Workshop on Hybrid Energy and Energy Storage Systems
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Session 1: Challenges in developing enabling technologies and tools for hybrid energy and energy storage systems

Eugenio Domínguez, HESStec

Today, to increase sustainability, utilities and large energy consumers are working to deploy renewable energy solutions. ESSs (Energy Storage Systems) are historically proposed as the key player to achieve smarter grids, with a high penetration of renewable energies. They are deployed to solve stability problems, mismatching between generation and consumption, and a large list of events and issues that a utility, generation plant owner or grid operators have when taken cumulatively result in suboptimal capital efficiency. This is a dramatic pain point for operators.

HESStec's aim is to provide a better understanding on the design and modelling of a HESS (Hybrid Energy Storage System) solutions (hardware/software platform based on the combination of several energy storage technologies, along with enhanced power electronics and energy management systems), its sizing and assets optimization methods and how the energy storage lifetimes can be extended at the same time that multiples services are provided, allowing them to capture multiple benefits streams to offset system costs. This issue is crucial for improving the profitability of new business models.

This approach and methodology for sizing and operation is extended from a HESS to other assets in the same grid or microgrid, such as power sources/loads (including all the power electronics-based items), thanks to the virtualization of assets by means of their behavioral models and its implementation using the State of Function tool (SoF). By using this method, operation of the assets is optimized, performing a decoupling between power and energy and providing the best possible response in every moment operating any of the flexible assets in the grid, depending on their real-time state and its past operation. In-depth topics:

Questions for discussion

1. Decoupling between power and energy application: which quantitative and qualitative benefits does it provides is compare with other solutions based on non-hybrid approaches?
2. How important is the virtualization in this method? What do you need from the asset developers? And from the grid operator? Which advantages to they take instead?

Case study:

Thermal and chemical storages for 2030 and beyond

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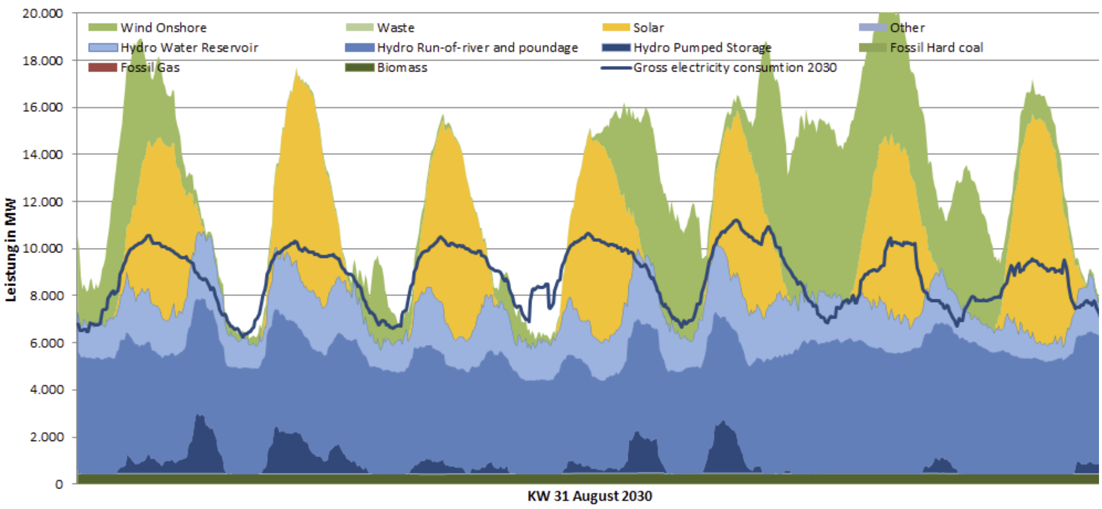
Two factors, i) the increase in the share of renewable energy sources in the grid and ii) the progressing decarbonization, will require a drastic expansion of thermal storage capacities in industrial plants and processes and chemical storages in future infrastructure. The expected electricity price fluctuations in 2030-2050 scenarios make energy storage economically extremely attractive, especially for thermal storage, where energy can easily be stored in the required form. For seasonal electricity storage, power-to-gas will most probably be the method of choice. Excess heat from power to X to power cycle can be utilized either directly, or via heat pumps and/or thermal storage devices, where X could be e.g. hydrogen, ammonia or methane. Depending on the application, different storage concepts are preferred. This talk shall give a brief overview of the whole concept and show where different storage technologies might kick in.



Electricity production (area) and demand (dark blue line) in Austria in August 2030 [1]

[1] G. Pauritsch, 100% erneuerbarer Strom – Speicherbedarf für das Stromsystem, Energiegespräche 2018, Wien

Case study:

Title: *"A two-stage stochastic optimization model for the calculation of the water value in an isolated hybrid diesel/wind/pumped-storage power system"*

Authors: Daniel Fernández-Muñoz and Juan I. Pérez-Díaz

Abstract: the authors present a two-stage stochastic optimization model to calculate the water value in the isolated hybrid diesel/wind/pumped-storage power system (with no natural inflows in the upper reservoir) of El Hierro Island in The Canary Archipelago. The proposed model is based on linear programming and takes into account in an approximate manner that the start-up cost of the diesel units depends on the time passed since the last shut-down. First, a deterministic version of the proposed model is used to compute the system water values in a set of scenarios. The water values are then used as input for the day-ahead generation scheduling. The scheduling cost is compared with the one obtained as a result of a detailed mixed integer linear programming (MILP) model with the same time horizon as the proposed model. Second, the water values obtained with the proposed model have been compared with those obtained with its deterministic version in another set of scenarios, and both have then been used as input for the day-ahead scheduling model. The results obtained in the paper indicate that the proposed two-stage stochastic optimization model can provide acceptable water values with a short computational time and that the use of a detailed MILP model is impractical for the TSO to compute the system water value in their day-to-day work.

Session 2: Linking different storage technologies

Antonio Morandi, University of Bologna

Energy storage is a key technology for modern electric power systems. Its introduction in the grid contributes to cope with the inherent imbalance between load and generation, which is becoming very acute due to increasing penetration of green dispersed generation in the energy mix. Furthermore, application of energy storage at the customer site can provide immunity with respect to voltage disturbance, UPS service and power modulation. A classification of energy storage technologies can be made based on the power they can provide, the duration of the delivery and the number of deep charge/discharge cycle that they can withstand. No unique storage technology exists able to span the entire range of characteristics appropriate for all applications. The most suitable storage technology must be chosen from case to case. Hybrid systems, obtained by combining different storage technologies, represent a convenient option in many situations.

Superconducting Magnetic Energy Storage (SMES) offers complementary characteristics with respect to other storage methods: high charge and discharge power, fast response, high number of cycles, high round trip efficiency. Its exploitation in combination with energy intensive storage technologies (e.g electrochemical batteries) enables the feasibility of cost-effective hybrid storage systems (Energy Intensive + Power Intensive), able to meet all the needs both at the customer and at the grid level. The state of the art of SMES technology is reviewed. Possible use of SMES in combination with batteries or other storage technologies is discussed with reference to a few case studies (smoothing of renewables and Fast Charging Stations for EV)

Question 1: Does a power profile suitable to be split in a "high power / low energy" and a "high energy / reduced power" component exist in the real world? What can be a case study?
Question 2: Is there a power intensive storage technology able to bring a substantial - not marginal - benefits to batteries? Can SMES succeed in this?

Case study:

Challenges in developing tools for hybrid energy and energy storage systems: SMES Interfacing, a Case of study

Xavier Granados, Scientist of the Spanish Agency for Scientific Research, in the Institute of Materials Science of Barcelona.

A short introduction of the linking of several energy sources/vectors leads to the need of transforming the several sources and storage ways to an unique vector corresponding to the needs of the consumers. In case of using electricity as the common vector the redistribution of the several resources, the coordination depends strongly on the response times and limitations in the control of the power deliverable or stored by the resources. Introducing a fast and robust storage system allows enhanced flexibility of the coordination and energy resources dimensioning. A simple electrical car is proposed as case of study.

Session 3: Linking transportation and their energy storage systems to the grid

Jörg Burkhardt, hySOLUTIONS

hySOLUTIONS is a subcompany of the public transportation company HOCHBAHN which currently operates ca. 900 busses in Hamburg, Germany. As decided by local authorities, only electric busses will be purchased from 2020 on. With this strategy, HOCHBAHN foresees to replace all of its diesel busses by battery electric busses until 2030.

The busses will be mainly charged over night at the bus depot (150 kWel/bus) by electricity from the electric grid and will contain a battery with a capacity of about 250 kWhel/bus. Due to degradation effects the batteries are expected to be used for about 5 years until they are replaced by new batteries. An idea is to use a part of these old batteries (ca. 45 MWhel/a) in second life applications, for example in stationary electricity storages to be installed at the bus depots.

Regarding the energy supply, the main questions arising from the above strategy are:

- How can we increase the amount of renewable electricity being charged by the busses?
- What kinds of operation and business models are applicable if we use second life batteries in stationary electricity storages at the bus depot? Which of them help us in linking transportation to the electric grid?

Case study:

Power-to-molecules – Converting renewable electricity and CO_2 into chemicals for mobility, industry and energy storage

Michael Klumpp, Marcel Loewert, Hannah Kirsch, Sarvenaz Farsi, Francisco Vidal Vázquez, Alexander Wunsch, Giulia Baracchini, Peter Pfeifer and Roland Dittmeyer

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Abstract

As recently being emphasized by the IPCC, in order to limit global warming, our energy system has to be changed unprecedently. Obviously, the share of renewables in the electricity sector has to be increased drastically. However, wind and sun do not deliver a constant level of electricity over daytime and season, and the electricity consumption also shows considerable fluctuations. Furthermore, the most effective sites for wind energy generation are often not located where electricity is needed. This demands a paradigm shift in order to successfully develop and implement an integrated energy system based on local, small scale plants of energy generation from renewable sources combined with decentralized energy conversion and storage in a smart, interlinked manner.

A major focus of research of the Institute for Micro Process Engineering of the Karlsruhe Institute of Technology (KIT), is on the catalytic conversion of "green" hydrogen e.g. from water electrolysis using renewable electricity together with CO_2 potentially captured from thin air into valuable chemicals for energy storage as well as for utilization in transportation and chemical industry. In this contribution, the basic concept of autarkic, modular decentralized Power-to-Molecule plants is presented with special focus on the related research within the large-scale research infrastructure Energy Lab 2.0 currently being built by the Helmholtz Centers KIT, German Aerospace Center, and Forschungszentrum Jülich.