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OPERATING MODES POWER SUPPLY MOTOR-FAN ON DIESEL LOCOMOTIVES FROM TRACTION SYNCHRONOUS GENERATOR

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Summary. The analysis of the power modes of asynchronous motor fans traction from the synchronous generator, which working the locomotive in service.

Keywords: asynchronous motor fans, synchronous generator, locomotive.

INTRODUCTION

On diesel locomotives type 2TE116 power asynchronous motor fan (AMF) of cooling devices is carried out by the traction of a synchronous generator (TSG), which is also a load of traction rectifier unit (RU) and the traction motors (TD). TSG voltage at each position of the controller driver varies depending on the current generator according to the external characteristics of TSG + RU [Zakharchuk 1998]. Current TSG is determined by the profile path, weight, train speed. Thus, the condition of the train eventually determine the voltage and frequency on the stator AMF. Fig. 1 shows the range of values of phase voltage U_p TSG ГС-501A of the frequency f (a, b, c, d) and the voltage ml required for the optimal values of efficiency asynchronous drive with ventilatory load, according to law $U/U_r = (f/f_r)^2$.

OBJECT OF RESEARCH

Objects of researching are asynchronous motor-fans installed on cooling devices the locomotive 2TE116, with changing phase voltage and frequency of the traction generator.

PURPOSE OF RESEARCH

The purpose of research was to determine the relationships between the outer and the rated power of asynchronous motor-fan in operating modes. Objects of study are.

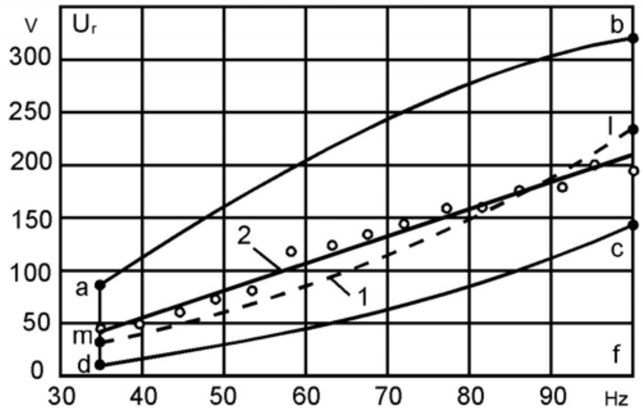

Fig. 1. Range of phase voltage U_p of the traction generator ГС-501A (a, b, c, d) of the frequency f : 1 – of the frequency optimal law of supply for the AMF; 2 – average operational values U_p

RESULTS OF RESEARCH

Experience in operating diesel-powered 2TE116 AMF from TSG proves that if a motor with fan load stands at bench trial power modes corresponding to points ***b*** and ***c*** (fig. 1), the electric reliability in operation is ensured. In this case, to ensure efficiency in the AMF point 10 requires an unsaturated magnetic system in the rated mode ($f_r = 100$ Hz, $U_r = 400\,V$), induction in the air gap must not exceed 0.65 Tesla. To validate AMB at ***b*** to inflate the bounding power of conventional short-circuited AMF 1.5 times. Hence the linear current load in the rated mode should be selected in 1.5 times less. With the overall power of serial motor-fan AMF37 equal to 37 kW on the locomotive 2TE116 allowable load on the shaft at rated speed 24 kW, i.e., at 1.54 times smaller.

Fig. 2 shows the histogram of power modes serial AMF in the operation of the locomotive 2TE116 № 400 in the South-Eastern Railway (depo registry Elets) within 60 hours (phase voltage, frequency, power).

According to the results of operational tests are constructed average operational values of phase voltage at the AMF (fig. 1, line 2) and histograms of frequency distribution voltage (fig. 3 a) and relative power $P'_2 = P_2 / P_{2n}$ in the fan shaft (fig. 3, b). According to the analysis of operating conditions power AMF (fig. 1-3) are defined average operational values of supply frequency $f_{aop} = 60\,Hz$, voltage $U_{aop} = 110V$, power at the shaft motor-fan $P'_2 = 0{,}32P_{2r}$, which suggests that the AMF work with power mode and significantly below rated load ($f_r = 100\,Hz$, $U_r = 230V$).

When TD powered from the TSG via the RU voltage curve, the supply AMF differs significantly from the sinusoid, which results in the appearance of higher harmonics in the voltage curve TSG [Kolesnik 1978].

Determine the impact of higher voltage harmonics on the characteristics of TSG AMF in operating conditions of the locomotive. This is possible only after analysis of all possible modes of operation RU.

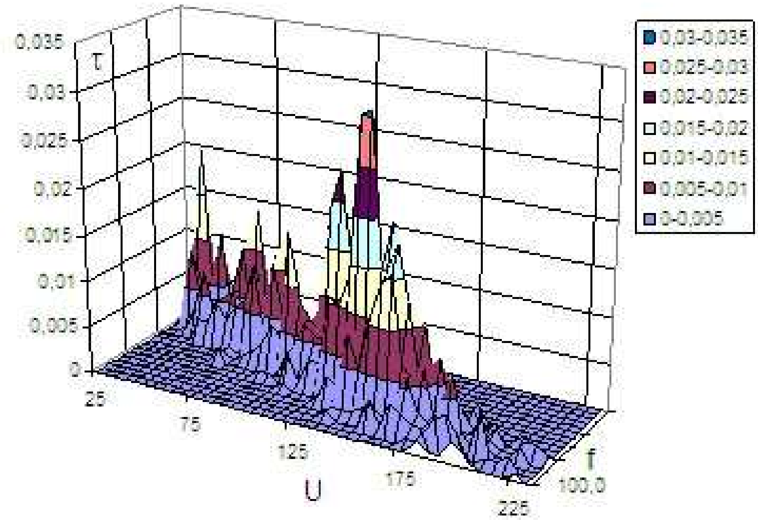

Fig. 2. Histogram of power modes
AMF in the operation of the locomotive 2TE116

In the six-phase system of TSG- RU work gates each three-phase rectifier bridge is determined by the same laws as in the work of an independent bridge.

Consider the operation of the rectifier load as a TD serial excitation with the inductive reactance comprising inductances of armature winding, extension and the main poles, which are assumed to be infinitely large.

There are three basic modes of operation of the bridge rectifier, which are characterized by different values of switching angles and delays.

Table 1 shows: the rectified voltage U_d from the e.m.f. phase $E_p = U_{1P} + j \cdot I_1 \cdot X$, rectified current I_d and switching reactance X; switching angles γ and delay α of E_p, I_d, X.

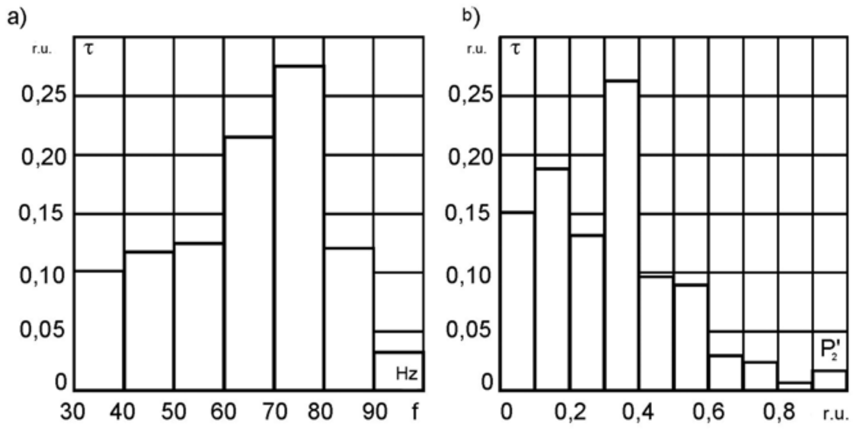

Fig. 3. Histograms of the distribution relative power P'_2 and frequency f AMF power, which operating the locomotive 2TE116

Expression table 1 on the external characteristics of fig. 4 define the modes of TSG–RU–TD for locomotive 2TE116. From fig. 4 that in operation the predominant mode of operation is the first RU $I_d < I = 4320\text{A}$ in the $\gamma < 50°$, the second mode is possible only briefly to disperse the train.

Phase power supply for TSG AMF $U_p = U_d / 2{,}4$ [Tolstov 1983].

Table 1. **Basic dependence characterizing the modes of operation rectifier in the TSG –RU–TD**

Modes of the rectifier	Formulas external characteristics and attitudes $\frac{U_d}{E_p} = f(\gamma,\alpha)$	The formulas for the angles and switching delay $\gamma,\alpha = \varphi(I_d, E_p)$
The first mode $\gamma \le 60°$ *P1*	$U_d = 2.34 \cdot E_p - 0.955 \cdot I_d \cdot X$; $\frac{U_d}{E_p} = 2.34\frac{1+\cos\gamma}{2}$	$\cos\gamma = 1 - \frac{0.818 \cdot I_d \cdot X}{E_p}$
The second mode $\gamma = 60°$ $0 < \alpha < 30°$ *P2*	$U_d = \sqrt{4.12 \cdot E_p^2 - 2.74 I_d^2 X^2}$; $\frac{U_d}{E_p} = 2.03[1 - \sin(\gamma - 30°)]$	$\sin(\gamma - 30°) = 1.41\frac{I_d \cdot X}{E_p} - 1$
Third mode $\alpha = 30°$ $60° < \gamma < 120°$ *P3*	$U_d = 4.05 \cdot E_p - 2.87 \cdot I_d \cdot X$; $\frac{U_d}{E_p} = 2.03[1 - \sin(\gamma - 30°)]$	$\sin(\gamma - 30°) = 1.41\frac{I_d \cdot X}{E_p} - 1$

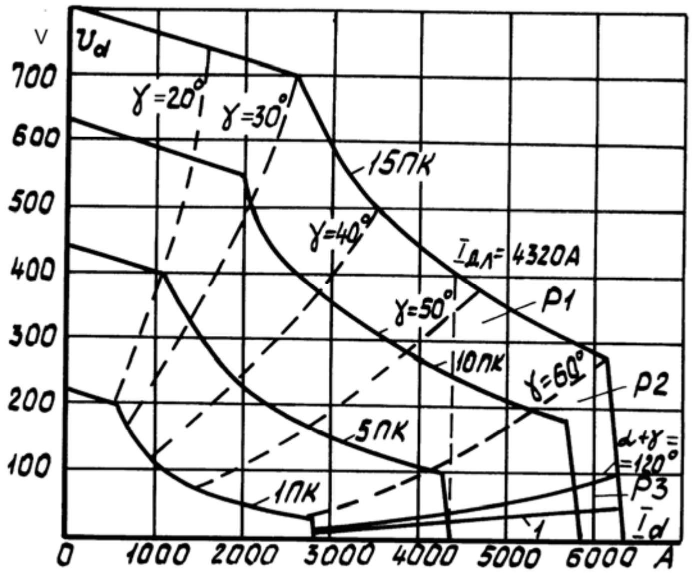

Fig. 4. Modes of TSG-RU-TD: 1 – limitation on chaining

In the voltage curve TSG working on a symmetrical load, no harmonics are multiples of three [Kostenko 1973]. Also, do not contain higher harmonics of even order, because TSG voltage curve is symmetric about the horizontal axis.

Determination of the 5-th and 7-th harmonics for voltage TSG possible by the Chebyshev method.

Results of the analysis of higher harmonic 5-th and 7-th order are shown in fig. 5, which implies that the operation at $\gamma < 50°$ 5-th and 7-th harmonic voltage TSG does not exceed 20, and 10% (respectively) the first harmonic.

AMF is calculated, as we know, a certain amount of the rated voltage at rated frequency. Are determined by the rated current, the dimensions and parameters of AMF. When connected to a machine sinusoidal voltage of its characteristics with sufficient accuracy are consistent with the calculation. Nonsinusoidal voltage at each of harmonics has to AMF its influence in accordance with its amplitude, a frequency of and the corresponding parameters of the AMF.

Determine the influence of higher harmonic voltage on the parameters of AMF

Electromagnetic moment from the higher voltage harmonics defined with respect to the rated point:

$$\frac{M_v}{M_r} = \frac{K_v^2}{v^4} \cdot \frac{K_{1S}}{\sqrt{v \pm 1}}. \tag{1}$$

where: K_v – coefficient characterizing the content of v-th harmonic voltage is determined for $v = 5, 7$ AMF of fig. 5, K_{1S} – the multiplicity of starting moment AMF.

From (1) it follows that with increasing harmonic order v, generated moment is significantly reduced under other equal conditions.

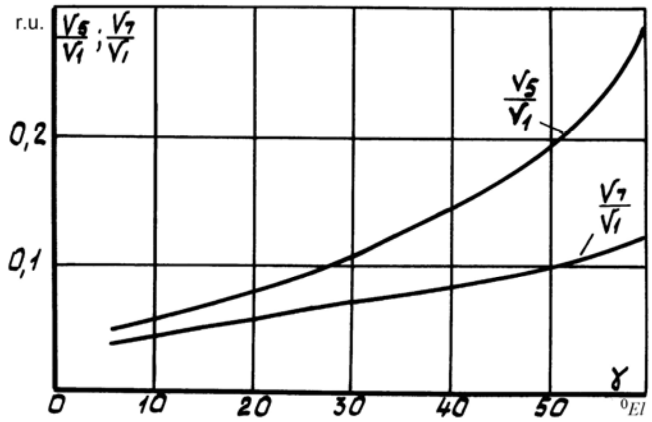

Fig. 5. The dependence of the harmonic 5-th and 7-th order voltage TSG from angle commutation RU

The ratio of total losses in the steel $\sum P_{st}$ to losses in the steel from the first harmonic P_{st1}

$$\overline{P}_{ST} = \frac{\sum P_{st}}{P_{st1}} = 1 + \frac{V}{V - V_2} \sum_{v=5,7...} \left(K' \cdot \frac{K_v}{v} \right)^2 . \tag{2}$$

The ratio of losses in the stator windings $\sum P_{1el}$ and rotor $\sum P_{2el}$ in relation to the losses of the first harmonic of AMF, when powered nonsinusoidal voltage:

$$\overline{P}_{1EL} = \frac{\sum P_{1el}}{P_{1el1}} = 1 + \sum_{v=5,7...} \frac{K_v^2}{v^4}; \tag{3}$$

$$\overline{P}_{2EL} = \frac{\sum P_{2el}}{P_{2el1}} = 1 + \sum_{v=5,7...} \frac{K_v^2}{v^4 \sqrt{v \pm 1}}. \tag{4}$$

From the expressions (2) - (4) it follows that losses in the AMF significantly decreases are in increasing order harmonics under other equal conditions.

If you do not take into account the effect of the magnetization loop, the power factor of AMF for the higher harmonics [Kostenko 1973]

$$\cos \varphi_v = \frac{r_1 + \frac{v r_2'}{v \mp 1}}{\sqrt{\left(r_1 + \frac{v r_2'}{v \mp 1} \right)^2 + v^2 \left(x_1 + x_2' \right)^2}} . \tag{5}$$

This formula shows that the $\cos\varphi$ is very low, i.e. currents produced by the higher voltage harmonics are almost purely inductive. Correspondingly, one can assume that the influence of higher harmonic voltages on AMF, which powered by TSG is equivalent to an increase in the inductances x_1 and x_2' with all its consequences - a decrease in $\cos\varphi$, η and $M_{\max}$. Moreover, the influence of non-sinusoidal voltage effect is relatively small, even with a significant distortion of the voltage curve. For example, if the amplitude of the fifth and seventh harmonic voltages on the AMF is 29% and 12% of the amplitude of the fundamental harmonic (fig. 5), which powered by TSG, which corresponds to short-term operation of the locomotive (fig. 4), while $\cos\varphi$ decreased is estimated at 2%, compared with $\cos\varphi$ at sinusoidal voltage, coefficient of efficiency η 1%, which is unimportant, which powered by AMF TSG.

CONCLUSIONS

1. Which powered by the traction synchronous generator bounding units, overall power must be increased in 1.5-1.6 times in comparison with a rated capacity.

2. The actual operating power modes differ significantly from the rated modes: average operating the frequency $f_{aov} = 0.6 f_r$, voltage $U_{aov} = 0.48U_r$, power on the shaft of the motor-fan $P'_2 = 0.32P_{2r}$, therefore, for optimizing the design parameters of AMF is necessary to consider the operational modes of supply and AMF.

3. The influence of higher harmonic voltages on the AMF when powered by TSG decreases $\cos\varphi$ by 2%, coefficient of efficiency η 1%, which is unimportant which powered by AMF TSG.

REFERENCES

1. Zakharchuk A.S., 1998.: Power modes controlled asynchronous motor-fan of the traction synchronous generator for heavy-duty diesel pick-up / News Shidnoukrainskogo Sovereign University. - Lugansk. Vol. 5 (15). - p. 142-151.
2. Kolesnik I.K., Kuznetsov T.F., Lipevka V.I., 1978.: Power diesel locomotives to the ac dc / - M.: Transport - 149 p.
3. Tolstov J.G., Mostkova G.P., Korolev F.I., 1983.: Three phase semiconductors rectifiers. - Moscow: USSR Academy of Sciences - 428 p.
4. Kostenko M.P., Piotrowski L.M., 1973.: Electrical Machines. Part II. - L.: Energy - 648 p.
5. S.P. Filonov, A.I. Gibalov, V.E. Bykovsky, 1985. Locomotive 2TE116 / - M.: Transport - p.328.
6. Gervais G.K., 1984.: Industrial tests of electrical machines. - Moscow: Energiya - 346 p.
7. Ivanov-Smolensky A.V., 1980. Electrical Machines: A Textbook for universities. - Moscow: Energiya - 928 p.
8. Kopylov I.P., 1986.: Electrical Machines: A Textbook for universities. - M.: Energoatomizdat - 360 p.
9. Kopylov I.P., Goryainov F.A., Klokov B.K., 1980.: Design of Electrical Machines: A Textbook. Handbook for universities - Moscow: Energiya - 496 p.

10. Kopylov I.P., 1996.: Mathematical modeling of electrical machines. Moscow: Higher School - 318 p.
11. Zakharchuk I.A., 2007.: Analysis of the traction unit in operational mode with synchronous generators for traction and power of the locomotive / Visn. Shidnoukr. Nat. University. № 8 (114) Part 2 - P. 17 - 26.
12. Rudenko V.S., Senko V.I., Chizhenko I.M., 1978.: Converting equipment. Kiev, Highest School - 424 p.
13. Sipaylov G.A., Kononenko E.V., Ferrets G.A., 1987.: Electrical Machines (special rate). - M. Higher School - 378 p.
14. Treschev I.I., 1980.: Electromechanical processes in the AC machine. - L.: Energy. Leningr. Depart. - 344 p.
15. Wojciech A.A., Popovic A.N., 1983.: The method of analysis modes of asynchronous motor power of nonsinusoidal voltage In the book: Problems converter equipment. - Kiev. Institute of electrodynamics. - p. 251-254.
16. Kopylov I.P., 1980.: The use of computers in engineering - economic calculations (Electrical Machines): Textbook - M. High School - 256 p.
17. Zarifian A., Nikitenko A., Kolpahchyan P., Khomenko B., 1996.: Mathematical modelling of oscillatory processes in a traction drive with AC motors // Proceedings of the 2nd Europen Nonlinear Oscillations Conference. Prague. September 9 – 13 Vol. 2 - p. 269 - 272.
18. Kuzmich V.D., 1971.: Accessories locomotives and consumption of power / Accessories Locomotive Trudy MIIT. – M.: Transport. – Vol. 394 - p. 3-16.
19. Nekrasov O.A., Rachmaninoff V.I., 1977.: Rotational speed of the motor-fan and power savings / Electric and diesel traction № 3. - p. 44-46.
20. Zakharchuk A.S., 1999.: Managing asynchronous motor-generator electric locomotive fans / Visn. Shidnoukr. University. № 6 - p. 140-152.

ЭКСПЛУАТАЦИОННЫЕ РЕЖИМЫ ПИТАНИЯ МОТОР-ВЕНТИЛЯТОРОВ НА ТЕПЛОВОЗАХ ОТ ТЯГОВОГО СИНХРОННОГО ГЕНЕРАТОРА

Александр Захарчук, Игорь Бухтияров

Аннотация. Проведен анализ режимов питания асинхронных мотор-вентиляторов от тягового синхронного генератора при работе тепловоза в эксплуатации.

Ключевые слова: тяговый синхронный генератор, асинхронный мотор-вентилятор, тепловоз в эксплуатации.