Energy recovery device for mining and lifting machines

Nikolay Barbashov*, *Anastasia* Polyantseva, and *Vladislav* Smirnov

Moscow Bauman State Technical University (BMSTU), Moscow, Russia

Abstract. The article discusses methods of increasing the efficiency of lifting and mining machines. The methods of implementing the principles of braking energy recovery are considered. The advantages and features of the operation of flywheel batteries are substantiated. Examples of devices and well-known patents in this field are given. The application of the author's patent is proposed, which allows to increase the efficiency of lifting machines and reduce their energy consumption. The description of the patent and the justification of its effectiveness are given. Conclusions about the possibility of introducing a patented device into the equipment of lifting and mining machines are drawn.

1 Introduction

The main reasons for different problems with wide energy consumption for mining and lifting machines is their operation mode, which consist of acceleration and braking. For example, in hybrid transport vehicles, the energy recovery devices allow to reduce energy losses by up to 50%, depending on the frequency of braking processes [1-4]. Various types of pneumatic, electric and flywheel energy accumulators have been used in practice in the mining, lifting and transport industry [5-7]. In such machines as conveyors, conveyors, escalators, lifts, energy recovery is used less often [8-9]. Nevertheless, significant and difficult to predict load changes lead to the fact that the drive motors run almost idle for long periods of time. The use of frequency converters allows you to adjust the operating mode of the engine depending on the load of the conveyor. At the same time, energy consumption is reduced by several tens of percent, and sometimes at times [10]. In those systems where frequent stops of the conveyor belt are provided, it is even possible to achieve the return of braking energy to the supply network.

2 Materials and methods

Various frequency converters are effectively used, for example, of the "ERATON-FR" type.

* Corresponding author: barbashov@bmstu.ru

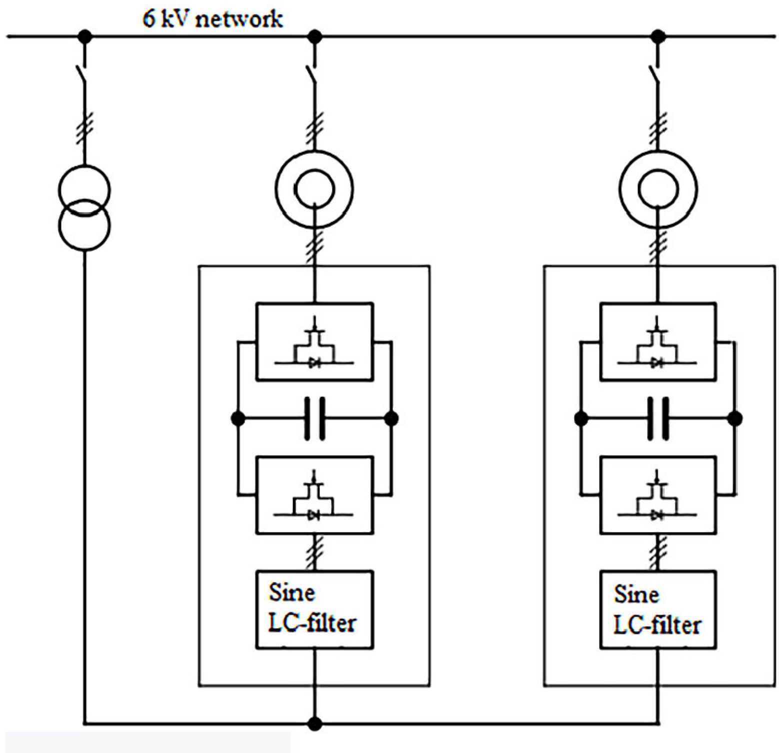

Fig. 1. Block diagram of the start-up device of the twin-motor conveyor based on "ERATON-FR".

These devices allow for a smooth increase in the torque of the electric motor before starting and a smooth stepless increase in the speed of the electric motor during acceleration [11-12]. The acceleration rate is programmed. During the acceleration of the conveyor, rotary inverters of a multi-motor electric drive ensure the alignment of the moments (currents of the rotors) of electric motors. After the end of the conveyor acceleration, rotary inverters ensure the stabilization of the conveyor speed and equalization of the load of electric motors [13-14].

Frequency converters also provide a braking mode with energy recovery, which allows you to return energy to the network and thereby increase the energy efficiency of the conveyor [15-16].

Adjusting the speed of the conveyor belt depending on the weight on it allows you to:

significantly save energy;

reduce the wear of the mechanical part of the conveyor;

increase the working life of mechanical equipment;

Due to the use of speed control of the conveyor belt using a frequency-controlled electric drive, the following effect was achieved:

- High efficiency of the conveyor with a frequency converter (97.5%).
- Alignment of the moments of the drive motors of the conveyor powered by frequency converters
- Less fragmentation of the rock at the sites of pouring.
- Ease of automation and operation without involving personnel.
- Elimination of excess moments and current disturbances in the motor.
- Minimization of dynamic loads in the entire drive unit of the machine, as well as during the start of movement and the movement itself.

- Reduction of the amount of heat generated by the drive.
- Simplification of control systems.
- Greater flexibility in movement, the possibility of rapid changes in the control algorithms of machines and technological processes.
- Complete information about the passage of the technological process and the operation of all machines separately when using the data transmission mode.
- Ease of localization of the location and causes of the drive accident.
- Good protection of electric motors of drives from possible overloads and damage.
- Optimal use of machines and their drives.
- The return of braking energy to the network during a conveyor stop or in the case of a conveyor transporting rock after a stop, while maintaining a high power and action index.
- Reducing the wear of conveyor brake covers, especially when transporting rock after a stop.
- An increase in conveyor productivity by 20% due to the possibility of supplying conveyor motors with voltage with a frequency of up to 60Hz using a frequency converter.

According to the Russian scientist, Professor N.V. Gulia, a flywheel drive with mechanical power extraction is superior to all other types of drives in terms of specific energy intensity and efficiency, and in terms of specific power this superiority is more than an order of magnitude. His research shows that the use of a flywheel drive with mechanical power take-off instead of any other types of drives in a hybrid powertrain will significantly reduce energy losses during machine operation.

According to the largest European organization EERA (European Energy Research Alliance), which unites more than 250 organizations, research centers and universities, it was found that the flywheel energy accumulator is the most effective for use in various fields, including the transport and lifting industry. The main advantages of using a flywheel battery are high reliability, low wear and a significant reduction in harmful emissions into the atmosphere. Other advantages were also mentioned:

- Reduces the load on traction power equipment and braking systems.
- Provides efficient, safe and reliable energy storage and transmission.
- High charging speed.
- Large operating temperature range.
- Increase in peak power.
- Allows you to reduce the power of substations and their number.
- Can provide backup power in case of disconnection.
- Does not use environmentally harmful materials and does not produce radiation.
- When used as a hybrid engine together with diesel, it can significantly increase efficiency and reliability.

When lowering loads, for example, if it is necessary to evacuate people from high-rise buildings, it is possible to use a flywheel device (Figure 2). The load 3 is connected to the belt 2. The transfer mechanism to the flywheel 1 is a belt, which together with two pulleys is a variator and serves as a load-bearing element. During the winding process, the gear ratio of the variator changes and the kinematic braking of the load occurs, since its potential energy is converted into the kinetic energy of the flywheel. The landing speed is determined by the kinetic energy reserve of the flywheel, which is related to the law of change in the gear ratio and the radius of the belt. After disconnecting the load, the tape is automatically wound into a roll to ensure subsequent descent. A cable can be used as a tape for energy recovery of the descending load in the elevator mono (Figure 2).

 https://doi.org/10.1051/e3sconf/202341701002

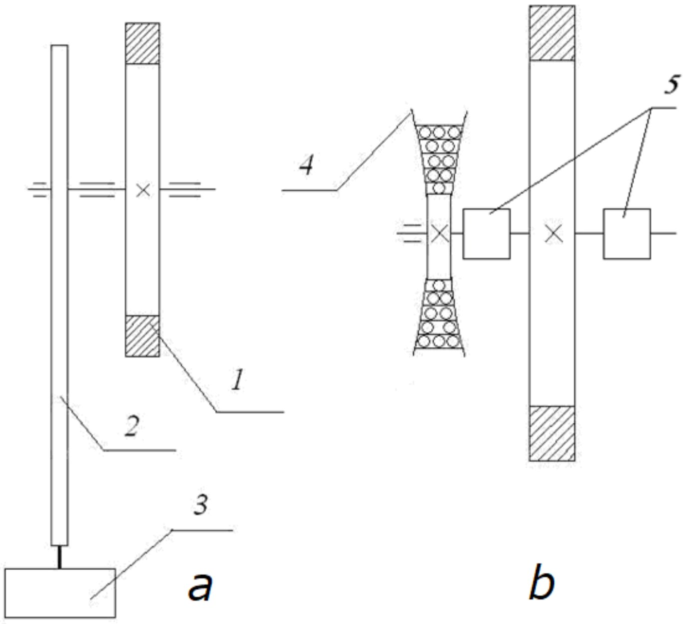

Fig. 2. A device for emergency descent of people from the building (a) and a flywheel recuperator of the elevator (b). 1 – flywheel; 2 – tape; 3 – cargo; 4 – drum; 5 – switching device 1.

Powerthru has created and implemented a flywheel energy accumulator in various types of industrial equipment. The developer suggests using a flywheel to regulate the voltage in the electrical network, as well as to ensure uninterrupted power supply in various institutions. It is also possible to use it for hybrid cars.

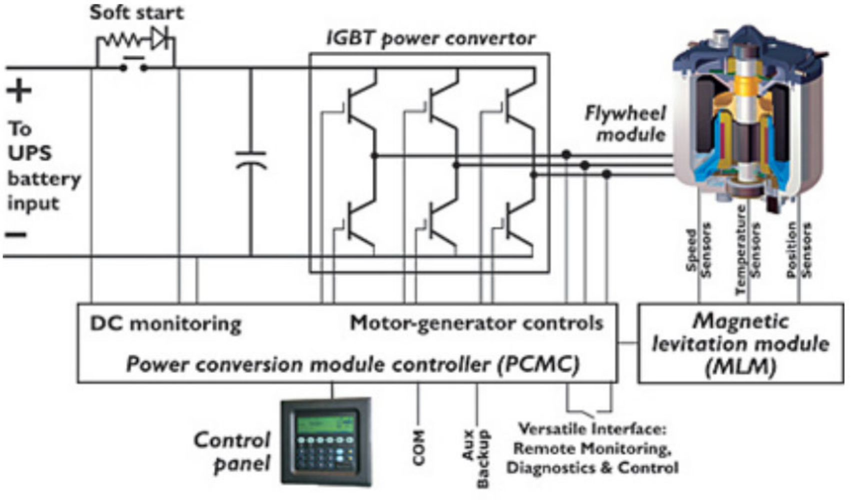

Fig. 3. Operation diagram of the Powerthru flywheel energy accumulator.

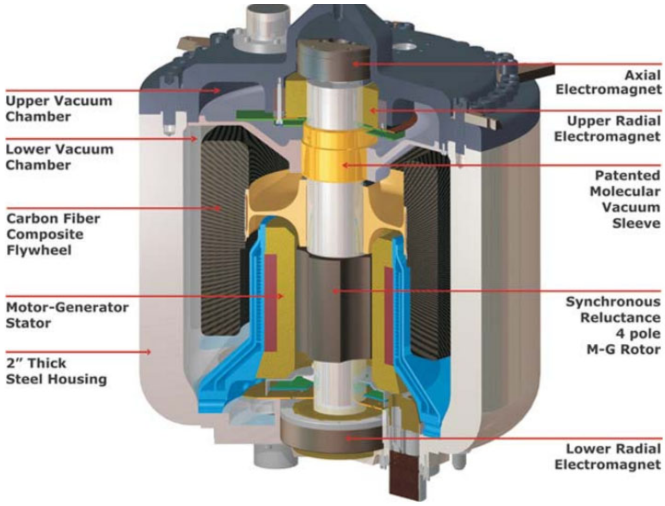

Fig. 4. The device of the Powerthru flywheel energy accumulator.

3 Results and discussion

The analysis of the possibility of ensuring the recovery of braking energy of mining machines shows that the potential energy available during the descent of the load can be used to increase the kinetic energy of the flywheel, which has a significant energy storage capacity. The energy stored by the flywheel reduces the kinetic energy reserve of the load and thereby reduces the speed of its descent. It is proposed to control the flywheel with the help of an additional reversible DC electric machine operating in engine mode and mechanically connected to the flywheel, and powered by a traction motor switched to generator mode when the load is lowered. When lifting the load, the energy flow goes in the opposite direction and the mechanical energy of the flywheel is converted by an additional reversible machine into electrical energy to power the traction motor. Energy losses can be compensated by the control device from the DC network.

Thus, to control energy recovery, it is necessary to use an additional reversible machine and an electrical control system.

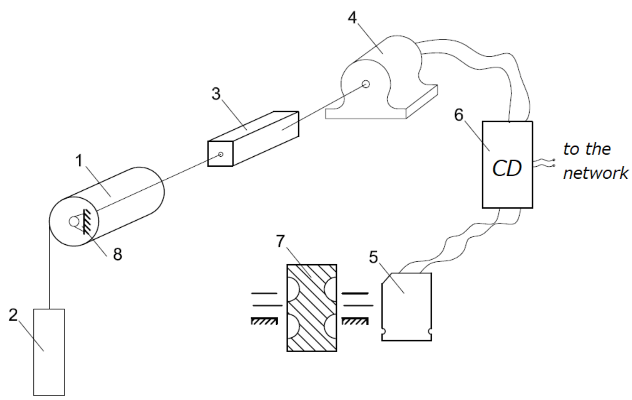

Fig. 5. Diagram of a device for implementing drawing.

Figure 5 shows a diagram of a device for implementing a method for recovering braking energy of a lifting machine, where: 1 - a cable pulley; 2 - an elevator; 3 - a gearbox; 4 - a reversible DC electric machine; 5 - a reversible DC electric machine; 6 - a control device; 7 - a flywheel; 8 - a housing.

The cable pulley 1 is mechanically connected to the load 2 and the gearbox 3, which is also mechanically connected to a reversible DC electric machine 4 operating when lifting the elevator in traction motor mode. The reversible DC electric machine is mechanically connected to the flywheel 7.

The control device 6 is connected to reversible electric machines 4 and 5 by electric circuits and a DC network. The cable pulley 1, gearbox 3 and reversible DC electric machines 4 and 5 are enclosed in the housing 8.

The proposed method of recovery of braking energy of a lifting machine consists in the fact that the mechanical connection between the cable pulley, the generator and the engine is carried out by means of an open gear transmission between the gear ring mounted on the end of the cable pulley and the gears mounted on the shafts of the generator and the engine. These gears are engaged alternately when lifting the load and lowering it to control the recovery of braking energy. Also, to implement more efficient control of braking energy recovery, additional reversible DC electric machines are used, one of which operates in engine mode, and the other in generator mode, depending on the descent or lifting of the load, and the connection between them is carried out by an electric control device connected to the power supply.

The use of this device makes it possible to increase the efficiency of braking energy recovery of the lifting machine and the reliability of its operation.

4 Conclusion

An analysis of the characteristics of foreign lifting and transport machines shows that their specific energy consumption is 30% lower than domestic ones, which is achieved by the recovery of braking energy, the use of acceleration engines and the choice of the optimal ratio of the main engine and the recovery body. The Bauman Moscow State Technical University has proposed and patented new ways to improve the economic and dynamic performance of machines in operation by controlling the moment of switching from acceleration to braking and their automatic balancing.

References

1. A. Kartashov, B. Kositsyn, G. Kotiev, S. Nazarenko, D. Dubinkin, E3S Web of Conferences (2020)
2. A.S. Ivanov, M.M. Ermolaev, A.V. Chirkin, Russian Engineering Research **4**, 275-282 (2020)
3. Z.M. Boriskina, O.O. Baryshnikova, International Journal of Mechanical Engineering and Robotics Research **9** 76-79 (2020)
4. M.M. Ermolaev, M.N. Zakharov, Y.V. Sinitsyna, Russian Engineering Research **41**, 189-193 (2021)
5. A. Osipkov, R. Poshekhonov, G. Arutyunyan, A. Basov, R. Safonov, Journal of electronic materials **10**, 195-203 (2017)
6. A.L. Nosko, W. Tarasiuk, I.A. Sharifullin, E.V. Safronov, Journal of Friction and Wear **41** 347-353 (2020)
7. P. Shiriaev, K. Shishov, A. Osipkov, L. Tishchenko, Journal of electronic materials **4** 1998-2009 (2019)

8. S.E. Lyuminarsky, I.E. Lyuminarsky, E.S. Lyuminarskaya, Journal of Physics: Conference Series **1301** (2019)
9. S.E. Lyuminarsky, I.E. Lyuminarsky, E.S. Lyuminarskaya, *Features of Determining the Efficiency of the Cam Wave Generator of the Wave Gear*, IOP Conference Series: Materials Science and Engineering, **971(4)** (2020)
10. A.S. Muravyev, V.A. Shishkina, N.V. Buzunov, A.B. Kartashov, D.M. Dubinkin, Sh. Nozirzoda, *Research of control algorithm of traction drive of a mining dump truck using simulation models of motion*, in Journal of Physics: Conference Series (2021)
11. E.N. Khobotov, M.A. Ermolova, *Formation of Work Plans and Schedules at Enterprises with Conveyor Assembly* IFIP Advances in Information and Communication Technology (2021)
12. K. Evseev, B. Kositsyn, G. Kotiev, A. Stadukhin, I. Smirnov*, Development of the conceptual design of vehicles for off-road container transportation for mining applications* Web of Conferences (2021)
13. A.S. Ivanov, S.Y. Goncharov, Russian Engineering Research **41**, 697-700 (2021)
14. S.A. Polyakov, E.M. Kuleshova, L.I. Kuksenova, A.V. Medovshchikov, IOP Conference Series: Materials Science and Engineering **996(1)** (2020)
15. M.N. Zakharov, M.M. Ermolaev, A.V. Zaitseva, Russian Engineering Research **40**, 720-125 (2020)
16. A.S. Ivanov, S.V. Murkin, Russian Engineering Research **41**, 994-998 (2021)