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Voltage Characteristics: An Overlooked Contributor to Power Quality Assessment

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ABSTRACT

This report presents the power Quality Assessment of Electrical faculty building of Wroclaw University of Technology, Poland. From a regulatory viewpoint, the European Union has been a front-runner in developing and implementing quality of supply standards through its application of European Standard EN 50160. Some Countries have used EN 50160 as the basic standard for their national quality of supply regulations. But the statistical models of Standard allow eight hours per week of unregulated power quality and utilities compliance (or non-compliance) is assessed regardless of the severity of any events.

This report will outline and execrate the state of EN 50160 toady; its benefits and possible areas of improvement, including those suggested by European utility regulators themselves. The Standard Will be compared to national quality of supply standards from countries around the world to identify best practices and contrast the differences. In conclusion, a framework for quality of supply regulation will be proposed that will ensure that compliant utilities are providing a level of service that meets expectations of their customers.

Keywords: Voltage characteristics, Compliance Limits, Power Quality.

INTRODUCTION

The history of EN 50160 dates back to 1989 and the European Union directive 89/336 for Electromagnetic Compatibility. Intended to ensure the reliability of distribution networks and proper operation of equipment connected to them, so called EMC directive led to a 1989 definition of the physical characteristics of low and medium voltage distribution systems by the organization UNIPEDE, and finally in 1994 a standard on Voltage characteristics of electricity supplied by general distribution systems [1-2]. This standard was developed was developed by a working group under European Committee for Electro technical Standardization (CENELEC) and was given the designation European Norm 50160 or EN 50160 [1-2].

The original mandate for EN 50160 was limited to low and medium voltage distribution systems and specifically the following characteristics of supply voltage: frequency, magnitude, waveform and symmetry of three phase voltages. Low voltage is defined with upper limit of 1kV RMS and medium voltage with an RMS value between 1kV and 35kV. In the original scope, higher voltages were not considered [3].

Supporting the requirement to define voltage characteristics in terms of frequency, magnitude, waveform and symmetry, EN 50160 provided definitions and in some cases measurement methods and compliance levels for ten characteristics of the supply voltage [4]:

1. Power System frequency
2. Supply System Voltage Variations
3. Rapid voltage Changes (and flicker)
4. Supply Voltage dips
5. Short interruptions

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6. Long Interruptions
7. Temporary over voltages
8. Supply voltage unbalance
9. Harmonic voltage
10. Mains signaling voltage

Table01. *Permissible Limits for System Voltage characteristics in accordance with EN 50160*

Supply Voltage Characteristics	Statistical Evaluation	Permissible Limit
Power Frequency	99.5% of time in a week 100% of time in a week	50 Hz ± 1% 50 Hz + 4% and -6%
Supply Voltage Variations	95% of time in a week	U_C ± 10%
Rapid Voltage changes & Flicker	95% of time in a week	Plt ≤ 1
Supply voltage dips	1 year	Unknown
Short Interruptions	1 year	Unknown
Long interruptions	1 year	Unknown
Temporary Over voltages	1 year	Unknown
Supply voltage unbalance	95% of time in a week	< 2%
Harmonic Voltage	95% of time in a week 95% of tome in a week	THD < 8%
Mains Signaling Voltage	95% of time in a day	9% for 100 Hz 1% for 100kHz

Table.01 depicts the compliance limits associated with EN 50160 for different characteristics of system voltage.

ISSUES WITH EN 50160 [5]

The primary issues with EN 50160 from being a comprehensive power quality standard can be broken down into five major aspects

I. As a consensus driven standard, with equal representation from all countries, it reflects the lowest common agreed upon value for PQ limits.

II. Many of the most costly and most common PQ phenomena (dips, swells and interruptions) do not have permissible limits but only indicative values.

III. The scope of this standard is very much limited to medium voltage (35kV) networks and below

IV. Measurement methods for each characteristics are not defined. By allowing utilities to evaluate compliance with undefined measurement methods, it will be impossible to compare results or apply fair noncompliance penalties.

V. Many characteristics are evaluated for less than 100% of the measurement interval. This allows

- No limit on supply voltage variations, flicker, voltage unbalance, individual harmonics or THD for 8.4 hours/week
- No limit on mains signaling for 1.7 hous/week

CASE STUDY

Since the Assessment of Power Quality of System voltage at Electrical faculty of Wroclaw University of Technology Poland, is done with following defined parameters

- ❖ Nominal Voltage = 230,00V
- ❖ Nominal Frequency = 50,00Hz
- ❖ Voltage Swells = 110%
- ❖ Voltage Dips = 90,00%
- ❖ Interruptions = 1%
- ❖ Short Interruptions = 180,000s

A. Power Frequency Assessment

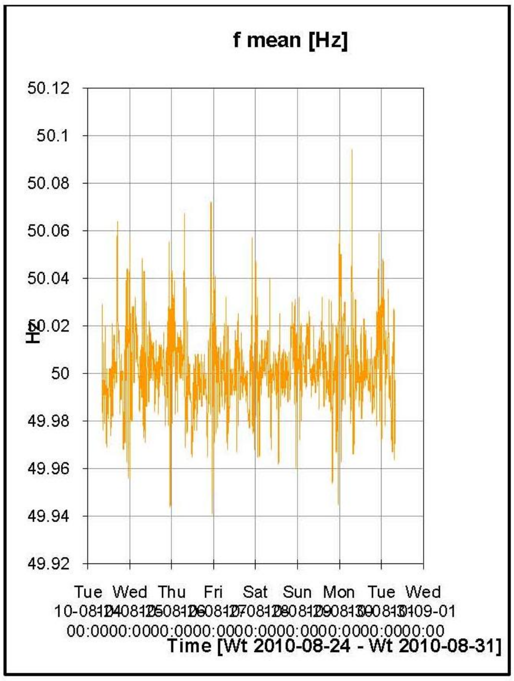

Figure01. *Variation of Power frequency of System Voltage*

Table02. *Maximum and Minimum of power Frequency of System Voltage*

Assessment Power Frequency Variations	
Interval	**Value**
f10sec Min	49.491
f10sec Min	50.094

Figure.01 shows the weekly recorded power frequency values of one of the building of Wroclaw University of Technology, Poland collected in the year 2010. From Table.02, we can visualize that the values of system frequency are under permissible limits and therefore is no any single value that violets the defined frequency compliance upper and lower declared limits (i-e. 49.5 Hz & 50.5 Hz) [6]. Since the control of system frequency is the matter of system stability.

B. Voltage Variations

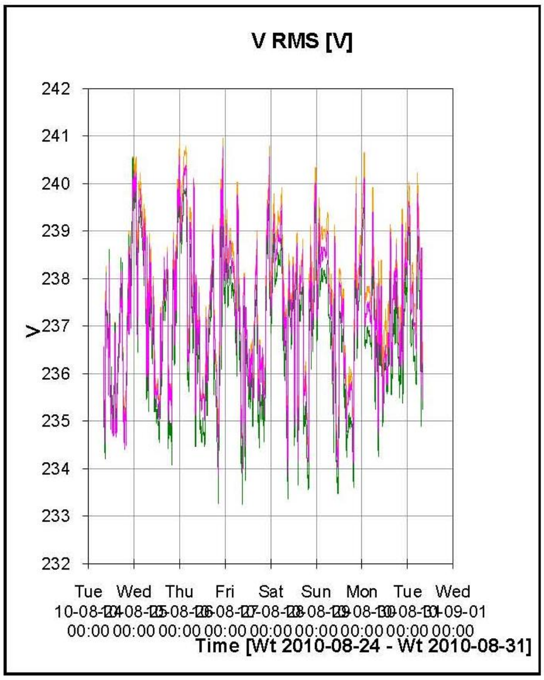

Figure02. *Variation of RMS value of System Voltage*

Table03. *Maximum and Minimum of RMS value of System Voltage*

Assessment of Variations of System voltage				
Interval		**V RMS L1**	**V RMS L2**	**V RMS L3**
U10min	Min	233.95	233.24	233.84
U10min	Max	240.95	240.54	240.76

Figure.02 illustrates the weekly reported data of RMS value of system voltage being supplied at one of the building of Wroclaw University of technology, Poland. Table. 03 shows that the recorded voltage is under the declared limits of EN 50160 (i-e. 207 V and 253V) [6], hence of quality of voltage is maintained, as no any diversion of recording is observed. Since the voltage variations depend upon customer and network conditions.

C. Flicker Severity

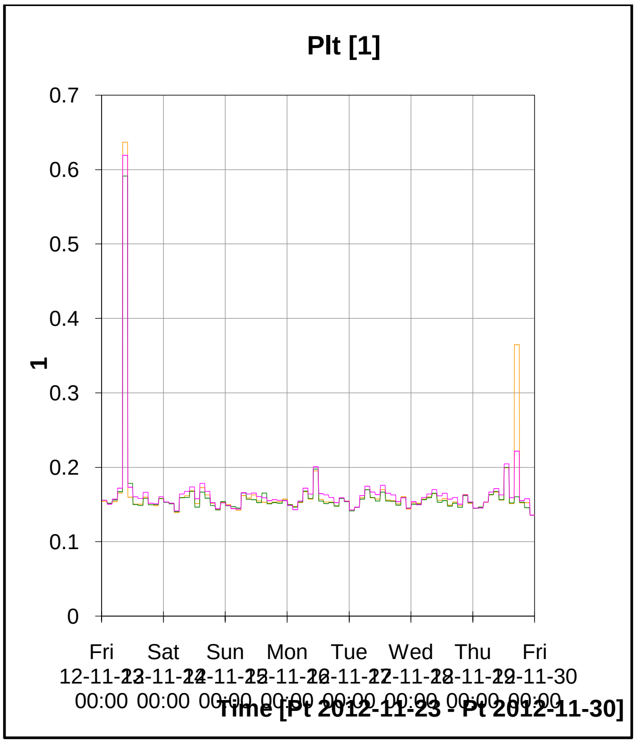

Figure03. *Investigation of Long term flicker severity*

Table04. *Maximum and Minimum value of Plt recorded at 2 hour interval*

Assessment of Long Term Flicker Severity				
Interval		**L1**	**L2**	**L3**
Plt2h	Min	0.08	0.084	0.087
Plt2h	Max	0.51	0.258	0.264

Figure.03 shows the intensity of long flicker severity observed over an interval of one week. Since under the normal running conditions, during the each one week period the long term severity Plt caused by voltage fluctuations should be less than or equal to 1 for 95% of the time [6]. So this statement proves correct, as we ponder over table.04, where Maximum value of Plt is less than 1, for all three phases. Since Plt is always calculated from a sequence of twelve Pst values over 2h time period.

D. Voltage Unbalance

Table06. *Maximum and Minimum value of Voltage unbalance*

Assessment of Voltage Unbalance		
Interval		**% „Neg/pos"**
„Neg/pos" 10min	Min	0.043
„Neg/pos" 10min	Max	0.271

Figure.05 depicts the asymmetry of System voltage. Voltage unbalance is a condition in which the voltage between the line to line or phases to phase are not equal. Since at normal operating conditions, during the one week period the RMS value of negative phase sequence component of system voltage should be within the range of 0% to 2% of positive sequence component [7]. With this statement when we observe the table.06, we can conclude that maximum and minimum ratio between negative and positive sequence component of voltage are within the limits and hence results stood good.

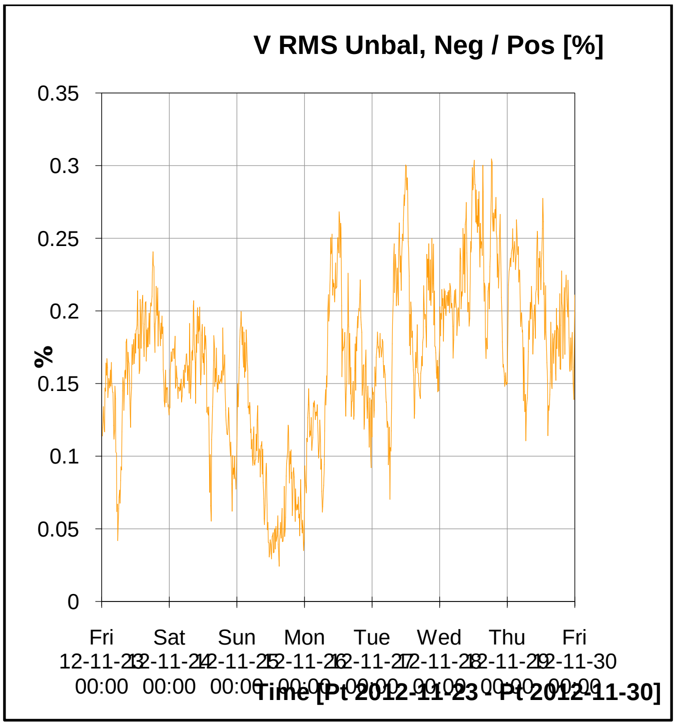

Figure05. *Visualization of System voltage unbalance*

E. Assessment of Harmonics

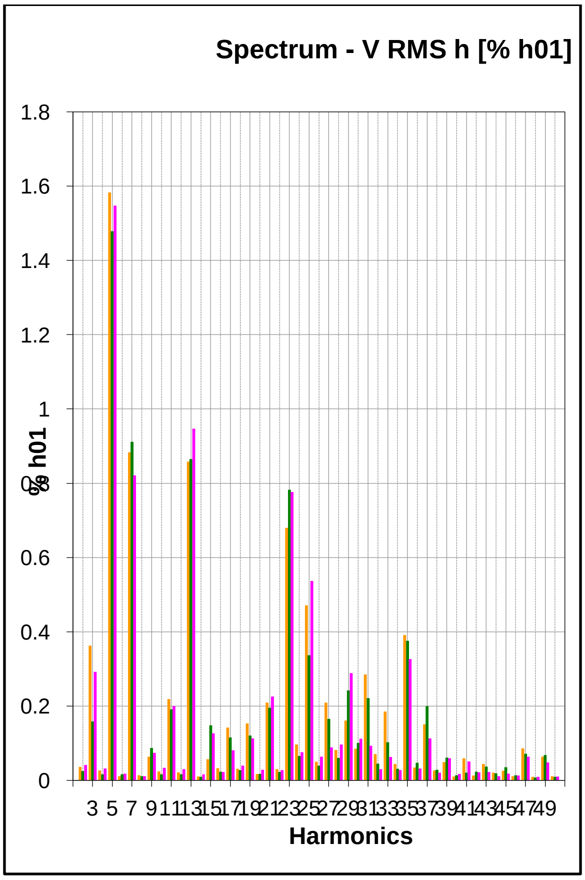

Figure06. *Visualization of System Voltage Harmonics Spectrum*

Table07. *Assessment of Recorded Odd and Even harmonics in accordance with Compliance Limits*

Assessment of System Voltage Harmonics					
Order	**Limits**	**V RMS h [% h01]**	**V RMS h [% h01]**	**V RMS h [% h01]**	**Assessment**
N	**[%]**	**L1**	**L2**	**L3**	**Compliance Limits [Y/N]**
2	0.00…2.00	0.0355	0.0243	0.0407	Y
3	0.00…5.00	0.362	0.1574	0.2913	Y
4	0.00…1.00	0.0261	0.0156	0.0313	Y
5	0.00…6.00	1.5821	1.478	1.5464	Y
6	0.00…0.50	0.0103	0.0156	0.0169	Y
7	0.00…5.00	0.8824	0.9107	0.8205	Y
8	0.00…0.50	0.013	0.0107	0.0107	Y
9	0.00…1.50	0.0625	0.0863	0.0736	Y
10	0.00…0.50	0.0235	0.0153	0.0325	Y
11	0.00…3.50	0.2182	0.1904	0.1987	Y
12	0.00…0.50	0.0203	0.0154	0.0289	Y
13	0.00…3.00	0.8576	0.8645	0.9465	Y
14	0.00…0.50	0.0099	0.009	0.0155	Y
15	0.00…0.50	0.0556	0.1474	0.1262	Y
16	0.00…0.50	0.0318	0.0221	0.0214	Y
17	0.00…2.00	0.1417	0.1148	0.0804	Y
18	0.00…0.50	0.0302	0.0269	0.0388	Y
19	0.00…1.50	0.1528	0.12	0.1119	Y
20	0.00…0.50	0.0166	0.0165	0.0279	Y
21	0.00…0.50	0.2089	0.1945	0.2251	Y
22	0.00…0.50	0.0295	0.0215	0.027	Y
23	0.00…1.50	0.6788	0.7813	0.7751	Y
24	0.00…0.50	0.096	0.0647	0.0749	Y
25	0.00…1.50	0.4706	0.3358	0.5359	Y

Figure.06 visualizes the harmonic spectrum averaged over a week. Since under the normal operating conditions, during each one week period, the RMS value of each individual harmonic voltage should not cross the given compliance limits given in Table.07. Notice that no values of harmonics are inserted in table.07, of order higher than 25 [7], as they are usually small in nature, but heavily fickle due to resonance effects.

F. THD Assessment

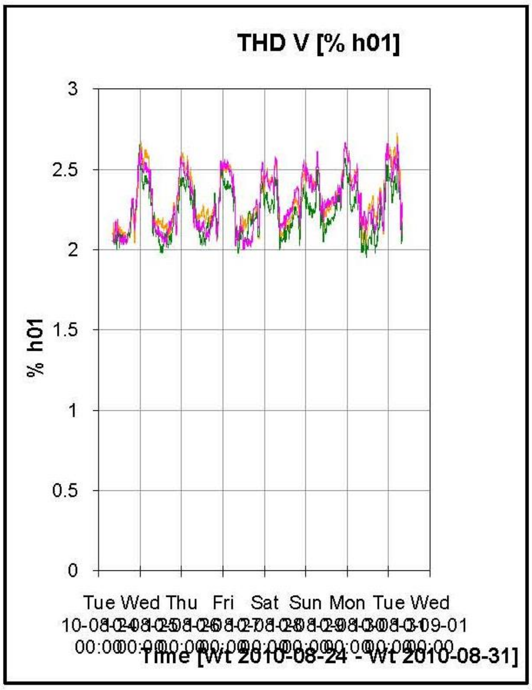

Figure07. *Visualization of THD averaged over a week*

Table08. *Maximum and Minimum Value of % THD for Individual Line*

Assessment of THD			
Interval	**L1**	**L2**	**L2**
THDV 10min %Min	3.032	1.954	2.001
THDV 10min %Max	2.727	2,657	2.666

Figure.07 illustrates the variation of THD, recorded over an interval of a week. Since the THD of the system voltage including all the harmonics up to order 40, should be less than or equal to 8% [7]. With this we can confirm that THD of given system voltage is within the defined limit as can be visualized from table.08.

CONCLUSION

From the above results and Analysis we can conclude that all the System voltage characteristics recorded over period of a week are under defined limits and hence the Quality of power at Electrical faculty of Wroclaw University of technology , Poland is assured, expect the occurrence of abnormal conditions. However, when we review the quality of Supply Standardization, efforts that utilities and regulators have focused on the most pressing local problems. Applying the recommendations in this report, derived from EN 50160, would provide a common framework for quality of supply regulation and a necessary first step towards globally acceptable limits.

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