Trends in Power Quality

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Contents

- **Results from long term harmonic and flicker measurement in Austria**
- **Discussion flicker - lamp type**
- **Application of wide area PQ monitoring in Austria**
- **Unified PQ-index for benchmarking**
- **Towards Voltage Quality Regulation in Europe – An ERGEG Conclusions Paper**

Selected results from long term monitoring of power quality in Austria

- Flicker
- Harmonics

Power quality measurement results by Association of Austrian Electricity Companies (VEÖ)

VEÖ-Journal, April 07, *Spannungsqualität: Koordinierte Messungen österreichischer EVU, Teil XIII/XIV*, p.38-41

Power quality measurement results from regional grid operator

Power quality measurement by VEÖ

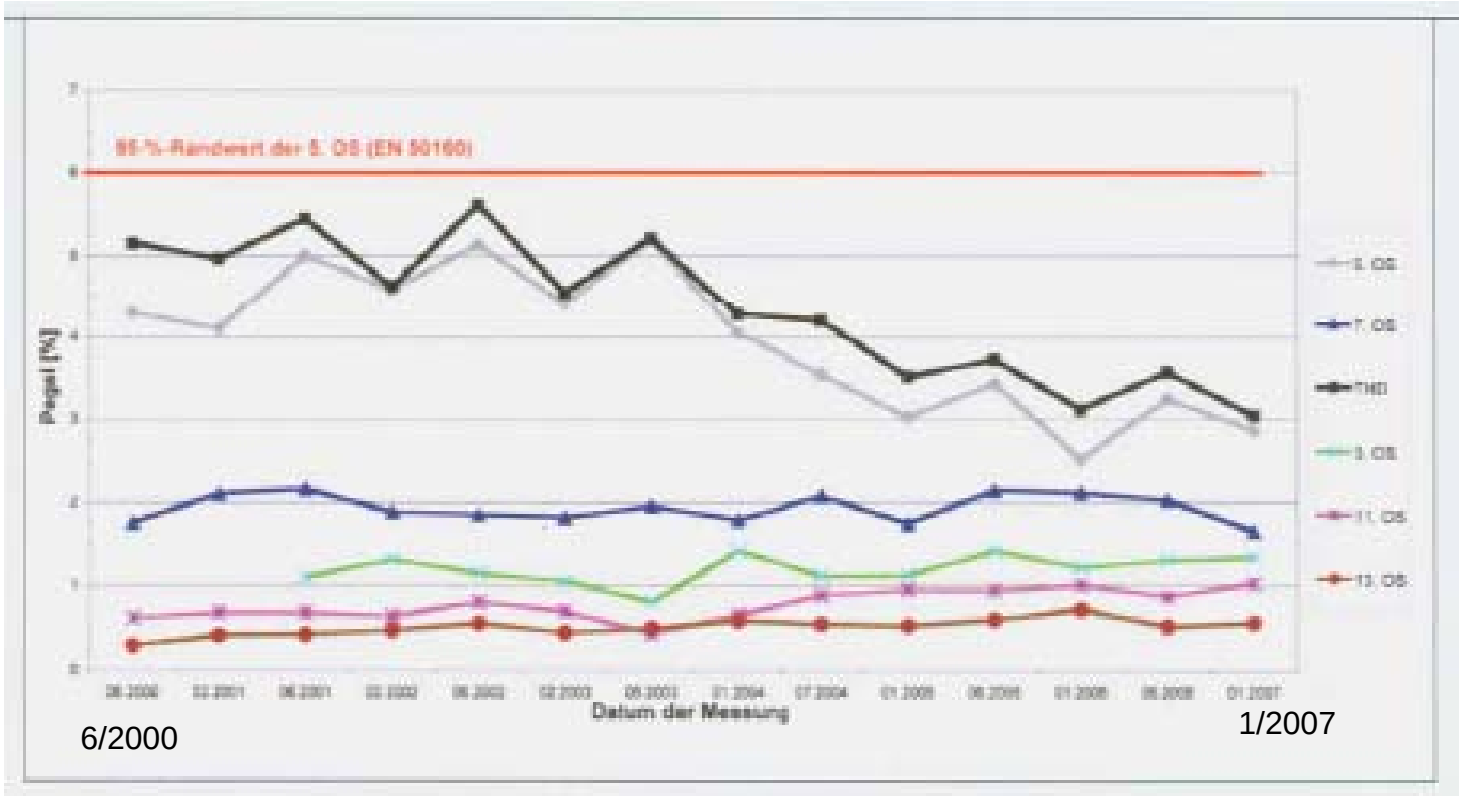
- random sample of measurement locations
- each year one week in summer, one week in winter

no.	date	participating grid operators	LV	MV	HV
1	6/2000	17	24	8	8
2	1/2001	15	34	9	11
3	6/2001	12	31	9	10
4	1/2002	12	34	17	11
5	6/2002	14	41	21	12
6	1/2003	13	38	20	17
7	6/2003	8	14	4	9
8	1/2004	14	33	10	11
9	6/2004	15	51	30	8
10	1/2005	15	47	30	9
11	6/2005	15	63	32	9
12	1/2006	12	47	29	11
13	6/2006	12	50	28	10
14	1/2007	14	47	30	11

Power quality measurement by regional grid operator

- continuos power quality measurement since 2002
- 7 MV locations, 7 LV locations

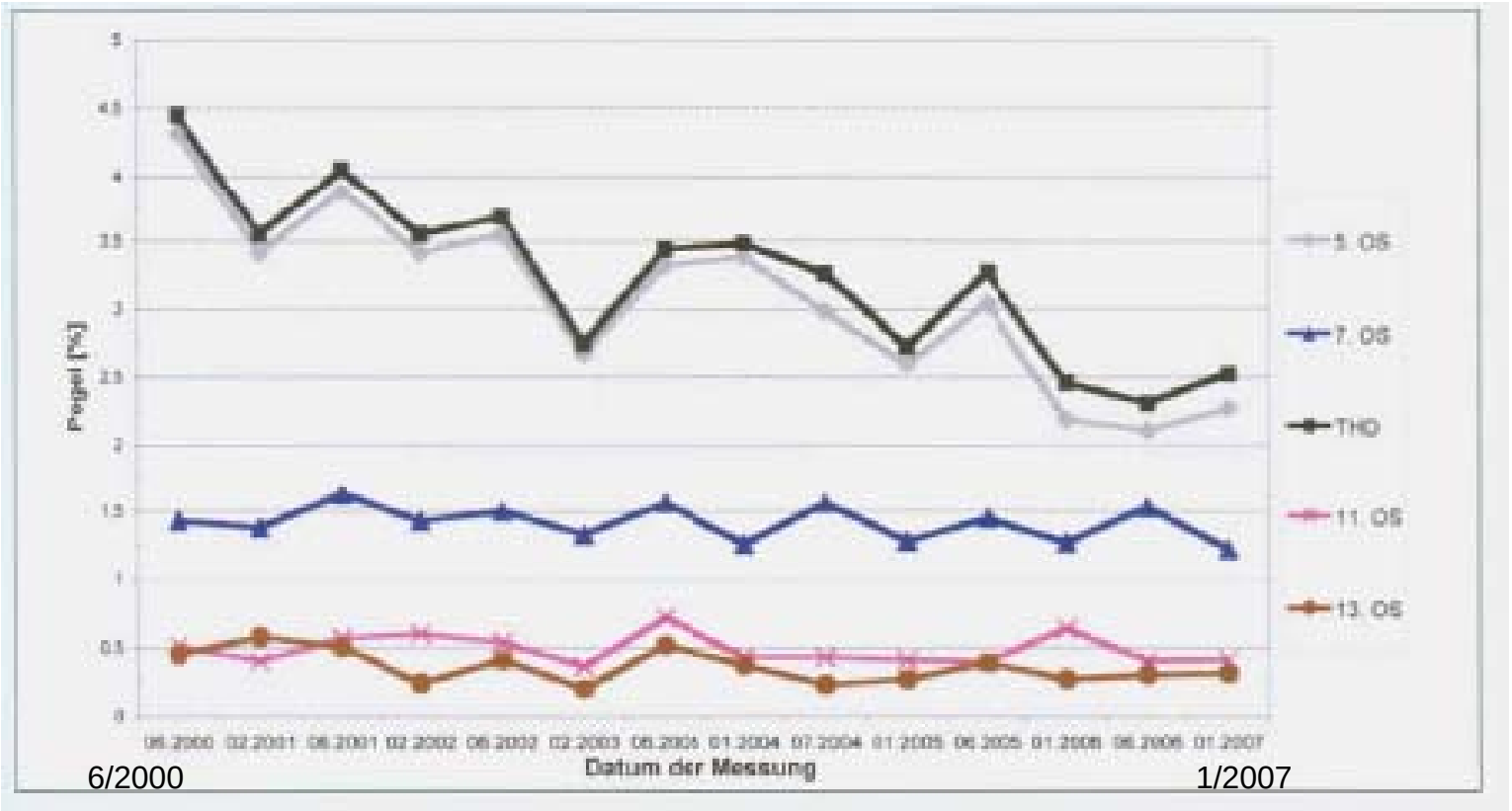
Harmonics in LV, 95% quantile of VEÖ measurement



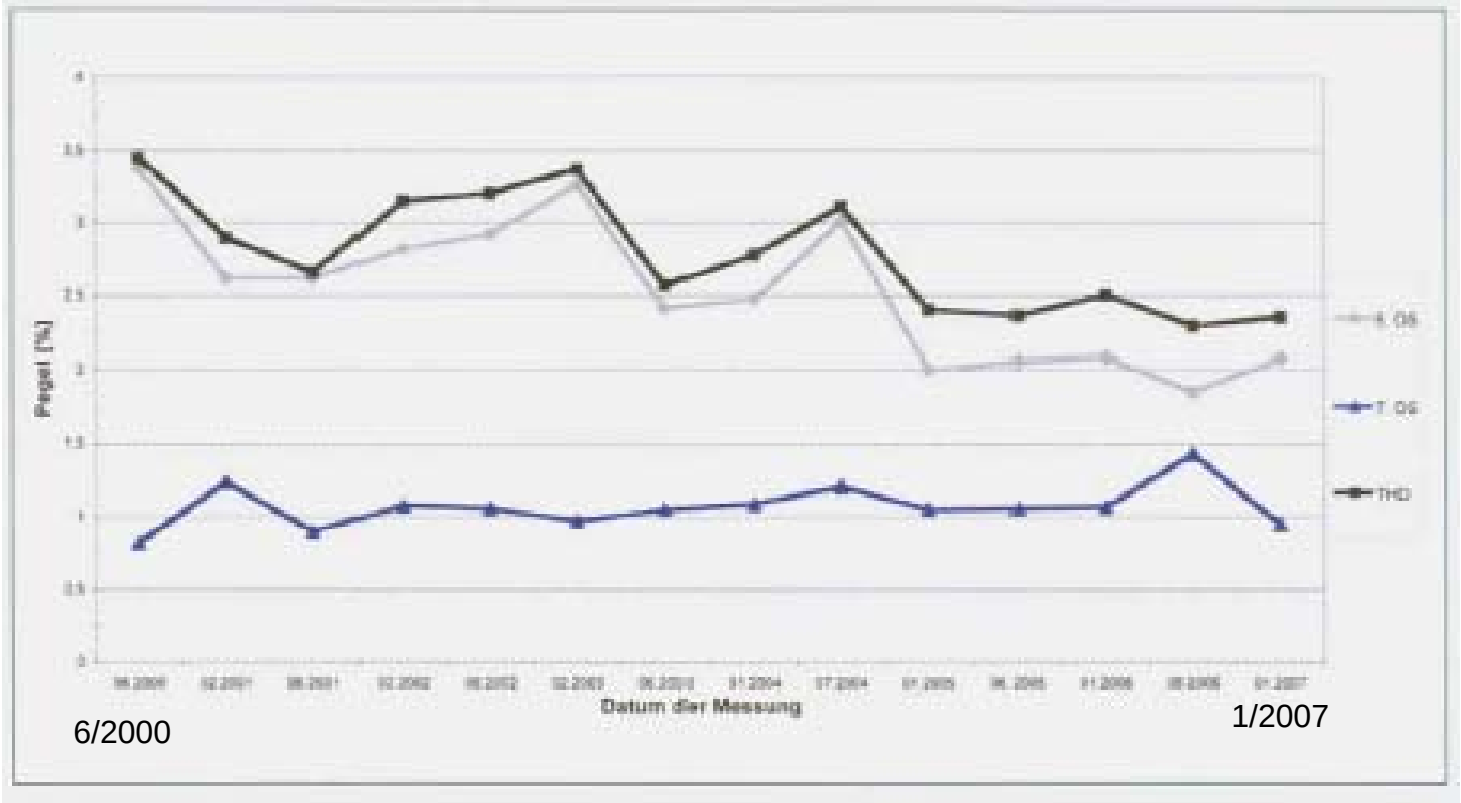
6/2000

1/2007

Harmonics in MV, 95% quantile of VEÖ measurement



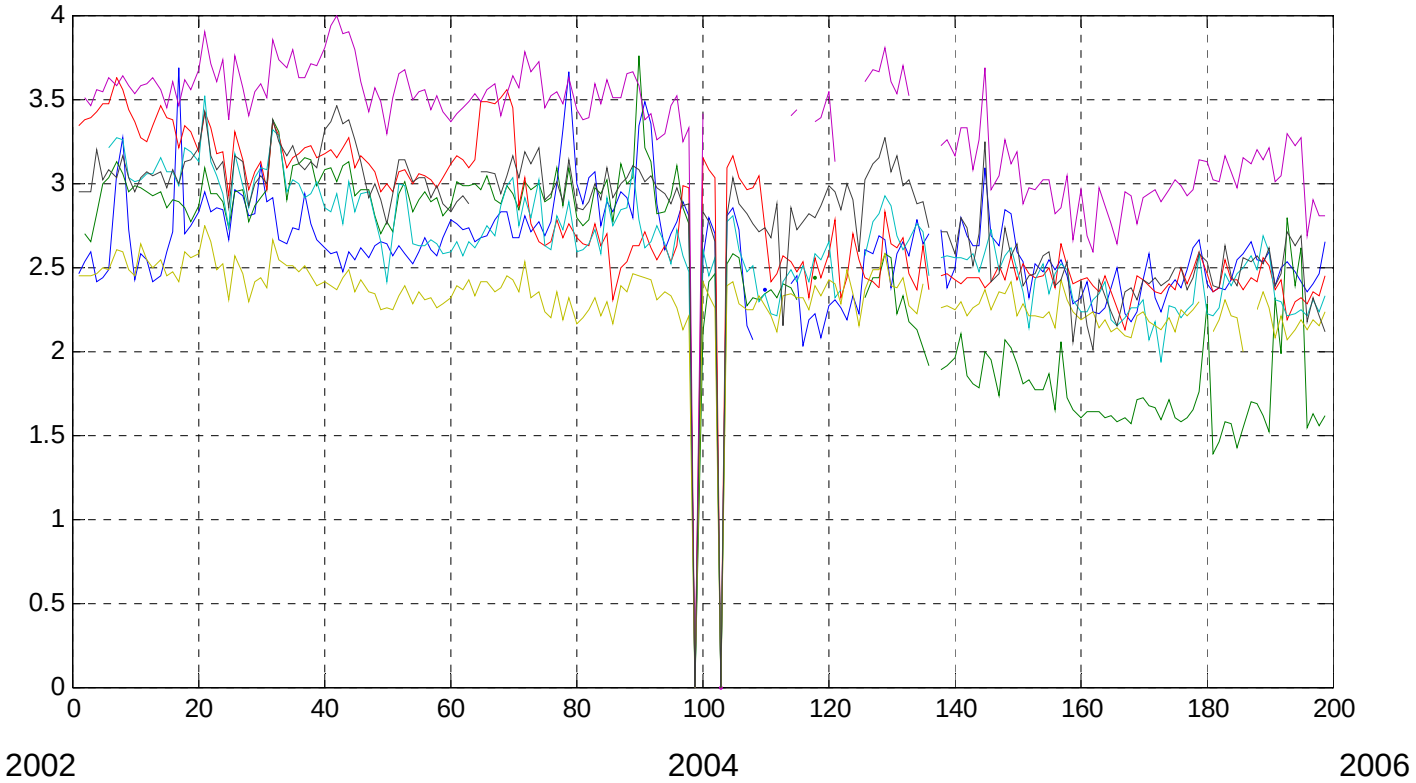
Harmonics in HV, 95% quantile of VEÖ measurement



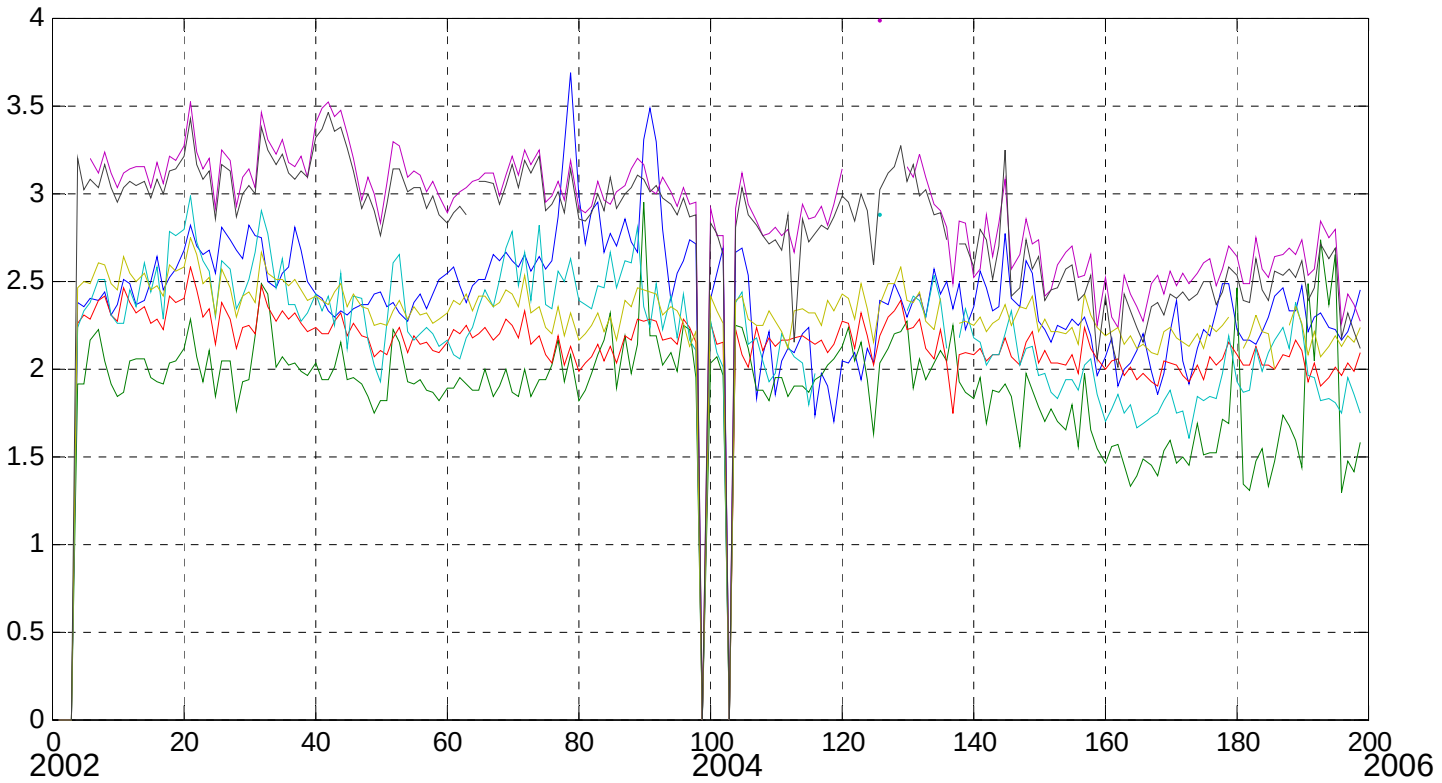
6/2000

1/2007

THD in LV, weekly 95% quantile, regional measurement



THD in MV weekly 95% quantile, regional measurement

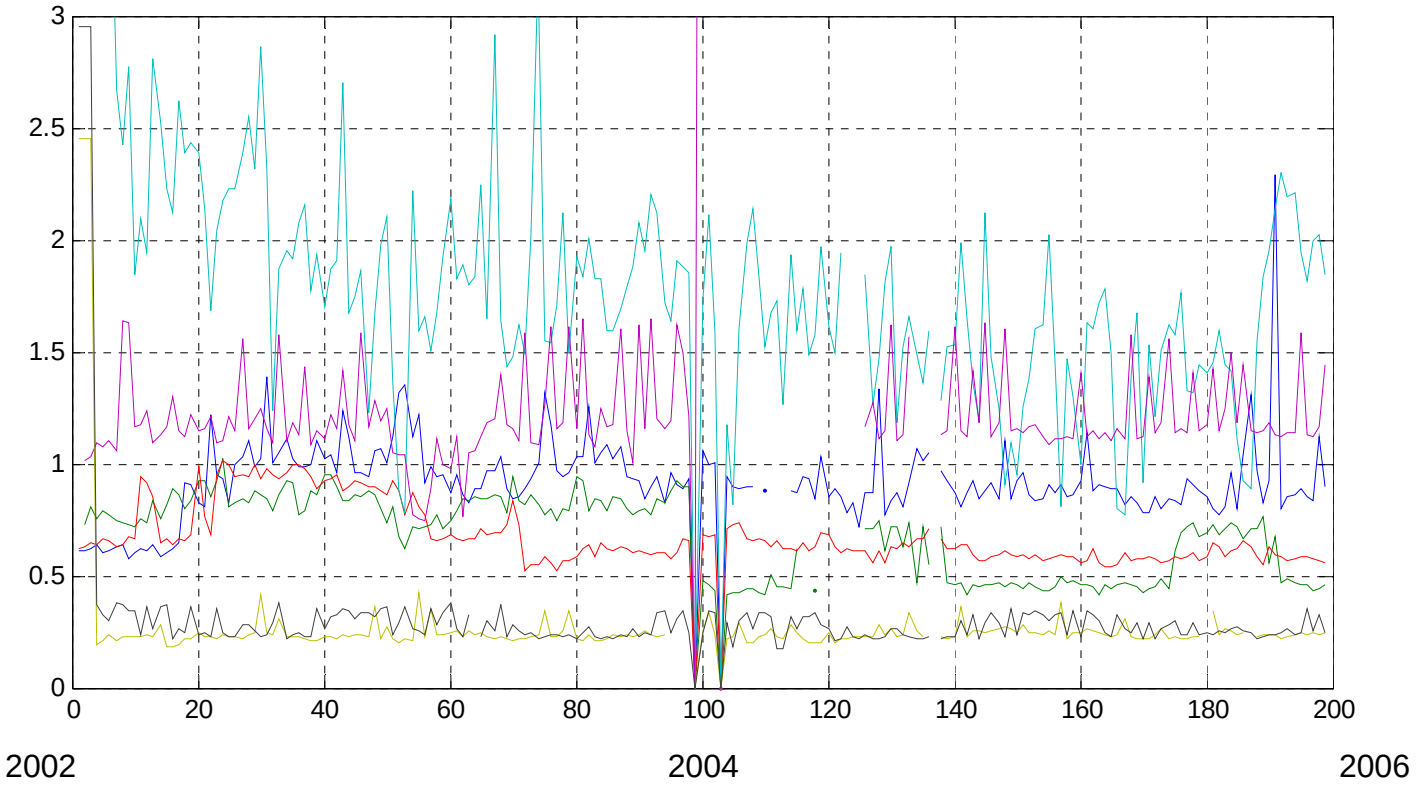


- THD is dominated by 5th harmonic
- Clearly decreasing trend for 5th harmonic and THD
- Constant level for 7th, 11th, 13th harmonic
- More electronic devices in operation, less power for individual device
- larger variation of phase angle, especially for 5th harmonic

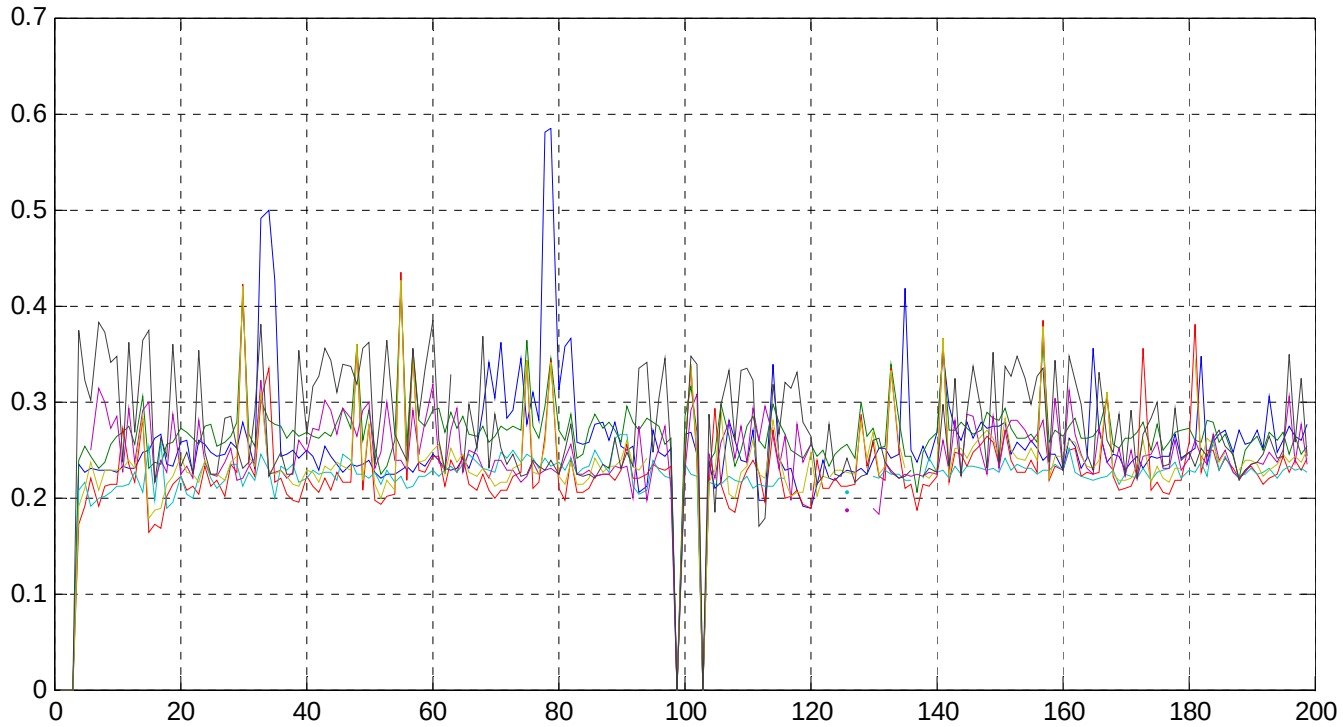
Results from VEÖ measurement, LV, no trend published

	LV
Plt	1,02
Pst	0,91

PST, weekly 95% LV, regional measurement



PST, weekly 95% MV, regional measurement



Disturbing limit:

- Slovenian study: Complaints starting with Pst 1.3

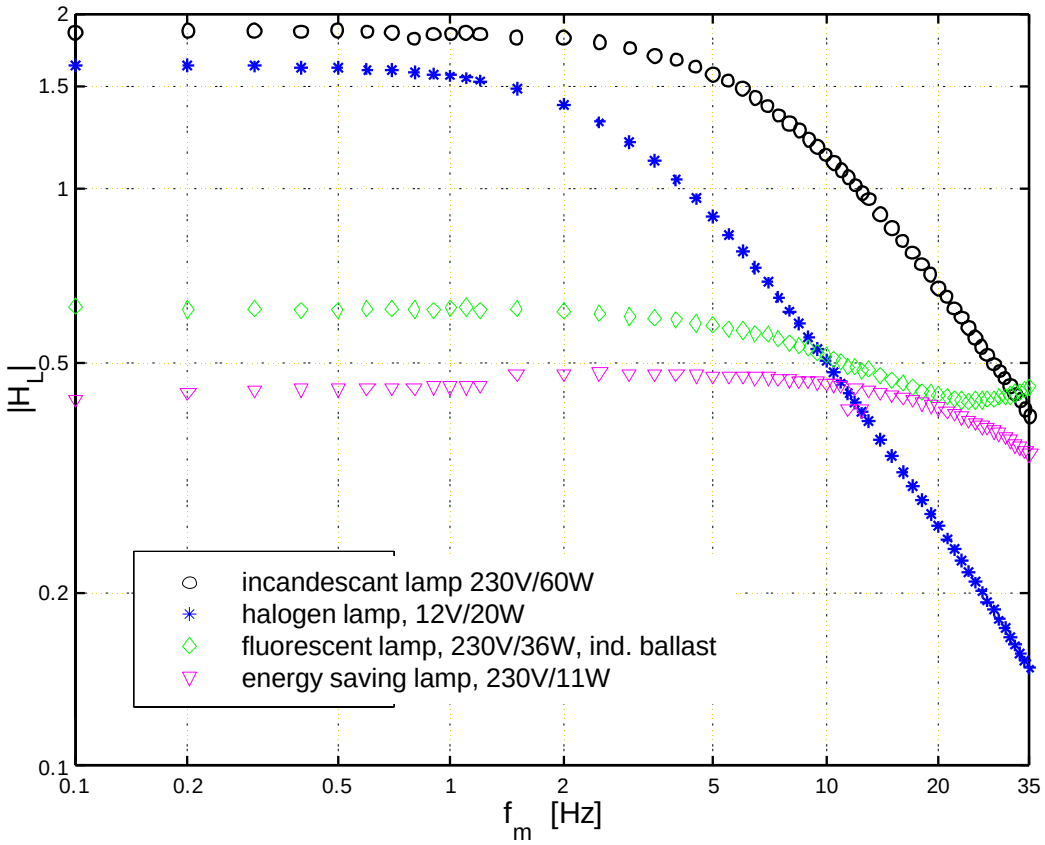
Changes in lighting technology:

- From Nov 2008, the importation of non compliant lighting (including incandescent globes) into Australia will be banned and from Nov 2009 the retail sale of non compliant lighting (including incandescent globes) will be banned.
- The UK announced plans to phase out the sale of incandescent light bulbs by 2011.
- Italy will ban the sale of incandescent light bulbs as of 2010.
- The European Union has proposed a ban on incandescent light bulbs, planned to come into effect in the near future.

⇨ Adaptation of flicker limit

⇨ Adaptation of measurement procedure (filter)
(like IEC 61000-4-15 for 110 V-lamps

Adaptation of measurement procedure (filter)



source: Hennerbichler, TU Vienna

Permanent wide area measurement of power quality:

- low voltage level excluded
- serve the long-term observation of the power quality
- show possible development trends
- find specific values that characterize the power quality of a network

Legal base in Austria: Elektrizitätsstatistikverordnung 2007 (electricity statistics regulation 2007)

§ 13. Grid operators are obliged to record power quality
- area-wide for MV grids, using appropriate statistic method
- spot sample for LV grids
- measurement period from 1.1. 0:00 to 31.12. 24:00 (=permanent)

Challenge for economic reasons:

– Minimum number of necessary measuring devices

– Optimal mounting place

→ Avoid redundant measuring results and information loss

Parameters to be considered:

– network topology (radial network, meshed network)

– network impedance (line length, cable, overhead line)

– disturbing sources

- single, independent disturbing sources with high rated power
- evenly distributed disturbing sources with similar characteristics

–disturbances from superior HV grid

Grid calculation

- based on grid‘s admittance matrix
- creation of synthetic time courses of disturbing currents for each node
- calculation of distorted voltage

Correlation and regression

- analysis of all combinations of calculated voltage time courses due to correlation and regression
- applying limits for correlation coefficient and regression coefficient results in binary matrix

Determination of optimal measuring location

- minimizing number of measuring devices
- checking infrastructure of locations (PT available, communication facilities)

Example harmonics

$$\begin{pmatrix} \underline{V}_{h1} \\ \vdots \\ \underline{V}_{hK} \end{pmatrix} = \begin{pmatrix} \underline{Z}_{11} & \cdots & \underline{Z}_{1K} \\ \vdots & \ddots & \vdots \\ \underline{Z}_{K1} & \cdots & \underline{Z}_{KK} \end{pmatrix} \cdot \begin{pmatrix} \underline{I}_{h1} \\ \vdots \\ \underline{I}_{hK} \end{pmatrix}$$

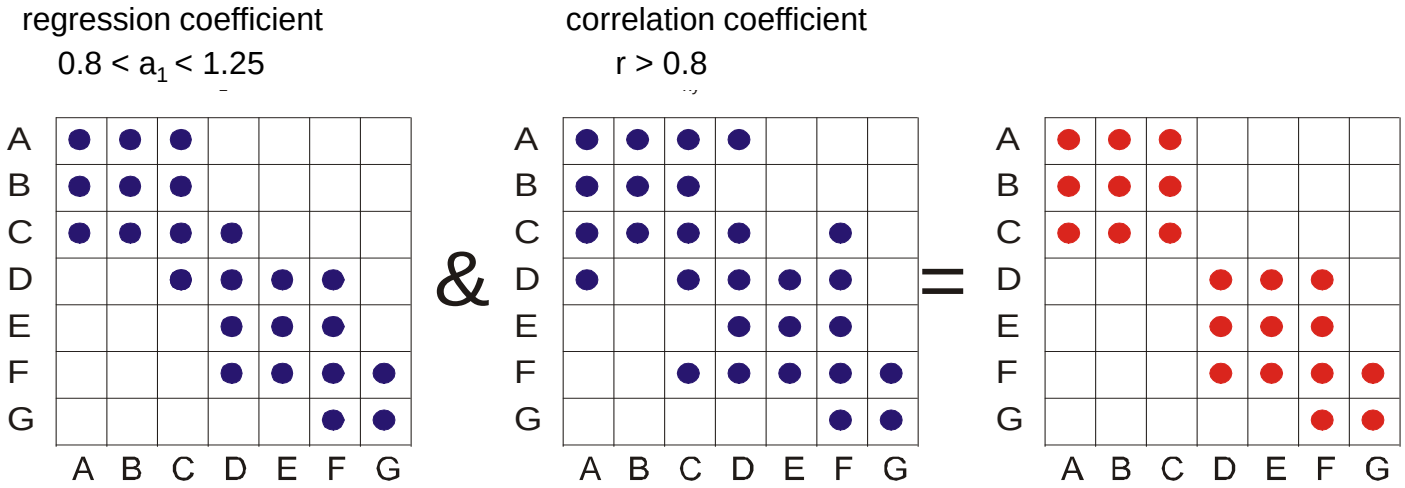
V_h …Harmonic voltage

I_h … harmonic current from disturbung load

$\underline{Z}$ … grid‘s impedance matrix

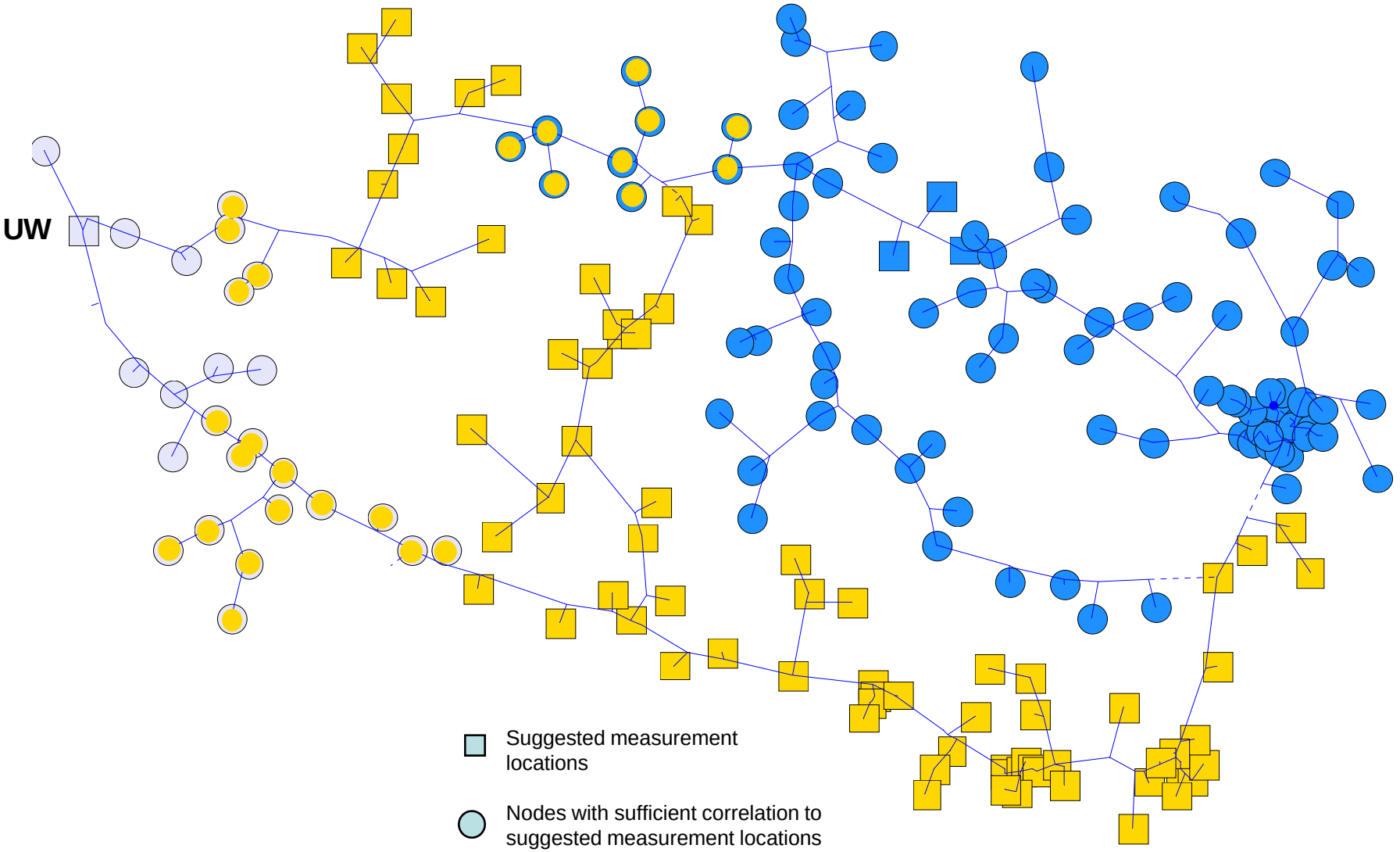
- creation of synthetic harmonic current time course (10-min rms values for a week) based on customer structure
- calculation of harmonic voltage time course with impedance matrix
- applying correlation and regression analysis to all combinations of voltage time series to detect similar „measurement results“

Combination of binary result matrices from correlation and regression analysis



- Adequate sorting of nodes in matrix
- Determination of clusters with similar behaviour
- Number of clusters equals minimum number of measurement devices

PQ monitoring

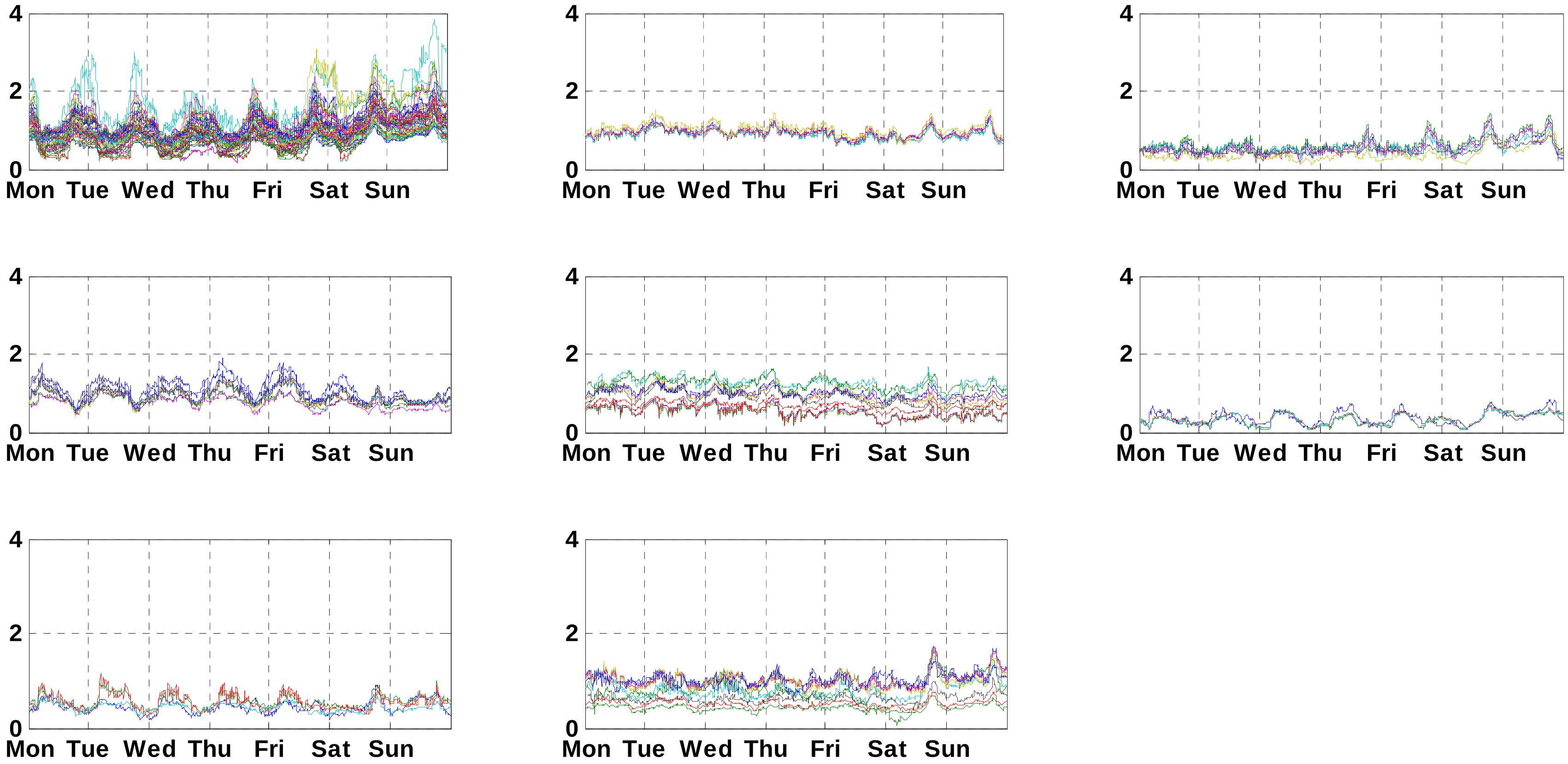


- In 2004 an Austrian grid provider started to install an area wide power quality monitoring system.

- Meanwhile 200 measuring devices were positioned accordingly to the results of the study in 40 MV grids of the above mentioned grid operator. The proposed method achieved a coverage of about 18 to 60 stations by one measuring device

- After one year successful operation it is possible to evaluate the developed method according to its ability to cover up the area-wide power quality. This evaluation resulted in further approvements of the algorithm.

Examples for measured time courses (5th harmonic)



2 main characteristics identified:

- 5th harmonic level dominated by housholds,
  high level in the evening (TV prime time) and on weekends,
  lower level during working hours

- 5th harmonic level dominated by (light) industry,
  constant high level during working hours,
  decreasing level during evening and weekend

From theory, single phase power electronic devices (household, office) and three phase power electronic devices (industry) show 150° phase shift in 5th harmonic current, leading partly to cancellation.

⇨ Basic knowledge of customer structure – which means basic knowledge of the harmonic current phase angle - is required

Revision of method:

- improvement in consideration of influence of high voltage grid

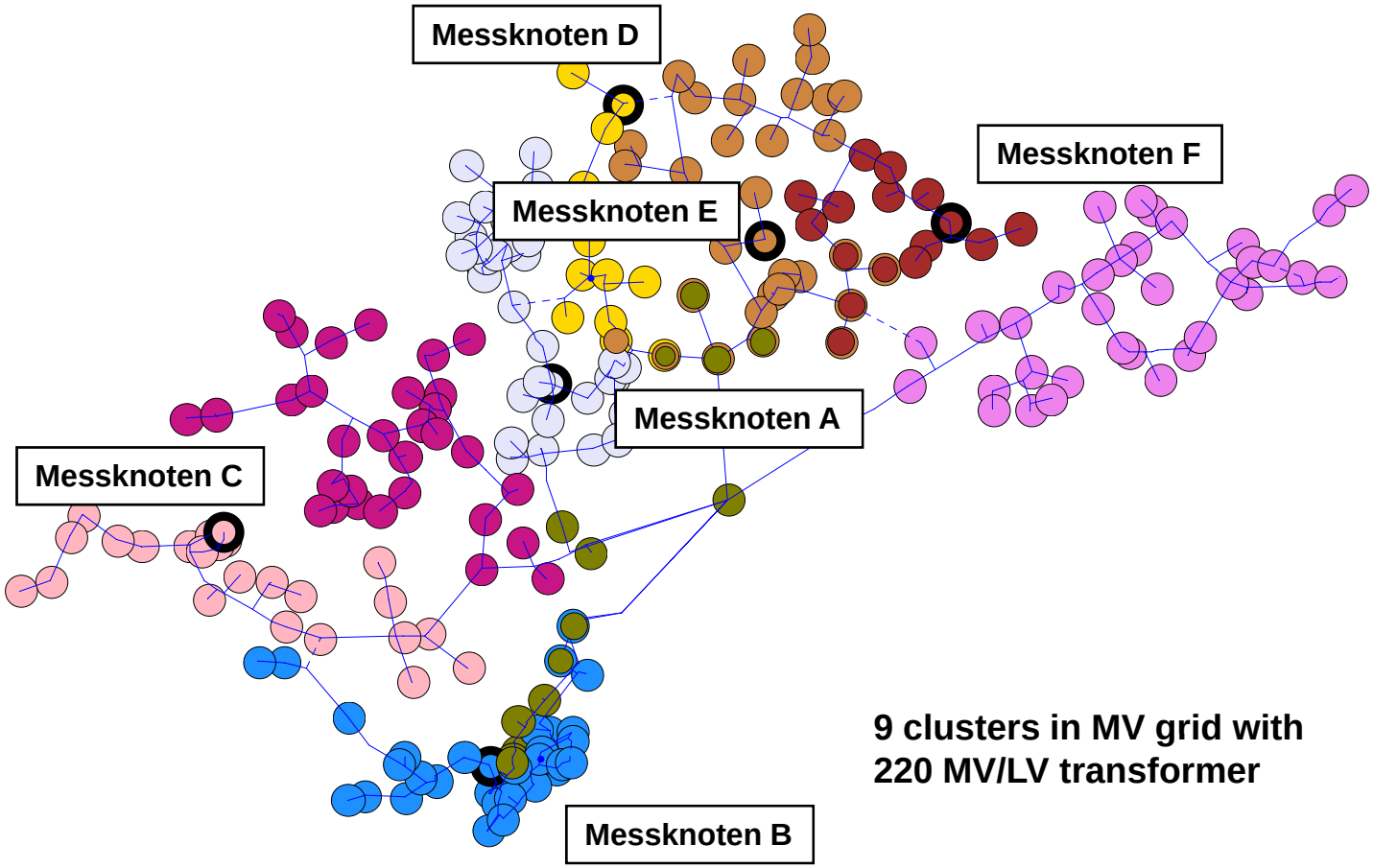
- improvement in consideration of harmonic current of phase angle

- improvement in assumption of fluctuating load currents causing flicker

⇨ results in better consistency of simulation and real measurement results

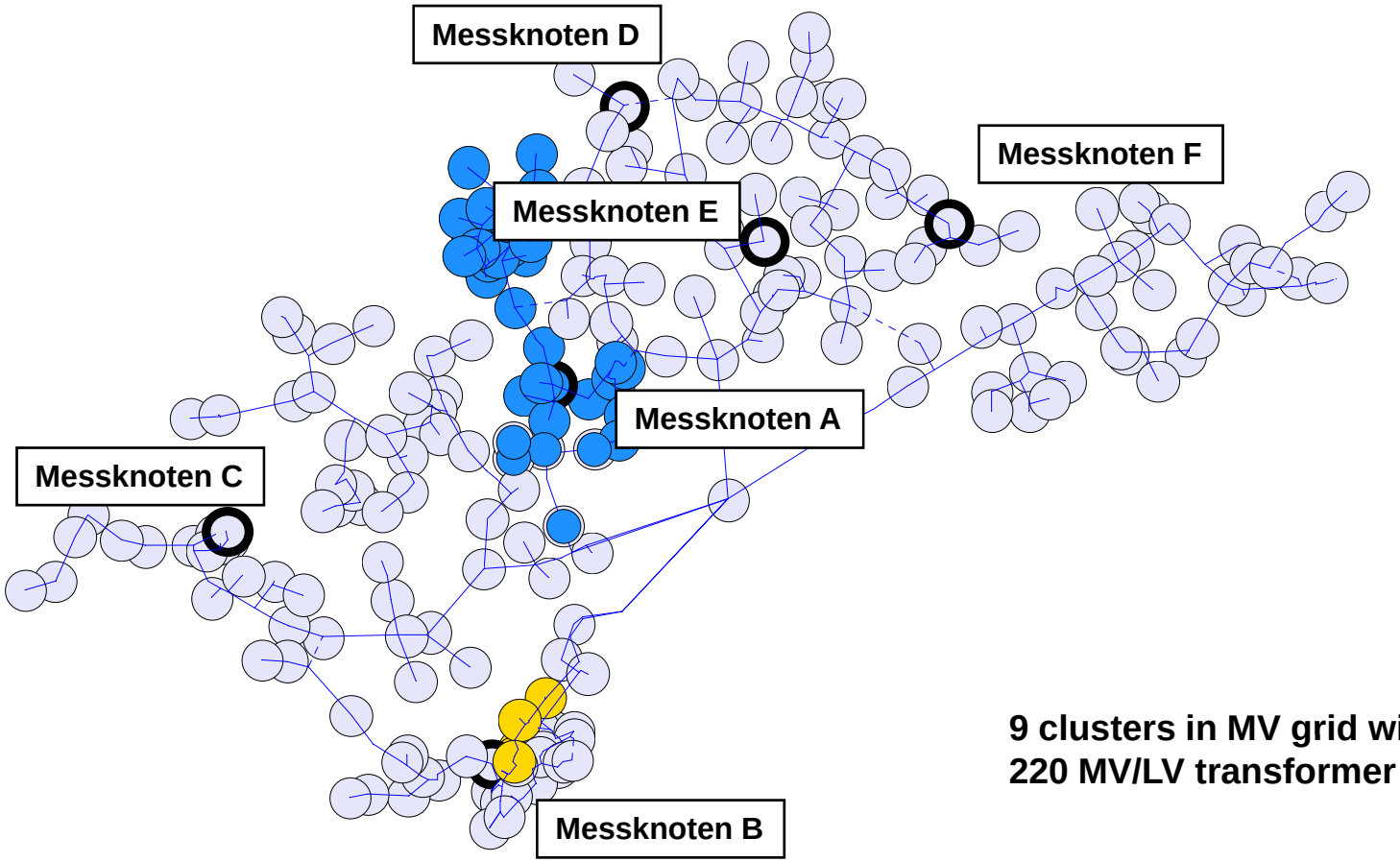
⇨ decreased number of necessary measurement devices

Modification of method



9 clusters in MV grid with
220 MV/LV transformer

Modification of method



9 clusters in MV grid with
220 MV/LV transformer

Time range

- Statistical evaluation, distribution of approx. one year measurement (52416 values)
- Statistical evaluation, distribution of one week measurement (1008 values)

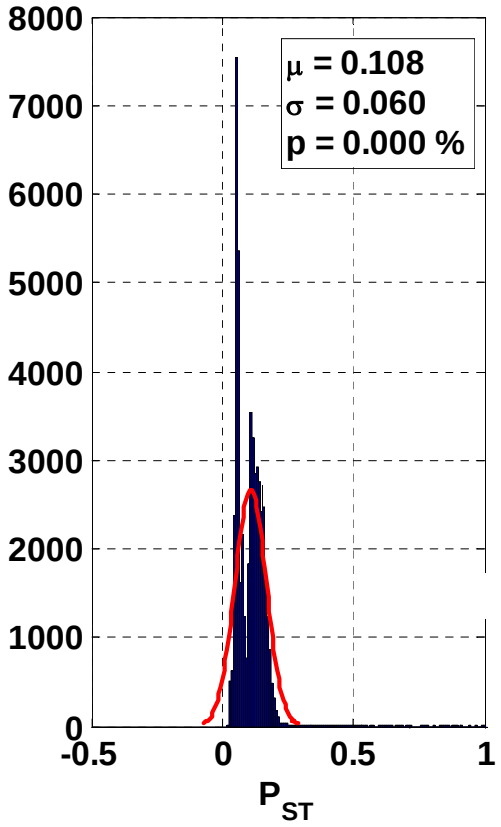
Analyzed parameters

- flicker (P_{st}-values)
- harmonics (5^{th} harmonic, 10 min average values)

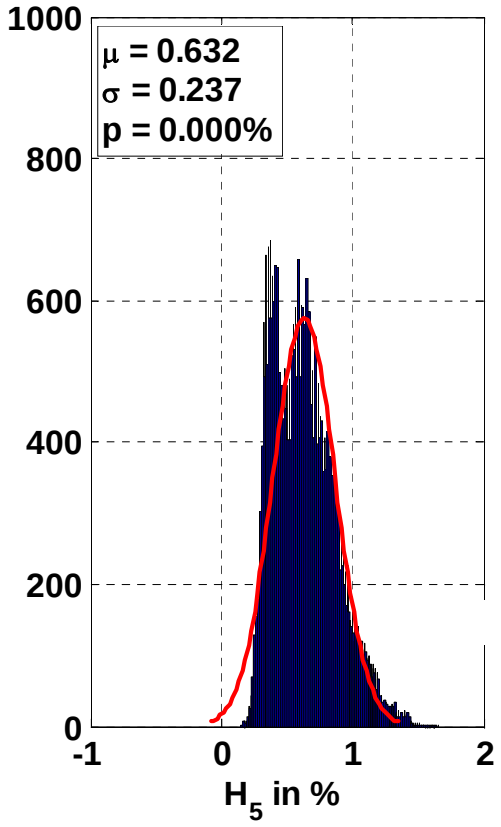
Typical no normal distribution,

⇨ statistic methods based on normal distribution might lead to wrong results

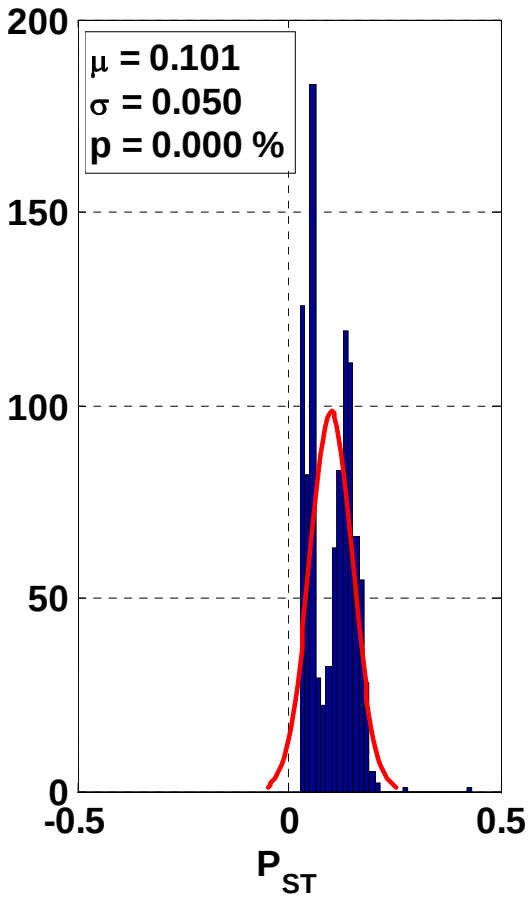
Flickerlevel, approx. one year measurement
no. of 10 min values: 52416



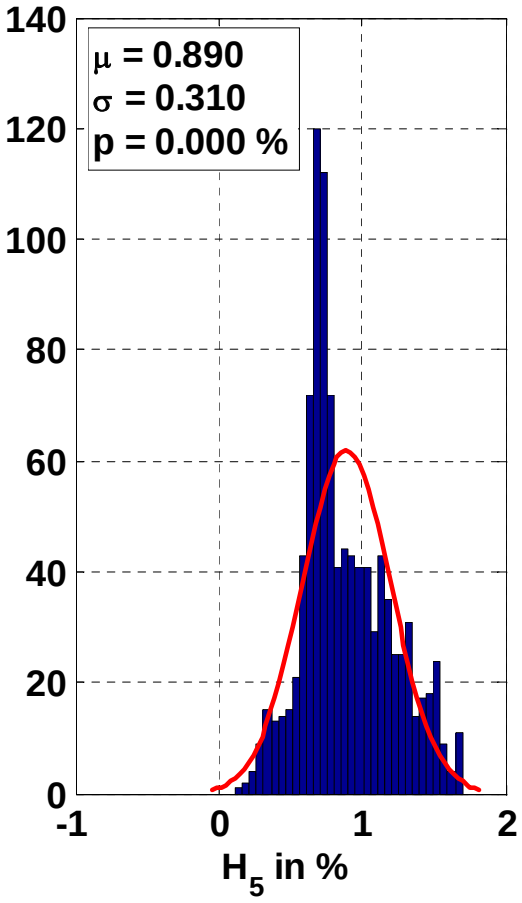
5th harmonic, approx. one year measurement
no. of 10 min values: 52416



Flickerlevel, one week measurement
no. of 10 min values: 1008



5th harmonic, one week measurement
no. of 10 min values: 1008



Combining results (Perrera)

Continuos measurement:

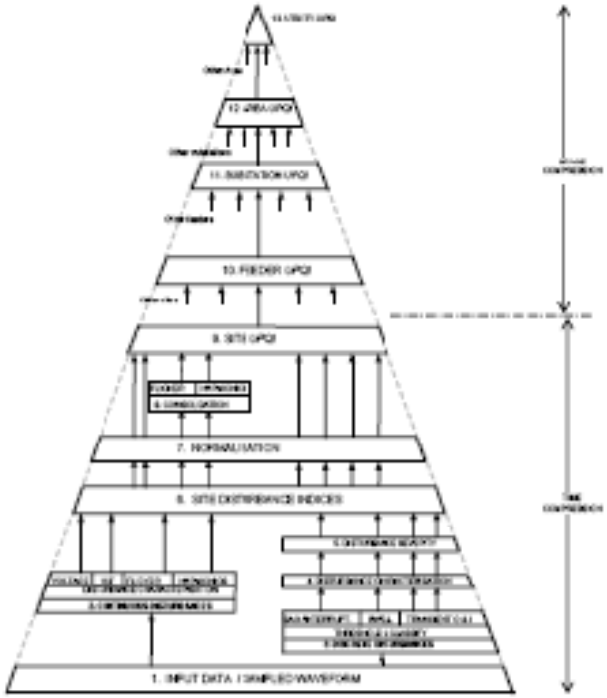
3 phases x (P_{st} + 40 harmonics + THD + unbalance + voltage level + frequency)

x 1008 10min-values = 136080 values/week,instrument

Additional: event triggered measurement

➡ data compression is necessary!

- compression in time domain
- local compression
- combining of PQ-parameters



Publications:
University of Wollongong
(S. Perera e.a.)

Data compression

1. Compression in time domain:

   level 1: 10 min average

   level 2: weekly 95% quantile

   level 3: annual value, mean/maximum value of weekly 95% quantiles

2. Local compression:

   level 1: cluster, containing 1 instrument

   level 2: MV-grid, containing several cluster

   level 3: grid operator, operating several grids

   level 4: nation wide parameter

Compression method:

mean/max value of weekly 95% quantiles, weighting according power, no. of customers,...

3. Combining of PQ parameters

- Scaling to pu-values,
  refer measurement values to power quality limits

- Combining of parameters, calculating Unified Power Quality Index UPQ
  with specific weighting parameters a_i (specification needs a lot of discussion)

mean value

$$UPO = \frac{\sum_i a_i \cdot PQ_i}{n}$$

maximum value

$$UPQ = max\left\{a_i \cdot PQ_i\right\}$$

Gosbell, Perrera

$$UPQ = \begin{cases} max\left\{a_i \cdot PQ_i\right\} & \text{für } max\left\{a_i \cdot PQ_i\right\} < 1 \\ 1 + \sum_i \left(PQ_i - 1\right) & \text{für } max\left\{a_i \cdot PQ_i\right\} \geq 1 \end{cases}$$

Possible use of the Unified Power Quality Index

- Chance for regulation authorities to detect and quantify power quality problems also without deep knowledge
- Benchmark for comparison of different grids within a country
- Benchmark for international comparison
- Measure for use in regulation formula (power quality regulation)

Towards Voltage Quality Regulation in Europe – An ERGEG Conclusions Paper

July 2007

based on:

- **Public Consultation Paper: Towards Voltage Quality Regulation In Europe**
- **Evaluation of the Comments Received**

Main focus: revision of EN 50160

- **Improve definitions and measurement rules**
  - Close gaps (e.g. between dips and voltage variation)
  - Definition of rapid voltage changes
  - Definition of interruption
- **Limits for voltage variation**
  - 95% -> 100%
- **Enlarge the scope of EN 50160 to high and extra-high voltage systems**
  - Usually very specific
- **Consider duties and rights for all parties involved**

- **Avoid ambiguos indicative values for voltage events**
- **Introduce limits for voltage events differentiated according to the network characteristics**

  Analysis of influencing factors:

  - **under control of grid operator (protection system, ARC, maintenance,..)**
  - **out of control of grid operator (regional lightning density, snow,...)**

- **Power quality contracts**

  Scope of EN 50160 ?

ERGEG Conclusions Paper

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