Abstract
Nowadays the issue of electric energy saving in public transport is becoming a key area of interest, which is connected both with a growth in environmental awareness of the society and an increase in the prices of fuel and electricity. It can be achieved by reducing the transmission losses in a supply system or by the improving the usage of the regenerative breaking. The article presents an analysis of applying these two options for increasing recovery energy by application of Smart Grid solutions in public transport systems. Analysis will be based on the example of trolleybus transport system in Gdynia.

Keywords trolleybuses, Smart Grid Systems, energy recuperation, electric traction, traction substation, energy savings

1. Introduction
The development of zero-emission public transport is one of the elements of the horizontal EU policy. Municipal transport is currently responsible for 40% of CO₂ emissions of the entire road transport in Europe. The transport sector is responsible for 30% of total energy consumption and 27% of greenhouse gas emissions. Greenhouse gas emissions must be reduced by 60% by 2050 [1, 2]. What is more, the instability of prices of liquid fuels has an extremely negative impact on the economy. Therefore, it becomes necessary to use more alternative energy sources in public transport [3, 4].

An alternative to liquid fuels is electricity. Today, we may notice an increase in the popularity of electric cars and electric buses powered by automotive batteries; however, the most effective way of providing electricity to vehicles is still a unipolar overhead line, as is the case for rail vehicles, or a bipolar line in the case of trolleybus service. Unfortunately, a large part of Europe’s electricity is obtained from thermal power stations, which are also a source of greenhouse gas emissions. For this reason, the development of electric means of transport is actively supported by the European authorities, as evidenced e.g. by funding initiatives popularizing ecological municipal transport systems from the Community budget. An example of such a project is Trolley [6], which was implemented in the years 2010–13 and was aimed at popularization of trolleybus service and development of energy-saving technologies applied therein. A similar project is the Actuate project, which aims to highlight the importance of driving techniques for the energy consumption of electric transport and the implementation of the so-called eco-driving concept. Currently, a group of selected European cities implements the Dyn@mo project whose aim is the development of modern, energy-efficient technologies in public transport. The program directed solely at the technical aspect of energy efficiency of tram service is Oxiris, which involves transport companies and manufacturers of broadly understood electrical equipment for trams [5, 6]. The purpose of the article is to point out the importance of the spatial structure of municipal overhead line power supply system to energy consumption and to demonstrate the possibility of reducing the energy consumption of municipal transport with Smart Grid solutions.

6. Conclusions
Introduction of two Smart Grid tools is presented in the article:
- bilateral supply of overhead catenary,
- charging station for electric buses.

The synergy of these solutions allows for increase of energy recovery, with the small financial investments. As shown by simulation analysis, with the proper introduction of elements of the Smart Grids, it is possible to achieve performance close of regenerative braking close to efficiency using supercapacitor banks. However, the costs involved in the construction of the Smart Grids are many times smaller than those related to supercapacitor banks. What is more, the Smart Grids are capable of reducing transmission losses in the supply system.

A key element in determining the effective use of recuperation is the topology of the overhead line. In the case of supply areas with a significant number of vehicles, i.e. with high traffic volume or high intensity, the use of braking energy in the vehicle – vehicle path is very visible,
which removes the need for additional devices absorbing recovery energy, such as supercapacitor banks or substation inverters. The failure to use recuperation energy occurs in areas with low traffic.

Accordingly, to increase the use of energy recovery, at first it is necessary to consider the possibility of reconfiguring the supply system, which will facilitate the flow of braking energy. In many situations, very good results can be achieved at a low cost. Small substation power supply areas galvanically isolated from the rest of the network should be avoided. Supply areas of such substations should be interconnected to create the largest area of recuperation energy flow.

Therefore, it is recommended to introduce bilateral supply of the overhead line to allow for an increase in the utilization rate of recuperation and reduced transmission losses. Bilateral power supply may be used both in central and in decentralized power supply systems. Examples of bilateral power supply solutions were presented in the previous section of the article. The power supply system designed taking into account the flow of recuperation energy is able to accept the vast majority of the recovered energy. The use of banks is appropriate in the areas of the overhead line of a specific nature, i.e. in mountainous areas or ones of unusual traffic distribution.

An important element that could improve the use of recuperation energy are charging stations for electric buses. Electric buses have become an increasingly popular means of transport in the cities; however, their charging poses a problem. It requires the construction of charging stations, which is related to the need of preparing appropriate infrastructure whose main element is the transformer stations for bus charging points. To this end, an overhead line for a tram or trolleybus transport can be used (Fig. 5), which has many advantages. In such a case, the existing infrastructure may be used, so there is no need to build additional transformer stations. In addition, the charging stations for electric buses are an alternative for the banks of recuperation energy, which requires only minor capital expenditures. Currently, hubs integrating many means of municipal transport, such as buses, trams, trolleybuses and trains are built. Such hubs may be also used for integration of power systems. Those places are characterized by common braking of vehicles, which results in a significant amount of generated recuperation energy. As indicated by the measurement tests, recuperation is most intense in locations of frequent starting and stopping. Therefore, in these places it is reasonable to build electricity charging points.

References


