Selection algorithm and prospects for the use of modern energy storage devices used in vehicles

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Abstract. The paper considers the problem of energy-saving technologies in urban electric transport. The possibility of upgrading the rolling stock by installing a storage device is considered. This article analyzes the common energy storage devices used in the electric transport system. It is shown that one of the main ways to increase the energy efficiency of a vehicle is the use of a storage device. It has been revealed that the most promising and satisfying basic requirements for the electric transport system are a supercapacitor-based storage device.

1. Introduction

Technical requirements for the energy storage devices used in city electric transport. The design should take into account that the storage device must have optimal properties with small weight and size that provide high specific power and high specific energy.

At present, the development of energy storage devices is increasingly being used in autonomous vehicles, power systems, and transportation systems as a whole. Equipment with associated storage devices requires a detailed analysis nowadays drives type definition, to the greatest extent meets the set requirements arising from the performance and parameters of the vehicle.

For comparison, modern energy storage from the perspective of their use in electric transport sets out the basic criteria that they must meet:

- is the specific energy consumption, which determines the weight and overall dimensions storage device;
- the unit cost of the storage device;
- life lesson – "charge-discharge";
- simplicity and accessibility of service;
- the value of the energy loss and the storage time;
- during storage charge;
- the speed and depth of discharge;
- time reverse power;
- job security.
Currently, there are different types of energy storage devices: electromechanical, mechanical, electrochemical, inertia, inductive, capacitive, and so on. For energy storage in vehicles are most widely used, are three main types of energy storage:

- electromechanical;
- electrochemical;
- capacitive;

Storage and storage in the storage device take place in different ways. Electrochemical render and store energy as a result of chemical reactions, capacitive energy accumulators store energy in the form of the electric field of the electric charge, mechanical store potential energy or kinetic energy. An electromechanical energy storage devices, store and store mechanical energy with its subsequent conversion efficiency and in the form of electric energy.

2. Electromechanical energy storage

Electromechanical drives are a device serving to store and storing mechanical energy with its subsequent conversion efficiency and in the form of electric energy.

The electromechanical energy store as inertial drive is used the electric machine rotor. Depending on the type and purpose of electromechanical drives, they contain different electrical machines. In place of the DC electrical machine may be used various machines AC - synchronous or asynchronous, but the output lines between the traction substations and said machine must be switched reversible converter of electric energy. Drive power intensity determined by the moment of inertia of the rotating part (rotor) and its frequent rotation.

Kinetic accumulators of electric energy, comprising flywheel energy storage during the charging cycle and give it in the discharge cycle, the control system of the generator, the motor and gearbox. However, these energy storage devices have several disadvantages:

- restriction of the maximum circumferential speed of the DC machine collector;
- electrical accumulators kinetic energy with asynchronous and synchronous designs are difficult to consume much energy during start-up, of which 55-65% is converted into heat;
- the main difficulty in developing kinetic battery with an asynchronous motor is the problem of the asynchronous generator voltage regulation over a wide range of variation of the rotational speed;
- on the basis of kinetic batteries require synchronous machines the rotor position sensor as a complex-frequency inverter for current regulation [1].

3. Electrochemical energy storage devices

Electrochemical energy storage device is called chemical sources. As with other types of energy storage batteries for basic operation, modes are the charging and discharging. In electric truck, batteries are widely used as auxiliary, and emergency backup power sources.

Modern trolleys are available in the batteries, which carry not only the power of the auxiliary circuits’ equipment, but also stand-alone course. Advantages of electrochemical storage devices:

- high efficiency;
- possibility of prolonged energy storage;
- quiet operation;
- absence of mechanical movements;

Rechargeable battery according to the materials, which enter into chemical reactions [2], are:

- nickel-cadmium (NiCd);
- acidity lead (Lead Acid);
- Lithium-ion (Li-ion);
- a nickel-metal hydride (NiMH);
- Lithium Polymer (Li-pol);

battery durability is estimated service life or the number of charge-discharge cycles. It depends on:

- a resource that is embedded in an electrochemical system;
- the battery design;
- operating conditions;
After analyzing the Table 1, information can be concluded from all existing batteries, the most suitable for the needs of electric vehicles, batteries are based on lithium.

### Table 1. Quantitative comparison of the accumulation type batteries.

| Battery            | LeadAcid | NiCd  | NiMH  | Li-ON   |
|--------------------|----------|-------|-------|---------|
| Specific energy, W h / kg | 25 ... 50 | 30 ... 80 | 40 ... 120 | 100 ... 180 |
| Rated voltage AB, V | 2        | 1.2   | 1.2   | 3.7     |
| The number of discharge / charge cycles | 500-800 | 2000 | 800   | 3000-5000 |
| Power density, W / kg | 180      | 150   | 250-1000 | 1800    |
| The average charge time, hour | more than 10 | 8 | 6 | 2 |
| The average self-discharge per month,% | 4 | 20 | thirty | 7 |
| Minimum operating temperature | - 20 | - 40 | - 20 | - 20 |
| the need to discharge | twice in half a year | once a month | once in three months | not necessary |
| The average cost per kWh | 150 | 400-800 | 250 | 450 |

4. **Electrochemical capacitors**

Supercapacitors belong to the same class of devices holding by function and its parameters, an intermediate position between the battery energy storage and conventional capacitors [3, 4]. They have a power consumption of about three orders of magnitude greater than conventional capacitors of the same size so are called super.

High capacity is achieved by reducing the spacing to a few nanometers, and the effective area of the plates. A decisive factor in achieving high specific energy consumption is the electrode surface area.

For charging, the supercapacitors can use a DC source, DC voltage, switching off in parallel with the capacitor battery, fuel cell, DC-DC converter.

Supercapacitors following advantages can be isolated [5]:
- the dependence of the cell voltage of the application, rather than on its chemical composition;
- high accumulated power;
- high power density;
- simple charging method which does not require the use of special circuits registration process and the charging voltage;
- rapid charge-discharge without risk of overcharging;
- low impedance;
- life of 10-12 years;

Disadvantages supercapacitors:
- high speed of discharge;
- the inability to use the full power of the linearity of the discharge voltage;
- an inverse dependence of the capacitance-voltage, whereby to produce a high voltage at a given value of capacitance necessary to sequentially include a plurality of capacitors;

Designing schemes based supercapacitor usually begins with the definition of energy consumed for each discharge cycle, and the voltage level required for the proper functioning of the scheme Modern
designer can solve this problem in two ways: using the battery (or energy source) capable of providing a large current pulse, or in parallel to attach a less powerful battery supercapacitor (hybrid solution) [7, 8].

The leaders in the production of electrical double layer capacitors are companies «Maxwell», «Epcos», «Nesscap», «Evans Capacitor», «Elton» [9]. The characteristics of some samples are shown in Table 2.

Table 2. Characteristics supercapacitors.

| Manufacturer | Maxwell       | Eaton         | Nesscap       | Panasonic   |
|--------------|---------------|---------------|---------------|-------------|
| Item Type    | VSAR 0650 P270 | HV3550-2R5307-R | ESHSR200 0C0002R7 | HL-50       |
| Capacity     | 650           | 300           | 2000          | 50          |
| Rated voltage| 2.7           | 2.5           | 2.7           | 2.7         |
| Stored energy, Wh | 0.66       | 0.26          | 2.03          | 0.05        |
| Internal resistance mOhm | 0.8       | 7             | 0.33          | 15          |
| Specific energy, Wh / kg | 4.1       | 3.8           | 5.2           | 2.7         |
| The specific power, kW / kg | 6.8       | 3.2           | 6.7           | 1.4         |
| Mass, kg     | 0.16          | 0.069         | 0.39          | 0.019       |
| The number of cycles | 106       |               |               |             |

Use of an electrochemical capacitor as a buffer energy source can give a significant gain in terms of certain important characteristics [10].

Stored specific energy is calculated according to the formula applied to all types of capacitors:

$$E = \frac{C \cdot U^2}{2m},$$

where

- $E$ - specific energy per unit mass, J / kg;
- $C$ - capacitance capacitor;
- $U$ - operating voltage, V;
- $m$ - mass kg;

5. Conclusion

This article analyzes the common energy storage used in electric transport system. It was shown that one of the main ways of increasing the energy efficiency of the vehicle is the use of the storage device. It found that the most promising and satisfying the basic requirements for electric transport system is a drive-based supercapacitor. Compared with lithium-ion batteries, capacitors of the double electric layer have a significantly higher specific power and allow a large number of charge-discharge cycles. The main disadvantage of supercapacitors is the relatively low specific energy consumption.

References

[1] I Yu Loshkarev, and A S Chernyshov 2013 Unbrakable control. Features of methods of nondestructive testing. In the collection: Actual problems of power engineering of agrarian and industrial complex Materials of IV International scientific and practical conference. Edited by A.V. Pavlova. 184-186

[2] Vorfolomeev G N, Evdokimov S A, Malozyomov B V, Schurov N I, and Shalnev V O 2004 Reliable sources of a feed of the direct current. In the collection: 8th Korea-Russia International Symposium on Science and Technology Proceedings: KORUS 2004. sponsors: Tomsk Polytechnic University, University of Ulsan, Novosibirsk State Technical University 316-320

[3] Malozyomov B V, Babaeva O V, and Andreev A I 2014 Posteriori analysis of the reliability of transport systems. Scientific problems of transport in Siberia and the Far East. 1-2 93-95
[4] Malozyomov B V, Wilberger M E, and Kulekina A V 2015 The most typical damage and methods of diagnosing the traction motor. *Transport: science, technology, management*. 10 60-65

[5] Daimer J 2005 Graphite electrode for electrothermal reduction furnaces, electrode column and method for making graphite electrodes. *Patent for invention RUS 2374342 12.05*

[6] Shabalina A V, Lapin I N, and Belova K A 2015 Graphite electrodes for electric arc furnaces. *Black metals*. 12 (1008) 20-21

[7] Nikolaev A A, Nikolaev A V, Kirpichev D E, and Tsvetkov Yu V 2008 Formation of a diffuse cathode spot on a graphite electrode with an arc discharge. *Physics and chemistry of material processing* 43-48

[8] Grosse K U 2012 Non-destructive testing and technology for monitoring the technical condition of structures for quality control and supervision of construction sites. *ALITinform: Cement. Concrete. Dry mixes*. 6 62-77

[9] Shchurov N I, Porsev E G, and Vil'berger M E 2009 Asymmetrical and nonsinusoidal operation modes of multipulse rectifiers. *Russian Electrical Engineering*. 80(12) 680-684

[10] Borisenkov S, Votintsev A, and Roth H 2003 Quality control: non-destructive testing of brazed joints using X-ray radiation. *Components and technologies*. 28 168-170