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Increase in reliability of frequency converters of agricultural objects

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Abstract. The article presents ways to improve reliability of agricultural semiconductor frequency converters. It is shown that an increase in reliability of semiconductor converters can be achieved increasing the power reserve. At the same time, if the economic indicator is chosen as an optimization criterion, the coefficient of failure-free operation reaches no more than 0.8. In the event that resulting coefficient of failure-free operation is allowed according to operating conditions, selected criterion can be successfully applied at design stage of semiconductor converters.

1. Introduction

Modern semiconductor converters feeding agricultural objects should implement basic operating modes (nominal and overload) while maintaining reliability indicators. Thus, improving reliability of system is an actual scientific and technical task.

Reliability of the electrical system is a property perform preassigned functions, keeping in time values of established performance indicators with specified limits corresponding to required modes and conditions of use.

Reliability is the complex property which depending on purpose and conditions of operation of the agricultural electric drive, includes such properties of system as reliability, longevity, maintainability and storage apart, or a certain combination of these properties. In the modern literature [1], in describing the reliability of a system, the concept of probability of failure-free operation $P(t)$ is often used, the probability that within a given time t of operating the system there will not be a single failure.

2. Problem statement

The formulated scientific and technical problem of increasing reliability indexes of semiconductor converters can be solved with implementing following sub-tasks:

- analysis of requirements of technological process for reliable indicators of semiconductor converters;
- the decision for the problem of increasing the reliability indicators criterion of minimum expenses;
- analysis of the results;
- taking into account temperature modes operation of frequency converters.



3. Analysis of requirements to reliable indicators of semiconductor converters

The probability of system failure-free operation R_{sys} is the multiplication of failure-free operation probabilities all elements, included in the P_i . The motor and converter are the main elements of electric drive system, reliability determining of the all complex. Exactly for them will consider the probability of failure makes sense [2].

The calculated working capacity of induction motors is less than 15 years with produce 40000 hours or 4.5 years continuous operation (power induction motors 4A series from 0.37 kW to 400kW). Produce is less 20000 hours of stator armature and calculated produce is less than 14000 hours of bearing. The probability of failure Paem asynchronous electric motor for industrial performance is less than 0.9 for 10 thousand hours of produce. In other words, this means that asynchronous motor will never fail with probability of 0.9 during produce of 10 000 hours [3]. The satisfactory value of the probability failure-free operation P_p is 0.9 during 10 000 hours for converter.

On the reliability of all electrical installations are divided into three categories: the first category, from which emit a special group, the second and third categories of electrical consumers, this is known from classification rules for electrical appliances [4].

As a rule blowers, pumps, compressors, fans, are the first category of reliability, but on some industries (metallurgical, chemical) to a "special" group from the same category. Exhausters BOF production is categorized as special consumers, as their uninterrupted operation is required for trouble-free shutdown of production with preventing aim threats to lives of people, explosions and fires.

An example of electrical equipment from the "special" group on electrical safety can be the electric drive of pipeline valves for nuclear power plants. In table I the quantitative values are given of probability of failure-free operation mechanisms of pipe fittings nuclear power plant [5].

Table 1. The quantitative values of probability failure-free operation mechanisms for pipeline fittings nuclear power plants

№	Name	Probability of trouble-free operation for the period before the overhaul, not less than
1	electric drive and EMF	0.95
2	electric drive with intermediate gear	0.93
3	with human control	0.98
4	with human control with intermediate gear	0.96
5	with human remote control	0.96
6	with human remote control with intermediate gear regulating armature:	0.94
7	security systems	0.96
8	normal operation systems important for safety	0.94
9	other normal operation systems	0.9

It is possible to emphasize that in the modern industry production reliability reaches to the fore and one is determining factors of operation along with efficiency and profitability.

4. Increasing of the reliability semiconductor transmitter on economic criteria

The causes reducing the reliability of equipment produce at all stages of the life cycle of its existence: design, fabrication, installation and operation. The operational reliability of the equipment depends not only on the underlying reliability that is created on the first three stages, but also on the level of its operation, maintenance and repair (TM&R). Improving reliability is not the final point, but a means to

achieve efficient operation of the equipment. Theoretically, it is possible to achieve the level of reliability close to unity, however, the costs to ensure this indicator can negate the usefulness of its application.

In figure 1 experimental data of Girkina Y. V. [6], reflecting the dependence of costs on the creation and maintenance of industrial equipment reliability. The exponential shape of the curve dependence cost from the probability of failure-free operation depends on exponential (normal) law of distribution probability failure-free operation.

After analyzing the dependencies, we can draw some conclusions [7]. All industrial electrical applications can be divided into three categories, on the basis of curves general level of costs. In the I zone are electrical non-critical industries, where it is more profitable to make a new cheap and unreliable device than produce expensive reliable equipment or upgrade and repair old one [8]. In the II zone are general-purpose machinery their reliability on range from 0.5 to 0.8. Such reliability can be achieved at rather low cost for maintenance and repair, as well as an increased amount of object creation [9]. The objects in zone III have high reliability and are used in industries where there is a threat to life and health of people in case of equipment failure. To objects of the third category of metallurgical production, can be the mechanism of oxygen exhauster converter. Costs increase for the creation of equipment with increase in basic reliability is seen from analysis of relationship between reliability and costs [10]. Especially significant this increase in the value of reliability of 0.8 and above. Optimal operational reliability is equal to 0.8...0.9, is specified value of the reliability of metallurgical equipment. Typically, this level is in the range 0.8...0.95. For particularly critical parts of gamma-percent life reaches to 99.9% (e.g., for manned space technology) [11].

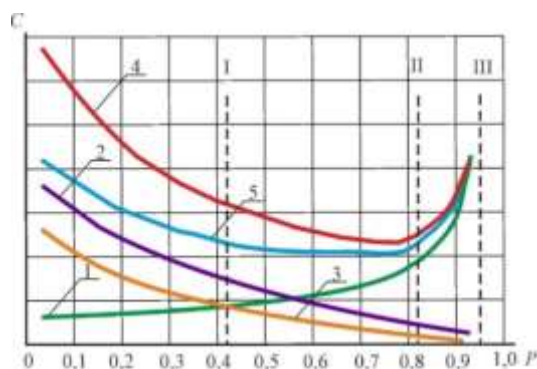


Figure 1. Dependence of level of expenses C on creation and operation equipment from reliability P : 1 - the cost of creating, 2 - costs for maintenance and repair, 3 - the cost of modernization, 4 - total costs taking into account modernization, 5 - total costs without modernization.

Speaking about the curve of total costs, optimal level of reliability without upgrading is only 0.7...0.8, which meeting the requirements of metallurgical production [12].

The character curves in zones of high reliability of 0.95...1 can be explained as follows [13]. Eliminating the negative effects of the main factors that affect system reliability, greater impact on the reliability starts to render other, previously unimportant factors reduce the impact which is also required to expend funds [14]. The highest number of failures (90%) occurs because of a failure of the machine's windings [15]. If produce a set of measures make insulation of windings newest materials to improve dissipation of heat from heating elements, improve the quality ventilation and cooling, then foreground will be failures because of bearing failure, although before renovation, failure rate of the machines for this reason accounted for a small share, only 5 to 8% [16]. If now main focus of measures increase reliability of machine do improve bearings and achieves good results, unsatisfactory (but on a higher level) will again be indicators of the windings, which will lead to new round of modernization and multiple increase in the cost of facility improvement [17].

Another explanation for asymptotic form of the cost curves when approaching unit value of reliability is that when such high reliability (0.99 and above), very large role of operational factors, human factor and force majeure [18].

The determination of optimal longevity equipment is based on the economic approach [19]. In figure 2 dependencies on present cost of production of useful time [20]. By summing all costs get general

dependence of production costs on lifetime of machine. She has distinct minimum $C_{\min}$, which corresponds to specific service life. The service time of machine, which reaches lowest cost per unit of output, is considered the best time T_{opt} its service on physical wear [21].

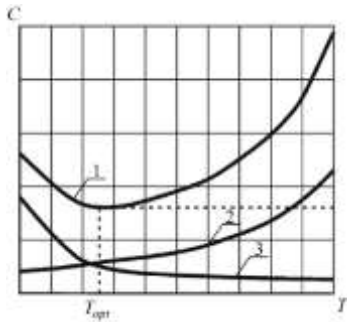


Figure 2. Dependence of the cost of production C on the service life T : 1 - the amount of costs; 2 - operating costs; 3 - depreciation charges.

There are devices that in a state of storage some part of the operating time, i.e. do not perform their main tasks. The largest part of the failures for these devices, associated with corrosion and the harmful effects of dirt, dust, temperature and moisture [22]. Most of the failures associated with wear, fatigue or mechanical damage of parts and assemblies. For devices most of the time used intended for doing useful work. Failure rate of the elements of the object are considerably lower in the idle state, than in working condition. So, this ratio corresponds to 1:10 for the electromechanical equipment, the ratio is 1:30 for mechanical elements [23].

In summary, about the necessity of balance between the reliability indices of the electric and capital costs of its creation and operation, based on the requirements of a particular mechanism in specific circumstances [24].

5. Account of temperature modes operation on reliable indicators of frequency converter

The power transistors are considered to be the least reliable element of the semiconductor power converter. Experimental and statistical studies of the power transistors were to assess reliability indicators of the frequency converters, the most common for electric drives in the industrial facilities [25].

Values of correction coefficients of atrans were the obtained first and foremost, using coefficient calculation method [26], to determine the probability of failure-free operation of the transistors depending on the load factor K_N at an operating temperature of the transistor 200C and 500C (see figure 3) [27].

$$K_N = \frac{P_{fact}}{P_{pos}}$$

For the transistors the coefficient of electrical load is determined by the ratio of the actual total power dissipated in transitions in continuous or pulsed mode, maximum power dissipation in [28].

Catalog ABB – known manufacturer of semiconductor converters was used for plotting this dependence (figure 3) [29].

Figure 3 shows that for the same value of the load on transistor 1 is equal to the correction factor at the temperature of 500OC is about 2.5 times higher than the correction factor 200C [30]. The value of the probability of the semiconductor converter, is calculated using the coefficient method when operating with a temperature of 500C would be much lower [31] than the probability of the same converter is loaded with the same load, but working with the best cooling conditions [32].

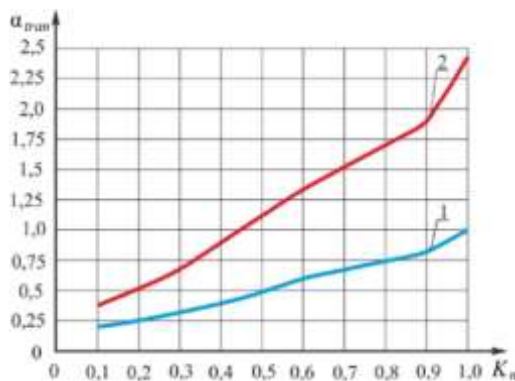


Figure 3. Dependence of the correction factor for transients on the load factor of the transistor K_H at various temperatures transistor: 1 -Trans = 200C, 2 -Trans = 500C.

The calculations performed [33] and analyzed on the obtained dependences of the magnitude of failure-free operation of a transistor designed for a rated current of 15A from the margin of power dissipation at different temperatures [34]. The results are shown in figure 4 [35].

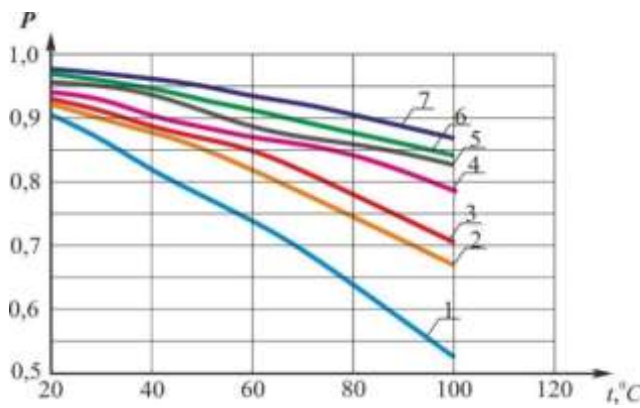


Figure 4. Dependence of failure-free operation P of a transistor with an operating time of 10 000 hours, from a reserve of dissipated power P and ambient temperature t : 1 - $P_{fact} = P_n$, 2 - $P_{fact} = 1,35 \cdot P_n$, 3 - $P_{fact} = 1,6 \cdot P_n$, 4 - $P_{fact} = 2,3 \cdot P_n$, 5 - $P_{fact} = 2,7 \cdot P_n$, 6 - $P_{fact} = 3,3 \cdot P_n$, 7 - $P_{fact} = 4,1 \cdot P_n$.

Probability is reduced to 0.5 with increasing temperature of the transistor on the 800S of failure [36], which effectively means an equal probability of working and non-working state for the allotted for transistor operation time. acceptable indicators of reliability 0.8...0.85 (see figure 4) [37] are the two supply transistors in power at operating temperatures of 80-100 degrees [38]. A further increase in redundancy leads to a multiple rise in the cost of the inverter, however, transistors become less susceptible to the temperature, as they are already designed for high currents [39].

6. Conclusion

Increase in reliability of agricultural semiconductor converters can be achieved by increasing power reserve. At the same time, if economic indicator is chosen as an optimization criterion, the coefficient of failure-free operation reaches no more than 0.8. In event that resulting coefficient of failure-free operation is allowed according to operating conditions, selected criterion can be successfully applied at design stage of semiconductor converters.

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