Flow battery operating in hybrid energy storage system

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Introduction

Hybrid energy storage systems (HESS) claim to have techno-economical parameters superior to storage systems based on a single technology [1] in terms of system cost, lifespan, reliability and flexibility. A proper application of HESS however requires a proper approach to system design and control. Some control architectures have been reviewed in literature, mostly including hierarchical control [2]. Practical development of HESS controls integrated with a microgrid is stated as an important issue for future development.

This paper discusses practical demonstration of a HESS including VRFB system, that is installed in KEZO Research Centre, Jablonna, Poland and development of its controls.

Hybrid energy storage demonstration

KEZO is a living-lab that forms a microgrid with enough power production capacity to sustain itself. It is equipped with a number of local sources (180kWp PV, 100kWe CHP, 12kW wind turbine) and loads (office and lab buildings, HVAC components, EV chargers) with a custom developed building management system forming a modern local power system.

To further extend the abilities to balance energy in the microgrid and to research other functions of energy storage in a system, a HESS has been developed. The heart of the system is the H2 EnerFLOW 410 VRFB system with 12kW continuous power and 100kWh capacity (Figure 1). More battery technologies have been added indoors as listed in Table 1 and shown in Figure 2. In total a 60kW, 180kWh HESS is formed.

Battery	Power	Capacity
Vanadium Redox Flow VRFB	12kW	100kWh
Lithium Iron Phosphate LFP	24kW	24kWh
Advanced Lead Carbon ALC	16kW	24kWh
GEL Lead Acid	8kW	32kWh
Total HESS	**60kW**	**180kWh**

Table 1. Hybrid energy storage demonstrator - battery list

Energy management in the microgrid is held by a set of microgrid controllers manufactured by DEIF. Their fundamental functions include maintaining power balance at the grid connection point as well as island forming on grid failure events. In a typical grid-connected scenario the control system provides battery setpoints to achieve zero net export.

Figure 1. H2 EnerFLOW 410 battery container

Figure 2. HyStore indoor batteries: Advanced Lead Carbon, Lithium Iron Phosphate and GEL Lead Acid

HESS operation

The described HESS has been tested practically with a variety of energy profiles. KEZO exhibits a seasonal pattern of production and load (surplus PV energy in summer, heavy heat pump load in winter), and a variable energy usage pattern (resulting i.e. from lab experiments or EV charging). Total microgrid load varies from 20 to 80kW while RES generation can reach up to 180kW.

Figure 3 shows an example profile of HESS operation. The control system is set to limit power drawn from the grid between 0 and 20kW. A typical baseload of 20kW with a periodical operation of a 25kW heat pump and daily pattern of PV generation are visible.

This example uses two batteries, forming a flow-lithium hybrid, for demonstration purposes. Existing controllers allow to set battery priorities - VRFB is set as a primary 'energy source' with full DoD allowed, while LFP is set to 'power source' mode with a limited DoD. Setting the VRFB as a base source allows the lithium type battery to be used as a peak source and thus saving its operation cycles.

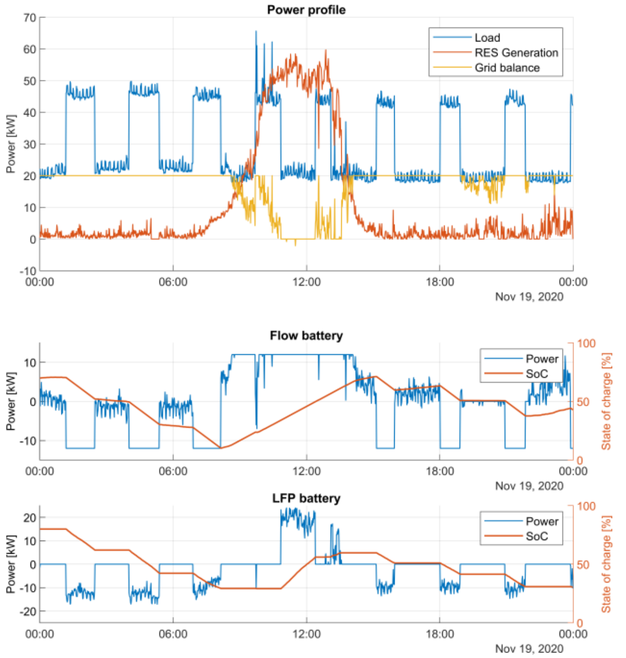

Figure 3. Daily profiles of a flow-lithium hybrid system

Control system development

The system described above shows only an example of a fundamental rule-based approach to HESS control. Optimal allocation and scheduling of each battery type requires the development of advanced control methods. The aim is to increase the economic benefits from HESS, capturing multiple energy services with a single installation. What is more, HESS provides the possibility to optimize battery cyclic performance by proper scheduling and adjusting operation depending on specific battery models. For this reason *HyStore* management system is developed as a local controller plus optimization server architecture, as shown in Figure 4.

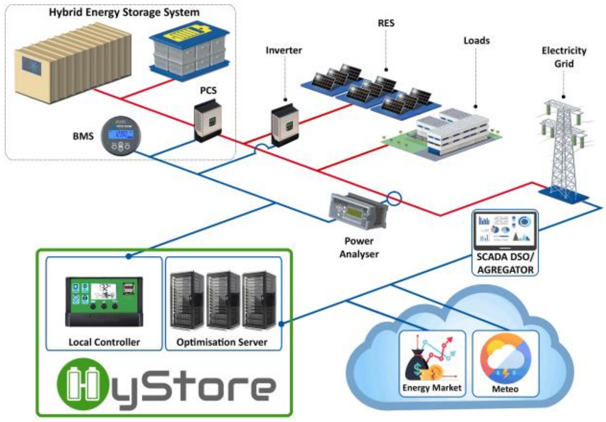

Figure 4. Block scheme of the *HyStore* hybrid energy storage management system

Conclusion

HESS demonstrator operating in KEZO site aims to demonstrate practical benefits of a hybrid energy storage configuration for microgrids. Hybrid storage appears to be suitable for various scenarios including islanded systems, local balancing, EV charging support and more. *HyStore* project aims to develop HESS control system based on optimization approach.

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