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ANALYSIS OF MODES TRACTION FREQUENCY CONVERTER

Annotation: *Results of research of energy flows circulating through the traction Converter of frequency. The results obtained can be used in the synthesis and development of systems of automated control of traction power for a typical transport and load-lifting, and General industrial systems of electric drives.*

Key words: *automatic control system, traction inverter, traction transmission, recuperation.*

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АНАЛІЗ РЕЖИМІВ РОБОТИ ТЯГОВОГО ПЕРЕТВОРЮВАЧА ЧАСТОТИ

Анотація: *Наведено результати дослідження енергетичних потоків, що циркулюють крізь тяговий перетворювач частоти. Отримані результати можливо використовувати при синтезі та розробці систем автоматичного керування тягових електропередач для типових транспортних та вантажопідйомних, а також загальнопромислових систем електроприводів.*

Ключові слова: *система автоматичного керування, тяговий інвертор, тягова електропередача, рекуперація.*

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АНАЛИЗ РЕЖИМОВ РАБОТЫ ТЯГОВОГО ПРЕОБРАЗОВАТЕЛЯ ЧАСТОТЫ

Аннотация: *Приведены результаты исследования энергетических потоков, циркулирующих сквозь тяговый преобразователь частоты. Полученные результаты можно использовать при синтезе и разработке систем автоматического управления тяговых электропередач для типовых транспортных и грузоподъемных, а также общепромышленных систем электроприводов.*

Ключевые слова: *система автоматического управления, тяговый инвертор, тяговая электропередача, рекуперация.*

Statement of the problem. In the system of traction power traction Converter can perform the role of a source of voltage or current. The provision of a traction Converter of properties similar to the properties of an ideal voltage source (DC) is provided by the introduction of the internal control loops of feedback voltage or current of the Converter. The quality of the conversion of electrical energy one can assess the ability of the traction inverter to reproduce the change of control actions with minimal distortion [1-3]. When you build structures and traction control systems with frequency converters need to consider the electromagnetic transients, the nature of which is determined by the mode in which the traction Converter [4-6]. Therefore, such studies are relevant.

The purpose of the study. The study of energy flows circulating through the traction inverter.

The main material. At no load induction motor consumes current, conventionally divided in the theory of electrical machines [7] for the reactive component, which is determined mainly by the magnetizing current and the active component, which is determined by the time of idling and loss in the engine. The reactive component in the system of the Autonomous voltage inverter – asynchronous motor closed contour: the filter capacity of the inverter and motor windings, or in accordance with the selected equivalent circuit, the magnetizing circuit. The active component of current flows through the rectifier. In addition, the rectifier provides charging of the filter capacitor, compensating for the loss of flow through the filter reactive current component and leakage currents. That is, flows through the rectifier, the total current determined by the load and the losses in the Converter. In the generator mode of the induction motor changes the direction of the active current component that defines the following modes when braking, which are determined by the rate of change of frequency inverter (slip frequency), the magnitude of the primaries of mass and static moment on the motor shaft:

- the energy stored in the rotor of the motor and the traction elements transmission, the braking process is completely dissipated in the active resistance of the windings of the motor and the traction elements of the Converter without exceeding the values of currents and voltages in excess of the permissible;
- the energy stored in the rotor of the motor and the elements of the traction power returns to the power source, causing an increase in the voltage on the filter capacitor and the currents through the keys of the traction inverter voltage in excess of acceptable values [8].

The first mode is a characteristic for the case of slow changes in the frequency of the stator with a significant static torque given to the motor shaft [9]. The second mode, as a rule, emergency and requires special measures to prevent failure of the circuit elements. This mode occurs when significant primaries masses and rapid changes of frequency inverter, which causes a sharp increase in the slip [10]. The active component of the stator current that is proportional to the slip, increases the charge of the filter capacitor, which leads to saturation of the motor and further growth of the reactive component of the stator current. During recovery in the traction system on the basis of the Autonomous voltage inverter can distinguish four distinct phases, as shown in Fig. 1.

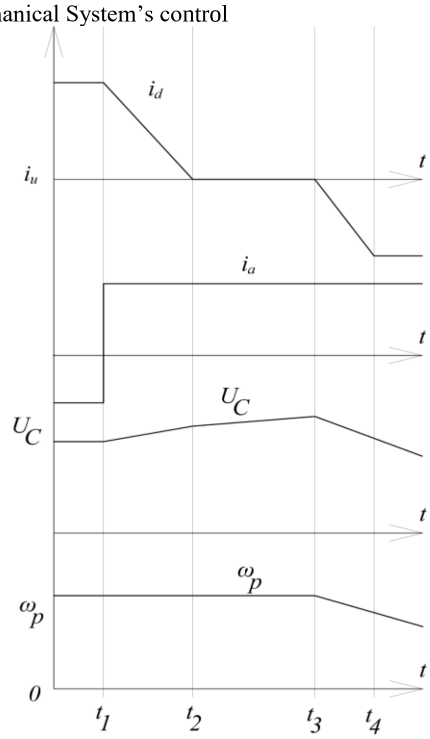

Fig. 1. The selection characteristic areas of traction power in the process of recuperation

In this case we assume that the variation of slip occurs abruptly at time t_1. Thus, the active component of the stator current (current of the traction inverter) i_a changes sign. Then the filter capacitor capacity $C_ф$, decreasing charging current of the rectifier i_d and the current of the inverter i_a. In most cases, part of the participation of the rectifier in the charging of the capacitor for practical calculations can be neglected due to the fact that the descending current from time t_1 to time t_2 is considerably less time no-current pause from time instant t_2 to time instant t_3. The section from time t_2 until time t_3, the capacitor is charged by a current of the traction inverter. We also believe that the slip of the motor is unchanged. then the charging current of the capacitor is constant. The influence of the ripple current due to reactive energy exchange between the windings of the traction asynchronous motor and the capacitor, the voltage on the capacitor is neglected due to their smallness.

The section from time point t3 to time point t4 turns on the traction inverter starts operation.

Conclusions. 1. Studied the flow of energy circulating through the traction inverter.

2. The obtained results may be used in the synthesis and development of automatic control systems, traction power model for transport and lifting, as well as General industrial electric drive systems.

References

1. Аранчий Г. В. Тиристорные преобразователи частоты для регулируемых электроприводов [Текст] / Аранчий Г. В., Жемеров Г. Г., Эпштейн И. И. – М. : Энергия, 1968. – 128 С.

2. Башарин А. В. Управление электроприводами [Текст] / А. В. Башарин, В. А. Новиков, Г. Г. Соколовский. – Л. : Энергоиздат. Ленингр. отд-ние, 1982. – 392 С.

3. Булгаков А. А. Частотное управление асинхронными электроприводами [Текст] / Булгаков А. А. – М. : Энергоиздат. – 1982. – 216 С.

4. Кулагін Д. О. Проектування систем керування тяговими електропередачами моторвагонних поїздів : монографія [Текст] / Д. О. Кулагін. – Бердянськ : ФО-П Ткачук О. В., 2014. – 154 С.

5. Кулагін Д. О. Спосіб апроксимації кривої намагнічування тягового асинхронного двигуна [Текст] / Кулагін Д. О. // Електротехніка та електроенергетика. – 2013. – №2. – С. 66-70.

6. Рудаков В. В. Асинхронные электроприводы с векторным управлением [Текст] / Рудаков В. В., Столяров И. М., Дартау В. А. – Л. : Энергоатомиздат, Ленинградское отделение. – 1987. – 136 С.

7. Слежановский О. В. Системы подчиненного регулирования электроприводов переменного тока с вентильными преобразователями [Текст] / Слежановский О. В. [и др.]. – М. : Энергоатомиздат, 1983. – 256 С.

8. Столяров И. М. Электромеханические преобразователи [Текст] / И. М. Столяров, В. В. Рудаков. – Л. : ЛГИ им. Г.В. Плеханова, 1978. – 462 С.

9. Тиристорные преобразователи частоты в электроприводе [Текст] / [А. Я. Бернштейн и др.] ; Под ред. Р. С. Сарбатова. – М. : Энергия, 1980. – 328 С.

10. Шрейнер Р. Т. Математическое моделирование электроприводов переменного тока с полупроводниковыми преобразователями частоты [Текст] / Шрейнер Р. Т. – Екатеринбург : Изд-во УРО РАН, 2000. – 654 С.

References

1. Aranchii G. V. Tiristornye preobrazovateli chastoty dlya reguliruemykh elektroprivodov [Thyristor frequency converters for speed drives], Moscow, *Energiya,* (1968), 128 p. (In Russian)

2. Basharin A. V., Novikov V. A., Sokolovskii G. G. Upravlenie elektroprivodami [Control of electrical drives], Leningrad, *Energoizdat. Leningr. otd-nie,* (1982), 392 p. (In Russian)

3. Bulgakov A. A. Chastotnoe upravlenie asinkhronnymi elektroprivodami [Frequency control of asynchronous electric drives], Moscow, *Energoizdat,* (1982), 216 p. (In Russian)

4. Kulagin D. O. Proektuvannya sistem keruvannya tyagovimi elektroperedachami motorvagonnikh poyizdiv : monografiya [Designing of control systems of traction electrical transmission EMU-trains], Berdyans'k, *FO-P Tkachuk O. V.,* (2014), 154 p. (In Ukrainian)

5. Kulagin D. O. Sposib aproksimatsiyi krivoyi namagnichuvannya tyagovogo asinkhronnogo dviguna [Method of approximation of a curve of magnetization asynchronous traction motor] *Elektrotekhnika ta elektroenergetika,* (2013), no. 2, pp. 66-70. (In Ukrainian)

6. Rudakov V. V., Stolyarov I. M., Dartau V. A. Asinkhronnye elektroprivody s vektornym upravleniem [Asynchronous electric drives with vector control], Len-

ingrad, *Energoatomizdat*, *Leningradskoe otdelenie*, (1987), 136 p. (In Russian)

7. Slezhanovskii O. V. Sistemy podchinennogo regulirovaniya elektroprivodov peremennogo toka s ventil'nymi preobrazovatelyami [Century System of slave control of AC drives with valve converters] Moscow, *Energoatomizdat*, (1983), 256 p. (In Russian)

8. Stolyarov I. M., Rudakov V. V. Elektromekhanicheskie preobrazovateli [Electromechanical converters], Leningrad, *LGI im. G.V. Plekhanova*, (1978), 462 p. (In Russian)

9. Bernshtein A. Ya., Tiristornye preobrazovateli chastoty v elektroprivode [Thyristor frequency converters in the drive], Moscow, *Energiya*, (1980), 328 p. (In Russian)

10. Shreiner R. T. Matematicheskoe modelirovanie elektroprivodov peremennogo toka s poluprovodnikovymi preobrazovatelyami chastoty [Mathematical modeling of AC electric drives with semiconductor frequency converters], Ekaterinburg, *Izd-vo URO RAN*, (2000), 654 p. (In Russian)

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