THE ARC FURNACES – A SOURCE OF DEFORMED STATE

Gabriela RAȚĂ

"Stefan cel Mare" University of Suceava str. Universitatii nr.13, RO-720225 Suceava

Abstract. An arc furnace is an unbalanced, nonlinear and time variant load that produces unbalance, harmonics and interharmonics related with flicker effect. This paper presents the analysis of harmonics from the arc furnaces. We make some experimental determinations at the distribution substation "Radiatoare" Suceava, in the supply bay of S.C. ROMUPS S.A.. In this moment operate the IHF 3/A arc furnaces.

Keywords: arc furnace, harmonics, virtual instrument, quality indices, data acquisition.

Introduction

The electric arc furnaces [1] are used for melting and refining metals, mainly iron in the steel production. Now days, arc furnaces are designed for very large power input ratings and due to the nature of both, the electric arc and the meltdown process, these devices can cause large power quality problems on the electrical net, mainly harmonics, interharmonics, flicker, and voltage imbalances.

The voltage-current characteristic of the arc is non-linear, what can cause harmonic currents. These currents, when circulating by the electric net, can produce harmonic voltages, which can affect other users. The beginning [2] of the meltdown process is the most critical part of the cycle in terms of disturbances.

Method description

We make some experimental determinations at the distribution substation "Radiatoare" Suceava, in the supply bay of S.C. ROMUPS S.A.. In this moment operate the IHF 3/A arc furnaces.

This is the three-phase direct arc furnace, with cylindrical shell. The arc furnace is supply with 200 V from the 2000 KVA transformer. This transformer is supply from the 6 KV substation of S.C. ROMUPS Suceava.

The data acquisition for the voltage and the current we make with the digital oscilloscope – TDS 310 from Tektronix, differential probe (for voltage) - MX9000 and Hall probe (for current). Fig. 1 presents the connecting of the measurement systems.



Fig. 1 - The connecting of the measurement systems

We transfer the date in the PC with the help of WaveStar 23 program.

It may be save these dates both text format and graph format. The dates in the text format are readied with LabVIEW [3]. We present a virtual instrument, in LabVIEW 7 Express, for the analysis of deforming state at the arc furnaces, in the last part of the paper.

For the validation of the results obtained with the VI we use the VIP SYSTEM 3 etalon (harmonics and energy analyzer).

Virtual instrument

The following time is one hour. In this time we acquisition the data. We select 60 measurement windows. Each window have the width equal with 200 ms. Therefore the real measurement time is 1200 ms. Because the current from the arc furnace is more deformed than voltage, we analyse just current data.

The VI permits to:

- take the dates from the text file
- obtain the amplitudes and phases spectrum for deformed signal
- save the date, after the FFT application, in EXCEL files, for the analysis
- extract 40 current harmonics both RMS values and percent of fundamental
- calculate the quality indices for the deforming state

One portion of front panel for the designed virtual instrument is shown in Fig. 2.

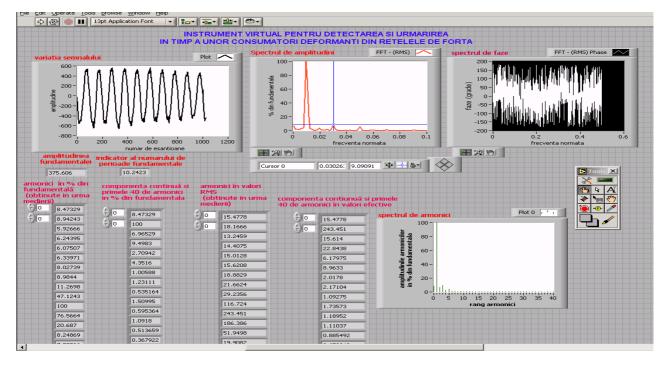


Fig.2 Front panel of virtual instrument - part 1

As it can be seen in Fig.2, the deformed signal can be visualized in the graphic windows – variation of signal. The last waveform that can be seen in this diagram is the electric current of the arc furnace, from the last measurement window. The indicator "spectrum of amplitudes" shows the amplitudes of current harmonics, which depend by normalized frequencies. The continuous component and the current harmonics, for every measurement window,

The VI read a text file, where the data from measurement windows are structured on the columns.

could be read with the help of array and table indicators from the front panel (Fig. 3). The part 3 of the front panel (Fig.4) contains: indicators for RMS, mean and maximally values of the deformed signal, the indicators of deforming state (the form factor, the harmonic distortion, the crest factor, the total harmonic distortion etc) which are result after programme running.

With the help of the control element we select the standardized value of THDI.

program	n complex	: curenti2	.vi Front I	Panel *												_
	Operate I		se <u>W</u> indo			<u></u>	- 65-									ি
\$ 6	×	T3pc Ap	plication	Jine 💌	*		0.04									
INDEX rivelele armonicilor în valori RMS (obtinute în urma aplicarii FFT) pentru fiecare fereastra de masurare											armonici în % din fundamentală (obtinute in urma medierii)		componenta continuã si primele 40 de armonici in % din fundamentala		onici	
	F49	F50	F51	F52	F53	F54	F55	F56	F57	F58	F59 🔺	÷o	8.47329	(+) 0	8,47329	spectrul de armonici
0											14.62203	÷) o	8,94243	÷10	100	100-
1											16.88682		5.92666	90	6.96529	
2	1.61449	1.88687		0.74097		14.56163					9.72634					opinou estana 40 - 40 - 40 - 20 -
3 4						18.10978					9.41391		6.24395		9.4983	E 2
5	1.00114		1.02120			7.33688					4.64252		6.07507		2.70942	a a a - 60 -
5	1.11196		0.59900			6.45383					5,94382		6.33971		4.3516	<u></u>
7	1.75047	0.86908	0.23648			13.79962					15.48067		8.02739		1.00588	· · · · · · · · · · · · · · · · · · ·
в	9.43847	8.72464	7.61626	11.06168	8.81285	6.92530	39.22676	119.0890	10.61852	0.53002	30.18455					
9						210.0458							8.9844		1.23111	Fe .= 20
10 A1						479.6109							11.2698		0.535164	0-11111111111111
11						363.5955							47.1243		1.50995	0 5 10 1
12		0.55304				83.75762					59.50670 16.04669		100		0.595364	ra
13	0.90801				0.34624			26.24035		2,40099	14.01681		76.5664			Tools 🗙
15	0.27443		0.25321	0.07659		6.35619				1.05864	5,61086				1.0918	
16	0,41502	0.75826				7,74160					3.17225		20.687		0.513659	<u> </u>
17	0.30774	0.48311	0.86308	0.04014	0.28128	7.12861	27.33058	28.40776	3.42858	0.56872	4.44054		8.24869		0.367922	
<													7.28316		0.460703	🔶 🍋 🕎
THE																i
				a strander and												
			cilor în % fereastr			alã						arm	onici în valo	ori		
INDEX	pentr	u fiecare	fereastr	a de mas	surare			50	50	540	F 14	RM	S			
INDEX	pentr F1	F2	fereastr F3	a de mas	F5	F6	F7	F8	F9	F10	F11	RM (ol	S otinute in u	rma	component	a continuuă și primele
INDEX	F1 2.591	F2 6.556	fereastr F3 10.303	a de mas F4 0.675	F5 8.286	F6 0.891	10.415	2.554	3.376	3.670	3.971	RM (ot mer	S	rma		a contiunuă și primele nici în valori efective
	F1 2.591 7.072	F2 6.556 4.559	fereastr F3 10.303 12.622	a de mas F4 0.675 2.838	F5 8.286 11.334	F6 0.891 1.924	10.415 9.661	2.554 3.351	3.376 0.411	3.670 6.687	3.971 6.056	RM (ol	S otinute in u	rma	40 de armo	nici în valori efective
	F1 2.591	F2 6.556	fereastr F3 10.303	a de mas F4 0.675	F5 8.286	F6 0.891	10.415	2.554	3.376	3.670	3.971	RM (ot mer	S stinute in u lierii)	rma	40 de armo €)□ [nici în valori efective 15.4778
INDEX 0 1 2 3 4	F1 2.591 7.072 6.406	F2 6.556 4.559 1.237	fereastr F3 10.303 12.622 9.114	a de mas F4 0.675 2.838 11.549	F5 8.286 11.334 3.252	F6 0.891 1.924 5.483	10.415 9.661 3.734	2.554 3.351 3.391	3.376 0.411 8.099	3.670 6.687 5.062	3.971 6.056 5.159	RM (ot mer	S ptinute in u dierii) 15.4778 18.1666	rma	40 de armo	nici în valori efective
INDEX 0 1 2 3 4 5	Pentro F1 2.591 7.072 6.406 3.054	F2 6.556 4.559 1.237 3.281	fereastr F3 10.303 12.622 9.114 8.800	a de mas F4 0.675 2.838 11.549 17.935 11.840 4.739	F5 8.286 11.334 3.252 2.431	F6 0.891 1.924 5.483 5.768	10.415 9.661 3.734 0.888 4.129 1.255	2.554 3.351 3.391 5.310	3.376 0.411 8.099 11.300	3.670 6.687 5.062 3.382 6.274 5.666	3.971 6.056 5.159 1.489	RM (ot mer	S tinute in u 15.4778 18.1666 13.2459	rma	40 de armo (-) ₀ (-) ₀ (-) ₀	nici în valori efective 15.4778
INDEX 0 1 2 3 4 5 5 5	Pentri F1 2.591 7.072 6.406 3.054 2.109 8.111 8.981	F2 6.556 4.559 1.237 3.281 5.357 4.944 8.425	F3 F3 10.303 12.622 9.114 8.800 11.962 12.370 9.461	a de mas F4 0.675 2.838 11.549 17.935 11.840 4.739 11.428	F5 8.286 11.334 3.252 2.431 2.585 5.175 13.817	F6 0.891 1.924 5.483 5.768 4.676 2.566 1.719	10.415 9.661 3.734 0.888 4.129 1.255 2.031	2.554 3.351 3.391 5.310 5.640 6.428 5.458	3.376 0.411 8.099 11.300 10.886 8.547 3.013	3.670 6.687 5.062 3.382 6.274 5.666 6.514	3.971 6.056 5.159 1.489 4.788 12.706 11.985	RM (ot mer	S tinute in u lierii) 15.4778 18.1666 13.2459 14.4075	rma	40 de armo (-) 0 (-) 0 (-) 0	nici în valori efective 15.4778 243.451
INDEX 0 2 3 3 4 5 5 7	F1 2.591 7.072 6.406 3.054 2.109 8.111 8.981 3.061	F2 6.556 4.559 1.237 3.281 5.357 4.944 8.425 9.189	F3 10.303 12.622 9.114 8.800 11.962 12.370 9.461 10.603	a de mas F4 0.675 2.838 11.549 17.935 11.840 4.739 11.428 4.661	F5 8.286 11.334 3.252 2.431 2.585 5.175 13.817 13.779	F6 0.891 1.924 5.483 5.768 4.676 2.566 1.719 3.305	10.415 9.661 3.734 0.888 4.129 1.255 2.031 6.106	2.554 3.351 3.391 5.310 5.640 6.428 5.458 0.943	3.376 0.411 8.099 11.300 10.886 8.547 3.013 11.988	3.670 6.687 5.062 3.382 6.274 5.666 6.514 8.803	3.971 6.056 5.159 1.489 4.788 12.706 11.985 3.477	RM (ot mer	S tinute in u 15.4778 18.1666 13.2459	rma	40 de armo (-) 0 (-) 0 (-) 0	nici in valori efective 15.4778 243.451 15.614 22.8438
INDEX 0 1 2 3 4 5 5 7 3	F1 2.591 7.072 6.406 3.054 2.109 8.111 8.981 3.061 5.954	F2 6.556 4.559 1.237 3.281 5.357 4.944 8.425 9.189 9.131	Fraestr F3 10.303 12.622 9.114 8.800 11.962 12.370 9.461 10.603 21.745	a de mas F4 0.675 2.838 11.549 17.935 11.840 4.739 11.428 4.661 4.502	F5 8.286 11.334 3.252 2.431 2.585 5.175 13.817 13.779 11.008	F6 0.891 1.924 5.483 5.768 4.676 2.566 1.719 3.305 5.662	10.415 9.661 3.734 0.888 4.129 1.255 2.031 6.106 13.385	2.554 3.351 3.391 5.310 5.640 6.428 5.458 0.943 7.007	3.376 0.411 8.099 11.300 10.886 8.547 3.013 11.988 8.899	3.670 6.687 5.062 3.382 6.274 5.666 6.514 8.803 11.859	3.971 6.056 5.159 1.489 4.788 12.706 11.985 3.477 2.703	RM (ot mer	S tinute in u lierii) 15.4778 18.1666 13.2459 14.4075	rma	40 de armo (-) o (-) o (-) o	nici in valori efective 15.4778 243.451 15.614 22.8438 6.17975
0 1 2 3 4 5 5 7 3 9	Pentr F1 2.591 7.072 6.406 3.054 2.109 8.111 8.981 3.061 5.954 40.192	F2 6.556 4.559 1.237 3.281 5.357 4.944 8.425 9.189 9.131 47.410	F3 10.303 12.622 9.114 8.800 11.962 12.370 9.461 10.603 21.745 63.716	a de mas F4 0.675 2.838 11.549 17.935 11.840 4.739 11.428 4.661 4.502 37.537	5Urare F5 8.286 11.334 3.252 2.431 2.585 5.175 13.817 13.779 11.008 45.953	F6 0.891 1.924 5.768 4.676 2.566 1.719 3.305 5.662 44.235	10.415 9.661 3.734 0.888 4.129 1.255 2.031 6.106 13.385 49.618	2.554 3.351 3.391 5.310 5.640 6.428 5.458 0.943 7.007 47.275	3.376 0.411 8.099 11.300 10.886 8.547 3.013 11.988 8.899 47.868	3.670 6.687 5.062 3.382 6.274 5.666 6.514 8.803 11.859 31.148	3.971 6.056 5.159 1.489 4.788 12.706 11.985 3.477 2.703 37.092	RM (ot mer	S dierii) 15.4778 18.1666 13.2459 14.4075 15.0128 15.6208	rma	40 de armo (-) 0 (-) 0 (-) 0 (-) 1 (-) 1 (hici in valori efective 15.4778 423.451 15.614 22.6438 6.17975 8.9633
0 1 2 3 4 5 5 5 7 3 9 10 A1	F1 2.591 7.072 6.406 3.054 2.109 8.111 8.981 3.061 5.954 40.192 100.000	F2 6.556 4.559 1.237 3.281 5.357 4.944 8.425 9.189 9.131 47.410 100.000	F3 10.303 12.622 9.114 8.800 11.962 12.370 9.461 10.603 21.745 63.716 100.000	a de mas F4 0.675 2.838 11.549 17.935 11.840 4.739 11.428 4.661 4.502 37.537 100.000	F5 8.286 11.334 3.252 2.431 2.585 5.175 13.817 13.779 11.008 45.953 100.000	F6 0.891 1.924 5.483 5.768 4.676 2.566 1.719 3.305 5.662 44.235 100.000	10.415 9.661 3.734 0.888 4.129 1.255 2.031 6.106 13.385 49.618 100.000	2.554 3.351 3.391 5.310 5.640 6.428 5.458 0.943 7.007 47.275 100.000	3.376 0.411 8.099 11.300 10.886 8.547 3.013 11.988 8.899 47.868 100.000	3.670 6.687 5.062 3.382 6.274 5.666 6.514 8.803 11.859 31.148 100.000	3.971 6.056 5.159 1.489 4.788 12.706 11.985 3.477 2.703 37.092 100.000	RM (ot mer	15.4778 18.1666 13.2459 14.4075 15.0128 15.6208 18.8829	rma	40 de armo (-) 0 (-) 0 (-) 0 (-) 1 (-) 1 (nici in valori efective 15.4778 243.451 15.614 22.8438 6.17975
0 1 2 3 4 5 5 5 7 7 8 9 9 10 A1 11	F1 2.591 7.072 6.406 3.054 2.109 8.111 8.981 3.061 5.954 40.192 100.0000 83.010	F2 6.556 4.559 1.237 3.281 5.357 4.944 8.425 9.139 9.131 47.410 100.000 70.502	F3 10.303 12.622 9.114 8.800 11.962 12.370 9.461 10.603 21.745 63.716 100.000 57.711	F4 0.675 2.838 11.549 17.935 11.840 4.739 11.428 4.661 4.502 37.537 100.000 83.935	F5 8.286 11.334 3.252 2.431 2.585 5.175 13.817 13.779 11.008 45.953 100.000 75.375	F6 0.891 1.924 5.483 5.768 4.676 2.566 1.719 3.305 5.662 44.235 100.000 74.760	10.415 9.661 3.734 0.888 4.129 1.255 2.031 6.106 13.385 49.618 100.000 73.982	2.554 3.351 3.391 5.310 5.640 6.428 5.458 0.943 7.007 47.275 100.000 78.804	3.376 0.411 8.099 11.300 10.886 8.547 3.013 11.988 8.899 47.868 100.000 71.760	3.670 6.687 5.062 3.382 6.274 5.666 6.514 8.803 11.859 31.148 100.000 92.719	3.971 6.056 5.159 1.489 4.788 12.706 11.985 3.477 2.703 37.092 100.000 81.608	RM (ot mer	S derii) 15.4778 18.1666 13.2459 14.4075 15.0128 15.6208 18.8829 21.6624	rma	40 de armo (-) 0 (-) 0 (-) 0 (-) 0 (-) 1 (-) 1 (hici in valori efective 15.4778 423.451 15.614 22.6438 6.17975 8.9633
0 1 2 3 4 5 5 5 5 7 8 9 9 10 A1	F1 2.591 7.072 6.406 3.054 2.109 8.111 8.981 3.061 5.954 40.192 100.000	F2 6.556 4.559 1.237 3.281 5.357 4.944 8.425 9.189 9.131 47.410 100.000	F3 10.303 12.622 9.114 8.800 11.962 12.370 9.461 10.603 21.745 63.716 100.000	a de mas F4 0.675 2.838 11.549 17.935 11.840 4.739 11.428 4.661 4.502 37.537 100.000	F5 8.286 11.334 3.252 2.431 2.585 5.175 13.817 13.779 11.008 45.953 100.000	F6 0.891 1.924 5.483 5.768 4.676 2.566 1.719 3.305 5.662 44.235 100.000	10.415 9.661 3.734 0.888 4.129 1.255 2.031 6.106 13.385 49.618 100.000	2.554 3.351 3.391 5.310 5.640 6.428 5.458 0.943 7.007 47.275 100.000	3.376 0.411 8.099 11.300 10.886 8.547 3.013 11.988 8.899 47.868 100.000	3.670 6.687 5.062 3.382 6.274 5.666 6.514 8.803 11.859 31.148 100.000	3.971 6.056 5.159 1.489 4.788 12.706 11.985 3.477 2.703 37.092 100.000	RM (ot mer	15.4778 18.1666 13.2459 14.4075 15.0128 15.6208 18.8829	rma	40 de armo () 0 () 0 1 1 1 1 1 1 1 1 1 1 1 1 1	htic in valori efective 15.4778 243.451 15.614 6.17975 8.9633 2.0178

Fig.3 Front panel of virtual instrument – part 2

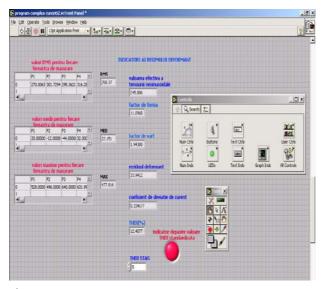


Fig.4 Front panel of virtual instrument – part 3

With the help of the control element we select the standardized value of THDI. This value is compare with the THDI obtained with the programme. We can see on the front panel the button for the signalling overshoot of the standardized value.

Figure 5 shows the diagram window for the harmonics amplitudes calculation both RMS values and percent values.

Fig. 6 illustrates the calculus block of the deforming state indicators. The input is the harmonic spectrum of current from the arc furnace.

This block gives to the output RMS value of the deformed signal and the indicators of deforming state. With the help of build array structure we extract 40 harmonics and continuous component by the amplitudes spectrum, after FFT application. THDI obtained is compare with the standardized value.

The level of current harmonics are calculate with the programme illustrates in fig. 7.

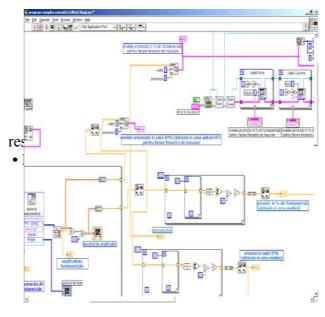


Fig.5 Diagram window – part 1

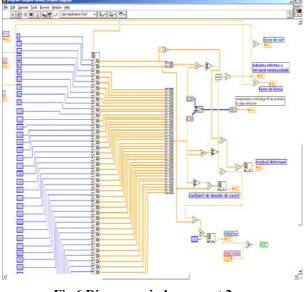


Fig.6 Diagram window – part 2

In table 1 is present the current harmonics spectrum from the arc furnace, which are obtained with the help of programme.

 Table 1 – the harmonic spectrum of the current from the arc furnace

Harmonic range	2	3	4	5	7	9	11	13
In/I1 (%)	6.9	9.4	2.7	4.3	1.2	1.5	1	0.3

We compare these values with the values obtained with VIP SYSTEM 3 etalon and we can say that they are approximately equal.

We can see in this spectrum the even harmonics. It can be observed that the 3rd harmonics is highest. The harmonics amplitudes decrease with the harmonics range increase. THDI for the arc furnace is higher than the standardized value.

Therefore the 2nd, 3rd and 5th harmonics are higher than the values given by PE 143/2001 [4].

The form factor and the crest factor are also higher than the values for the sinusoidal state.

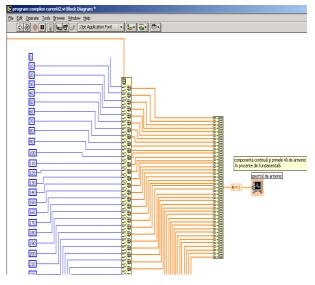


Fig.7 Diagram window – part 3

Conclusions

An instrument for deforming state analysis of arc furnace was designed.

The proposed instrument can determine up to the 40rd harmonic of current and provides important indices, such as rms value of harmonics, harmonic distortion, crest factor, total harmonic distortion.

The instrument can be use to evaluate waveform distortion. Numerical and graphical results are available in real-time.

All the indicators of the deforming state for the IHF 3/A arc furnace are above the standardized values.

References

- [1] Anxo, M.P.A., Perez, M.D., An Improved Time Domain Arc Furnace Model for Harmonic Analysis, IEEE Transactions On Power Delivery, Vol. 19, No.1, January 2004
- [2] Beites, L.,F., Mayordomo, J.,G., ş.a., Harmonics, Interharmonics and Unbalances of Arc Furnaces: A new frequeny domain approach, IEEE Transactions On Power Delivery, Vol. 16, No.4, October, 2001Analog Device
- [3] LabVIEW, Databook, 1996
- [4] Normativul PE 143/2001