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The study of higher harmonics imported by a variable frequency converter of the AC engines

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Abstract. Harmonic currents generated by power electronics based devices create serious power quality problems in facilities. This paper presents the results of the Asynchronous engine control via variable frequency converter and focuses on the network pollutions generated by this device. An analysis of measured values of voltage and current of 5th and 7th harmonics is presented. The study was conducted using an experimental simulation System for Monitoring of the Qualitative and Quantitative Indicators of Electricity Networks, equipped with two AC engines.

1. Introduction

The presence of harmonic distortions in the grid requires the measurement of complex parameters of the distorted signals. In practice, harmonic voltage measurements are easier to perform. To accurately determine the disturbances measuring the voltage is not very appropriate. Because there is a certain difficulty in measuring the harmonic voltages, namely their relatively low amplitude compared to their currents. For this reason, measuring voltage at different points of the grid gives close results as results values, therefore it does not allow finding the exact source determination. But the measurement of the harmonic current allows easy and accurate determination of harmonic impurities [3].

2. The main sources of harmonics.

The loads that introduce substantial distortions called "non-linear loads" can be divided into the following main groups:

- Static converters - frequency converters of electrical engines, UPS, power supplies-in most cases, these devices incorporate a rectifier that is their link to the power distribution network and on which the generated distortions depend.
- The inverters of photovoltaic installations;
- Electric arc furnaces with rectifiers;
- Luminescent and discharge lamps[1],[2].

2.1. Standardization base

The requirements for modern electrical and electronic devices, as well as the permissible levels of harmonics in their power supply, are defined in several European standards, as following:

-The European standard EN50160-3, which defines requirements for the voltage characteristics of power supply networks. The standard introduces levels of compatibility of the voltage harmonics, depending on the type of equipment. According to EN50160-3 the equipment is three classes - 1, 2 and 3. Class 1 is sensitive systems and equipment, including computers, communication equipment

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and medical equipment. Industry and public networks are included into Class 2, and Class 3 devices, which highly pollute the power network.
- The recommended measures and requirements for the control of harmonics in power supply systems are introduced by the IEEE 519 standard. The maximum values of the current harmonics consumed by the power supply network as well as the maximum voltage distortion values at the input point of a user's power supply are defined.
- Another standard for harmonic network pollution is IEC61000. In its part IEC61000-3-2, the permissible emission levels of harmonic currents are regulated for equipment with an input current of less than 16A/phase. Accordingly, the allowed hormonal emissions for equipment with an input current greater than 16A / phase are introduced in IEC61000-3-4. The document states the levels of compatibility of the harmonics by voltage.
- The standardization base also covers the Electromagnetic Compatibility Directives 89/336/ EEC and 93/68 / EEC concerning equipment whose normal operation could be affected by harmonic distortions and pollutants [3] [4].

2.2. Harmonics sources and effects on electrical networks

Harmonics cause overheating and bursts in transformers, engines, cables and other conductive assemblies and explosions and failures in power condensers. They also cause electronic card failures, faulty operations in switches and other protection equipments. Measurement and reading faults in sensitive equipments can be considered as failures caused by harmonics. It can also state that harmonics cause losses due to the increase in RMS current.

If one or more of above given items are observed in the facility, harmonic sources at electrical substructure of the facility should be analyzed. Harmonics generated from harmonic sources in the facility shall not only negatively affect the facility but also the connected grid. This should be considered when a facility is being examined for harmonics [1].

In modern practice, there are various energy monitoring systems that help industrial management both to study the harmonics network and to collect the necessary data in real time. Timely analysis of quantitative and qualitative indicators leads to the minimization of energy losses.

3. The experimental monitoring system

The study was conducted using the experimental simulation System for Monitoring of the Qualitative and Quantitative Indicators of Electricity Networks, equipped with two AC engines: one as AC drive shaft and the other as three-phase current generator. Three halogen lamps are used for a load in the system.

Figure 1. The experimental monitoring system

Using the variable frequency converter, we set different shaft rotation speeds, within the framework recommended for experimental monitoring system

4. Using the variable frequency drive

The experimental monitoring system is equipped with the variable frequency device *i*G5A. This type of frequency converters provide sensorless vector control, PID control, and ground-fault protection through powerful built-in functions [7].

For the correct functionality of the frequency converter, the following configuration is required:

- ✓ AC source supply;
- ✓ MCCB or Earth leakage circuit breaker (ELB);
- ✓ AC reactor;
- ✓ Network analyzer;
- ✓ Installation and wiring.

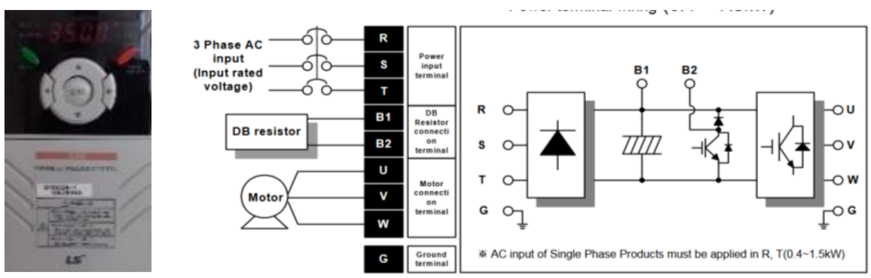

Figure 2. The variable frequency drive- iG5A

The use the frequency drive allows a smooth adjustment of the AC engine speed, which improves the performance and improves the performance of the experimental system. In this study, we change shaft rotation speeds by setting the recommended frequencies for the type of AC engine (31Hz÷37Hz).

5. The network analyzer

The power line analyzer is used to accurately monitoring the basic electrical parameters in a three-phase network. The instrument measures constant voltage and current according to EN 61000-4-30 [6].

Figure 3. The network analyzer - PLA33

The network analyzer has 6 internal energy meters for consumed and supply active, reactive inductive and reactive capacitive energy.

The device measures and shows also particular odd harmonics of voltage and current up to 19th harmonics.

6. The experimental data

In the present study, the basic electrical parameters are current, voltage, different power types, power factor, voltage and current values of 5th and 7th harmonics that dominate in the experimental network. The measured parameters are described in the Fig.4.

№	Frequency	L1,L2,L3	U	I	P	Q ind	Q cap	S	cosφ	U5	I5	U7	I7
	Hz		V	A	W	VAr		VA	-	%	%	%	%
1	32	L1	236	0,54	44,5	0,6	36,0	134,0	0,93	1,96	91,9	1,28	88,9
		L2	234	0,65	-43,9	0,0	32,8	158,0	0,79	1,44	98,8	1,24	92,1
		L3	235	0,76	-38,7	59,8	0,00	181,0	0,5	1,77	94,0	1,30	95,3
2	33	L1	235	0,64	63,0	3,1	0,7	150,0	0,99	2,01	94,5	1,25	94,3
		L2	235	0,78	-55,5	0,0	43,0	184,0	0,79	1,47	99,1	1,16	89,2
		L3	236	0,91	-44,8	44,4	0,00	216,0	0,48	1,81	92,0	1,29	95,1
3	34	L1	235	0,65	63,7	2,7	0,0	153,0	1,00	1,98	90,0	1,30	88,5
		L2	234	0,78	-52,1	0,0	41,0	184,0	0,78	1,46	99,0	1,18	92,4
		L3	235	0,90	-43,1	75,9	0,0	212,0	0,49	1,79	94,0	1,29	93,3
4	35	L1	235	0,66	61,1	1,7	9,8	190,0	1,00	2,01	92,2	1,23	90,8
		L2	234	0,67	-53,1	0,0	41,0	183,0	0,75	1,48	97,0	1,60	90,6
		L3	235	0,87	-44,8	73,9	0,00	211,0	0,49	1,81	94,8	1,41	93,0
5	36	L1	235	0,67	64,00	3,1	0,3	159,0	1,00	1,90	94,4	1,20	91,8
		L2	235	0,75	-49,1	0,0	43,3	178,0	0,74	1,35	96,0	1,14	88,9
		L3	234	0,89	-40,6	78,2	0,00	230,0	0,45	1,36	94,1	1,27	93,3

№	L	Frequency	U	I	P	Q ind	Q cap	S	cosφ	U5	I5	U7	I7
		Hz	V	A	W	VAr		VA	-	%	%	%	%
1	L1	32	234	0,39	30,0	0,0	5,6	91,8	0,87	1,91	91,0	1,48	83,2
	L2		232	0,39	-16,3	0,0	15,4	97,0	0,28	1,81	79,1	1,48	92,3
	L3		234	0,42	-4,9	13,6	0,0	94,2	0,44	1,76	91,2	1,35	74,6
2	L1	33	235	0,38	28,6	0,0	8,5	95,1	0,88	1,94	89,0	1,60	85,0
	L2		235	0,42	-11,3	0,0	14,9	95,8	0,58	1,78	97,7	1,47	98,6
	L3		236	0,41	-9,3	13,8	0,00	94,5	0,35	1,76	0,0	1,42	39,8
3	L1	34	234	0,39	28,3	0,00	5,3	153,0	0,88	1,94	88,7	1,48	79,2
	L2		231	0,41	-13,6	0,0	22,7	184,0	0,52	1,75	71,6	1,49	98,4
	L3		234	0,42	-14,0	109,0	0,0	213,0	0,46	1,73	97,8	1,35	86,4
4	L1	35	235	0,42	22,9	0,0	9,4	99,0	0,88	1,80	99,3	1,48	87,2
	L2		228	0,47	-16,4	0,0	27,5	115,0	0,45	1.74	88,9	1,48	95,8
	L3		234	0,37	-1,8	0,0	0,00	87,0	0,00	1,72	0,00	1,35	25,0
5	L1	36	234	0,39	28,4	0,0	1,7	94,6	0,97	1,78	84,4	1,41	88,9
	L2		232	0,41	-15,8	0,0	20,2	97,6	0,50	1,74	73,5	1,48	95,1
	L3		233	0,42	-14,0	13,7	0,00	98,4	0,43	1,69	72,8	1,28	79,6

№	L	Frequency	U	I	P	Q ind	Q cap	S	cosφ	U5	I5	U7	I7
		Hz	V	A	W	VAr		VA	-	%	%	%	%
1	L1	32	234	0,57	50,2	0,0	5,2	140,0	0.99	1,56	100,0	1,08	86,6
	L2		233	0,69	-36,2	0,0	42,6	155,0	0.63	1,80	96,0	1,25	98,0
	L3		236	0,66	-32,7	48,5	0,0	160,0	0.53	1,97	96,0	1,48	94,2
2	L1	33	233	0.68	56,7	0,0	7,5	153,0	0.99	1.59	101,0	1.12	91.3
	L2		234	0.71	-39,1	0,0	50,6	169,0	0.63	1,78	92,0	1,27	97,20
	L3		236	0.72	-36,2	57,0	0,00	174,0	0.52	1.92	94,0	1.52	91,6
3	L1	34	233	0.70	64,4	0,00	6,8	163,0	0.99	1.58	96,6	1.07	83,9
	L2		234	0.80	-47,5	0,0	56,0	188,0	0.62	1.78	94,3	1.23	99,2
	L3		236	0.79	-42,4	68,6	0,0	188,0	0.55	1.90	96,3	1.50	95,1
4	L1	35	233	0.75	72,0	0,0	6,8	177,0	0.99	1.58	99,4	1.06	86,3
	L2		234	0.86	-51,3	0,0	60,8	206,0	0.62	1.76	95,4	1.26	96,6
	L3		236	0.86	-47,2	67,5	0,00	205,0	0.55	1.91	95,3	1.51	93,70
5	L1	36	233	0.82	73,3	0,0	18,5	189,0	0.98	1.58	99,4	1.09	88,1
	L2		234	0.95	-60,9	0,0	80,6	238,0	0.61	1.82	91,3	1.19	96,0
	L3		236	0.91	-56,6	67,0	0,00	211,0	0.58	1.91	96,1	1.48	93,3

Figure 4. Experimental data

As a result of the study, we note the high values of I^5 (%) and I^7 (%) due to the fact that the frequency converter research is made on idle engine.

Dependencies of the studied harmonic currents and voltages from the frequency (f,Hz) are shown in the following diagrams.

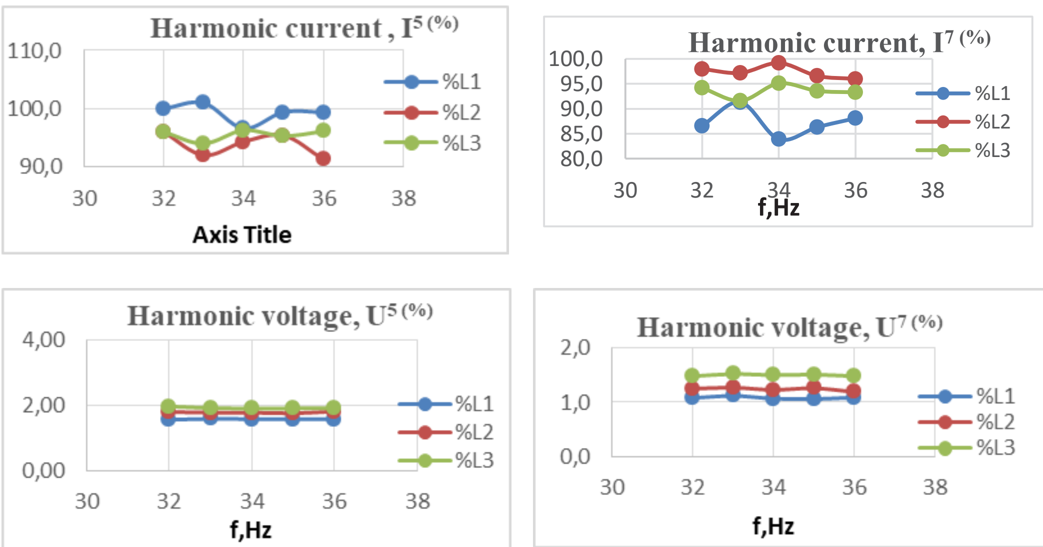

Figure 5. Diagrams of studied harmonics

	Frequ-ency	U	I	P	Q		S	cosφ	U5	I5	U7	I7
					ind	cap						
	Hz	V	A	W	VAr		VA	-	%	%	%	%
1	32	234	0.57	50.20	0.00	5.20	140.00	0.99	1.56	100.0	1.08	86.6
		233	0.69	-36.20	0.00	42.60	155.00	0.63	1.80	98.0	1.25	98.0
		236	0.66	-32.70	48.50	0.00	160.00	0.53	1.97	98.0	1.48	94.2
2	33	233	0.68	56.70	0.00	7.50	153.00	0.99	1.59	101.0	1.12	91.3
		234	0.71	-39.10	0,00	50.60	169.00	0.63	1.78	92.0	1.27	97.20
		236	0.72	-36.20	57.00	0.00	174.00	0.52	1.92	94.0	1.52	91.6
3	34	233	0.70	64.40	0.00	6.80	163.00	0.99	1.58	96.6	1.07	83.9
		234	0.80	-47.50	0.00	56.00	188.00	0.62	1.78	94.3	1.23	99.2
		236	0.79	-42.40	60.60	0.00	188.00	0.55	1.90	96.3	1.50	95.1
4	35	233	0.75	72.00	0.00	6.80	177.00	0.99	1.58	99.4	1.06	86.3
		234	0.86	-51.30	0.00	60.80	206.00	0.62	1.76	95.4	1.26	96.6
		236	0.86	-47.20	67.50	0.00	205.00	0.55	1.91	95.3	1.51	93.6
5	36	233	0.82	73.30	0.00	18.50	189.00	0.98	1.58	99.4	1.09	88.1
		234	0.95	-60.90	0.00	80.60	238.00	0.61	1.82	91.3	1.19	96.0
		236	0.91	-56.60	67.00	0.00	211.00	0.58	1.91	96.1	1.48	93.3

Figure 6. Selected data

At frequency range 33Hz ÷ 35Hz the experimental simulation system generates the lowest possible harmonic currents and voltages.

7. Conclusion

In connection with the requirements of modern electrical and electronic devices, as well as the permissible levels of harmonics in the electrical network, there is a need to use real-time electrical monitoring systems. The presented System for Monitoring of the Qualitative and Quantitative Indicators of Electricity Networks, equipped with different power AC engines, a corresponding frequency devices and a network analyzer, has the ability to determine the 3rd, 5th and 7th harmonics, usually generated by such type of electrical devices.

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