

Method of electric vehicle braking energy recovery

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Abstract. Currently, the issue of the use of network power storage devices is increasingly being discussed. A promising technical solution is to combine a flywheel and a motor-generator motor on one shaft. Such an association can be called electromachine energy accumulators. Its main disadvantage should be considered the management difficulties. In this regard, it is possible to use an energy recovery system to reduce energy consumption and increase stability in the power grid. Such devices can reduce energy costs and increase the efficiency of vehicles. Such a solution can be useful and effective for the development of electric transport and reducing energy costs.

1 Introduction

As a rule, high-voltage direct current is used for the operation of urban electric transport. An important task for electric transport is in the organization of the braking energy recovery system [1,2]. Electrochemical batteries have many disadvantages that prevent them from being used effectively for their tasks:

- 1) A large weight per unit of stored energy
- 2) Low reliability and a limited quantity of charge-discharge cycles before failure, while the requirements of necessary brakes for stops are huge
- 3) High cost and weight, reducing the payload
- 4) Environmental hazard, complexity of maintenance and disposal
- 5) Low speed of charging and discharging processes, not commensurate with the required braking speed of cars.

In this regard, searches are being conducted for another type of batteries to be introduced into vehicles. For example, mechanical batteries have high reliability and resource, as well as low cost in manufacturing. They are also eco-friendly, and their disposal does not pollute the environment [3,4].

Professor N.V. Gulia, Director of R&D at Kombarko CJSC, who can deservedly be considered the founder of this direction, has achieved significant success in improving the efficiency of transport vehicles by recovering braking energy into flywheel drives. Professor N.V. Gulia have developed the super-flywheel device and is working on the creation of a supervariator mechanism - a wide-range flywheel drive. An important factor is the ability to save and reuse braking energy [5,6]. Engineers have long tried to preserve the kinetic energy

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storage devices) and mechanical (based on pneumatic accumulators, hydraulic accumulators) storage devices.

The idea of joint use of internal combustion engines and electric motors was embodied in railway transport and heavy-duty dump trucks [9]. A battery has been added to the new schemes of hybrid power plants of lifting and transport vehicles. Thus, the hybrid works with both liquid fuel and energy from an electric battery. The main advantage of the hybrid drive of lifting and transport vehicles is the reduction of fuel consumption due to the recovery of braking energy. The reduction is achieved by automatic control of both engines using an on-board computer, starting from the start of the internal combustion engine and its timely shutdown when stopped, with the possibility of movement without starting the internal combustion engine from the electric motor on the energy of the battery, and the recovery of braking energy by using a reversible electric motor as a generator to recharge the battery.

The use of hybrid lifting and transport machines has a positive effect on improving the environment. A big role is played by the complete stop of the internal combustion engine during idle time indoors [10]. And the use of batteries of significantly lower capacity than in electric vehicles simplifies the problem of recycling used batteries.

Another significant advantage of the hybrid lifting and transport machine is its good dynamic characteristics. In the case when a sharp increase in the traction load is necessary, both an electric motor and a conventional internal combustion engine (and in some models an additional accelerating electric motor) are switched on simultaneously. This makes it possible to save on installing a less powerful internal combustion engine, which works most of the time in the most favorable mode for itself. Such uniform redistribution and accumulation of power, followed by rapid use, allows the use of hybrid power devices in vehicles. Despite the fact that electric motors have sufficient torque, in terms of weight and dimensions, their performance is worse than the internal combustion engine. Therefore, developers still install not too powerful electric motors in a number of models, reducing their dimensions. At the same time, in order to sum up the capacities of different engines, combined torque transmission schemes are used, with direct transmission of mechanical torque, directly from the internal combustion engine to the wheels.

An interesting method and scheme of the braking energy recovery device, shown in Figure 2, was developed by BMW. This method, called "stop-start", differs in that when braking, part of the kinetic energy is stored in an intermediate flywheel installed between two clutches in series with the gearbox.

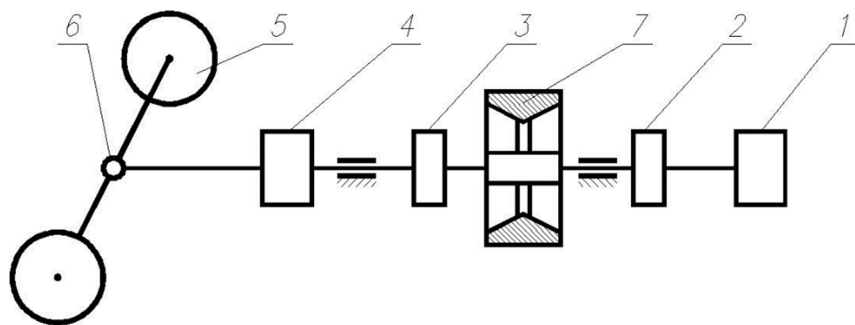


Fig. 2. Block diagram of the BMW stop-start recovery device: 1 – internal combustion engine; 2,3 – clutches; 4 – gearbox; 5 – driving wheels; 6 – main gear; 7 – flywheel.

A stop-start braking energy recovery device is interesting to discuss. When using this technique, kinetic energy accumulates in the flywheel, which is located in the middle between the gearbox and the car engine. This allows you to turn off the engine at the moment when it is necessary to stop the car. Then the speed of the flywheel can be equated to the speed of the motor shaft before the braking process begins. When accelerating the vehicle, the kinetic energy accumulated in the flywheel can be used. Also, part of the energy can be spent on starting the internal combustion engine.

This well-known "stop-start" method has the following disadvantages:

- 1) Only part of the kinetic energy that is in the flywheel before braking is recovered and a significant part of the energy stored in the transmission is lost;
- 2) Energy recovery is performed when the internal combustion engine is completely stopped, which is not always necessary when stopping;
- 3) Additional energy is spent on starting the stopped internal combustion engine. The dynamic performance of the machine does not improve, since the energy of the flywheel is spent on starting the internal combustion engine, and not on acceleration.

A similar scheme was developed by Mercedes-Benz, in which the drive wheels are driven using reversible hydraulic machines.

A special feature of this system is the hydraulic volume continuously variable transmission built into the differential, which controls the differential. Tests have shown that the dynamic qualities of the system with a flywheel battery do not decrease.

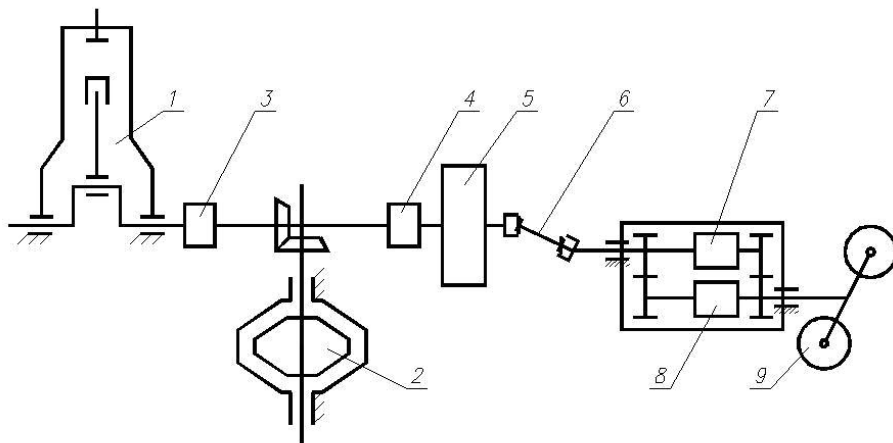


Fig. 3. Hybrid drive scheme with flywheel battery and hydraulic transmission: 1 – internal combustion engine; 2 – flywheel; 3-4 – clutches; 5 – gearbox; 6 – driveshaft; 7 – differential; 8 – hydraulic transmission; 9 – driving wheels.

A similar scheme for the recovery of braking energy was later developed by Bosch. Its difference is the connection of the internal combustion engine and the flywheel with a planetary differential and a two-speed gearbox. The recovery of braking energy is provided by two reversible hydraulic machines controlled by a mechanical stepless drive from the internal combustion engine.

3 Results and discussion

In order to effectively apply the principles of energy recovery for electric transport, it is necessary to transfer the recovery mechanism to an external circuit. This solution will allow

you to place the battery outside the transport vehicle. The schematic diagram of the device is shown in the Figure 4.

It is necessary to create an opportunity to use the braking energy recovery technique in electric vehicles, and at the same time avoid various problems associated with a large mass of electric batteries or a complex control and maintenance system required for hydraulic and pneumatic batteries. The proposed solution should have a low cost, and not increase the weight of the vehicle.

The essence of solving the problem of using braking energy recovery in electric transport can be expressed by a simple idea.

The scheme of the proposed device is shown in Figure 4, in which the designations of Figure 2 are preserved: 1 - shaft; 2 – mechanical accumulator; 3 – reversible electric machine; 4 - vehicle device of control; 5 – main engine; 6 – current collector; 7 – external electric power; 9 – electric circuit; 10 - computer microcontroller device.

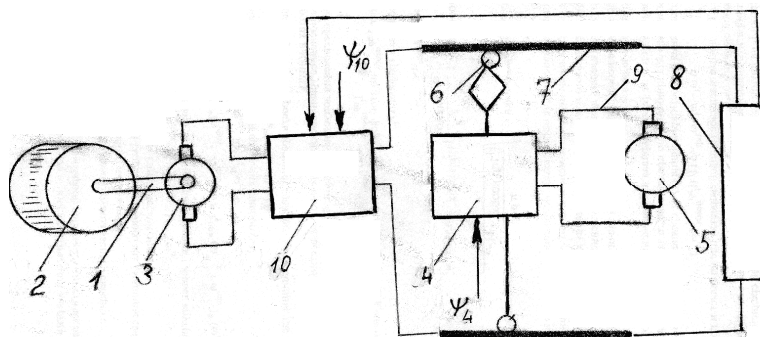


Fig. 4. Scheme of the proposed device.

The basic principle of operation of the developed braking energy recovery system for electric vehicles is as follows. During vehicle braking, the control system switches device 3 to engine mode. In this case, the kinetic energy reserve of the flywheel accumulator increases. During braking of the vehicle, the voltage of the external power supply decreases, and the control system turns off the device 3. If it is necessary to increase the speed or accelerate the vehicle after it stops, the power consumed from the external network increases. Then the control system switches device 3 to the accumulation mode, reduces the number of revolutions of the flywheel and returns the energy back to the power grid.

4 Conclusions

The use of energy recovery for electric vehicles provides the following advantages:

1. Electricity costs are reduced as part of the energy is returned back to the grid
2. It can recover braking energy in the DC network when working on the line of one machine.
3. The weight of the machine becomes smaller, so we can improve the load capacity or reduce the overall dimensions.

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