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Indirect Thermal Protection of Asynchronous Electric Motor against Exceeding the Maximum Permissible Heating Temperature Value

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Abstract. *The purpose of the work is to study and to develop methods of indirect thermal protection of asynchronous electric motors with a squirrel-cage rotor, taking into account the processes of heat release and heat removal. The existing systems of indirect protection of an asynchronous electric motor against overtemperature are considered based on the observer model of stator windings resistance for electric motors. The requirements for an indirect protection system have been developed. The types of electric motors for simulation experiments have been determined. A simulation model has been developed to determine the electrodynamic characteristics. The accuracy of the observer has been analyzed. A block diagram of a protection system against exceeding the maximum permissible temperature of the stator windings of an asynchronous electric motor has been developed.*

Keywords: *asynchronous motor, protection, insulation, resistance, stator, winding, sensor, temperature, speed, dynamic characteristic.*

Introduction. Improving technical and economic indicators, reliability and safety of operation of manufactured equipment is an important scientific and technical task. One of the ways to solve this problem is the use of electronic means of protection against electric drive overload, which provide increasing reliability and service life of mining equipment.

In compressors, winches, crane facilities, drilling rigs, plow sets, an unregulated electric drive with an asynchronous electric motor (AM) of the 4A series has been widely used. In the above machines and mechanisms, the electric motor operates, as a rule, in the intermittent mode [1].

Induction motors with a squirrel-cage rotor (SCR) are usually designed for the service life of 15-20 years without major repairs, subject to the requirements of the technical operating conditions specified in the passport data of the electric motor. However, in real life there is a significant deviation from the nominal operating modes. This is primarily caused by violation of the rules of technical operation: technological overloads, environmental conditions, reduction of insulation resistance, violation of cooling. All the above factors significantly affect increasing the temperature of the stator windings of the electric motor. Failure to take this factor into account sharply reduces reliability of operation. Exceeding the permissible temperature leads to premature destruction of the winding insulation and significant reduction of the motor service life.

The basic characteristic of the load modes of the electric motor is the thermal one. The operation of an induction motor with a short circuit is always accompanied by its heating, which is caused by the processes occurring in it and energy losses. The standard service life of the electric motor is ultimately determined by the permissible heating temperature of its insulation [2].

Analysis of the existing methods. Protection of asynchronous electric motors with short-circuit rotors against overheating is traditionally implemented on the basis of thermal current protection or built-in temperature sensors. Built-in temperature sensors are used only in newly produced AMs with short circuit rotors.

In the vast majority of engines in operation, there is used thermal current protection [3], which does not accurately take into account the actual temperature conditions of the AM with short circuit rotors, as well as its temperature time constants.

In the indirect thermal protection of an asynchronous electric motor with a short circuit, bimetallic plates are included in the power circuits of the stator windings, and when the maximum permissible stator current is exceeded, these bimetallic plates heat up and disconnect the stator power from the power source.

The disadvantage of this method is that the protection reacts not to the heating temperature of the stator windings but to the amount of heat released without taking into account the operating time in the overload zone and the actual cooling conditions of the AM with a short circuit. This does not allow using in full the overload capacity of the electric motor and reduces the performance of equipment operating in the intermittent mode due to false trips.

There is also used thermal protection [4, 5] based on measuring the stator current value, calculating the delay time for disconnecting the electric motor from the power source as a function of the current value, and turning off the electric motor power when the specified setting is exceeded. However, this method does not take into account the electric motor heat transfer, the conditions for its cooling and the actual heating of the stator windings, which also does not allow using in full the permissible overload capacity of the electric motor operating in the intermittent mode, and reduces its performance due to false trips.

Research methods. The essence of the proposed technical solution consists in the fact that in the method of indirect protection of the stator winding of an asynchronous electric motor against exceeding the maximum permissible value of the heating temperature based on measuring the instantaneous values of the stator current and voltage in the starting mode of the asynchronous electric motor with short circuit, calculating the temperature of the stator windings and turning off the power supply of the electric motor when the specified value is exceeded, they measure the instantaneous values of voltage and current of the stator windings in the start mode, indirectly calculate the angular velocity, determine the dynamic electromechanical characteristic, calculate the number of pulsations of the electric motor current during the start-up period and when the number of pulsations of the set value corresponding to the permissible heating temperature of the stator windings, turn off the electric motor [6].

To achieve the result that consists in protecting the asynchronous electric drive in case of exceeding the maximum permissible value of the heating temperature of the stator winding, in addition to essential features, such as the presence of a driving device, a current sensor and a starter that cuts off voltage from the AM stator winding, there is additionally introduced a voltage sensor that measures the instantaneous values of the linear three-phase voltage of the stator winding, a unit for indirect calculating the angular velocity, a unit for calculating the dynamic electromechanical characteristic, a unit for calculating the temperature of the stator winding, a device for logical comparing output signals of the driving device of the block for calculating the temperature of the stator winding.

In the course of operation of an asynchronous electric motor in the intermittent mode, the stator winding of the electric motor is heated, which leads to changing its resistance according to the formula:

$$R_s = R_0(1 + aT),$$

where R_s – is stator resistance, Ohm;

R_0 – is stator windings resistance with the temperature of 0°C, Ohm;

a – is the temperature coefficient of stator resistance, 1/K;

T – is the temperature, °C.

Changing stator windings resistance of the electric motor is proportional to the temperature of its heating.

With increasing stator winding resistance associated with heating, the time constant of the stator windings decreases, which leads to increasing the number of current ripples in the starting dynamic electromechanical characteristic, and this number is proportional to the heating temperature of the stator windings of the electric motor.

Research results. In the process of simulation experiments for the electric motor 4A2S0S4Y3, the effect of changing stator windings resistance at the nominal speed of 3000 rpm has been determined in the start mode accompanied by a fourfold surge of the stator starting current. The study has been carried out for the power of 75 kW in the temperature range of 20°C÷300°C, the upper limit of which has been determined by the class of insulation of the stator windings [7, 8].

Some of the simulation results in the temperature range from 20°C÷250°C are shown in Figures 1-4.

It is seen from the family of the dynamic electromechanical characteristics for various temperature values presented in Figures 1-4 that the number of pulsations (Table) that have achieved fourfold rated stator current, depends on the temperatu-

Results of determining current pulsations number for the SCR AM with the power of 75 kW and 3000 rpm with varying the temperature of stator windings

Motor type	4A2S0S4Y3					
P, kW	75					
η, rpm	3000					
T, °C	20	80	125	200	250	300
Number of pulsations	5	5	6	6	7	7

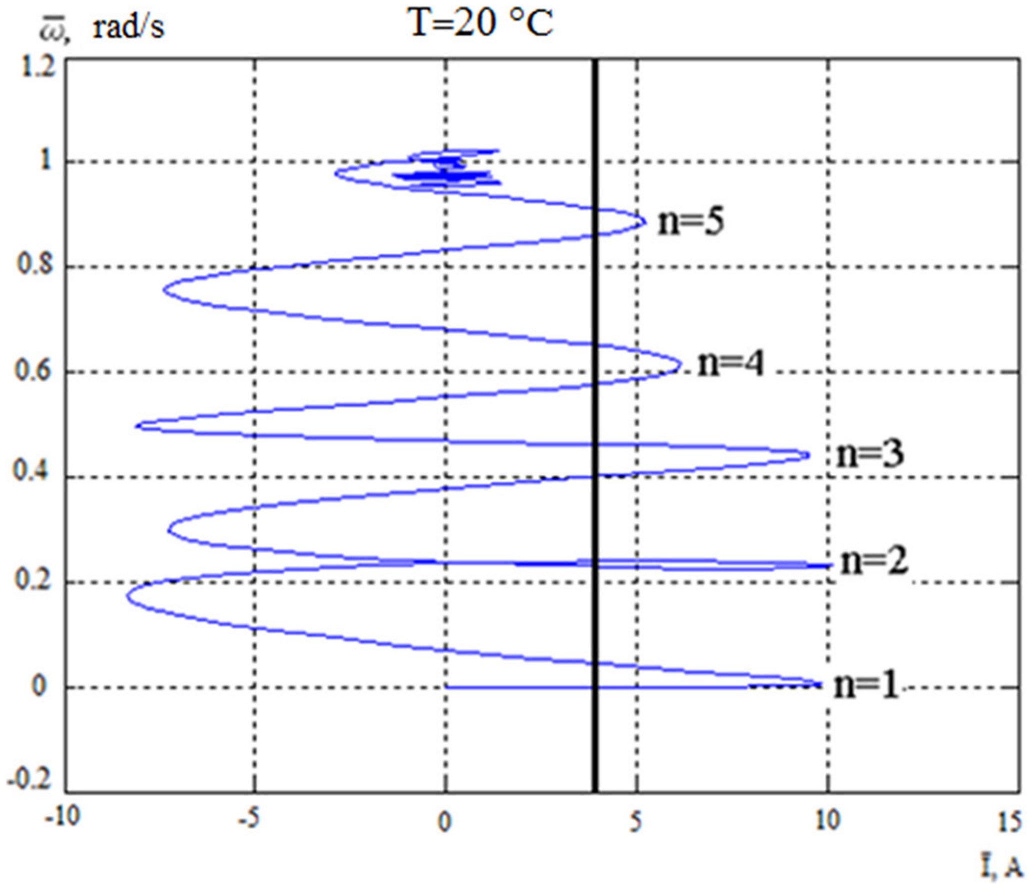

Figure 1 – Dynamic characteristic of the SCR AM in the start mode for the temperature of 20°C with 3000 rpm

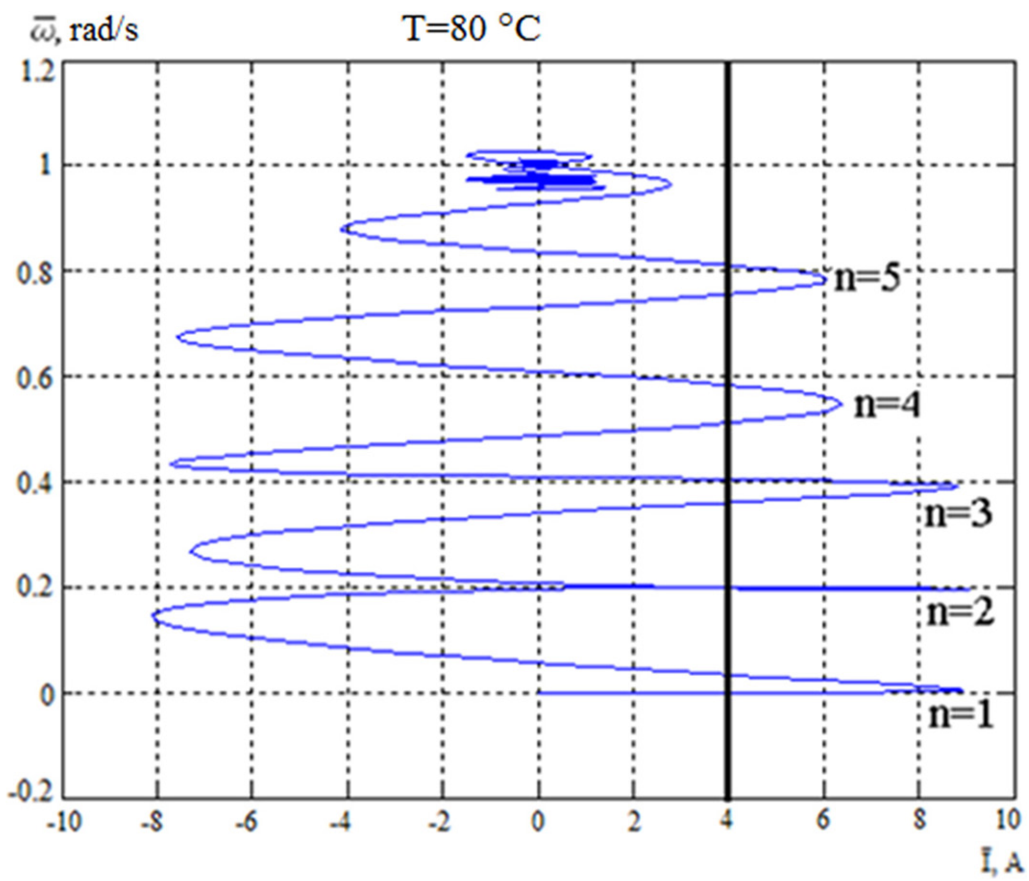

Figure 2 – Dynamic characteristic of the SCR AM in the start mode for the temperature of 80°C with 3000 rpm

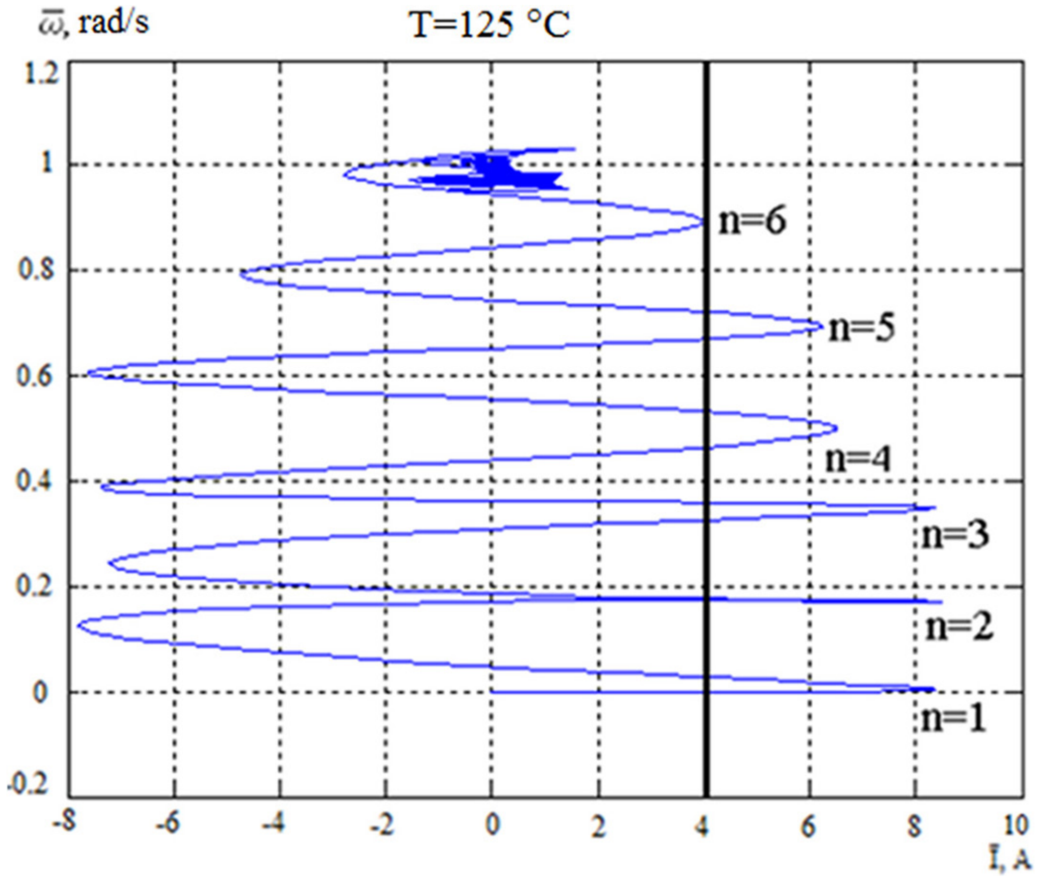

Figure 3 – Dynamic characteristic of the SCR AM in the start mode for the temperature of 125°C with 3000 rpm

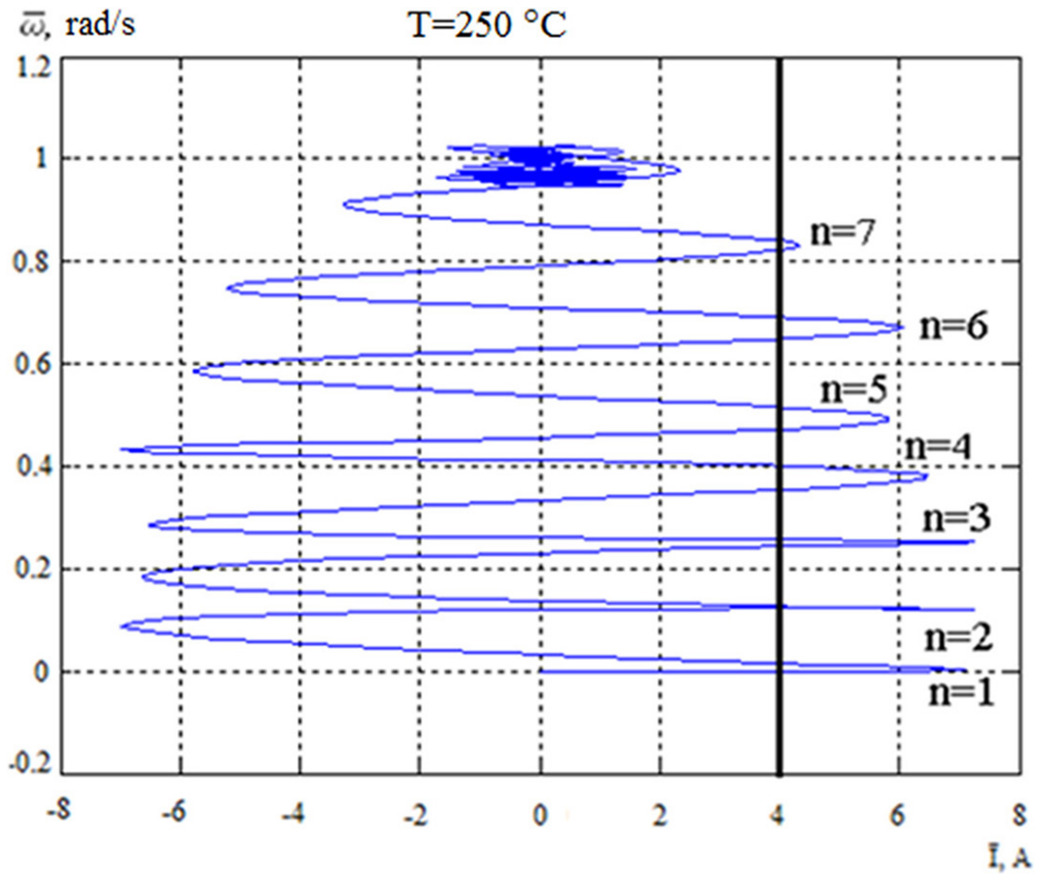

Figure 4 – Dynamic characteristic of the SCR AM in the start mode for the temperature of 250°C with 3000 rpm

re. The graphic form of the dependence is shown in Figure 5.

The results obtained confirm that in the range of 20°C-300°C the number of current pulsations depends on the stator windings temperature, i.e. it can be stated that the method of thermal protection proposed is suitable for asynchronous motors with a squirrel-cage rotor.

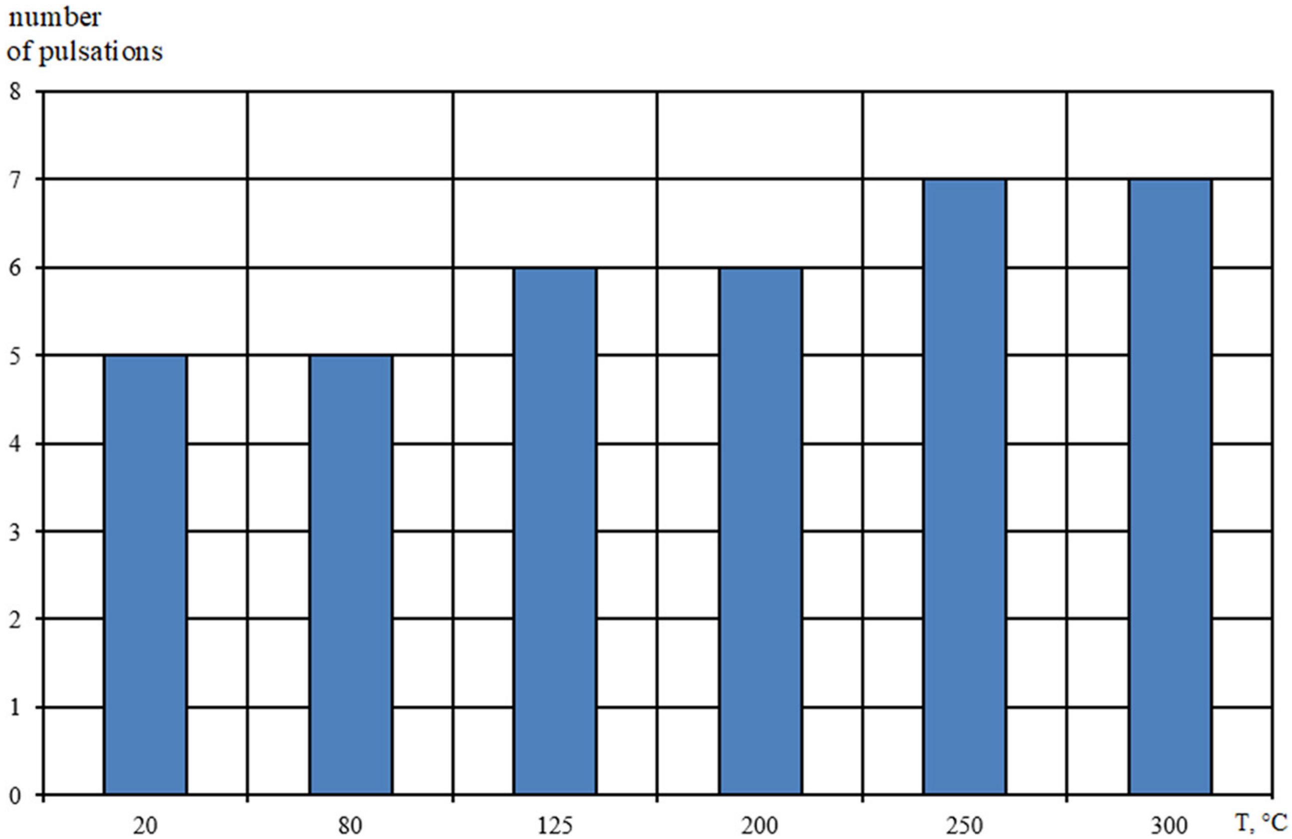

Figure 5 – Current pulsations number dependence on the stator winding temperature in the start mode of the SCR AM with the power of 75 kW and 3000 rpm

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Асинхронды электр қозғалтқышын қыздыру температурасының рұқсат етілген ең жоғары мәнінен асып кетуден жанама жылу қорғау

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Аңдатпа. *Жұмыстың мақсаты қысқа тұйықталған роторлы асинхронды электр қозғалтқыштардың жылу бөлу және жылу шығару процестерін ескеретін жанама жылу қорғау әдістерін зерттеу және өңдеу болып саналады. Электр қозғалтқыштары үшін статор орамаларының кедергісін бақылаушы моделі негізінде асинхронды электр қозғалтқышын температураның жоғарылауынан қорғайтын жанама жүйелері қарастырылды. Жанама қорғау жүйесіне қойылатын талаптар әзірленді. Имитационды эксперименттерді жүргізу үшін электр қозғалтқыштарының түрлері анықталды. Электр динамикалық сипаттамаларды анықтау үшін имитациялық модель жасалды. Бақылаушының дәлдігіне талдау жасалды.*

Кілт сөздер: *асинхронды электр қозғалтқышы, қорғау, изоляция, кедергі, статор, орам, датчик, температура, жылдамдық, динамикалық сипаттама.*

Косвенная тепловая защита асинхронного электродвигателя от превышения максимально допустимого значения температуры нагрева

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Аннотация. *Целью работы являются исследование и разработка методов косвенной тепловой защиты асинхронных электродвигателей с короткозамкнутым ротором, учитывающие процессы тепловыделения и теплоотвода. Рассмотрены существующие системы косвенной защиты асинхронного электродвигателя от превышения температуры на основе модели наблюдателя сопротивления обмоток статора для электродвигателей. Разработаны требования к косвенной системе защиты. Определены типы электродвигателей для проведения имитационных экспериментов. Для определения электродинамических характеристик разработана имитационная модель. Выполнен анализ точности наблюдателя.*

Ключевые слова: *асинхронный электродвигатель, защита, изоляция, сопротивление, статор, обмотка, датчик, температура, скорость, динамическая характеристика.*

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