig, energieffektiv, miljøvenlig, fleksibel og langtidsholdbar løsning til lagring af vedvarende energi fra vind, sol og bølger.

I flowbatteriet bindes og opbevares energien elektrokemisk i en væske, hvor energien først omsættes og afleveres som elektricitet, når der igen er behov for den.

Målet er, at der skal udvikles en løsningsmodel til, hvordan et flowbatteri kan designes med ydelser på over 15 MW effekt og 80 MWh el-lagring.

Det er Nordisk Energirådgivning, der har dannet et konsortiet sammen med virksomhederne Inter Terminals, VisBlue, Tyréns, Skanda og Dansk Energirådgivning A/S.

Læs også: Mollerup Golf Club tester solceller og batterier til lagring af strøm

De seks virksomheder har til sammen de nødvendige kompetencer til at undersøge tekniske og designmæssige løsninger for anvendelse af store flowbatterier til el-energilagring.

Projektet skal sætte rammerne for et kommende pilotprojekt, der demonstrerer teknologien i praksis.

Ulempe: Investeringsomkostninger
Selvom flowbatterier både er en billig og energieffektiv løsning til lagring af vedvarende energi, så er der dog den ulempe, at flow-batteriet har en høj investeringspris, som hidtil har gjort, at markedskræfterne i sig selv ikke har kunnet modne og udbrede teknologien.

Der er altså knyttet en høj investeringspris til de flowbatterier, man ser i dag.

- Dog er pris pr. op-/genafladningscyklus lavere en andre batteriteknologier, da flowbatteriret har en lang levetid på typisk over 20 år, og elektrolytten er fuld ud genanvendelig efter de 20 år, oplyser parterne bag projeket.

Virksomhederne i konsortiet har fået til opgave at finde en løsning, som omkostningseffektiviserer etableringsudgiften til flowbatterier.

Læs også: Grønt batterifirma vil tredoble omsætningen

- Omkostningseffektiviseringen skal ske dels via skalering af teknologien dels ved udnyttelse af eksisterende tanklagringsanlæg og tilkobling i eksisterende energiinfrastruktur, oplyser konsortiet.

Energi-lagring i stor skala
Får projektkonsortiet tilegnet sig den rette viden og erfaring om store omkostningseffektive flowbatterier, kan det bruges til at positionere Danmark som foregangsland inden for teknologien, idet Danmark vil være blandt de første lande i verdenen til at implementere el-energilagring i storeskala.

Konsortiet skal frem til foråret 2021 lave en forundersøgelse, som skal afdække de designmæssige og tekniske løsninger, som det vil være nødvendigt at belyse og kvantificere, før det vil være muligt at opføre og tilslutte et effektivt el-energilager i det kollektive danske elforsyningsnet.

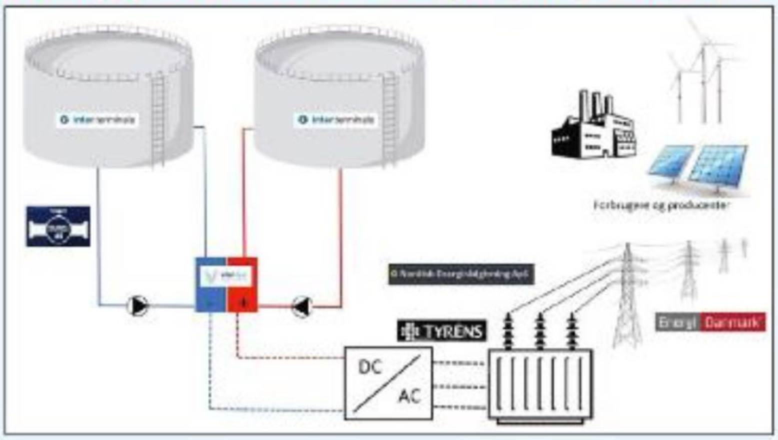
Forundersøgelsen skal afsluttes med en anbefaling på en teknisk og budgetsat løsningsmodel, som det vil være muligt at anvende som arbejdsgrundlag for etablering af et pilotprojekt, hvor flowbatteri-teknologien skal testes i virkelighedsnære forhold.

Projektet er støtte af det Det Energiteknologiske Udviklings- og Demonstrationsprogram (EUDP).

Mere om: Dansk Energirådgivning | EUDP | flowbatterier | Nordisk Energirådgivning | Skanda | Terminals | Tyréns | Visblue

Aktuelt

Flowbatterier kan muliggøre effektiv el-energilagring i storskala



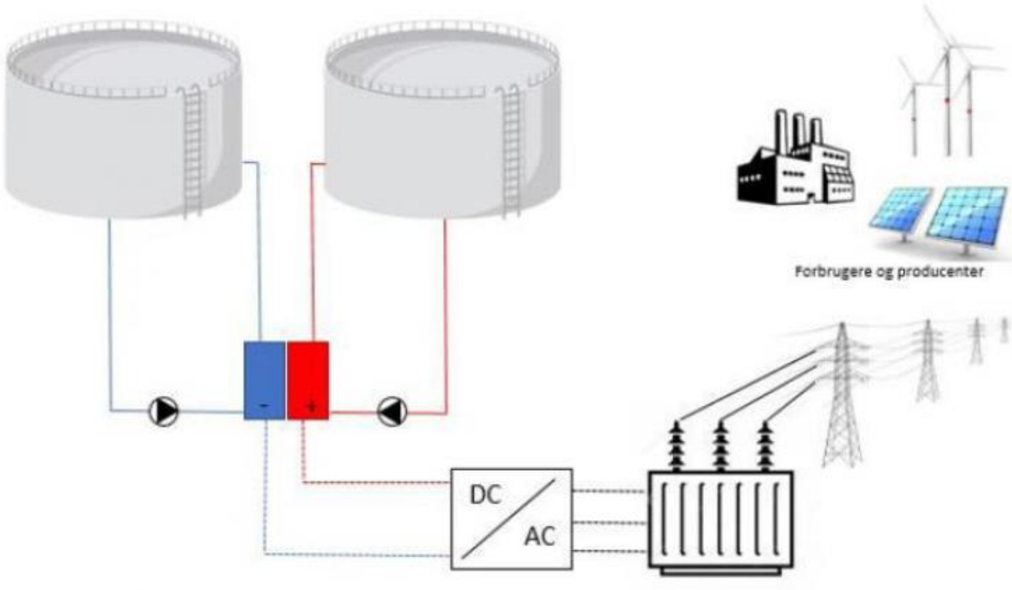
Et projektkonsortium bestående af seks private virksomheder vil med midler fra den offentlige tilskudspulje EUDP udvikle en løsningsmodel til omkostningseffektiv energilagring i det kollektive elnet. Projektet tager udgangspunkt i flowbatterier og skal sætte rammerne for et kommende pilotprojekt, der demonstrerer teknologien i praksis.
Med baggrund i det øgede behov for el-energilagring har Nordisk Energirådgivning ApS dannet et konsortium bestående af virksomhederne Inter Terminals A/S, VisBlue ApS, Tyréns A/S, Skanda A/S og Dansk Energirådgivning A/S. Tilsammen har de seks virksomheder de nødvendige kompetencer til at undersøge tekniske og designmæssige løsninger for anvendelse af store flowbatterier til el-energilagring.
Projektet sætter fokus på flowbatterier, som anses som værende en billig, energieffektiv, miljøvenlig, fleksibel og langtidsholdbar batteriløsning til lagring af vedvarende energi fra vind, sol og bølger. I flowbatteriet bindes og opbevares energien elektrokemisk i en væske, hvor energien først omsættes og afleveres som elektricitet, når der igen er behov for den.

Høj investeringspris

Ulempen ved flowbatteriet er dog en høj investeringspris, som hidtil har gjort, at markedskræfterne i sig selv ikke har kunnet modne og udbrede teknologien. Derfor har virksomhederne i konsortiet også fået til opgave at belyse en løsning, som omkostningseffektiviserer etableringsudgiften til flowbatterier.
Store energilagre, som flowbatterier kan bidrage til, er med til at sikre en høj forsyningssikkerhed i elnettet i fremtiden, hvor der kommer mere uforudsigeligt, vedvarende energi i elnettet.
Samtidig muliggør batterilager tilsluttet elnettet, at energien afleveres direkte tilbage til elnettet efter lagring, modsat andre lagringsteknologier der omhandler konvertering til mindre anvendelige energimedier, for eksempel varme.
Får projektkonsortiet tilegnet sig den rette viden og erfaring om store omkostningseffektive flowbatterier, kan det bruges til at positionere Danmark som foregangsland inden for teknologien, idet Danmark vil være blandt de første lande i verden til at implementere el-energilagring i storskala.

Pilotprojekt

Når de samarbejdende virksomheder er færdige med forundersøgelsen i foråret 2021, vil konklusionerne skulle bruges til at sætte rammerne for et kommende pilotprojekt, der skal demonstrere flowbatteri-teknologien i virkelighedsnære forhold.
Projektet udføres som en del af det Det Energiteknologiske Udviklings- og Demonstrationsprogram (EUDP), hvor konsortiet til dels med egne midler arbejder på udvikling af bæredygtige, integrerede energilagringsløsninger.
EUDP er en offentlig tilskudsordning, som støtter ny teknologi på energiområdet, der kan bidrage til at indfri Danmarks målsætninger inden for energi og klima.
Der vil løbende blive lagt informationer vedrørende pilotprojektet på Nordisk Energirådgivnings hjemmeside www.nordisk-energiraadgivning.dk. Det endelige resultat forventes offentliggjort i foråret 2021.



Princip-skitse af et flowbatteri direkte tilsluttet i nettet.
Foto : Nordisk Energirådgivning/NELT

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Kommercielle aktører vil have nettilsluttede batterier fritaget for tariffer

Et konsortium bestående af fem virksomheder mener, at kommerciel ellagring i stor skala lige nu bremses af dobbelt tarifering, da batterier i visse tilfælde betragtes både som en produktions- og en forbrugsenhed.

Martin Bernth
8. dec 2020 05:00

Teknologien er sådan set ved at at være moden. Flowbatterierne har med sit potentiale for nem opskalering af kapaciteten alle muligheder rent teknisk for at indgå i understøttende funktioner for elnettet.

Men det er umuligt at få økonomi i kommercielle el-lagringsanlæg, fordi deres rolle ikke er klart defineret i det danske elsystem. Sådan lyder det fra projektkonsortiet NELT, som består af en række danske energirådgivere og leverandører af tankanlæg.

»Det en udfordring, at batterier i dag ikke er defineret som et separat produkt i elnettet. Der skelnes kun mellem forbruger eller producent. Batterier betragtes som både forbruger og producent i elnettet, idet batteriet tager energi fra nettet og lagrer, indtil det leveres tilbage i nettet igen, når der er behov for det,« forklarer Kristian Hegner, ingeniør og medejer i Nordisk Energirådgivning samt medstifter af konsortiet NELT. Han fortsætter:

»Det betyder, at batteriet bliver straffet med afgifter og tariffer ved både opladning og afladning, og denne dobbeltbeskatning gør det kommercielt umuligt at etablere et stort batterianlæg i det danske elnet.«

Parterne er netop nu i gang med en række forundersøgelser, der – med støtte fra EUDP – blandt andet skal klarlægge potentialet i at konvertere gamle olietankanlæg til store flowbatterier, som eksempelvis kan hjælpe med at opretholde spændingskvalitet og peakshaving.

Ifølge Kristian Hegner er grundtanken i det nuværende eltarif- og afgiftssystem, at el er en flygtig størrelse, som det er umuligt at gemme. Derfor afregnes energiformen, når den er i bevægelse, men med udsigt til storskala energilagring i batterier er den grundantagelse falsk. Derfor er det nødvendigt at gentænke hele systemet, mener han.

Dette arbejde er dog med al sandsynlighed i gang inden for murene i Klima-, energi- og forsyningsministeriet, hvor det nye elmarkedsdirektiv tilsiger, at medlemslandene skal udarbejde tariferingsmodeller af en række nye aktører i elmarkedet, såsom borgerenergifællesskaber og energilagringsenheder. Tarifferne skal baseres på en til formålet udarbejdet cost-benefit analyse, men det har ikke været muligt at opklare, hvor langt arbejdet er.

Flowbatterier er billig el-lagring

Flowbatterier har en række fordele i forhold til lagring af el i forsyningsskala. Energilagringskapaciteten er nærmest ubegrænset, da det blot et et spørgsmål om større tanke, der kan rumme de to elektrolyt-væsker, som gemmer den elektrokemiske energi.

De kan også levere effekt relativt hurtigt, da det er et spørgsmål om at pumpe elektrolytterne ind i de centrale elektrokemiske celler, hvor udveksling af ioner i de to væsker gennem en membran får en strøm til at løbe.

Ifølge Energistyrelsens Energikatalog kan den mest udbredte og modnede type af flowbatterer – vanadium redox – reagerer med en hastighed på helt ned til 100 millisekunder, hvis batteriet holdes i tomgang med pumperne tændt og væsken klar i reaktionscellerne.

Derudover har de usædvanligt lang levetid set i forhold til andre batteri-teknologier – op til 20 år selv uden begrænsninger i antallet af ladecyklusser. Især dette forhold giver ifølge Energikataloget flowbatterierne den laveste lagringspris pr. kWh blandt alle de batteriteknologier, der i dag findes i forsyningsskala.

Vigtig buffer for elnettet

De fleste storskala flowbatterier bruger metallet vanadium i sine elektrolyt-opløsninger, men udbuddet er og prisen svinger meget og har de seneste år oplevet store prishop. Ifølge Kristian Hegner kan elektrolytten udgøre så meget som mellem en tredjedel og halvdelen af de samlede omkostninger til et anlæg.

Derfor har virksomhederne i konsortiet NELT satset på en lidt mindre moden, men billigere flowbatteri-teknologi af typen zink-luft. Teknologien har den fordel, at den kan anvende ståltanke som beholdere af elektrolytterne.

Idéen er, at udnytte instrastrukturen på kraftværkssites, som enten er taget ud af drift, eller har droslet meget ned på aktiviteterne, på en ny måde ved at konvertere de gamle tankgårde til energilagrinsstationer.

Undervejs i arbejdet med forundersøgelserne er konsortiet også stødt på en række andre cases, hvor lagringsenheder direkte tilsluttet nettet lige nu er efterspurgt.

»Vi har talt med en række vindmøllefolk, som var interesserede i at koble batterier på det punkt, hvor ilandføringen møder elnettet. På den måde kunne de tilslutte større effekt på havet, uden at være afhængige af at vente på netforstærkninger inde på land,« siger Kristian Hegner og tilføjer, at mange af de nye solcelleanlæg har samme problematik.

Desuden vil en kommende elektrificering med højtemperaturs varmepumper i industrien også føre til et behov for en form for buffer imellem fabrikkernes større elforbrug og nettet, hvis kapacitet Kristian Hegner forudser vil komme under pres mange steder.

Afskaf tarifferne

Kristian Hegner rejser selv muligheden for, at det var elsystemets ansvarlige, som selv sørgede for at udbygge og drifte en lagringskapacitet i nettet, men forestiller sig ikke, at det bliver ad den vej, at udviklingen vil ske. Energinet må ikke eje produktions- og forbrugsanlæg, som reglerne er i dag.

Derfor tyder meget på, at udbygning af el-lagring i forsyningsskala er op til kommercielle aktører, og det kræver altså ifølge NELT-konsortiet, at batteriet udelukkende pålægges afgifter for det, det belaster nettet med, og belønnes for den ydelse, den bidrager med.

»Afregningsforholdene i Danmark for TSO/DSO-tarifferne vil medføre en ekstra driftsøkonomisk udgift på flowbatterierne, der skal tillægges systemtabet på 20-30 % ved op- og afladning. Samlet set vil systemtabet og omkostninger til tarifferne medføre, at det ikke vil være muligt for private virksomheder og aktører at etablere store flowbatterier, der er tilkoblet Danmarks hovedelforsyningssystem,« siger Kristian Hegner.

Konsortiet anbefaler derfor, at tarifferne på både transmissions- og distributionsniveau helt fjernes for store batterier, der tilkobles og anvendes i elnettet.

Foruden Nordisk Energirådgivning består NELT-konsortiet af Dansk Energirådgnivning, Inter Terminals, Tyréns og Skanda.

ENERGILAGRING

Martin Bernth
Uddannet journalist fra Danmarks Medie- og Journalisthøjskole. Har i flere år har dækket de teknologier, der skal drive den grønne omstilling. Har også tidligere skrevet om energi for Ingeniøren

Vil vi nå i mål med den grønne omstilling, skal vi kunne lagre energi fra sol og vind

Fremtidens elforsyning er uden tvivl grøn, men den er også ustabil og ineffektiv, hvis ikke vi får indbygget store energilagre i elnettet, som kan gemme den fluktuerende vedvarende energi. Heldigvis findes teknologien til energilagring allerede, det er blot er spørgsmål om at få den opskaleret og implementeret.

I Danmark har vi en ambition om at være uafhængige af fossile brændsler i 2050. Midlet til at opnå målet virker meget lige til: vi skal have mere energi fra sol og vind i vores energisystem, således vi kan dække det stigende elforbrug med grøn energi. Udfordringen ved at omstille energiforsyningen fra fossile brændsler til grøn energi er dog, at energiproduktionen svinger, som solen skinner og vinden blæser.

Elnettet skal være i balance

I Danmark er der blevet investeret massivt i at udbygge den grønne energiproduktion med vindmøller og solceller. Det er en vigtig brik i den grønne omstilling, men ifølge Kristian Hegner, ingeniør og medejer i Nordisk Energirådgivning, er det afgørende, at vi indbygger lagerkapacitet i elnettet og ikke blot udbygger med mere vedvarende energi.

”Hvis vi ikke indtænker lagerkapacitet i elnettet, vil vedvarende energi aldrig kunne dække Danmarks samlede elforbrug hele året rundt. Vi kan bygge vindmøller nok til, at de i teorien kan dække 100 % af elforbruget. I praksis vil møllerne dog producere alt for meget, når det blæser godt, men stadigvæk ikke nok når der kun er lidt vind. Reelt set vil møllerne derfor kun kunne dække 70 % af elforbruget, selvom de i teorien skulle kunne levere 100 %”, siger Kristian Hegner.

Skal elnettet være i balance, er der altså brug for, at store energilagre bliver indtænkt i det fremtidige grønne energisystem. Disse lagre vil gøre det muligt, at vi i perioder med overproduktion kan lagre energien til perioder, hvor elforbruget overstiger produktionen.

Flowbatterier er en del af løsningen

Energilagring har heldigvis fået mere opmærksomhed de seneste år, hvilket har resulteret i en udvikling af både eksisterende og nye teknologier i markedet. Nogle af disse teknologier viser et stort potentiale for at kunne implementeres i det danske elnet med henblik på at skabe balance i forsyningen.

Det forklarer Kristian Hegner, der sammen med sin kompagnon i Nordisk Energirådgivning, Nicolaj Rotbøl, har samlet et projektkonsortium, som undersøger nogle af disse muligheder for el-lagring i storskala. Konsortiet består af virksomhederne Nordisk Energirådgivning, Dansk Energirådgivning, Inter Terminals, Hofor Vind og Skanda, der med støtte fra Det Energiteknologiske Udviklings- og Demonstrationsprogram (EUDP) har fundet frem til en effektiv el-lagringsløsning, som involverer flowbatterier.

Flowbatteri-teknologien går ud på, at energien fra sol og vind bindes og opbevares i en elektrokemisk væske. Når energien skal bruges igen, omsættes den og afleveres den tilbage i elnettet som elektricitet. I projektkonsortiet har man bl.a. kigget på en flowbatteri-løsning, som anvender zinc-air, hvilket på nuværende tidspunkter vurderes til at være én af de billigste og mest energieffektive teknologier til el-lagring.

Men hvorfor etablerer vi så ikke flowbatterier som energilagre i elnettet?

Det vil kræve store investeringer at få implementeret flowbatterier som lagerkapacitet i det danske elnet, men Kristian Hegner minder om, at sådan var det også med vindmøller og solceller:

"Vindmøllerne er i dag den billigste måde at producere grøn strøm på, men det er de kun blevet, fordi vi har videreudviklet teknologien og investeret massivt i den i mere end 40 år. Nu er næste skridt, at vi skal være villige til at investere teknologier, som kan skabe balance i det grønne elnet".

Desuden pointerer Kristian Hegner, at det samlet vil være billigere at indbygge lagerkapacitet i elnettet, fremfor udbygning af elnettet eller produktionsanlæg, der kun ville være behov for i spidsbelastningsperioder.

Flowbatterier kan blive det næste eksporteventyr – hvis lovgivningen tillader det

Der er andre lande, som er længere med at udvikle og teste forskellige flowbatterier, men teknologien er stadig et sted, hvor Danmark kan blive foregangsland, forklarer Kristian Hegner og uddyber:

"Gør vi plads til at flowbatteriteknologien kan modnes i Danmark, eksisterer der et kæmpe eksportpotentiale i at opskalere flowbatteriet og gøre det omkostningseffektivt."

Skal vi udnytte eksportpotentialet, kræver det dog ændringer i den nuværende danske lovgivning og indtjeningsstruktur relateret til elnettet.

"Det en udfordring, at batterier i dag ikke er defineret som et separat produkt i elnettet. Det skelnes kun mellem forbruger eller producent. Batterier betragtes som både forbruger og producent i elnettet, idet batteriet tager energi fra nettet og lagrer, indtil det leveres tilbage i nettet igen, når der er behov for det. Det betyder, at batteriet bliver straffet med afgifter og tariffer ved både opladning og afladning, og denne dobbeltbeskatning gør det kommercielt umuligt at etablere et stort batterianlæg i det danske elnet", forklarer Kristian Hegner og henviser til, at det politisk set haster at få gjort plads til energilagring i takt med at andelen af vedvarende energi i elnettet stiger.