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Zuerst erschienen in:
2005 IEEE Russia Power Tech . - Piscataway, NJ, 2008. -
ISBN 978-5-932080-34-4, insges. 5 S.
DOI: 10.1109/PTC.2005.4524730

Identification of the Dominant Harmonic Source in the LV Network on the Base of Anomalous Power Flows Considerations

H. Schau, A. Novitskiy

Abstract—**The localization of the dominant harmonic distortion source in the electrical network is one of the practical tasks in the consideration of the power quality in electric power systems. The conventional methods of the estimating of the impacts of the utility and the customer to the harmonic distortion at the network node are the harmonic power flow analysis as well as the correlation analysis of the harmonic voltage and current phasors. The practical use of both methods is discussed below by means of the example of the identification of the dominant harmonic source in the LV supply feeder of an industrial consumer. Based on the analysis carried out it is shown that the direction of harmonic active power flows is a more common and reliable criterion in comparison with the correlation analysis for the identification of dominant harmonic sources in electric power systems.**

Index Terms—**Harmonic distortion, harmonic power flow analysis, correlation analysis, measurement, power quality.**

I. Introduction

KEEPING of power quality in electric power systems means that it is necessary to analyse the spread of the distortion in the electric power system, to analyse the interaction between different distortion sources, and to locate distortion sources.

Localization of the dominant harmonic distortion source in the electrical network is one of the practical tasks when estimating the contribution of the utility and the customer to the harmonic distortion at the electrical network node under consideration.

On the base of the theory of harmonic power flows in circuits with non-sinusoidal voltages and currents developed by BUDEANU (1927) [1], in [2] it was recommended to determine the direction of harmonic power flows for the localization of the dominant harmonic source in symmetrical balanced three-phase electrical networks.

In [3] – [6] it was shown that the harmonic power flow theory taking into account the decomposition of voltages and currents into symmetrical components (FORTESCUE transformation) can be used for the localization of dominant harmonic distortion sources in three-phase electrical networks under non-symmetrical and non-sinusoidal conditions, too.

The common criterion for the localization of the dominant harmonic source in a supply feeder connected to the network node under consideration is the direction of harmonic active power flow (**anomalous power flow**) which is always emitted from the dominant harmonic source.

But the harmonic power flow estimation in real electrical networks requires to determine not only the magnitudes of harmonic voltage and current phasors as accurately as possible but also the corresponding phase angles. As an alternative method for the localization of the dominant harmonic source in the power system the use of the correlation analysis only for the magnitudes of the harmonic voltage and current phasors was recommended in [2], [7].

The practical use of both methods above mentioned is discussed below by means of the example of the identification of the dominant harmonic source in the supply feeder of an industrial consumer. The necessity of the carrying out of the on-site measurements in all phases of the three-phase system is shown.

II. Measurement Results

Fig. 1 shows the THD as well as the 5th and 3rd harmonic voltage time behaviours (one minute mean values) at the 0.4 kV supply bus of an industrial consumer. It can be seen that the THD at the bus is fully determined by 5th harmonic. It can be seen also the different character of changes of the harmonic values at the weekend in comparison with the corresponding harmonic levels during the workdays for presented harmonics.

Fig. 2 shows the measured 5th and 3rd harmonic currents, the harmonic active power flows as well as the correlation diagrams for the harmonic magnitudes. In Fig. 2 the one minute mean values of the harmonic quantities are presented.

It can be seen from Fig. 2 that the harmonic currents are significantly decreased during the weekend in comparison with the harmonic current levels over the workdays. This is connected with the switching-off of the main consumer load at the weekend. Irrespectively of the change of the harmonic voltage levels at the weekend (5th harmonic voltage level is increased, 3rd harmonic voltage level is decreased) the

This work was supported in part by the SWSZ power utility.

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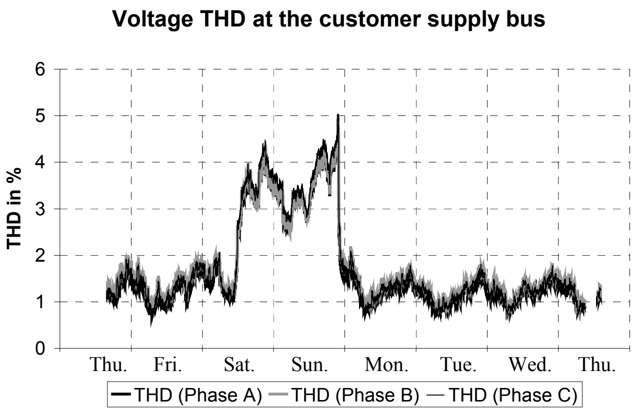
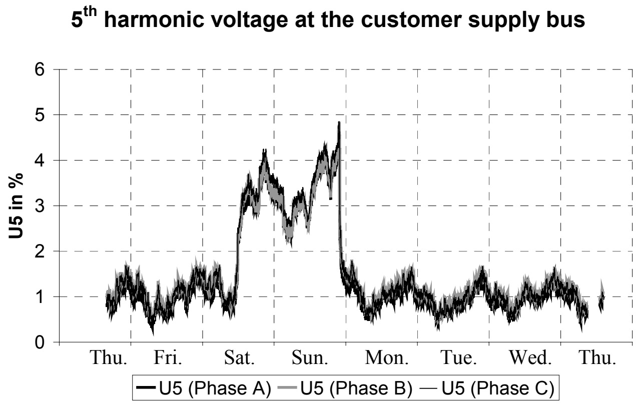
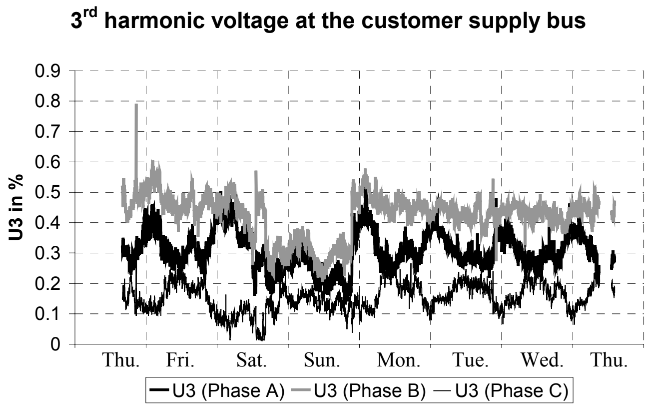
harmonic active power flow levels are decreased during the weekend, too.



a)



b)



c)

Fig. 1.

It can be seen from Fig. 2 that the 5th harmonic currents have practically the same values in each phase of the three-phase system over the full measurement time. The 5th harmonic active power flows have also similar levels in each phase and have the same direction during the week. The signs of the 5th harmonic power flows are positive during the full measurement time. According to [2] – [6] it means that **the utility is the dominant 5th harmonic source** during the week under consideration.

Taking into account the correlation between 5th harmonic voltage and fundamental harmonic current levels over the workdays (the distortion voltage decreases with the increase of the load current, Fig. 2d)) this conclusion is also confirmed by considerations of [8].

The analysis of the 3rd harmonic time behaviour shows that the 3rd harmonic currents as well as the 3rd harmonic active power flows are non-symmetrical in the three-phase system (Fig. 2e), f)) in the case under study. The active power flows in the phase "A" and in the phase "C" are different in their directions. Taking into account the correlation analysis results it could be concluded that the utility is the *3rd harmonic dominant source according to the measurement results for the phase"A"* (Fig. 2h)), *the consumer is the 3rd harmonic dominant source according to the measurement results for the phase "C"* (Fig. 2j)). It means that the location of the 3rd harmonic dominant source in the system utility-consumer under study can not be determined by separate consideration of harmonic processes in different phases of three-phase systems.

However the dominant harmonic source in the three-phase system under non-symmetrical conditions can be reliably identified in some cases taking into account the common relation of the power in a three-phase system as a sum of all phase power or all sequence power using symmetrical components considerations.

Fig. 3 shows the 3rd harmonic three-phase active power flow (30 and 60 minute mean values) during the week.

From Fig. 3 it can be seen that the 3rd harmonic three-phase active power flow is mainly directed from the consumer to the utility during the workdays and from the utility to the consumer during the weekend. It means that **the consumer is the dominant 3rd harmonic source during the workdays** (main consumer load in operation), **the utility is the dominant 3rd harmonic source during the weekend** (only background load in operation by consumer).

Taking into account the decomposition of the 3rd harmonic voltages and currents into symmetrical components the impacts of the utility as well of the consumer on the common harmonic distortion at the LV network node under consideration can be estimated.

Fig. 4 shows the active power flows of the symmetrical components on the 3rd harmonic (one minute mean values) as well the summarized 3rd harmonic power flow on workday (Fig. 4a)) and on Sunday (Fig. 4b)) at the network node under consideration.

From Fig. 4a) it can be seen that the **negative sequence** 3rd harmonic active power flow is negligible during the workday. The summarized 3rd harmonic active power flow during the workday is mainly generated as a sum of the **positive sequence** 3rd harmonic active power flow coming from the utility (the values of the active power are positive) and the **zero sequence** 3rd harmonic active power flow emitted from the consumer (the values of the active power are negative).

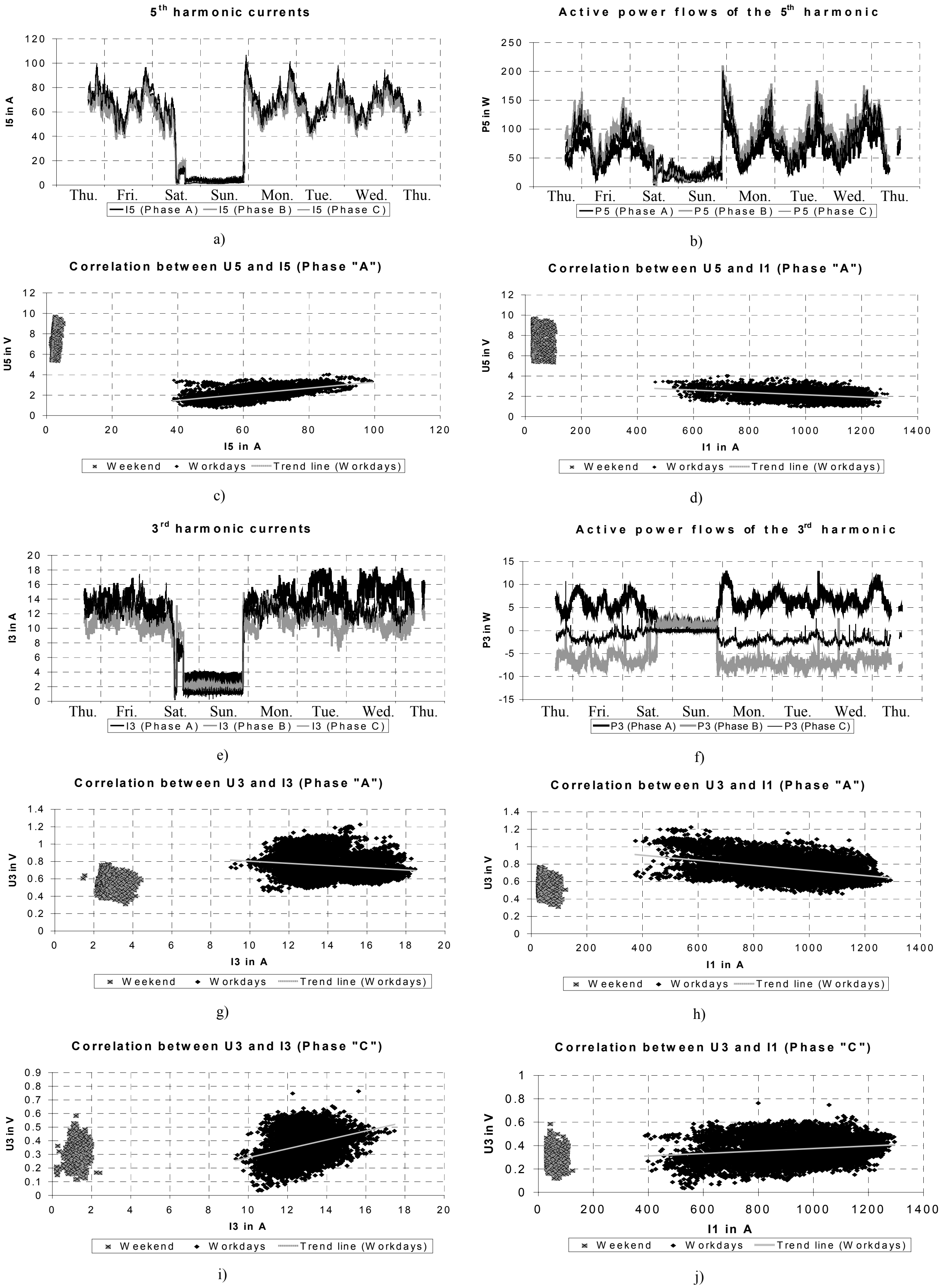

5th harmonic currents
I5 in A
Thu. Fri. Sat. Sun. Mon. Tue. Wed. Thu.
I5 (Phase A) I5 (Phase B) I5 (Phase C)
a)
Active power flows of the 5th harmonic
P5 in W
Thu. Fri. Sat. Sun. Mon. Tue. Wed. Thu.
P5 (Phase A) P5 (Phase B) P5 (Phase C)
b)
Correlation between U5 and I5 (Phase "A")
U5 in V
I5 in A
Weekend Workdays Trend line (Workdays)
c)
Correlation between U5 and I1 (Phase "A")
U5 in V
I1 in A
Weekend Workdays Trend line (Workdays)
d)
3rd harmonic currents
I3 in A
Thu. Fri. Sat. Sun. Mon. Tue. Wed. Thu.
I3 (Phase A) I3 (Phase B) I3 (Phase C)
e)
Active power flows of the 3rd harmonic
P3 in W
Thu. Fri. Sat. Sun. Mon. Tue. Wed. Thu.
P3 (Phase A) P3 (Phase B) P3 (Phase C)
f)
Correlation between U3 and I3 (Phase "A")
U3 in V
I3 in A
Weekend Workdays Trend line (Workdays)
g)
Correlation between U3 and I1 (Phase "A")
U3 in V
I1 in A
Weekend Workdays Trend line (Workdays)
h)
Correlation between U3 and I3 (Phase "C")
U3 in V
I3 in A
Weekend Workdays Trend line (Workdays)
i)
Correlation between U3 and I1 (Phase "C")
U3 in V
I1 in A
Weekend Workdays Trend line (Workdays)
j)

Fig. 2.

From Fig. 4a) it can be seen that the 3rd harmonic emission from the customer is characterized by practically constant values of the harmonic active power during the workday. It means that the disturbing consumer load is balanced in relation to the emitted 3rd harmonic. It can be concluded that the 3rd harmonic unbalance at the network node under study is caused by the power utility impact during the workday.

The larger absolute values of the zero sequence 3rd harmonic active power emitted by the consumer in comparison with the absolute values of the positive sequence 3rd harmonic active power coming into LV network from the utility result in the domination of the consumer impact on the 3rd harmonic summarized distortion at the network node under study on the workday.

From Fig. 4b) it can be seen that the summarized 3rd harmonic active power flow during the weekend is practically equal to the **positive sequence** 3rd harmonic active power flow emitted by the utility (the values of the active power are positive). This confirms the conclusion mentioned above that the utility is the dominant 3rd harmonic source at the LV network node under consideration during the weekend.

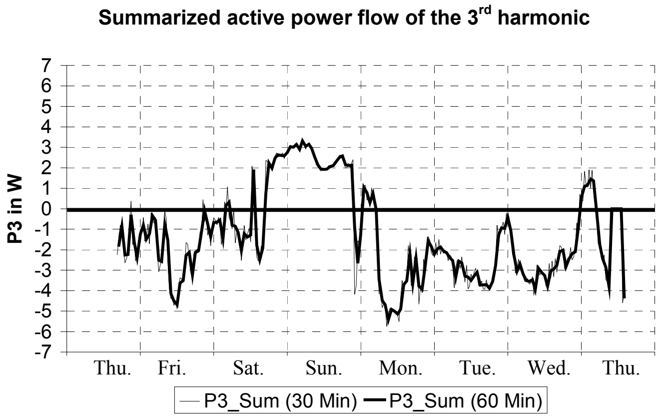


Fig. 3.

III. Summary

Based on the analysis carried out it can be concluded:

1. On-site measurements in all phases of the three-phase system are necessary for the reliable identification of dominant harmonic sources in electric power systems in the common case.

2. The direction of harmonic active power flow is a more common and reliable criterion in comparison with the correlation analysis for the identification of dominant harmonic sources in electric power systems.

3. The analysis of the symmetrical components of the harmonic active power is advised for the identification of the consumer and utility impacts on the summarized harmonic distortion under non-symmetrical conditions.

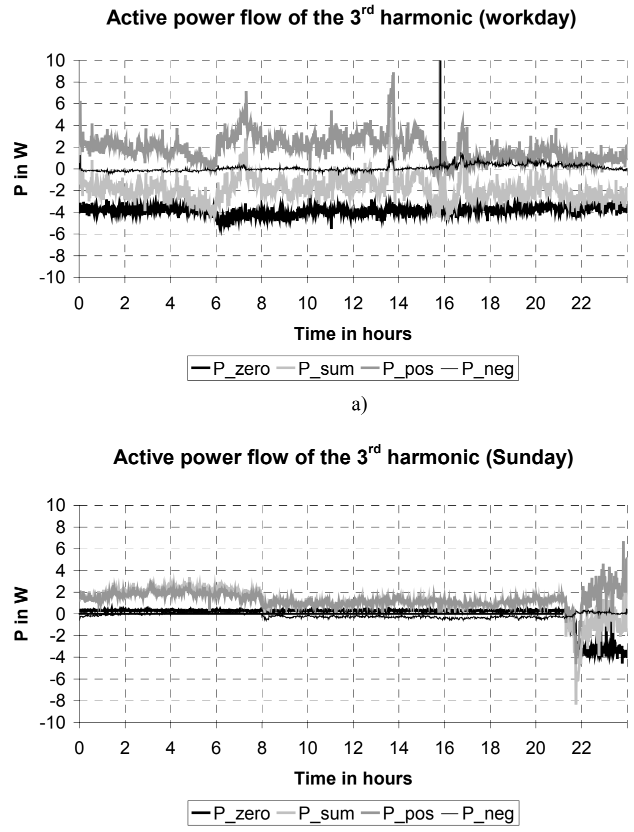


Fig. 4.

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