

DETERMINATION OF THE CURRENT HARMONICS INTRODUCED IN THE GRID BY THE D.C. - SUPPLIED CONSUMERS

■ **Abstract:**

This work is presenting a determination mode of the current harmonics for a supply circuit of a d.c. motor, to which the loading is adjusted by another identical motor, connected as generator. Their determination is achieved by direct measurement with an energy analyzer CA8334.

■ **Keywords:**

current harmonics, single-phased power rectifier, distortion factor

■ **WORK'S PRESENTATION**

For the current harmonics' study it was achieved a circuit of relatively reduced power using a d.c. motor of 750 W coupled directly with another motor, identically with the first one, which is connected as generator, to which the loading can be adjusted by means of a slide rheostat. The electric circuit's diagram (fig. 1) allows the adjustment of the motor's supply voltage using a single-phased autotransformer. Will be analyzed the current harmonics for three different loading situations of the generator, respectively three values for the slide potentiometer, at three different supply voltages. Determinations of the current harmonics, as well as the THD factor, are made with a three-phased energy analyzer CA8334 which allows the calculation of these parameters as follows:
1 sec RMS values for voltage and current

$$V_{rms}[i] = \sqrt{\frac{1}{NechSec} \cdot \sum_{n=0}^{NechSec-1} V[i,n]^2} \quad (1)$$

where: V_{rms} single rms voltage $i+1$ phase;

$$V_{avg}[i] = V_{rms}[i]$$

$$U_{rms}[i] = \sqrt{\frac{1}{NechSec} \cdot \sum_{n=0}^{NechSec-1} U[i,n]^2} \quad (2)$$

where: U_{rms} compound rms voltage $i+1$ phase

$$U_{avg}[i] = U_{rms}[i]$$

$$A_{rms}[i] = \sqrt{\frac{1}{NechSec} \cdot \sum_{n=0}^{NechSec} A[i,n]^2} \quad (3)$$

where: $A_{rms}[i]$ - Effective current phase

$$i+1; A_{avg}[i] = A_{rms}[i]$$

Calculation of harmonic bins:

By FFT (16 bits) 1024 samples on 4 cycles without windowing (CEI 1000 -4-7). From real and imaginary parts, each bin calculated on each phase V_{harm} , U_{harm} and A_{harm} in proportion to the fundamental value and the angles V_{ph} , U_{ph} , and A_{ph} between each bin and the fundamental.

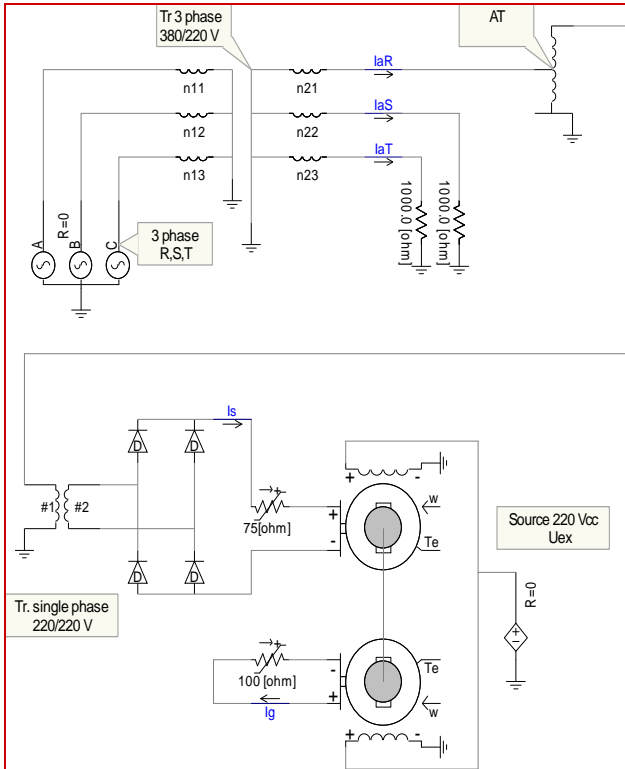


Figure 1 The d.c. motor's control circuit

This calculation is done with the following principle: Module in % : $\text{mod}_k = \frac{c_k}{c_1} \times 100$ angle

in degree: $\varphi_k = \arctan\left(\frac{a_k}{b_1}\right)$

$$\text{with } \begin{cases} c_k = |b_k + ja_k| = \sqrt{a_k^2 + b_k^2} \\ b_k = \frac{1}{512} \sum_{s=0}^{1024} F_s \times \sin\left(\frac{k\pi}{512} s + \varphi_k\right) \\ a_k = \frac{1}{512} \sum_{s=0}^{1024} F_s \times \cos\left(\frac{k\pi}{512} s + \varphi_k\right) \\ c_0 = \frac{1}{1024} \sum_{s=0}^{1024} F_s \end{cases} \quad (4)$$

c_k is the amplitude of frequency $f_k = \frac{k}{4} f_1$, F_s is sampled signal, c_0 is the DC component, k is the ordinal number (spectral bin).

Calculation of the distortion factor (DF): There are calculated two global values which give the relative quantity of harmonics: total harmonic distortion (THD) against the fundamental and the distortion factor (DF) and DF against the effective value (RMS).

$$V_{thd} [i] = \frac{\sqrt{\sum_{n=2}^{50} V_{harm} [i, n]^2}}{V_{harm} [i, 1]}$$

$$U_{thd} [i] = \frac{\sqrt{\sum_{n=2}^{50} U_{harm} [i, n]^2}}{U_{harm} [i, 1]}$$

$$A_{thd} [i] = \frac{\sqrt{\sum_{n=2}^{50} A_{harm} [i, n]^2}}{A_{harm} [i, 1]} \quad (5)$$

$$V_{df} [i] = \frac{\sqrt{\frac{1}{2} \sum_{n=2}^{50} V_{harm} [i, n]^2}}{V_{rms} [i]}$$

$$U_{df} [i] = \frac{\sqrt{\frac{1}{2} \sum_{n=2}^{50} U_{harm} [i, n]^2}}{U_{rms} [i]}$$

$$A_{df} [i] = \frac{\sqrt{\frac{1}{2} \sum_{n=2}^{50} A_{harm} [i, n]^2}}{A_{rms} [i]} \quad (6)$$

Multiplying the voltage's harmonics factor with the current's harmonics factor, results the power's harmonics factor. Differentiating the voltage's harmonic phase angle with the current's harmonic phase angle, results the power's phase angle.

- different ratios

$$PF[i] = \frac{W[i]}{VA[i]} \text{ power factor, phase } i + 1$$

$$\cos(\varphi[i]) = \frac{\sum_{n=0}^{N_{chSec}-1} V_{F}[i, n] \cdot A_{F}[i, n]}{\sqrt{\sum_{n=0}^{N_{sec}-1} V_{F}[i, n]^2} \cdot \sqrt{\sum_{n=0}^{N_{sec}-1} A_{F}[i, n]^2}} \quad (7)$$

Cosinus angle between the voltage's fundamental and the phase current $i + 1$

$$PF_3 = \frac{PF[0] + PF[1] + PF[2]}{3} \quad (8)$$

Total power factor various types of energy

$Wh[0, i] = \sum_{T_{int}} \frac{W[i]}{3600}$ active energy consumed $i + 1$ phase;

$VAR_{hL}[0, i] = \sum_{T_{int}} \frac{VAR[i]}{3600}$ for $VAR[i] \geq 0$ Reactive inductive energy consumed $i + 1$ phase;

$VAR_{hC}[0, i] = \sum_{T_{int}} \frac{VAR[i]}{3600}$ for $VAR[i] \leq 0$ Reactive capacitive energy consumed $i + 1$ phase.

Table 1

Motor loading	Is [A]	Ig [A]	IaR[A]	THD[%]
min	2.4	1.2	2.1	14.6
med	3.1	1.8	3	15.1
max	4.1	2.5	3.8	15.5

There are obtained the amplitude values of the harmonics of rank 3,5,7,9, 11..... and the THD factor calculated for there values of the harmonics. In the first stage, are determined the current harmonics and the THD for the situation when the insulation transformer is missing (Tr single-phase). The results will be written in a table (table 1) and, for exemplification, there are presented two graphics with the harmonics' values and the THD's value for a medium loading (fig. 2), respectively for a maximum loading (fig. 3).

d.c. motor of 50 V, 100 V, 150 V at loading of the generator with minimum, medium and maximum load. The values are written in the table (table 2) and for the supply voltage of 100 V will be presented two distinct situations, at a medium loading of 50 % from the value of the generator's loading potentiometer (fig.4) respectively maximum, 10% from 75 Ω (fig.5).

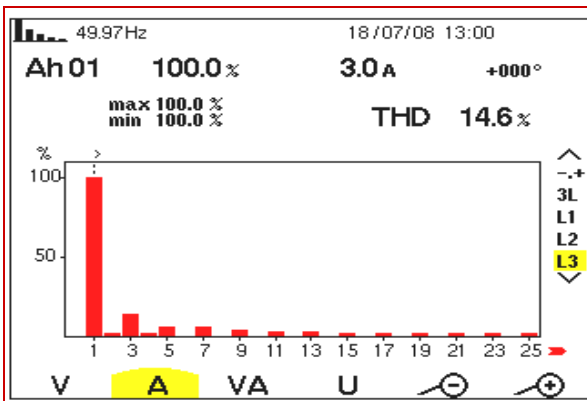


Fig. 2 Harmonics spectrum for a loading of 50%

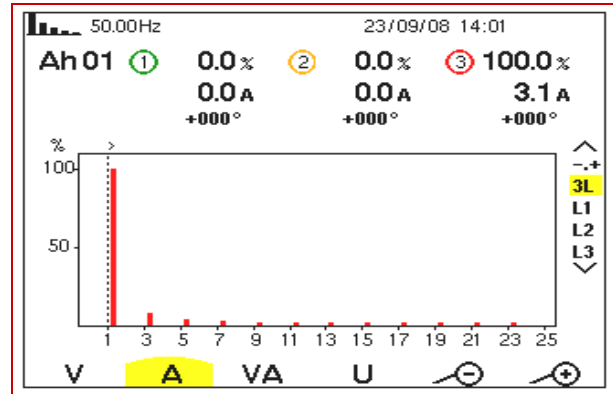


Fig. 4 Harmonics spectrum for a loading of 50% with insulation transformer

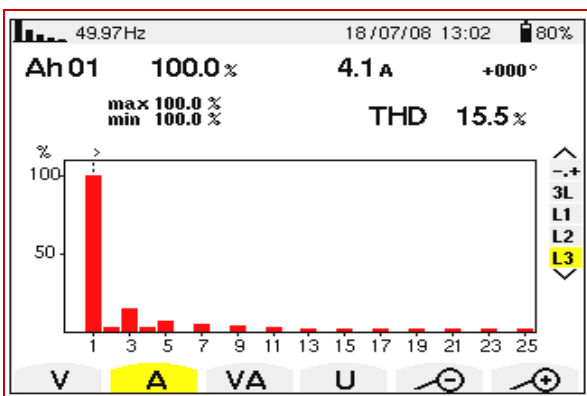


Fig. 5 Harmonics spectrum for a loading of 100%

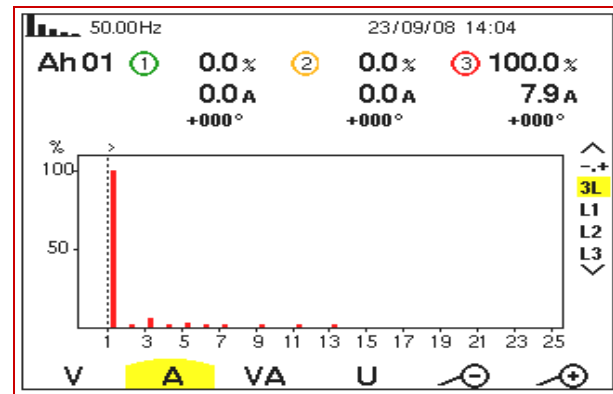


Fig. 5 Harmonics spectrum for a loading of 100% with insulation transformer

Table 2

Voltage [V]	Motor loading	Is [A]	Ig [A]	THD [%]
50	min	0.8	0.5	13.2
	med	0.9	0.65	14.8
	max	1.1	1	16.3
100	min	5.9	1.5	6
	med	6.7	1.8	5.9
	max	7.9	2.75	3.5
150	min	8.4	1.55	4.8
	med	9	2	4.7
	max	10.4	2.7	4.6

In the circuit is introduced the insulation transformer (Tr single-phase), and are rerunned the measurements for the supply voltages of the

CONCLUSIONS

In case of the circuit without insulation transformer from fig. 2 and fig. 3 can ne noticed a relatively small reduction of the distortion factor regarding the load currents at medium and maximum loading.

In case of the circuit with insulation transformer from fig. 4 and fig. 5, beside the pronounced THD's reduction, is noticed also a more pronounced reduction between the situation of medium loading and maximum loading of the d.c motor.

It can be easily noticed the reduction of the distortion factor in case of introducing the insulation transformer. Although the harmonics' values are relatively reduced related to the

fundamental, is obtained a relatively high THD factor, especially at small load currents. By increasing the load current, the harmonics' effective value is not really reducing. The finding of the THD's reduction is due to the relative reduction of the ration between the harmonics' values and fundamental. Reduction of THD is achieved by using of passive filters at small rank harmonics, completed by a power active filter.

REFERENCES

- [1] MANUELA PANOIU, CAIUS PANOIU, MIHAELA OSACI, IONEL MUSCALAGIU, *Simulation Result about Harmonics Filtering using Measurement of Some Electrical Items in Electrical Installation on uhp eaf, WSEAS TRANSACTIONS on CIRCUITS and SYSTEMS, Volume 7, 2008, ISSN: 1109-2734, January 2008.*
- [2] ANGELA IAGAR, GABRIEL NICOLAE POPA, IOAN ŞORA, *Analysis of electromagnetic pollution produced by line frequency coreless induction furnaces, WSEAS TRANSACTIONS on SYSTEMS, January 2009, volume 8, Issue 1 ISSN 1109-2777;*
- [3] DEV PAUL, D.C. *Traction Power System Grounding, IEEE TRANSACTIONS on INDUDTRY APPLICATIONS, vol.38, no.3, May-June 2002;*
- [4] HEINZ W. van der BROECK, HANS-CHRISTOPH SKUDELNY, *Analytical Analysis of the Harmonic effects of a PWM A.C. DRIVE, IEEE TRANSACTIONS on POWER ELECTRONICS, vol 3, no.2, April 1988;*
- [5] ALAN K. WALLACE, RENE SPEE, *The Effects of Motor Parameters on the Performance of Brushless D.C. Drives, IEEE TRANSACTIONS on POWER ELECTRONICS, vol.5, no.1, January 1990*

AUTHORS & AFFILIATION

¹ IOAN BACIU,

² CORINA DANIELA CUNȚAN,

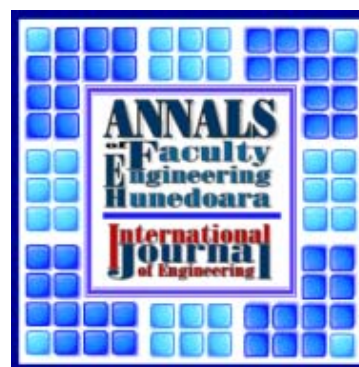
³ ANGELA IAGĂR

^{1. 3. 3.} FACULTY ENGINEERING OF HUNEDOARA,
ELECTRICAL ENGINEERING & INDUSTRIAL
INFORMATICS DEPARTMENT, UNIVERSITY
"POLITEHNICA" TIMISOARA, ROMANIA



**ACTA TECHNICA CORVINIENSIS
– BULLETIN of ENGINEERING**
ISSN: 2067-3809 [CD-Rom, online]

copyright ©
University Politehnica Timisoara,
Faculty of Engineering Hunedoara,
5, Revolutiei,
331128, Hunedoara,
ROMANIA
<http://acta.fih.upt.ro>



**ANNALS
of
FACULTY ENGINEERING HUNEDOARA
– INTERNATIONAL
JOURNAL of ENGINEERING**
ISSN: 1584-2665 [print, online]
ISSN: 1584-2673 [CD-Rom, online]

copyright ©
University Politehnica Timisoara,
Faculty of Engineering Hunedoara,
5, Revolutiei,
331128, Hunedoara,
ROMANIA
<http://annals.fih.upt.ro>