

The 4th BR on EQS

Main findings on voltage quality

Karstein Brekke (kab@nve.no)

Co-chair of the CEER Electricity Quality of Supply TF

NVE – Norwegian Water Resources and Energy Directorate

Workshop ERSE “The 4th European Benchmarking Report on Quality of Electricity Supply and the Portuguese evolution”, Lisbon, 23th June 2009

Content

Main findings on voltage quality

- Introduction
- Regulation
- Monitoring systems in place
- Voltage quality data



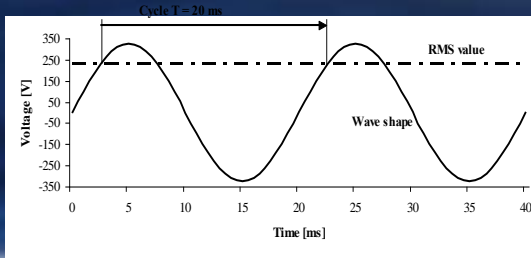
Content

Main findings on voltage quality

- Introduction
- Regulation
- Monitoring systems in place
- Voltage quality data

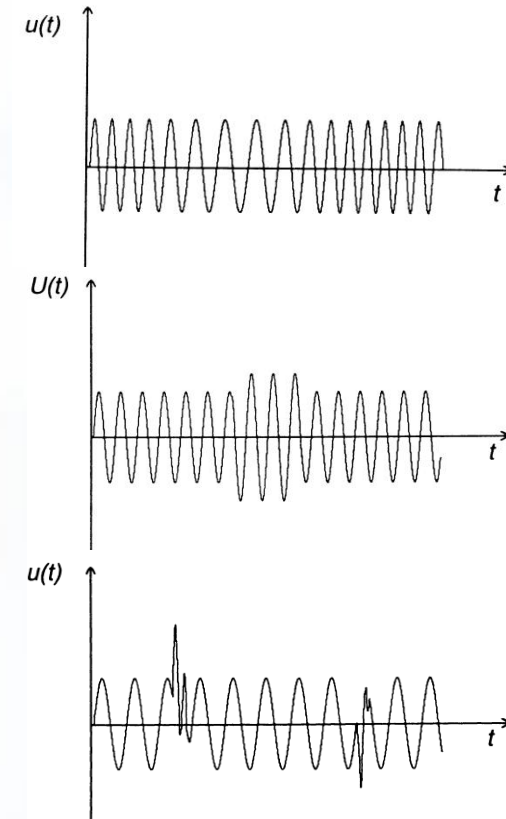


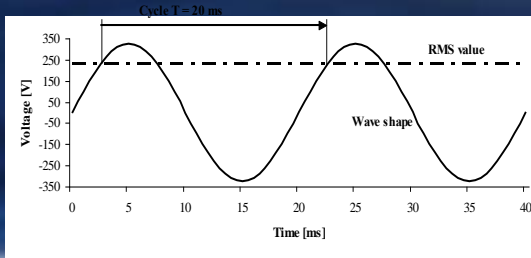
- What is voltage quality?
- What influences on the voltage quality?
- European and global standards, EMC



Voltage disturbances

- **Voltage frequency**
 - Frequency and time deviation
- **Voltage RMS value**
 - Supply voltage variations
 - Voltage dips
 - Voltage swells
 - Rapid voltage changes
 - Voltage fluctuations (flicker)
 - Voltage unbalance
- **Voltage wave form**
 - Harmonic voltages
 - Interharmonic voltages, subharmonic voltages
 - Transient overvoltages
 - Signal voltages superimposed on the supply voltage





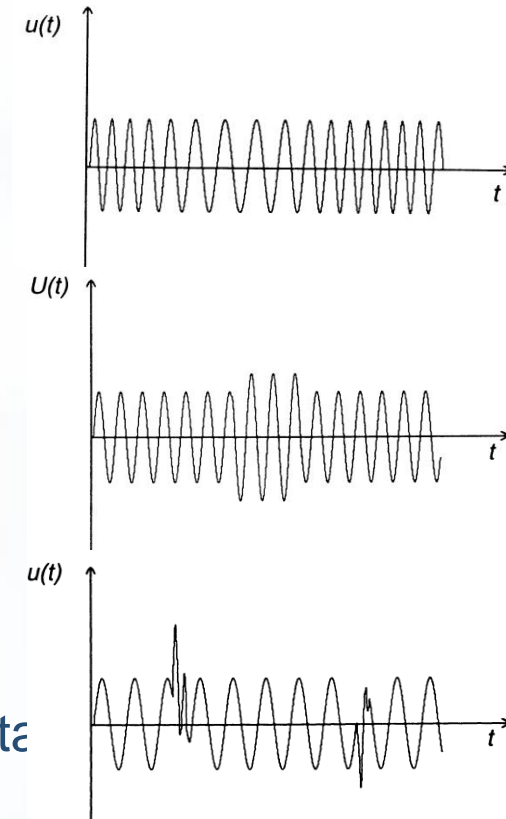
Voltage disturbances

- **Continuous phenomena**

- Frequency and time deviation
- Supply voltage variations
- Rapid voltage changes
- Voltage fluctuations (flicker)
- Voltage unbalance
- Harmonic voltages
- Interharmonic voltages
- Subharmonic voltages
- Signal voltages superimposed on the supply voltage

- **Voltage events**

- Transient overvoltages
- Voltage dips
- Voltage swells



Content

Main findings on voltage quality


- Introduction
- Regulation
- Monitoring systems in place
- Voltage quality data



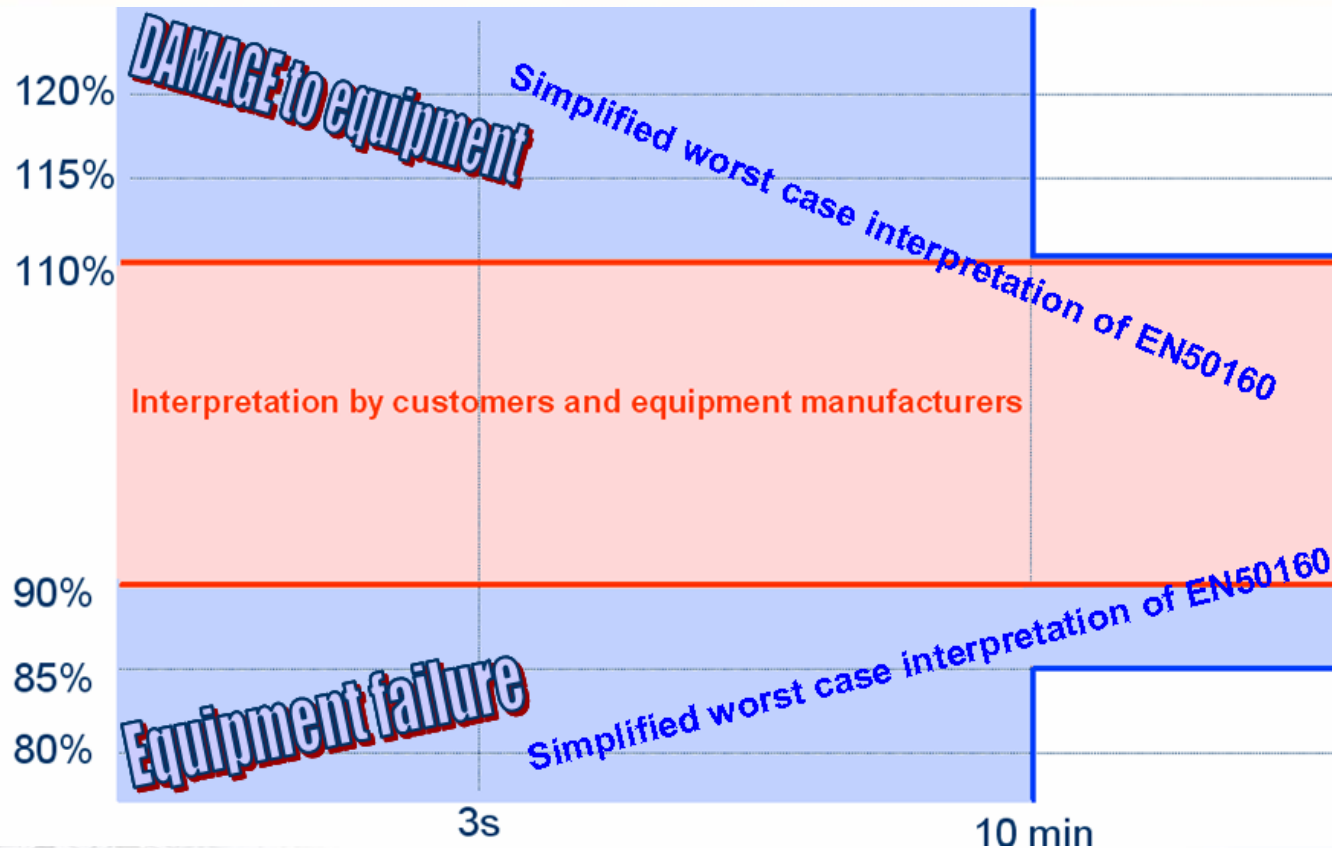
Stakeholders' general view

- What to be defined as satisfactory level of quality of supply may differ between various stakeholders, including
 - Distribution and transmission system operators
 - End-users
 - Equipment manufacturers

Scale

- 
- Regulator
 - Aims at ensuring a quality that is beneficial for the society as a whole
 - Take into account all public and private interests

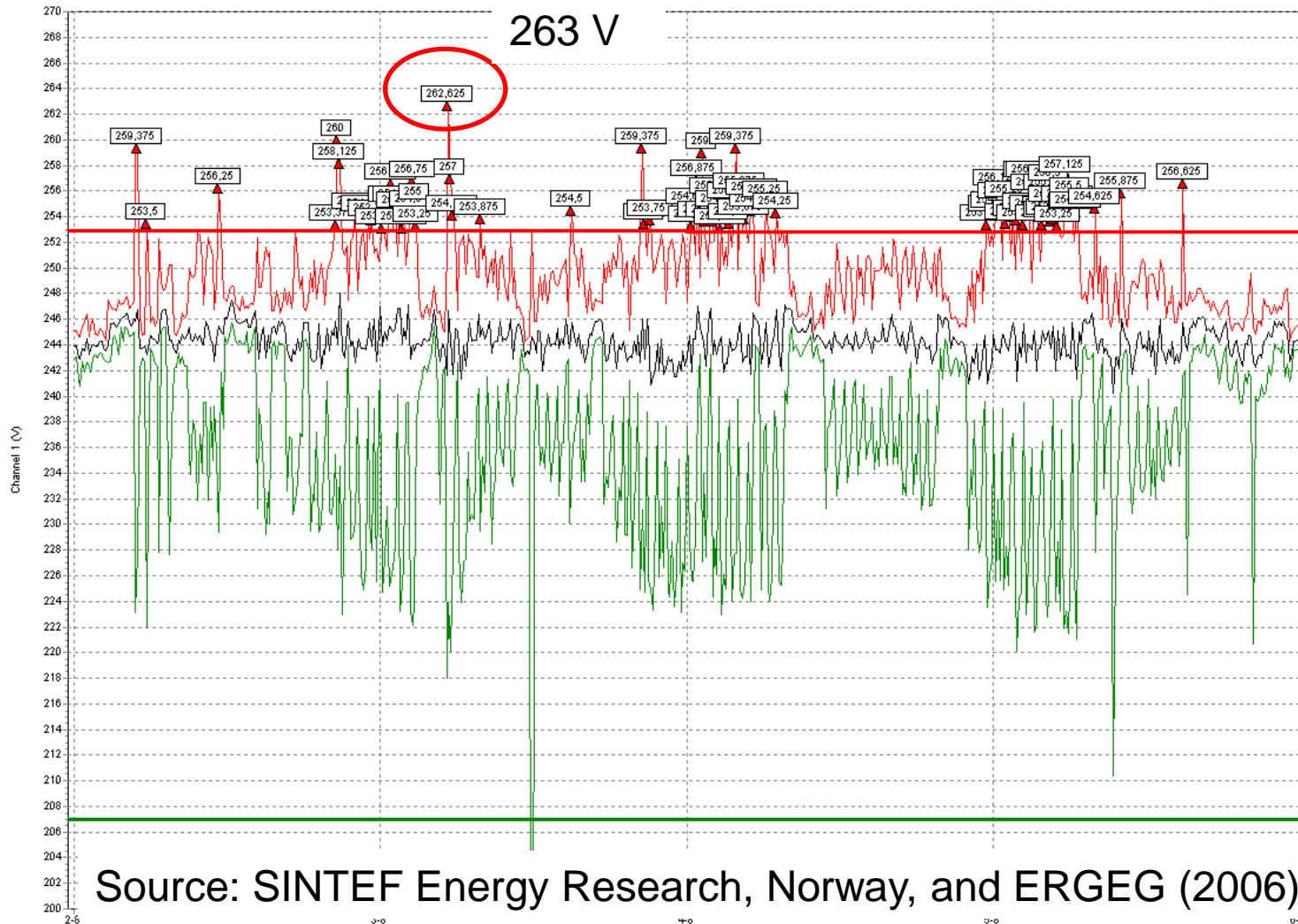
Supply Voltage Variations



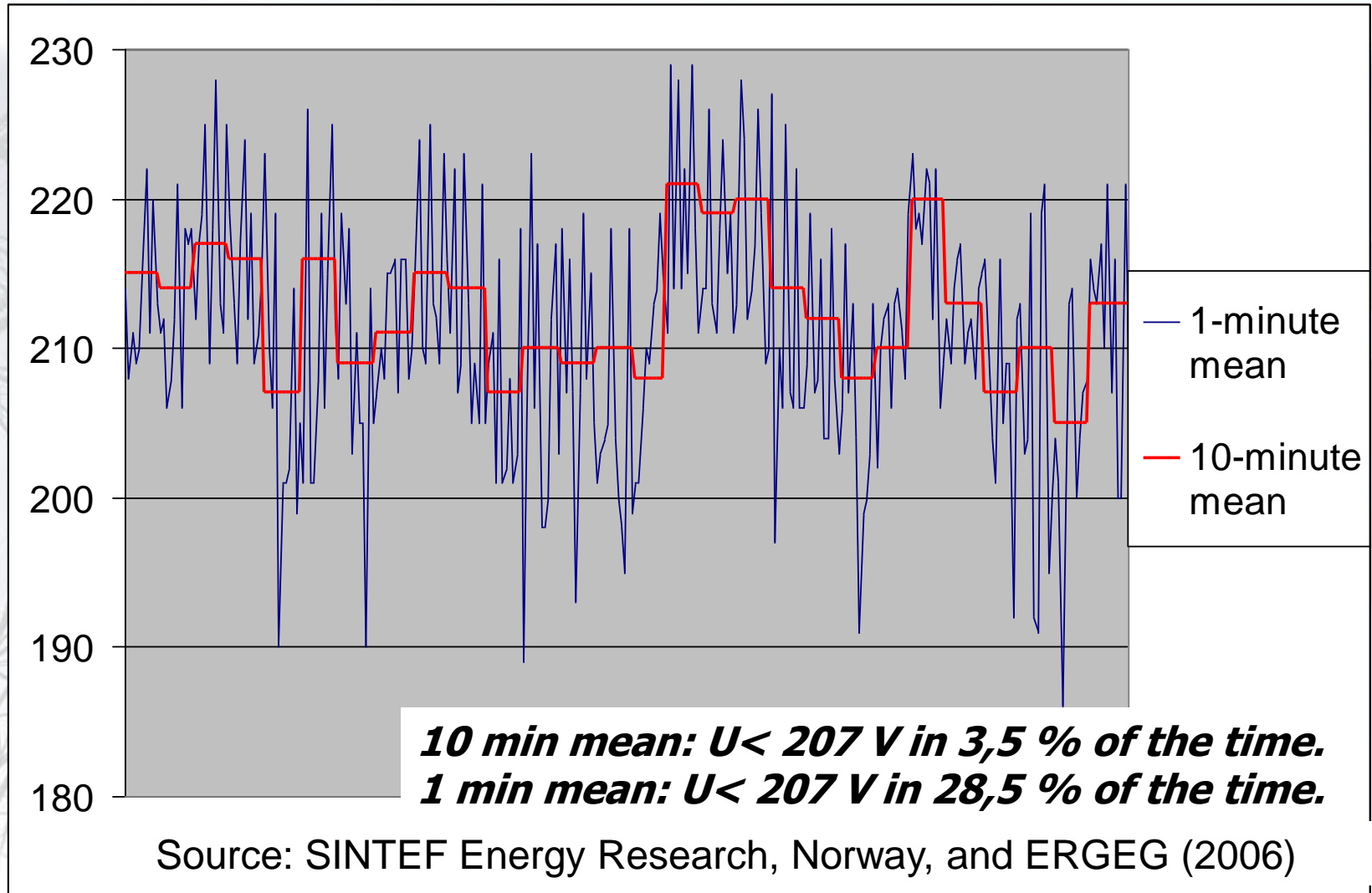
Interpretation of today's limits in EN 50160 as regards slow supply voltage variations

Source:
Mr Helge Seljeseth, CEER workshop on Voltage quality standards, Milan September 29th 2006 and ERGEG (2006)

Supply Voltage Variations



Supply Voltage Variations



Supply Voltage Variations

- Solutions at national level
- Norway
 - LV: 1 min mean values 10% 100% of the time
- Hungary
 - LV: 10 min mean values 7.5% 95% of the week
 - LV: 10 min mean values 10% 100% of the time
 - LV: 1 min mean values 15% 100% of the time
- More details can be found in the:
4th Benchmarking Report on Quality of Electricity Supply



Voltage Quality Regulation

| Voltage characteristics in EN 50160 | Countries with a different regulation or standard |
|-------------------------------------|--|
| Supply voltage variations | ES, FR*, HU, NO (only for LV customers), PT (only for EHV-HV customers) |
| Flicker | NO (requirements for both P_{st} and P_{lt}), PT (only for EHV-HV customers) NL (maximum limit for P_{lt}) |
| Voltage dips | NO, FR* (customised engagement on request only for MV and HV customers) |
| Voltage swells | NO, FR* |
| Transient overvoltages | FR* |
| Voltage unbalance | FR*, NO, NL |
| Harmonic voltage | FR*, NO, PT (only for EHV-HV customers), NL (maximum limit for THD, 5 th and 7 th harmonic) |
| Interharmonic voltage | None |
| Mains signalling voltage | None |
| Single rapid voltage changes | NO |

(*) In France the voltage quality limits are set in the contracts between the customer and the distribution/transmission operator; the regulator surveys the contracts but does not set standards.

Voltage Quality Regulation

| Regulatory framework for individual verification | Country |
|---|--|
| Distribution companies compelled to provide voltage quality individual measurements when requested by the customer or after complaints. | AT, BE, CY, CZ, DE, EE, FI, FR, HU, IT, LT, LV, NO, PL, RO, PT |
| Proposal stage | SE |
| No legal obligation | EE, ES, LU, SL, UK |

Content

Main findings on voltage quality

- Introduction
- Regulation
- Monitoring systems in place
- Voltage quality data



| Country | Period of monitoring | Number of measuring units installed | | | |
|---|---|--------------------------------------|---------------------|-------------------|-----------------------|
| | | EHV and HV | MV | LV | <i>total</i> |
| Belgium Federal Belgium Flemish Belgium Wallonia Belgium Brussels | Not available | 223 nd 0 - | 5 nd 137 - | 0 nd 0 - | 228 nd 137 - |
| Czech Republic | Transfer points TS/DS since 1/1/2006 Delivery points 110 kV since 1/1/2007 | 20 at 220/110 kV 42 at 400/110 kV | | | 62 |
| Denmark | Since 2007 | | 8 | | |
| France | Since 1995 | 636 (of which 3% in MV) | About 30,000 | | About 30,636 |
| Greece | Since 2008 | | | 500 | 500 |
| Hungary | Since 2003 | | | 400 | 400 |
| Italy | MV since February 2006 HV and EHV since January 2007 | 165 | 600 | | 765 |
| Luxembourg | Depends on system operator as previously (prior to new electricity act) not mandatory. | | nd | nd | nd |
| The Netherlands | Since 2004 (EHV and HV) Since 1996 (for all DSOs) | 8 (220-380 kV) 20 (50-150 kV) | 60 ⁽¹⁾ | 60 ⁽¹⁾ | 148 ⁽¹⁾ |
| Norway | Since 2006 ⁽²⁾ | nd ⁽²⁾ | nd ⁽²⁾ | ⁽²⁾ | nd ⁽²⁾ |
| Portugal | 2006 ⁽³⁾ | 64 | 90 | 131 | 285 |

⁽¹⁾ Several monitoring instruments to perform yearly at least 60 measurements of one week each at both the MV and LV network.

⁽²⁾ In Norway a previous voluntary monitoring campaign was also carried out 1993-2003; see annex for more information.

⁽³⁾ In Portugal the number of units has been increasing since 1999; the first year that ERSE received information about voltage quality characteristics.

| Voltage disturbance | Belgium | Czech Republic | France | Greece | Hungary | Italy | The Netherlands | Norway | Portugal |
|--------------------------------|---------|----------------|-------------|--------|---------|-------------|-----------------|-------------|----------|
| Power frequency ⁽¹⁾ | HV | HV | EHV, HV | LV | | EHV, HV | | | All |
| Supply voltage variations | HV, MV | HV | EHV, HV, MV | LV | LV | EHV, HV, MV | All | | All |
| Single rapid voltage changes | | HV | | LV | | EHV, HV, MV | All | EHV, HV, MV | |
| Flicker | HV, MV | HV | EHV, HV | LV | | EHV, HV, MV | All | | All |
| Voltage unbalance | HV | HV | EHV, HV | LV | LV | EHV, HV, MV | All | | All |
| Harmonic voltages | HV, MV | HV | EHV, HV | LV | LV | EHV, HV, MV | All | | All |
| Voltage dips | HV | HV | EHV, HV, MV | LV | LV | EHV, HV, MV | | EHV, HV, MV | All |
| Voltage swells | HV | HV | MV | LV | LV | EHV, HV, MV | | EHV, HV, MV | |
| Transient overvoltages | | HV | | LV | | | | | |
| Interharmonic voltages | | HV | | LV | | | | | |
| Mains signalling voltages | | HV | | LV | | | | | |

⁽¹⁾ In all countries the power frequency is monitored and managed by the interconnected European transmission system operators and international system operation agreements. This table only refers to what is monitored by voltage quality instruments in place for continuous monitoring.

| Country | Initiative |
|------------------------|---|
| Belgium HV | TSO |
| Belgium MV | DNO |
| Czech Republic | TSOs and DNOs |
| Denmark | DNO |
| Greece | Regulator |
| France | TSO and DNOs |
| Hungary | Regulator |
| Italy | Regulator |
| Lithuania | TSOs and DNOs |
| Luxembourg | TSOs and DNOs |
| The Netherlands | TSOs and DNOs |
| Norway | Regulator |
| Portugal | Quality and Service Code issued by General Directorate of Energy and Geology |

Content

Main findings on voltage quality

- Introduction
- Regulation
- Monitoring systems in place
- Voltage quality data



Data reported

- Six countries reported data on voltage dips
- Two countries reported additional actual data (annex)
- Non-comparable data

TABLE 3.24 NORWAY: AVERAGE NUMBER OF VOLTAGE DIPS PER YEAR IN LV NETWORKS WITH REFERENCE TO MEASURING SITES

| Residual voltage u | Duration t (ms) | | | | | |
|----------------------|----------------------|--------------------|----------------------|------------------------|-------------------------|--------------------------|
| | $20 \leq t \leq 100$ | $100 < t \leq 500$ | $500 < t \leq 1,000$ | $1,000 < t \leq 3,000$ | $3,000 < t \leq 20,000$ | $20,000 < t \leq 60,000$ |
| (%) | | | | | | |
| $90 > u \geq 65$ | 17 | 14 | 4 | 3 | 0 | 0 |
| $85 > u \geq 70$ | 9 | 2 | 2 | 0 | 0 | 0 |
| $70 > u \geq 40$ | 10 | 3 | 0 | 0 | 0 | 0 |
| $40 > u \geq 1$ | 6 | 1 | 0 | 0 | 0 | 0 |
| $1 > u$ | 3 | 4 | 1 | 0 | 0 | 0 |

TABLE 3.25 NORWAY: AVERAGE NUMBER OF VOLTAGE DIPS PER YEAR IN MV NETWORKS WITH REFERENCE TO MEASURING SITES

| Residual voltage u | Duration t (ms) | | | | | |
|----------------------|----------------------|--------------------|----------------------|------------------------|-------------------------|--------------------------|
| | $20 \leq t \leq 100$ | $100 < t \leq 500$ | $500 < t \leq 1,000$ | $1,000 < t \leq 3,000$ | $3,000 < t \leq 20,000$ | $20,000 < t \leq 60,000$ |
| (%) | | | | | | |
| $90 > u \geq 65$ | 13 | 9 | 3 | 1 | 0 | 0 |
| $85 > u \geq 70$ | 5 | 2 | 1 | 0 | 0 | 0 |
| $70 > u \geq 40$ | 7 | 2 | 0 | 0 | 0 | 0 |
| $40 > u \geq 1$ | 4 | 0 | 0 | 0 | 0 | 0 |
| $1 > u$ | 1 | 2 | 1 | 0 | 0 | 4 |

TABLE 3.26 NORWAY: AVERAGE NUMBER OF VOLTAGE DIPS PER YEAR IN HV NETWORKS WITH REFERENCE TO MEASURING SITES

| Residual voltage u | Duration t (ms) | | | | | |
|----------------------|----------------------|--------------------|----------------------|------------------------|-------------------------|--------------------------|
| | $20 \leq t \leq 100$ | $100 < t \leq 500$ | $500 < t \leq 1,000$ | $1,000 < t \leq 3,000$ | $3,000 < t \leq 20,000$ | $20,000 < t \leq 60,000$ |
| (%) | | | | | | |
| $90 > u \geq 65$ | 9 | 6 | 2 | 0 | 0 | 0 |
| $85 > u \geq 70$ | 3 | 1 | 1 | 0 | 0 | 0 |
| $70 > u \geq 40$ | 4 | 0 | 0 | 0 | 0 | 0 |
| $40 > u \geq 1$ | 1 | 0 | 0 | 0 | 0 | 0 |
| $1 > u$ | 1 | 1 | 0 | 0 | 0 | 1 |

TABLE 3.27 NORWAY: AVERAGE NUMBER OF VOLTAGE DIPS PER YEAR IN EHV NETWORKS WITH REFERENCE TO MEASURING SITES

| Residual voltage u | Duration t (ms) | | | | | |
|----------------------|----------------------|--------------------|----------------------|------------------------|-------------------------|--------------------------|
| | $20 \leq t \leq 100$ | $100 < t \leq 500$ | $500 < t \leq 1,000$ | $1,000 < t \leq 3,000$ | $3,000 < t \leq 20,000$ | $20,000 < t \leq 60,000$ |
| (%) | | | | | | |
| $90 > u \geq 65$ | 3 | 2 | 1 | 0 | 0 | 0 |
| $85 > u \geq 70$ | 1 | 1 | 0 | 0 | 0 | 0 |
| $70 > u \geq 40$ | 1 | 0 | 0 | 0 | 0 | 0 |
| $40 > u \geq 1$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $1 > u$ | 0 | 0 | 0 | 0 | 0 | 1 |

Data reported

TABLE 3.29 PORTUGAL: NUMBER OF VOLTAGE DIPS IN TRANSMISSION DELIVERY POINTS AT 60 KV - 2007)

| Residual voltage u (%) | Duration t (s) | | | | | |
|-----------------------------|------------------|--------------|--------------|-----------|---------|----------|
| | [0,01 ; 0,1] | [0,1 ; 0,25] | [0,25 ; 0,5] | [0,5 ; 1] | [1 ; 3] | [3 ; 20] |
| [10,20] | 122 (1.9) | 31 (0.5) | 14 (0.2) | 4 (0.1) | 3 (0) | 0 (0) |
| [20,30] | 23 (0.4) | 18 (0.3) | 7 (0.1) | 1 (0) | 1 (0) | 0 (0) |
| [30,40] | 30 (0.5) | 12 (0.2) | 2 (0) | 1 (0) | 1 (0) | 0 (0) |
| [40,50] | 23 (0.5) | 2 (0) | 1 (0) | 0 (0) | 0 (0) | 0 (0) |
| [50,60] | 15 (0.2) | 1 (0) | 3 (0) | 1 (0) | 0 (0) | 0 (0) |
| [60,70] | 22 (0.3) | 0 (0) | 1 (0) | 0 (0) | 0 (0) | 0 (0) |
| [70,80] | 14 (0.2) | 0 (0) | 0 (0) | 1 (0) | 0 (0) | 0 (0) |
| [80,90] | 3 (0) | 1 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| [90,99] | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |

In brackets is the average number of dips per measuring unit

Conclusion

- Voltage quality needs to be regulated
- Individual verification of voltage quality to customers
- Countries should consider monitoring voltage quality continuously and publish results regularly.
 - Dissemination of experiences and harmonisation is envisaged
 - Workshop on voltage quality monitoring
- 11 countries reported monitoring schemes
- 6 countries reported actual voltage quality data
- Continued cooperation with CENELEC and further revisions of the EN 50160

Thank you for your attention!

www.energy-regulators.eu



Mark your diary for the World Forum on Energy Regulation IV

October 18-21, 2009

Athens, Greece

www.worldforumiv.info

Thank you for your attention!

www.energy-regulators.eu

kab@nve.no