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How To Choose Electric Drive According IEC 60034-1 ?

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SUMMARY

The standard IEC 60034-1 defines 10 duty types (S1 – S10) of electric drives and recommends how to choice electric motor. Only 3 duty types (S8, S9 and S10) are categorized as variable speed drives without recommendation which control speed method to use. Duty types S4 – S7 with heavy starting, braking and continuous work with no-load intervals are treated as constant speed regimes. In the paper proposals for using different types power converters in duty types of electric drives as convenient control speed method are given. Non-active energy consumption question is presented through measurements with power analyzer. The examples of drives in coal power plant illustrate the described problem. Use of variable speed drives is favored as way for environment pollution decreasing.

KEYWORDS

Electric drive, duty type, speed control, power converter, fan, pump, transport band.

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Introduction – Choosing of modern electric drive generally consists of define of load (working machine), electric motor, power converter and control system. It is regulated through standards, IEC 60034-1 is among the most famous and used. In this standard "Duty" is a statement of the loads on the working machine with their duration and sequence, including, where appropriate, starting, electric braking, no-load and rest. "Rating" is the totality of numerical values of the electrical and mechanical quantities, with their duration and sequence, assigned to the machine by the manufacturer and stated on the rating plate and at which the machine complies with the agreed conditions. The number of duty types is flexible and changeable question. It was 8, 9 but now is 10, which depends on technology advance. The correct choosing of electric drive is a base for good exploitation and consumption of electric energy. In coal thermal power plant choosing of pumps, fans and conveyors drives is very important not only for working of plant, but also for environment pollution.

Duty types in IEC 60034-1 – The capacity of electrical machine is certainly temperature dependent and therefore the duty type may significantly affect the rating. The presentation of duty types is through curves: load depending of time, losses depending of time, temperature depending of time and speed depending of time for VSD. Today IEC 60034-1 distinguishes between 10 (ten) types of duty: S1 – Continuous duty, S2 – Short-time duty, S3 – Intermittent Duty, S4 – Intermittent duty with starting, S5 – Intermittent duty with starting and electric braking, S6 – Continuous operation periodic duty, S7 – Continuous operation periodic duty with electric braking, S8 – Continuous operation periodic duty with related load –speed variation, S9 – Continuous operation duty with non-periodic load and speed variations, S10 – Continuous operation duty with discrete constant loads variations. In Fig.1 are presented basic duty types S1, S2 and S3. Fig.2 shows duty types S4 and S5. Fig.3 deals with duty types S6 and S7. In Fig.4 are presented duty types S8, S9 and S10 with load and speed variations.

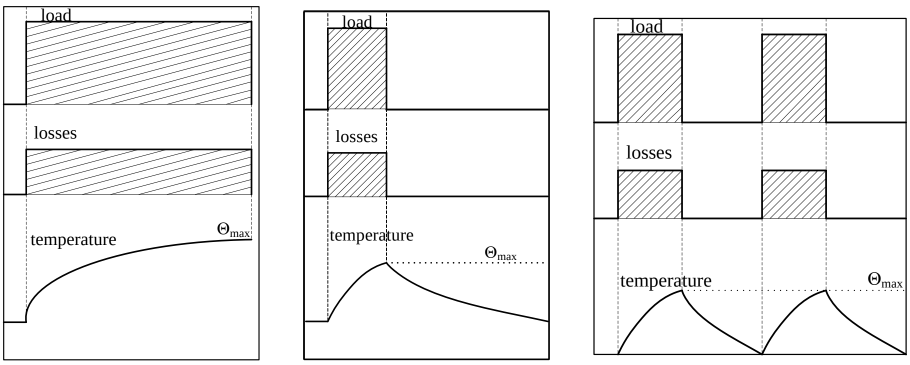

Fig.1 Basic duty types S1, S2 and S3

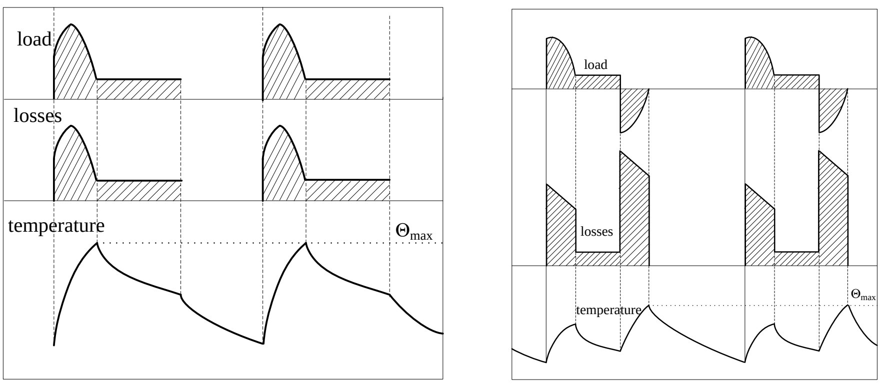

Fig.2 Duty types S4 and S5 with influence of starting and braking (now with VV converters)

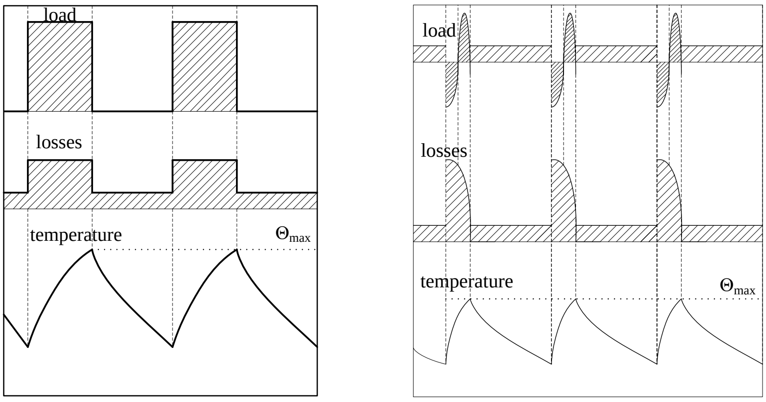

Fig.3 Duty types S6 and S7 with continuous periodic operation (now with VV converters)

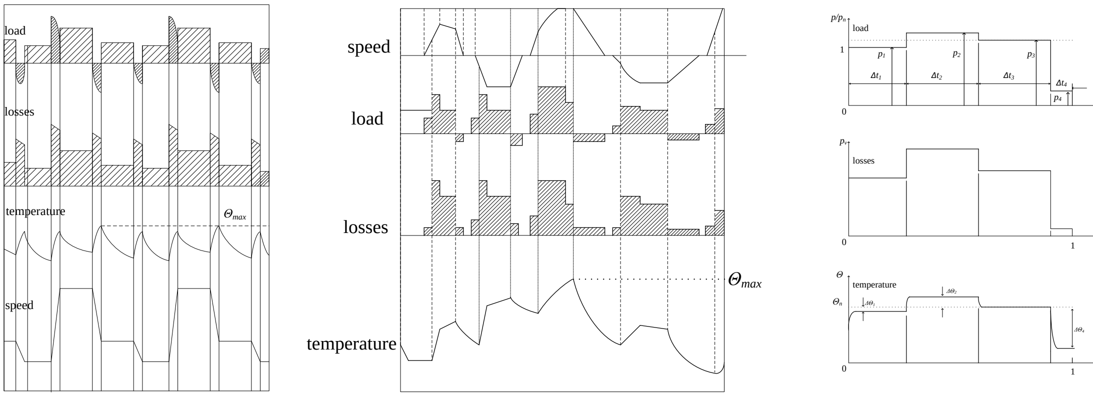

Fig.4 Duty types S8, S9 and S10 with load and speed variations (now with VVVF converters)

Duty types S1, S2, S3, S4 and S5 are with rest, interval when drive's speed is zero. Duty types S6, S7, S8, S9 and S10 are without rest. In S6 and S7 there are no-load intervals with no-load speed. Every next duty type is heavier than previous. Although primarily specified for motors, some duty types, e.g. S1, S2, are also applicable to generators.

Variable speed drives (VSD) regarding IEC 60034-1 – It is evident that in IEC 60034-1 only duty types S8, S9 and S10 are VSD. From the other side, in modern electric drives with heavy starting and braking, soft starting/braking devices are used. However it influences on losses and quite different situation than now in adequate curves in S4 and S5 duty types. In no-load conditions in modern electric drives there are speed variations too, in direction of decreasing losses. So, appropriate curves in S6 and S7 duty types should change. Simply, in modern electric drives in duty types S4, S5, S6 and S7 speed variation is in use, so they are VSD. In IEC 60034-1 types of power converters for variable speed are not discussed. In this paper, according state of art in electric drives, for duty types S4, S5, S6 and S7 variable voltage (VV) power converters are recommending. For duty types S8, S9 and S10 variable voltage and variable frequency (VVVF) power converters are recommending. In this situation consumption of non-active energy is not negligible, because it is more than 10 % of total consumed energy, as can see from measurements with power analyzer. Speed control system could be simple like U/f control, or field oriented control and direct torque control in the heaviest case. Through example of electric drive in coal power plant REK Bitola, North Macedonia, previous statements will prove. Additionally effects on environment pollution decreasing will present and discuss.

Case study - The following figures represent the measurement which is made with instruments:

Basic plate data of iduction motor type 2.RZKIT-355-Mk-6 are 120 kW/742 min^{-1}, 80-300V, 10-37.5Hz, η=88,5 – 94,7 %, $cos\varphi$=0,855 – 0,860, 284A.

Energy measurement is conducted on electric drive for transport with DTC controlled converter using these instruments product of FLUKE: 1735 Power Data Logger, 105 B Scope-meter 100MHz, 41 B Power Harmonics Tester and 345 PQ Clamp-meter. These power measurement instruments compiles with IEC 61000-4-3 Class A standard which defines measurements methods and ensure reliable and precise results. From FLUKE data catalogue for Power Data Logger 1735, sampling rate is 10,24 kHz and that means that the instrument can measure up 50 harmonics.

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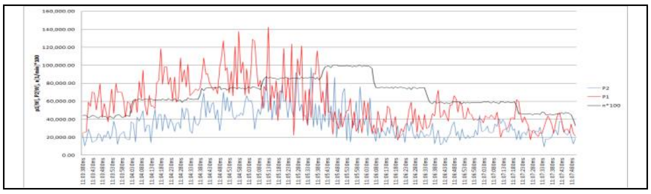

Fig.5 Graphical representation of P_1, P_2 and speed

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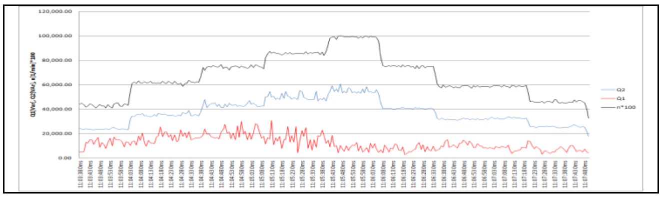

Fig.6 Graphical *representation* of Q_1, Q_2 and speed

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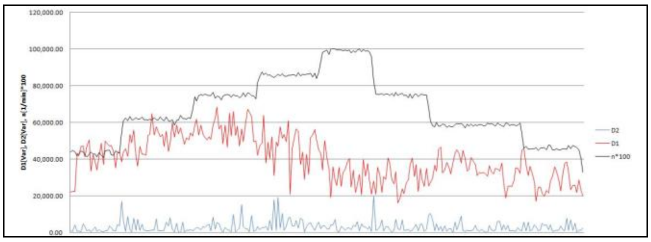

Fig.7 Graphical representation of D_1, D_2 and speed

The results from measurements are given in Fig.5 to 7. In figures are shown active power P_1, Q_1 and D_1 which is measured before the power converter, in the line side (with subscript 1-red color), and active power P_2, Q_2 and D_2 which is measured after the power converter, in the motor side (with subscript 2-blue color). For better representation the speed measurement is multiplied with coefficient 100.

As we see from Fig.5 active power P_1 is significant greather than P_2 when IM is accelerating. On other case for reactive power, from Fig.6 Q_1 is smaller than Q_2 and when speed change reactive power Q_2 foloves changes of speed. From Fig.7 distortion power D_1 is signficant greather than D_2. These means that distortion power migrate in power network (400 V in the bucket wheel SRs 1050).

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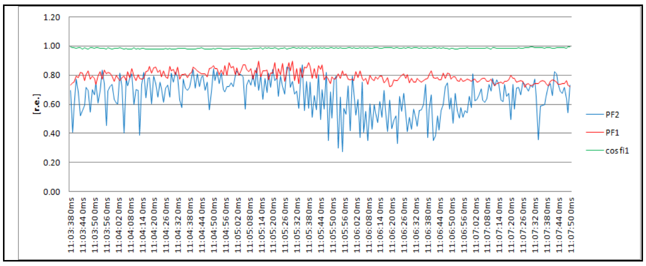

Fig.8 Representations of power factor-PF and cosφ

As we can see from Fig.8 the power factor *PF* contains harmonics, and it varies in range 0,74<*PF*<0,81. For fundamental frequency, the power factor varies in range 0,98<*cos*φ<0,99. It is obviously that the manufacturer of power converter is correcting *cos*φ, because the price of reactive power is much lower than price of active.

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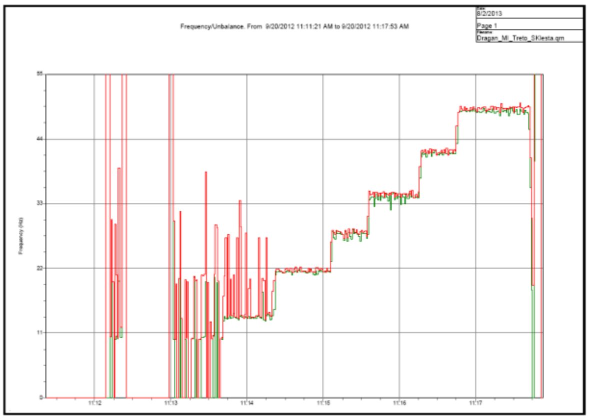

Fig.9 Changes of freqencies-speed when IM accelerated

Changes of speed of the IM is in six steps when motor accelerated and from Fig.9 these frequencies is 14, 20, 25, 32, 39.5 and 50 Hz. Harmonics which are producet from converter is presented in folowing figures. Measurement was made with osciloskope Fluke 105 B Scope Meter for 32 and 50 Hz.

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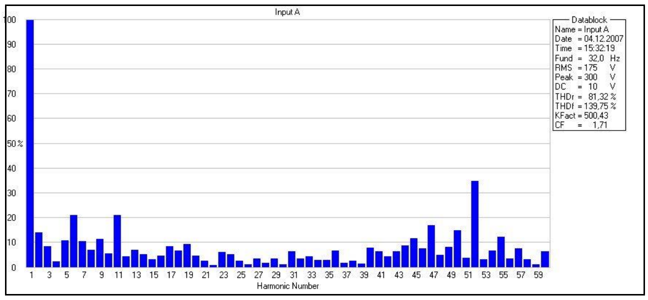

Fig.10 Voltage harmonics at 32 Hz

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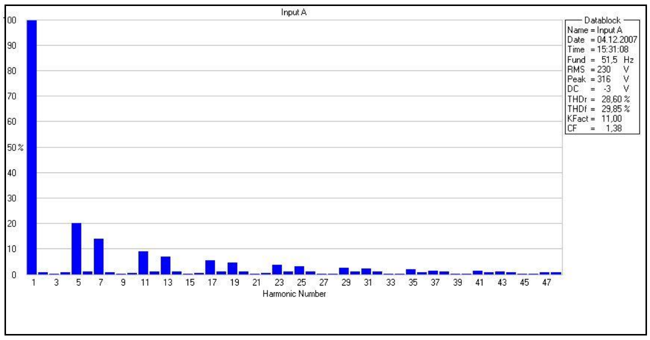

Fig.11 Voltage harmonics at 51.5 Hz

Fig.10 and 11 represent harmonical specter at motor side (after converter). At smaller speed amount of harmonics is greater than when IM works with nominal speed.

Appearance of distortion power means that we have harmonics in the energy power system. On the line side measurement with Fluke 41 B Power Harmonic Tester [6] were made, and according to these measurements the graphical representation for base frequency f=20 Hz is:

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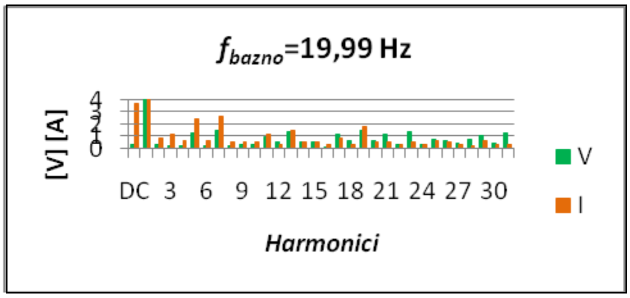

Fig.12. Voltage and current harmonics for one phase for duration of one cycle

From Fig.8, 10 and 11 we see that the induction motor is polluted with very high voltage and current harmonics. This fact means that the mathematical models of the induction motor must take in consideration the effect of harmonics influence on the parameters of the motor [10] and [14].

Also from Fig.7 and 12, line side network is polluted with distortion power D_1 and high harmonics when IM works with small speed (f=20 Hz).

In the following table measurements at the line side of power converter are presented:

Table 1. *Measurements at the line side of power converter*

f **Hz**	I_1 **A**	PF_1	***cosφ***	P_1 **W**	Q_1 **VAr**	D_1 **VAr**	S_1 **VA**
10,2	36,3	0,740	0,990	24871	4893	22469	33873
15,0	54,6	0,760	0,990	37480	7715	31536	49586
20,6	95,9	0,810	0,980	65087	14553	50068	83396
29,4	59,2	0,770	0,980	40208	8405	33000	52691
37,8	80,4	0,800	0,980	54604	11448	40600	69000
43,6	85,3	0,790	0,990	58493	12200	45208	74927
49,7	68,7	0,790	0,990	47139	15036	61023	78562

Table 1 represents the measurements for specific speeds of the induction motor. From the table it is obvious that the reactive power is smaller compared to the active (*cosφ* is constant and his value is high), but distortion power is in range with active power e.g. $0{,}77 \leq \frac{P_1}{D_1} \leq 1{,}34$.

This means that the power converter produces high harmonics and high values of distortion power. This may cause problems in the power network, power converters, transformers, induction motors and power capacitor banks and will increase the production of green house gases CO_2, SO_2, N_2O and produce environmental pollution [8].

Table 2. *Measurements at the motor side after power converter*

f Hz	***U_2 V***	***I_2 A***	***PF_2***	***P_2 W***	***Q_2 VAr***	***D_2 VAr***	***S_2 VA***
10,2	128,8	59,8	0,863	19601	11487	985	22698
15,0	129,8	612	0,844	20103	12785	946	23805
16,6	134,3	54,1	0,823	17473	12473	3322	21210
20,6	172,7	64,8	0,718	24134	23355	922	33597
22,5	187,2	64,9	0,722	25950	25102	3695	35915
29,4	204,5	60,8	0.655	31400	40223	3399	50914
30,8	252,8	87,4	0,820	51122	35621	931	62315
37,7	313,1	66,9	0,699	42991	43856	1562	61432
37,8	313,3	56,1	0,616	31400	40223	3399	50914
42,8	356,8	60,1	0,671	42627	47748	8249	63474
43,6	361,3	50,3	0,509	27507	46814	5735	53993
49,7	403,0	51,9	0,505	42627	47748	8249	63474

When the speed increases, by increasing the voltages on the motor clamps, the injection of reactive power Q_2 increases. Value of Q_2 directly depends on magnetic fluxes which appear into the motor and we can see that Q_2 is greater than P_2. Because of that reason power factor PF_2 decreases to values of 0,863 to 0,505. In cases of greater speeds, the power losses increase because of the increase of Q_2.

Conclusion – In this paper the standard IEC 60034-1 as way for electric drive choice is discussed. Comments concerning variable speed drives in different duty types are given, so as recommendations for choice of power converters and speed control system. Measurements show that consumption of non-active energy is not negligible. Revision of IEC 60034-1 concerning VSD and energy consumption is necessary, particularly for S8, S9 and S10. Improved air pollution conditions in the case of coal power plant REK by help of VSD Bitola are presented.

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