# IMPROVING THE RELIABILITY OF POWER SUPPLY OF INDUSTRIAL ENTERPRISES THROUGH THE APPLICATION OF HYBRID ENERGY STORAGE DEVICES

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**ABSTRACT.** The article presents a comparative analysis of various types of energy storage devices, considers the possibility of using a hybrid energy storage device as a compensator of short-term oscillations of active power. The features of the joint use of batteries and supercapacitors are presented. A simulation model of a hybrid energy storage device was built to evaluate the efficiency of sharing and determining the applications of such storage devices.

**Keywords:** supercapacitor, battery, hybrid energy storage system

**ПОДОБРЯВАНЕ НА НАДЕЖДНОСТТА НА ЕЛЕКТРОСНАБДЯВАНЕТО НА ПРОМИШЛЕНО ПРЕДПРИЯТИЕ ЧРЕЗ ИЗПОЛЗВАНЕ НА ХИБРИДНИ УСТРОЙСТВА ЗА СЪХРАНЕНИЕ НА ЕЛЕКТРОЕНЕРГИЯТА**

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**РЕЗЮМЕ.** Статията представя сравнителен анализ на различни видове устройства за съхранение на енергия, разглежда възможността за използване на хибридно устройство за съхранение на енергия като компенсатор на кратки трептения на активната мощност. Представени са характеристиките на съвместната употреба на акумулаторни батерии и суперкондензатори. Създаден е симулационен модел на хибридно устройство за съхранение на енергия, за да се оцени ефективността на споделянето и определянето на приложенията на такива устройства за съхранение.

**Ключови думи:** суперкондензатор, акумулаторна батерия, хибридни устройства за съхранение на електроенергия

## Introduction

The most significant indicator of the quality of electricity, which occurs when there is a sudden decrease in the voltage of the electric network below 0.9 Unom (Unom – rated voltage) – is a voltage failure. After the failure, the voltage is restored to the initial or close level after a certain period of time - from 10 ms to several tens of seconds. Its reduction can vary from 10 to 100% of the nominal. A voltage drops of 100% can be considered as a short-term power interruption. Failures are the most critical emergency violations. They lead to shutdowns and overloading of electrical equipment and electricity consumers.

The easiest way to protect sensitive processes from failures is installation of energy-intensive storage between energy sources and the consumer.

## Comparative analysis of energy storages

So far, a wide range of drives has been created. They are built on different principles, differing both in technical and economic indicators as well as in functional purpose. Among these devices, batteries should be distinguished. The analysis of the data of energy storage devices is presented in Table 1.

Table 1. *Characteristics of various types of batteries*

| | Capacity of one element, A*h | Energy density, W*h / kg | Number of cycles charge / discharge | Allowable charge temp. range,°C | Allowable discharge temp. range,°C |
|---|---|---|---|---|---|
| Lead Acid | 26–3000 | 30–60 | 200–1200 | -20–50 | -20–50 |
| Li-ion | 40–800 | 80–160 | 700–3000 | 0–45 | -20–60 |
| NiCd | 10–1100 | 45–80 | 1500 | 0–45 | -20–65 |
| Ni-NaCl | 40–200 | 140–190 | 3000–7000 | 0–45 | -20–65 |
| NiMH | 0,3–7 | 60–120 | 300–500 | 0–45 | -20–65 |

The disadvantages of lithium-ion and nickel-cadmium batteries are the high cost and service life, which directly depend on the number and nature of the charge-discharge cycles in operation. These are the most widely used storage devices for industrial energy. Exactly these characteristics are the main limiting factors in the widespread use of electric power storage devices. Devices based on fully controlled semiconductor devices, such as dynamic voltage distortion compensator or static reactive power compensator (STATCOM), are widely used.

There is another limiting factor of battery application, namely the response time of the drive. The response time of the batteries is up to 60 ms according to the Electric Power Research Institute, USA. This factor can have a significant impact when choosing a power storage device, as for some technological processes power outages even at 20 ms are critical.

However, supercapacitors (SC) practically lack the above-mentioned disadvantages. The distinctive features of supercapacitors are their ability to quickly charge an unlimited number of times and discharge over time from a few milliseconds to tens of minutes, giving high power to the load. The disadvantages and limiting factors of SC application are the relatively low energy density and the high self-discharge. It is also worth noting that the response time of the SC is from 1 μs. More detailed characteristics of the SC are presented in Table 2.

Given these factors, it is currently promising to use the battery in conjunction with the SC to compensate for the shortcomings and combine the advantages and to create a hybrid energy storage system (HESS).

Table 2. *Characteristics of supercapacitors*

| | Capacity of one element, kF | Energy density, W*h / kg | Number of cycles charge / discharge | Allowable charge temp. range,°C | Allowable discharge temp. range,°C |
|---|---|---|---|---|---|
| SC | 0.5–12 | 1–10 | >500 000 | -40–65 | -40–65 |

## Simulation model of hybrid energy storage

The present study developed a simplified model of hybridisation of a battery and a supercapacitor, presented in Figure 1.

This model involves a lithium-ion battery and a block of capacitors with the appropriate characteristics. The simulation did not take into account the temperature effect and the aging effect of batteries. Battery self-discharge is not presented.

The Boost and Buck/Boost converter model is shown in Figure 2.

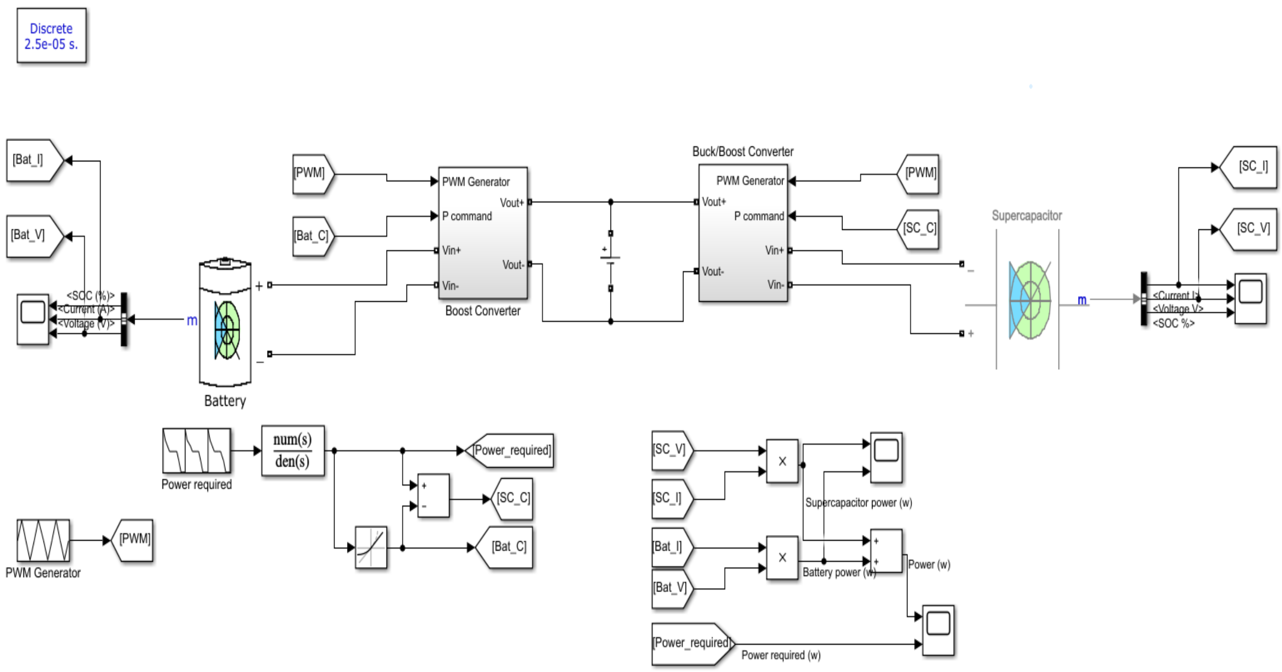
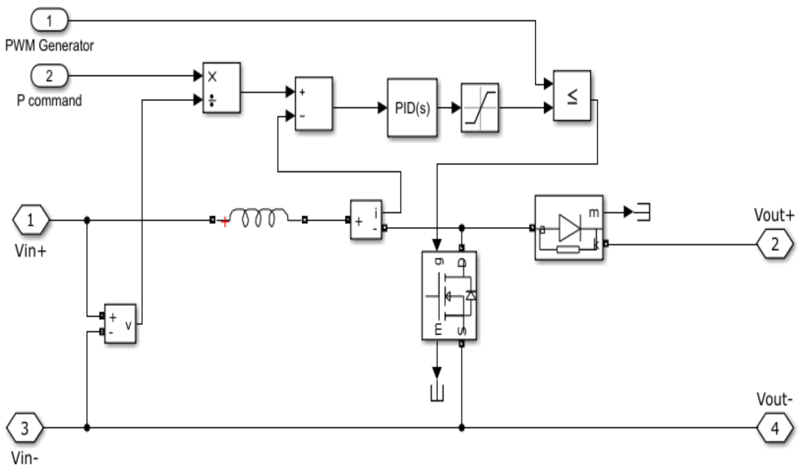
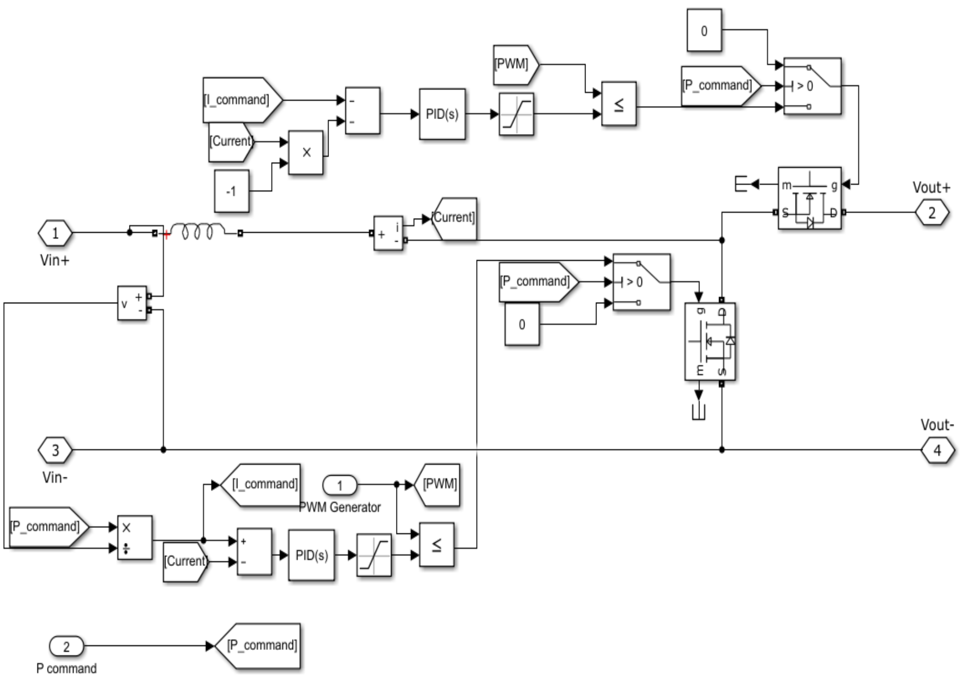



**Fig. 1. Battery and supercapacitor hybridisation model**




**a)**




**b)**

**Fig. 2. a) the Boost converter model; b) The Buck/Boost converter model**

Using the simulation, the following results were obtained (Figure 3):

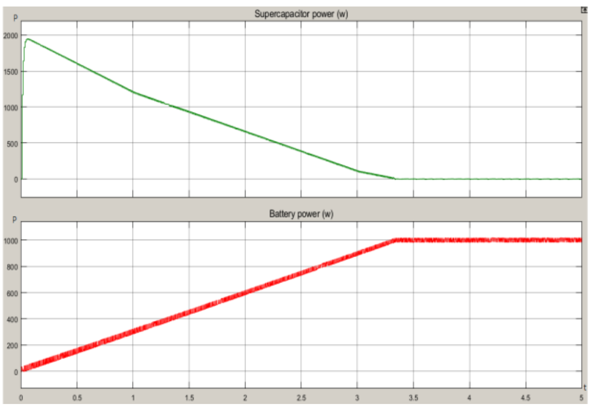



**Fig. 3. The graph of the power generated by the battery and the block of supercapacitors**

After analysing the data dependencies, the differences in the nature of the power output to the network were noted. Since the feature of the SC is a fast discharge with a large amount of power output to the network, it is logical to use this drive to compensate for peak loads. Rechargeable batteries are inherently slow to discharge, gradually giving power to the network, which will allow compensation for long-term power dips. It is also worth noting the increase in the life cycle of batteries by reducing the impact of peak loads when used together with supercapacitors.

Figure 4 below shows the graph of the power supplied to the network by the hybrid energy storage.

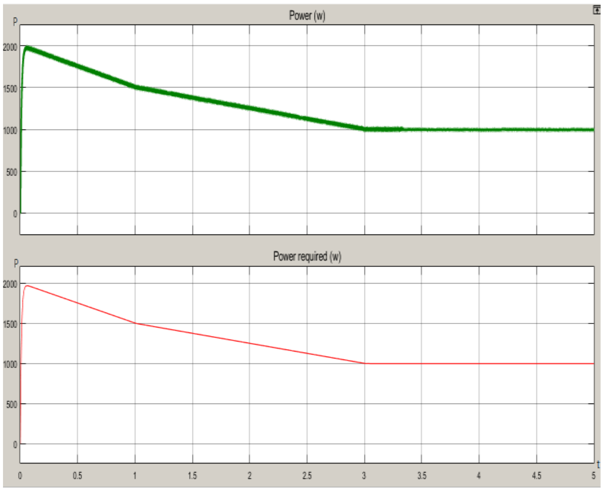



**Fig. 4. The graph of the power generated by the hybrid energy storage system**

## Conclusions

Based on the obtained results, it is possible to conclude that joint application of batteries and blocks of supercapacitors can perform a number of important functions:

- alignment of load graphs in the network;
- damping of short-term oscillations of active and reactive power and frequency;
- ensuring uninterrupted power supply of substations and especially responsible consumers;
- ensuring stable and sustainable operation of decentralised and non-traditional sources operating both autonomously and as part of a unified power supply system.

However, a number of issues that are not addressed in the article remain, namely, when creating hybrid energy storage devices, the issue of balancing the SC remains relevant [8]. As it is known, due to the low rated voltage of supercapacitors, the use occurs when they are connected in series. In the production of supercapacitors there is some variation in the parameters of the capacitance. In this regard, the problem arises from the different charge rates of supercapacitors, since there is a probability of overcharging the supercapacitor, which can cause its breakdown. There is a need to limit the voltage of the supercapacitor when charging. It is also necessary to take into account that the electric power output to the load from the storage device is carried out under the condition that the electric power quality parameters are observed. This requires solving the issue of electromagnetic compatibility of objects with regard to their economic efficiency.

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