EN 50160 ED.3 AND VOLTAGE QUALITY IN THE CZECH REPUBLIC

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ABSTRACT

The paper describes the development of voltage quality in the Czech distribution networks evaluated from long-term monitoring as well as by shorter measuring campaigns.
Since 2005, the voltage quality in 62 connection points between TN and DN has been monitored. Later it's extended by monitoring of 110 kV/MV transformer outputs and at selected consumers in the 110 kV, MV and LV networks.
The paper describes the summary of selected quality parameters changes including an example of fifth harmonic evaluation for 59 feeding nodes 110 kV and connected nodes 22 kV and 0,4 kV.
In another Czech region, two years measurement of LV events took place in 2003 – 2005 in approx. 150 distributional stations MV/LV. The results of measurements are divided into groups respecting regions (correlates with terrain types – lowlands, mountains), feeding transformer stations 110 kV, year seasons, event type. Measured data are analysed also with respect to contemporary criteria.
For 80 selected LV networks from the whole Czech Republic, the paper presents results of on-going measuring campaigns (6 cycles since 2006), as well as the influence of possible change of limit evaluation from 95% measuring intervals to 99% and 100% on keeping stated limits for these networks according to EN 50160 Ed.2 (2007) and EN 50160 Ed.3 (2010).
On a sample of measured values, differences between evaluation of ten-minutes and one-minute intervals are shown.

VQ IN POINTS OF DELIVERY BETWEEN TN AND DN

Figure 1 shows number of monitored nodes, where some values were beyond its limits. It also shows total level of VQ parameters during the measuring campaigns 2007–2009 in points of delivery between PS and DS (they were measured in 62 nodes on the 110kV level). Limit value was mostly violated by short time flicker Pst (nodes feeding arc furnaces) and also long time flicker Plt, when the higher values than of Pst was caused by the evaluation algorithm. Higher operating voltage level in some 110 kV grids causes tolerance band violation. Other parameters are mostly within limits.

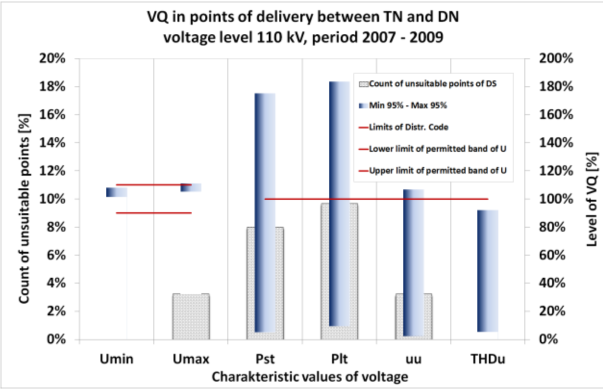

Figure 1 – Total PQ in 62 points of delivery between TN and DN

COMPARISON OF FLICKER LEVELS BETWEEN DIFFERENT VOLTAGE LEVELS

Figure 2 shows distribution of Pst110kV/Pst22kV and Plt110kV/Plt22kV (95%) in feeding nodes 110/22kV.
16 nodes (110/22kV) were evaluated after cca 2 years monitoring. It is obvious, that in more than 50% cases the ratio Pst 110kV/Pst22kV is less than 1, which means that in those cases the source of flicker was in the MV level.

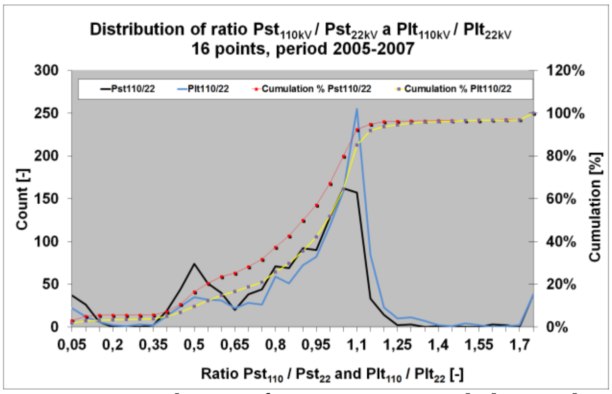

Figure 2 – Distribution of Pst_{110kV}/Pst_{22kV} and Plt_{110kV}/Plt_{22kV}

LONG-TERM PQ MONITORING HV/MV/LV

In the power company CEZ (in the North Moravia) the monitoring of a number of selected parameters of the quality of electrical energy (harmonics, flicker, unbalance) is being done in cooperation with research laboratories of the Department of Measurement and Control and Department of Electrical Power Engineering, Faculty of Electrical Engineering and Computer Science, VSB - Technical University of Ostrava.
Monitoring of the power quality was gradually done in individual parts of the company. The measuring was done in a complex way within the HV, MV and LV distribution (Figure 3). The program of complex quality of electrical energy evaluation was done in 59 LV distribution transformer station. The composition of consumption in the LV network was similar in all measured localizations – i.e. a mix of family houses and blocks of flats and small services. In accordance with the Standard CSN EN 50 160, the measuring and evaluation of the power quality of single points was done in one week intervals, while the parameters of quality were evaluated for 10 minute intervals in the course of measuring. The measurement is separated to 6 stages. As individual parts of the company have 8-10 feeding nodes 110 kV, the monitoring was organized in half-year cycles, thus the whole program lasted for 3 years.

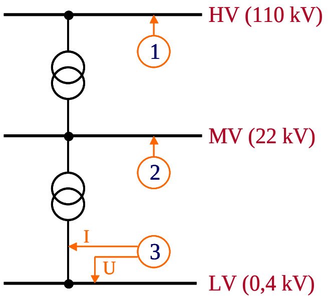

Figure 3. Ideal connection diagram of measuring points

In single feeder points they evaluate measured data in all phases and on all voltage levels:

- Selected voltage harmonics (3., 5., 7., 9., 11.)
- Flicker
- Unbalance

THE TRENDS OF CHANGES

As it was stated, the monitoring of the quality parameters was started in 1997 in all feeding points and was done during three years. In 2002 the second cycle of monitoring was completed in the same sites, therefore it is possible to evaluate the trends of change during three years. In 2005 the third cycle and in 2008 the fourth cycle of monitoring was completed and in 2010 the fifth cycle of monitoring was started after 1 year time-out in 2009.
In the Table 1 the changes of the selected quality parameters are summarized (selected harmonics, flicker and unbalance) during the first 3 years in the LV, MV and HV network. In the Table 2 and Table 3 the changes of the selected quality parameters are summarized during the second and the last 3 years.

Table 1. Trends of changes of the selected quality parameters during the first 3 years (in years 1997-2002)

	LV	MV	HV
3rd harmonic (%)	0,056	0,056	0,183
5th harmonic (%)	0,157	0,335	0,065
7th harmonic (%)	0,095	0,111	0,040
9th harmonic (%)	0,006	-0,018	-0,050
11th harmonic (%)	0,015	0,016	-0,001
P_{st} (-)	0,157	0,135	0,113
P_{lt} (-)	0,118	0,077	0,131
Unbalance (%)	0,088	0,135	-0,017

Table 2. Trends of changes of the selected quality parameters during the second 3 years (in years 2000-2005)

	LV	MV	HV
3rd harmonic (%)	-0,016	-0,026	0,089
5th harmonic (%)	0,204	0,181	0,106
7th harmonic (%)	0,204	0,193	0,073
9th harmonic (%)	0,026	-0,009	-0,012
11th harmonic (%)	0,075	0,036	0,001
P_{st} (-)	-0,034	-0,093	-0,024
P_{lt} (-)	-0,005	-0,079	-0,080
Unbalance (%)	0,043	-0,052	0,169

Table 3. Trends of changes of the selected quality parameters during the last 3 years (in years 2003-2008)

	LV	MV	HV
3rd harmonic (%)	-0,004	-0,019	-0,067
5th harmonic (%)	-0,334	-0,303	-0,082
7th harmonic (%)	-0,017	-0,022	-0,004
9th harmonic (%)	0,010	-0,006	-0,002
11th harmonic (%)	0,024	0,021	0,022
P_{st} (-)	0,008	0,048	0,050
P_{lt} (-)	-0,022	0,022	0,050
Unbalance (%)	-0,066	-0,058	-0,176

As for harmonics, the results are relatively positive, the values of individual harmonic components are significantly below the values of compatible levels, changes after 3 years are minimal. As for unbalance, the changes are also quite small.
As for flicker, in years 1997-2002 the situation was worse, the increase of Pst and Plt parameters was relatively low in relation to the level 1,0 (10-16%), but in relation to the real values the increase was significantly higher (around 40%). But in years 2000 – 2005 there was stabilization or even decrease of flicker parameters.
The fourth cycle of measurement indicates rather stagnation of quality parameters.

MEASUREMENTS IN THE CZECH LV NETWORKS

For the reason of preventing the inefficient network components refurbishment prior to their lifetime in cca 80 representative LV networks, VQ was measured in the years 2006–2010. Those grids were cable,overhead and mixed, feeding mixture of family houses and blocks of flats and small premises. Every grid was measured on the begin, in the middle and at the end of chosen LV feeder. Number of nonconforming grids from 80 in every measuring campaign is in tab.4. VQ characteristics are compared with the EN 50160ed.2, most frequently were not met long term flicker Plt limits.

Table 4 – Figures of nonconforming LV networks

	Measuring campaign						
Parameter	I.	II.	III.	IV.	V.	VI.	VII.
$U_{max(95\%)}$	0	0	1	0	1	1	0
$U_{min(95\%)}$	2	1	5	1	6	2	1
$U_{max(100\%)}$	0	3	2	4	1	3	1
$U_{min(100\%)}$	7	6	7	4	6	4	1
Pst	37	22	23	24	19	22	22
Plt	42	37	25	33	22	29	27
uu	4	5	4	2	6	11	1
THDu	0	0	0	0	0	2	0
Cumulative	45	40	31	36	28	30	27

Proposals of EN50160 standard considered also other than 95% percentile for voltage levels (one week campaign, 10min. measuring intervals, range Un ± 10 %). Voltage quality evaluation for VI campaign was recalculated for different percentiles, as illustrated in tab. 5.

Table 5 – Figures of nonconforming LV networks

	α [%]					
Parametr	5	4	3	2	1	0
$U_{max}(100-\alpha)$	1	1	1	2	2	3
$U_{min}(100-\alpha)$	2	3	3	4	8	11

Level of every single VQ parameter was different for every campaign. To assess level of fluctuation, differences between every monitored VQ parameters were calculated. Their range was assessed for every periodically monitored node as difference between max. and min. measured value in every campaign. Consequently, the range of fluctuations was related to the limits of parameters and expressed in percentage. Histogram is presented in the Figure 4.

Simultaneously, with VQ measurements, the network impedance was measured too, as a grid characteristic. Fig.5 brings Pst dependance on the network impedance. For better clarity the Fig.5 show also limits of flicker Pst and reference impedance.

EVENTS IN LV NETWORKS 2002 - 2005

Voltage events on LV side of DT MV/ LV were measured on more than 150 DT in the South Moravia region [about 1.4 million inhabitants, 60 towns, about 1000 villages and 9500 DS].

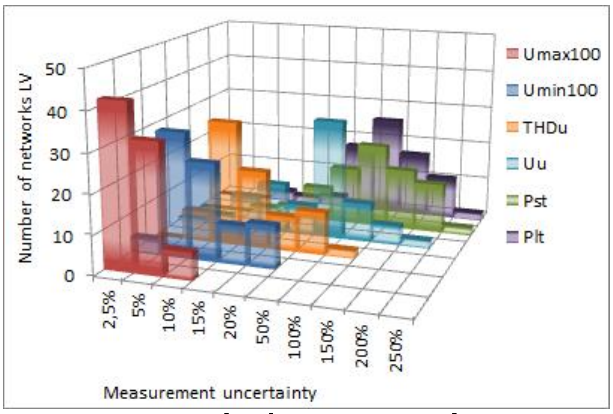

Figure 4 – Uncertainly of measurement values

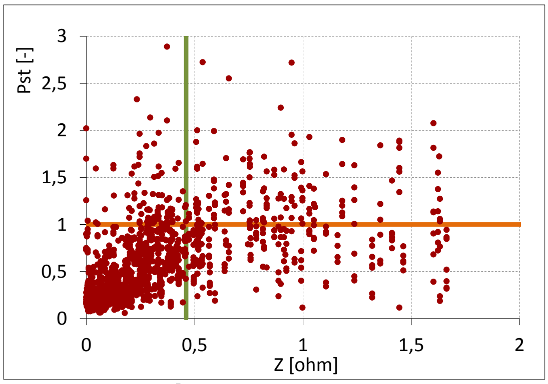

Figure 5 Dependence Pst on Z

Half of region is lowland and another half is unplanned up to 800m above sea level.

Measured data was statistically evaluated according to CSN_EN_50160 standard, with consideration of year and season [Figure 6 and Tab.6 – 8]. Evaluation of 95 percentile is in the Tab.9.

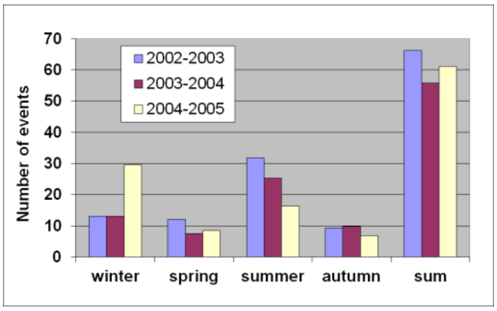

Figure 6 – Average number of events for one mesuring point in a season

Table 6: Average annual number of voltage increase for 1 measured point

Season	T≤ 0,1s	0,1s<T≤1m	1m<T≤ 3m	T>3m	Summ
12/2002 -11/2003	0.09	0	0	0.23	0.32
12/2003 -11/2004	0.05	0.04	0.01	1.06	1.15
12/2004 -11/2005	0.03	0.02	0	0.02	0.06
12/2002-11/2005	0.05	0.03	0	0.57	0.64

Tabuka 7: Yearly average number of voltage interruptions in one point

Season	T<=0,1 s	0,1s<T <=0.5s	0,5s<T <=1s	1s<T< =3s	3s<T< =20s	20s<T< =1m	1m<T< =3m	T>3m	Summ
12/2002-11/2003	0.46	0.13	0.01	1.16	0.14	0.45	0.95	1.62	4.91

12/2003-11/2004	0.13	0.2	0.02	1.31	0.34	0.57	0.58	1.7	4.66
12/2004-11/2005	0.12	0.1	0.01	1.95	0.29	0.91	0.78	1.46	5.55
12/2002-11/2005	0.19	0.04	0.02	1.47	0.28	0.68	0.72	1.61	5.01

Tabulka 8: Yearly average number of voltage dips in one point from 12/2002 to 11/2005

Filter ON	T<=0.1s	0.1s<T <=0.5s	0.5s<T <=1s	1s<T <=3s	3s<T <=20s	20s<T <=1m	1m<T <=3m	Summ
X<=5	0.05	0.29	0.03	3.02	0.39	1.16	1.3	6.24
5<X<=20	0.35	1.11	0.06	1.03	0.17	0.49	0.67	3.88
20<X<=40	0.71	1.8	0.14	0.63	0.08	0.19	0.4	3.95
40<X<=70	6.76	8.87	0.87	0.38	0.04	0.03	0.03	17
70<X<=85	11.6	10.2	2.82	1.62	0.25	0.16	0.16	26.8
S	19,45	22.29	3.92	6.68	0.93	2.03	2.56	57,92

Tabulka 9: 95% percentil of voltage dips in one point 12/2002 - 11/2005

Residual voltage	T<=0.1s	0.1s<T <=0.5s	0.5s<T <=1s	1s<T <=3s	3s<T <=20s	20s<T <=1m	1m<T <=3m	Summ
0<=U<=5%	1.05	0.35	0.33	6.96	1.39	2.76	2.79	15.6
5%<U<=20%	1.05	7.11	0.92	10.7	1.35	3.67	4.67	29.5
20%<U<=40%	2.52	5.09	0.92	3	0.46	1	1.67	14.7
40%<U<=70%	18	19	3.43	1.67	0.39	0.35	0.33	43.2
70%<U<=85%	25.7	20	9.34	4.16	0.46	0.46	0.47	60.6
S	48.35	51.6	14.9	26.5	4.05	8.24	9.93	163.55

Figure 7 shows average number of voltage dips for the one measured point in every monitored year.

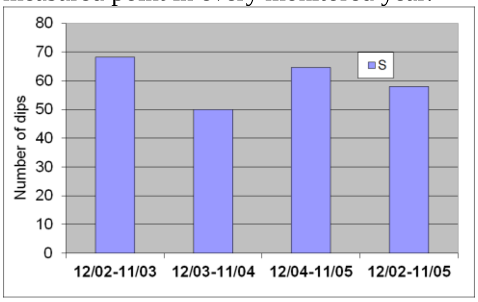

Figure 7 – Yearly average number of voltage dips in one point

RESULTS

Because of the present ambiguity of voltage events and deviations definitions, evaluation respected operation conditions of LV grids and appliances.
Different occurrence and type of voltage events on the countryside lines and town cables was found according to valid standard with using 2% Unom hysteresis and not considering the time coincidence of more not related events.

INFLUENCE OF CHANGEOVER TO 1 MINUTE MEASURING INTERVAL

To assess impact of changeover to 1 minute measuring interval, 6 measurements on LV grids A were performed (countryside lines MV and mixed LV cable grid) and 13 measurements on LV grids B (cable terminal MV and cable grid LV).
For the A group, increase of difference between 1minute measurements and 10minute measurements was up to 6,3%Unom. For the B group, increase of difference between 1minute measurements and 10minute measurements was only up to 1,91%Unom. The difference between values for 1minute and 10minute measuring interval rose with rising network impedance.

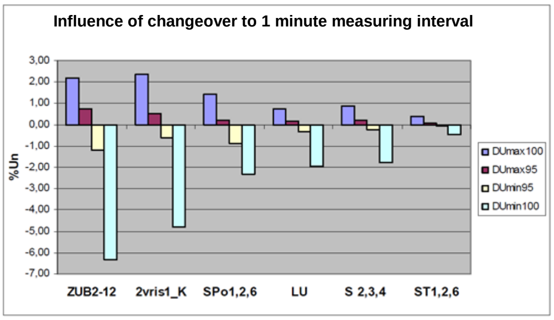

Figure 8

CONCLUSIONS

Evaluated values of one week VQ long term measurements are varying significantly in all voltage levels especially flicker values in LV networks with long feeders.
Measurements on 110kV grids show the points, where only todays VQ limits for flicker were exceeded. From the distribution of short term flicker Pst on the HV grid 110kV and MV grid 22kV, it is possible to see, that in more than half cases the source of flicker is in the 22kV level.
From the results of 3 years measurements on the HV, MV and LV level, it was found that voltage unbalance and voltage harmonics change are only marginal. Different results are for flicker, where it is possible to see gradual rising.
During the 3 years period on 150 measuring points, 8864 events were registered with time durations up to 3 minutes and 559 events with duration up to 24 hours. Significant coincidence was found between the number of voltage events and climate conditions.
Changeover to 1minute measuring interval can cause rising of grids number where VQ limits are violated (up to 6.3%).

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