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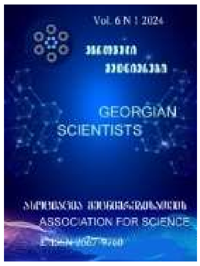

MODERNIZATION OF FUNCTIONAL CONVERTERS USED TO CONTROL ELECTRIC DRIVES

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Abstract:

In this article, features of using bridge converter circuits to control AC motors in railway automation computer systems are discussed. Special attention is paid to evaluating the efficiency of converter circuits. It is shown that utilizing low-frequency operation modes of power switches can significantly increase converter efficiency as part of the coupling devices. A technical solution is proposed for implementing five-wire AC motor control circuits consisting of a five-phase bridge conversion circuit. A brief overview of the modern element base used to construct inverters is provided, along with an assessment of electronic components from the perspective of analogous device selection potential. Additionally, the use of electromagnetic relays as functional converters is considered, providing increased reliability and electrical safety.

Keywords: functional converter; electric drive; three-phase asynchronous motor; safe control; inverter; bridge circuit; efficiency; pulse width modulation; transistors with isolated gate; small-sized relays; mechanical circuit opening.

1. INTRODUCTION

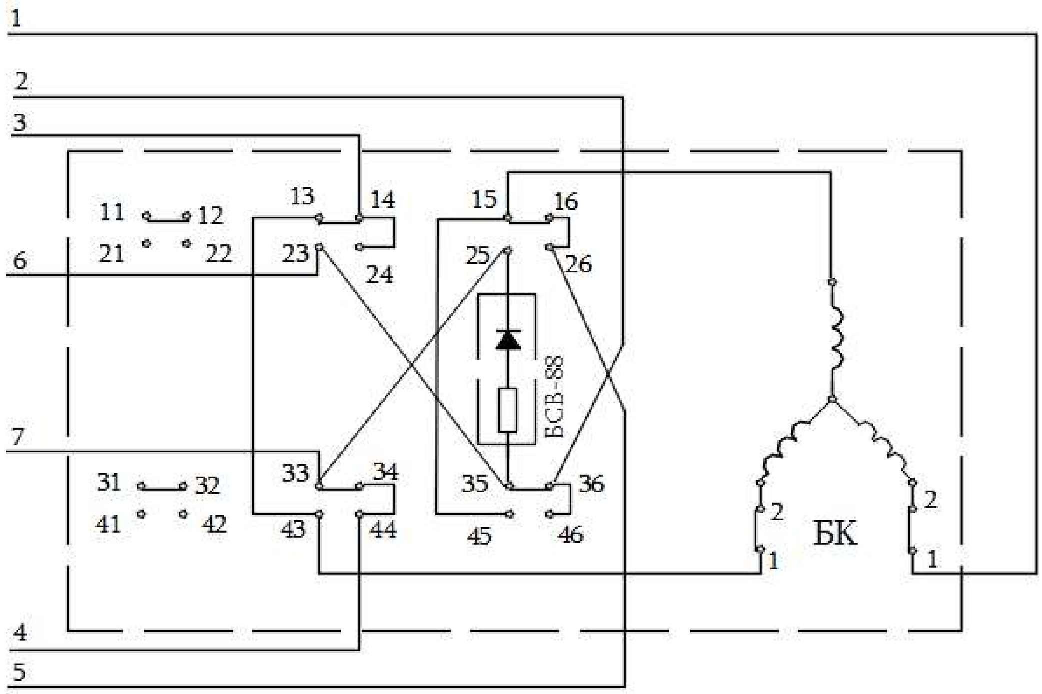
The management of floor objects in computer systems for railway automation requires the use of special interface devices which have an asymmetric failure characteristic. Such devices can be created based on elements with an asymmetric failure, with electromagnetic relays of the first reliability class most often considered as candidates. However, a more technologically advanced solution is the use of contactless circuits utilizing a semiconductor element base. Safety in this case is ensured through one of two methods:

1) The use of functional converters with an asymmetric failure, allowing activation of the executive object only when the semiconductor elements are confirmed to be in dynamic operation;

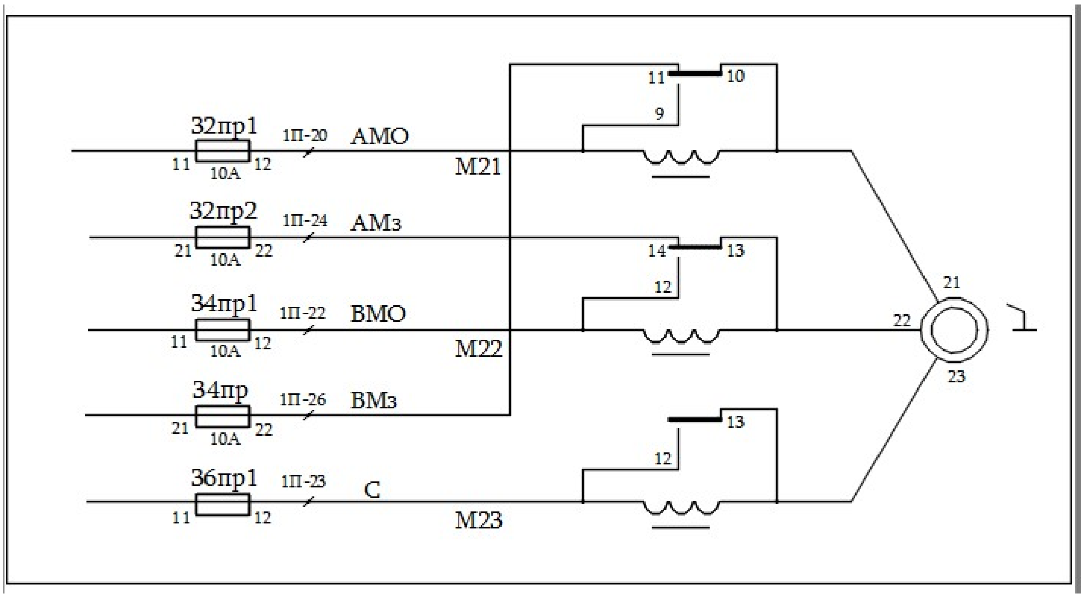
2) Periodic checks on the functionality of the semiconductor switches, with disconnection of power from the executive objects in case failure is detected.

2. BASIC PART

In modern converter circuits for capacities up to several tens of kilowatts, field-effect transistors with an Isolated Gate or Isolated Gate Bipolar Transistors (IGBTs) are used as switching devices. The main advantage of transistors with an isolated gate is their insignificant power consumption from the source of control signals. This makes it possible to use relatively simple circuit solutions for the formation of control signals which are implemented, as a rule, in microelectronic design. When developing converters for electric drives, it is preferable to use IGBT transistors. These transistors combine the positive qualities of field and bipolar devices and, at operating voltage values of the order of several hundred volts, have a smaller static loss than that of MOSFETs. The diodes connected in parallel to the transistors are designed to recover the energy stored in the inductive component of the converter load. These diodes, as a rule, are part of modern power transistors designed for use in converter circuits.



It should be noted that converters are often performed in the form of micro assemblies that include the necessary set of power components [6] and not on individual transistors. In some cases, such micro assemblies include control signal generation circuits and converter protection circuits for use during emergency operation. Such micro assemblies are commonly referred to as Intellectual Power Modules (IPM). The use of IPMs instead of individual transistors and microcircuits is a progressive option, since it simplifies product circuitry and reduces dimensions. However, it is necessary to consider that presently the design and circuit layouts within these micro assemblies are not standardized. This factor significantly complicates the process of selecting analogous power elements for the converters. Therefore, according to the authors, the use of separate power switches remains relevant as it reduces developer dependence on specific electronic component manufacturers' products. Theoretically, the control signals for the power switches of a three-phase bridge converter can be generated by the computing means of the automation system. However, in practice it is preferable to utilize a separate control signal generator. This can be explained in terms of improving computing efficiency within the system, as well as mitigating damage to power components in case of malfunctions in the control computing complex operations. Previously, transistor and microelectronic circuits with "rigid logic" were utilized to construct such generators. Nowadays, microcontrollers are leveraged for this same purpose significantly simplifying circuit solutions, enabling advanced operating algorithms and facilitating easy reconfiguration of control signal timing parameters without hardware changes. Safe control of the generator can be provided through various methods—for example, by supplying power to the generator from a low-power functional converter with an asymmetric failure operating under the influence of dynamic signals from the control computing complex.



Developing railway automation systems necessitates highly reliable equipment, with hardware redundancy being one of the ways to improve reliability. When reserving interface devices, it is necessary to consider that the outputs of the main and backup sets of equipment are essentially combined with each other since they work on the same outdoor objects. This negatively impacts the efficiency of redundancy, since failure of one equipment set can affect the performance of another set. To alleviate this influence, a preferred approach involves the mechanical opening of the output circuit in presently unused hardware. Furthermore, mechanically opening the circuit can serve as an independent method of enhancing the reliability of equipment subjected to overvoltage from cable lines connecting interface devices and executive objects. Finally, the use of mechanical opening is an effective method of ensuring electrical safety for service personnel. This holds particularly true when transformers are absent at the output of power circuits. In the event of power switch failures, the appearance of a constant voltage hazardous to humans on cable network elements and floor objects becomes a potential concern.

The only method of implementing mechanical circuit breaking is the use of electromagnetic relays or similar devices (for example, contactors). In the presence of a functional converter with an asymmetric failure, there is no need to use relays that meet the requirements of the first class of reliability. Widely distributed and inexpensive small-sized relays designed for mounting on a printed circuit board can be used. The only requirement for these relays being their contact system is designed for the operating current flowing in the circuit of the measuring object. The control of these relays should be implemented in such a way that the relay is switched on before the converter starts working and the switch–off is after the end of the converter circuit. This will allow the relay to operate in switching mode at zero current, thereby eliminating the formation of an arc and sparking at the contacts. As a result, the service life of the relay will correspond to its mechanical resource, which is usually much longer than the electrical resource of the relay at rated load. Therefore, in most cases, the relay resource will not be a limiting factor in determining the service life of equipment. Thus, the use of electro-magnetic relays as part of interface devices based on functional converters can be considered appropriate, since this contributes to increased reliability and electrical safety. At the same time, the term "contactless interface device" will have a relative character and mean that the semiconductor element base in such devices ensures control safety and takes on the task of switching the operating current in the circuit, eliminating the main disadvantages of traditional relay circuits.

3. CONCLUSIONS

One of the most important criteria for the efficiency of interface devices based on functional converters used for high-power loads, such as electric drive motors, is the efficiency coefficient. In order to achieve a higher efficiency as well as improved weight and size parameters, such technical solutions should be chosen that do not require the use of transformers and avoid high switching frequencies of the switching elements. Accordingly, bridged conversion schemes are the most suitable solution. One example of a practical implementation of this concept is the safe coupling equipment for controlling AC switch drives in the MPC-MPK system.

The use of PWM, which provides for a high switching frequency of switching elements, should not be an end in itself for the developer. Rather, using PWM is only justified when truly required for specific tasks—such as voltage scaling or ensuring operation of elements sensitive to the form of the alternating voltage.

The use of bridge converters provides extensive possibilities for implementing multi-wire motor control schemes. This is especially important for controlling electromechanical hitching drives on subways, which require separate wires for different operational zones

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Модернизация функциональных преобразователей, используемых для управления электроприводами

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Резюме: Одним из важнейших критериев эффективности устройств сопражения на основе функциональных преобразователей, используемых для мощных нагрузок, таких как электродвигатели привода, является коэффициент полезного действия. Для достижения высокого уровня КПД (эффективности) и улучшения массогабаритных показателей следует выбирать технические решения, не требующие использования трансформаторов, и избегать высокой частоты переключения коммутационных элементов. В соответствии с этим наиболее подходящим решением являются мостовые схемы преобразования. Одним из примеров практической реализации этой концепции является оборудование безопасного соединения для управления приводами выключателей переменного тока в системе МПС-МПК. Использование ШИМ, обеспечивающего высокую частоту переключения коммутирующих элементов, не должно быть самоцелью для разработчика и оправдано только в тех случаях, когда это действительно необходимо для решения конкретных задач: например, масштабирования напряжения или обеспечения работы элементов, чувствительных к форме переменного напряжение.

Использование мостовых преобразователей открывает широкие возможности для реализации многопроводных схем управления двигателями, что особенно важно при управлении электромеханическими приводами автостопа в метро, где требуются отдельные провода для различных участков работы

ფუნქციონალური გარდამქმნელების მოდერნიზაცია, რომლებიც გამოიყენება ელექტროამძრავების სამართავად

მერაბი ჩალაძე, ალექსანდრე დუნდუა, მურთაზ პაპასკირი, შალვა ლომსაძე, გრამიტო გელენიძე

აბსტრაქტი

ნაშრომში განხილულია მაღალი სიმძლავრის დატვირთვისთვის გამოყენებული ფუნქციუონალური გარდამქმნელების ეფექტურობის ერთ-ერთი ყველაზე მნიშვნელოვანი კრიტერიუმი, როგორიცაა მისი ელექტროამძრავის ძრავების მარგი ქმედების კოეფიციენტი. მქკ-ს (ეფექტურობის) მაღალი დონის მისაღწევად და წონისა და ზომის მაჩვენებლების გასაუმჯობესებლად უნდა შეირჩეს ტექნიკური გადაწყვეტილებები, რომლებიც არ საჭიროებს ტრანსფორმატორების გამოყენებას და თავიდან უნდა იქნას აცილებული გადართვის მაკომუტირებელი ელემენტების მაღალი სიხშირეები (გადართვის რაოდენობა). ამის მიხედვით, გარდამქმნელების ხიდური ელ.სქემები ყველაზე შესაფერისი გამოსავალია. ეს გადაწყვეტილება პრაქტიკული განხორციელების ერთ-ერთი მაგალითია უსაფრთხო МПС-МПК ტიპის სისტემაში მაკომუტირებელი ელემენტების გამოყენება. ამ სისტემით შეიძლება შემდეგი საკითხების გადაჭრა: მაგალითად, ძაბვის მასშტაბირება ან ალტერნატიული ძაბვის ფორმის მგრძნობიარე ელემენტების მუშაობის უზრუნველყოფა.

ხიდური გარდამქმნელების გამოყენება, რომელებიც აფუძნებს მრავალ სადენიანი ელ.სქემების საშუალებით ელ.ამძრავების მართვას, აქტუალურია მეტროპოლიტენებში ელექტრომექანიკური ავტოსტოპების (ავტოსდექები) მართვის დროსაც.

საკვანძო სიტყვები: ფუნქციონალური გარდამქმნელი, ელ.ამძრავი, სამფაზა ასინქრონული ძრავა, ინვენტორი, ხიდური ელ.სქემა, მარგი ქმედების კოეფიციენტი.