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DIAGNOSING OF ELECTRO - MECHANICAL CONVERTERS BY USING A METHOD OF FREQUENCY MODULATION ANALYSIS

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Abstract

This paper describes methods for the diagnosing of aircraft electro-mechanical converters, used by the Aircraft Equipment Laboratory , Avionics Division , Polish Air Force Technical Institute (PAFTI). Each of them has been discussed on the basis of systematized, available theoretical knowledge verified by using results of the authors' laboratory research.

Especially is exposed the diagnostic method , elaborated by these authors and implemented under their supervision, based on measuring and analyzing the parameters of one of the components of the direct current pulsations. The method is called FAM-C (where FM stands for frequency modulation , A – alternating current, C – the method's development level). Also, a related method based on measuring and analyzing one of the components of DC pulsations , is presented. It is called FDM-A (where FM stands for frequency modulation, D – direct current, A – the method's development level) . Results of laboratory tests are also attached.

Possible using the converter groove pulsations during rotor's rundown phase after external feeding the excitation winding, has been also discussed – in this case DC motor turns into DC generator. This makes it possible to apply the FDM-A method. As DC generator usually shows a few times greater resolving power, it is possible to monitor mechanical elements which generate higher frequencies. To highlight the problem, have been discussed effects of physical phenomena which influence the forming of output voltage pulsation component of DC generators .

Keywords *: technical diagnostics , electro-mechanical converter , frequency modulation , FAM-C and FDM-A diagnostic methods , machine rundown phase.*

1. Introduction

Converter constitutes an electro-mechanical device which converts one kind of electric energy into another one. Onboard aircraft electric power converters serve to supply local electric power networks with alternating current [1]. The electro-mechanical converter is a set of two electric machines seated onto common shaft :

a) compound , separately excited DC motor,
b) synchronous generator [2].

The electro-mechanical converter converts 28 V direct current into the one-phase alternating current of 115 V and 400 Hz, the three-phase current of the line-to line voltage of 3×36 V and 400 Hz frequency, or a current of a special voltage and frequency.

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[1] In special installations , e. g. weapon systems , can be also met an output voltage of 10 kHz frequency of direct current with keying, and other ones as well. However they are not onboard electric power installations and this paper does not cover them.

[2] In certain designs two generators fixed onto common shaft are used, such as in PTO-1000/1500W converter.

The device is a secondary voltage source of great stability of parameters (as compared with that of the primary electric power source , i.e. onboard alternating current generator). To ensure stabilization of output voltage and frequency the so called control box is applied.

In modern aviation the application of electro-mechanical converters has been definitely left out because of their low energy efficiency, large weight and high level of noise. However on older types of aircrafts such converters are still in use. Simultaneously this is a simple assemblage of two electric machines. Rotors of the two machines have a common shaft whose ends are seated in two bearings. The mechanical simplicity of the converter's design makes it possible easily to identify failures of mechanical elements during its monitoring by means of the FAM-C method. The electro-mechanical converters constitute a small-size driving set which faces a.o. wear kinds typical for large machinery sets, such as assembling and wear defects.

The converters used in Polish Air Force aircrafts had not and have not any diagnostic devices [3] which could make it possible to monitor their wear progress - and in the opinion of these authors the portable measuring stands (i.e. a ground-based control board of electric power unit) fitted with indicating instruments : voltmeter, ammeter and frequency meter , cannot fulfil such function.

Theoretically , the most accurate information (in this case – diagnostic information) is gained directly from its source , but not from indirect agents as then the information may be very distorted. Hence it should be strongly stressed that a diagnostic system should be applied to make it possible to check current technical state of converters. It will be short- term forecasts.

Another problem constitutes long-term forecasts. They are more and more important in view of necessity to make savings in military aviation. Hence in practice , overhaul lives of a.o. converters are as a rule extended. Failures defined by servicemen as defects , e.g. of a radio receiver , really result from incorrect work of a converter, and inversely. In such situation it is urgent task to elaborate a precise diagnostic tool for making it possible to earlier assess technical state of converters and elaborate a long-term forcast (for 100÷200 h long flight). Such diagnostic systems should ensure the monitoring and comprehensive assessment of technical state of converters. Then the operation according to a current technical state will be possible – now it is run according to duration of operation time (acc. „ flying time hours" as well as acc. „calendar period").

In this paper the authors describe the investigations realized during their professional activity [4]on aircrafts , which make it possible to locate defects on the basis of parametric models at disposal, determined either in special standards or resulting from multi-year practical experience. The FAM-C method elaborated in the PAFTI plays here an important role.

Also, are described laboratory tests where determined defects were introduced and resulting changes in diagnostic parameters were measured. The tests have been aimed at determination of a comprehensive set of diagnostic levels for electro-mechanical converters of different types. Consequently, it can make it possible to elaborate field diagnostic testers being small, light and friendly in use. As assumed , both the FAM-C and FDM-A method have been comprehensively used [1, 2, 5, 6, 9-11, 13, 18], as well as the „classical" parameters of electric power quality [15] measured. Both the mechanical defects (state of bearings, assembling errors) and electrical defects (failures of filtering system, rotational speed stabilization system and generator's winding, worsening of comutation state of brushes of motor) have been located.

2. Frequency methods for testing aircraft converters - FAM-C and FDM-A method

The FAM-C method [1, 2] was elaborated in the 1990s in the PAFTI and has been still under systematic development. Shortly, it can be said that it is based on observations of dynamics of natural vibrations of particular units of a driving set . The synchronous generator converts mechanical natural vibrations into electrical vibrations. By analyzing changes in output voltage frequency

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[3] In the conclusions of this paper a preliminary design concept of such diagnostic device is proposed.

[4] Projects on extension of operating lives of aircrafts and those connected with investigations of aircraft accidents.

modulation it is possible to diagnose a driving set, as the run of changes of instantaneous frequency (of output voltage of synchronous generator) :

$$f_{\mathrm{i}} = f(t) = \sum_{j=1}^{j=m} 2\pi f_{ej}(t) \tag{1}$$

is a discrete representation of the run of angular speeds of particular units of the driving set :

$$\omega(t) = \sum_{j=1}^{j=m} \omega_{mj}(t) = \sum_{j=1}^{j=m} 2\pi f_{mj}(t) \tag{2}$$

where :

j – number of an observed subassembly or kinematic pair,

f_{mj} – frequency of mechanical vibrations , characteristic for a given subassembly or kinematic pair,

f_{ej} – frequency of electrical vibrations, which discretely maps frequency of mechanical vibrations , characteristic for a given subassembly or kinematic pair.

In the Laboratory of Aircraft Electric Power Equipment and Electric Drives , Polish Air Force Technical Institute , it is possible to carry out observation , by using the FAM-C method, of instantaneous values of output voltage on the plane (t, f_{i}) as well as to represent characteristic sets on the plane (f_{p}, ΔF). In view of that both the machines (generator and driving motor) are seated onto common shaft it is hard to expect many characteristic sets in the converter to occur. Due to a common nominal speed a defect , e.g. an eccentricity of generator rotor and an eccentricity of driving motor rotor, will be placed in the same characteristic set. Characteristic points of a skewness defect of both the machines [13] will be placed as a rule in another set than characteristic points of an eccentricity defect. The eccentricity defect will be characterized by a set of base frequency equal to the first harmonic of rotational speed of converter's rotor (Tab. 1 and 2) , and the skewness defect – that equal to its second harmonic. And, superposition of the both defects – that equal to to the first subharmonic of rotational speed.

3. Laboratory tests of converters with controlled defects, by means of FAM-C method

Tests of electrical parameters of converters having different controlled (introduced by researchers) wear levels of their electrical and mechanical elements , were performed. The tests were carried out both by using classical methods (fast Fourier transform) and novel ones (e.g. the FAM-C method). Real wear level was assessed by using mechanical measurements . The tests concerned the PAG-1F, PT-500 and PO-750 converters. The converters were adjusted to introducing controlled assembling errors (Fig. 1) : eccentricity, skewness of rotor rotation axis against stator symmetryaxis . One- and three –phase measurement systems (Fig. 2 and 3) made it possible to monitor the above specified assembling errors . The both measurement systems were described in detail in [3].

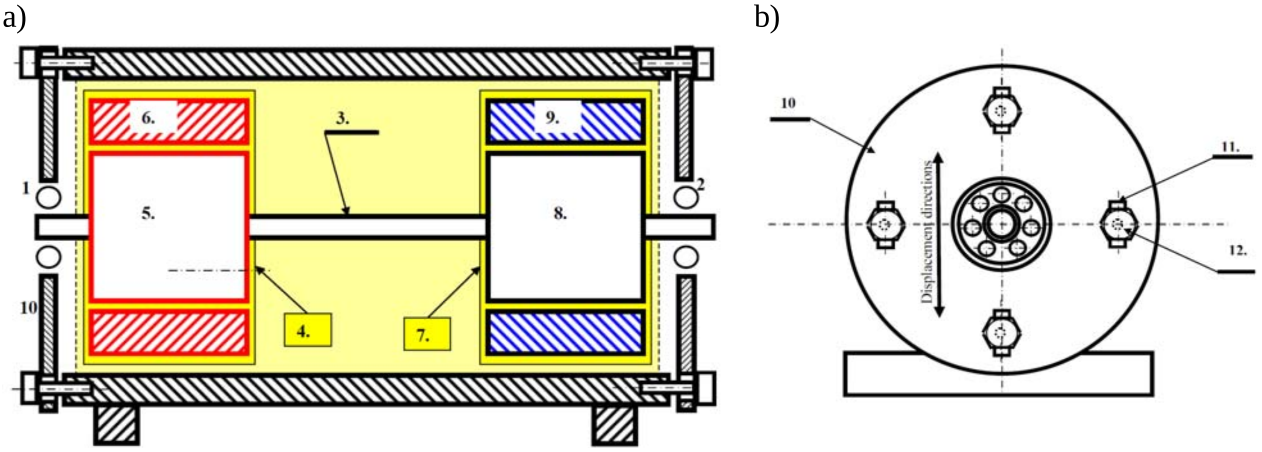

Fig. 1. Simplified assembly drawing of electro-mechanical converter adjusted (in PAFTI) to introducing controlled assembling errors : a) longitudinal section, b) view from the side of side cover bearing disc. 1, 2 – rolling bearing, 3 – shaft, 4 – DC motor, 5 – rotor of DC motor, 6 – stator of DC motor, 7 – AC generator, 8 – rotor of AC generator, 9 – stator of AC generator, 10 – bearing disc (side cover), 11 – vertically milled grooves, 12 – fasting bolt.

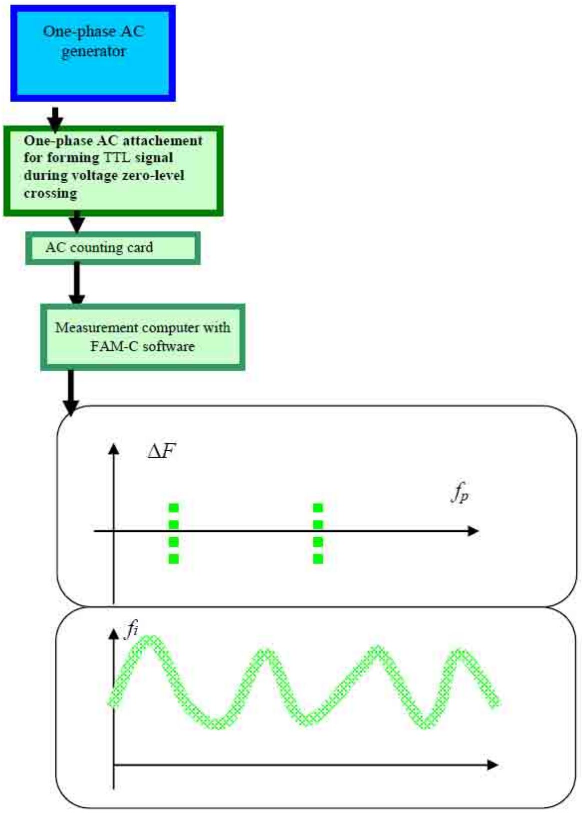

Fig. 2. Way of obtaining diagnostic signal from a tested one-phase converter (or generator) by using FAM-C method

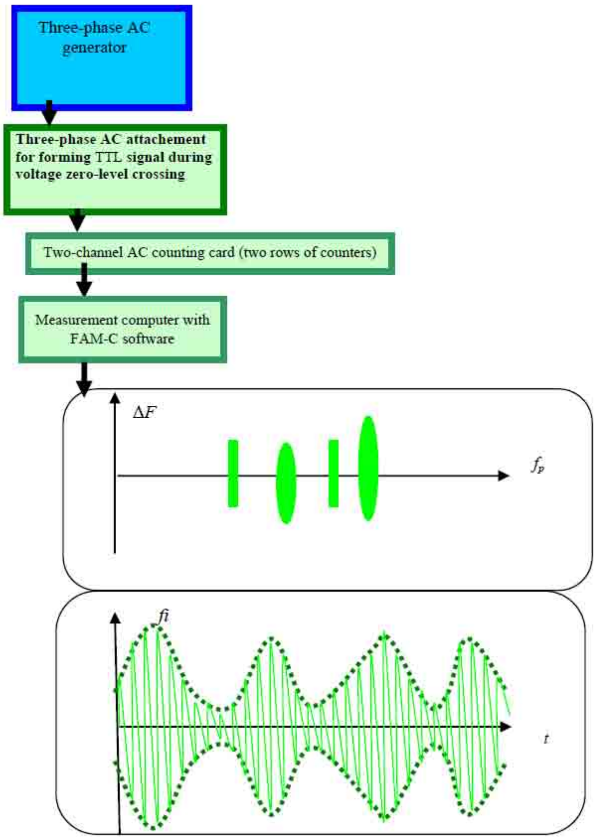

Fig. 3. Way of obtaining diagnostic signal from a tested three-phase converter (or generator) by using FAM-C method

Next, the tests of electrical parameters of converters having different controlled wear levels of elements, were performed. The tests concerned the following „defects" :

a) electrical ones – changes in brush pressure of electric motor,
b) mechanical ones – changes in geometry of position of rotor rotation axis against stator symmetry axis : change of skew angle, change of eccentricity value.

The tests were performed by using both classical methods (Fourier fast transform) and novel ones (e.g. the FAM-C method). Real wear level was assessed by using mechanical measurements. Detailed discussion is given in the successive chapter.

3.1. Lowered comutating brush pressure

The PAG-1F converter serves for electro-mechanical conversion of 28 V DC voltage into three-phase voltage of the 3×36 V effective line voltage at the frequency $f_{uN} = 400$ Hz. The converter is composed of two electric machines :

- DC motor,
- three-phase AC generator.

Observations made with the use of FAM-C method showed , in the initial state (i.e. before changing brush pressure) the fluctuations in running the instantaneous frequency $f_i = f(t)$, of the amplitude $A = 2\Delta F = 7{,}5$ Hz. The fluctuations were stable as regards both their amplitude and frequency (Fig. 5 and 6). The mean frequency level was equal to 431,25 Hz. The fluctuation frequency of the run $f_i = f(t)$ was equal to $f_p = 50$ Hz (Fig. 4). The images of $\Delta F = f(f_p)$ revealed also some characteristic sets of different f_p - values (Fig. 6).

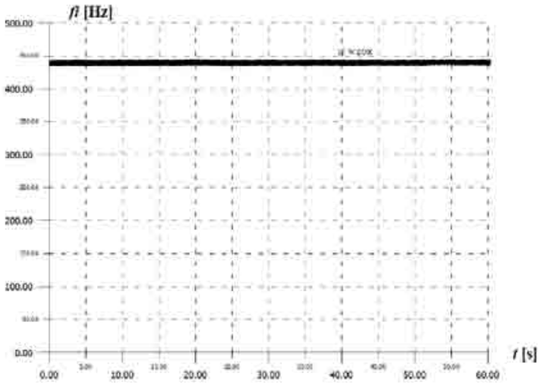

Fig. 4. Run of changes in instantaneous frequency of PAG-1F converter before changing comutating brush pressure of electric motor

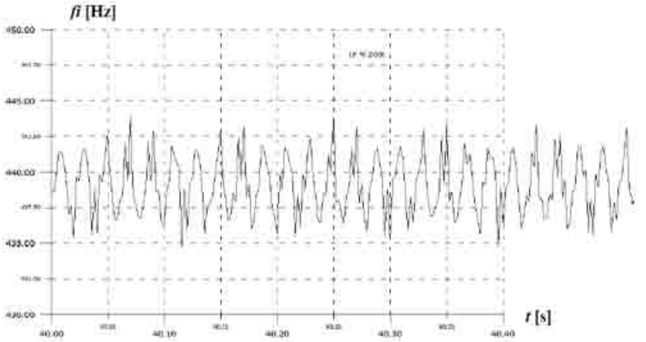

Fig. 5. Run of changes in instantaneous frequency of PAG-1F converter before changing comutating brush pressure of electric motor (initial state) – enlargement

In the **PAG-1F** converter, pressure of one brush was lowered - then increased sparking occurred under its operation. Mean frequency of initial voltage after failure decreases by abt. 50 Hz (it reaches the level of abt. 350 Hz). In the runs $f_i = f(t)$ the fast-changing component measured by means of the one-phase attachement FAM-C, shows the frequency of abt. 50Hz (Fig. 7 and 8). The slow-changing component is characterized by the deflection duration time t_{od} ~5÷10 s and the amplitude increase ΔF~3÷25Hz. Sudden „jumps" of frequency level of the amplitude ΔF = abt. 7 Hz , occur stochastically. In the run shown in Fig. 8 can be observed some „undercuts" which probably result from the edge catching of a brush of regular pressure on certain edges of comutator bars. The images $\Delta F = f(f_p)$ show decrease of f_p -values of particular sets and increase of height of characteristic sets (Fig. 9).

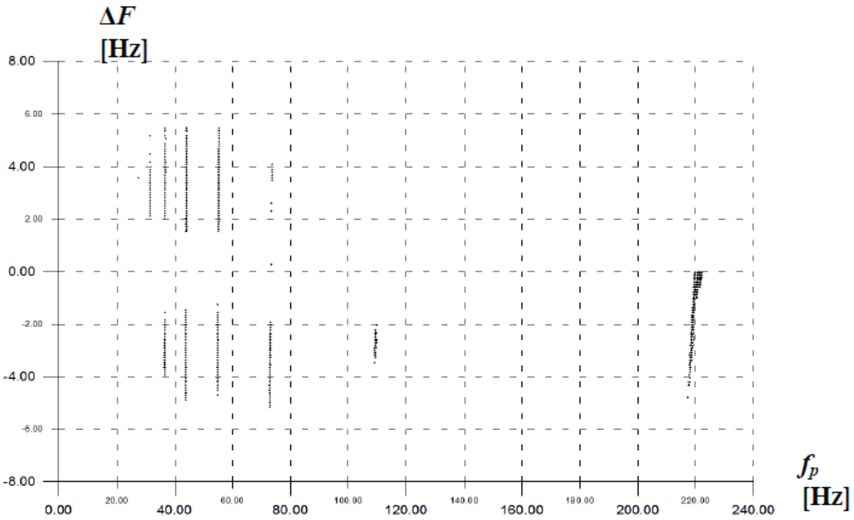

Fig. 6. Characteristic sets of PAG-1F converter before changing comutating brush pressure of electric motor (initial state)

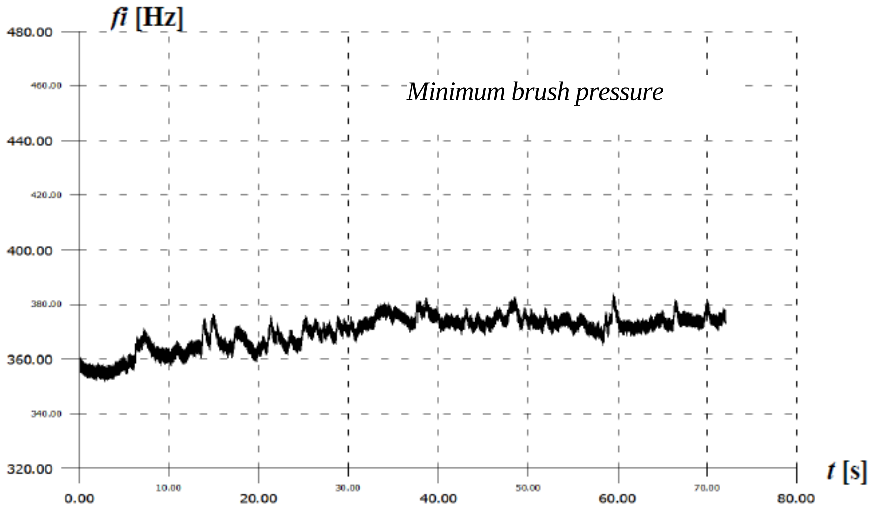

Fig. 7. Run of changes in PAG-1F converter's frequency at comutating brush pressure lowered below its permissible value

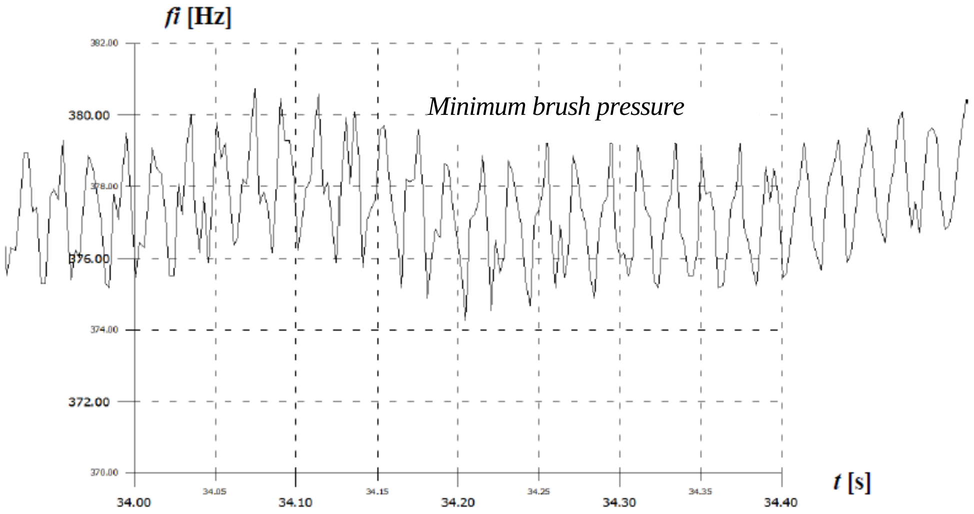

Fig. 8. Run of changes in PAG-1F converter's frequency at comutating brush pressure lowered below its permissible value - enlargment

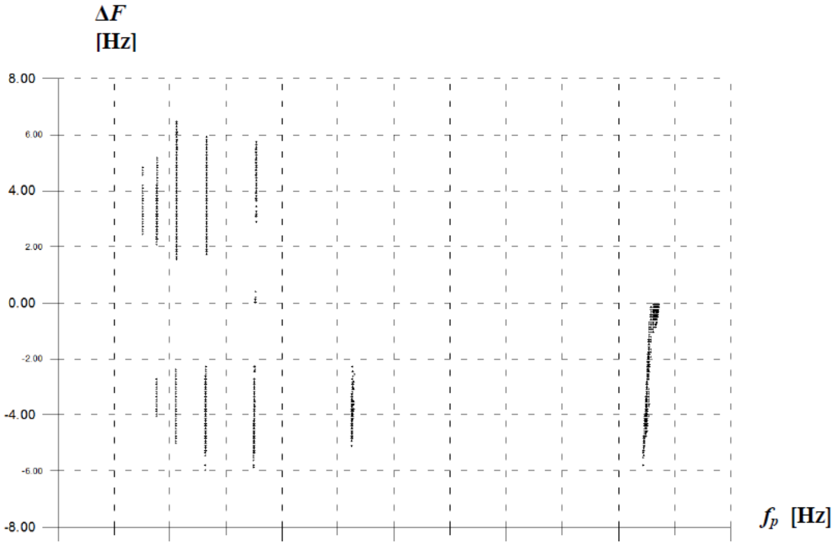

Fig. 9. Characteristic sets of PAG-1F converter at comutating brush pressure lowered below its permissible value

3.2. Skewness of rotor rotation axis against stator symmetry axis

The skewness was obtained by milling longitudinal, vertically orientated enlargement of assembly holes for blots fixing side cover (bearing seating plate) to cylindrical part of the machine. By displacing one bearing disc (side cover) upwards and the other downwards a measurable skew angle could be set.

For the PAG-1F converter before displacing its side cover **,** was obtained a run in which modulations of abt. 75 Hz frequency can be observed. They were located close to the first subharmonic of rated rotational speed , that shows that some small eccentricity and skewness in seating the rotor against stator took place (according to calculations the value of the skew angle in question amounted to about 0,0079 ^{o}) . In the case of skewing the rotor by the angle of abt. 0,04^{o} (Tab. 1, p. 6) the frequency of the second harmonic of rated rotational speed begins to dominate. The value of the fluctuation amplitude of the „run" of instantaneous frequency, increases from the level of ΔF = 4,11 Hz (0,95% in relation to the mean frequency value) to ΔF = 13,94 Hz (1,09%).

For the PT-500C converter before displacing its side cover **,** was obtained a run in which modulations of abt. 200 Hz frequency can be observed. They were located close to the first harmonic of rated rotational speed of converter's rotor , that shows that some small eccentricity and skewness in seating the rotor against stator took place . In the case of skewing the rotor by the angle of abt. 0,2^{o} (Tab. 1, p. 8) the frequency of the second harmonic of rated rotational speed starts to dominate. (Fig. 11). The value of the fluctuation amplitude of the „run" of instantaneous frequency increases from the level of ΔF = 0,17 Hz (0,04% in relation to the mean frequency value) to ΔF = 12,29 Hz (1,02%).

For the PO-750 converter before displacing its side cover **,** was obtained a run in which modulations of abt. 175 Hz frequency can be observed. This is close to the first harmonic of rated rotational speed, that shows that some small eccentricity and skewness in seating the rotor against stator took place . In the case of skewing the rotor by the angle of abt. 0,2^{o} (Tab. 1, p. 10) the frequency of the second harmonic of rated rotational speed starts to dominate. The value of the fluctuation amplitude of the „run" of instantaneous frequency increases from the level of ΔF = 0,24 Hz (0,067% in relation to the mean frequency value) to ΔF = 1,87 Hz (0,52%).

Because of not satisfying the Kotelnikov-Shannon condition, the above presented data should be taken only as a rough information - the assessment of relations between skewness and frequency modulation should be made with the use of the FDM-A method during machine rundown phase.

At increasing values of the skew angle between rotor rotation axis and stator symmetry axis it can be observed that the amplitude of modulation of the instantaneous frequency equal to the second harmonic of rotational speed, also increases. The amplitude of the modulations increases along with increasing values of the skew angle (Tab. 1).

In Tab. 2 are presented the values for classifying mechanical defects with respect to their size (A – very low wear, B – mean level of wear, C – high level of wear, D – very high level of wear, i.e. taking-out of service).

3.3. Eccentricity of rotor rotation axis against stator symmetry axis

Parallel displacement of rotor rotation axis against stator symmetry axis was made by using the vertically orientated, longitudinally enlarged by milling , assembly holes for bolts fastening side cover (bearing seating plate) to cylindrical part of the machine, prepared for realization of the preceding tests. By displacing both the bearing seating plates downwards a measurable eccentricity value could be set.

For the PAG-1F conveter before displacing its side cover**,** was obtained a run in which modulations of abt. 75 Hz frequency can be observed. This is close to the first subharmonic of rated rotational speed, that shows that some small eccentricity and skewness in seating the rotor against stator took place. In the case of setting the eccentricity value a = 0,2 mm (Tab.1, p. 11) the value of the fluctuation amplitude of the „run" of instantaneous frequency increases from the level of ΔF = 4,11 Hz (0,95%)

to that of 13,94 Hz (1,09%). For the PT-500C conveter before displacing its side cover**,** was obtained a run in which modulations of abt. 200 Hz frequency can be observed. This is close to the first harmonic of rated rotational speed, that shows that some small eccentricity in seating the rotor against stator took place and 200 Hz frequency occurred. In the case of setting the eccentricity a = 0,35 mm (Tab. l, p. 15) the value of the fluctuation amplitude of the „run" of instantaneous frequency increases from the level of ΔF = 0,17 Hz (0,04%) to that of 12,29 Hz (1,022%).

For the PO-750 conveter before displacing its side cover**,** was obtained a run in which modulations of abt. 175 Hz frequency can be observed. This is close to the first harmonic of rated rotational speed, that shows that some small eccentricity and skewness in seating the rotor against stator took place. In the case of setting the eccentricity a = 0,4 mm (Tab. l, p. 13) the value of the fluctuation amplitude of the „run" of instantaneous frequency increases from the level of ΔF = 0,24 Hz (0,067%) to that of 0,52 Hz (0,52%).

At increasing values of the eccentricity between rotor rotation axis and stator symmetry axis it can be observed that the amplitude of modulation of the instantaneous frequency equal to the second harmonic of rotational speed, also increases. The amplitude of the modulations increases along with increasing values of the eccentricity. (Tab. 2).

The values for classifying mechanical defects with respect to their size to particular diagnostic classes, are presented in Tab. 2.

4. Tests of the converters during their rundown phase

The rundown phase is an energy state of a driving set, in which the machine brought up to its rated speed, is deprived of external power supply . In this case two complexes of physical phenomena appear, namely :

a) **decreasing level of the rotational speed *n*** (usually quasi-fluent), along with time counted from the instant of stopping external power supply, of particular , mutually coupled kinematic pairs, through successive lower and lower rated speeds (Fig. 10) ; for each of the speeds different dynamic phenomena can be observed , a.o. occurrence of different local mechanical resonances (Fig. 11);

b) **decomposition of dynamics of driving set's motion** into kinematic links individually vibrating within constraints and limits resulting from their design.

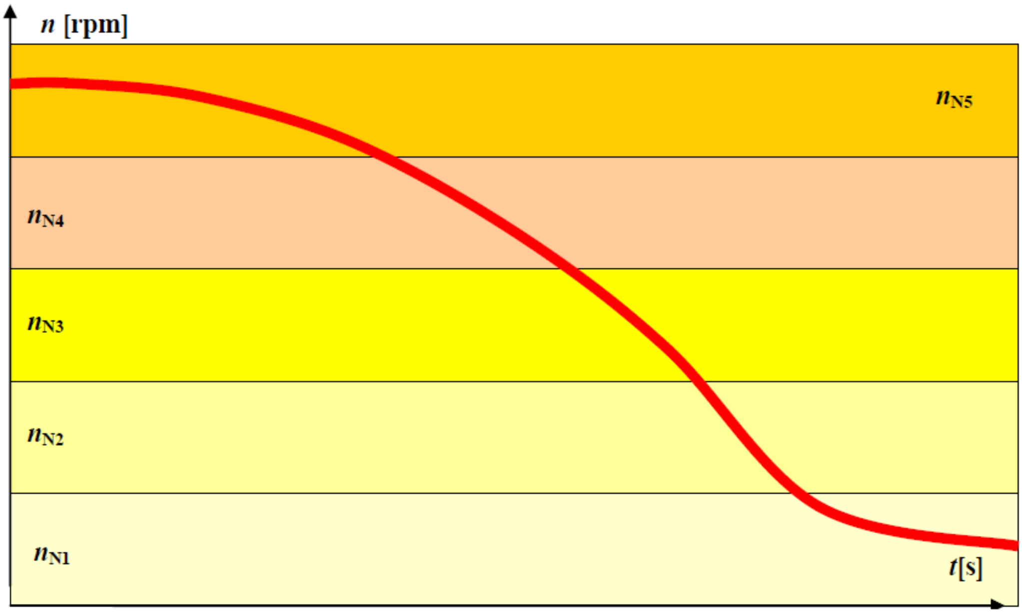

Fig. 10. Run of changes in mean rotational speed after switching-off power source, with marked bands of the rated speeds {nN1, nN2, nN3, nN4, nN5} – slow-variable component

Tab. 1. Statement of parameters of selected assembling defects of converters as well as parameters of their representation in electrical phenomena

No.	Type of converter	Value of linear displacement mechanically measured		Distance between supports	D_N	β	a	$f_{\max}$	$f_{\min}$	$f_{śr}$	ΔF	Parameters of defects according to electrical calculations	
		A_1	A_2	L								a	β
-	-	mm	mm	mm	mm	°	mm	Hz	Hz	Hz	Hz	mm	°
1	PAG-1F	0,3	0,2	145	55,5	0,19757	0,1	1290,32	1281,23	1285,5	9,09	0,0981	0,15506
2	PT-500C	0,35	0,35	203,3	69,3	0,19728	0	1224,36	1183,78	1203,2	40,58	0	0,65866
3	PT-500	0,35	0,35	203,3	69,3	0,19728	0	1212	1200	1203,2	12	0,1727	0,19478
4	PO-750	0,5	0,0	258	70	0,11104	0	356,57	354,7	355,84	1,87	0	0,08169
5	PAG-1F	0,01	0,01	145	55,5	0,0079	0,01	434,59	430,48	432,51	4,11	0,13185	0,2084
6	PAG-1F	0,3	-0,2	145	55,5	0,03951	0,5	1287,83	1273,89	1277,8	13,94	0,1513	0
7	PT-500	0,01	0,01	203,3	69,3	0,00564	0,01	402,58	402,41	402,49	0,17	0,00732	0,00825
8	PT-500	0,35	0,35	203,3	69,3	0,19728	0,35	1208,46	1196,17	1202,32	12,29	0,17709	0,19964
9	PO-750	0,03	0,03	258	70	0,01332	0,03	357,77	357,53	357,7	0,24	0,01174	0,01043
10	PO-750	0,5	0	258	70	0,11104	0	356,57	354,7	355,84	1,87	0	0,08169
11	PAG-1F	0,3	-0,2	145	55,5	0,03951	0,2	1287,83	1273,89	1277,8	13,94	0,15137	0,23925
12	PT-500	0,35	-0,35	203,3	69,3	0	0,35	1208,46	1196,17	1202,32	12,29	0,17709	0,19964
13	PO-750	0,5	-0,4	258	70	0,02221	0,4	338,7	338,18	338,58	0,52	0,02688	0,02387

Tab. 2. Statement of limit states obtained from the frequency analysis method

l. p.	Kind of defect	Class	PAG-1F			PT-500C			PO-750		
			ΔF	$f_{śr}$	f_p	ΔF	$f_{śr}$	f_p	ΔF	$f_{śr}$	f_p
			Hz	Hz	Hz	Hz	Hz	Hz	Hz	Hz	Hz
1	Lowered brush pressure	**A**	<10	>380	0,2 ÷ 0,02	<10	>380	0,1 ÷ 0,025	< 8	>390	0,1 ÷ 0,025
		B	10÷25	350 ÷ 380		10÷25	360 ÷ 380		8 ÷ 15	370 ÷ 390	
		C	>25	<350		>25	≤360		> 15	≤370	
2	Skewness	**A**	< 0,3%$f_ś$	-	400	< 0,3%$f_ś$	-	400	-	-	-
		B	0,3 ÷ 0,8%$f_ś$	-	400	0,3 ÷ 0,8%$f_ś$	-	400	-	-	-
		C	0,8 ÷ 1,1%$f_ś$	-	400	0,8 ÷ 1,1%$f_ś$	-	400	-	-	-
		D	>1,1%$f_ś$	-	400	>1,1%$f_ś$	-	400	-	-	-
3	Eccentricity	**A**	< 0,3%$f_ś$	-	200	< 0,3%$f_ś$	-	200	< 0,2%$f_ś$	-	200
		B	0,3 ÷ 0,8%$f_ś$	-	200	0,3 ÷ 0,8%$f_ś$	-	200	0,2 ÷ 0,4%$f_ś$	-	200
		C	0,8 ÷ 1,1%$f_ś$	-	200	0,8 ÷ 1,1%$f_ś$	-	200	0,4 ÷ 0,5%$f_ś$	-	200
		D	>1,1%$f_ś$	-	200	>1,1%$f_ś$	-	200	>0,5%$f_ś$	-	200

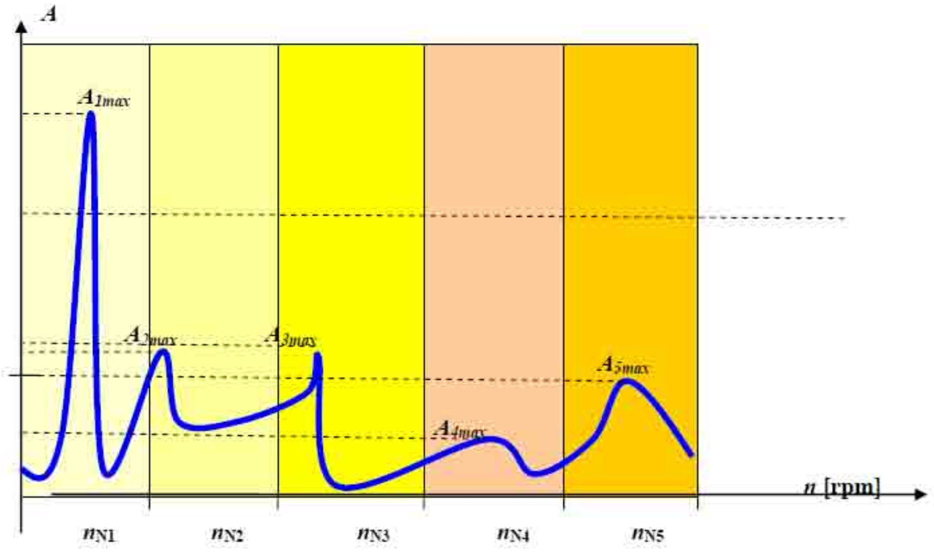

Fig. 11. Local resonance phenomena observed for rotational speed after switching-off power source, with marked bands of the rated speeds {n_{N1}, n_{N2}, n_{N3}, n_{N4}, n_{N5}} – exemplified by results of the Fourier analysis $A = f(n)$

In manuals of aircraft equipment producers and also aircraft operational instructions are contained many limitations for rundown time of rotary machines (in engine instructions it is called in a different way). According to practice and literature premises the shorter rundown time the greater total resistance moments of a given mechnical set. Therefore in many instructions to control rotor bearing units is recommended. Moreover, during rundown time natural decomposition of all driving set subsystems into independent kinematic pairs, occurs. The pairs , to a large extent independent from neigbouring kinematic pairs , perform angular oscillations called free vibrations . Fading time of the oscillations depends on dry friction component as well as that of viscous friction, i.e. wet one, as well as on possible air damping (at higher levels of rotational speed). Frequency of the oscillations depends on many factors , e.g. :

- inertia moment– the greater inertia moments the greater period of natural vibrations, i.e. the lower frequency;
- flexibility – the greater flexibility coefficient (the greater moment of force accumulated in an element during its deformation by unit twisting angle), the shorter period of natural vibrations, i.e. the greater frequency.

During converter's rundown phase , frequency of exitation acting onto its particular mechanical units , smoothly decreases. Therefore it is possible to generate and locate resonance excitations of particular mechanical units of a converter , e.g. bearing supports . Their locating and observing is very important from the point of view of determination of their survivability and issuance of a credible service forcast. For bearing supports a measure of hazard state is mechanical Q-factor of a resonance system – if $Q > 10$ it is recommended to withdaw a given system from operation. If excitation frequency is close to natural (free) vibration frequency of a given system then danger of occurrence of a resonance will appear. Machinery shafts , due to their abruptly varying cross-section , weight , mass unbalance and bearing gaps , constitute complex vibrating sytems. Resonance vibrations of one element affect other elements of the system. In such system can happen several critical speeds (Fig. 12) which are usually calculated by approximation methods. If , for instance , certain number of rotating masses, e.g. m_1, m_2, m_4, … , m_n, are fixed onto a shaft then critical speed of the whole system can be calculated from Dunkerlev formula in the following form :

$$1/\omega_{kr}^2 = 1/\omega_{kr1}^2 + 1/\omega_{kr2}^2 + 1/\omega_{kr3}^2 + \ldots + 1/\omega_{krm}^2$$

Stresses resulting from resonance vibrations can lead to fatigue failures. Angular speed at which a resonance occurs , is called the critical speed (ω_{kr2}^2) and expressed as follows :

$$\omega_{kr2} = (g/l)^{1/2}$$

which , for engineering practice , can be expressed in the following form :

$$n_{kr} \approx 300\cdot(1/f)\ \text{[rpm]}$$

where : f – statical deflection [cm], g – gravity acceleration.

It should be strongly stressed that shafts should not operate with such rotational speed. They should work with the so called rated speed lower at least by 15 % from ω_{kr2}. The permissible values of shaft deflection are roughly as follows :

$$(0{,}0002\div0{,}0003)\cdot l \text{ – for machine shafts,}$$

$$(0{,}005\div0{,}01)\cdot m_u \text{ – for toothed reduction gears,}$$

where :

l – distance between neighbouring supports, m_u – module pitch of a gear.

4. Final comments

In this paper was presented a way of diagnosing the selected defects of electro-mechanical converters : lowered comutating brush pressure , skewness of rotor rotation axis against stator symmetry axis , eccentricity of rotor rotation axis against stator symmetry axis. The tests were carried out in PAFTI laboratory by using the novel diagnostic methods called FAM-C and FDM-

A, based on analysis of dynamics of changes in output AC voltage of converter. The FAM-C method makes it possible a.o. to determine values of eccentricity of rotor rotation axis against stator symmetry axis , value of skew angle between the axis , value and dynamics of changes in radial clearances of bearings. The FDM-A method (based on the use of observations of changes in frequency modulation of component pulsation of DC generator) makes it possible to observe rolling uniformity of elements of rolling bearings , detect their resonance states , monitor resistance moments of particular bearing supports.

Also, were described theoretically the tests of converters during their rundown phase , carried out in the PAFTI practice. To this end , AC motor , after running –up its rotor , was converted into DC generator . DC generator is of a much greater resolution than AC one, thus it is possible to monitor fast-varying diagnostic processes such as vibrations of rolling bearings. Tests of converters during their rundown phase make it possible not only to increase the resolution - it is simultaneously another type of diagnosing a mechanical object (not only electro-mechanical converters). This way a versatile image of dynamic structures of a much greater number of mechanical units than that during monitoring a converter at only one rotational speed. can be fast obtained.

Generally, these authors demonstrated that the representations obtained experimentally at increasing controlled parameters of mechanical defects and electrical faults can be monitored by means of the FAM-C and FDM-A methods . In the methods two types of representation are used : form of characteristic sets, form of runs of instantaneous frequency in function of time. The methods in question are characterized by a high sensitivity in determining size of a defect – for increasing value of a defect parameter distinct increase in height of its characteristic set was observed.

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