# Determination of Harmonics Level in Local Electrical Distribution System

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*Abstract* – **In this work the calculated results for harmonics level are presented. The results are for local electrical distribution system – company "Plastic Products" – the town of Sredetz – Bulgaria. The experimental investigation is done. The goal of this determining the reason for damages and to propose variants of technical – economical decision for solving of the arising problems.**

*Keywords* – **Power factor, THD, Harmonics.**

## I. Introduction

The character of production line needs the usage of power nonlinear (electrically) charges.

This leads to generation of harmonics in electrical distribution (ED) system of the enterprise [1-3].

There is difficultness for compensation of power factor and that is why the losses in the network go higher (increase).

As a result there is very often damage of compensation devise.

Very often these are its capacitor batteries.

The problems with similar character were revealed in electrical distribution system of "Plastic Products" - town of Sredetz, Bulgaria.

With the lack of possibility compensation devise to be introduced in normal exploration mode, the company pays significant taxes to Electrical Distributing Companies - EVN. It is due to low values of power factor.

The additional financial losses are realized and from increased electrical losses, depending on circulated harmonics in ED-system.

It was necessary the investigation of electrical distribution system to be performed.

It was done using power analyzer, which gives a possibility to receive data as for powers (active "P", passive "Q"), as well as for power factor cosφ.

Some of the parameters for the quality of electrical energy could be determined using coefficients THD (total harmonic distortion) by voltage and current and amplitude – frequency spectrum of the harmonics [4-5].

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## II. Determination of the Coefficient of Voltage Nonsinusiadility on the Bus of Substation

### *1.1. Short description of the object.*

The industrial unit "Polystirol" is supplied from the transformer TM-630 with short circuit voltage $u_{sc}$=6%.

The short circuit power on the primary side of the transformer is $S_{sc}$=25 MVA.

From the busses of the substation are supplied:

- Current rectifier connected in "Larionov" with power 120 kW and working with cosφ=0,7;
- Five asynchronous motors with next characteristics:
  - nominal power 22 kW;
  - nominal power factor $\cos\varphi_n$ = 0,92;
  - multiplicity of starting moment $t_s$ = 1,2;
  - multiplicity of starting current $k_s$ = 6;
  - efficiency with nominal charge $\eta_n$ = 0,92;
  - nominal slip $s_n$ = 2,66%;
  - ratio between power losses in stator and total losses in nominal load $\gamma$ = 0,3.

Average monthly cosφ of industrial unit "Polystirol" is 0,7.

### *1.2. Methodology for analytical determination of the THD and capacitor's power.*

- Creating of equivalent circuit for the fifth harmonic for one phase, as a thyristor rectifier is replaced with equivalent current source, but power transformer, asynchronous motors and supplying system are replaced with their resistances – (Fig. 1).

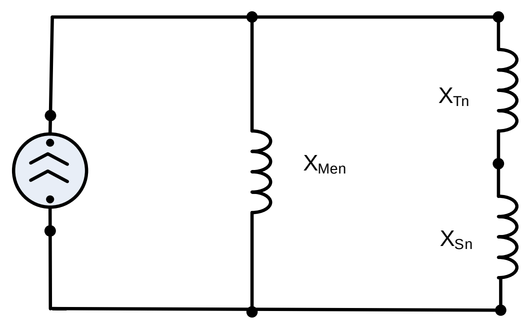


Fig. 1. Equivalent circuit.

- Determination element reactances in the electrical power supplying circuit [6]:

- *System reactance:*

$$x_{S_n} = k_x \frac{U^2}{S_{S_{cs}}} n = 4{,}16 \times 10^{-3}\ n \qquad (1)$$

Where:

- U – voltage, U = 400 V;
- $Ss_{cs}$- short circuit power;
- n - harmonic number;
- $k_x$ – coefficient, $k_x$ = 0,65.

- *Transformer reactance*:

$$x_{Tn} = \frac{k_x u_k U^2}{S_T} n = 0{,}013409\, n \qquad (2)$$

Where:

- $k_x$ – coefficient, $k_x$ = 0,88;
- $S_T$ – transformer Apparent power;
- U – nominal voltage of the motors (V).

- *Equivalent reactance of five asynchronous motors*:

$$x_{Me_n} = \frac{1}{5} k_x \frac{U^2 \cos\phi_n}{k_s P_n} \sin\phi_s n = 0{,}1647\, n \qquad (3)$$

Where:

- $k_x$ – coefficient, $k_x$ = 0,78;
- Pn – pated power;
- $k_s$ – ratio between starting current $I_{start}$ and rated current $I_n$; $k_S = I_{Start} / I_n$;
- $\sin\varphi_S$ – starting sinφ;
- $\sin\varphi_n$ = 0,9469. It is determined in dependence on power factor in the start of motor;
- $\cos\varphi_S = \cos\varphi_n \left[ \frac{t_S}{(1 - S_n) k_s} + \gamma k_S (1 - \gamma) \right] = 0{,}3215$ (4)

- *Total equivalent reactance for relevant harmonic*:

$$x_{en} = x_{M_{en}} \frac{\left(x_{S_n} + x_{T_n}\right)}{\left(x_{M_{en}} + x_{S_n} + x_{T_n}\right)} n \qquad (5)$$

The sequence number of the harmonic of Larionov rectifier are 5, 7, 11, 13, 17, 19 etc.

- Determining of current of the base harmonic, which is determined by the equation:

$$I_n = \frac{I_1}{n} \left[ \frac{\sin\left(\frac{n\gamma}{2}\right)}{\frac{n\gamma}{2}} \right] \quad \gamma = 12^0 \left(0{,}2094\ rad\right) \qquad (6)$$

Where:

- In – relevant harmonic current;
- $I_1$ – fundamental harmonic current;
- γ – thyristor commutation angle.

$I_1$ is a current of the base harmonic, which determined by the equation:

$$I_1 = \frac{P_n}{\sqrt{3} U_n \cos\varphi} = 247{,}44\ A \qquad (7)$$

- Determining of voltage of the n- harmonic:

$$U_n = I_{e_n} x_{e_n} \qquad (8)$$

- Determining of coefficient THD:

$$THD_n = \sqrt{3} k_1 k_2 \frac{\sqrt{\sum_{n=5}^{19} U_n^2}}{U_1} 100 = 3{,}96\% \qquad (9)$$

- $k_1$, $k_2$ - correction coefficients.

- Determining of the necessary compensation capacitive power:

For a moment load of the industrial unit is:

$$Q_{cap} = P\left(tg\varphi_1 - tg\varphi_2\right) = 180\ kVA \qquad (10)$$

In this case:

$$x_{cap} = 2{,}66\ \Omega \qquad (11)$$

Comparing the calculating inductive reactance with capacitive it is seen that is possible appearance for the 13 – th harmonic.

### *1.3. Experimental results.*

Using power analyzer *Circutor* are determinate:

- Coefficient total harmonic distortion (THD). The derived result is closed as a value to the theoretical calculation (Fig. 2).

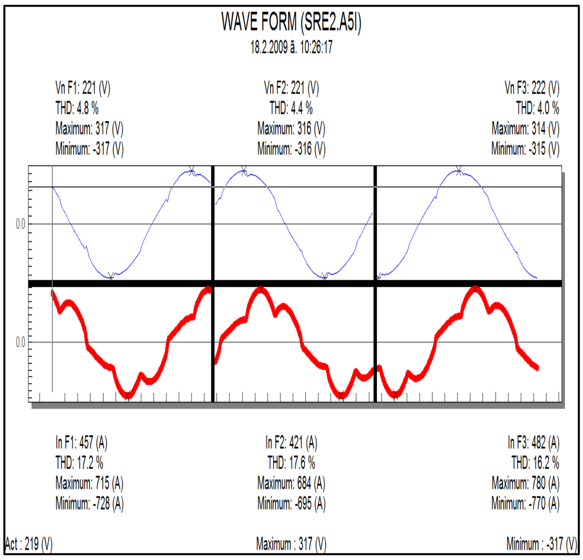


Fig. 2.

- Harmonious composition of the current (Fig. 3,a and Fif.3,b):

| Phase current3 | | |
|---|---|---|
| Irms (A):488 | THD (%):16.2 | |
| Fundamental (A):482 | Disphase (c):85.7 | |
| **Harmonic** | **Amplitude (%)** | **Disphase (?)** |
| 7 (-) | 3.143 | 64.3 |
| 8 (-) | 0.136 | 119.3 |
| 9 (+) | 0.332 | 265.1 |
| 10 (-) | 0.101 | 120.1 |
| 11 (-) | 3.798 | 322.0 |
| 12 (+) | 0.210 | 287.4 |
| 13 (+) | 0.366 | 129.9 |
| 14 (+) | 0.075 | 186.5 |
| 15 (-) | 0.276 | 309.9 |
| 16 (-) | 0.116 | 145.4 |
| 17 (+) | 1.792 | 359.0 |
| 18 (-) | 0.110 | 331.3 |
| 19 (-) | 0.218 | 276.3 |
| 20 (-) | 0.055 | 234.4 |
| 21 (-) | 0.191 | 340.9 |

Fig 3,a.

| Phase voltage3 | | |
|---|---|---|
| Vrms (V):222 | THD (%):4.0 | |
| Fundamental (V):222 | Disphase (c):127.1 | |
| **Harmonic** | **Amplitude (%)** | **Disphase (?)** |
| 7 (-) | 0.535 | 329.8 |
| 8 (-) | 0.107 | 211.0 |
| 9 (+) | 0.086 | 128.5 |
| 10 (-) | 0.070 | 82.4 |
| 11 (-) | 1.172 | 110.5 |
| 12 (+) | 0.067 | 67.3 |
| 13 (+) | 0.078 | 211.4 |
| 14 (+) | 0.055 | 17.0 |
| 15 (-) | 0.155 | 290.4 |
| 16 (-) | 0.044 | 207.5 |
| 17 (+) | 0.763 | 249.4 |
| 18 (-) | 0.060 | 213.9 |
| 19 (-) | 0.120 | 50.5 |
| 20 (-) | 0.065 | 145.0 |
| 21 (-) | 0.132 | 80.3 |

Fig. 3,b.

From the Figure 2 is clear that the biggest energy influence of the current harmonics as disturber 5, 7, 11, and 17 harmonic.

Although that 13-th harmonics has not big weight only 0,366% from the base, it is the main factor for arising resonances.

## III. Conclusion

The investigations performed onto the work of the electrical energy system of the local company “Plastic Products” give the reason to make a decision, that there is a big pollution with harmonics.

They are generated from the part of the technological electrical equipment, used in the production of plastic material.

The equipment has strongly expressed nonlinear character as an electrical charge.

The problems, which arise in the work of the compensation capacitor device for increasing cosφ are as a result of the resonance current processes.

They arise between the capacitors of compensation device and inductances as elements of electric network.

As a result the capacitive batteries of the compensation device is overload by current and from this by power over the limited levels.

This is the reason for their damages in going out from the working condition.

The calculation which are done are closed to the experimentally received results.

The failure of the capacitor batteries is connected with the arising current resonance phenomena as a result of the harmonics and following current and from this power overloads over limited levels.

It is proofed the possible resonance for the 13 –th current harmonics.

Dissolving the existing problem is connected with dissolving of the problem with the pollution of electrical supplying system with harmonics.

This can be reached in the way their filtering or changing of the resonance areas.

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