# ON-SITE POWER QUALITY MEASUREMENTS IN SLOVAK TRANSMISSION AND DISTRIBUTION NETWORKS

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## *ABSTRACT*

*This paper analyzes the power quality within Slovak Transmission and Distribution Networks. The work was performed in the framework of the European Metrology Research Programme Project "Metrology for Smart Electrical Grids", Work Package 3 – Tools for portable and remote measurement of Power Quality [1].*

## INTRODUCTION

Power quality monitoring is the process of gathering, analyzing, and interpreting raw measurement data into useful information. The process of gathering data is usually carried out by continuous measurement of voltage and current over an extended period. The power quality measurement and the data acquisition is based on the existing standards: EN 50160 [2] which provides recommended levels for different power quality parameters, including a time-based percentage during which the levels should be kept and IEC 61000-4-30 [3] provides measurement methods, describes measurement formulas, sets accuracy levels and defines aggregation periods.

## DESCRIPTION OF THE MEASUREMENTS

The power quality measurement campaigns were performed at Slovak Distribution Network Operator (DNO) and at Slovak Transmission System Operator (TSO).

### Case study 1: Influence of the photovoltaic (PV) source connected with the distribution network

Measurement location was at western part of Slovakia, nominal voltage 230V, current transformers ratio: 150A/5A, accuracy class 0,5 and system under investigation: 3-phase with neutral. The measured parameters were according to the standard EN 50160. The measurement procedure was according to the standard IEC 61000-4-30, Class A.
We used the measurement equipment based on the: Power Quality Analyzer and transducers (voltage sensors 600 V; current clamps 50A/5A).
Power Quality Analyzer was calibrated prior starting on-site measurements. Current transformers were calibrated before installation within the measurement location.

### The results of the measurements

The power quality (PQ) measurements were performed within the period June (before the PV panels were installed) and July 2012 (after the photovoltaic panels were installed, 2 months on-site measurement campaigns). Below are the statistics charts (fig. 1 and 2) according to the standard EN 50160: Voltage Variations, Harmonics, Unbalance, Mains Frequency, Events Database and Flicker.

Legend for the charts:
- RED colour: at least 95% of the values of one week have to be within the 95% tolerance range.
- BLUE colour: 100% of the values of one week have to be within the 100% tolerance range.

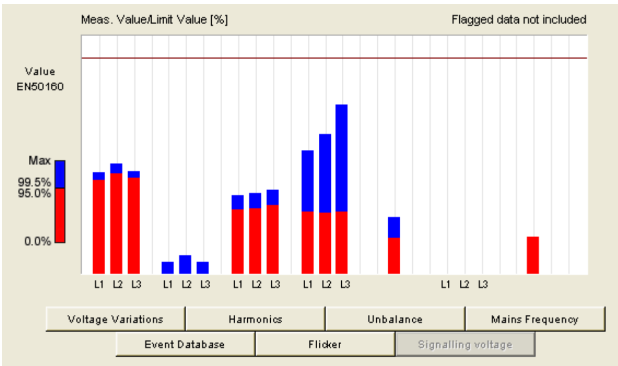


Figure 1. EN 50160 Statistics June 2012

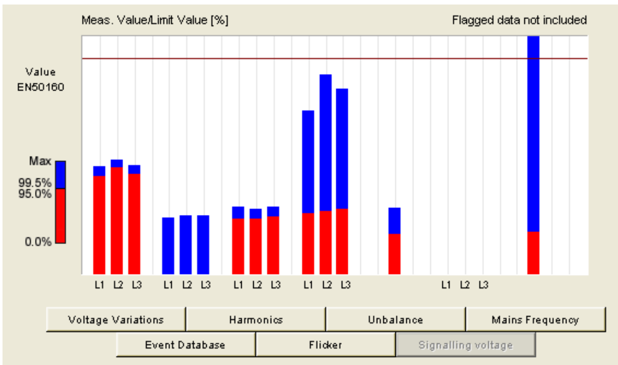


Figure 2. EN 50160 Statistics July 2012

As we can see in figures 1 and 2: in July, after the PV panels were installed, the number of events was increasing and the values of the Main Frequency were over the limits of the standard EN 50160, comparing with June.

In fig. 3 (a) and 3(b) we have the Events Database and Charts within June 2012 PQ measurement campaign.

| Quantity | Unit | L1 / L1L2 | L2 / L2L3 | L3 / L3L1 |
|---|---|---|---|---|
| Voltage Dips V | [V] | ***** | ***** | ***** |
| Short Interruption V | [V] | ***** | ***** | ***** |
| Voltage Dips 3-ph V | [V] | ***** | ***** | ***** |
| Short Interruption 3-ph V | [V] | ***** | ***** | ***** |
| Rapid Voltage Changes V | [V] | ***** | ***** | ***** |
| RMS Lower Limit V | [V] | ***** | ***** | ***** |
| RMS Upper Limit V | [V] | ***** | ***** | ***** |
| RMS Delta V | [V] | ***** | ***** | ***** |
| Frequency Lower Limit V | [Hz] | ***** | ***** | ***** |
| Frequency Upper Limit V | [Hz] | ***** | ***** | ***** |
| Oscilloscope-Max V | [V] | ***** | ***** | ***** |
| Oscilloscope-Wave V | [V] | ***** | ***** | ***** |
| THD V | [V] | ***** | ***** | ***** |

Figure 3(a)

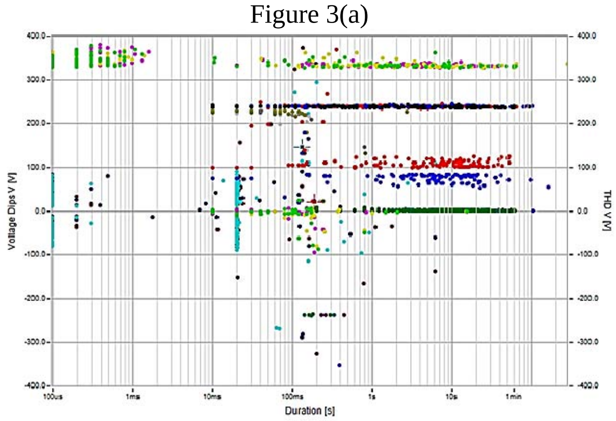


Figure 3(b).

In fig. 4(a) and 4(b) we have the Events Database and Charts within July 2012 PQ measurement campaign.

| Quantity | Unit | L1 / L1L2 | L2 / L2L3 | L3 / L3L1 |
|---|---|---|---|---|
| Voltage Swells V | [V] | ***** | ***** | ***** |
| Voltage Dips V | [V] | ***** | ***** | ***** |
| Short Interruption V | [V] | ***** | ***** | ***** |
| Long Interruption V | [V] | ***** | ***** | ***** |
| Voltage Swells 3-ph V | [V] | ***** | ***** | ***** |
| Voltage Dips 3-ph V | [V] | ***** | ***** | ***** |
| Short Interruption 3-ph V | [V] | ***** | ***** | ***** |
| Long Interruption 3-ph V | [V] | ***** | ***** | ***** |
| Rapid Voltage Changes V | [V] | ***** | ***** | ***** |
| RMS Lower Limit V | [V] | ***** | ***** | ***** |
| RMS Upper Limit V | [V] | ***** | ***** | ***** |
| RMS Delta V | [V] | ***** | ***** | ***** |
| Frequency Lower Limit V | [Hz] | ***** | ***** | ***** |
| Frequency Upper Limit V | [Hz] | ***** | ***** | ***** |
| Oscilloscope-Max V | [V] | ***** | ***** | ***** |
| Oscilloscope-Wave V | [V] | ***** | ***** | ***** |
| THD V | [V] | ***** | ***** | ***** |

Figure 4(a).

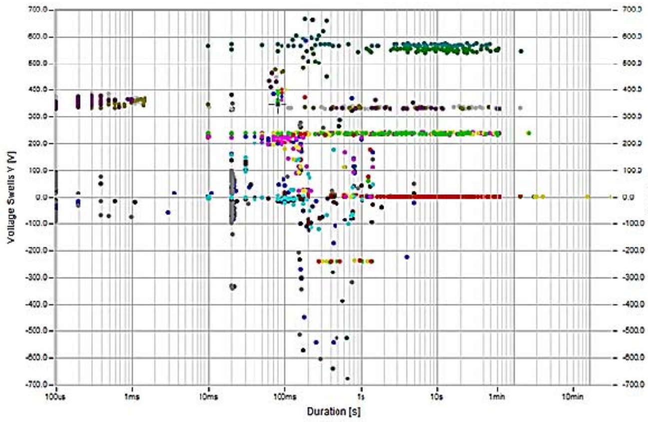


Figure 4(b).

Comparring the figures 3(b) and 4(b): the type of Events (Voltage Swells and Dips, Short or Long Interruption etc.) was increasing after the PV were installed.

With PV panels, some problems occur when the electricity produced by the panels was flowing to the distribution network.

Possible causes of these problems are: inverter controlled equipment stops because it detects a fault on the commercial power supply or malfunction of peripheral equipment or power cannot be sold to the distribution network due to voltage fluctuation of the commercial power supply.

**Case study 2: Power Quality measurements in a HV/MV substation at Transmission System Operator**

Measurement location was at central part of Slovakia, current transformers ratio: 1600A/1A, voltage transformers ratio: 110 kV/100 V, accuracy class 0,2 and system under investigation: 3-phase with neutral. The measured parameters were according to the standard EN 50160. The measurement procedure was according to the standard IEC 61000-4-30, Class A.

We used the measurement equipment based on the: Power Quality Analyzer and transducers (voltage sensors 100 V; current clamps 10A/1A).

Power Quality Analyzer was calibrated prior starting on-site measurements. Current and voltage transformers were calibrated before installation in the substation.

**The results of the measurements**

The power quality measurements were performed within the period August and September 2012 (2 months on-site measurement campaigns). Below are the statistics charts (fig. 3 and 4) according to the standard EN 50160: Voltage Variations, Harmonics, Unbalance, Mains Frequency, Events Database and Flicker.

Legend for the charts:

- RED colour: at least 95% of the values of one week have to be within the 95% tolerance range.

- BLUE colour: 100% of the values of one week have to be within the 100% tolerance range.

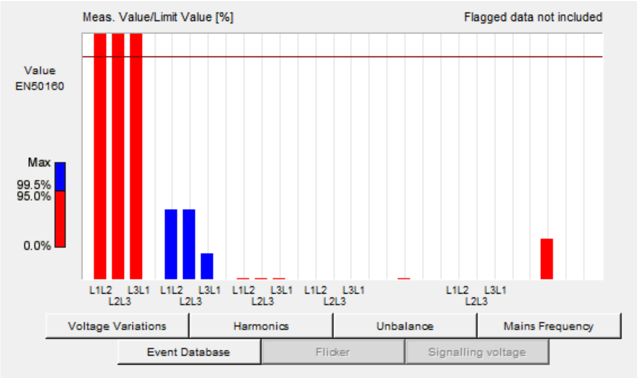


Figure 5. EN 50160 Statistics August 2012

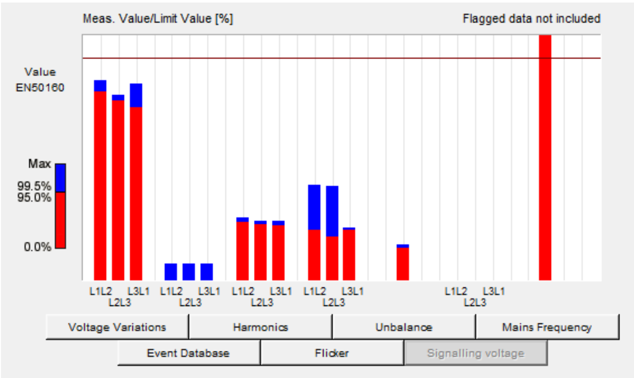


Figure 6. EN 50160 Statistics September 2012

As we can see in figures 5 and 6 the Voltage Variations and Mains Frequency were over the limit of the standard EN 50160.

In fig. 7(a) and 7(b) we have the Events Database and Charts within the PQ measurement campaign: August 2012

| Quantity | Unit | L1 / L1L2 | L2 / L2L3 | L3 / L3L1 |
|---|---|---|---|---|
| Voltage Swells V | [kV] | ***** | ***** | ***** |
| Voltage Dips V | [kV] | ***** | ***** | ***** |
| Voltage Swells 3-ph V | [kV] | ***** | ***** | ***** |
| Voltage Dips 3-ph V | [kV] | ***** | ***** | ***** |
| RMS Lower Limit V | [kV] | ***** | ***** | ***** |
| RMS Lower Limit V | [kV] | ***** | ***** | ***** |
| RMS Upper Limit V | [kV] | ***** | ***** | ***** |
| RMS Upper Limit V | [kV] | ***** | ***** | ***** |
| Ripple control signal V | [kV] | ***** | ***** | ***** |
| Transient events V | [kV] | ***** | ***** | ***** |
| TID V | [kV] | ***** | ***** | ***** |

Figure 7(a).

Comparing the figures 7(a) and 8(a): the type of Events was higher within August measurement campaign.
The obtained results can be used by Slovak DNO and TSO to improve the quality of the power delivered to the customers.

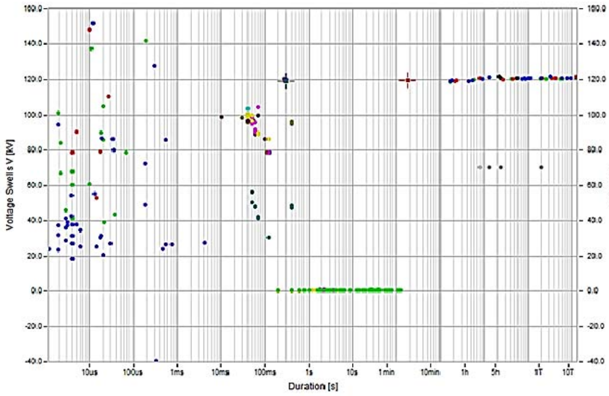


Figure 7(b).

In fig. 8(a) and 8(b) we have the Events Database and Charts within the PQ measurement campaign: August 2012

| Quantity | Unit | L1 / L1L2 | L2 / L2L3 | L3 / L3L1 |
|---|---|---|---|---|
| Voltage Swells V | [kV] | ***** | ***** | ***** |
| Voltage Dips V | [kV] | ***** | ***** | ***** |
| Long Interruption V | [kV] | ***** | ***** | ***** |
| Voltage Swells 3-ph V | [kV] | ***** | ***** | ***** |
| Voltage Dips 3-ph V | [kV] | ***** | ***** | ***** |
| Long Interruption 3-ph V | [kV] | ***** | ***** | ***** |
| Rapid Voltage Changes V | [kV] | ***** | ***** | ***** |
| RMS Lower Limit V | [kV] | ***** | ***** | ***** |
| RMS Lower Limit V | [kV] | ***** | ***** | ***** |
| RMS Upper Limit V | [kV] | ***** | ***** | ***** |
| RMS Upper Limit V | [kV] | ***** | ***** | ***** |
| Ripple control signal V | [kV] | ***** | ***** | ***** |
| Transient events V | [kV] | ***** | ***** | ***** |
| THD V | [kV] | ***** | ***** | ***** |
| TID V | [kV] | ***** | ***** | ***** |
| Harmonics V | [kV] | ***** | ***** | ***** |
| Harmonics V | [kV] | ***** | ***** | ***** |

Figure 8(a).

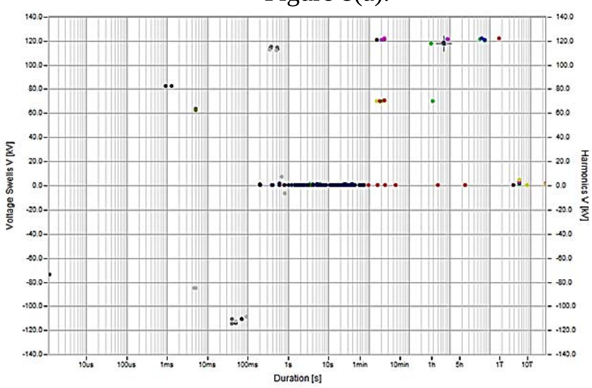


Figure 8(b).

## REFERENCES

[1] Gert Rietveld – VSL, the Nederlands, Project Protocol "Metrology for Smart Grids", October 2010.
[2] EN 50160:1999, "Voltage characteristics of electricity supplied by public distribution systems"
[3] IEC 61000-4-30:2003, "Testing and measurement techniques – Power quality measurement methods"