DETERMINATION OF SPECIFIC ELECTRICITY CONSUMERS' WHICH HAVE GREAT IMPACT ON HARMONIC DISTORTION OF VOLTAGE WAVEFORM

Marinko STOJKOV
HEP-ODS – Croatia
marinko.stojkov@hep.hr

Kruno TRUPINIC
HEP-ODS – Croatia
kruno.trupinic@hep.hr

Darko POLETO
HEP-ODS – Croatia
darko.poleto@hep.hr

ABSTRACT

New technology era is based on electronic devices which increase proportion of nonlinear characteristics in total distribution power system load. So, it is expected to appear increment of true harmonic distortion (THD) of voltage waveform, what is one of main power quality parameters. Electricity supply companies have obligations to control and maintenance these parameters within allowed boundaries according to en 50160. The most important steps of inspection of THD are based on measurements in real network in order to lookout and recognize specific consumers' which are responsible for power quality reduction on their connection points to network. Although these consumers' are large sources of THD, usually they even don't know about their impact; and sometimes they require better power parameters from electricity supply company. Here, a new procedure is proposed for determination of each consumer impact on THD of voltage waveform.

INTRODUCTION

This paper shows existent consumers'' nonlinear electrical apparatus feedback impact on distorted harmonics wave form of the supplied voltage on the power distribution connection point. In the matter of fact, evaluation of that impact for new electrical apparatus is simpler because weekly measuring can be done before connection and after connection on electricity network. From the difference between these two measuring the level of consumers'' nonlinear electrical apparatus feedback impact can be double checked and calculated from consumers'' power plants, installation and electrical apparatus project documentation.
That sort of existent consumers'' check is hard to execute because of the consumers'' weekly disconnection inability for voltage quality measuring without electrical apparatus impact.

MEASURING CONTROL OF CONSUMERS'' NONLINEAR ELECTRICAL APPARATUS FEEDBACK IMPACT

The supplier executes voltage quality measuring on consumers'' power distribution connection point without electrical apparatus impact in the following cases:

- neighboring consumers' complaints on a poor voltage quality,
- determining poor voltage quality by routine plant measuring ,
- greater connection power at the consumers' end, which is defined by following condition:
  - S_{3PK}/S_P < *1000* for middle voltage consumers'
  - S_{3PK}/S_P < *150* for low voltage consumers',

where S_{3PK} is short connection point power, and S_P consumers'' connection power,

- bigger part of the nonlinear consumers'' electrical apparatus, what can be seen from the consumers'' technical documentation.

The third case condition shows that nonlinear load impact is greater in weak points of the distribution system, better saying in greater impedance and smaller power of three pole short connection.

Distorted wave power voltage dependant of nonlinear load

Additional increase of the total distorted harmonics wave (power) voltage THDU on consumers'' power distribution connection point caused of nonlinear load depends of:

- Participation of nonlinear load shown by total distorted harmonics of consumers'' electrical apparatus load – THDI.
- Value of the total electrical apparatus load – power I,
- The distribution system power on a connection point expressed with the power system impedance Z or with three pole short connection power $S_{3PK.}$

$$\Delta\ THDU = f\,(\,I,\ THDI,\ Z\,) \qquad (1)$$

Or interconnection of these:

$$\Delta\ THDU = k \cdot I \cdot THDI \cdot Z \qquad (2)$$

Where is:

Δ THDU	Value of additional increase of the total distorted harmonics wave (power) voltage caused of nonlinear electrical apparatus load,
I	Total power of consumer's electrical apparatus,
THDI	Total value of consumers'' electrical

apparatus distorted harmonics,

Z Power system impedance on the connection point,

k Relation variable determining nonlinear load influence in exact impedance network point on harmonics distortion voltage supply increment.

Linear and nonlinear load examples

Figure 1 shows parallel interrelated period diagram THDU and THDI for pure linear load. It is easy to see that a current harmonics distortion is totally equal to a voltage harmonics distortion. It is clearly expected, because a current harmonics distortion THDI is generated by a voltage harmonics distortion THDU existence in electricity supply. Based on this diagram in the case of nonlinear load periodic diagram THDI according THDU is:

- Always greater magnitude,
- Different wave form,

as shown on Figure 2. So, the difference between momentary values of THDI and THDU in every moment is generated exclusively by nonlinear consumers'' electrical apparatus which connection point the diagram is measurement recorded. The THDI value itself does not contain nonlinear load value, so multiplying THDI by the total consumers' current value I produces value I·THDI which is the base for consumers' nonlinear apparatus load influence on THD load increment of electricity supply. The Figure 3 shows parallel interrelated period diagram of THDU and I·THDI relative to max. values. Greater value of I·THDI has significant impact on THDU value.

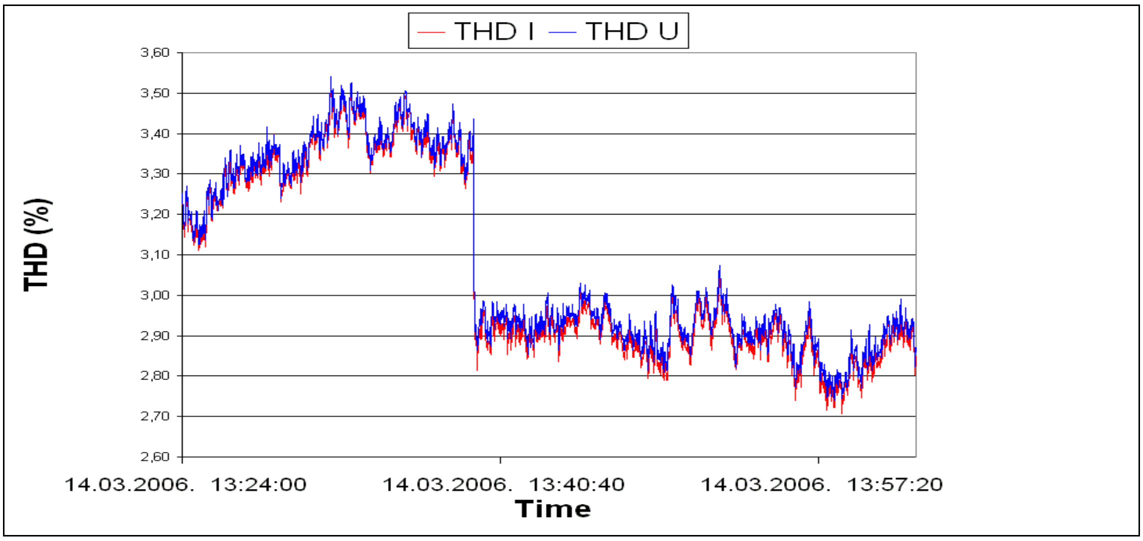

Figure 1. Period diagram THDU and THDI for pure linear load

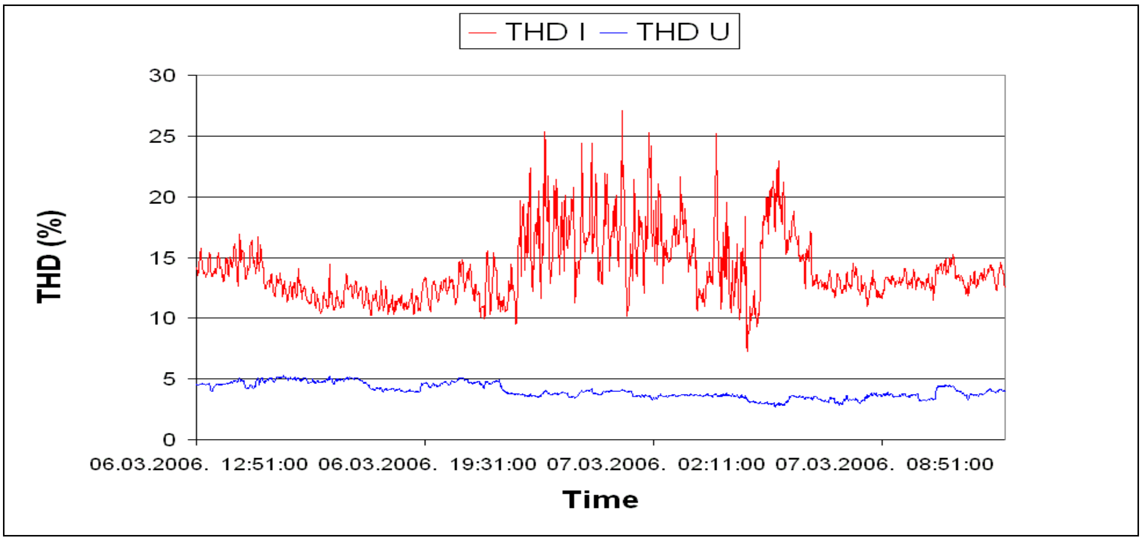

Figure 2. Daily diagram THDU and THDI for non-linear load

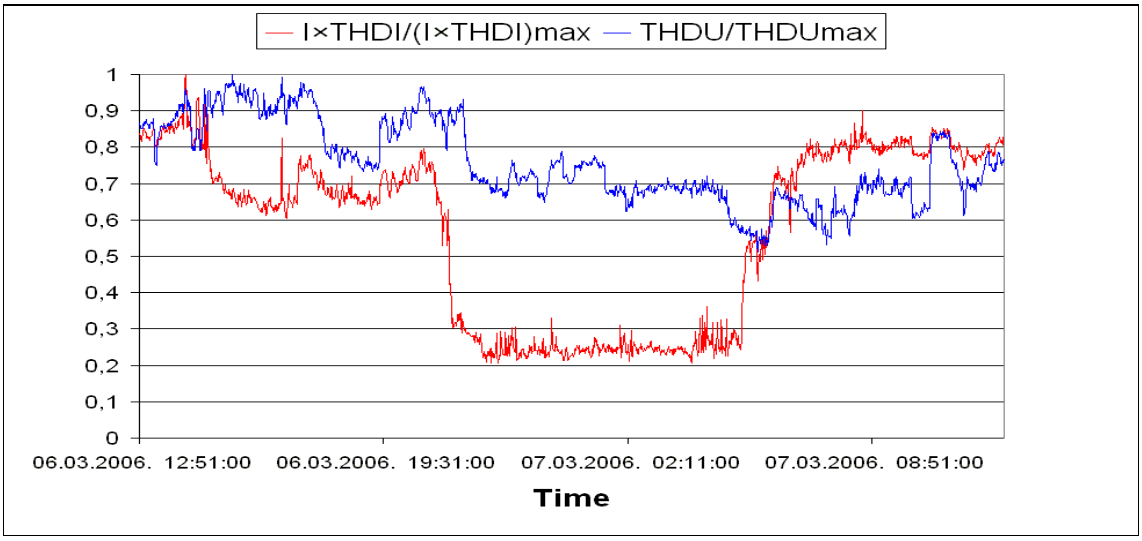

Figure 3. Daily diagram of THDU and I·THDI relative to max. values

The Figure 4 shows main objective this paper deals with – determining Δ THDU based on known I·THDI and Z. In essence, in any point of the distribution system unknown relation variable k, following methods can be applied.

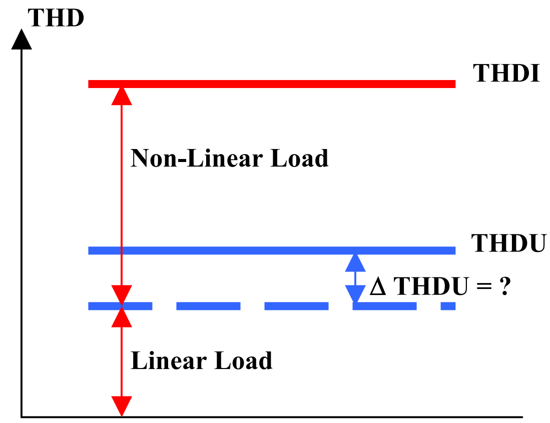

Figure 4. Determining Δ THDU based on I·THDI and Z

Determining Δ THDU

Determining Δ THDU generated by nonlinear consumers' load on the distribution network connection point is conveyed by the network impedance change of monitored points.

A The network impedance change due to variable measuring spots

Here, simultaneous measuring of voltage quality and consumers' load parameters are performed in two different network spots with different impedances. The example of a power transformer simultaneous measurement on MV and LV side the consumer is getting electricity from, as shown on the Figure 5. Comparative daily diagram recorded $THDU_{MV}$ and $THDU_{LV}$ is shown on the Figure 6. The increment of $THDU_{LV}$ values according to $THDU_{MV}$ value is caused by:

- Non transfer of 3n LV harmonics to the MV side of transformer because of triangle winding form on the MV side,
- Harmonics voltage distortion increment due to an impedance increase from Z_{MV} to Z_{LV}.

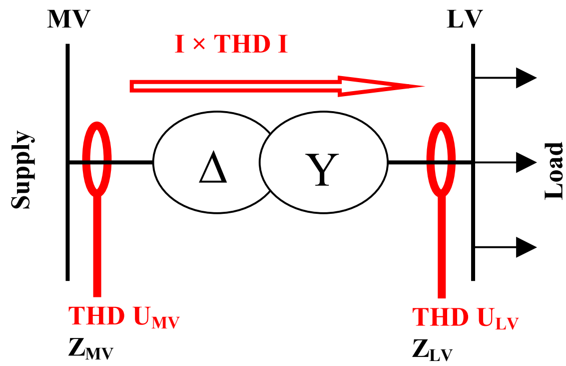

Figure 5. Simultaneous measurement on MV and LV side

Considering only second mentioned cause and inserting in the relation (2) the following expressions are derived:

$$\Delta\, THD\; U_{LV} = \Delta\, THD\; U_{\Delta Z} \cdot \frac{Z_{LV}}{\Delta Z} \qquad (3)$$

$$\Delta\, THD\; U_{MV} = \Delta\, THD\; U_{\Delta Z} \cdot \frac{Z_{MV}}{\Delta Z} \qquad (4)$$

where is:

$\Delta\ THDU_{LV}$ Value of additional total harmonics distorted voltage increment caused by nonlinear consumers' load on LV bus bars,

$\Delta\ THDU_{MV}$ Value of additional total harmonics distorted voltage increment caused by

	nonlinear consumers' load on MV bus bars,
$\Delta\ THDU_{\Delta Z}$	Value of additional total harmonics distorted voltage increment caused by nonlinear consumers' load on power
	Transformer impedance ΔZ,
Z_{LV}	Network impedance on LV bus bars,
Z_{MV}	Network impedance on MV bus bars,
ΔZ	Transformer impedance, or impedance difference Z_{LV} and Z_{MV}.

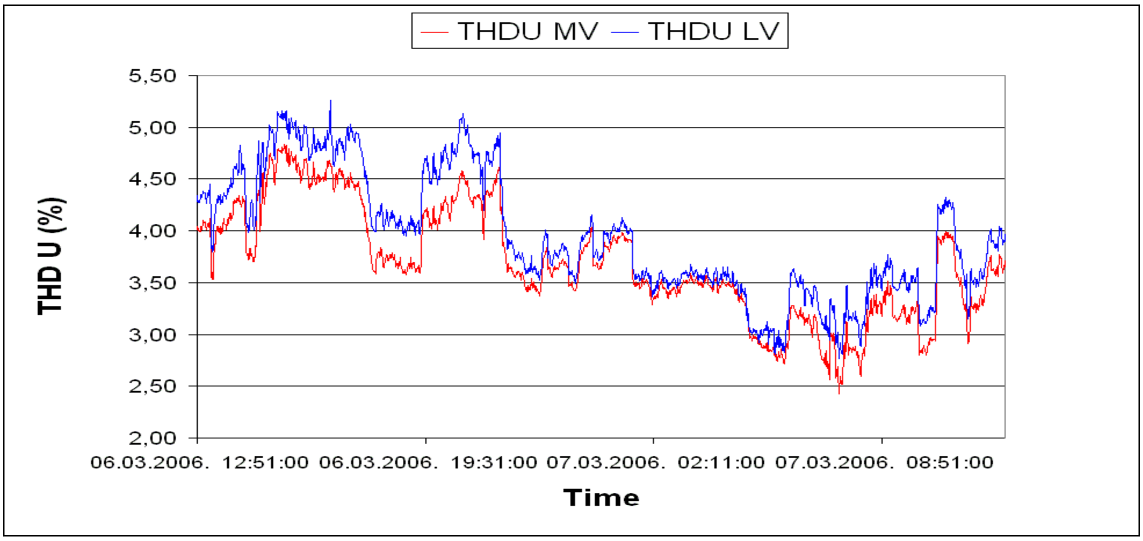

Figure 6. Comparative daily diagram recorded $THDU_{MV}$ and $THDU_{LV}$

B Network impedance periodic change

Change of the network impedance Z in exact spot THD level is changed too. If the network impedance Z decreases, THDU decreases too, and if the network impedance Z increases, THDU increases too.
Likewise, value of the Δ THDU is generated by nonlinear load I·THDI of the particular consumer.

In the case with impedance Z_1 ratio is:

$$(\Delta\ THDU)_1 = k \cdot I \cdot THDI \cdot Z_1 \quad (5)$$

and likewise with impedance Z_2:

$$(\Delta\ THDU)_2 = k \cdot I \cdot THDI \cdot Z_2 \quad (6)$$

so:

$$\frac{(\Delta\ THD\ U)_1}{(\Delta\ THD\ U)_2} = \frac{Z_1}{Z_2} \quad (7)$$

Further, in the both of the cases appearing moments of maximum and minimum non linear consumers' load measured on a consumer connection point are observed - $(I \cdot THDI)_{1max}$, $(I \cdot THDI)_{1min}$, $(I \cdot THDI)_{2max}$ and $(I \cdot THDI)_{2min}$. These values determine relations (2), and with aided relation (7) an equation system is solved.
Conclusive answers are the totals THDU in these marginal cases of maximum and minimum non linear loads with the network impedances Z_1 and Z_2.
An example for simple network's impedance change is connecting and disconnecting of one power transformer which is in parallel line with one or more other transformers, as shown on Figure 7.

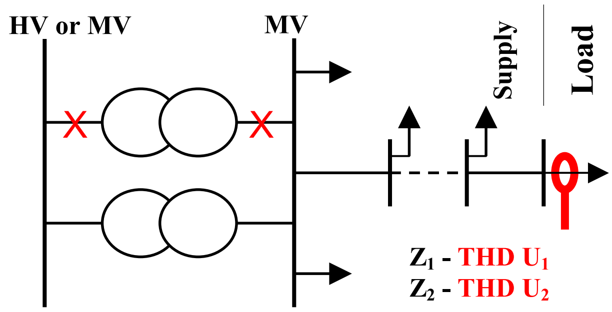

Figure 7. Network impedance periodic change

CONCLUSION

Each power system's end-user and belonging non linear load impacts total harmonics distortion level of supplied voltage. Partial consumer voltage harmonics distortion can be determined in a connection points by proposed measurement and calculation methods. These methods execution don't need existent consumers' disconnection to supply network.

REFERENCES

[1] Roger. C. Dugan, Mark F. McGranaghan, H. Wayne Beaty, Marek Samotyj: 1995, *Electrical Power Systems Quality*, McGraw-Hill Book Companies, USA

[2] Leonardo Power Quality Initiative, *www.lpqi.org,* 2007