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Reliability of magnetic modulation DC converters

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ABSTRACT: Monitoring of the operation mode of autonomous power supplies with magnetically modulating DC converters and system control, differential sensitivity, improve accuracy and reliability.

I.INTRODUCTION

Currently, a large number of current converters (dc converter) are known and this creates certain difficulties in choosing the required type, specific design of these converters. In this regard, it is advisable to classify dc converter, which will reveal their fundamental and design features. Some are devoted to the classifications of high AC current transducers, while others are devoted to the classifications of high DC current transducers. Currently, there is no generalized and detailed classification of direct current sensors.

II.ENERGY EFFICIENCY

Reliability is one of the main characteristics not only of the MPPT, but the possibility of the correct performance of the measuring transducer of its required function under the given operating modes and operating conditions for a certain period of time is called reliability. [5]

Failures (violation of device performance) are divided into:

complete and partial;

catastrophic and parametric;

independent and dependent;

sudden and gradual;

persistent, temporary and intermittent.

Failures occurring as a result of a violation of mechanical, electrical and thermal strength are called sudden, and failures caused by a change in the output value under the influence of accompanying physical phenomena or due to the influence of the phenomenon of aging and wear are called gradual.

For the developed MDCC, the most unreliable parts are a sensitive element made of a ferromagnetic core with windings wound on it, and an electronic circuit with the corresponding elements (Fig. 1-2).

Taking into account that the ferromagnetic core is less susceptible to the influence of external influences in comparison with the windings and circuit elements, in this paper we will restrict ourselves to considering the reliability of the windings developed by the MDCC.

Failure of the windings of the MPPT mainly occurs as a result of:

- breaks due to corrosion in exposed areas of the insulated wire,

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- short circuit of the turns, due to mechanical or thermal damage to the electrical insulation of the wire,
- breakdown of insulation due to overvoltages or violations of the electrical insulation of the wire,
- breakage of the insulated wire due to electrolysis in its exposed places,
- reduction of insulation resistance due to deterioration of electrical insulation properties due to temperature, pressure, time, etc.

III. RESULTS AND DISCUSSIONS

Wire breaks during winding should be eliminated by the correct choice of the wire tension force during its winding, and breaks caused by thermal stresses in the winding and frame should be prevented by the correct calculation of the thermal conditions of the winding when working in a hot and cold environment.[2]

Windings used in inductors, as a rule, have point damage. If the probability that a short circuit to the case or to the adjacent winding layer will not occur at the point of a point damage is equal to m_e, then with the number of damages per unit length of the wire equal to n and with the length of the wire L, the probability of no damage will be equal to:

$$m = m_0^{nL} = m_0^{\alpha\varepsilon L}, \qquad (1)$$

where $\alpha \approx \frac{n}{\varepsilon}$– the number of damage, per unit elongation

$$\varepsilon = \frac{\Delta L}{L}.$$

The latter is defined as:

$$\varepsilon = \frac{\Delta l}{l} = \varepsilon_1 + \varepsilon_2 + \varepsilon_3 = \frac{d_1}{D+d_1} + \frac{N_п}{SE} + \alpha_т \Delta T, \qquad (2)$$

here ε_1– relative elongation of the outer part of the coil during winding due to bending along the diameter or perimeter

D - ferrite core

$d_1 = d + 2h$– copper wire diameter

d– copper wire diameter

h– thickness of insulating material

ε_2– relative elongation during winding due to the

N_c, E– wire modulus

$S = \pi d_1 h$– wire section

ε_3– relative elongation of a wire as a result of a change in temperature

ΔT - windings compared to the normal temperature for the wire

α_T– temperature coefficient of expansion of wire material.

Initial winding reliability (reliability in terms of the absence of a short circuit during manufacture) (at $\Delta T = 0$) will be equal to:

$$P_н = m^{nL} = e^{(ln m_0)\alpha\varepsilon_3 L} = 1. \qquad (3)$$

An increase in temperature (ΔT>0) leads to the destruction of the electrical insulation of the wire, resulting in a short circuit of the turns and layers of the winding.

Therefore, there is a need for a detailed study of winding failures due to thermal changes.[4]

The dependence of the insulation service life on the heating temperature of the winding is determined using the following formula:

The dependence of the insulation service life on the heating temperature of the winding is determined using the following formula:

$$C_x = C_0 e^{-b(T_x - T_{доп})}, \qquad (4)$$

where C_0– rated life of electrical insulation ($C_0 = 1000\ hours$);

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$T_{доп}$– permissible heating temperature ($T_{доп} = 85^0 - 90^0$C); $b -$ coefficient, which is 0.07 for paper, cotton and mica in the air; T_x– winding heating temperature; C_x– service life of electrical insulation at winding temperature T_x.

If the modulating or measuring winding is operated at a temperature T_{x1} for a time t_1 (summer period), and at a temperature T_{x2} for a time t_2(winter period), then, in accordance with (4), it is possible to determine the service life of electrical insulation, respectively, at temperatures T_{x1} and T_{x2} as follows:

$$C_{x1} = C_0 e^{-b(T_x - T_{доп})} , \qquad (5)$$

$$C_{x2} = C_0 e^{-b(T_x - T_{доп})}. \qquad (6)$$

The service life of the insulation is found by the well-known formula

$$C = \frac{C_{x1} C_{x2}}{x_1 C_{x2} + x_1 C_{x2}} = 2C_0 \frac{e^{b \cdot T_{доп}} e^{-b(T_{x1} + T_{x2})}}{e^{bT_{x1}} + e^{bT_{x2}}} , \qquad (7)$$

Where $x_1 = \frac{t_1}{t_1 + t_2} = \frac{1}{2}$ and $x_2 = \frac{t_2}{t_1 + t_2} = \frac{1}{2}$; $t_1 = t_2 = \frac{C_0}{2}$.

The reliability of the winding with respect to the absence of short circuits in the turns and the layer is defined as:

$$P_{sh.f} = e^{-\lambda_2 t}, \qquad (8)$$

here $\lambda_1 = \lambda_0 e^{b(T_x - T_0)}, \lambda_0 -$ failure rate at temperature $T_0 = 20^0 C$.

The next cause of failure is corrosion of the wire material. The process of corrosion of the material is observed in places where the insulation is damaged, where the material is exposed and has direct contact with air. In addition, corrosion of the wire under the insulation layer occurs due to the diffusion of atmospheric oxygen through the insulation. The latter goes slowly, it must be kept in mind, as a rule, for wires that do not have violations in the electrical insulation layer.[1]

The reliability of the winding in terms of wire breakage is determined by the following formula:

$$P_{edu.} = e^{-\lambda_2 t}, \qquad (9)$$

where $\lambda_2 = \frac{1}{C_{av}}$– failure rate (danger); $C_{av} -$ the average life of the wire when exposed to corrosion at elevated temperatures and erosion of the wire due to leakage currents.the average life of the wire when exposed to corrosion at elevated temperatures and erosion of the wire due to leakage currents.

The service life of a wire in the presence of only corrosion is defined as

$$C_1 = C_0 e^{-\alpha(T_x - T_0)} , \qquad (10)$$

Where $\alpha = \frac{W_0}{RT_0^2} = 0{,}01 - 1{,}0 -$ parameter, depending on the concentration of aggressive substances; W_0– activation energy; R - is the gas constant.

The overall reliability of the windings is determined by the product

$P_{sh.f}$ and $P_{edu.}$, other,

$$P_{\Sigma} = P_{sh.f} P_{edu.} e^{-(\lambda_1 + \lambda_2)t}. \qquad (11)$$

The calculation results show that the service life of the insulation C_i decreases with increasing heating temperature T_x. Therefore, it is advisable to investigate the reliability due to the destruction of electrical insulation from heating above the permissible temperature.[3]

When the temperature changes in the range $\Delta T_x = 0 \div 5$ [°C], the intensity (hazard) of failures changes within $\lambda_1 = (0{,}10 \div 0{,}12) \cdot 10^{-5} [hour^{-1}]$, while the reliability is in the interval $P_{sh.c}$=0,912 ÷ 0,882.

The service life of the wire $C_п$ at high temperatures is determined for λ=0.01 and is in the range (1÷0.951) C_0 [h], the corresponding failure rate is

$\lambda_2 = (1 \div 1{,}047) \cdot 10^{-5} [hour^{-1}]$, and the reliability of the winding in terms of breakage at t=C_0fluctuates in the range (1÷0.956).

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The overall reliability is calculated by formula (11). Its value is within the limits (0.983÷0.831), which meets the requirements of control and management systems for the AIP operation modes for the reliability of the MDCC.[2]

Thus, the modulating and measuring windings are the main elements that lead to the failure of the developed MDCC, in which failures occur due to a short circuit or open circuit. MDCC, in which failures occur due to a short circuit or open circuit. It has been established that at the allowable wire heating temperature equal to Tadm=90℃, and its fluctuation from 20℃ to 110℃, the reliability of the developed MDCC is within (0.983÷0.831), and at Tadm=140℃ and within the same range of temperature fluctuations - (0.985÷0.910).[1]

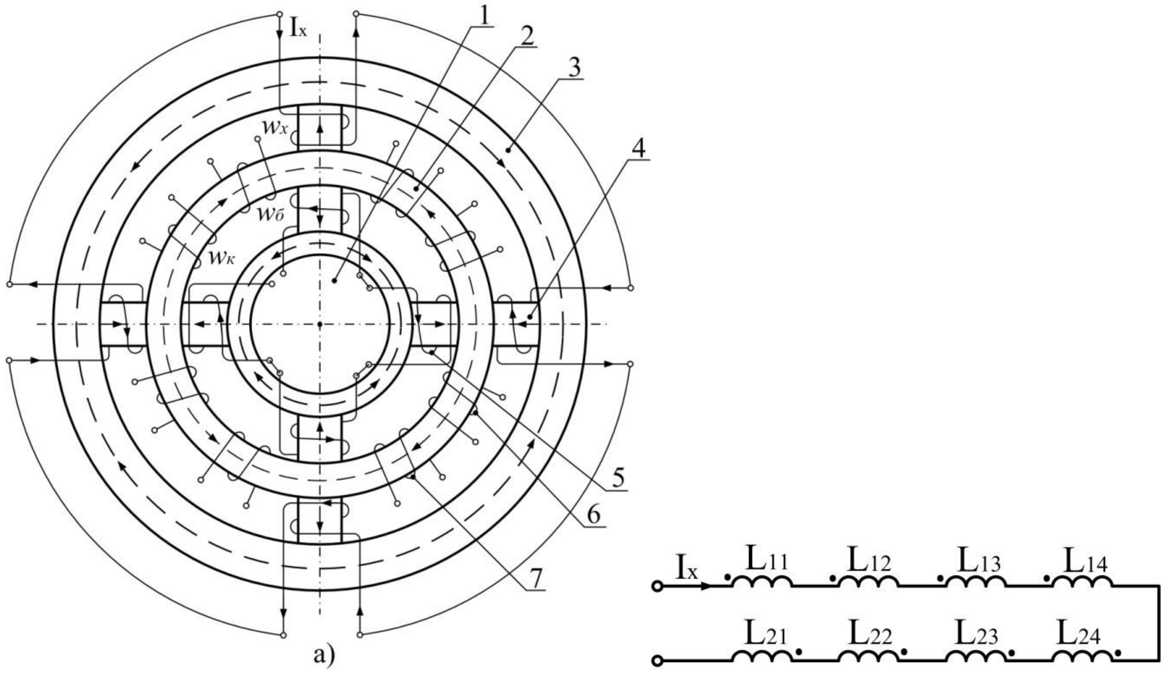

Fig.1. Structural (a) and electrical circuit for connecting sections of the winding with converted current (b) of the MDCC

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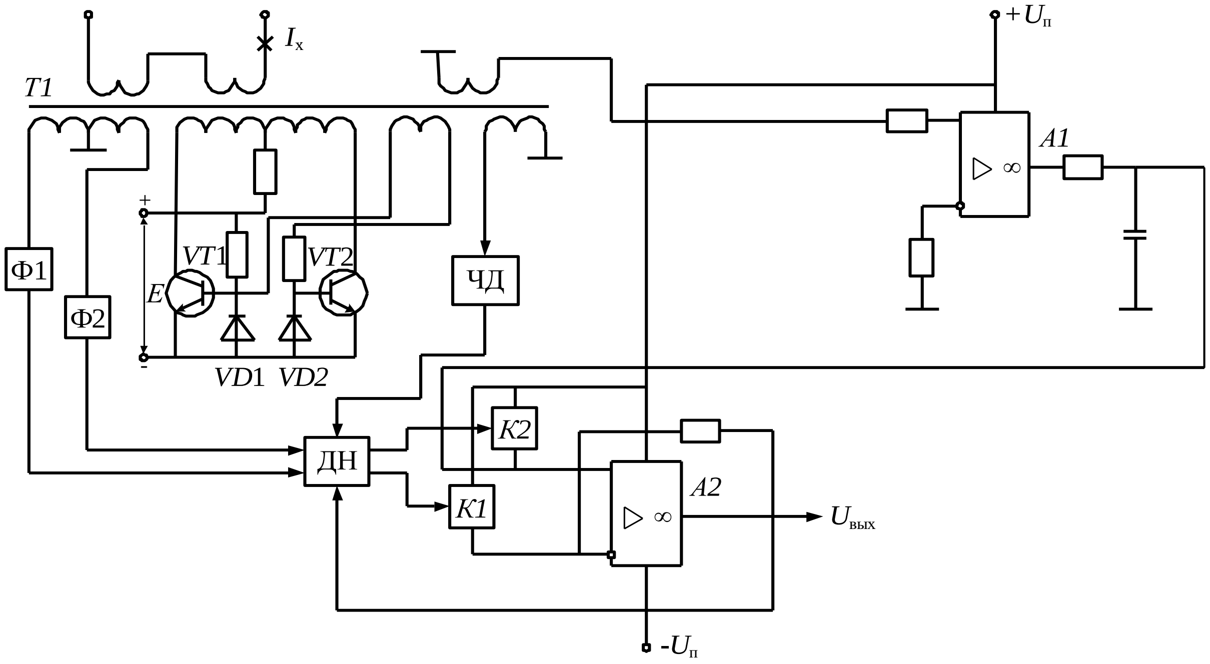

Fig. 2. MDCC with current direction memorization magnetic system

IV.CONCLUSION

Thus, generalizing it can be said that the PT, controlling the charging currents of the AB in the APS, the following requirements are imposed:

- high reliability;
- low power consumption;
- high measurement accurary;
- sensitivity to the direction of current in the controlled circuit;
- small weight and dimensions.

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