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The Hybrid Energy Storage System based on lithium-ion batteries and supercapacitors for Local Generation Systems

A. ZHUK, K. DENSCHIKOV, E. BUZOVEROV
JIHT RAS,
A. NOVIKOV, N. NOVIKOV*,
JSC «R&D CENTRE @ FGC UES»
Y. KUCHEROV,
JSC "SO UPS"
Russia
novikov_nl@ntc-power.ru

Nowadays one of important area is creation and technology development of electic energy storage systems (EESS). Availability of large – scale EESS in power grids, as an intermediate device between the generator and the consumer, could provide a significant contribution to balancing production and consumption of electric energy.

Interest in EESS is now greatly increased due to development of Smart Grids, where EESS is one of the key elements. EESS can provide a number of important functions in Smart Grids, the most important of wich is ensuring of stable and sustainable operation of the decentralized and renewable power sources, which can run either while connected to the main power network or while islanded.

To improve the technical and economic characteristics of the battery EESS, a new approach for stationary electric power industry is proposed, which, however, can be considered to a certain extent proven in developing traction systems for electric and hybrid vehicles. The approach is to develope EESS, based on the combination of battery and supercapacitor.

The battery have acceptable capacity (for lithium-ion systems 90 - 150 W·h/kg), but relatively small (3000 - 5000 cycles) resource. Moreover a battery (as well as any other chemical current source) in a high power applications dramatically reduces its capacity and life cycle.

Supercapacitor have low energy (1.5 W·h/kg) but a large number of cycles up to 10^6. Supercapacitor can easily deal with heavy load currents. For a given initial voltage its maximum power, as at conventional capacitor, is determined only by the circiut impedance and the supercapacitor's impedance. The combination of batteries and supercapacitors in one hybrid EESS may obtain effective application.

The goal of the experimental part were the design, development and testing in close to real conditions of the hybrid EESS prototype of, at least, 100 kW and 100 kW·h.

To perform tests, experimental system have been developed. It includes an independent source of power (gas turbine power module) of up to 1.5 MW, the set of active and reactive loads and necessary measuring and switching devices.

The developed hybrid EESS - HES-100 - consists of the following modules: a lithium-ion battery 100 kW·h; Supercapacitor bank; two grid inverterseach of 100 kW.

The tests were performed at the following operation modes:

- Island operation of HES-100 with local load ;
- Active power and frequency regulation due to load switch in main grid;

- Reactive power flow control from -100% ÷ + 100% of nominal load

- Load harmonics supression ;

- Negative sequence control;

-Uninterruptible Power Supply (UPS) with single inverter circuit (short off-line period).

The main results of the work:

1. A hybrid EESS for ensuring of stable and sustainable operation of the decentralized and renewable power sources, which can run either while connected to the main power network or while islanded is proposed

2. A hybrid EESS with rated capacity of 200 kW and a power consumption of 100 kW·h is developed and tested.

3. A set of tests which show additional benefits of using hybrid scheme are performed:

- Current charge and discharge of the battery are smooth in relation to its operation without supercapacitors, which is beneficial to the system balancing (equalizing voltage) battery cells;

- Demonstrated the ability to compensate for short-term perturbations of the network without having to involve the battery to improve short-cylce efficiency;

- At periodic load changes with a period up to 10 seconds at the power up to 100 kW provided stabilization flows of active power from the network using supercapacitors.

- Ability of short-term forced drive mode with power output at twice the nominal.

4. A comparison of the cost-effectiveness of traditional ways of regulating peak loads and by using a hybrid energy storage system, combined-cycle plants, peak gas turbines, gas engines and technology V2G have been made. It is shown that the hybrid energy storage system is an effective of regulation to meet the peak load up to 1 hour with additional fast and deep switch events, energy system allow for quick response to different perturbations and have functional flexibility to compensate for significant fluctuations in frequency, active and reactive power.