Abstract
The question of the efficient recovery of braking energy is becoming increasingly important, with emphasis on improving the energy efficiency of the economy. The effectiveness of recovery in rail vehicles is limited, inter alia, by the possibility of consumption of recovered energy. One way to improve the recovery efficiency is building energy storage devices in substations, on the network and in rail vehicles. Such storage devices have to work in two modes: as a reservoir of power, compensating for the ripple current, or as a reservoir of energy, supplying vehicles for longer periods. Presently, power storage systems may be made using ultra-capacitors that have a possibility to make hundreds of thousands cycles of high current and low energy. Applications of the battery storage allows the storage of large amounts of energy, but not for high-frequent cycle. The solution to the problem are hybrid storage systems which combine the features of power and energy storage tank. They can be made on the basis of existing batteries and ultra-capacitors. The size of stored power and energy depends upon the volume designated for each part. The article explains how power and energy capacity change versus ratio of the volume destined for battery and ultra-capacitor. Another solution is to use modern LTO and LIC cell, which combine features of batteries and capacitors. The article presents a comparison of the power and energy of storage systems made from these hybrid cells. Construction of a storage tank capable of storing both power and energy and for providing high number of cycles opens the way to new supplying solutions for rail vehicles like periodical charging of the vehicle storage system.

Introduction
Nowadays, in the era of struggle for reduction of CO₂ emissions and energy consumption of economy rail vehicles with recuperation of braking energy became standard. Energy recovery involves converting the vehicle's kinetic energy into electricity again and feeding it to a traction network [10]. Ideally, this energy could be transmitted to the public distribution network or completely consumed by other vehicle. Only then the energy saving effect would be the most significant. Unfortunately, pulses of power demand typical for rail vehicles pose a problem for operators of distribution system as they cause difficulties with voltage regulation and, above all, the emergence of voltage dips and flicker effect. This is particularly troublesome for other energy consumers.

The widespread introduction of energy recovery could increase energy savings thereby reducing the energy consumption of economy and the environmental impact of emissions, particularly CO₂. Unfortunately, in addition to the pulses of consumed power the pulses of generated power would arise when regenerated energy occurred. So now distribution systems operators defend themselves against receiving recuperation energy from railway networks. Investments in utility grid will be enforced by the deterioration of voltage quality, the increase of short circuit power in system, the emergence of two-way energy flows all enforcing a change in protection system organization.

Conclusions
Modern electrochemical cells and ultra-capacitors allow for flexible selection of the storage system to the demand. The constructor has a choice of different technologies depending on the nature of energy and power fluctuations that will be compensated by the storage system. Characteristically, the cyclic applications of high power is better to use ultra-capacitors, and for energy ones with fewer number of cycles, batteries.

In applications where there are two components – power and energy – hybrid storage systems should be used. It allows further customizing of the magazine to the needs. This reduces energy losses, the weight and volume of the storage system while increasing life time.

Proper allocation of capacity or available volume between the two types of storage devices is difficult. The designer must take into account the size of two components of compensated power flow – energy and power one. An impor-
tant element to take into account in the planning of division of load between the two components of the storage is the slope of current rise.

Modern storage elements like LTO or LIC may replace the hybrid magazine. LTO cells are dedicated to work more as energy storage and LIC more as power storage. Both should be used in an area where cells NMC or LFP have too few cycles and power, and ultra-capacitors too little energy.

References


