Storage4EU

THE AGE OF STORAGE HAS ONLY JUST BEGUN

#Storage4EU

Storage4EU is a collection of innovative and inspiring storage projects supporting the energy transition while ensuring a stable, secure, and affordable operation of our electricity grids.

Storage4EU is an initiative of the European Association for Storage of Energy to show the immense value of energy storage across Europe.

Discover more:

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EASE SECRETARY GENERAL

Patrick Clerens
EASE Secretary General

A decade ago, energy storage – with the exception of pumped hydro storage - was viewed as a niche technology with limited applications. It was considered too costly and largely unnecessary, as there was little need for flexibility in a system run on dispatchable thermal generation.

Energy storage has since grown in leaps and bounds, while the energy system has undergone dramatic transformations. The installed capacity of variable renewables – mainly wind and solar – increased by roughly 70% between 2005 and 2015. Cost declines and ambitious deployment targets mean that renewables will continue to be deployed around Europe. Digitisation and decentralisation have also contributed to fundamental changes in how the energy system operates.

The widespread deployment of renewables increases the need for flexibility at all timescales in the system. Energy storage – along with other solutions such as demand-side response, grid extension, and flexible thermal generation - can help the system cope with increasing shares of renewables. As its value for the system has grown, many storage technologies have experienced significant cost reduction and efficiency improvements, as well as innovations in business models and applications.

Today, energy storage is considered one of the key ingredients of the low-carbon energy system, characterised by very high shares of renewables, decentralisation, citizens' participation, and digitisation.

Storage can not only help the electricity system cope with higher shares of renewables, it can also help decarbonise the heating, cooling, and transport sectors through sector integration.

The European storage sector is incredibly diverse. There are dozens of storage technologies in R&D and on the market today (for example, pumped hydro storage, li-ion batteries, liquid air energy storage, power-to-gas, sodium sulphur batteries, supercapacitors, flow batteries, thermal storage, ...), which can be deployed in different configurations in order to suit a specific location and set of applications.

In Storage4EU, we are showcasing some of the most innovative and inspiring storage projects supporting the energy transition while ensuring a stable, secure, and affordable operation of our electricity grids.

While energy storage is deploying rapidly, EU policies and regulations are not yet up to speed. We need a clear, technology neutral regulatory framework that recognises the value that storage can bring to the system. Barriers to deployment must be removed. For instance, in some markets, storage is currently unable to access key balancing and ancillary services markets. Some services that storage could provide do not have clear remuneration systems.

A long-term view of the different revenue streams must be possible for investors to have enough certainty to invest in storage projects. Also, there is a need to harmonise grid charges, taxes, and fees applied to energy storage across the EU.

Finally, more funding must be made available for research, development, and demonstration of storage technologies. With the support of our members, EASE is working to address these many barriers, so that storage can live up to its full potential in supporting the energy transition. Storage4EU shows the immense value of energy storage across Europe, a sector that is brimming with innovation and creativity.

We hope you enjoy this snapshot of the storage sector. In many ways, the 'age of storage' has only just begun, and we are excited to see what new innovations and ideas will emerge in the coming years.

“IN STORAGE4EU, WE ARE SHOWCASING SOME OF THE MOST INNOVATIVE AND INSPIRING STORAGE PROJECTS SUPPORTING THE ENERGY TRANSITION WHILE ENSURING A STABLE, SECURE, AND AFFORDABLE OPERATION OF OUR ELECTRICITY GRIDS“

FOREWORD BY DAVID POST

CHAIRMAN OF EASE TECHNOLOGY AND VALUE ASSESSMENT COMMITTEE AND HEAD OF BUSINESS DEVELOPMENT GLOBAL THERMAL GENERATION AT ENEL

Over the past several years, energy storage has evolved from being considered a relatively minor player to being considered as one of the key enabling technologies that will help us transition to a low-carbon energy system.

David Post
Chairman of Technology and Value Assessment Committee

This growth shows no signs of stopping: energy storage capacity is expected to increase significantly over the next decade, at a rate of 5-10 GW per year worldwide.

This growth is mostly due to the strong penetration of intermittent renewable capacity and the closing of thermal plants, which impose on systems the need for alternative solutions – like energy storage and demand side response - to assure the necessary security and flexibility.

The accelerating rollout of storage capacity is due to a strong decrease in costs of batteries: lithium-ion battery costs have decreased substantially over the last two years, a trend expected to continue in the future. This cost reduction is driven by technological improvements, growing manufacturing capacity, and an increase in volume orders accelerated by the increase of EV sales.

While until now "in-front-of-the-meter" battery energy storage system (BESS) technology has led the storage developments, the "behind-the-meter" systems (systems installed on the customer's side of the utility meter) are growing fast and will represent a major development opportunity in the future.

Other storage technologies are also developing, leading to improvements in efficiency and to declining costs. Hybrid storage systems (combination of two or more storage technologies) are also gaining traction. Many different storage facilities are showcased in Storage4EU, and their immense benefits for the system are evident.

Energy storage provides a variety of services and benefits to the network such as spinning reserve, frequency regulation, power plants' efficiency increase, imbalance reductions as well as energy arbitrage (charge at off-peak and discharge at peak hours).

Alongside developments in technologies, new applications and business models for storage are emerging. In terms of business models, for stand-alone systems, investors are mostly targeting full-tolling agreements (100% capacity payment) or a mix of a floor capacity payment with merchant revenues. For hybrid battery energy storage system projects (batteries coupled with thermal generation), the return is mostly related to the cost savings (fuel and/or penalties) or improved production profile of the thermal plants.

Policymakers, however, have not kept up with the rapid pace of innovation and growth in the storage sector; although some countries have issued regulation for energy storage, many countries still lack specific rules for energy storage. However, more and more regulators have started to debate the need for specific regulation, while an increasing number of tenders for storage capacity is being launched worldwide.

EASE is working hard to ensure that the EU regulatory framework supports the development and deployment of energy storage, so that it can live up to its potential in supporting the energy transition.

"ENERGY STORAGE PROVIDES A VARIETY OF SERVICES AND BENEFITS TO THE NETWORK SUCH AS SPINNING RESERVE, FREQUENCY REGULATION,POWER PLANTS' EFFICIENCY INCREASE, IMBALANCE REDUCTIONS AS WELL AS ENERGY ARBITRAGE"

GENERATION AND BULK SERVICES

WINDGAS FOR THE ENERGY TRANSITION WITH UNIPER'S POWER -TO-GAS PLANT

Generation and Bulk Services | Uniper

For a successful energy transition, we will need large scale energy storage in order to ensure the security of supply. Uniper therefore operates the pilot plant WindGas Falkenhagen, Germany, where we have been demonstrating how renewable electricity can be used for the production of hydrogen by electrolysis, since August 2013.

This "green hydrogen" is then fed into the natural gas network effectively storing the excess power produced from renewable electricity generation. The Falkenhagen power-to-gas plant has an output of 2 MW and generates 360 cubic meters of hydrogen per hour. Falkenhagen in Brandenburg is an ideal location due to its high wind generating capacity and the well-developed power and gas infrastructure already in place.

In May 2018, the power-to-gas site was expanded by a methanation plant to offer even more possibilities of storage for renewable energies. The new methanation plant provides for the generation of "green" methane. In this second stage, hydrogen from regenerative energy sources is converted into methane (CH_4), i.e. synthetic natural gas (SNG), using CO_2 from a bio-ethanol plant. This constitutes an important contribution to the success of the energy transition, because green methane in contrast to green hydrogen can be used in a wider variety of ways. It can be made available to a variety of markets, such as the manufacturing sector, the electricity and heating market as well as the mobility sector.

Moreover, it provides for unrestricted use of the natural gas infrastructure, including for transport and storage. This stored energy is then available as backup whenever there is an insufficient supply of solar and wind power.

The new methanation plant was built right next to the PtG pilot plant and consists of several components. A prototype honeycomb catalytic reactor for methanation is installed and is being tested during the project. The methanation plant produces up to 57 m^3/h of SNG (at normal pressure and temperature), which equates to an output of 600 kWh/h. By comparison: the same amount of energy could heat a 50-m^2 apartment for a month. Moreover, the heat generated by the process is used by a nearby veneer plant.

WindGas Falkenhagen is part of the Horizon 2020 project STORE&GO, which aims to bring the technology to a level to be integrated in the daily operation of European energy grids. Uniper Energy Storage GmbH builds and operates the new plant together with thyssenkrupp Industrial Solutions AG, the research centre of the DVGW (German Association for Gas and Water) and the Karlsruhe Institute of Technology (KIT). thyssenkrupp and KIT designed the reactors for methanation and KIT is also providing scientific assistance to the project.

WINDGAS FALKENHAGEN IS PART OF THE HORIZON 2020 PROJECT STORE&GO, WHICH DEMONSTRATES THE PRODUCTION AND STORAGE OF RENEWABLE GASES."

EMERGENCY BLACK START CAPABILITY: GE'S ENERGY STORAGE BATTERY SYSTEM

Generation and Bulk Services | GE

Located in California, this 33MW / 20MWh battery system complements the integration of renewable resources and will increase grid flexibility and reliability by providing solar ramping, frequency regulation, power balancing and black start capability for an adjacent gas turbine.

The black start capability was activated on May 10, 2017, when the newly installed energy storage battery system successfully supplied the electricity needed to start a 44-megawatt combined-cycle natural gas turbine without relying on the external transmission network. To stabilise the power plant, the energy storage battery system was then converted, by design, to become an energy load consumer.

Although it is implemented in the US, it has similar use-cases in Europe in optimising the operational profile and the related emissions of fossil fired power plants. Frequency regulation and primary control reserve are already services marketed in Europe and could benefit from the presented hybrid approach.

HYBRID EGT ALLOWS MORE EFFECTIVE USE OF RENEWABLES

Generation and Bulk Services | GE

The LM6000 Hybrid Electric Gas Turbine integrates a 10 MW/ 4.3 MWh energy storage battery system and a ground-breaking control system capable of providing quick start and fast ramping to balance variable energy supply.

Variable energy supply happens when renewable production falls following weather conditions or the time of the day. The system provides enough time coverage to allow the gas turbine to start and reach its designated power output. It does not need to burn fuel and consume water in stand-by mode, reducing greenhouse gas emissions and pollution by 60 percent and water consumption by approximately 45 percent. In 2017, the Hybrid EGT received Edison Electric Institute and ESNA innovation awards.

The LM6000 Hybrid Electric Gas Turbine is located in US but has similar use-cases in Europe in optimising the operational profile and the related emissions of fossil fired power plants. Frequency regulation and primary control reserve are already services marketed in Europe and could benefit from the presented hybrid approach.

THE REVOLUTION OF ENEL GREEN POWER

Generation and Bulk Services | Enel

In some of the thirty countries where it works, Enel Green Power has already successfully installed various systems able to store energy and make it available when there is greater need, in order to balance demand and supply on electrical grids.

In Italy, the first EGP-brand storage system came about in 2015, in Potenza Pietragalla, Basilicata. Integrated with the wind farm of the same name, it's able to store 2MWh of energy and helps guarantee the stability of the electrical grid. Also in 2015, the first storage system (1 MW / 2 MWh) in a photovoltaic plant was built in Sicily, at the Catania 1 solar park, with an installed capacity of 8 MW. These two examples represent milestones for EGP in the field of storage solutions and a key step forward for the entire technological supply chain related to renewables.

The experience and know-how EGP has gained over the years has allowed them to create an innovative micro-grid with very high technological content at Cerro Pabellón, in the Chilean part of the Atacama Desert. The developed system integrates a 125-kWp photovoltaic plant with a Hybrid Energy Storage System (HyESS), based on lithium ion batteries (132 kWh) and hydrogen storage (1 MWh).

In Germany, the first 2-MW/2-MWh section of the Cremzow plant, in the state of Brandenburg, is already in operation. The lithium ion battery-based plant, which will reach its full size of 22 MW / 34 MWh by the end of 2018, will store the energy produced by the nearby wind fields and provide regulation services for the German grid.

However, the history of storage is still to be written. In the future, it is expected that a decrease in battery costs and the arrival of new technologies on the market can increase the speed of their deployment and integration with renewable sources to guarantee greater flexibility, and a production profile focused on the specific needs of customers and the grid.

The presence of storage systems, in fact, increases the value of a renewable plant, since it allows for a wide range of ancillary services, such as frequency and voltage adjustment and grid rebooting, which are necessary to guarantee the security of an electrical system.

THE LEVEL OF TECHNOLOGY USED IN THE ATACAMA DESERT IS A MODEL OF A HYBRID STORAGE SYSTEM INTEGRATED WITH RENEWABLES THAT CAN BE EXPORTED TO THE OTHER COUNTRIES WHERE WE WORK, TO REMOTE LOCATIONS AND TO ISLANDS

TÂMEGA HYDRO COMPLEX: IBERDROLA'S FLAGSHIP PROJECT IN PORTUGAL

IBERDROLA

Generation and Bulk Services | Iberdrola

This project involves the construction of Gouvães, Daivões and Alto Tâmega hydropower plants, which will be erected over the Tâmega River, in the north of Portugal.

The EIB finances this development with 650 million euros, out of a total investment of more than 1.5 billion euros. The three power plants will have a total installed capacity of 1,158 MW and will be capable of producing 1,766 GWh per year.

Iberdrola has started the assembly of the first turbine for the pumped hydroelectric power plant at Gouvães. This plant will include an underground cavern with four reversible pump turbines, generating a total power of 880 MW.

1,766 GWh
per year

CORTES-MUELA: THE LARGEST PUMPED-HYDRO STORAGE PLANT IN EUROPE

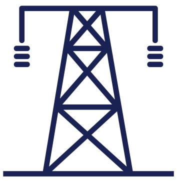
Generation and Bulk Services | Iberdrola

The Cortes-La Muela complex located in Júcar River (Spain) has a total installed capacity of 1767 MW. It includes the largest pumped hydroelectric storage plant in Continental Europe.

La Muela I and La Muela II power plants feature 7 X 212 MW reversible turbines. Two reservoirs with up to 524 metres altitude difference allow water to be stored in the upper reservoir and used to produce electricity during peak consumption times.

Pumped hydroelectric storage is the most cost-effective large scale storage method. It provides stability and flexibility to the electrical system, as it can produce large amounts of power with fast response times without any greenhouse gas emission.

TRANSMISSION GRIDS



ENEL DEVELOPS A STAND-ALONE BATTERY ENERGY STORAGE SYSTEM IN UK

Transmission Grids | Enel

The UK electricity market has experienced the gradual shutdown of conventional thermal generation units during the last years while increasing amounts of intermittent renewables have been connected, reducing the inbuilt system inertia.

The resultant rise in frequency volatility has increased the requirement for faster response times by National Grid, the UK TSO. At the time of the tender in 2016, National Grid's fastest service was the Firm Frequency Response (FFR), with response times for Primary and Secondary FFR of 10 seconds and 30 seconds respectively. The deployment of EFR, with a sub-second response time, has provided NG with greater control over frequency deviations, resulting in a cost saving for the system.

In summer 2016, National Grid's Enhanced Frequency Response (EFR) tender brought forward investment in eight battery storage facilities in the UK. The auction process secured 201 MW of capacity for a 4 year contract at prices between 7 and 11.97 £/MWh, at a total cost of £65.95 million over four years.

In May 2017, Enel acquired the BESS Tynemouth project from Element Power, an European based energy developer and operator. The project has one of the highest contract prices by National Grid (11,49 £/MWh). With a nominal capacity of 25MW/12.5MWh (end of life), the project represents the largest stand-alone BESS for Enel Group.

The project was built during the second half of 2017 under an EPC contract with RES (Renewable Energy System), using a lithium-ion battery provided by Samsung and put in operation in June 2018.
BESS Tynemouth will operate under a four-year Enhanced Frequency Response (EFR) contract with National Grid to provide grid balancing services and, after four years, the project will participate to the ancillary services market.

The UK is one of the most advanced markets in the world for utility-scale battery storage systems and one of the first in having set a frequency regulation tender well suited for stand-alone battery storage projects. Moreover, the country offers several revenue stream opportunities, including both regulated and market remuneration schemes. This has resulted in rapid deployment of BESS across the UK over the past three years, with different storage projects winning an EFR contract and also targeting different ancillary service market schemes.

Enel's BESS Tynemouth project has marked an important milestone in the growth of Enel Group in the stand-alone battery energy storage systems sector and has allowed Enel to gain experience and strategic knowledge in building such projects which can be applied to other markets.

TYNEMOUTH BATTERY ENERGY STORAGE SYSTEM IS THE LARGEST STAND-ALONE BATTERY ENERGY STORAGE SYSTEM OF ENEL GROUP

ENSURING GRID STABILITY WITH EUROPE'S LARGEST VARIABLE SPEED PUMPED STORAGE PLANT

VOITH **Transmission Grids** | **Voith**

Solar and wind power make a significant contribution to Portugal's electricity generation capacity and, because these technologies are weather dependent, the grid is vulnerable to fluctuations in supply.

This makes it the perfect place to build a pumped storage plant powered by a state-of-the art technology that helps ensure grid stability. Technology Group Voith supplied the plant with two variable speed pump turbines each with a rated output of 390 MW each, two asynchronous motor-generators with a rated output of 440 MVA each, the frequency converter and control systems. as well as the hydraulic steel components. The generator sets are the largest and most powerful of their kind in Europe. The plant operator is the Portuguese utility company Energias de Portugal (EDP).

Variable speed, constant reliability

Thomas König, responsible for Electrical Balance of Plant at Voith Hydro, explains how the technology works: "A conventional synchronous machine turns at a fixed speed in time with the 50 Hz grid frequency. In contrast, the mechanical rotation speed of the doubly fed induction machine (DFIM) machines can vary, which has two main advantages. Firstly, the new systems allow a fast and flexible response to active and reactive demand from the power grid – supply can be varied to meet demand. Secondly, they offer additional stability in cases of a voltage drop, reducing the likelihood of a blackout and enabling the system to resume operation much faster if one occurs. That's because when the voltage drops by significantly more than 5% below normal, the turbines and DFIM motor-generators at Frades II can retain stability for up to 600 milliseconds – four times longer than a fixed-speed power unit. This can mean the difference between normal operation and a widespread power outage."

Ultimately, DFIM technology delivers optimal operation in both turbine and pump modes, while fulfilling TSO (role assumed in Portugal by REN) requirements for grid fault behaviour by injecting fast active and reactive power when it is needed in both modes. Another key aspect of this technology (and perhaps the most relevant in terms of value creation) is the ability to provide power variation in pump mode, which can deliver the grid's needed teleregulation during off-peak hours, making Frades II the only plant in Iberia to do so without having to generate surplus power.

A model for the future

Since the Frades II plant entered commercial operation, it bears Europe's largest variable-speed units. And because grid stability and ensuring energy supply reliability are becoming more important everywhere, Frades II has provided a template that will be replicated around the world.

> "THE KEY OF THIS PLANT IS A SPECIAL ASYNCHRONOUS MOTOR-GENERATOR THE DFIM, OR DOUBLY FED INDUCTION MACHINE"
>
> **THOMAS KÖNIG**
> **SITE MANAGER, VOITH**

TERNA'S PILOT STORAGE PROJECTS TO TEST AND VALIDATE THE USE OF ELECTRO-CHEMICAL STORAGE

Transmission Grids | Terna

The rapid increase in electricity generation plants using non-programmable renewable sources (NPRSs) in Italy in recent years has had an increasingly tangible impact on processes for management of electricity flows (dispatching) and the safe operation of the national electricity system in general.

In order to optimise generation from renewable sources and at the same time ensure increased security management margins in the electricity system, Terna has identified energy storage as one of the possible solutions to the problem. This is why Terna has planned the installation of technologies in strategic locations across Italy and connected to the National Electricity Transmission Grid (NTG). This innovative use of storage systems has led Terna to launch an experimental programme aimed at implementing pilot projects designed to test and validate the use of electro-chemical storage at the "utility-scale" level.

The first project, launched by Terna in 2011, is focused on large-scale storage plants, connected to sections of the high-voltage (HV) grid in southern Italy, which are critical due to the high levels of penetration from NPRSs. With the primary focus on reducing congestion volumes, Terna conducted a public tender process leading to the selection of the NAS battery technology (sodium/sulphur) as the most suitable for the purpose. The total storage programme of 35 MW is composed of three plants, each connected to the NTG via a 20/150 kV Electrical Substation. The project operation enables the optimisation of the primary objectives (mitigating congestion from NPRSs) and the effective experimentation with highly innovative grid delivery services (e.g. experimental calibration of the primary regulation and secondary regulation of frequency, development of new and advanced dispatching services, etc.).

More experimental in nature and structured like a true energy storage laboratory, the second project (Storage Lab) was launched in 2012, and consists of 16 MW of multi-technology storage systems, aimed at increasing the safety margins of the HV networks on Italy's two largest islands (Sicily and Sardinia). With 13.4 MW total capacity already installed (21.2 MWh storage capacity), the Storage Lab project is the only one of its kind in the world in terms of the variety of available technologies and the innovative nature of the control systems. The individual storage units are lithium (9.2 MW, 5 types), Sodium Nickel-Chloride (3.4 MW, 2 types) and vanadium redox flow (0.85 MW, 2 types) based. To complement the existing technological portfolio, Terna also plans to install super-capacitor systems in the near future. With the Storage Lab project, Terna is able to experiment with the main storage technologies currently available on the market and test their performance in terms of supporting essential conventional services such as primary frequency regulation, secondary frequency regulation and Defence System easement.

The outcome of the experiments conducted by Terna will help us to place an emphasis on technological development in the sector and accelerate the integration of such resources in the dispatching service markets as well as in the national electricity system in general.

THIS INNOVATIVE USE OF STORAGE SYSTEMS HAS LED TERNA TO LAUNCH AN EXPERIMENTAL PROGRAMME AIMED AT IMPLEMENTING PILOT PROJECTS DESIGNED TO TEST AND VALIDATE THE USE OF ELECTRO-CHEMICAL STORAGE AT THE "UTILITY-SCALE" LEVEL.

35MW

total storage programme

EDF INAUGURATES ONE OF THE MOST POWERFUL BATTERY SYSTEMS IN EUROPE

Transmission Grids | EDF

"Change" is probably the best word that qualifies the UK energy landscape of the last decade. Through bold decisions and strong commitment on climate, the UK is changing its energy system and paving the way towards a new secure, affordable and low carbon energy future.

When National Grid, the Great Britain system operator, launched its first consultation on Enhanced Frequency Response back in 2016, EDF through its affiliates, engineering teams and R&D arm was among the first to welcome this announcement and put forward its expertise in order to design, build and now operate the largest project awarded at the end of the competitive process. Enhanced Frequency Response is a new dynamic service set by National Grid, where active power must change rapidly (sub 1 second) as a function of the system frequency.

Batteries are of course technically well placed to provide this service due to their fast response to a given power request. Moreover, the technology neutral call for tender issued by National Grid also confirmed that they are cost-competitive for such needs, as winners of the call for tenders were finally all battery storage projects.

West Burton B is a CCGT gas power station situated in the county of Nottinghamshire in England, approximately 250km north of London. Commissioned in 2013, it comprises 3 units and has a total capacity of about 1.3 GW.

EDF Ingeum's engineering skills enabled this pioneering step for EDF to deploy a large battery energy storage asset within a conventional plant to create such an innovative "energy park". This project also leveraged 25 years of experience in energy storage at EDF's R&D. Such commitment has enabled the development of key skills and tools to support technology selection, confirm key performance indicators, prototype and validate integrated solution in a representative environment and optimise business models.

In a changing energy landscape, EDF is ramping up its efforts to develop electricity storage solutions and become the European leader in this field. Within the framework of its ambitious electricity storage plant, EDF's goal is to develop 10 GW of additional storage around the world by 2035 (€8 billion investment), on top of the 5 GW already operated by the Group.

EDF'S 49 MW BATTERY STORAGE FACILITY IS ONE OF THE LARGEST PROJECTS IN THE NEW FREQUENCY CONTROL SYSTEM DEPLOYED ACROSS THE UK TO IMPROVE POWER SYSTEM STABILITY

HIGHVIEW POWER LAUNCHES LAES PLANT IN THE UK

Transmission Grids | Highview Power

True long-duration energy storage addresses challenges of rising energy demand and balancing the grid. On 5 June 2018, the world's first grid-scale Liquid Air Energy Storage (LAES) plant was officially launched by Highview Power, the world leaders in LAES technology.

The 5MW plant at the Viridor Pilsworth site in Greater Manchester, UK, was opened by Professor John Loughhead OBE FREng FTSE, Chief Scientific Adviser at the UK Government Department for Business, Energy & Industrial Strategy (BEIS). The plant was developed in partnership with recycling and renewable energy company, Viridor, and enabled in part by over £8m of funding from BEIS. The LAES plant, which can provide enough power for about 5,000 average-sized homes for several hours, will undergo a full testing programme during its first year of operation.

Operated remotely by demand response aggregator KiWi Power, the plant will demonstrate how LAES can provide a number of reserve, grid balancing and regulation services. Yet the opportunity is far greater: true long-duration energy storage is critical to enable the broader deployment of renewable energy, overcome the intermittency of solar and wind energy, help smooth peaks and troughs in demand, and provide the UK with a stable and secure source of home-grown energy. LAES technology can scale to hundreds of Megawatts, meeting the peak energy demand of urban areas from small towns to large cities. LAES plants could easily store enough clean electricity generated by a local windfarm to power a town of around 100,000 homes for many days, not just a few hours. And with the demonstration of LAES technology at the 5MW scale, the plant paves the way for the wider adoption of LAES technology globally.

LAES technology makes use of a freely available resource, the air, which is stored as a liquid and then converted back to a gas, involving an expansion process that releases stored energy, and this drives a turbine to generate electricity. In addition to providing energy storage, the LAES plant at Pilsworth converts waste heat to power using heat from the on-site landfill gas engines. LAES plants use no exotic metals or harmful chemicals; the plant comprises mostly of steel, and the components have a design life of between 30 to 40 years. At the end of life, a LAES plant can be decommissioned and the steel recycled. LAES plants can be located at the point of demand which makes them highly flexible and able to supply energy to help urban areas keep the lights on.

> "LAES TECHNOLOGY IS THE ONLY LARGE SCALE, TRUE LONG-DURATION AND LOCATABLE ENERGY STORAGE TECHNOLOGY AVAILABLE TODAY AT AN AFFORDABLE COST."
>
> **GARETH BRETT**
> **CHIEF EXECUTIVE OFFICER, HIGHVIEW POWER**

BATTERY STORAGE FOR THE ENERGY TRANSITION IN AACHEN

Transmission Grids | Uniper

As the share of renewable energies in the electricity mix increases, so does volatility. Therefore, it is becoming increasingly important to be able to store energy on a large scale. Battery storage technologies are a sensible option. They can help to integrate renewables into the energy system by offsetting their fluctuating, difficult-to-predict generation capacity in the short term.

The modular battery storage M5BAT in Aachen, Germany, is ideally suited to test the technical and economic suitability of large-scale battery storage systems. The project started in July 2013 and will run until December 2018. As part of this joint project, Uniper and its partners have installed a stationary battery system in a specially converted building.

The battery system has a storage capacity of 5 MWh and bundles various battery storage technologies. We are currently testing the application possibilities and economic viability of the different battery technologies. The knowledge gained from this project will help us design future strategies for the use of battery storage, deploying the battery technology best suited to meet the local requirements.

M5BAT is located next to a transformer and RWTH Aachen University research centres. The battery storage system will be used in various markets for research purposes, for example to provide primary control power.

This energy storage system project provides important insights for the entire energy industry and contributes to making battery technologies usable for the energy transition. This is underlined by the partial funding of the project by the German Federal Ministry of Economics and Energy (BMWi).

5 MWh

The battery system has a storage capacity of 5 MWh and bundles various battery storage technologies.

TALLAGHT SMART GRID MAXWELL ULTRACAPACITORS' FREQUENCY RESPONSE

Transmission Grids | Maxwell Technologies

Ireland intends to achieve 40 percent renewable energy by 2020. Most of this electricity comes from large-scale wind farms with only limited connection to the UK.

FREQCON deployed Ireland's first combined ultracapacitor & energy storage facility for the Tallaght Smart Grid Testbed in South Dublin County. The 300 kW / 150 kWh system was developed to demonstrate that a combination of lithium-ion batteries, Maxwell Technologies ultracapacitors, and FREQCON power converters can provide fast frequency response to enable high renewables penetration.

40%

Ireland intends to achieve 40 percent renewable energy by 2020

ENGIE DROGENBOS PROJECT: A BRIDGE BETWEEN BUSINESS AND RESEARCH

Transmission Grids | Engie

The Drogenbos project consists of five batteries, having different cell technologies and coming from different suppliers, piloted separately or as a whole for a total of 6 MW/6MWh.

This initiative is one of the first storage installations in Belgium dedicated to the frequency regulation service with batteries. ENGIE Laborelec actively contributed to the project by defining technical requirements and selecting the suppliers.

ENGIE Laborelec is in charge of the monitoring of the batteries in the long term, which will be implemented through its battery health monitoring services. The fifth technology was chosen with a higher C-rate to enlarge the flexibility of the whole system.

6 MW/6 MWh

project consists of five batteries for a total of 6 MW/6MWh

DISTRIBUTION GRIDS

LARGE-SCALE LITHIUM-ION AND NAS® HYBRID BATTERY SYSTEM DEMONSTRATION PROJECT LAUNCHED IN NIEDERSACHSEN

NGK

Distribution Grids | NGK

Japan's New Energy and Industrial Technology Development Organization (NEDO); the Ministry for Economics, Labour and Transport of Niedersachsen of the Federal Republic of Germany; EWE-Verband, an association managing the electric power supply to 17 districts and four cities in Niedersachsen; and EEW Holding have agreed to jointly implement a demonstration project of a large-scale hybrid battery system.

On 19 March 2017, Mr. Furukawa, Chairman of NEDO; Mr. Lies, Minister for Economics, Labor and Transport of Niedersachsen; Mr. Schönecke, Association Director of EWE-Verband; Mr. Bramlage, Deputy Association Director of EWE-Verband; and Mr. Röhler, Managing Director of EEW Holding signed a memorandum of understanding. At the same time, Hitachi Chemical Co., Ltd.; Hitachi Power Solutions Co., Ltd.; and NGK Insulators, Ltd., Japanese companies commissioned by NEDO to implement the project, and EWE AG, an energy provider in Germany, have agreed to collaborate in the project and concluded an implementation document.

11.5MW/22.5MWh

An innovative hybrid system with 4MW/20MWh NAS battery and 7.5MW/2.5MWh Li-ion battery

The demonstration project is carried out over a three-year period from April 2017 to March 2020 and was launched in Varel, Niedersachsen, which has been actively introducing renewable energy, particularly large-scale wind power, in recent years.

The project aims to build a large-scale hybrid battery system using lithium-ion batteries and NAS® batteries that can stabilise the distribution grid, and thereby controlling the electric power supply and demand balance, by charging and discharging storage batteries. Another aim is to establish an innovative business model for electricity trading using the system, in collaboration with Germany's enera project.

The large-scale hybrid battery system was built using lithium-ion batteries from Hitachi Chemical, NAS® batteries from NGK Insulators, and a power grid information and battery control system from Hitachi Power Solutions.

It was designed by taking advantage of the features of lithium-ion batteries with a high power charge/discharge output and of durable, large capacity NAS batteries, combined with a power grid information and battery control system that communicates information in and outside of balancing groups in cooperation with EWE AG's electricity trading system. Through this system, the four functions of primary control reserve supply, secondary control reserve supply, balancing within a balancing group, and reactive power supply that stabilise local power voltage will be realised to replace the functions of conventional power plants. Electricity trading will be executed in line with the EWE Group's electricity trading system. The demonstration project also aims to establish business models so as to make the system attractive to power generation and electricity trading companies in and outside of Germany, thereby expanding the hybrid battery system in the future.

THIS PROJECT CONTRIBUTES TO THE SUCCESS OF THE ENERGY TRANSITION IN GERMANY AND CAN BE REGARDED AS A BLUEPRINT FOR WORLDWIDE DEPLOYMENT AND THUS, OFFERS CONSIDERABLE OPPORTUNITIES FOR THE NIEDERSACHSEN ECONOMY

MICRO GRID OF SAN AGUSTÍN DE GUADALIX FOR THE OPERATION OF DISTRIBUTED RESOURCES

IBERDROLA

Distribution Grids | Iberdrola

Iberdrola has installed a micro grid facility in the Campus of San Agustín, composed of 3 Li-ion batteries of 170kW/250kWh, several photovoltaic plants, a Building Management System, EV charging points and wind generation.

This project is focused on the interaction between the dispatching centre and distributed energy resources. The first objective was to adapt the distribution management system. The DSO will have to be able to operate the grid, enabling all these elements connected to the grid or temporarily off-grid, and the systems must be ready for that. Co-ordinated operation of several storage systems to provide services to the grid has also been tested.

170kW/250kWh

Micro grid facility, composed of 3 Li-ion batteries of 170kW/250kWh

THE H2020 STORY PROJECT RESEARCHES NEW ENERGY STORAGE TECHNOLOGIES

Distribution Grids | CENER

The H2020 STORY project is researching new energy storage technologies and their benefits in the distribution networks and involves 18 Partner Institutions in 8 different European countries.

Preliminary results obtained in STORY's Spanish plant demonstrate that even with the regulatory restrictions applied, the peak power can be reduced by about 20% as well as the energy consumption from the grid during peak hours (17.00-23.00) to amount to overall savings of up to 8%.

Estimates from simulations with an advanced energy management strategy allowing the battery to charge from the grid, reveal that power peak reductions of up to 50% in peak hours and overall savings up to 20% are possible.

ENERGY STORAGE SUBSTATION FOR GRID RESILIENCY AND MV RENEWABLE NTEGRATION

Distribution Grids | Iberdrola

Iberdrola is installing its first 1,25MW/3MWh Li-ion battery for real operation on the Spanish grid, at the end of a long feeder in the region of Murcia.

The plant is located in an area prone to adverse weather events with difficult accessibility in a confluence of several 20kV lines. In case of an outage, the battery, which will be operational by the end of 2018, will maintain the power supply to the neighbouring villages, deciding automatically the line or lines to be fed by the battery and the size of the electrical island considering the current demand and local generation.

1,25MW/3MWh

Iberdrola is installing its first 1,25MW/3MWh Li-ion battery

CUSTOMER SERVICES

THE PHOTON FARMER'S BROMINE BATTERY TECHNOLOGY

The International Bromine Council

Customer Services | BSEF

Renewable, low-carbon energy systems are part of the strategy to address global climate change while meeting our energy needs but we are not there yet with these climate friendly systems. Lots of electricity is not consumed at the time it is produced. More energy storage is needed so that electricity is not wasted and can be provided continuously.

Clever energy storage strategies and systems are required. One such example is the Photon Farmer. A farmer cannot depend on when the sun shines or when the wind blows to milk his cows.

Farms, the ideal locations for solar and wind energy storage

To run a farm, a lot of energy is needed. Our traditional energy system is based on large, central production facilities and many small users. The production of energy is then in line with the demand. Optimally matching supply and demand is not that self-evident with renewable energy. Here is where bromine-based flow battery technologies can help.

The Photon Farmer – a dairy farm located in Vierakker in the Eastern Netherlands – is now testing this revolutionary energy storage system. The 57.5-hectare family-owned sustainable and highly automated farm houses 100 cows, and has a large shed roof with a 50kW rooftop solar system.

Just as most farms, there's even paddock space for windmills if needed. The aim of this project is to make this farm become completely grid independent, and to explore the best business model for storage of locally produced renewable energy. Positive results should serve as an example for other projects inside and outside the agricultural business. With this goal in mind, the Photon Farmer has obtained financial backing from the European Union.

Bromine-based flow batteries are making it happen

The Photon Farmer is the first project in its region to test the Redflow ZBM2 intelligent battery management system, and to profit by it. The Redflow ZBM2 battery is a bromine-based flow battery. It is the ultimate renewable solution for smart grid en-

ergy management. The advantages of this energy storage system are notable. Decreasing power demand at peak hours lowers the electricity usage.

By deploying power when it is needed the most, energy waste is minimised. And users are assured that operations can continue in the event of power outage. Redflow's unique battery is fire safe and non-flammable – because of both its design and the used bromine electrolyte – and can operate at high ambient temperatures. With the 100% daily depth of discharge and the delivery of 10 kWh of sustained storage (warranted for 10 years), the flow battery delivers superior energy storage performance. On top of that, there is no loss of energy storage capacity over time.

The reduction of the impact of energy consumption through improved efficiency, and successful deployment of renewable sources, present both financial growth and environmental benefits. That is why – in 2016 – the unique storage design was nominated for the Responsible Care Award by the VNCI, and why BSEF supports this innovation in energy storage.

FLOW BATTERIES CAN BE RECHARGED RAPIDLY BY REPLACING THE ELECTROLYTE WHICH IS STORED OUTSIDE THE CELL. THESE RECHARGEABLE BATTERIES CAN BE LEFT FULLY DISCHARGE INDEFINITELY.

INTERVIEW WITH ROWENA MCCAPPIN – GLEN DIMPLEX PROJECT DIRECTOR

Customer Services | Glen Dimplex

Q. What did the RealValue project involve and what was Glen Dimplex's role?

A. Glen Dimplex was the coordinator of RealValue, a three-year research and innovation project which received €12M through Horizon 2020, involving 13 partners across five member states, representing the entire electricity value chain. Our 'Quantum' Smart Electric Thermal Storage space and water heating appliances, known as 'SETS', were installed in 750 properties across Ireland, Germany and Latvia and connected to each country's power grid.

The project has delivered a huge leap forward in learning around how small-scale energy storage systems, when aggregated together, can help bring maximum value from clean energy in a more environmentally conscious world.

Q. What were the outcomes of RealValue and the added value for energy storage?

A. RealValue has demonstrated the role that Quantum SETS can play as thermal storage devices for energy balancing, grid security and supply, decarbonisation and integration of RES, network congestion and demand-side management, whilst simultaneously offering enhanced end-user experience in terms of increased comfort and control, and greater energy-efficiency.

As well as proving the effectiveness of the technical solution, within the project building and energy system modelling was carried out to assess the relative suitability of European countries for SETS into the future. Regulatory analysis assessed the market readiness for the RealValue solution and identified the most interesting business cases. We were also highly involved in BRIDGE, the European Commission Initiative for knowledge sharing between Horizon 2020 Smart Grid and Energy Storage projects. This provided unrivalled opportunity to share experiences from RealValue, and learn from other like-minded organisations, which is a crucial aspect of any R&D process.

Q. Where next for Glen Dimplex?

A. We believe that the home of the future will be all-electric and fully connected; Glen Dimplex's future direction will be defined by this vision. Everyone will be able to become an active player in the energy transition world, but in a simple way. It will all add up to more energy efficiency, more control, more comfort – and the potential for new revenue streams and lower bills.

"EVERYONE WILL BE ABLE TO BECOME AN ACTIVE PLAYER IN THE ENERGYTRANSITION WORLD, BUT IN A SIMPLE WAY"

ENGIE'S IMPROVED SAFETY OF BATTERY STORAGE SYSTEMS

Customer Services | ENGIE

Safety is the first priority of any plant. ENGIE improved the level of safety standards by developing integration guidelines.

These provide technical assistance to integrators and project managers for the safe operation of batteries.

Engie Laborelec proposes different services to help project managers and operators of batteries:

- Workshops on safety risks per technology and adapted mitigation solutions;
- Project-specific technical recommendations ranging from the choice of the cell chemistry and characteristics, the sizing, to integration of safety measures;
- Support for Root Cause Analysis: evaluation of batteries failure modes.

ENGIE PEER2PEER (P2P) ENERGY COMMUNITIES

Customer Services | ENGIE

The P2P Energy Communities project consists in developing a global energy community platform, enabling the creation and daily energy management of communities, compatible with grid issues.

The (distributed) assets considered within the project are, amongst others, photovoltaics installations, residential batteries, and electric vehicles. The project is rolled out among 70 residential users (peers).

ENGIE provides through Laborelec:

- An optimised algorithm design matching the customers' energy profiles (production, consumption, storage);
- A remote control through manufacturer specific interfacing of batteries for the project;
- Low-cost sub metering development, roll-out and data processing;
- A definition of a fair distribution of the common generated value to stabilise the community interaction.

ISLANDS AND ISOLATED AREAS

EDF BUILDS THE ENERGY TRANSITION IN THE FRENCH ISLAND OF SEIN

Islands and Isolated Areas | EDF

Less than 2 km long and 500m large: Sein Island is a totally disconnected territory from the mainland. With its own electrical system, the island was totally powered by diesel generators until the beginning of 2017.

Faster than anywhere else, the islanders became aware of the consequences of climate change, especially the rising water that could flood this piece of land if nothing changes. The need for a radical energy transition is obvious. Therefore the local community was eager to take up the challenge early, more than ten years ago, with energy efficiency measures led together with EDF. Sein Island was the first French municipality to be fully equipped with LED public lighting, resulting in an 80% decrease in public lighting energy consumption.

A first PV rooftop and a self-consumption building kicked off the development of renewables on the island in 2016. Since then, very ambitious objectives have been set: renewables shall cover 50% of the electrical needs by 2023, and reach 100% in 2030, making this territory a pioneer and a reference for the rest of the French electrical system. Currently, around 130kW of photovoltaic rooftops are connected to the grid, and a 250kW wind turbine is expected in the next two years. However, the equation is not so simple. The population on the island fluctuates as much as the tides: 120 inhabitants in winter, up to 1500 during the summer period. The electrical system will have to cope with a combination of renewable energy intermittency and rapid load fluctuation. With its expertise on micro-grids, EDF SEI helps Sein island to take up this challenge.

An innovative architecture, developed in collaboration with EDF R&D, enables the insertion of renewables in the grid with the help of a storage system to adapt offer to demand and ensure the security of power supply. The solution is based on a centralised storage system installed together with an intelligent control system, developed by EDF's affiliate EDF Store & Forecast. A first 200kW/180kWh li-ion battery was installed in May 2017, enough to enable the target of 50% renewables when the wind turbine will be connected.

The energy optimisation software (Energy Management System) monitors and controls in real time the generation and storage units, and can control other flexibility resources as well, such as demand management. The solutions of this unique project in France could afterwards apply to other micro-grids or non-interconnected areas.

THE MICRO-GRID SOLUTION, BASED ON STORAGE AND A CENTRALIZED EMS, WILL BE ABLE TO MEET THE 50% RENEWABLE TARGET BY 2023

MAXWELL ULTRACAPACITORS PROVIDING RESILIENCY TO ISLAND MICROGRIDS

Islands and Isolated Areas | Maxwell Technologies

Island grids and off-grid microgrids require stable sources of power and are the most sensitive to power fluctuations from intermittent solar and wind energy generation. Fraunhofer Institute for Solar Energy Systems ISE has established a flexible hybrid energy storage system using intelligent energy management for reliable and resilient supply of power and energy from renewables.

Located on Borkum Island in the North Sea, the storage system consists of 1MW/10kWh of Maxwell ultracapacitors and 500kW/500kWh of Li-ion battery. The ultracapacitors smooth out power peaks and increase the battery lifetime by removing peak power demand and cycling demands from the battery.

500kW/500kWh

System consists of 1MW/10kWh of Maxwell ultracapacitors and 500kW/500kWh of Li-ion battery

SAFT LI-ION ENERGY STORAGE OPTIMISES WIND POWER FOR THE FAROE ISLANDS

saft

Islands and Isolated Areas | Saft

SEV, the Faroe Islands utility, has commissioned Europe's first fully commercial Li-ion energy storage system (ESS) operating in combination with a wind farm. Saft's containerised solution is helping to maintain grid stability so that the islanders can capture the full potential of their new 12 MW Húsahagi wind farm.

SEV has a green vision for 100 percent renewable electricity production by 2030 by making full use of the Faroe Islands' abundant wind and hydro energy resources, together with emerging technologies like photovoltaics and tidal energy. By 2030, SEV will double its current 314 GWh annual demand for electricity. "Saft and ENERCON were our partners for the Li-on battery and energy conversion systems. So far the ESS is functioning exactly as planned and the benefits of energy storage are clear." Terji Nielsen – SEV R&D Manager

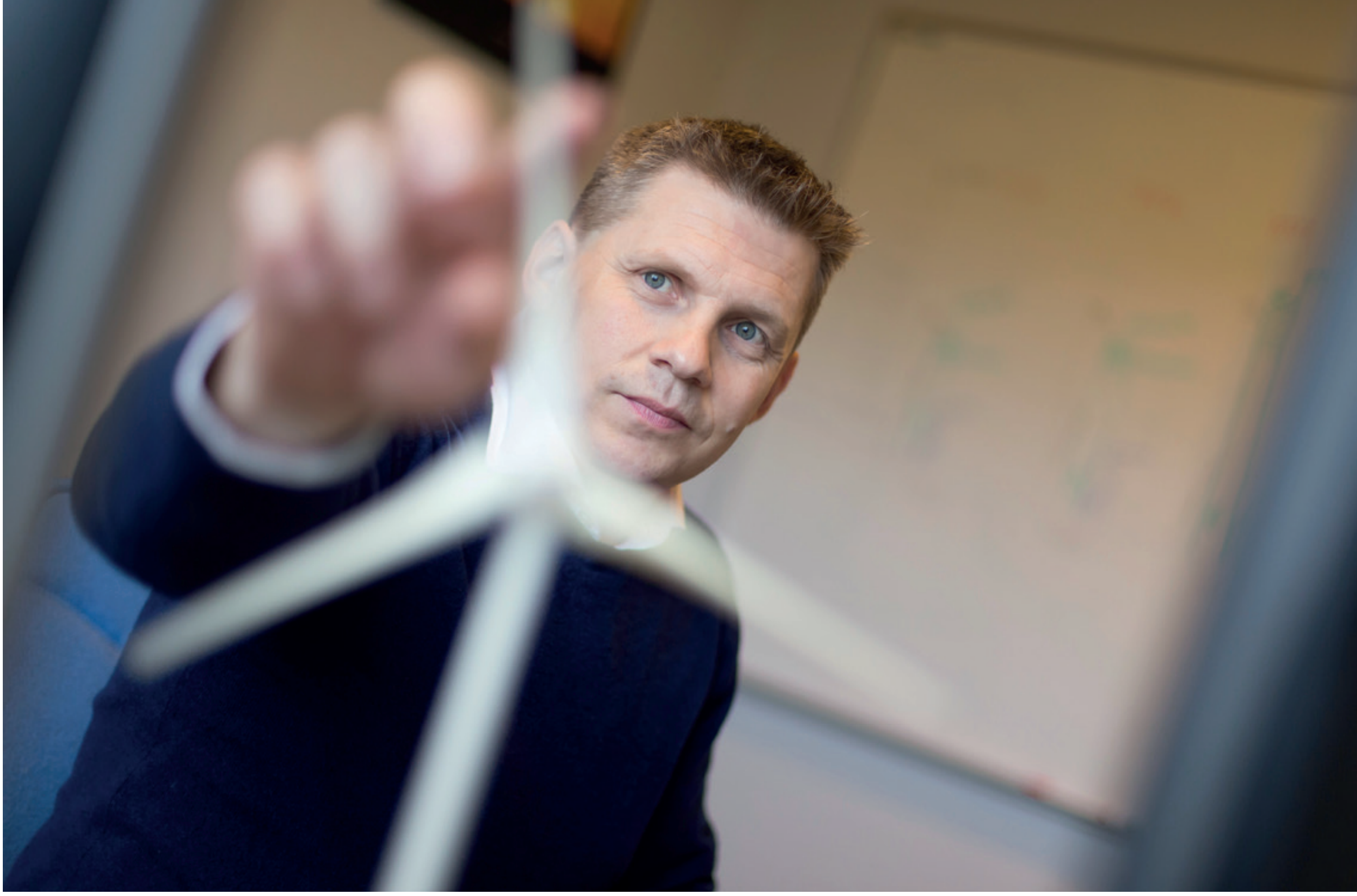
Overcoming the variability of wind power

The latest step in SEV's renewable energy programme is a new 12 MW wind farm located in Húsahagi, on the island Streymoy. Since coming on line in 2014, the wind farm has increased the islands' wind share to 26 percent of total electricity production.

To overcome short-term variations linked to the variable nature of wind, lasting from seconds to minutes, a 2.3 MW Li-ion ESS has been deployed. It provides ramp control to smooth out sharp increases and decreases in power, as well as frequency response and voltage control services. The use of energy storage thereby helps to minimise curtailment of wind generators during periods of high wind and low consumption.

Saft Intensium® Max solution

The 2.3 MW ESS at the Húsahagi wind farm comprises two Saft Intensium® Max High Power containerised Li-ion batteries. They were delivered in standardised 20-foot containers for ease of transportation and installation. Along with the battery



modules, they integrate the communications interface, battery management and cooling and fire prevention equipment. The batteries are combined with ENERCON's power conversion and control equipment. The ESS is designed to limit short term power variations of the wind farm in order to maintain grid stability. Due to the high power capability of the ESS, only 700 kWh of storage capacity are needed for this operation which requires the equivalent of several full discharge cycles per day over an estimated lifetime exceeding 10 years.

Successfully enhancing grid stability for SEV

The Húsahagi ESS was commissioned in December 2015. Since then, it has reduced the variability of power flows at the grid connection point (up to 5MW/min) by a factor of 15 to 20. As a result, the standard deviation of the grid frequency is reduced by about 50%. Furthermore, curtailment is reduced as SEV can operate the plant in period of strong wind variations, which increases the energy production by 5GWh per year and saves 1000t of fuel.

With SEV's operational expertise in renewable energy allied to Saft's leading-edge energy storage technology it is already making a significant contribution to enhancing grid stability.

Saft ESS solution- key benefits

- Enhanced grid stability
- Increased wind energy harvesting, reduced fuel consumption and CO_2 footprint
- Providing ancillary services such as frequency control
- Reduced Capex and short payback period of the ESS, which enables multiple high power discharges per day over its long life time

SAFT'S CONTAINERISED SOLUTION IS HELPING TO MAINTAIN GRID STABILITY SO THAT THE ISLANDERS CAN CAPTURE THE FULL POTENTIAL OF THEIR NEW 12 MW HÚSAHAGI WIND FARM

EDF STORES RENEWABLES WITH BATTERIES AND HYDROGEN TO MAKE AN ISOLATED VILLAGE ENERGY AUTONOMOUS

Islands and Isolated Areas | EDF

The Cirque of Mafate (700 inhabitants) is located in the center of Reunion island, France (Indian Ocean). Due to its morphological features, this magnificent classified UNESCO World Heritage site cannot be connected to the electric grid and was energised with diesel gensets.

EDF (Electricité de France), with the cooperation of POWIDIAN (a French SME), designed an installation that provides electricity produced by 100% renewable sources. This is achieved by using hydrogen-batteries technology, previously tested in mountain refuges, which provides very long term storage capacity. Called SAGES (Smart Autonomous Green Energy System), this installation is made of photovoltaic panels, lithium-ion batteries assuring a short term energy storage (1 or 2 days), and a whole hydrogen system (with a water electrolyser, a hydrogen storage system and a fuel cell) for long term energy storage (almost 5 days).

In order to satisfy the user power demand, first, the power produced by the photovoltaic panels is used. When this power is not sufficient, the complementary part is supplied by the batteries. When their state of charge decreases below 30%, the remaining needed power is produced by the fuel cell, using the stored hydrogen.

Conversely, if the photovoltaic panels produce an excess of power, this excess is used to charge the batteries or to produce hydrogen by the electrolysers. The storage system is currently servicing a school, a medical office and an office of the "Office National des Forêts". Commissioned in 2017, it successfully has guaranteed continuous and carbon-free electricity supply since then.

10GW/2035

EDF's goal is to develop 10 GW of additional storage around the world by 2035

The advantages of this technology are many: it allows 100% renewable energy generation, with no pollutants and zero carbon emission, in a landscape where diesel gensets were previously polluting the site. It guarantees security of supply for the inhabitants and especially for public services such as the school and medical office. The economics of this system are also positive, because of the very high supply costs of the fossil fuel previously used in the gensets (due to the specific geographical location of Mafate). Energy storage is one of the key elements of microgrid systems.

This is why EDF has developed specific expertise in microgrid systems and several EDF business units are already developing microgrid projects and solutions in various geographies. For instance, in the US, EDF Renewables works to tailor the wide range of microgrid solutions. In a changing energy landscape, EDF is ramping up its efforts to develop electricity storage solutions and become the European leader in this field. Within the framework of its ambitious electricity storage plant, EDF's goal is to develop 10 GW of additional storage around the world by 2035 (€8 billion investment), on top of the 5 GW already operated by the Group.

IN THE CIRQUE OF MAFATE, REUNION ISLAND, EDF DEVELOPS HYDROGEN AND BATTERY TECHNOLOGIES TO PROVIDE 100% RENEWABLE ELECTRICITY

ENERGY STORAGE TECHNOLOGIES AND APPLICATIONS

EASE supports all energy storage technologies and believes that they should be addressed agnostically. In order to show and clarify the diversity of storage technologies, we suggest a classification into five families: chemical, electrical, electrochemical, mechanical, and thermal.

The members of a family may change due to technological evolutions, but the categories reflect the five storage principles, which remain valid regardless of technological change. Therefore, the examples in each category should not be seen as an exhaustive list.

Chemical
- Ammonia
- Drop-in Fuels
- Hydrogen
- Methanol
- Synthetic Fuels
- Synthetic Natural Gas

Electrochemical
- Classic Batteries
  - Lead Acid
  - Li-Ion
  - Li-Polymer
  - Li-S
  - Metal Air
  - Na-Ion
  - Na-NiCl$_2$
  - Na-S
  - Na-Cd
  - Na-MH
- Flow Batteries
  - Vanadium Red-Ox
  - Zn-Br
  - Zn-Fe
- Hybrid Supercapacitors

Electrical
- Supercapacitors
- Superconducting Magnetc Energy Storage (SMES)

Mechanical
- Adiabatic Compressed Air
- Diabatic Compressed Air
- Liquid Air Energy Storage
- Flywheels
- Pumped Hydro

Thermal
- Latent Heat Storage
- Sensible Heat Storage
- Thermochemical Storage

Energy storage can be integrated in the energy system at various levels, from power generation to the transmission and distribution grids to the consumer. Energy storage does not fit neatly into any of these three segments but plays a role in all of them. Therefore, energy storage is often referred to as the fourth element of the energy system.

To show the immense value energy storage can provide at all levels of the system, EASE has identified the possible energy storage applications and organised them by segment of the energy system:

RENEWABLE GENERATION

- Distributed generation flexibility
- Capacity firming
- Limitation of upstream disturbances
- Curtailment minimisation

CONVENTIONAL GENERATION

- Support to conventional generation
- Black start
- Arbitrage

TRANSMISSION

- Primary frequency control
- Secondary frequency control
- Tertiary frequency control
- Participation to angular stability
- Investment deferral
- Improvement of the frequency stability of weak grids

DISTRIBUTION

- Capacity support
- Reactive power compensation
- Distribution power quality
- Limitation of upstream disturbances
- Intentional islanding
- Contigency grid support
- Dynamic local voltage control

CUSTOMER SERVICES

- Continuity of energy supply
- End-user peak shaving
- Time-of-use energy cost management
- Particular requirements in power quality
- Compensation of the reactive power
- Limitation of upstream disturbances

EASE MEMBERS

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