Abstract
In the paper, the basic function of an Automatic Train Operation (ATO) called target braking has been discussed. The most important assumptions of this function have been discussed in detail. The authors’ simulation model, which was developed to study the impact of the propulsion systems on the precision of train braking, has been described. The adopted model of movement of rail vehicles and the methodology of determining the braking precision of target metro trains have been described. Subsequently, simulation results of the investigation of influence of operating parameters on braking precision and braking time have been presented. The simulation model verification and the preliminary statistical elaboration of the measuring results have been presented.

Introduction
Traffic conditions present in the underground are unique because the distance between trains is short, they move with a high speed ($v \approx 90$ km/h) and platforms are short. Therefore, it is required to apply specialized systems which can provide traffic safety, which in terms of speed restrictions, is ensured by Automatic Train Protection (ATP) system. Once the system has been provided with appropriate data, it can calculate safety speed for each train or all trains travelling along the same line. By executing a specified algorithm, ATP devices do not allow to exceed safety speed as it includes control of the power transmission and braking system. The ATP system is initiated only if the driver exceeds permissible speed e.g. signaled by a semaphore. Automatic Train Operation (ATO) is an example of systems which can be of help in the underground. This one is responsible for supporting the driver of the train. Target braking is one of the functions performed by an ATO system. It relies on automatic train stopping at the stations, where braking process is fully controlled by an on-board device. Precision braking is an important stage of underground train ride as it is required to stop a train in a platform with limited length. The average length of the subway train is about 100 m, length of the platform for reasons of space savings in the tunnel is very similar. At the 1st line of Warsaw underground, traffic safety provides a system commercially called SOP-2 [1]. It is a type of an ATP system which is enriched in the ATO system function – the target braking of train in the platform. The system performs its tasks by a continuous data transmission, which is achieved by using a wire loop placed between the rails. There are used two basic types of rolling stock: type “81” trains driven by a DC motor and type “Metropolis” powered by an AC motor. In the literature, there is no information about a simulation model which cooperates with a braking controller and which was developed to carry out calculation of precision braking [2, 4, 5, 6, 9, 10, 11]. Therefore, a simulation model (in the text also called the Simulator) dedicated to study the impact of the propulsion systems on the precision of train braking has been created and positively verified. The scope of research presented in this paper relies on calculation of the influence of operating parameters on target braking, for the selected type of rolling stock. The results allow for an analysis of static and dynamic parameters of the target braking process performed in subway conditions.

Conclusions
As part of the work, following general conclusions can be proposed:
- From the examined operating parameters, the reduction of available braking force and the addition of resistance to motion have the greatest impact on the precision of braking. The obtained outcomes can be generalized to most kinds of rolling stock operating with an ATO system,
- Supreme precision has been obtained for the initial braking speed $v_p$ in the range of 50÷90 km/h (mean values of the train speed),
- Conducted studies can support existing ATO systems by improving the accuracy of automatic train stopping on the platform. The increase of accuracy of target braking improves the safety of passengers e.g. by minimizing the risk of falling on the tracks. For platforms with double doors (so-called closed platforms), exact
stopping of the train will play a key role in the evacuation of passengers in case of fire or a terrorist attack.

- The created tool can be used to support the process of designing automatic train operation systems,
- A software recreation of target braking is possible,
- The major effect of the work is the developed target braking model. The model allows for performance in dynamic conditions the target braking process and it provides the ability to calculate braking accuracy,
- The research results of braking accuracy are consistent with a normal distribution.
- The simulator allows calculating the quality factor, which makes possible the assessment of generated braking curve, which is an additional research interest.

References
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 DynaMO 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 [3, 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. 4), 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. These banks 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


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


Abstract
The validation of an electric traction network simulator is addressed by selecting testing conditions and considering three performance indexes that evaluate amplitude, slope and other curve features. A common interpretation scale is proposed to verify their agreement. Moreover, since the most complex cannot be fully used without a graphical representation of its output, this is simplified, in order to conclude the validation with an estimate of accuracy that is as close as possible to the classical declaration that accompanies instrumentation.

1. Introduction
The use of simulation tools aims at replacing experimental methods and measurement campaigns with significant savings in terms of time and cost. Simulation allows also verifying configurations that cannot be reproduced in practice, but represent exceptional worst-case events and parameter combinations. The evaluation of electrical interoperability by simulation was already accepted and suggested [1-5] for the following phenomena:

- the useful voltage, i.e. the average pantograph voltage available when absorbing traction power, calculated per train or per network area;
- the power factor and displacement factor for ac systems, with the same meaning used in industrial supply networks;
- harmonics and inter-harmonics, caused by the interaction of distorting loads and generators, namely trains during power absorption, and the same trains during braking and electric substations;
- dynamic interaction between trains and the supply network, with possible electrical instability, resonances, supply distortion and considerable reactive power flow.

Especially when safety decisions are taken based on the simulation results, simulation models need to be validated, establishing their adequacy, accuracy, range of validity, as any other instrument [6]. Models of electric networks and electric equipment share a similarity of representation with the physical system, that ensures plausibility of model outcome. Despite the electrical equations of each sub-circuit and cell are in principle simple (e.g. component and Kirchhoff equations), the interaction of the many network elements and parameters is very complex and results in overall non-linear relationships, that are hardly treated in closed form or with analytical methods.

The validation of a simulation model aims at verifying that it meets its intended use, in terms of overall requirements and user’s expectations and that it is used within its domain of validity. Besides the verification and validation of single modules during simulator development and the matching of model basic attributes and relations with the physical system, the most relevant part of the validation process is represented by the characterization of the accuracy of model output with respect to reference data. The validation of a simulator using dynamic techniques is performed by executing test runs on reference cases. Simulated and measured data shall be compared, covering various configurations and parameter combinations, and including a preliminary evaluation of the quality of experimental data (in terms of their metrological characteristics). Data may for clarity assumed as electrical quantities (e.g. voltage, current, impedance) considered as frequency-domain spectra [4][5], normally characterized as amplitude and phase response.

When comparing simulated and experimental data of this kind, several features normally catch the observer’s eye and may be used to quantify the degree of similarity [8-10]. The shape of the curves and the relevant distinctive elements (e.g. frequency and amplitude of resonance peaks and anti-peaks, slopes, etc.) orient the choice towards specific performance indexes [10], preferable for several reasons: robustness to noise, adequate response for peaks and slopes, ability to cope with a relatively large uncertainty of experimental data.

More than one performance index is useful to cross-check indexes themselves and avoid biasing and distortion of judgment and validation results. Comparing performance index values is of course not so straightforward, because they have different ranges and different sensitivities to...
curve characteristics: they were tested extensively on sample curves in [9].

This work, starting from past analyses of performance indexes [9][10], addresses how to obtain a clear simple statement of accuracy of a railway traction network simulator. Despite the extended literature about validation of simulation models, no clear and unique interpretation of results can be identified. The objective of this work is twofold: compare results of a more elaborated index like Feature Selective Validation (FSV) with simpler indexes such as Theil and Mod. Pendry, to verify the degree of agreement; propose a simple method to consider validation results as the outcomes of an experiment indicates an error or deviation in the comparison of the curves, characterized e.g. by a mean value and dispersion, or by a confidence interval.

To this aim in Section 2 the Verification and Validation process is presented, together with a description of indexes used in this work. The followed validation process in the specific case is described in subsection 2.4. The real system which the measurement data refers to is the test ring in Velim described in Section 3. The validation outcomes are reported and discussed in Section 4.

5. Conclusions

This work has considered the validation of a simulator for electric traction network against experimental data by using and comparing three different performance indexes, Theil, Modified Pendry and FSV. The effort is twofold: trying to express the similarity scores of the indexes in a way so that they are comparable and quantifying the similarity error between model and measurement data so that it may be used to characterize the accuracy of the simulator, as if it were a measuring instrument.

Theil and Mod. Pendry indexes have a 0-1 output scale, but evaluate different characteristics of the curves, being based on the amplitude comparison the former and the normalized derivative comparison the latter. FSV method does not fit a 0-1 scale in principle but observing the very bad similarity cases are of no use, the output scale may be mapped in a 0-1 range. Interpretation categories may be used for comparison.

A direct relation of indexes to classical error metrics (absolute deviation, rms, etc.) was considered and some inconsistencies identified, so that the problem is still under investigation. Using ADM on the original data, rather than on transformed data (as dictated by IEEE 1597.2 standard) indicates smaller differences. Regarding the validation of traXsim simulator FDM index that measures slope and concavity confirms an excellent correspondence with experimental data. On average the classical error may be estimated around 15-20% over the 1.6-20 kHz range (about 1% at fundamental, as shown years ago in a publication based on measurements on the Italian Alta Velocità [16], but a quantitative correspondence with the proposed performance indexes is still under investigation.

Acknowledgments

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References


Abstract

A 25 kV 50 Hz system is recognized as a system recommended for supply of electrified railways systems due to its significant advantages. However, there exist significant drawbacks in asymmetry introduced due to one-phase character of traction substations into 3-phase power supply.

When projects on development of a 25 kV 50 Hz power supply system are being worked out, it is required to analyse the influence of a traction substation on a supplying power system, and the level of expected asymmetry should be assessed and proper measures undertaken.

The paper presents results of research during which a comparative analysis of operation of different circuits with application of symmetrizing devices applied in 25 kV 50 Hz traction system substations. Simulation of different schemes and control methods were undertaken and as the most perspective symmetrizing device was recognized a local symmetrizing device with regulation of P and Q power between secondary windings of a Scott transformer.

Introduction

Nowadays in Poland interest and need towards construction of new high speed lines or reconstruction of the existing one for speed of trains above 200 km/h have increase. So it is necessary to prepare a new power supply system (25 kV 50Hz) in parallel to the existing one 3 kV DC for introduction in Poland. Thus it is worth undertaking a comparison of these two systems, especially from the point of view technical requirements and Technical Specification of Interoperability in Europe. Costs of required investment, service and efficiency are another important issues. 25 kV AC system has advantages comparing to a 3 kV DC system, but there are drawbacks observed as well, among them asymmetry caused in public power supply system and other negative influence on the technical infrastructure around the line [1,2,3,5,6,7,8].

AC supply systems are widely used for supplying trains reaching speeds above 200 km/h and there are the only ones recommended for high speed traffic above 250 km/h.

Conclusions

The comparative analysis of operation of different circuits showed that it is possible to construct a device for symmetrizing asymmetry in power supply caused by different types of transformers applied in 25 kV 50 Hz traction system substations.

The Steinmetz circuit proved to be a simple solution in terms of design, with 3-phase transformer applied for supply by one of three phases of the electric traction system secondary side.

In a case of application of a 1-phase 3-winding transformer with a controller of external compensator, it is possible to use two secondary windings for supplying two different traction circuits.

It is as also possible to develop a controlled external symmetrizing device for compensating reactive power taken by Scott transformer at the level (or even higher) of active power taken from power supply. Since in this case the transformer should be oversized with respect to the forecast load power, this circuit was recognised as non-perspective.

The local symmetrizing device with regulation of P and Q power between secondary windings of a Scott transformer proves to be the most prospective one. The device does not need application of any external symmetrizing, which allows for eliminating analogue switches from power circuits.

Spread of technology of modern transistors creates possibility of application of power electronic devices for economically effective high power (in a range of few MW) converters (rectifiers, converters).

Bibliography


Abstract
The paper describes use at computer simulation methods for the design of system to improve in quality matters. It focuses mainly on systems diodes and thyristors converters. The simulation results are exemplified their industrial applications. At the end of the paper is an example of AC – DC converter pickup with three – phase mains current sinusoidal. The results of simulation made it possible to build high – power devices (600 kW).

1. Introduction
The three major problematic factors in electrical power engineering are:
1. Increasing the efficiency of systems generating electrical power.
2. New sources of creating electrical power. i.e. renewable resources of energy
3. Quality of electrical power.
The themes of this paper are issues related to the design of devices capable of reducing passive power - Q and power distortion D and thus to improve the "quality of energy in the power system".
At this stage of the design of power compensation systems taking into account Q and D, appeared the possibility of using a compensation circuit design Q and D via computer simulations. Fig. 1, 2 , 3 - Are block diagrams of the three largest power devices used in industry and power engineering.

Fig. 1 - A block diagram of an inverter AC/DC/AC used in drive systems and frequency converters. For example: 50Hz to 60Hz

Fig. 2 - Block diagram of a wind power system.

Fig. 3 - A simplified schematic of a DC traction power vehicle with the possibility of energy recuperation.

Within these systems, mostly to convert line voltage AC power from DC voltage, are applied all kinds of rectifier circuits AC/DC. At the current stage of development of rectifier systems–converters AC/DC, diodes circuits are used or thyristors. In Fig. 4, 5 and 6 - Are shown typical voltages and current waveforms in circuits 6p, 12p and 24p for thyristor rectifiers.

Fig. 4 – Simplified diagram of thyristor rectifier 6p. Voltage and current waveforms in a Ch 4 - course of the current drawn from the mains (bottom right figure). THDI about 30 ÷ 40 %.

Fig. 5 – Simplified diagram drawing thyristor 12p . At the bottom of the drawing on the left side is shown the shape of one section of the current 6p . On the right, the shape of the current drawn from the network. THDI about 12 ÷ 16 %.
Fig. 6 – Simplified diagram of thyristor rectifier 24p. The right lower part of the figure shows the shape of the current drawn from the network.

Similar waveforms can be obtained for diode rectifiers. It is generally known [1,2,3] that the thyristor or diode rectifiers have a number of drawbacks which include:

1. Power obtained from the network via a current rectifier thyristor or diode device is greatly distorted - high value THD
2. In addition to the active power from the network a rectifier draws considerable value Q passive power and power distortion -value D.
3. Rectifiers 12p and 24p, demand even more complex construction of transformers.
4. In addition, the thyristor rectifier, depending on the angle of actuation has a changing value of THDI and passive power drawn from the mains.

More information on this topic can be found in references [1,2,3,4].

The biggest advantage today in the use of diode or thyristor rectifiers is undoubtedly the simplicity of their construction.

Below is depicted a view of a circuit processing AC-AC 50 Hz to 60 Hz with a capacity of 1.8 MVA produced by APS Energia.

Fig. 7 – An example of an industrial 50 Hz to 60 Hz inverter with a power of 1.8 MVA
As an input rectifier (change of AC 50 Hz to DC) of the device utilizing a thyristor rectifier 24p.

5. Conclusions
1. In industry, there are many devices that have a negative impact on electrical networks. Industrial systems currently developing hybrid filters can significantly reduce this negative impact.

With proper selection of the proposed construction of a filter in respect to their industrial applications today require all sorts of methods of computer computation.

2. The constant technical progress in the production of transistors of a given power will contribute to the increasingly widespread use of solid-state high-power three-phase rectifiers.

6. Literature
[4] *Materiały własne spółki APS Energia S.A.*
Abstract
Automotive spark plugs are electric parts connected to high-voltage ignition coil winding able to generate high-energy sparks necessary to ignite the air/fuel mixture. Breakdown of the spark plug air gap is one of the effects responsible for ignition noise resulting in electromagnetic interference to vehicle’s electronic systems, including radio receivers. To eliminate the electrical disturbances present with spark discharge automotive spark plugs are provided with an additional resistor connected in series with the center electrode. The noise-suppressing resistor is made of borosilicate glass and conductive particles mixture having significant influence on electric properties of the spark plug. The present paper focuses on investigation of glass seal resistor placement affecting electric field distribution. MATLAB simulation results of potential and electric field strength distribution are presented and discussed.

Introduction
Spark ignition combustion engines are used primarily in conventional and hybrid vehicles (e.g. Toyota Prius). Generally, they are equipped with an electric distributorless ignition system comprising a battery, ignition coil, electronic controller, high-voltage ignition cables and spark plugs. Spark plugs are dominant automotive parts required to ignite the air/fuel mixture drawn into combustion chamber, where it is compressed. They are an example of electric devices responsible for combustion process, lower exhaust emissions, fuel consumption and higher engine performance. Electrical discharge across the spark plug electrodes causes disturbances resulting in radio frequency interference. Furthermore, the disturbances can affect vehicle’s control modules, radio and telephone communication. According to international standards and directives [3, 4, 7] electromagnetic interference generated by automotive ignition system must be reduced to an acceptable level. There are several techniques and spark plug designs allowing ignition noise suppression in the vehicle’s electric power system such as high-voltage wires length reduction, resistor ignition cables, shielding, spark plugs with resistive or inductive suppressors [9, 11, 15, 16, 17, 19]. However, commonly used coil-on-plug ignition systems eliminate obsolete long ignition cables. Today’s spark plugs comprise most often a high resistance glass seal resistor to reduce effectively ignition-related noises and they can be used either with or without resistor ignition cables. Basically, the suppressor resistor is made of dielectric borosilicate glass containing some conductive particles [5, 9]. The presence of dielectric material placed inside of ceramic insulator and exposed to an electric field changes the distribution of potential and electric field strength. The electromagnetic interference problems were analysed in [14] by means of an electrostatic field representing electric field inside a spark plug. The idea based on the finite element method was applied to extract parasitic parameters of a spark plug. In this paper, the local electric field fluctuations caused by suppressor glass seal resistor were studied analytically and numerically (solution to Laplace’s equation). To illustrate the procedure, several simulations of potential and electric field strength distribution were performed. The simulation results show that the glass resistor location has significant influence on local potential and electric field strength values. The distribution of the local field is of practical importance considering partial discharge effect between center and ground electrodes across spark plug ceramic insulator.

Conclusions
In order to analyse better the electric field surrounding modern automotive spark plugs, a good way is to look closer at the glass seal resistor placement affecting electric field distribution. The modeling and simulation results have shown that the resistor connected in series to the center electrode affects significantly the potential and electric field strength distribution in the insulator as well in the resistor itself. An important feature is the borosilicate glass relative permittivity varying with combustion engine and spark plug temperature [13]. The borosilicate glass has a low and linear thermal expansion coefficient. Nevertheless, the temperature rise time should be short enough to reach the self-cleaning temperature as fast as possible. In this way fouling and misfire effects can be avoided. However, the thermal gradient can cause the mechanical stress...
resulting in resistor or insulator cracks. The electric field strength is a significant factor considering local partial discharges across the ceramic insulator. Although, the electric field modeling and simulations described in the paper were carried out for pure materials used to produce spark plugs insulators and glass seal resistors, it is possible to extend the analysis in the future to show how air intrusion and conductive particles presence can affect electric field distribution in spark plug resistors and insulators.

References
Abstract
In this paper the application of OpenTrack software for computer modelling of the line from Varaždin to Dalj is presented. It is 249,839 km long single track line with 25 railway stations and 32 additional train stops. The created model was tested on trains running times calculation where the comparison of simulation results with the official timetable data planned by infrastructure manager proved the quality of the model. In addition, comparison of energy consumption between diesel multiple unit (HŽ series 7121) and the train powered by diesel electric locomotive (HŽ series 2044) with five wagons is carried out.

Keywords: Railway line Varaždin - Dalj, computer modelling, simulation of railway operation

Conclusion
Computer modelling and simulation of railway operations is very useful decision support method for improvement of efficiency of railway system. Application of railway simulations can be used for decision making regarding infrastructure modification, selection of the most appropriate rolling stock or timetable planning process. In this paper modelling of the railway line from Varaždin to Dalj is presented. The model was tested on train running time calculation and the comparison in energy consumption between selected diesel multiple unit (HŽ series 7121) and train powered by diesel electric locomotive (HŽ series 2044) with five wagons. Thereby the simulation results proved the quality of the model.

References
[2] Huerlimann, Daniel; Nash, Andrew. *OpenTrack Simulation of Railway Networks Version 1.6*
Abstract.
The paper presents investigation of the influence of the AC autotransformer power supply system on the energy quality in a public grid. The research includes construction of a laboratory model of AC autotransformer railway power supply system. The model consists of a power substation with a Scott transformer, overhead catenary system with the inductances of the contact wire, parallel feeder and running rails, autotransformers and two trains. The first one with the inverter-asynchronous drive and the second with the diode rectifier and DC motor drive. The influence of the AC autotransformer system on the public grid considering all types of the disturbing influence including voltage unbalance, voltage harmonic generation and power fluctuation in aggregated.

1. Introduction.
AC electrified systems have the disturbing influence on the power quality in a public grid to which they are connected. In general this is caused by few factors. First of them, very often considered as the most significant is the unbalance of the load [1,2,3,4,5,7,14,15,16]. There are many different solutions which could be used to mitigate the influence of this factor. The most reasonable of them in terms of costs is implementation of Scott-connected or V-connected transformer. The specifics of these solutions has been investigated by many authors [6,11]. The next factor influencing the power quality is the harmonic content in a current drawn by locomotives, as in many countries most of them are equipped with the diode or thyristor rectifiers [8]. The last disturbing factor which is specific for all electrification system is unpredictable peak power demand (power strike) [13]. Most of the papers consider each of this phenomenon separately, while they appear simultaneously in the same system and are mutually related. It is necessary to mention that the influence of each of the factors above on energy quality depends on the short circuit power at the point of common coupling – PCC. The different solutions are used to mitigate the disturbing influence of the railway system when the short circuit power is not high enough and the parameters of the energy quality doesn’t meet the values specified in the appropriate standards. In EU the following documents are applicable: EN 50160 [9], IEC 61000-3-6.

Conclusions.
It should be noticed that the factors in the AC railway power supply system leading to the disturbances of the power quality and the effects caused by each of them are mutually linked. It could easily be proved that both current unbalance provided to the public grid as well as the harmonic values of the current depend on the power and the position of each vehicle.
The lowest instantaneous voltage occurs during the test in option 3 in which the maximum voltage unbalance is much higher than in option 4, it testifies that the power demand was the highest in case with the diode rectifier. However comparing the windings RMS current values (Fig. 8-11) from which the current unbalance, based on the formula (2) could be obtained with the voltage unbalance shown in Fig. 13-14, it could be noticed that the voltage unbalance is not, in this case dependent on the Scott transformer secondary currents, analogously to the current unbalance, according to the formula (2). For example the maximum unbalance factor is higher in option 3 (7.1%) than in option 1 (3.7%), regardless that the current ratio between secondary Scott transformer is much higher in option 3 than in option 1, where is close to 0.

With regards to the harmonic content, a few examples are used to explain the specifics of the phenomenon which take place in the system. During the test in option 2 the peak power occurs at around 13 second of the test (Fig 9). Figure 16 shows that even harmonics achieve the maximum value when the load of the Scott transformer winding is between 60 and 70 % of the maximum load value. In the meanwhile the odd harmonics are maximum, when the load is maximum. Figure 17, which presents the voltage harmonics in option 3 shows that during the switching off of the diode rectifier the harmonics caused by the constant work of the asynchronous drive are being “compensated” by the harmonics derived from the rectifier.
The results presented in the paper are focused only on some, the most representative, of the aspects of phenomenon taking place in the system. The voltage unbalance values obtained during the tests show that the relation (2) under the real conditions could not be used to determine the value of the current unbalance factor and based on this voltage unbalance. In order to achieve more precise relation the further investigation is required. It will include the new realization of the locomotive models, more coherent with the reality including the possibility of the step switching of the load – the situation of passing the section insulator. The expand of the laboratory model will enable to create more precise model of the system.

Literature
[3] V. Matta, G. Kumar.: Unbalance and voltage fluctuation study on AC traction system.
Abstract
The narrow-gauge railway line St. Pölten – Mariazell, originally steam-powered, was electrified with the single-phase system 6.5 kV 25 Hz at an early period. Several considerations during the life-cycle of this famous line resulted in maintaining that exceptional power supply system. The article describes the core topics of genesis, development and improvement of the related system components between 1908 and 2015.

Introduction
The single-phase electrified Mariazellerbahn runs from St. Pölten, capital of the province of Lower Austria 60 km westbound of Vienna, on the Rhine – Danube Corridor (TEN 17) to Mariazell in Styria. The single-track 760 mm line was opened in several stages between 1898 and 1907. Passing the Pielach Valley southbound, the line climbs from St. Pölten (267 m above sea-level) with a gradient of max. 2.8%, passing many tunnels and viaducts and turning in spectacular loops to an altitude of 892 m, reaching the summit in km 65.5 in the Gösingtunnel (2368 m long). Eventually, the track runs down to Mariazell (km 84, 849 m), famous for its Saint Mary pilgrim site. Breathtaking views along the whole route has given the line an outstanding position within the narrow gauged lines in Europe from its very beginning. Heavy transport demands showed an unexpected scale, and the steam-operated railway already reached its limit of performance in the first operational year. As a result of deep analyses concerning possibilities of capacity enhancement it was decided to electrify the line as soon as possible. In order to generate electrical power for traction needs it was proposed to use the water powers of Erlauf and Lassing rivers in that area by erecting a hydro-power plant at Wienerbruck. For reserve purposes as well as for times when water is scarce, the provision of large diesel engines in St. Pölten was suggested. To use surplus energy, it was envisaged to feed industry and households along the railway line. This long-term oriented strategy to provide electrical energy in a service area of more than 100 km trespassed for the first time the municipal level at that time. Therefore, the projects for power plants feeding the Mariazellerbahn were the origin of the countrywide electrification in Lower Austria and the roots of today’s Energieversorgung Niederösterreich AG (EVN).

A considerable reason for the choice of the alternating current system was the fact, that in the St. Pölten area several smaller hydro-power and steam-power stations were using the 25 Hz system already and it was foreseen to interconnect all these power plants. Furthermore, Siemens-Schuckert as the electrical supplier already had expertise in that field, since they supplied, among others, the Wien – Baden interurban railway, which had been operated in their core section with AC 500 V 25 Hz since 1906. Even though Siemens-Schuckert at that time fitted the normal gauge Budapest - Vács – Gödöllő line with a 10 kV 15 3/4

Fig. 1 - Layout of the Mariazellerbahn line St. Pölten – Mariazell - Gusswerk together with location of power stations. In fact Erlaufboden station was built instead of Trübenbach station. (Siemens-Schuckert, 1910)
Hz system and despite the fact that it became more and more evident that for the AC 50 Hz system a breakthrough could be expected, engineers of the Niederösterreichisches Landeseisenbahnamt were convinced by Siemens-Schuckert during a study tour across Europe to design the electrical power system both for railway propulsion as well as for industrial purposes with the frequency of 25 Hz.

The aim was, that a common distribution system should provide electrical energy for the whole region along the Mariazellerbahn route to strengthen the region both in their economical development and in their quality of life. Indeed, the interaction of Wienerbruck hydro-power station with both the Diesel power station at St. Pölten and the high-voltage transmission line Wienerbruck – St. Pölten together with the municipal power plant at St. Pölten and several others formed an interconnected system to serve as a model for coming developments.

References:
Abstract
Supercapacitors properties based on the electrostatic double layer and consequently the dielectric relaxation phenomena should be taken into account. The paper concerns the problem of the measurements of capacitance and dynamic properties of the supercapacitors. Some practical conclusions related to the description of parameters of supercapacitors are presented.

1. Introduction
The scope of applications of the supercapacitors dynamically rises e.g. in the field of energy saving. Supercapacitors properties based on the electrostatic double layer and consequently the dielectric relaxation phenomena should be taken into account. The paper concerns the problem of the measurements of capacitance and dynamic properties of the supercapacitors. Some practical conclusions related to the description of parameters of supercapacitors are presented.

Conclusions
On the basis of the study it can be concluded that the measurement method of supercapacitors capacity specified by IEC 62391-1: 2006 allows only approximate determination of the capacity of these elements. For accurate modeling of static parameters of these elements should be paid attention to the relationship between voltage and capacity described in the literature.
For accurate measurement of capacity and description of the work of supercapacitors in dynamic conditions it is necessary to take into account dielectric relaxation phenomena.

References
Abstract
In order to save energy used by electric urban transport, the special energy storage devices – ESDs (as batteries or ultracapacitances), which reuse recuperation energy of vehicles, are increasingly applied these days. They are commonly installed on-board of rolling stock. In network electric traction, the energy ESDs may be installed in a low voltage (up to 1.5 kV DC) power supply system (typically in traction substations or connected to catenary). The decision about installation of these devices is to be undertaken upon completing a technical and economic assessment of the proposed solution. The vital aspect of the issue is an amount of energy which may be saved, which is a function of type of route, traffic, rolling stock, place and energy capacity of the proposed energy storage device. Due to high power of vehicles as well as high technical demands (efficiency, protection against overvoltage, etc.) imposed on the ESD connected to a 3 kV DC network, the ESD has yet to find practical applications.

But increasing emphasis on energy saving in transport and technological growth will create opportunity for developing a technically effective design of the ESD.

The paper presents the method for calculating effectiveness of an energy storage device installed in a 3 kV DC traction substation. A study case consisting in effectiveness analysis of application of energy storage devices of two types: a battery and ultracapacitance in a 3 kV DC traction substation supplying a one-track mountain railway line. A set of traffic types and parameters of power supply have been taken into consideration. As a result of analysis, a year energy saving obtained due to different energy capacity of installed energy storage device has been presented. Trends in technology development are positive – due to increase of power and parameters and decrease of cost of basic elements – ultracapacitances and power electronic devices (IGBT). Increase of energy costs as well as law imposing greater CO₂ reduction will give another impulse for this kind of investment. Therefore, installation of ESDs in 3 kV DC railway traction may be soon justified.

Introduction
Energy saving resulting from introduction of a rolling stock equipped with regeneration should be considered comprehensively, from vehicles and their movement on a railway line to a power supply system. Rolling stock can be characterised by various technical specifications related to its operation, including regenerative braking. The manner of consuming and sending energy to the supply system is defined by TSI and standards concerning coordination between vehicles and a power supply system [26,27].

Technical opportunity allowing for energy regeneration during braking is a significant issue, however energy savings arising are not quite sufficient. Time of braking is typically short (tens of seconds) and a receiver of the generated by a braking vehicle electrical energy is to be operated in the zone of possible energy transfer from a braking vehicle to the one taking energy (power supply network is ‘receptive’). Lack of the receiver of braking energy (power supply is ‘not receptive’) will result in this energy being lost in a braking resistor. The time of braking can be prolonged when vehicles are running down-hill. Number of trains, which could take regenerative energy is limited by a time-table, which is influenced by the traffic capacity of a line. In this paper the main emphasis was placed on a one track mountain-type line. In this case excessive recuperation energy that appears will finally be lost in braking resistors. Application of the energy storage device could improve energy efficiency of a railway line section.

Application of the ESD became more and more popular in low-voltage DC urban transport systems such as: trams, trolleybuses or metro. Furthermore, what can be observed is peculiar boom in electric vehicles as mean of transport [1,2,3,5,7,10,11,12,16,18,20, 23,24,25]. However, in this case [21,22], 3 kV DC railway systems do not constitute a prevailing issue.
Conclusions

Application of the ESDs in low voltage DC urban traction has been rapidly developing for a number of years. Decision about their installation should be individually justified in each case following technical and economic study, as cost of ESD application is considerable. The most influential parameter is charging/discharging power and energy capacity of the device. It was obtained from the presented results for the specific case, in which the decrease of ESD energy capacity is even up to 50% of the maximum required energy that even though the investment costs are significantly reduced, application of the ESD does not equally influence energy savings.

There are positive trends in technology development observed – due to increase of power and parameters and decrease of costs of basic elements – ultracapacitances and power electronic devices (IGBT). Increase of energy costs as well as law imposing greater CO₂ reduction will give another impulse for this kind of investment.

Due to high power of vehicles as well as high technical demands (efficiency, protection against overvoltage, etc.) imposed on the ESD connected to a 3 kV DC network, the ESD has yet to find practical applications. But increasing emphasis on energy saving in transport and technological growth will create opportunity for developing a technically effective design of the ESD.

Rapid technological development together with additional advantages of the ESD application in 3 kV DC traction such as: lowering peak-power demand, application of the ESD as a reserve source of energy in case of emergency, reduction of CO₂ emission can make the discussed solutions not only feasible but justified from economic perspective (Fig. 6 presents exemplary results of years of investment return in the ultracapacitance ESD in a 3 kV DC traction substation considering its energy capacity $E_c$ and one-year energy savings $E_s$). Therefore, reasons for applying the ESDs in a 3 kV DC railway traction might soon become obvious.

Comparing with an inverter substation, the ESD as a solution for energy recuperation effectiveness increase seems to be a better option since the ESD increases re-use of energy within the electrified transport power supply system and does not require any additional permissions or agreements (concerning energy quality, billings or tariffs regarding energy returned to an AC system, etc.) from an AC power supply energy system operator.

References

2. ABB Review. SEPTA’s (Southeastern Pennsylvania Transit Authority) Wayside Energy Storage Project. ABB. edition 06.2014
8. Z. Juda Zastosowanie superkondensatorów w układzie zasilania w pojazdach trakcyjnych. X Międzynarodowa Konferencja MET’11 ”Nowoczesna Trakcja Elektryczna ” Poznań 29.09 - 01.10.2011,
9. G. Krawczyk Akumulacja energii w transporcie szynowym, Logistyka 3/2012,
11. T. Maciołek, A. Szelag, Z. Drażek Efektywność energetyczna zasobników energii w podstacjach systemu prądu stałego 3kV DC, Logistyka, 3/15, pp. 2990-3001
12. L. Mierejewski, A. Szeląg Akutualne kierunki ograniczania zużycia energii elektrycznej w transporcie kolejowym Technika Transportu Szynowego 7-8/2004, s. 35-41
14. Z. Pawelski Napęd hybrydowy dla autobusu miejskiego Wydawnictwo Politechniki Łódzkiej, Łódź Monografia nr. 890, 1996
17. J. Raczyński Pierwszy w Polsce tramwaj hybrydowy, TTS 10/2005, s 46-47
18. T. Solarek Ocena celowości stosowania w taborze trakcji tramwajowej kondensatorowych zasobników energii hamowania odzyskowego; TTS 12/09; s.52-54
20. A. Szelag, T. Maciołek, Z. Drążek, M. Patoka Aspekty efektywności i energooszczędności w procesie modernizacji układów zasilania trakcji tramwajowej, Pojazdy Szynowe, 3/2011, s. 34-42
21. A. Szelag, T. Maciołek A 3 kV DC electric traction system modernisation for increased speed and trains power demand-problems of analysis and synthesis. Przegląd Elektrotechniczny 3a/2013, s. 21-28
22. A. Szelag Wpływ napięcia w sieci trakcyjnej 3 kV DC na parametry energetyczno-trakcyjne zasilanych pojazdów, Wyd. INW Spatium Radom, 2013, s.158
23. A. Szelag Zwiększenie efektywności energetycznej transportu szynowego. Technika Transportu Szynowego 12/2008
24. A. Szelag Efektywność hamowania odzyskowego w zelektryfikowanym transporcie szynowym, Pojazdy Szynowe, 4/2009, s. 9-16
26. Standard EN 50163 Railway applications — Supply voltages of traction systems, 2004
27. Standard EN 50388 Railway Applications- Power supply and rolling stock. Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability, 2014
Abstract
After modifying the power supply system on the railway section it was put into test operation. One freight train was driven along section and current and voltages measurements were conducted in each electric traction substation. The obtained measurement results were analysed and compared with the simulation results of the developed software for train movement simulation. Maximum simulated results deviate from the maximum measurement results in the range of 3.2% in the worst case scenario. Maximum observed deviations between simulation and measurement results do not exceed 17.8%.

1. Introduction
In the planning/design of new railway lines, electrification or modification of power supply of the existing railway lines [1], the planned increase in transportation (increase the flow of railway lines, increasing the weight of the trains, the introduction of new locomotives with greater tensile power), the question is the appropriate infrastructure for power supply. The infrastructure for power supply of the 50 Hz AC railway system consists of electric traction substations (ETS), contact network (CN) and sectioning facilities, [2]. To determine the optimum position and installed power of the ETS it is necessary to:
1. Simulate the movement of trains, at any time, based on a planned timetable, to determine the position of trains and the active and the reactive power taking from the CN;
2. Calculate the present value of current and voltage in the contact network, apparent power load of ETS, apparent mean 15 minutes power, active power, reactive power, power factor I, heating (over temperature) of the contact wire etc. [2].

Estimation of energy consumption for electric trains is widely applied to the planning/design of power supply systems and the study of optimal driving strategies. Research on optimal driving strategies requires higher precision than power system planning/design since the latter usually takes the worst case scenario to consider safe margins.

Train movement simulation and the calculation of electric situation in the traction power supply system are the problems which are practiced by many authors, [3], [4]. In [5] Majumdar proposed four main stages of train movement including (1) acceleration, (2) balancing, (3) coasting and (4) deceleration. He showed that the total energy consumed in train operations is the product of force and displacement. He used coefficients for converting the work done in ton-km into electric power units. Majumdar also proposed a statistical method for estimating energy. In [6] Goodman developed single train and multi train simulation programs.

The voltage received by a train will vary with position and the simultaneous action of other trains in multi train model, while it remains a constant in a single train model. This is the main difference between two models in estimating energy consumption. Goodman considered detailed factors in his model, including substation, feeder cable and volt-drop, etc. In [7] the design of an electric train network simulator is described. The proposed software aims to help designing electric train power supply networks. It consists of two combined simulators namely a run time simulator and a network simulator. There are also commercial software for train movement simulation and the calculation of electric situation in the traction power supply system, [8], [9]. Many authors have studied the problem of energy consumption for electric traction. In [10] Martin discussed simulation in general. He showed 5% extension on run time can produce energy savings up to 20% on a suburban system, similar as in [11]. In [12] author developed a model which estimates power consumption at high precision with 2% deviation from a real situation. It is found that reducing maximum speed and tactfully performing coasting can reduce energy consumption about 7% ~ 20%. In [13] two models for estimating energy consumption of single train operation are presented. Paper [14] describes the work of simulating and analysing dynamic traction power supply system. It is based on dependent train movement in conjunction with traction power supply system simulation to establish a panorama view of the features.
This paper describes new software developed for train movement simulation and a comparison of simulation results with measurements.

6. Conclusions
Software, partly shown in this paper is primarily intended for designing electric traction infrastructure. Maximum simulated results deviate from the maximum measurement results of all 3.2% in the worst case scenario. Maximum observed deviations between simulation and measurement results do not exceed 17.8%. By comparing the simulation and measurement, the results show how developed software works quite well for the intended purpose.

Electric traction, besides representing unbalanced load (compound in two phases of 110 kV network) also affects on the voltage quality in the 110 kV network due to non-sinusoidal currents which diode locomotives take from the network.

7. Future work
Further development of the present software goes in the direction of the simultaneous simulation of the train movement and the traction load flow calculation. This will take into account the value of the voltage centenary in each train and the influence of the voltage to the speed-traction effort curve.

Acknowledgement
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References
RAILWAY TRANSPORT SYSTEM ENERGY FLOW OPTIMIZATION
WITH AN INTEGRATED MICROGRID

Hrvoje Novak, Mario Vašak, Marko Gulin, Vinko Lešić
University of Zagreb, Faculty of Electrical Engineering and Computing, Laboratory for Renewable Energy Systems, Croatia

Abstract

Railway transport system microgrid model is observed from the point of balancing energy flows between accelerating and decelerating trains, hybrid energy storage systems and a single supply substation connected to the main power grid. In this paper, an energy flow optimization of a railway system microgrid is presented. Optimization problem is formulated as a linear program that takes into account energy storage systems with corresponding charge and discharge efficiencies, actual electricity prices and simulated daily train consumption profiles. Performance of the proposed approach is verified through one-day simulation scenario with model predictive control scheme and by considering different prediction horizon lengths.

1. Introduction

Transport systems are considered as large energy consumers that accounted for 31.8% of overall energy consumption and for 1160.2 million tons of CO₂ emission in Europe in 2012 alone [1]. As a part of it, railway transport accounted for 2% of overall energy consumption and 7 million tons of CO₂ emission. For the same year in Croatia, 164.5 GWh were spent on transporting around 27.6 million passengers and 11 million tons of goods through the railway system [2]. Given the European Union climate and energy targets for 2020, also known as the 20-20-20 plan, it becomes important to improve the energy efficiency of the railway systems and market the “green image” of railway applications. Advances in information and communication technologies and electronics, together with more efficient and economically affordable energy storage systems, provide an opportunity for complex technical systems like railway transport to transform from passive loads that consume energy from the grid into more proactive entities with an ability to adapt to changing energy exchange terms and various demands of the power grid. In order to increase the energy efficiency of the railway system, a considerable amount of effort is invested on better utilization and efficiency of braking trains regenerative energy [3]-[13]. Electric trains in braking convert the mechanical kinetic energy to electrical energy and feed it back to the catenary. If another train is accelerating while supplied from the same substation, energy sent back to the catenary will be used for powering its acceleration. If there are no accelerating trains nearby, regenerated energy causes overvoltage that potentially damages the system infrastructure. The energy is then dissipated on train built-in resistors, or it is stored in energy storage devices if available. An opportunity is provided to tune train timetables in order to closely coordinate nearby trains such that the braking trains regenerative energy is immediately reused by accelerating trains [3], [4]. Introduction of onboard and stationary energy storage systems [5]-[13] for storing the regenerative braking energy for later use show that savings of up to 30% of regenerative energy are achievable. In order to further increase the economic effects related to energy flows of the railway system, it is necessary to implement a higher-level control system to take into account the possibility of different electricity prices throughout the day or changing acceptable power exchange levels imposed by the power utility.

The concept of microgrids brought possibility of dynamical optimization of the railway system total power consumption by means of distributed regenerative braking, renewable energy sources and storages, all of which transforms it to active participant in the power system [8], [9]. A clear microgrid structure is formable for each railway supply substation, where braking trains present distributed sources and the energy storage systems are installed in the substation. The microgrid energy management system balances the energy flows between accelerating trains energy consumption, decelerating trains energy production, energy storages and energy exchange with the grid. It takes into account declared price profile for energy exchange on the grid side, current state of the energy storage and prediction of trains energy consumption, and makes the decision when to buy/sell electrical energy from/to the utility grid and in which amount. Therefore each supply substation along the train route may be observed as an individual microgrid. By making a step-up further, the railway traffic system is observed as a chain of microgrids that can be coordinated in order to attain minimum cost for energy drawn from the grid while all the trains operate according to timetable and operational constraints along the routes.

Previous work on microgrid energy flow optimization is...
performed on a DC microgrid that consists of photovoltaic array, batteries stack and fuel cells stack with electrolyser, all connected to the grid via bidirectional power converter. Minimization of microgrid operating costs is formulated by using a linear program that takes into account energy storage devices charge and discharge efficiencies [14], [15]. The improvement in energy consumption efficiency has additional advantages for the railway operator and the power system in general: the use of the grid is more efficient and a smaller capacity is required; the railway operator becomes less dependent on the power grid; decentralization of the power system thus increasing its reliability and stability; finally, the amount of power that needs to be contracted is reduced and the operating costs are further decreased[4]. In this paper, a railway system microgrid is considered consisting of a hybrid energy storage system, distributed generation of nearby trains in braking and a bidirectional connection to the power grid through a supply substation. Microgrid energy flow optimization problem is defined as a linear program (LP) and a model predictive control (MPC) scheme with receding horizon philosophy is implemented. The performance of the proposed approach is verified on a one-day simulation scenario considering different prediction horizon lengths. This paper is structured as follows. In Section 2, a microgrid model is presented. In Section 3, the optimization problem and model predictive control scheme are formulated. Performance verification of the proposed approach is given in Section 4.

5. Conclusion
In this paper energy flow optimization in railway system with integrated microgrid is presented. Model predictive control scheme is implemented and the approach is verified for different prediction horizon lengths on a simulation scenario. It is shown that the proposed approach reduces the railway system operation costs through charging and discharging of the hybrid energy storage system, with better performance for longer prediction horizons. Choice of energy storage systems is validated as it is shown that supercapacitors are used for storing the regenerative braking energy, while batteries perform better at utilization of the difference in the electricity price profile throughout the day. Due to inherent complexity, the railway system is observed from two different control levels. The higher-level railway system optimization introduced here optimizes energy flows with respect to external grid conditions, state of the energy storage system and railway traffic. Lower, consumption level optimization, where each train is controlled to achieve least travel costs while maintaining the time-table and passengers comfort can be re-computed such that interaction of both levels is taken into account and the computed energy consumption profile on the lower level directly maximizes the global economic gain of the whole system operation. Price of energy exchange with the grid is for an individual train transformed through the higher coordination system and the economic cost is reduced by cooperative action of all the trains in balancing energy flows.

Acknowledgments
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References


Abstract
A collision between aircraft is one of the most sudden and catastrophic transportation accidents imaginable. These tragic events are rarely survivable – hundreds of people may die as the two aircraft are destroyed. Some airborne systems have been developed and are currently in use to prevent mid-air collisions. This article focuses on the widely fielded, crucial technology called the Traffic Alert and Collision Avoidance System (TCAS). TCAS has had extraordinary success in reducing the risk of mid-air collisions. Now mandated on all large transport aircraft, TCAS has been in operation for more than two decades and has prevented several catastrophic accidents. TCAS is a unique decision support system in the sense that it has been widely deployed (on more than 25,000 aircraft worldwide) and is continuously exposed to a high-tempo, complex air traffic system. TCAS is the product of carefully balancing and integrating sensor characteristics, tracker and aircraft dynamics, maneuver coordination, operational constraints, and human factors in time-critical situations. Missed or late threat detections can lead to collisions, and false alarms may cause pilots to lose trust in the system and ignore alerts, underscoring the need for a robust system design.

Introduction
Over the years, air traffic has continued to increase. The developments of modern air traffic control systems have made it possible to cope with this increase, whilst maintaining the necessary levels of safety. The risk of collisions is mitigated by pilots exercising the “see and avoid” principal and staying away from other aircraft and by ground based Air Traffic Control (ATC) which is responsible for keeping aircraft separated. Despite technical advances in ATC systems, there are cases when the separation provision fails due to a human or technical error. Any separation provision failures may result in an increased risk of a mid-air collision.
To compensate for any limitations of “see and avoid” and ATC performance, an airborne collision avoidance system, acting as a last resort, has been considered from the 1950s. In 1955, the use of the slant range was proposed between aircraft divided by the rate of closure or range rate for collision avoidance algorithms, i.e. time rather than distance, to the Closest Point of Approach (CPA). Today’s airborne collision avoidance system is based on this concept [1].
In 1956, the collision between two airliners, over the Grand Canyon in the USA, prompted both the airlines and the aviation authorities to advance the development of an airborne collision avoidance system. It was determined in the early 1960s that, due to technical limitations, the development could not be progressed beyond the overall concept.
During the late 1960s and early 1970s, several manufacturers developed prototype aircraft collision avoidance systems. Although these systems functioned properly during staged aircraft encounter testing, it was concluded that in normal airline operations, these systems would generate a high rate of unnecessary alerts in dense terminal areas. This problem would have undermined the credibility of the system with the flight crews.
In the mid-1970s, the Beacon Collision Avoidance System (BCAS) was developed. BCAS used reply data from the Air Traffic Control Radar Beacon System (ATCRBS) transponders to determine an intruder’s range and altitude. In 1978, the collision between a light aircraft and an airliner over San Diego, California led the US Federal Aviation Administration (FAA) to initiate, three years later, the development of TCAS (Traffic Alert and Collision Avoidance System) utilizing the basic BCAS design for interrogation and tracking with some additional capabilities.
Despite the terrifying prospect of a mid-air collision, aviation travel is incredibly safe. A person who flew continuously on a jet transport aircraft in today’s environment could expect to survive more than 11,000 years of travel before becoming the victim of a mid-air collision. This accomplishment has only recently been realized. The number of hours flown annually by jet transport aircraft has
more than quadrupled since 1970, but the rate of mid-air collisions over that period of time has dropped by an order of magnitude. The result is that today we can expect one mid-air collision every 100 million flight hours. Such an exceptional safety level was achieved through advances in air traffic surveillance technology and relentless attention to improving operational procedures. TCAS is one component of a multi-layered defense against mid-air collisions. The structure of airspace and operational procedures provide the first strategic layer of protection. Traffic flows are organized along airways at segregated altitudes to aid air traffic controllers in managing aircraft and predicting potential conflicts well before problems arise. Aircraft are normally kept three to five miles apart laterally or 1000 ft vertically, to provide sufficient safety margins. Air traffic control ensures that separation minima are not violated by issuing tactical commands (including altitude restrictions and heading change vectors) to the pilots in response to nearby traffic. Should these nominal traffic separation processes fail, the TCAS system aids pilots in visually acquiring potential threats and, if necessary, provides last-minute collision avoidance guidance directly to the flight crew.

It is obviously imperative that TCAS alert the flight crew early enough that evasive action can be taken. But it is also important that TCAS does not alert unnecessarily. Collision avoidance alerts represent high-stress, time-critical interruptions to normal flight operations. These interruptions, in addition to distracting the aircraft’s crew, may lead to unnecessary maneuvering that disrupts the efficient flow of traffic and may over time also cause pilots to distrust the automation. Monitoring and safety assessments led to a series of changes resulting in the latest international version of TCAS – referred to as Version 7.1, or the Airborne Collision Avoidance System (ACAS). Starting in January 2003, the International Civil Aviation Organization mandated the use of ACAS worldwide for all turbine-powered aircraft with passenger capacity of more than 30 or with maximum take-off weight exceeding 15,000 kg. In January 2005, that mandate was extended to cover aircraft with more than 19 passenger seats or maximum take-off weight of more than 5700 kg [2].

The real challenge lies in integrating new collision avoidance technologies with the existing systems and procedures. The Überlingen accident demonstrated the catastrophic outcome that can result from dissonance between two different decision makers in a time-critical situation: namely, an air traffic controller’s decision to request a descent and TCAS’s Resolution Advisory to climb. While this specific problem is being solved by improving pilot training to comply with RAs and refining the TCAS algorithms, related problems are likely to surface as unmanned aircraft and enhanced collision avoidance technologies mix. Ensuring compatible operation also extends well beyond TCAS or aviation to many integrated sensing and decision support system applications.

References

[5] Investigation Report AX001-1-2/02, Bundesstelle für Flugunfalluntersuchung (BFU, German Federal Bureau of Aircraft Accident Investigation), Braunschweig, Germany, May 2004

Conclusion

TCAS represents a clear success story in aviation safety. Its successful design was achieved through detailed consideration of sensor characteristics and the coupled dynamic interactions among pilots, air traffic controllers, and aircraft. The result is a fine balance that provides sufficient time to take action and that minimizes alert rates. As the Überlingen accident shows, however, safety can not be taken for granted, and areas of improvement will always exist in systems that rely on integrating humans and automation for information processing and decision making.
ISSUES OF SIGNALING SYSTEMS APPLICATION IN THE TRAMWAY INFRASTRUCTURE – A CASE STUDY

Adam Szelał, Marek Patoka
Warsaw University of Technology, Institute of Electrical Machines, Electric Traction Division, Poland

Abstract
The application of state of the art track circuits is getting more and more popular on the Polish tramway infrastructure. The electromagnetic interference between traction return current and track circuits has become significant not only in the railways. The paper describes implementation of modern track circuits in the Polish tramway infrastructure and related electromagnetic issues. The on-site survey and proper measurements were performed to identify the electromagnetic interference problems. Authors conducted the analysis concerning the track circuit application in the tramway infrastructure, presenting its weaknesses that influence safety and reliability of the system.

Introduction
Electric traction vehicles are equipped with power electronics equipment for traction and non-traction purposes. Power electronics systems enable smooth determination of traction characteristics depending on a set duty-cycle of motion. Structure of modern converters consists of semiconductors, typically IGBT, which apart from many advantages, posses a range of drawbacks - there are sources of electromagnetic noise. The latter makes the requirement of the electromagnetic compatibility (EMC) provision. In typical electric traction systems, running rails (RR) are operating as return conductors as well. As a result, the vehicle's input current flows not only in an overhead catenary (or 3rd rail) but also in the running rails. It could be expected though, that current harmonics flow in the RR, could be the reason of EMC issues.

Conclusions
Appropriate interpretation of the measurement results requires further attention. According to the enclosed diagrams (Fig. 2÷6), it could be stated that the tram might be the source of interference causing the track circuits failures. The current flowing in the tram's electrical circuits contained the higher frequencies components overlapped with the frequencies utilized by the applied signaling systems. Furthermore, these could be also seen in the magnetic field emission in the vehicle's surroundings. However, the above mentioned results are not sufficient reasons to state that the tram is the source of EMI in the infrastructure. Fortunately, prolonged works and cooperation of the tram inverter and track circuits manufactures with infrastructure operator and ETD were successful and the disturbances were eliminated. The slight changes were applied in the tramway electronic circuit (filters and electrical bonding improvement) and in the area of disturbed infrastructure (earthing and bonding analysis).

The main aim of this paper was not to present how to solve the problem of track circuit failures in the tramway infrastructure, but to emphasize the issue of insufficient preparation of signaling system implementation at such infrastructure. Issues related to EMI are complex and have to be analysed not only by infrastructure operators and manufactures of traction power electronics systems or track circuits, but also by appropriate institutions that will be responsible for developing specifications, standards and guidelines. Only after complete and comprehensive preparation of the overall system, the interfaces of all of the traction subsystems will be electromagnetically compatible and safe.

References


[10] Szeląg A., Maciołek T. A 3 kV DC electric traction system modernisation for increased speed and trains power demand-problems of analysis and synthesis. Przegląd Elektrotechniczny, 3a/2013, pp. 21-28


[13] EN 50121-2. Railway applications. EMC. Emission of the whole railway system to the outside world.

[14] EN 50121-3-1. Railway applications. EMC. Rolling stock. Train and complete vehicle.


[17] Szeląg, A., Steczek M. Analysis of input impedance frequency characteristic of electric vehicles with a.c. motors supplied by 3 kV DC system for reducing disturbances in signalling track circuits caused by the harmonics in the vehicle’s current. Przegląd Elektrotechniczny R.89, pp. 29-33, 3a/ 2013,


Abstract
The paper presents the concept of advanced and highly integrated IGBT propulsion and an auxiliary power supply converter for diesel electric multiple unit. The incoming power from the diesel-generator group is transformed into traction power by the propulsion converter. The auxiliary power supply converter supplies energy to the on board network and the vehicle battery directly from the same DC-link. Energy recuperated during braking is fed back into the DC-link, where it may be consumed by the auxiliary systems, or dissipated into heat by the braking chopper.

All propulsion and auxiliary supply equipment as well as cooling system are integrated into a roof-mounted converter box, while a high degree of functional integration as well as the maintenance cost optimized design are realized. The increased power density of the new generation converters enables compact and light-weighted vehicle designs.

1. Introduction
Based on a former joint venture with TŽV Gredelj the Končar group is designing a new generation diesel electric multiple unit (DEMU). For this purpose a thorough redesign of the converter has been made. Considerable experience gathered during the design, production, commissioning and exploitation of the previous generation converter has resulted in many improvements implemented in the new All-In-One converter KONTRAC GP550DE for Končar DEMU. GP550DE converter is realized with two separate inverter units both fed from the same DC-link and can be mounted on the roof. This implementation proved to be room and cost efficient given all the power units and other components are cooled with a single heat exchanger [1], [2]. The converter DC input is fed from a roof power pack (RPP) – three-phase generator with rectifier unit. The generator is powered by a diesel engine. Both the propulsion and auxiliary converter as well as the battery charger are controlled by the same digital control unit KONTRAC DCU222. The DCU222 and its subordinated FPGA and DSP cores ensure high performance measurement and control. The auxiliary converter powers the onboard three-phase and single-phase devices as well as the battery charger. All of the above mentioned features of the GP550DE converter enable the design and production of the Končar DEMU according to the newest safety demands and best passenger experience.

4. Conclusion
This converter offers a well-integrated solution for powering trains since it powers propulsion, auxiliary and battery loads. It has been designed to meet customer demand for a well-integrated and robust converter unit. In order to achieve high efficiency and dynamics, modern IGBT technology has been implemented. Because of experience gathered during exploitation of the previous generation converter high quality and reliability has been achieved. It must be emphasized that with minor corrections this converter is suitable to operate with various power sources, as long as they are 1000-2000 V DC.

4. References


Abstract
Some possibilities of the energy storage applications in the passenger rail transportation systems have been presented in the paper. An overview of the most suitable energy storage devices has been shown and common areas of the energy storage utilizations have been discussed.

Energy storage
Electricity storage is not a new idea. The Galvani experiment with the "animal electricity" was conducted in the 1780s and the first battery (a stack of copper and zinc plates, separated by brine soaked paper disks) was invented by Volta in 1799. The Daniell cell, invented in 1836, became the first industry standard and was adopted in telegraph networks. The first secondary (or rechargeable) battery was the lead–acid battery, invented in 1859 by French physicist Gaston Planté. In the 1880s, lead-acid batteries became the original solution for night-time source of DC energy in the private New York City area systems. They were used to supply electricity during high demand periods and to absorb excess electricity from generators during low demand periods for sale later. The usage of the batteries in electric power systems has been limited due to their relatively small capacity and high cost. However, since then about 2005 new batteries have been developed, providing significant energy storage capabilities. Some of the newer battery types seem to be competitive with alternative energy storage methods.

Conclusions
The regenerative braking in urban rail systems can reduce their net energy consumption between 10% and 45%, depending on the system characteristic [11]. The results of the author’s simulations [17] conducted for the Moscow underground system and the trains equipped with regeneration braking show that about 15% reduction of the energy consumption can be achieved. Additional benefits can be also expected: line voltage fluctuations can be suppressed, voltage drops at the feeder lines can be minimized, and power peaks can be mitigated. The additional advantage of the regenerative braking and energy storage is a lowering of the temperature in the underground tunnels and a reduction of the energy consumption for the temperature control and brake shoe dust reduction [3,20].

The aim of the paper was to present the possibilities of improvement of the electrified rail transport systems by use of the energy storage. The presented results show the increasing interest of the utilisation of the energy storage systems, which become the technologically matured devices, offered by the growing group of the manufacturers.

References


Abstract
Railway transport is the only transport mode, which cannot ensure fluent transport over internal EU borders. In that respect the traction powering systems’ differentiation is an important obstacle. Article points out associated challenges, possible solutions as well as risks especially those related to transitional periods together with proposed mitigation possibilities.

Introduction
Different power supply systems were introduced in Europe, due to several reasons. Firstly, because national railways were using national solutions provided by national or quasi national industry. Secondly, because when the railways were electrified it was not seen to be wise to facilitate passing borders by trains – namely by military trains. Thirdly, because when electrification started it was a must to keep the same system for all lines countrywide to preserve unity of the national networks. Since then perception of the railway as a transport mode changed significantly. Due to globalization processes industry is no longer subdivided between different countries. Armies no longer consider using trains for quick moving of military vehicles on medium distances (circa 300-1000 km e.g. between different countries in Europe) mainly due to evolution of military vehicles and due to revolution in other transport modes, which are offering at present competitive transport services. It is however still imaginable to use railway for transport of military vehicles on long and extra-long distances (circa 2000 km and more), especially having peace inside and possible conflicts outside outer EU borders. Adding EU economic freedoms: namely free movement of persons, and free movement of goods it is necessary to point that countrywide technical compatibility has to be replaced by European-wide rail transport coherency, and that is a real challenge.

Conclusions
Converging electrified rail transport towards European railway system capable to compete with other transport modes is a must. This is a challenge especially from the safety and technical compatibility point of view. Out of two possible solutions – the simple one and the reasonable one only the second is workable without unacceptable risks and very long transition periods lowering already very low railway competitiveness. Implementation of the second solution based on long time usage of multisystem traction units has already started and can be judged to be promising.

References
Abstract
This innovative system for rail traction power supply, christened "2x25 kV + +", is achieved by modifying the arrangement of the conductors on the catenary. This concept delivers a substantial decrease in impedance, opening up important avenues for optimisation in system design to improve power supply quality. It reduces the number of substations required for the operation of a railway line. This innovative idea can be implemented without any technological change of components in the catenary and / or sub-stations.

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1. Introduction
Every major railway operation activity today calls for higher standards in order to improve service quality and optimize costs. As a result, the power levels of traction units have generally increased to meet new operational needs.

These developments in the railway system have led to an increase in the voltage level of lines supplying traction power in order to attain higher short-circuit power levels, reducing the rate of imbalance caused to the national electricity grid.

In general the density of transmission lines in the national grid is lower where the level of voltage is higher, from high voltage such as 63 kV or 90 kV up to very high voltage such as 225 kV or 400 kV. The connection points between the national grid and transmission lines feeding the traction sub-stations consequently tend to be further apart when the national grid voltage is higher.

To respond to this more difficult and increasingly more common situation, we have devised a simple and robust "2x25 kV++" system. We subsequently filed a patent application for this innovative system.

9. Poland and Croatia
For Poland and Croatia, introduction of or conversion to 2x25 kV would obviously be a major policy decision. If this idea is being seriously considered, it would be worthwhile to also consider 2x25 kV++. As an example, Egis Rail is presently a partner in a consortium designing the modernization and double tracking of the Dugo Selo – Novska railway corridor where such a conversion could be of considered.
Abstract
Depleted resources of hydrocarbon fuels and environmental problems that arise from the mass application of internal combustion engines offer a chance for rapid development of electrified transport. The barriers currently limiting the mass introduction of electric cars to the general public are mainly due to constraints related to the search for a suitable electrical source for the vehicle and absence of the infrastructure to support electrified transport. With a sufficiently large financial outlay and increased involvement of the scientific and research communities, the quick resolution of these problems is undoubtedly possible.

Introduction
The development of electric car transport began in the first half of the 19th century and after a period of oblivion is back again. Not everyone knows that the pioneering vehicles that can be called cars were electric vehicles. Although the first car shall be deemed the design of the American Thomas Davenport of 1834, in Europe between 1832 and 1839, a Scottish businessman Robert Anderson invented the first crude electric carriage, and perhaps he is entitled to priority, [2]. The invention of the lead-acid batteries by Gaston Plante in 1865, their improvement by Camille Faure in 1881 and the development of better electric motors opened the way for the advancement of electric vehicles. Until the First World War, before the widespread polluting internal combustion (IC) engines, electric vehicles had beaten many speed and distance records. One of the most notable events of those times was the first time that a road vehicle crossed the barrier speed of 100 km/h with driver Camille Jenatzy on 29 April 1899, [2]. The electric vehicle, La Jamais Contente, powered by two electric motors with a total output of 100hp reached a maximum speed of 105.88 km/h. The threat of depletion of the profitable resources of hydrocarbon fuels used as a primary energy source for IC engines as well as the multi-level environmental and health hazards—generally threatening human existence—has necessitated the search for a way out of this impasse. The quick search for another resource that could be used for transport and that would also protect users from the serious health risks posed by IC engines became an imperative at the beginning of the XXI century. It is believed that the electric motor could be one such solution. The electric motor is environmentally friendly, is three times more efficient than the IC engine and perfectly meets the conditions required in drive vehicles, namely engine produced torque and power change as a function of speed. What is more, the electrical energy necessary for its operation could be acquired from sustainable energy sources.

Conclusions
Depleted resources of liquid fossil fuels and environmental problems spawned the reconsideration of electric vehicles. This is not an easy and fast process since it is determined by a number of factors. It is undoubtedly a positive fact that electric motors used to drive electric vehicles are more than three times as efficient as internal combustion engines and have the characteristics of change in power and torque produced as a function of speed perfectly matching the requirements stemming from vehicle propulsion. An inhibiting factor still requiring a solution is the electrical energy source in vehicles and the possibility of rapid recharging. Great efforts are being made to overcome the problems associated with widespread use of fuel cells in vehicles, which would help solve this problem. Optimists say that within half a century it will be possible to overcome this limitation and produce the necessary electricity for charging using eco-friendly renewable WWS energy sources. Some obstacles of possibly implementing the WWS system are political in nature, not technical. Despite the many difficulties in sales, there have been many interesting solutions for electric vehicles, but their primary drawbacks remain their high price, unsatisfactory recharging parameters requiring electrochemical sources of electricity, and the constraining conditions of the range and dynamics of these vehicles. It is well known that in order to achieve any success, properly educated people, financial expenses and time are needed. Larger financial outlays offer an opportunity to introduce the subject to a larger number of people and to accelerate the process. Unfortu-
nately, the published data show that since 1980 it is noted that in the most developed countries of the world, financial outlays are also rapidly declining in the area of scientific and energy research, indicating that time necessary to achieve success may be dangerously extended.

References
[1] Amory B.; Rezygnacja z węgla to czysty zysk, Świat nauki, nr 170, str. 54 – 63, 2005
[11] Lawler R., Tesla's 90 second battery swaps will power EVs faster than gas pumps fill tanks, access: http://www.engadget.com/2013/06/21/tesla-motors-battery-swaps-faster-than-gas
[14] Murray Ch.; Don’t hold your breath for Volkswagen’s Lithium-Air battery, Design News,
[16] Taylor A.; The Birth of the Prius. Toyota had to overcome punishing deadlines, skeptical dealers, finicky batteries, and its own risk-averse culture to bring its hybrid to market, access: http://archive.fortune.com/magazines/fortune/fortune_archive/2006/03/06/8370702/index.hhp
[18] Zorpette G.; W oczekiwaniu na supersamochód., Świat nauki, Nr 94, str. 20-22, 1999
Abstract
The paper deals with new software ensuring the tram vehicle ride according to the criterion of the minimum energy use. The tram is driven by vectorially controlled and field oriented three-phase induction motors. Traffic disturbances are taken into consideration and a tram ride can contain many cycles consisting of the starting, the running with the constant speed, the coasting and the braking.

Introduction
Nowadays energy saving within the tram traffic is very important. Many new solutions have appeared in this field, e.g. [1], [3 - 7]. Optimization of duration of the typical tram ride stages: the starting, the running with the constant speed, the coasting and the braking can decrease the energy use.

In the city, frequent changes of tram traffic conditions occur. The total and local, planned or unplanned speed limitations, intentional or unexpected stops, changes of the network voltage, changes of a size of the energy recuperation during the braking are typical for the tram city ride. Because of ride perturbations, the run between neighbouring tram stops can contain many cycles consisting of the starting, the running with the constant speed, the coasting and the braking. Sometimes these cycles can possess only some of above ride phases. The author of this paper has elaborated the original algorithms ensuring the minimum energy use taking the different tram traffic disturbances into consideration.

Application of vectorially controlled and field oriented three-phase squirrel-cage induction motors for tram drive ensures diminution of the weight and dimensions; also enlargement of the technical reliability is here important.

In this paper, the mathematical models both for the first part of the starting (constant magnetic flux, increase of the supply voltage at motor terminals) and for the second starting part (the rated motor supply voltage, decrease of the magnetic flux) have been presented. For the tram running with the constant speed, there was given the model ensuring the larger motor efficiency and better power factor. There was also described the optimization strategy giving the minimum energy consumption for the case of traffic disturbances and occurrence of many ride cycles. Exemplary tram ride with unplanned stop and calculation of the algorithm of the tram ride according to the criterion of the minimum energy use have been also presented.

Conclusions
For vectorially controlled and field oriented three-phase induction motors supplied from modern inverter systems, the author has elaborated new software determining the vehicle tram ride with the minimum energy use.

Within the new possibilities, traffic disturbances can be taken into account, e.g. the total and local, planned or unplanned speed limitations, intentional or unexpected stops, changes of a size of the energy recuperation during the vehicle braking.

The optimization of duration of the typical tram ride stages: the starting, the running with the constant speed, the coasting and the braking can decrease the energy consumption.

For traction three-phase squirrel-cage induction motors, it is interesting that the algorithm of energy saving tram traffic possesses both the phase of the vehicle running with the constant speed and the stage of the coasting. Because of traffic perturbations, the tram ride can contain many cycles consisting of the starting, the running with the constant speed, the coasting and the braking. Some cycles can have only some of the above ride phases. The algorithm of the energy saving control must be constantly updated. Application of a computer makes possible forecasting of the subsequent energy saving ride with minimum energy use.

Elaborated algorithms of the tram ride at minimum energy use make possible to save about 20% energy in comparison with the ride basing only on subjective decisions of a driver.
References


Abstract
The article presents instantaneous power flow through the selected elements of widely known DC-AC and AC-AC drive systems. The classic DC-DC drive system with a serial machine and a resistance starter is used as a comparative system. The presented values include: instantaneous value of power consumed from a network, instantaneous powers at inputs and outputs used in a static converter drive, power consumed by a traction machine and its developed torque. Power pulsation transfers up to the mechanical part of the system. Power pulsation is not directly visible, so the use of measuring devices is required, while mechanical pulsation not only causes damage to the elements in mechanical sub-assemblies of a system, but also can cause discomfort to the passengers of a vehicle. Considering the unavoidable power pulsation, while designing the whole system, would significantly increase the reliability of these modern and energy-saving drive systems.

Introduction
The last two decades have been marked by rapid development of converter traction drive. It stems from the fast growth of semiconducting elements as well as advanced progress in the technology of electric valves, miniaturisation and digitisation of control systems and progress in interference-free transfer of information. Under energy savings slogan, one might uncover undeniable progress in almost all areas of life. It applies to electric drive systems as well. Power electronics is with no doubt a drive force of the observed progress, however it seems like some aspects have been forgotten and insufficient actions have been undertaken, which resulted in serious negligence as fast as modernisation and adjustment of mechanical part elements are concerned. Increased reliability of the electrical part also highlighted the real size of the issues related to the mechanical part of traction drive systems.

Conclusions
- Supply networks of “constant voltage” allow for consumption of almost constant power, however they introduce harmonics into drive systems, and the influence of these harmonics can be intensified in converter systems as a result of their entanglement with harmonics of converter switching frequencies. (influence in signalling) [1.2.7.10]
- AC supply networks are loaded with almost constant power, but only with supply by 3-phase sinusoidal voltage. Single-phase networks supply only pulsing power with double network frequency. Pulsation of power consumed from a network with constant frequencies (2*16.7 Hz and 2*50 Hz and 2*60 Hz) can be relatively easy, but with large effort, compensated using a series resonance filter tuned precisely to double frequency of this network. This filter stores energy surplus that comes from a network in a half-period of power higher than the average value and it returns the energy immediately to the receiver in a half-period of deficit of power supplied by a network. The filter can be used in drive systems of AC-AC type.
- Very often, AC networks do not fulfil the condition of sinusoidal voltage and are the source of considerable amount of voltage harmonics as well as additional power pulsation.
- Power supplied by the AC network is limited by total impedance of the network and impedance of transformers that occur on a path to point of common coupling.
- Converter systems transfer energy in a pulse manner
- Each power conversion introduces new frequency harmonics and generates new entanglements.
- All energy converters generate in electrical machines pulsations of mechanical power.
- Amplitudes of these pulsations do not depend on load state of a machine, and are the same for the states of ride, idle state and braking. Only no-current idle state is void of these pulsations.
- Amplitudes and frequencies of these pulsations depend on manner of converter operation control.
- Power pulsations in electrical part can be reduced only in a very limited range.
- Power pulsations are transferred to the mechanical part of a drive and cause additional dynamic load for a transmission gear, decoupling parts and traction machines as well.
Pulsations are the cause of fast ageing of and damage to electro-mechanical elements of a power transfer system in converter traction drive systems.

When the power is transferred from the motor's shaft to the vehicle's axle, there must occur power pulsation smoothing, and high frequency storage of the energy surplus in elastic elements being capable of returning this energy under conditions of energy deficiency.

This task cannot be fulfilled in converter drive systems only by means of nose-suspension, and it is due to the too low frequency of potential reaction.

Nor is it fulfilled by a rubber coupling since rubber spacers can deform permanently very quickly.

However, this objective can be met only by elastic elements with high durability that are capable of storing considerable amount of energy and reacting very fast to the change of power being transferred.

Bibliography

[7.] G. Skarpetowski, Frequency domain supported calculation of voltage source converters supplying induction motors. W-wa 2005
[14.] A. Szeląż, Wpływ napięcia w sieci trakcyjnej 3kV DC na parametry energetyczno-trakcyjne zasilanych pojazdów (in Polish- Influence of voltage in 3 kV DC contact line on traction-energy parameters of supplied vehicles, Instytut Naukowo-Wydawniczy „Spatium”. Radom 2013, Poland
Abstract
The latest generation of traction drive systems is almost entirely equipped with asynchronous motors with power electronic converters. After years of rather sceptical approach to this technology, it is observed that these systems are gradually becoming more efficient. This fact is mainly concerned with application of maximum load of a converter and thermal load of a motor in order to create a traction characteristic compliant with demands. The paper presents rules and analytical basis for creating a traction characteristic of a vehicle. Two traction characteristics serve as an example here. Both of them are covered in the first zone of control with a constant stator flux. In the second zone, when the flux is reduced, one of these characteristics includes a section on a constant-power hyperbola, while an alternative characteristic includes a section along a line of constant current taken by the controlled machines. Both characteristics are coherent along a line of a torque limit due to the proximity of a break-down torque.

4. Conclusions
Curves (shapes) of vehicle traction characteristic with an asynchronous machine drive results from the requirements of a user commissioning a vehicle. As a comparative characteristic, may be applied the characteristic obtained with maintaining a nominal value of frequency in a rotor within the whole range of stator’s frequency. All the deviations from this characteristic are associated with additional expenses on a converter and a cooling system of all the elements of power transfer.

Increase of a torque in a zone of constant excitation causes increase of current, which means increase in commutation ability of the applied converter and requires proper enhancement of a cooling system of traction motors due to the required time of operation with maximum torque in this range of speed.

In the range of a weakened field, there are at least three possible methods of shaping a traction characteristic.

- The first one – further maintaining the same, constant value of torque
- The second one - decreasing torque in order to maintain the constant value of mechanical power (due to practically constant efficiency of a motor, it is possible to use in the control only power taken by the motor).
- And last but not least – to reduce the torque in order to maintain the constant value (as till now) of the current taken by the machine.

These three methods define completely different requirements towards commutation ability of a converter and capacity of a cooling system. Upon identifying machine parameters and defining the nominal point of operation, it is possible to calculate the shape of these characteristics using the formula presented.

References
[5.] S. Rawicki Energooszczędne przejazdy tramwajów ze sterowanymi wektorowo silnikami indukcyjnymi w dynamicznym ruchu miejskim, monograph, Poznań University of Technology, 2013


[8.] G. Skarpetowski *Frequency domain supported calculation of voltage source converters supplying induction motors*. Warsaw, 2005


[15.] A. Szelag *Wpływ napięcia w sieci trakcyjnej 3kV DC na parametry energetyczno-trakcyjne zasilanych pojazdów* (in Polish - Influence of voltage in 3 kV DC contact line on traction-energy parameters of supplied vehicles) Instytut Naukowo-Wydawniczy „Spatium”. Radom 2013, Poland
Abstract
The article presents the problem of application of a traction inverter control strategy consisting in selective elimination of harmonics (Selective Harmonic Elimination – SHE) for shaping the spectrum of traction current. The objective of this method is to reduce the conducted disturbances generated by a traction vehicle to the level below admissible values. The selection of the order of harmonics being eliminated from a voltage spectrum influences the values of the remaining voltage harmonics, hence the harmonics spectrum of current consumed from a DC network. The presented study aimed at developing the SHE method to the extent enabling its implementation to the real drive system. The article describes the results compared with limits existing in PKP (Polskie Koleje Państwowe – eng. Polish State Railways), however the presented methodology can be successfully employed for any applicable limits in DC electric traction systems.

Description of the problem
The problem of disturbing influence of traction vehicles in the track circuits of a rail traffic control system was thoroughly examined and described in a number of publications [2],[5],[10],[18],[24]. The article deals with the problem of application of the traction inverter control strategy consisting in selective elimination of harmonics (Selective Harmonic Elimination -SHE) [11],[17],[22] for shaping the spectrum of traction current. The objective of this method is to reduce the conducted disturbances generated by a traction vehicle to the level below admissible values [3],[4]. SHE method implemented into a traction drive system allows for elimination of the selected harmonics from the spectrum of voltage supplying traction motors (V_\text{out}) [20]. Content of harmonics in traction current (I_d) consumed by a traction vehicle from a supply system depends directly on the voltage harmonics spectrum V_\text{out}. The selection of the order of harmonics being eliminated from a voltage spectrum V_\text{out} influences the values of the remaining voltage harmonics, hence the harmonics spectrum of current consumed from a DC network (I_d). In the articles [15],[16], the authors presented the concept of SHE method modification consisting in replacement of selected harmonics elimination with reduction of harmonics to the set level (Selective Harmonic Reduction - SHR). Based on the results of conducted simulation tests, it was shown that the SHR method offers broader possibilities for control of traction current I_d harmonics values. Previous experience of the authors has shown that the SHR method gives positive results that allow for such selection of inverter key switching strategy, so it does not generate disturbances in the frequency ranges used by SRK devices. In previous publication the authors presented an overview of possibilities related to the SHR method application for traction purposes on the basis of a selected operation point of a drive system model. This paper describes the study extended by the analysis of the SHR method effectiveness in a full range of traction inverter frequencies, as it is in the case of vehicle's start-up. Additionally, some limitations related to this method and resulting from the admissible frequency of inverter's keys connections were taken into account.

Conclusions
The paper discusses the problem of the SHE method application and the possibility of using reduction of the selected harmonics instead of their elimination for the purpose of traction drive control. The implemented method would aim at limiting traction current harmonics to the level defined in the relevant regulations while maintaining traction drive parameters, such as drive torque and rotation speed. The results of simulation tests showed that by expanding the SHE method to the SHR method, as proposed by the authors, it is possible to select for any operation point of inverter drive system such set of switching angles, which would allow for fulfilling both, the criteria of compatibility as well as drive related criteria. Furthermore, factors determining the realizability of the calculation results, such as a maximum frequency of inverter's power transistors switching were taken into consideration. Materials presented in this article also prove that applying only the SHE method is insufficient. The similar approach, taking into account definition of the optimization problem was presented in [1],[8]. However factors applied in these works were re-
lated with the AC side of the inverter, not to the DC side, what is the main goal of presented paper.

The aim of the conducted studies was to develop the SHE method to the extent enabling its implementation to a real drive system. It requires to continue the research towards including many factors occurring in real systems, such as: various levels of supply voltage, abrupt changes of load torque, changeability of fixed drive torque, etc. It also calls for development of various sets of inverter’s keys switching strategies using the method similar to the described one as well as establishment of an algorithm allowing for smooth change between the sets together with the change of drive operation point. Naturally, the proposed strategy should cooperate with the currently used strategies for vector control. This method might also be applicable as an intervention method implemented in drive operation ranges, in which it is known that the commonly used methods cause the generation of disturbances for track circuits. The article describes the results compared with limits existing in PKP (Polskie Koleje Państwowe – eng. Polish State Railways), however the presented methodology can be successfully employed for any applicable limits in DC electric traction. Moreover, it is essential, in further work, to take into consideration influence of the parameters of the traction substation to avoid the possibility of resonance conditions between the propulsion system and power supply [7].

References


Abstract
In paper introduced a review of modern traction vehicle drive system with induction motors drive system (PMSM with a single or dual rotor) or BLDC motor with different configuration of magnetic circuit. For particular part of drive system proposed a quasi intelligent control system version smart control, enables multicriterial, predictive control of vehicle work system. In the paper presented also a selected diagnostic procedures enables monitoring of exploitations parameters, and prediction of probable failure state. For different vehicle work state realized a simulation models and crash test a computer models of exploitations failure.

1. Introduction
The mass-development of internal-combustion transport creates real threats of natural environmental pollution, generates excessive noise, twitches and vibrations, and can be also a source of climatic changes. One of the variants to reduce this impact is the application of new type drive system: electric or hybrid (electric motor, electric motor and internal-combustion engine, drive composed with internal-combustion engine and mechanical energy container). Hybrid vehicles are an economically and technically most simple solution. Augmenting of classical internal-combustion drive system, electric motor diminishes fuel consumption, reduces issue of impurities, keeping at this dynamics and comfort of the vehicle drive. In paper introduced a review of modern wheel vehicle drive system with induction motors drive system (PMSM permanent magnet synchronous induction motor with single or dual rotor) or BLDC motor with different configuration of magnetic circuit. For hybrid drive system proposed a quasi intelligent control system version smart control, enables multicriterial, predictive control of vehicle work system. In paper presented also a selected diagnostic procedures enables monitoring of exploitations parameters, and prediction of probable failure state. For different vehicle work state realized a simulation models and crash test a computer models of exploitations failure.

6. Conclusion
The control system of hybrid drive wheel vehicle should take into account: kind of the drive (internal-combustion drive, electric drive), hybrid drive, kinematic system of vehicle (kind of the ignition, system of the drive carriage), and exploitive (the ground configuration, maximum speeds and accelerations) parameters. The use of deck-computers in hybrid vehicle will assure a realization of composite algorithms of the control, aside from of the driver interference, economic works of the vehicle and safe the vehicle exploitation. Quasi- dynamic control algorithms:, the peck of modern measuring-sensors and intelligent control systems helping the driver work assure safe and energy-saving during vehicle exploitation. Diagnostic system installed in the vehicle signal potential damage states and prevent vehicle damage.

References
[4]. Engineering smart control system. Brochures of Siemens and ABB
[5]. Szymański Z.: Optimum control system of wheel and rail vehicle with hybrid drive system. Proceeding of International Conference MET’05, październik, Warszawa, 2005r, printed in polish
[6]. Szymański Z.: Multilevel control system of traction vehicle drive system with electric and hybrid drive. Czasopismo Techniczne Politechniki Krakowskiej nr.5, Kraków 2007r, in polish
[7]. Szymański Z. *Quasi dynamic model of traction vehicle with electric and hybrid drive system*. Czasopismo Techniczne Politechniki Krakowskiej nr.5, Kraków 2013r, in polish

Abstract
The paper deals with the problems of selection, sizing and obtaining energy management strategy in a hybrid energy supply system. The system consists of a number of energy storages and generators. The two-level optimization using genetic algorithm is presented. The algorithm work was considered in two states: static – while optimizing a HESS configuration with energy management strategy and dynamic while optimizing the strategy in real time. The aim of these research is to develop a method for selecting the optimum configuration of devices in a HESS and to optimize energy management strategy in real time, allowing for interference in the system configuration.

Introduction
Energy storage systems (ESS) are becoming one of the most important components that change overall system performance in various applications, ranging from the power grid infrastructure, electric traction system [1], to electric vehicles [2] and portable electronics. Yet, a homogeneous ESS has limited characteristics in terms of cost, energy and power density, lifetime, etc., by the energy storage technology that comprises the ESS. That issue can be solved by creating hybrid energy supply system (HESS) that contains not only different kinds of energy storages but also generators. That creates problems of selecting and sizing the devices and obtaining the energy management strategy, with which the paper deals.

The optimization of the HESS, consisting of several energy storage and power generation devices which have different dynamic models, can be inefficient without simultaneous optimization of energy management strategy. HESS sizing optimization was carried out in [3-5]. The interdependence between sizing and power split optimization of hybrid energy storage systems was described in [5]. To solve that problem, the two-level optimization algorithm was developed. The scheme of the DC line system considered in the research is shown in Fig. 1. On the first level of algorithm the optimization of the system configuration is carried out. In this calculation the initial energy management strategy is used. The result of the first level of calculations is power vector in which every value represents the power of each device in the system. On the second level, the energy management strategy is optimized. After selecting the best strategy for particular setup, it is given back to first level and the process is repeated. Such an approach to the problem of selection and power control allows not only the selection of the optimal devices power and minimize system cost, but also optimal utilization of individual components even after making changes to the system configuration. This allows disconnecting and adding devices to the system without interference in energy management strategy. Different, fixed energy management strategies for HESS were described in [6-7]

Conclusions
The aim of the research is to develop a method for selecting the optimum configuration of devices in a HESS consisting of energy storages and generators. Another element of the is to optimize energy management strategy in real time, allowing for interference in the system configuration. This work is a theoretical description of the solution of these problems. The use of two-level genetic algorithm optimization and the distribution system operation on static and dynamic states was accepted. The next stages of work will be simulation and computational research for adopted algorithms. The laboratory stand implementation of the dynamic power control system is being carried out.

References
[1] Szelał A.; Wpływ napięcia w sieci trakcyjnej 3 kV DC na parametry energetyczno-trakcyjne zasilanych pojazdów. INW Spatium. 2013


Abstract
The paper presents two mathematical models of railway current collectors both with two degrees of freedom. The first one, hereinafter Pantograph Articulated Model (PAM), has one degree of freedom in rotational motion and the second degree of freedom in translational motion. The second model, called henceforth as Pantograph Reference Model (PRM), has both degrees of freedom in translational motion. Differential equations of the PAM contain very complex coefficients dependent on rotation angles of individual arms. These coefficients can be determined analytically, based on the dimensional and material data of the collector. The mathematical formulation of the PRM is relatively simple, but the coefficients in differential equations of this model are equivalent. Defining them by way of analysis makes it necessary to adopt numerous simplifying assumptions. Application of the PRM is justifiable in many cases, particularly while analysing the interaction between the collector and the contact line. In order to ensure that the results of the analysis are reliable, it is necessary to define, with appropriate accuracy, the equivalent values of the PRM coefficients. This is usually done through experiments. The paper shows the way in which the PRM coefficient values are defined based on the PAM simulation. The advantage of the presented method is that it does not require a complex experimental setup.

Introduction
System commonly used for supplying electric railway vehicles consists of the overhead catenary along the track and current collectors placed on the roof of vehicles [6]. With the ever increasing speeds and power of the vehicles, the problem of the quality of dynamic cooperation of these elements is gaining in importance [10]. It is necessary to maintain contact force within a specified range to ensure continuity of contact and eliminate the phenomenon of arc, and on the other hand to reduce the risk of mechanical damage and to minimize wear of the contact strips and wires. On an open market of railway transport in the European Union are introduced Technical Specifications for Interoperability (TSI) and the detailed technical standards [2-5], as a condition for approval vehicles as well as new or overhauled catenaries into operation. In terms of verification a correct dynamic cooperation between pantograph and catenary, among others, it is required to carry out simulations based on so-called reference models. In TSI for current collector of any type and of various design was adopted a unified traditional lumped mass model. It consists of two equivalent masses, connected by springs and damping elements, which remain only in a translational motion in one axis and are subjected to external forces - see Fig. 1 on the right. This model of current collector will be called hereafter as PRM – Pantograph Reference Model. Besides normative requirements, the simplicity of the PRM due to the absence of complex nonlinear relationships and of masses in rotational movement qualifies it for such applications where a short simulation time is important, e.g. for so-called active pantograph systems. Although the structure of this reference model is relatively simple, it does not precisely reflect the real construction solutions of the current collector. The use of PRM for a specific type of pantograph therefore requires a determination of the relevant parameter values – the equivalent masses, stiffness and damping coefficients.

Values of PRM parameters are usually defined by analysing of displacements of the current collector elements in static and dynamic conditions, caused by the applied force with a known function in time domain. The aim of this analysis is to define the parameters of the PRM so, that it will respond similarly to the real current collector. The idea of such measurement is presented schematically in Fig. 1.
The above-mentioned analysis can be conducted based on experiments but it requires a suitably equipped measurement stand and is rather expensive [11]. It is also possible to carry out such analysis based on simulations with the use of the current collector model which takes into account the actual articulated construction and real physical parameters of the pantograph [8]. Such model will be called hereafter as PAM – Pantograph Articulated Model. This paper shows the way of determining the parameters of the PRM based on the PAM simulations. On the other hand, the use of simulation method makes it necessary to elaborate with sufficient accuracy the PAM.

The joint construction of current collectors makes it possible to raise the contact strips by rotating its arms in relation to joint axes. As a result the mathematical formulation of the PAM takes into account degrees of freedom in rotational motion [1]. The coefficients in differential equations of PAM are relatively complicated functions of the rotation angle of pantograph arms [9]. The complexity of these functions is caused by the fact that the gravity centers of the collector arms are moving along the trajectory with varying radius. These functions can be defined by way of analysis, based on the Lagrange formalism and on the known construction details of the arms. These arms are subjected to dynamic forces in the direction which is tangential or perpendicular to the trajectory of movement. Both components of these forces significantly influence the movement dynamics of the entire collector.

The PAM and PRM models are formulated in this paper. Also the issues of analytical determining the parameters of the PAM are discussed. Afterwards, the method for defining the parameters of the PRM, based on the PAM simulation is presented. Selected experiment and simulation results are presented and compared.

Conclusions

The model of a current collector which includes degrees of freedom in rotational motion takes into account the length of arms, the moments of inertia, the mass of arms and coordinates of their centers of gravity. Therefore it is a relatively accurate model, although, unfortunately, it is also rather complex and non-linear. All the coefficients in the equation of the current collector rotation dynamics are very complex functions of the rotation angle, which include trigonometric functions. The parameters of such a model, except from the friction coefficients, are defined in an unambiguous and relatively accurate way.

The model of a current collector which includes degrees of freedom only in the translational motion contains a number of parameters which are equivalent in their character. The values of these parameters are calculated based on approximate rules and are accepted within quite a wide scope without appropriate explanations. Determination of parameter values by way of experiments makes it necessary to prepare a suitably equipped and expensive measurement stand. Every modification of the construction of a current collector means, in this case, that an expensive prototype has to be built in order to determine the parameters again.

Any changes in the construction or material of a current collector can be unambiguously and easily transferred onto the parameters of the PAM model, which constitutes its significant advantage. It is possible, based on the PAM model, to determine unambiguously the equivalent parameters of the PRM model. In this paper the authors applied the Levenberg-Marquardt optimization method to define the minimum residuum, formulated on the basis of the least squares method. The parameters of this residuum were the desired values of equivalent parameters of the PRM model. The optimization procedure allowed for obtaining the parameters which ensure a high level of compatibility between the simulation results of the PAM and PRM models.

References

[4] EN 50119:2009 Railway applications. Fixed installations electric traction overhead contact lines

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Abstract

At present, on the PKP estate, the surges protection of the catenary DC 3 kV is realized by means of horn gap arresters (type 7310). Horn gap arresters are installed on towers in the distance about every 1200 m (on estates with enlarged storm intensity every 600 m) and on entries to traction substations to protect the devices and apparatus in the substations.

Horn gap arresters, thanks to the simplicity of their realization determined in the fifties of the last century, when about their installation decided, the cheapest and simplest solution comparing to other accessible at that time surge protection resources. Their characteristic point is practically the unlimited size of the load-carrying current capacity. The proper shape and contour of the whole device assure the correct course of the sequent current arc extinction.

As a result of using modern railway traffic control devices and their damage as a result of atmospheric origin surges, in PKP, works that estimate the activity of horn gap arresters, are done. In order to perform a comparative analytic estimation of horn gap arresters activity, accessible investigational works were surveyed, on the base of which horn gap arresters became exploited.

1. Introduction

Problems of the catenaries surge protection are closely connected to the suchlike subject matter of the whole electric traction devices protection (Fig. 1). All these devices joined with each other are electrically subject to the influence of exceeding their own magnitude surges over the normal voltage working. The large differentiation of these devices isolation quality (considerably lower for the traction substation and the rolling stock than for the catenary) extorts, also for economic purposes, the use of different surge protection systems and lightning arresters of different characterizations. So their analysis and selection can be managed independently.

Conclusions

The efficient external lighting rod protection and internal lighting rod protection (surge protection), should assure an unfailing work of devices. The selection of parameters of surges limiters should be preceded a scrupulous analysis of their threat rank. One of the methods can be also the analytic estimation. In the report, data concerning the existing damaging problem of catenaries caused with statics, were represented. Chosen results of research from the performed works concerning the introduction of the horn gap arresters exploitation, were represented. These materials will be used to the comparative analytic estimation of the horn gap arresters activity with reference to performed measurements.

References

[1] Badania pełne odgromników rozkowych wg projektu normy branżowej BN-87/9317 Zakład Trakcji Temat 53020 -7-300 -wrzesień 1987r. (zleceniodawca - producent odgromników rozkowych Spółdzielnia Pracy Produkcyjno-Uslugowej "Bałyk" w Słupsku
Część IV A pt: Zabezpieczenia przeciw napięciowe sieci 3 kV


[12] INBK Zakład Trakcji Elektrycznej z 1957 r. pt Zabezpieczenia i automatyka urządzeń elektrotrakcyjnych na PKP - temat nr IE-304/57 Część IV B pt: Zabezpieczenia przeciwprzepięciowe sieci 3 kV - Gl. referent Z. Roman


[20] В.Д. Радченко, С.Д. Соколов, Н.Д. Сухопрудский Перенапряжения и токи короткого замыкания в устройствах электрифицированных железных дорог постоянного тока. Трансжелдориздат, Москва, 1959


[22] M. Zielenkiewicz i inni SPRAWOZDANIE z wykonania pracy rozwojowej pn. Zasady realizacji ochrony przed porażeniem prądem z sieci trakcyjnej, ochrony odgromowej i przed przepięciami kolejowych urządzeń technicznych oraz infrastruktury powiązanej z tymi urządzeniami, w aspekcie eliminowania zagrożenia życia i uszkodzeń obiektów ETAP I, 2015©

