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Modeling of overheat process control of electric motor

Igors Uteshevs, Anatoly Levchenkov
Riga Technical University (Riga, Latvia)
igors.utesevs@rtu.lv, anatolijs.levcenkovs@rtu.lv

***Abstract*- the paper presents the research of heating electric traction motor, the temperature dependence of the load current and control impact. The process of heat in heating electric traction motor is given.**

I. INTRODUCTION

A negative impact of heat electric traction motor on insulation is given [9]. Negative factors, which take effect on the state of insulation, are loss of energy, the instability characteristics of the traction motor due to changes in resistance when heated, reduced mechanical strength of conductors and insulation, reducing the life of the insulation.

An ability to withstand impact heating temperature for a long time is needed to ensure reliable operation of electrical insulation, comparable to the time of normal operation without unacceptable degradation of its properties.

Losses in electric and magnetic circuit are defined by the presence of heat sources.

II. HEATING AND COOLING OF ANGLING OF ELECTRICAL EQUIPMENT

Loss of energy during the course of an electric current is determined by:

$$A = I^2 rt; \quad (1)$$

Uniform distribution of current across the conductor section of its resistance in DC networks is identified:

$$r_{-} = \rho \frac{1}{S}; \quad (2)$$

Where:

$$\rho = \rho_0 (1 + \alpha\theta); \quad (3)$$

ρ_0 - specific resistance of the conductor material at temperature 0 C^o;
α - temperature coefficient of resistance, C^o ;
θ - temperature of the conductor, C^o;

In networks of the AC:

$$r_{\sim} = r_{-} k_p k_B; \quad (4)$$

Where:
k_p - factor of the surface effect;
k_B - factor of proximity of other parts of conductor;

Electric motor is emitting heat in the process of energy transformation. Heat quantity of time is:

$$dQ_1 = \Delta P dt; \quad (5)$$

Amount of heat returned to the environment over time:

$$dQ_2 = A \cdot \tau \cdot dt; \quad (6)$$

Engine temperature expedience of environmental temperature $°C$:

$$\tau = \vartheta_{dz} - \vartheta_{vd}; \quad (7)$$

The amount of heat spent on heating of the engine:

$$dQ_3 = C d\tau; \quad (8)$$

The equation of thermal balance:

$$dQ_2 + dQ_3 = dQ_1; \quad (8)$$

or, taking into account the heat transfer engine:

$$A \cdot \tau \cdot dt + C d\tau = \Delta P dt; \quad (9)$$

The process of heating with an electric motor $\Delta P = const$:

$$\tau = \tau_{stab}(1 - e^{-t/T_{const}}) + \tau_{sak} e^{-t/T_{const}}; \quad (10)$$

The time of heating the motor up to the usual temperature:

$$t_{stab} = \frac{C}{\Delta P}\tau_{stab} = \frac{C}{A} = T_{const}; \quad (11)$$

It is necessary to determine the temperature of the motor due to influence of temperature on condition of its insulation [6]. This shall be observed:

$$\tau_{\max} \le \tau_{pl}; \quad (12)$$

Calculations of heating of traction motors are made using definition of the excess temperature of windings of electric motors on the ambient temperature. The greatest excess in temperature of windings of electric motors on the air temperature when the maximum temperature not exceeding 40 $°C$ is defined table:

TABLE I
INSULATIONS CLASSES

Windings	B	F	H
Anchors	120^0	140^0	160^0
Pole	130^0	155^0	180^0

III. DETERMINATION OF THE EXCESS TEMPERATURE OF TRACTION MOTORS

An overheated traction motor depends on current changes and is determined:

$$\tau = \tau_\infty \frac{\Delta t}{T} + \tau_0 \left(1 - \frac{\Delta t}{T}\right); \qquad (13)$$

Cooling of traction motors is identified:

$$\tau = \tau_0 \left(1 - \frac{\Delta t}{T}\right); \qquad (14)$$

Where:
τ - the greatest excess in temperature
τ_∞ - heat setting, which takes into account the excess temperature of windings
τ_0 - the initial excess temperature of windings
Δt - time interval
T - heat setting, which takes into account the conditions of heating

The greatest value of excess temperature of traction motors is identified:

$$\tau_P = \tau \cdot K_{SZ} K_{NZ}; \qquad (15)$$

Where:
K_{SZ} - factor snow
K_{NZ} - bringing rate of exceeding the temperature of windings traction motors to the estimated temperature of the circumfluent air.

IV. THERMAL DETERIORATION OF INSULATION

Materials used for insulation, almost inert, but with increasing temperature in these materials have arisen or drastically accelerates chemical reactions, leading to a change in the physical properties of materials making up the insulation, and as a consequence, the deterioration in the quality of insulation in general [9]. This process is called thermal aging of insulation.

The rate of thermal deterioration of insulation is determined:

$$v = v_0 e^{-W_A / kT}; \qquad (16)$$

Where:
v - the rate of chemical reaction
W_A - activation energy
k - Boltzmann constant
T - absolute temperature

The service life of insulation at various temperatures to determine:

$$\frac{\tau_1}{\tau_2} = 2^{-(T_1 - T_2)/\Delta T}; \qquad (17)$$

Where:
τ_1 - the service life of insulation at a temperature of
τ_2 - the service life of insulation
T_1 - temperature insulation, C^o
T_2 - temperature insulation, C^o
ΔT - increasing of temperature, which halves lifetime of the insulation, C^o.

During the insulation of electrical equipment is exposed to various stresses.

With aging of insulation under the effect of mechanical load life of insulation to identify:

$$\tau = \tau_0 \exp\left(\frac{W - \gamma\sigma}{kT}\right); \qquad (18)$$

Where :
τ_0 - parameter he strength properties of insulation;
W - parameter the strength properties of insulation;
σ - mechanical stress in the material of the load;
γ -parameter of sight properties of insulation;
k - Boltzmann constant;
T - absolute temperature K^0;

The term of the full uniform wear insulation is

$$\tau_{tr} = \delta \cdot e^{-\alpha \vartheta_0}; \qquad (19)$$

Under the rule of "six degrees" an increase of temperature leads to a reduction in the lifetime of insulation:

$$\frac{\tau_{\vartheta_0}}{\tau_{\vartheta_0} + 6} = \frac{\delta \cdot e^{-\alpha \vartheta_0}}{\delta \cdot e^{-\alpha(\vartheta_0 + 6)}}; \qquad (20)$$

Depreciation for the insulation depending on time:

$$\xi = \frac{t}{\tau_{tr}} = \frac{t}{\delta} e^{\alpha \vartheta_0}; \qquad (21)$$

Relative utilization:

$$\frac{\xi}{\xi_{nom}} = \chi = e^{\alpha(\vartheta - \vartheta_0)}; \qquad (22)$$

Insulation is working in intricate conditions of exploitation. For this purpose it is necessary to limit the intensity of processes of leading to the aging of insulation, in other words, to reduce operating at insulation electrical, thermal, mechanical and other loads [9].

Electrical insulation deterioration occurs due to partial discharges [10]. To reduce their impact on the insulation, it is necessary to determine the condition of the choice of allowable operating voltage:

$$U_{pel} < U_{DI}; \quad (23)$$

Where:
U_{pel} - allowable working stress;
U_{DI} - the voltage at which there is partial level;
Allowable operating voltage is detected:

$$U_{pel} = U_{DI} - 3\delta; \quad (24)$$

Where:
U_{pel} - allowable working stress;
U_{DI} - the voltage at which there are partial level;
δ - the standard deviation;
The maximum tension in the insulating box is detected:

$$E_{DI} = \frac{U_{DI}}{d} k_n; \quad (25)$$

Where:
d - thickness of insulation;
U_{DI} -the voltage at which there are partial level;

V. THE PRACTICAL EXPERIMENT

For a practical experiment to study the influence of windings currents on temperature and heat of insulation from the braking current stand was used, consisting of the following sites [3]:

1. Industrial controller Simatic CPU224 Siemens
2. Ethernet interface module CP343-1
3. Analog-digital conversion module EM235
4. Temperature sensor KTY81-120
5. LOGO! Power supply block
6. Frequency converter Emerson Commander SK
7. Asynchronous motor КД-50-У4
8. Generator ПТ МЗ 236
9. Computer XP510
10. Protective machines GE G61

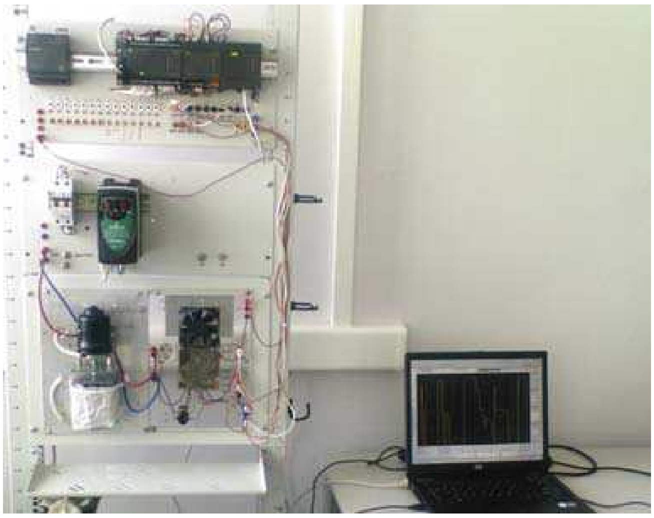

Fig . 1. General view of experimental stand based on the controller Simatic CPU224 Siemens

Software products needed for the research:

1. Step7 MicroWin 4.0.6 (Software for controllers Siemens 200-series)
2. PCAccess 1.0.3 (OPC Server Software for controllers Siemens 200-series)
3. CitectSCADA 6.10 (SCADA)
4. Microsoft Office Excel 2003

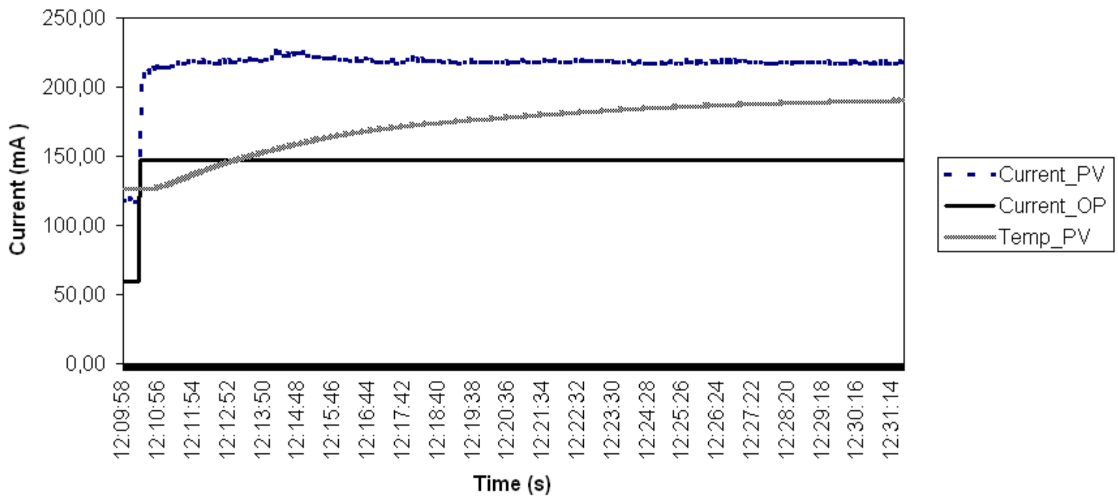

Fig. 2. Experimental graphs of temperature dependence of the motor current: "Current_PV" – current motor winding; "Current_OV" - impact direct of the controller; "Temp_PV" - motor temperature

Asynchronous electric motor of CD-50-U4 is driven via a frequency converter Emerson Commander SK 0.25 kW (0.33 to 200HP) 400V. As the load on the engine generator set AC PT MH 236. Modes and the trajectory of the engine braking take frequency converter Emerson Commander SK, which is controlled by control signals from the controller Simatic CPU224 Siemens.

Direct to the impact on industrial controllers Simatic CPU224 Siemens recorded out using software Step7 MicroWin 4.0.6, PCAccess 1.0.3, CitectSCADA 6.10 (SCADA), recording the measurement data using Microsoft Office Excel 2003. The work of the software carries out a laptop computer.

The relationship between the computer and industrial controllers Simatic CPU224 Siemens provided Ethernet interface CP343-1 module and analog-digital conversion EM235.

Dependence temperature changes of electric current recorded temperature sensor KTY81-120. Scheme lie low voltage industrial 220 v power supply through the LOGO! Power supply block and is protected by automatic circuit breakers GE G61.

The values of currents and temperature are presented in the trend in mA, and hail, for the calculation of their need to be translated into engineering units range 200-32000 (for current) and the range of 8832-32000 (for temperature), to purchase blocks of the PID regulator controller.

VI. CONCLUSIONS

In this paper dependence of temperature on the current engine load and exposure systems is investigate. The negative effects of heating electric motor on its insulation are provided.

Graphs of temperature dependence of the growth engine of the load current are given.

Heat insulation of electric motor windings to a temperature exceeding the acceptable cause of premature aging, loss of insulation properties and can lead to engine failure.

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