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TRANSLATION

PROBLEM OF RELIABILITY OF ELECTRIC MOTORS

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Problem of Reliability of Electric Motors[1]

by

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Studying the Remunerativeness of Motors. When planning a series or individual electric motors consideration should also be given to optimum commensurate, on one hand, expenditures for the manufacture of K_{d2} motors[2], determined basically by the intensity of the active parts, and on the other hand, directly depending upon them: cost of repairs

$$C = C_{p0}\frac{S}{S_0}\left[\text{rubles/year}\right]$$

cost for maintenance

$$C_c = C'_c + C''_{c0}\frac{S}{S_0}\left[\text{rubles/year}\right]$$

expenditures, due to the "disappearance" of motors in national economy because of their structural imperfectness

$$K_1 = K_{10}\frac{S}{S_0}\left[\text{rubles}\right]$$

cost of losses in electric power in motors and depending upon their additional losses in electric power system without expenditures for depreciation and fuel

$$C'_3 = 0.25\, R_d \frac{\eta_2 - \eta_1}{\eta_1\eta_2}\beta h_d\, C_3\left[\text{rubles/year}\right];$$

cost of electric energy C_3, rubles/kw.hr; cost of electric energy without consideration of expenditures for depreciation and fuel $C'_3 = 0.25\, C_3$; additional expenditures for the construction of electric power stations, substations and networks, necessary for generating, transformation and distribution of electric power, lost in motors,

$$\Delta K_3 = R_d \frac{\eta_2 - \eta_1}{\eta_1\eta_2}\beta \frac{h_d}{h_3} K_3\left[\text{rubles}\right];$$

additional expenditures for the construction of fuel installations, necessary for compensating the expenditures on electric energy, lost in the motors,

1. Completion. Beginning see in journal Élektrichestvo, 1961, No. 11.
2. Coefficient K_{d2} includes also conjugated additional capital expenditures in electrotechnical industry, metallurgy etc.

$$\Delta K_T = R_d \frac{\eta_2 - \eta_1}{\eta_1 \eta_2} \beta^{h_d} E_T K_T [\text{rubles}];$$

annual cost of conductor (wiring) materials when manufacturing motors

$$M_d = M_{d0}\left[\frac{(1-\eta_1)\eta_2}{1-\eta_2 \eta_1}\right]\left[1 - 2.5(\eta_2 - \eta_1)\right] [\text{t/year}]$$

and inversely depending upon them costs of these materials during repair and maintenance of the motors

$$M_p = M_{p0} \frac{S}{S_0} [\text{ t/year}];$$

$$M_c = M'_c + M''_{c0} \frac{S'}{S_0} [\text{ t/year}];$$

additional expenditures of conductor materials in networks of general and local use and at electric power stations due to excess losses in electric power in motors

$$\Delta M_3 = \alpha_1 M_d \frac{\eta_2 - \eta_1}{\eta_1 \eta_2} \beta [\text{t/year}];$$

ratio of equivalent weight in copper of the conductor materials, consumed by electric power stations and energy systems, to the weight of conductor material in electric motors α_1; expenditures at electric industry plants during the introduction of new series of motors K_3 [rubles]; expenditures and loss in national economy due to change in installation dimensions of new motors K_M [rubles].

The selection of final data about the magnitude of temperature rises and reserves of reliability in electric motors should be carried out on the basis of technical-economical calculations, on the basis of operational experience.

The conclusion about the remonerativeness of the developed motors can be made by comparing various calculated expenditures (P_3) by studying equation

$$P_3 = \frac{C_p + C_c + C_p + C''_3 + K_d - \Delta K_3 - \Delta K_T + K_M + K_p + K_1}{T_1} [\text{ rubles/year}]$$

for the minimum. It is advisable to express the values P_3 and their components in the function of motor efficiency or in the function of motors placed in capital repair (S) The standard service life is recommended as equalling 8 years[2].

2 Basic methodical conditions of technical-economical calculations in Power Engineering Elektrichestvo, 1959, No. 10.

The expenditures on conductor materials can be investigated by equation

$$P_{м}=M_{д}+M_{р}+M_{с}-\Delta M_{э}\ [m/zod]. \quad (1)$$

Investigation of equation (1) showed that a considerable increase in weight of conductor materials in motors is absolutely profitable.

Urgent Measures. Below are discussed measures, allowing to sharply increase the reliability of manufactured motors. These measures have been checked on a set of motors of one metallurgical plant, where their realization has increased motor reliabilit by many times.**

It is necessary to remove from industry motors of the single series A and AO and abstain from introducing into industry motors of the new single series A2 and AO2 fr the third to the sixth overall dimension inclusively as less reliable, unprofitable under conditions of national economy power indices.

Instead of the mentioned motors it is advisable to furnish users with presently manufactured so-called textile AOT or AO2T motors, having much higher power characteristics and reliability.

It is necessary in all series asynchronous motors of general designation, crane-metallurgical, explosion safe etc. to reduce the thermal stress of active parts by raising the class of insulation by one degree, not changing their standard capacity.

This measure is recommended first of all for crane-metallurgical DC series DP motors, roller conveyer series AR motors and explosion-safe motors.

Planning of motors with higher reliability. When designing new motors, for the purpose of assuring required reliability and to increase the level of energy characteristics it is necessary to do the following.

On the basis of native and foreign experience it is necessary that general purpose DC and AC motors with a capacity of from 2.5 kw and higher should contain reliability

** Exported from the USSR electric motors are distinguished by high reliability.

reserves with a coefficient, equalling 1.15. For motors with a capacity of up to 2.5 kw the reliability coefficient should be accepted as equalling 1.25.

During long lasting loading of motors equal to the product of rated power or coefficient of reliability, heating of the windings and parts of the motor should not exceed a maximum value, established by GOST for corresponding classes of winding insulations.

Independent from the fulfillment of these instructions to create the necessary reliability reserves the permissible heating of all windings and other parts of series motors, used in industry, construction, communal and agricultural undertakings at rated power, it should be below the maximum permissible values of heating motor windings, established by GOST, by the following value: a) for class A, E and B insulations - by 15°C; for class F - by 30°C; c) for class H insulations - by 50°C.

Maximum values of temperatures excesses, established by GOST, are permissible only for certain special motor constructions, especially designated for short service lives and low number of working hours per annum.

The high values of starting currents in motors reduce their reliability as result of considerable mechanical and thermal stresses originating during the starting.

Consequently the stable short circuit current in the stator winding of asynchronous motors with short circuited rotoe in braked state at rated frequency and network voltages should not exceed 6I rated, and for explosive safe motors with shorted rotor at the mentioned conditions $5.5I_{rated}$. For synchronous motors is necessary to limit the short circuiting current at above mentioned conditions at a capacity of up to 100 kw with a six-fold value of the rated; from 100 to 1000 kw - 6.5 fold and at a capacity of over 1000 kw - by a seven-fold value.

The "plus" tolerance + 15% to exceed the actual short circuit current over the calculated, permissible by GOST 183-55, should be annulled.

In conformity with the positive native and foreign operational experience it is necessary to limit the intensity of the calculated adiabatic temperature rise in the stator windings during braked state of asynchronous motors with shorted rotor and synchronous motors on the following level: a) at class A and E winding insulations - 3.5°C/sec; b) at class B and F winding insulations -4.5°C/sec; at class winding insulations - 5°C/sec.

It is necessary that the Committee on Standards at the Soviet of Ministers USSR should reaxamine and expend the efficiency scale for AC and DC motors and the capacitance coefficient for AC motors of all capacitances and designations, having established the power characteristics of motors on a much higher level, assuring their national economy profitableness.

From the state standard (GOST) should be eliminated points and remarks allowing during the use of greater "minus" tolerances to design and manufacture motors with reduced energy characteristics as compared with the ones indicated in standard scale.

Considerable losses in power in active steel of magnetic drives of motors with consideration of multiplication of losses in electric power systems absorb up to 2% of the entire electric power generated in the USSR. To "eliminate" these losses from motors is necessary forced ventilation, in turn considerably exceeding the non-productive losses in electric power in national economy.

In connection with the indicated one of the important trends of improving motors is the reduction in constant losses and heating levels of active steel by using special electrotechnical steel with low specific losses, and also by reducing the thickness of active steel sheets of magnetic drives (circuits) and losses for ventilation of machines.

To avoid break down of squirrel cafes of asynchronous and synchronous motors it is necessary to limit their heating within the following bounderies: a) during starting (aluminum cage) - 200-250°C; b) in braked state (aluminum cage) - 300-400°C; c) when starting (copper or brass cage)- not more than 300°C.

Rules Governing the use of Motors. To regulate the use of motors it is necessary to fulfill the following measures.

AC motors of single series A, AO, AOT or A2, AO2, AOT2 should not be accepted for mechanisms with repeated-short lived operational condition with connection frequency, exceeding 150 v per hr regardless of the flywheel moment of the mechanism. The attention of constructors and users should be called to the fact that these series of motors by the mechanical strength of the components and by their construction does not meet the operational conditions at much connection frequency.

The use of AC motors in explosive protected utilization at a connection frequency exceeding 200-250 v per hour is prohibited.

The use of AC electric drives with crane-metallurgical motors with phase and short circuited rotors at a connection frequency of more than 400 v per hr should be prohibited. At greater connection frequency the use of DC electric drives should be recommended.

The use of contactor-rheostat control of DC motors should be limited by a connection frequency equalling 800 per 1 hr. At a much higher connection frequency should be recommended the use of a rheostatless control system (URV-D and others) as assuring a more reliable and economical performance of motors.

Taking into consideration the strained operation of machine installations in the USSR and the considerable load of a majority of motors, working in repeated short conditions, the conditionality and inaccuracy of the methods of dimensioning the capacitances of these AC motors, as well as the considerable number of errors of machine construction plants and planning organizations when selecting these motors with reduced required power, for industrial application instead of rated working conditions with PV, equalling 15, 25 and 40%, it is necessary to define working conditions with PV= 25, 40 and 60°. The working conditions at PV=15% should be eliminated. The basic working condition for motors with repeated-brief working conditions should be the condition with PV = 40%. Nonpermissible should be considered the employment of protected series A, A2, P and others motors in workshops of industrial workshops containing considerable amounts of dust (regardless of its natura), emulsion vapors, caustic volatiles, as well as for outside installations.

Considering the mass nature of employing motors in conditions of brief temperature rises of the surrounding medium to above nominal calculated (southern and south eastern regions of the USSR, hot workshops etc) attention should be called toward the necessity of strictly considering the temperature of the surrounding medium, not permitting the use of motors for full rated power in all instances, when the temperature of the surrounding medium does only briefly exceed the nominal calculated temperature 35 or 40°C), for which the motor is intended.

Overloading motors in operation results in rapid failure of same, because the service life of motor windings decreases inversely proportionaly approximately to the eighth power of the load above the specific value. For presently manufactured motors this value at class A and E insulations of windings constitutes about 80% of the rated power, and at a class B insulation - 90%.

This investigation of operational reliability problems and the level of energy qualities of electric motors appears to be only the setting of the problem, but by far not its resolution.

The urgent need of raising the national economy remunerativeness of electric motors is evident from the following indices of the program of the Communist Party USSR. : " The achievement in the interest of society of maximum results at the least expenditures - the immutable rule for building our economy " and "the Production quality of Soviet Enterprises should be Considerably Higher than at the best capitalistic enterprises ".

Appendix. Certain Data on Electromotor Supply in the USSR[3]

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3. Calculated on the basis of data published in capitalistic press.

1. Total number of motor with a capacity of over 0.6 kw, manufactured in 1960 - about 3 million units.

2. Total power of motors (capacity of each one over 0.6 kw), manufactured in 1960 - about 25 million kw.

3. Total cost of all motors with a capacity of over 0.6 kw, established in national economy of the USSR (1961 prices without consideration of depreciation) - about 1.45 billion rubles.

4. Total cost of all motors with a capacity of over 0.6 kw, manufactured in 1960 - about 0.3 billion rubles.

If we base ourselves on the general data concerning the number and capacitance of motors, established in the national economy of the USSR, and also upon the basis of operational data, then the expenditures and loss because of their insufficient reliability and low power characteristics in 1960 were approximately as follows:

1. Total number of all motors with a capacity of more than 0.25 kw, which went for capital repair in 1960 - about 2.75 million units.

2. Total power of all motors (capacity of each one over 0.6 kw) which went into capital repair in 1960 - about 19 million kw.

3. Total number of operational personnel, occupied in repair and maintenance of motors in industry of USSR in 1960 - about 350 thousand people (of whom 10% was engineering-technical workers).

4. Total operational expenditures in 1960 for repair and maintenance of motors, loss in their stoppages, loss due to excessive manufacture of motors with insufficient reliability and expenditures for construction and equipping electro repairs shops and plants - about 1.2 billion rubles.

5. The average weighed efficiency of motors with a capacity of over 0.6 kw, working in the national economy of the USSR, about 87%.

6. Losses in electric power in motors and the losses in power generating systems

depending upon them, including the losses for natural needs of electric power stations[4]

in the year 1960: a) in kw/hr - about 30 billion; b) in rubles - about 0.36 billion; c) in percentages of generated electric power - about 10.

7. The power of electric stations, working in 1960 only to cover the losses in motors, - about 6.5 million kw.

8. Cost of electric power stations, substations and general and local networks, which generated, transformed and distributed electric power, consumed in form of losses in motors - about 0.6 billion rubles.

10. Amount of copper, consumed for repair of motors - about 25 thousand tons.

11. Manufacturing losses (for all types of industrial productions) due to motor stoppages - 0.25 - 0.5%.

Upon an increase in the average weighed efficiency of motors engaged in industry from 87 to 92% in 1965, as is evident from fig.1-3*** the following results will be attained:

1. Cost of motors of general capacity of 165 million kw rises by 2.18 billion rub.

2. Cost of equipment of electric stations, substations and general and local network will reduce by 0.83 billion rubles.

3. Cost of equipment for fuel enterprises will decrease by 0.62 billion rub.

4. Expenditures for repair and maintenance of motors will decrease by 1.15 million rub/annually.

5. Economy on electric power will be 20.8 billion kw.hr/year.

6. Number of personnel, working on repair and maintenance of motors, will be reduced to 256 thousand people.

7. Economy in conductor materials for this time with respect to copper equivalent will be no less than 100 thousand tons.

4-Part of these losses belong to losses in motors.
*** Fig.1-3 placed at the beginning of the authors report see Elektrichestvo 1961, No.11

8. Economical effectiveness at a service life: a) T = 1 year = 0.42 billion rub; 2) T = 4 year - 0.96 billion rub/annually; c) T = 8 years - 1.16 billion rubles/annually.

As is evident from the above given data, as result of insufficiency in operational reliability and low power characteristics of motors the national economy bears a considerable loss.

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