ERGEG Public Consultation

Towards Voltage Quality Regulation in Europe

Evaluation of the Comments Received

E07-EQS-15-04

18 JULY 2007

European Regulators' Group for Electricity and Gas
Contact: Council of European Energy Regulators ASBL
28 rue le Titien, 1000 Bruxelles
Arrondissement judiciaire de Bruxelles
RPM 0861.035.445

Table of contents

1. Introduction

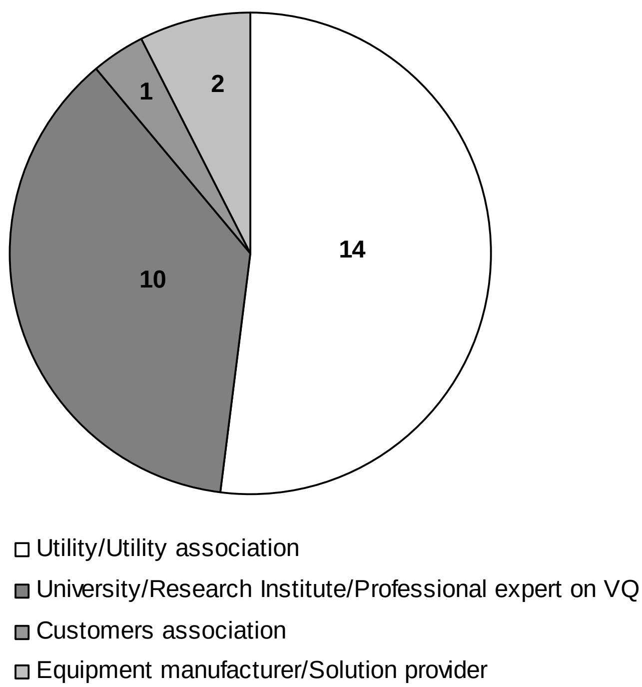
The ERGEG public consultation on the basis of the report "*Toward Voltage Quality Regulation in Europe* – E07-EQS-15-03" received 27 responses. Four respondents' classes have been identified as follows:

- Utility/Utility association (14 responses)
- Academia/Research Institute/Professional expert on voltage quality (VQ) (10 responses)
- Customers association (1 response)
- Equipment manufacturer/Solution provider (2 responses)

The table below shows the name of the respondent and its associated respondents' class.

Respondent		Country	Respondents' class
1	CIGRE/ CIRED/ UIE Joint Working Group C4.110 (convenor: Math Bollen)	-	Research Institute
2	Hervé Rochereau, - EDF Research and Development	France	Professional expert on VQ
3	Giovanni Mazzanti, teacher of Power Quality at the Faculty of Engineering, University of Bologna	Italy	Academia
4	Prof. Pierluigi Caramia, Unità di Cassino del GUSEE (Gruppo Universitario Sistemi Elettrici per l'Energia) and Ing. Pietro Varilone, Sezione di Cassino dell'AEIT	Italy	Academia
5	Enrico Tironi, full professor of Electrical Power Systems; Gabrio Superti Furga, full professor of Basic Electrical Engineering – Department of Electrical Engineering, Politecnico di Milano	Italy	Academia
6	Czech Association of the Regulated Power Supply Companies (CSRES)	Czech Republic	Utility association
7	Norwegian Electricity Industry Association (EBL)	Norway	Utility association
8	EON North Transdanubian Electricity Co.	Hungary	Utility
9	VDN (Verband der Netzbetreiber) *(Association of German electricity network operators under the umbrella of the German Electricity Association)*	Germany	Utility association
10	Association of Austrian Electricity Companies(VEO), Leo Windtner, President and Gerhard Bartak, Deputy Secretary General	Austria	Utility association
11	Dr Sasa Djokic, Lecturer, School of Engineering and Electronics, University of Edinburgh	Scotland	Academia
12	Groupement Européen des entreprises et Organismes de Distribution d'Energie (GEODE)	-	Utility association
13	The Association of Norwegian End-users of energy, Arne Kjeldsen, Chairman of the Board	Norway	Customers association
14	Attila Bodrogi, Service Quality Leader - Démász Hálózati Elosztó Kft	Hungary	Utility
15	Energy Networks Association, Nick Goodall	UK	Utility association
16	ENEL Distribuzione	Italy	Utility
17	SYNERGRID, Fédération des gestionnaires de réseaux Electricité et Gaz en Belgique, Ferdinand de Lichtervelde, Secretary General	Belgique	Utility association

Respondent		Country	Respondents' class
18	Hungarian Electricity Association as distributors, Dr. Norbert Boross, Secretary	Hungary	Utility association
19	EURELECTRIC	-	Utility association
20	Dejan Matvoz, Electric Power System Control and Operation Department, Milan Vidmar Electric Power Research Institute, Ljubljana	Slovenia	Research Institute
21	E.ON Hungária Zrt. (Hungary), Network Directorate	Hungary	Utility
22	Mark McGranaghan, EPRI (Electric Power Research Institute)	USA	Research Institute
23	QEnergia	Portugal	Solution provider
24	ESB Networks	Republic of Ireland	Utility
25	TW_TeamWare	Italy	Equipment manufacturer
26	V. Ajodhia and B. Franken, *KEMA Consulting*. "Regulation of Voltage Quality" - Work package 4 and 5 from project "Quality of Supply and Regulation". February 2007[1]	Netherlands	Expert
27	M.H.J. Bollen, *STRI AB, Sweden* and Paola Verde, *University of Cassino, Italy*. "A framework for Regulation of rms Voltage and Short-duration under Overvoltages". Februrary 2007[2]	Sweden Italy	Expert



[1] Not published on the Ergeg website due to copyright reasons.

[2] Not published on the Ergeg website due to copyright reasons.

2. Purpose of paper

This paper is a synthesis of responses received during the consultation process. The Regulators position can be found at the separate document "*Towards Voltage Quality Regulation in Europe. An ERGEG Conclusions Paper -.E07-EQS-15-03*"

All responses have been published on the ERGEG website:
http://www.ergeg.org/portal/page/portal/ERGEG_HOME/ERGEG_PC/ARCHIVE1/Voltage%20Quality.

However, as mentioned in the previous list, two background technical papers have not been published. Their contents have been taken into account in the synthesis as they have been sent as responses to the consultation.

This paper is complementary to the above mentioned ERGEG Conclusions Paper..It analyzes the main issues highlighted by respondents and is published in parallel on the ERGEG website.

3. Respondents' GENERAL views on EN 50160 revision

a) In general, **respondents welcomed ERGEG initiative to revise EN 50160**. The following general arguments have been expressed to support the improvement of EN 50160.

One utility association recognised the vital importance of service quality and in particular power quality for its customers, the need for continuous improvement and the specific role that regulators have in representing the interests of customers, while ensuring the financial sustainability of network operators. The utility association recognised that European regulators were correct in deciding to address concerns relating to power quality through dialogue with CENELEC, a process that has been ongoing. The consultation document has many interesting observations and suggestions for improvements which could be helpful.

One respondent from academia argued that regulation of voltage quality in European countries is needed for several reasons (increased load susceptibility and emission, needs of increased industrial process efficiency and productivity, absence of competitive markets especially in distribution sectors, deep changes in the last 10 years of electrical system structure and operation- from pure passive network to also active network thanks to distributed generation, and so on). Actual version of EN 50160 describes the average (in some cases minimum) voltage quality levels in European electrical systems rather than giving a framework of reference for voltage regulation. The revision of EN 50160 can give a general framework for regulation; it can state in an unambiguous way disturbances definition, and general limits for sharing responsibility among various parties. It can reflect new challenges of privatized and liberalized markets.

One utility association mentioned that documents on power quality should continuously be adjusted to actual needs, especially when the regulatory framework is changing.

One expert pointed out that voltage quality regulation is less advanced and detailed when compared with for example regulation of continuity of supply. This can be attributed to the higher degree of complexity involved in regulating voltage quality. Not only are there more dimensions involved, but also measurement is more complicated. Nevertheless, the importance of voltage quality and therefore the need for regulation is increasing. Effective regulatory systems need a deeper analysis of the issues.

One utility agreed with the objectives set out in the public consultation document. It is in the interest of licensees, regulators, appliance manufacturers and consumers to improve voltage quality and establish its regulatory environment.

One utility recognised the vital importance of voltage quality to electricity customers. Ultimately the correct function of the customer's equipment depends on the characteristic of the voltage and the design of equipment. Standards such as EN 50160 are the key of the coordination of electricity system design and equipment design such that correct function is achieved and damage to equipment is avoided. The participation of the European Regulators in the standards development process is welcomed. The Consultation Paper points to a number of aspects of EN 50160 which need to be addressed and represents an agenda for the review which is currently being undertaken by CENELEC. The opportunity to contribute to the process is welcomed.

One utility association specified that the two fundamental issues are the extension of scope of EN 50160 to transmission voltages and the need for improved quality of supply taking account of the balance of costs against the benefits of improved quality of supply.

One utility association mentioned that EN 50160 must provide clear guidelines for both the network operators and the grid's users, in order to determine or control the quality of the expected or provided services. The quality level set by the standard should not mean a downgrade in a given country compared to actual quality level and it should not imply an instant improvement pressure on distributors either.

One solution provider argued that for most of the industrial customers, voltage quality conformity according to EN 50160, while important as concept, has been useless. Its revision should be made keeping in mind:

- changing EN 50160 into a tool for consumers to really check voltage quality;
- avoid the definition of too complex and memory demanding equipments and systems for power quality monitoring that would at the end limit their use as a common tool;
- avoid turning immediately obsolete the present measurement equipments.

b) On the other hand, **most of the respondents moderated their support** by raising some difficulties in the revision of EN 50160. Some respondents expressed doubts about the interests of such a modification, while others pointed out the need of revising EN 50160 with the utmost caution.

For instance, one utility association argued that EN 50160 seems to be one of the most favoured documents of the total CENELEC Standardisation (in December 2006 all 22 voters were for the EN 50160). Furthermore, the very high power quality in Germany results in few complaints nowadays. Due to these facts and regarding the cost, the utility association does not see the need to monitor the voltage quality today. Necessary alterations of the regulatory scene on power quality should be implemented step by step, but not by a revolutionary regime. Making changes without reconsidering all impact factors could cause severe damage to the existing framework.

One utility association specified to support CENELEC actual standards as they are the result of a wide consensus between distributors, manufacturers and customers.

One utility association mentioned that from time to time problems emerge as a result of developing technologies. An example would be the impact of voltage dips on electronic equipment that developed so rapidly in the 1980s. This development took place at the same time as the development of EMC as a general issue. Experience shows that manufacturers of equipment do respond to their customers' needs when such issues arise. Actual standards were developed to identify the issue and equipment evolved at relatively low marginal cost to provide appropriate levels of immunity. Voltage dips now have little impact on users of modern PCs and other electrical equipment.

One utility association pointed out that EN 50160 has created a good framework and harmonisation for the follow up and monitoring of voltage quality problems and the development and use of adequate electrical equipment and installation. There is no evidence justifying the need to change limits in standards like EN 50160.

One utility specified that tighter ranges of variation of voltage characteristics would imply stricter connection rules for customers and lower emission limits for electrical appliances. In some countries, there is no evidence that customers claim for a better voltage quality. Power quality seems to be a problem only in particular networks for very few customers.

One utility association mentioned that in general, the ERGEG Consultation Paper suggests that limits in EN 50160 could be tightened and indeed have already been tightened in some countries. It is also important to bear in mind that there are ideas on new ways of utilising the electric network and in particular distributed generation which need to be taken into account. Tighter limits are only desirable if they yield a real benefit to customers. The fundamental keystone to any justification for changing existing power quality standards is that the customer must be shown to benefit from the changes introduced. Adapting networks to adhere to a new voltage quality standard would involve a combination of extra measures (e.g. replacement of overhead lines by covered conductors) or the use of more expensive network configurations (e.g. split networks). It would be expected that changes to meet new requirements would take a considerable time (several decades).

One utility pointed out that in the future, when establishing limits and indicative values it is important to take into consideration that power supply will never be free of faults and outages due to its nature (complicated technology). One should not promote false illusions to customers with regards to the continuity of the service. At the same time the achieved quality must be maintained and improved, a near ideal situation must be achieved. The results of satisfaction surveys conducted in the utility supply area among mass consumers show that less than 10% of the consumers are willing to make financial contribution for a better quality power supply. The utility misses solid facts which would support the need for improved voltage quality (measurement results, statistics). Voltage quality should only be improved gradually, taking the achieved quality level of the given country as a basis (a level which consumers accepted).

One utility mentioned that it faces particular challenges in relation to voltage quality. For a significant proportion of customers voltage quality is not conform to EN 50160 at the moment. Significant investment is being made to reinforce the networks so that voltage quality will conform to this norm. Tightening standards will bring further difficulties which are not desirable.

c) To conclude with the general comments collected, it has to be noted that **two specific issues have been raised through those general views on EN 50160** by a large number of respondents. These issues relate to:

- External links that should be considered by ERGEG when revising EN 50160, as collaboration with other working groups and compatibility of EN 50160 with other existing standards widely used;
- Necessary costly investments on networks in case of improvement of EN 50160.

Collaboration and compatibility with existing international standards

One respondent from academia, two experts and two utility associations recommended collaboration with other existing working groups of other organisations, or expressed the need for EN 50160 to be in line with other existing international standards or documents.

Firstly, EN 50160 has to be in line with the EMC Basic Publications which are the reference for EMC standards that govern the relationship between equipment and supply system. The EMC community standards, guides and technical reports should be considered, specially:

- IEC TR 61000-2-8: voltage dips and short interruptions on public electric power supply systems with statistical measurement results;
- IEC TR 61000-2-14: overvoltages on public electricity network;
- IEC/EN 61000-2-2: compatibility levels for low frequency conducted disturbances and signalling in public LV power supply systems;
- IEC/EN 61000-2-12: compatibility levels for low frequency conducted disturbances and signalling in public MV power supply systems;
- IEC 61000-4-11: basis for the responsibility-sharing curve (method for immunity tests against voltage dips for equipment);
- IEC 61000-4-30: definitions of measurement methods and event characteristics.

These EMC standards have been worked out since around three decades. It appears as being self-evident, that any modification to EN 50160 values would need modifications to the EMC standards at the same time. This coordination should be done considering the time delay between the implementation of a new EMC standard, its coming into force, new electrical equipment and systems meeting the new limits and old electrical equipment and systems disappearing from the market and users' applications. Indeed, before discussing new values for EN 50160, a comprehensive review of the existing EMC standardization building is required.

Installation standards (for LV: IEC/EN 60364) and IEC 60038 (standard voltages) are also basic standard that should be considered.

Studies to ascertain costs and benefits comparable in different sectors and/or different countries made by international working groups as CIGRE JWGC4.107 could be also very helpful. Some other CIGRE working groups are also dealing with the issue of power quality regulation, but they are still perhaps two to three years away from any final conclusions and recommendations.

It should be kept in mind that EN 50160 is a result of a recognized standardization process, expressing a consensus between stakeholders.

Cost/benefit considerations

Some respondents (from academia, research institute, expert, utility associations, customers association and utility), through their general comments on the revision of the EN 50160 standard, raised financial issues. The revision of the EN 50160 should be done in a cost efficient way for the whole society. According to these respondents a deep costs and benefits analysis should be conducted before any change of the norm.

Additional operating costs could arise if stricter maintenance and monitoring regimes are necessary. At the same time, capital costs will arise due to additional reinforcement requirements if limits are changed.

Most of the respondents mentioned that the number of customers' complaints is negligible. Thus, energy users in general would not be willing to meet the costs of a higher quality of supply that affects very few users with special needs. These special needs are currently addressed, and can realistically only be addressed, on an individual basis. It must be recognised that in some countries, there is significant expenditure already required to improve voltage quality to conform to the existing EN 50160 standard. Tightening of the standard risks increasing the level of expenditure required.

While there is some information on costs of perturbations in power quality in the consultation document, the costs of providing a more stable supply are in general not presented. One way in which to provide confirmation would be to measure the number of complaints in areas where disturbance recorders are present, so as to assess the impact of disturbances on the customer.

The use of Guidelines as a means to address customer problems is another approach that can be very effective at much lower cost given that the number of cases where there are problems is relatively small.

4. Respondents' views on the ERGEG recommendations to CENELEC for revising EN 50160

4.1. Contents

This paper presents the respondents' views related to each recommendation proposed by ERGEG for the revision of EN 50160. Indeed, the consultation was aimed to collect opinions on the proposals outlined below

(1) Improve definitions and measurement rules

(2) Limits for voltage variations – avoid "95%-of-time" clause and avoid long time intervals for averaging measured values

(3) Enlarge the scope of EN 50160 to high and extra-high voltage systems

(4) Avoid ambiguous values for voltage events

(5) Duties and rights of all parties involved should be defined

(6) Introduce limits for voltage events according to network characteristics

(7) Develop the concept of power quality contracts

Future of voltage quality regulation

Sections 1 to 7 correspond to the 7 ERGEG recommendations given to CENELEC in order to revise and improve EN 50160. The section "future of voltage quality regulation" offers a view of respondents' expectations related to power quality in the future. For each of those sections, a synthesis of responses collected through the consultation process is presented.

4.2. Definitions and measurement rules

ERGEG recommendation:

Improve definitions and measurements rules[3]

In detail:

Not all voltage quality parameters are defined in a totally satisfactory manner in EN 50160. Sometimes other standards can help defining some parameters in greater detail, but for the sake of simplicity and clearness EN 50160 should be reviewed in order to incorporate advancements in definitions. A large international consensus on VQ definitions should be actively searched for. To ensure good and uniform measurement of results of voltage quality parameters, it is of paramount importance that the same parameters are uniformly defined. EN 50160 includes both good and poor definitions for voltage quality parameters. The present state of EN 50160 cannot, therefore, ensure uniform calculations, registrations and measurements of voltage quality parameters. Based on this, some proposals for improving definitions are described in technical detail in Appendix 3.1 of the Consultation paper.

[3] Also see chapter 2.2 in the ERGEG Conclusions Paper on Voltage Quality Standards E07-EQS-15-03 published in parallel with the present Evaluation of Comments Report in the ERGEG website www.ergeg.org.

In the following part, problems are raised and solutions are proposed, as a contribution to the debate among experts and different standardisation bodies.

Firstly, some types of voltage events appear to require improvements in definitions:

- Rapid voltage changes, which are currently defined in EN 50160 as: "a single rapid variation of the RMS value of a voltage between two consecutive levels which are sustained for definite but unspecified durations." It is evident that this definition needs reconsideration. The NVE proposal for defining rapid voltage changes, described in details in Appendix 3.1 of the Consultation paper, may be considered. Rapid voltage changes are important for two reasons: (1) they are source of visual annoyance for human eyes, and (2) they are a symptom of insufficient short-circuit power in the point of connection.
- Supply voltage dips are currently defined in EN 50160 as "a sudden reduction of the supply voltage to a value between 90% and 1% of the declared voltage. Conventionally the duration of a voltage dip is between 10 ms and 1 minute". This definition, whilst being useful and correct, could be re-evaluated for some aspects:
  - The threshold for distinguishing dips and interruptions. This is currently set at 1% of retained voltage. This should be considered to move to 10%, given the inherent accuracy of VQ recorders, and the possibility of voltage being induced because of power lines nearby.
  - The threshold for distinguishing dips and rapid voltage changes. This is currently set at 90% of retained voltage. This should be evaluated taking into consideration electrical equipments critical levels for different durations (as an example, the ITIC curve can be considered) including the voltage drop inside customers' installation. Further, experience on both the number and different causes of dips and rapid voltage changes close to the today's threshold may play a role.
  - The minimum duration of a voltage dip. This is currently set to 10 ms. A voltage dip begins when the $U_{rms(1/2)}$ falls below the dip threshold where $U_{rms(1/2)}$ is the value of the RMS voltage measured over 1 cycle (20 ms), commencing at a fundamental zero crossing, and refreshed every half cycle (10 ms), c.f. IEC 61000-4-30. Due to this, it is possible to measure a supply voltage dip with duration of 10 ms. According to the ITIC curve, a dip duration at 10 ms will however not harm electrical equipment. This should be looked into.
  - The maximum duration of a voltage dip. This is currently set at 60 s (1 minute). This should be looked into taking into consideration dip duration caused by typical dip causes. If the maximum duration shall be lowered, a new definition for longer durations may be needed.
- Temporary (power frequency) overvoltages (voltage swells), which are currently defined in EN 50160 as "an overvoltage, at a given location, of relatively long duration". A voltage swell is the opposite phenomena to a voltage dip and should be equally well defined. According to the ITIC curve and experience from research environment a voltage swell with duration of only 10 ms may damage equipment. This should be taken into account when defining the parameter. See appendix 2 of the Consultation paper for more details.

Secondly, some problems are still open regarding VQ measurement. Among these is the issue of total uncertainty in case of VQ measurements on MV networks, due to the contribution of voltage transducers. To address these measurement problems with sound definitions and measurement methods, a preliminary step towards setting VQ standards is necessary. Measurements of power quality should be carried out in accordance with relevant international standards. As regards measurement methods, it is in general satisfactory to refer to IEC 61000-4-7, IEC 61000-4-15 and IEC 61000-4-30[4], given that EN 50160 is changed with proper definitions (also see Appendix 3.2 of the Consultation paper). Further, calibration traceability for the different parameters is of paramount importance[5]. It is doubtful that there is traceability for each of the voltage quality parameters described above. This should be looked into.

Thirdly, short interruptions should be defined as interruptions having duration comprised from 1 second up to and including 3 minutes, separately from transient interruptions[6] with duration below 1 second. A further harmonization in operational rules for calculating main continuity indices for both short and long interruptions (SAIDI, SAIFI and MAIFI)[7] is openly recommended, especially for rules on sequences of interruptions affecting the same customers. Operational procedures currently used in European countries, generally inherited by the former integrated utility, are still too different and hinder full comparability, especially for re-interruptions and short/transient interruptions.

Lastly, some aggregated indicators could be developed not only for continuity of supply but also for voltage variations and events. Among these, SARFI[8] could be introduced as reference indicator for voltage dips, in relationship with the classification of dip severity.

Respondents' views:

The consultation process collected 23 responses on the proposal of improving definitions and measurement rules of EN 50160. Different subjects are included in this first ERGEG recommendation. The table below describes the scope covered by the different respondents' classes. Comments are then synthesised subject by subject.

	General comments	**Rapid voltage changes**	**Voltage dips/swells and interrupt-ions**	**Measure-ment issues**	**Indicators**	**Other comments**
2 Experts	X			X		
3 Research institutes		X	X	X	X	
3 Universities	X	X	X	X	X	

[4] The only suggested change to IEC 61000-4-30 is about the specification of accuracy class for measurement instruments. A new class (class S) is currently under public inquiry and its approval would contribute to an easier diffusion of VQ measurement cases. CEER considers that class S can be adopted for contractual applications, even for disputes. Class A could be used only for calibration.

[5] In the International Vocabulary of Basic and General Terms in Metrology (1993) traceability is defined as: "Property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties."

[6] In EN 50160 it is stated that "the duration of approximately 70% of short interruptions may be less than 1 second". In some countries, like France and Italy, interruption with a duration of maximum one second are counted separately from other short interruptions.

[7] Some continuity indices are defined in the American standard IEEE1366 Guide for Electric Power Distribution Reliability Indices. Continuity indices are widely used among European countries, but not always in the exact same way. It is therefore considered to be a need to define continuity indices at European level. Some of the uncertainties are especially as regards counting sequences of interruptions and defining Major Event Day.

[8] Source: CIGRÉ JWG C4.07 "Power Quality Indexes and Objectives", 2004

7 Utilities associations	X	X	X	X	X	
5 Utilities	X	X	X	X	X	X
1 Customers association	X					
1 Solution provider				X		
1 Equipment manufacturer	X	X				
Total of responses	**13**	**7**	**8**	**11**	**9**	**1**

4.2.1. General comments

Thirteen respondents provided general comments on the ERGEG recommendation of improving definitions of voltage quality parameters and their measurement rules. All of them supported improvement of definitions and measurement rules, except one utility association, which stated that no evidence could justify the need to change measurement principles.

Some respondents (from academia, expert, utility and utility association) mentioned that proposals should be in line with international standards settled by the EMC community (IEC SC77A). The utility added that this improvement should be carried out within Cenelec TC8X/WG1. The utility association suggested that reconsideration of measurement procedures and parameters could only be made appropriately by adjusting IEC 61000-4-30.

Three utility associations and two utilities noted that this improvement should be done in order to achieve the widest international consensus between all parties involved (distributors, manufacturers, consumers, regulators, standardization organisations).

One utility association pointed out that some of the perceived weaknesses in existing definitions seem to arise from inadequate understanding of the interaction between one definition and another (for instance, rapid voltage changes and voltage fluctuations definitions). This idea is developed later in this section.

One respondent from academia mentioned that definitions of voltage quality parameters should refer on a three phase base, and not on a single phase base as it is today. As long as systems are generally three-phase, with three line-to-ground voltages and three line-to-line voltages, many ambiguity and complexities arise. It is not clear whether each phase should be considered separately, or if a suitable average between phases should be assumed. Three-phase systems are more than a simple superposition of three single phases and must not be viewed in this rough manner. It is convenient to separate the single phase applications and norms from specific three-phase applications and norms. Important feature of three-phase systems is that sinusoidal positive sequence is the reference condition instead of simple sinusoidal.

4.2.2. Rapid voltage changes

Seven respondents expressed their comments on the definition of rapid voltage changes and on the related proposal made by ERGEG in its consultation paper.

One utility association agreed with the definition of rapid voltage changes given by the Norwegian regulator (NVE) and recommended by ERGEG. It makes easier to measure rapid voltage changes the same way by different measuring instruments (different suppliers).

One equipment manufacturer suggested characterizing a rapid voltage change with the following criteria:

- steady-state rapid voltage change (difference from final and starting steady voltage levels);
- positive peak voltage during the rapid voltage change (value and relative time from the start of rapid change);
- negative peak voltage during the rapid voltage change (value and relative time from the start of rapid change).

This would allow determining a more complete definition and possible limit values. Furthermore, actual measuring equipments are already able to collect such parameters.

One utility association mentioned that the issue on rapid voltage changes is addressed by the definition of voltage fluctuations. It is these fluctuations which actually cause flicker problems, rather than single voltage changes. Also, flicker can arise from voltage fluctuations from large industrial processes remote from the local network and not necessarily due to the local fault level.

Apart from its definition, one respondent from a research institute suggested to set a limit for the P_{st} indicator, and not only for the P_{lt}. Indeed, there could be a lot of disturbing events in the 2 hours averaging interval considered with the P_{lt}. This limit should be set a bit higher than for the P_{lt} indicator.

One respondent from academia suggested that, concerning rapid voltage changes, single-phase measurements have to calculate rms over at least half a period, whereas on three-phase systems faster and simpler measurement results are possible. Corresponding definitions should be elaborated.

One utility association mentioned that definition of rapid voltage changes is a complex task, especially with respect to the stochastic behaviour of consumer's equipment in distribution grids.

4.2.3. Voltage dips/swells and interruptions

Eight respondents expressed their comments on the definition of voltage dips/swells and interruptions.

Two respondents from academia and one utility expressed their comments on the change of the threshold for distinguishing dips and interruptions from its actual value, 1%. Due to practical reasons related to measurements, one respondent from academia and a utility agreed with this proposal. While the respondent from academia suggested setting the threshold at 10% as in other related international standards, the utility suggested that increasing the lower limit to 5% would be enough. The respondent from academia also mentioned that this distinction should not be correlated with the residual voltage value. The distinction should be linked with the fact that the upstream active power system is becoming passive, or in other words the power system impedance seen by the customer is increasing dramatically. Thus the installation is not capable to sustain, even at values inferior to the reference voltage, any kind of voltage. The distinction between voltage dips with depth between 90% and 99% of the reference voltage, and interruptions with depths between 99% and 100% of the reference voltage should be completed by the duration of those events.

Threshold for distinguishing dips and rapid voltage changes: One respondent from academia disagreed with the change of the threshold from its current value of 90%, as this limit is widely (i.e. internationally) accepted, and also used by a majority of equipment manufacturers as one of the built-in equipment immunity requirements. One respondent from a research institute suggested that before changing this threshold, a more comprehensive definition of a voltage dip is necessary, with a classification including severity and type of the voltage dip. This should be done in cooperation with industry standards activities (IEEE 1564 and CIGRE C4.1).

One respondent from academia mentioned that sub-cycle (i.e. very short) dips and interruptions with duration between 10 ms and 20 ms, or even shorter, could cause malfunction or tripping of some types of equipment (e.g. ac coil contactors, adjustable speed drives, etc.); this means that the ITIC requirements for equipment immunity are not always or universally applicable, and that the minimum duration of a voltage dip should not be increased.

One respondent from a research institute suggested that the maximum duration of a voltage dip should be coordinated with the slow voltage variation characterization. For instance if slow variations are measured with one minute intervals, it becomes a good dividing point for the maximum duration of voltage dips. This aspect should be coordinated with industry standards activities (IEEE 1564 and CIGRE C4.1).

One utility association disagreed with the change of voltage dips definition, as many power quality instruments use the present EN 50160 threshold. Another utility association mentioned that this definition is a complex task, especially with respect to the stochastic behaviour of consumer's equipment in distribution grids. One respondent from academia noted that if rms voltages are used for characterisation of very short dips and interruptions (shorter than a few periods), this will result in errors for both dip magnitude and dip duration; stronger correlation of dip definitions with instantaneous voltages is, therefore, necessary if more precise information about dip events is required. One respondent from academia one from a research institute and one utility association pointed out that definitions of voltage dips and interruptions should cover all events in three phase networks (this is not the case of the EN 50160, CLC/TR 50422 and IEC 61000-4-30). If voltage in one phase or two phases sags below 5%, it is evaluated neither as a dip nor as an interruption. It can also happen, that during one event voltage sinks in one phase and swells in another phase.

One utility association disagreed with the change of the short interruptions definition. Another respondent from a research institute mentioned that international definitions for the maximum duration of short interruptions range from 1 minute to 5 minutes.

One respondent from a research institute suggested that the definition of voltage swells should be coordinated with the definition of voltage dips.

4.2.4. Measurement issues

Eleven respondents expressed their opinions on measurement issues.

One respondent from academia pointed out that national and international monitoring campaigns should be strongly supported. However, clear interpretation of recommended measurement techniques and procedures should be provided, in order to maximise the use and exchange of all obtained information.

One utility and three utility associations mentioned that the introduction of a monitoring and planned measuring system on a customer by customer basis would represent important costs for network companies that must be included in the distribution tariffs. A cost benefit analysis should be conducted. One utility association added that investment into sophisticated measurement systems and their continuous maintenance should better be used for structural grid improvements.

One respondent from a research institute pointed out that it will not be practically feasible to perform measurements of voltage dips at each point of connection. Guidelines are needed on the preferred locations for measurements. A reasonable compromise to be further studied is a combination of measurement locations at a limited number of locations in the network and locations at or near the point of connection of large customers sensitive to voltage dips. Almost all domestic customers and a substantial part of commercial customers are not affected by voltage dips. It is not useful to enforce compulsory system-wide measurement and reporting. A measurement compromise worth further study is installing measurement equipment in all main distribution substations (at MV side of the HV/MV transformers).

Studies have shown that these substations are the point-of-common-coupling for the majority of voltage dips so that measurements at these locations will form, after some minor corrections, a reasonable estimate for the performance experienced by customers supplied from these locations. Measurement and analysis issues, like the three-phase character of voltage dips, the location and connection of monitors, the geographical spread of the monitors, and time-aggregation, should be included in the discussion at an early stage. Appropriate choices have to be made to prevent the resulting indices from giving the wrong messages. In this respect a liaison with IEC TC 77A WG 09 is highly recommended.

One expert pointed out the different issues that arise when measuring the different voltage quality parameters. As demonstrated by a number of regulators in Europe, monitoring short interruptions is very much feasible. For short interruptions with duration of 1 to 3 minutes, one could rely on manual reporting and/or SCADA systems. However, for shorter interruptions and voltage dips, it may be necessary to install specific voltage quality measurement devices. In order to measure all short interruptions and all voltage dips, measurement devices would need to be installed throughout the network, which is not practically feasible. For those events (up to some seconds) one should therefore rely on statistics. For flicker, supply voltage variations and harmonic distortion, a sound monitoring program on sensibly selected nodes is required to provide a general statement about harmonic distortions in the network. However, it is suggested to focus only on excursions of the disturbances outside the normal range. For flicker, the number of customers for which the minimum flicker severity limits are not met is a better indicator. For supply voltage variations, this could be done by monitoring the share of the 10-minutes/1-minute average values which are not within the specified range. Another possibility is to focus on the share of connection points on which the minimum standard is not met. Similarly, for harmonic distortion, it is suggested to monitor the share of time and/or locations where the standard has not been met.

One utility pointed out that it must be clarified whether regulation should apply on measured performances or on the perceived quality by the customer. Presently, breakdowns on LV networks start at the customers' reporting.

One solution provider pointed out that the absence of a clear definition for recording information on dips and swells avoids the identification of causes and origin for these events. There are two objectives in voltage quality continuous characteristics measurements. The first is to verify compliance with standard limits; the second is to characterize their statistical distribution and time eventual dependency. Counting time intervals outside limits can be easily done in real time with minimum memory spent. Long time recording is, on the other hand, essential for statistical and dependence characterization. While shorter than 10-minute integration periods are interesting, their use would result in very demanding memory sizes that in turn could lead to very expensive monitoring systems which conflicts to their "democratization".

As a compromise solution, the use of the already defined basic 10/12 cycle integration periods for the different variables (acc. to IEC 61000-4-30), from which all the other integration periods are derived, can be used to record, in each 10-minute interval, the extreme values for those 10/12 cycle basic measurements. The long term recording of the extreme 10/12 cycle values in each 10-minute interval provides a good image for the characteristic and can even be used for comparison with standard limits for compliance. The complexity and memory cost for such a function would have a very limited impact in most of the existing instruments and systems. RMS recording for voltage and current with ½ cycle resolution (1 cycle window, sliding each ½ cycle) should be made, including phasor symmetrical components for both voltage and current in order to have a posterior treatment trying to identify location and source for the event (upstream (external to the customer), downstream (internal to the customer), type of possible source).

Two utilities suggested that the duration for a measure of a voltage dip could be set at 40 ms (instead of 10 ms). According to the ITIC curve, 10 ms long dips are not harmful for consumers' equipments and 20 ms long dips are harmful only if the voltage drops under 70%. Thus, it could be expedient to enlarge measuring cycle of dips to 40 ms, and even in this way, still many dips that do not cause consumer disturbances will be measured. This is confirmed by long measuring experiences and examinations of many voltage complaints.

They also suggested that the duration for a measure of a rapid voltage change could be set at 40 ms as well. According to measurement and practical experiences, a typical rapid voltage change caused by electric appliances usually lasts no more than 40 ms. This duration could also be used as measurement interval for the pre-/post- change status.

One utility and one respondent from academia mentioned that voltage hysteresis is a fundamental problem of almost all present-day measuring tools. A voltage fluctuating around the lower limit (90%) causes a lot of (even several hundred-thousand) voltage-dip registrations or overflow in the meters, while using an adequate hysteresis these states (around limit) can be voted as a single or some *long term* dips. So dip event will only come to an end when voltage increases above 90% in some degree. Standard IEC 61000-4-30 suggests 2% hysteresis for typical cases which is an acceptable value. Thus, the dip begins when the voltage falls below the dip threshold and ends when the voltage is equal to or above the dip threshold plus the hysteresis voltage (92%). This functionality may be implemented by meter-manufacturers in a few years.

Two utilities suggested that it is necessary, with a large number of measurement devices, to control the general level of the harmonic pollution (simpler, cheaper devices), while specific harmonics related issues require purpose-built specialized devices.

4.2.5. Indicators

Nine respondents expressed their comments on the use of aggregated indexes.

Several respondents (from academia, research institute, utility association and utilities) considered that aggregated indexes (including SARFI) can be very useful for global regulation or for an evaluation of the network performance. However, such a simpler evaluation of performances should be compensated by local regulations based on aggregated indexes or not. The respondent from a research institute added that a single index should not aggregate different power quality characteristics. The utility association added that an EU-wide harmonised application of main continuity indexes would be useful.

Two utility associations estimated that aggregated indexes may be useful for a customer who wished to optimise the point of manner of obtaining a new connection. However, specific customers already connected see no benefit and they are able to install their own monitoring equipment if they wish.

One utility association considered that operational rules for calculating main continuity indices for both long and short interruptions should not be harmonised. These are two different concepts: one is of continuity (interruptions higher than 3 minutes) requiring manual recovery in order to repair (permanent) faults; the other is of voltage quality, i.e. short interruptions that are automatically recovered due to transient or semi-permanent faults. However, one utility expressed their support to such a harmonisation.

4.2.6. Other comments

One utility expressed its opinion on the **definition and measurement of voltage unbalance**. In LV networks phase voltages should be measured, and in MV networks line voltages should be measured while measuring voltage unbalance, because standards concern nominal voltages, which are phase voltages in LV networks, and line voltages in MV networks (ERGEG recommended line voltages instead of phase voltages for the definition of unbalance in page 44 of the Consultation paper).

4.3. Voltage variations

ERGEG recommendation:

Limits for voltage variations:

- remove "95% of time" clause and replace it with 100% of "normal operating conditions"

- remove long time intervals for averaging measured values[9]

[9] Also see chapter 2.3 in the ERGEG Conclusions Paper on Voltage Quality Standards E07-EQS-15-03 published in parallel with the present Evaluation of Comments Report in the ERGEG website www.ergeg.org.

In detail:

Most of the limits for voltage variations in EN 50160 are typically given for 95% of the time. This means that, according to EN 50160, for 8 hours every week there can be severe voltage deviations in the supply voltage without exceeding the limits in the standard. This is the case even when the variations are of such a character that the network company should be able to cope with them. This is a huge problem for customers. The manufactures will not design equipment for handling the remaining 5% of the time, which leaves customers to deal with the risk. 95% of the time may be satisfactory for statistical purposes but not in order to protect against equipment damage or equipment failure.

The clause of 95-%-of-time (applicable to most of the parameters in EN 50160) is too loose and is, therefore, not protecting customers. Ideally voltage quality requirements should apply for 100% of the time (at least 100% of normal operating conditions). Different provisions should apply only for the consequences of exceptional events – that should be better defined[10] – and for taking into account certain special conditions of network management (as for instance back-feeding to restore supply after faults). Allowing different provisions for certain conditions is most (if not only) relevant for deviations that do not lead to severe damages for electrical equipment. If a certain condition causes voltage deviation that may lead to damage for electrical equipment, than for the customer it is better to experience an interruption.

An extremely critical point is also the time interval used for averaging measured values in order to verify limits of voltage variations (especially as regards supply voltage variations and flicker severity). As seen in chapter 2.4 of the Consultation paper, the currently used 10-minute average is related only to thermal effects and may hide some voltage variations that could damage equipment. Hence, a change of the time interval used to average measured values should be considered consistently with the 95%-of-time issue. Hungary and Norway deal with this problem in two different ways. Hungary uses the 10-minutes average methodology for verifying the minimum and maximum compatibility levels of voltage threshold at 95% of the time, but all 10 minutes averages of the supply voltage shall be within the range of Un+10/-15% (no exemption for remote areas). The country also uses the 1-minute average methodology for verifying the maximum limit of voltage threshold at 100%. Norway uses only the 1-minute average methodology for verifying the minimum and maximum limits for supply voltage variations at 100% of the time.

In general, limits for supply voltage variations should be very clear and uncontroversial. All limits for voltage variations should be given by the term shall, in order to ensure compliance. The new revision project of EN 50160 (prEN 50160:2006) does not seem to be very consistent with this need for clarity, as in requirements for supply voltage variations in LV networks it is written that voltage variation should not exceed $U_n \pm 10\%$ (under normal operating conditions). But the old test method has been kept with no changes in respect of the current edition of the norm. Further, the envisaged review of voltage tolerance band for reducing it[11] has not been started yet. Of course, for the limits to supply voltage variations different solutions can be adopted for LV, MV and HV customers. For the latter, declared voltage U_c is a better reference than nominal voltage U_n. Figure 1 shows how different stakeholders interpret the today's limits in EN 50160 differently. There is indeed a need for clarity.

[10] EN 50160 gives a rather long list of exceptional events, which should also be discussed in dialog with different stakeholders including the CEER.

[11] A clear address in a reduction in the tolerance band for supply voltage variations is given in the CENELEC harmonisation document HD 472S1.

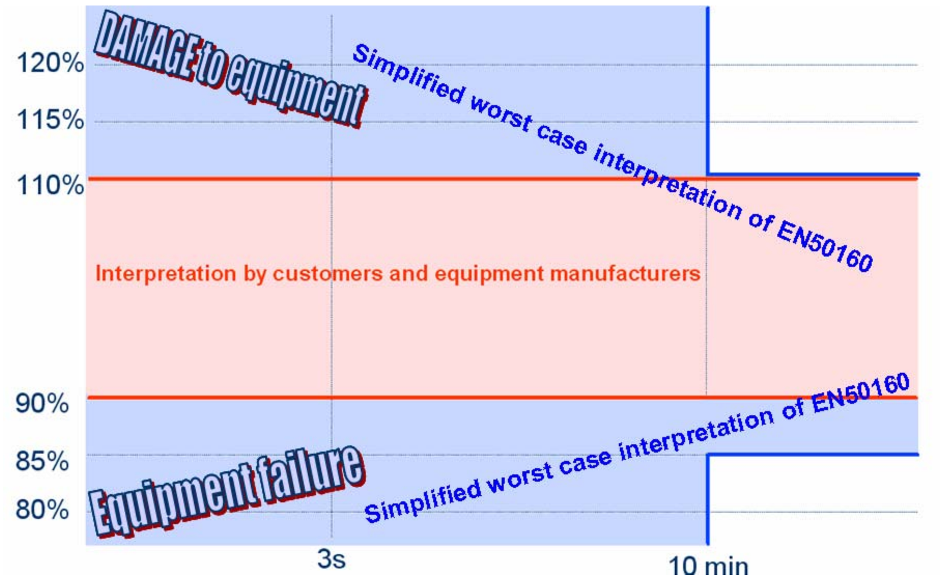


Figure 1 – A picture of interpretation of the today's limits for voltage variations by different stakeholders. (Courtesy of: Mr Helge Seljeseth (SINTEF), workshop CEER on Voltage quality standards, Milan September 29th 2006)

Respondents' views:

The consultation process collected 20 responses on the proposal of revising limits for voltage variations. Each respondent treated different themes included in this second ERGEG recommendation, as shown below in the table. Comments are then synthesised theme by theme.

	95% of the time	10 minutes average	±10% Un	Exceptional events
2 Experts		X	X	
2 Research institutes	X	X	X	
4 Universities	X	X	X	X
6 Utilities associations	X	X	X	X
4 Utilities	X	X	X	X
1 Customers association		X		
1 Solution provider	X	X		
1 Equipment manufacturer		X	X	
Total of responses	**14**	**15**	**10**	**4**

4.3.1. 95% of the time

Fourteen respondents expressed their comments related to the 95%-of-time clause that applies for most of the limits for voltage variations.

Several respondents (from academia, utility, utility associations, research institute and solution provider) agreed that the **“95%-of-time” clause should be avoided and limits should apply for 100% of the time**.

One respondent from academia argued that changing the “95%-of-time” clause would provide efficient, transparent definition and use of “minimum guaranteed voltage quality standards”.

Since the 10 minutes already provide a lot of averaging, one utility association and one respondent from a research institute suggested that using a limit that applies 100% of the time should be possible, as far as exceptional circumstances are clearly described and allowed for.

One respondent from a research institute noticed that actual limits based on the 95% of time do not even apply during some extraordinary events. It means that the 5% of the time during which limits do not apply, is also available at normal operating conditions, which is not acceptable. This respondent also pointed out that 5% of the time represents 8.4 hours per week, which is too much.

Four utility associations, two utilities and one respondent from academia expressed their **support to the statistical approach of the EN 50160** concerning limits for voltage variations.

Among them, the respondent from academia and two utility associations argued that probabilistic terms seem conceptually correct, because of the randomness of disturbances. However, the respondent from academia agreed that given the current voltage quality in many European countries, a higher percentile could be chosen, e.g. 99% in order to account for better levels of voltage quality. Furthermore, he added that the extremely-generic phrase “during one week, during one day” seems problematic and inaccurate, as any reference is made to the occurrence –also in “normal operating conditions” –of particular loading conditions that can take place in particular days or period, due to climatic and seasonal factors, working days/weekends, etc.

The other two utility associations and one utility argued that the network structure, especially for low voltage, is based on statistical concepts. The utility associations explained that a low-voltage customer is allowed to switch-on any equipment at any time he wants. For a typical public customer, consumption amounts to 30 kW. In practice, the low-voltage grid is designed for a statistical consumption of about 2-4 kW for each customer. In consequence, there is a low but certain probability that the total actual power consumption of a low-voltage grid may exceed the designed value. In this case, any power quality phenomenon may exceed given limits. For that reason, today standardisation on power quality is dealing with probabilities – mostly 95%. This approach is the best economical solution for all parties concerned, and is based on a long and good experience throughout Europe. According to this point of view, the utility commented that some allowance must be made for the occasional coincidence of loads when measuring voltage variations against the lower limit.

One utility association and three utilities pointed out that ensuring 100% would have significant **cost (tariff) consequences.**

Two utilities proposed an interim solution that could be to increase the 95% to 97%, implemented in a couple of years. Another solution could be to apply a time interval (for 5% of the time according to the 95% criteria), stating that the 10 minutes mean voltage can only be in the 85-90% band for two, or maybe one, hour(s) at maximum 2 times a day. Using this condition probably does not put serious plus-load onto Grid Companies, and in turn assures consumers' satisfaction in a real manner.

The other utility mentioned that implementing 100% of the time would require more onerous design criteria which would lead to greater expenditure on new connections and on reinforcing the network. Customers would prefer to endure very occasional reduction of performance of equipment rather than fund the extra investment that would be required to deliver voltage above -10% during 100% of the time.

The utility association argued that this application of probability parameters to the EN 50160 values is based on an economic optimum consideration, as any change to more stringent specifications would result in costs for supply networks. The costs, which some single specific customers with higher sensitive equipment may afford for a better power quality would be socialized to be borne by all customers, what appears as not justified.

Two utility associations argued that changing the 95%-rule would **not be compatible with the EMC limits**. One of them mentioned that the 95%-rule is the present basis for measurement and setting limits for supply voltage, flicker and harmonics. Any adjustment in these values would require amendments to planning, statutory and EMC standard limits.

4.3.2. 10 minutes average

Fifteen respondents expressed their comments related to the 10 minutes average that applies for the limits related to voltage variations (especially as regards supply voltage variations and flicker severity).

Several respondents (from academia, research institute, experts, solution provider and customers association) agreed that the **10 minutes average is not appropriate**.

The respondent from academia argued that changing the averaging time would provide efficient, transparent definition and use of "minimum guaranteed voltage quality standards".

The customers association argued that there is a lack of short time deviations definitions from the generally defined delivery quality.

The respondent from a research institute and the customers association argued that a lot of power quality problems for users are hidden by this averaging value. Similarly, the expert mentioned that the 10 minutes interval adopted by EN 50160 neglects voltage excursions of several minutes which are averaged out in the 10 minutes average. These voltage variations may well influence or damage whilst remaining undetected under the EN 50160 definition.

One utility accepted that in principle it may be appropriate to have an additional limit based on a shorter averaging interval than 10 minutes in order to protect equipment failure against short duration overvoltages. In this case the limit should be higher than +10% as in practice equipment can withstand higher voltages than Un +10% for short periods. This needs to be discussed with equipment manufacturers. The 10 minutes value has been set to avoid excessive number of tap change operations and consequential higher maintenance costs and reduced lifetimes. The settings on voltage regulating relays are such that it would take 1 minute for the first tap change to occur and 1.5 minutes approximately to recover from such an event. So if customers' voltage was at +6% before the event, it would be at +16% for 1 minute before the tap change operations would restore the voltage to target range. This has to be considered when setting a limit based on a shorter averaging interval.

Six utility associations, two utilities, one equipment manufacturer and one respondent from a research institute **disagreed with the proposal of changing the 10 minutes average value** to a shorter one.

Among them, two utility associations mentioned that the 10 minutes evaluation period is necessary to reflect tap-changer operating times and short-term unusual combinations of circumstances. This is a question of balance, reflecting the fact that the use of equipment is substantially random at the level of individual supply points. Customer loads are also defined on a 10 minutes basis.

Another utility association argued that additional limits for effects within the 10 minutes period are already described by additional phenomena, e.g. dips, swells, temporary overvoltages.

Another utility association mentioned that in order to avoid breaching the 1 minute limit, the design of the network and operating criteria (e.g. limits on customers) would have to be designed for wider excursions –this would add significant costs.

Three utility associations and one respondent from a research institute considered that protecting equipment against damage or failure due to short-duration overvoltages is an issue for the individual equipment product (EMC immunity) taking account of the characteristics of the specific products. It seems inappropriate to seek to transfer the manufacturers' legal responsibility into EN 50160. According to a utility association, equipment can mainly be protected against voltage swells by higher voltage immunity or fast disconnection in case of overvoltage; swells should be measured by 10 ms-average values, as in the case of voltage dips.

One utility association considered the simultaneous modification of the 95% clause and the 10 minutes average value neither appropriate nor justified.

Two utilities, one utility association and the equipment manufacturer suggested that protecting equipment against events shorter than the today's 10 minutes average limit must be handled in the scope of overvoltage events and not in the shorter time interval averaging.

According to this point of view, one utility association and the equipment manufacturer noted that damages to equipments can occur due to short events, e.g. an overvoltage lasting for few seconds, but having small effect on the averaged value, even on a 1 minute average basis. Therefore it seems more effective to regulate the number of events (dips and swells) already detected by proper measuring equipments instead of reducing the average time. The average time must be a parameter to control the supply voltage variations steadiness along the time and not the element to detect the presence of events.

The equipment manufacturer and one utility mentioned that the actual measuring equipments are already able to operate with average time shorter than 10 minutes (e.g. 1 minute). However, the equipment manufacturer mentioned that it must be taken into account that reducing the average time results in an increment of data collected and communication times.

One utility association mentioned that investments related to measurements needed when applying a 1 minute averaging period are estimated as being in the range of several tens of billion euros, only for Austria.

4.3.3. ±10% voltage variations band

Nine respondents expressed their comments related to the voltage variations band defined in the EN 50160 standard.

Some of them (from academia, research institute, equipment manufacturer and experts) **agreed with the establishment of a narrower band** than ±10% for voltage variations.

The respondent from academia and the equipment manufacturer estimated that narrower voltage variation range (less than 10%) can give benefits also for long term effects on insulated equipment. The useful life of insulated equipment of solid type strongly depends on actual value of voltage in respect to electro-thermal life model. One expert added that a long-term exposure of equipment to voltages above or below its design voltage may impact the lifetime of the equipment. The phenomenon is well known for incandescent lamps where the lifetime decreases very quickly with increasing voltage. For rotating machines both an increase and a decrease in voltage could reduce the lifetime. A consistently high or low voltage could lead to an increase in current and thus an increase in losses in the distribution network and in the equipment.

The respondent from a research institute mentioned that the combination of ±10% limits with the 10 minutes average and the 95% clause can lead to poor quality for an important number of customers, while respecting the standards. This should be avoided.

The equipment manufacturer pointed out that a narrower band (e.g. 7.5% Un) in respect to the actual (-15% +10% Un) for 100% of the time can optimize the design of equipments, avoiding the oversize of power supply circuits for the normal operating conditions saving resources and manufacturing costs. The regulated binding limits for supply voltage variations must be strictly inner standardized immunity operating range of electrical equipments (e.g. binding limit 7.5% Un vs. operating range of equipments 10% Un) in order to avoid controversy in case of borderline network conditions, where even a small (and unavoidable) voltage drop between the point of connection and the customer equipment can determine an ambiguous interpretation of an event. In such cases even a calibrator class measuring instrument could not resolve the dispute, and in any case it does not seem a sound solution to be depending only from the accuracy level of the instrument. The presence of a “dead zone” between the binding limit and the immunity range of equipments resolves the critical situations (voltage drops, instruments accuracy, noise or disturbance over transducers, etc…) and sets a clear relationship between the two counterparts, improving altogether the overall quality of the system.

One expert mentioned that a Swedish power-quality standard recommended that the supply voltage to electric motors should be between 95 and 105% of the nominal voltage. A draft version of the Norwegian power-quality standard proposed that the average rms voltage over one week should be between 94 and 106% of the nominal voltage. One of the reasons for setting this requirement was to limit the risk of short-duration overvoltages. The network performance for normal operation should be described by means of statistical values. Instead of allowing the voltage to be outside of these curves a percentage of time, allowance could be given for a number of events with certain duration.

Four utility associations, one utility and one respondent from a research institute **disagreed with the establishment of a narrower band** than ±10% for voltage variations.

Among them, two utility associations argued that no clear justification has been put forward for reducing the range of voltage variations from Un±10% to a narrower band. The present range has been found to be acceptable and economic over many years in most European countries.

The utility mentioned that its system is designed to maintain LV voltage above -10% of Un (207 V) in normal conditions and -15% in N-1 contingencies. Meeting this objective is already challenging because of continually increasing load on the networks. Substantial expenditure is being incurred to improve the networks to meet these criteria. Therefore, the 10% lower limit for normal network configurations should be retained and the perspective of tightening the ±10% to a narrower band seems to be inappropriate.

The respondent from a research institute estimated that there can be benefits in terms of loss reduction of tighter voltage control, especially as a way of allowing conservation voltage reduction to be implemented. However, this is not likely to be sufficient justification for stricter voltage control.

One utility association stated that a tightening of the voltage band could only be made if the measurement intervals were extended, e.g. to 15 minutes, which would be consistent with the standards used for metering equipment. If the averaging interval were changed from 10 minutes to 1 minute, the admissible voltage band would have to be loosened in order to avoid high grid investments.

Two utility associations pointed out that the **integration of distributed generation** into networks is continuously decreasing the usable voltage band and any tightening will reduce the potential penetration of distributed generation, which is in opposition to the EU goals in the field of renewable energy and small scale generation.

One utility association and one utility stated that **tightening the voltage variation band would imply considerable costs**. According to the utility association, any change would result in severe additional financial burdens to network operators, amounting to several hundred billion euros for all Europe. In the utility's case, if it were required to ensure that voltage is no lower than Un-10% for N-1 conditions, substantial investment would be required. It would be necessary to reconductor 75% of the three-phase overhead MV lines system and 50% of the 38 kV overhead lines. The cost would be in the region of 700 million euros. This is approximately €1,000 per customer located in rural areas. As the N-1 contingency arises only occasionally, the utility's view is that customers would prefer to accept the temporary reduction in equipment performance rather than fund this investment.

4.3.4. Exceptional events

Two utilities, one utility association and one respondent from academia expressed their comments related to the definition and treatment of exceptional events.

The two utilities and the utility association suggested that exceptional events should be regulated. One utility suggested that the definition of an exceptional event should not only be based on the designed level of the network as done in Hungary, but also on the network environment. Indeed, it is important to take into consideration the fact that breakdowns occurring during an exceptional weather are primarily due to the network environment (e.g.:

falling trees). Furthermore, the multiplication of extreme weather conditions should be considered. The other utility suggested allowing national regulators to monitor performance against specified targets with rules that allow adjustments for periods of exceptional weather. For simplicity, the smaller definitions of exceptional events should be used for interruptions and for voltage events.

The respondent from academia suggested that the norm should define better the unpredictable, largely random event concept. Thus, it would be possible to identify the responsibility of the various parts involved in a less arbitrary way.

4.4. scope of EN 50160

ERGEG recommendation:

Enlarge the scope of EN 50160 to high and extra-high voltage systems[12]

In detail:

The present EN 50160 limits and indicative levels apply only to MV and LV networks. Incidents or actions leading to voltage variations or voltage events occur also at higher voltage levels than those to which final customers normally are connected. Voltage disturbances at one voltage level may be transferred to lower or higher voltage levels. This will however depend upon several factors among other network structure and short circuit power. In general, it is easier for disturbances to be transferred from higher to lower voltage levels due to differences in the short circuit power. Voltage quality standards should be developed and should apply to all voltage levels, including HV and EHV.

Respondents' views:

The consultation process collected fourteen responses on the proposal of enlarging the scope of EN 50160 to high and extra-high voltage systems.

a) Among the respondents, **nine of them totally agreed with the ERGEG position**.

One respondent from a research institute argued that setting limits for HV and EHV voltage levels is important as a DSO cannot do anything when bad power quality is delivered from the TSO, especially concerning short interruptions and flicker.

Some of the respondents suggested some directions to follow in order to enlarge the EN 50160 standards to HV and EHV voltage levels. Those suggestions are presented below.
One utility association pointed out the specific technical circumstances of high and extra-high voltage levels that have to be taken into account:

- (n-1) criterion;
- Reserve capacity that must be held in evidence for balancing energy;
- Few PCCs with customers;

[12] Also see chapter 2.4 in the ERGEG Conclusions Paper on Voltage Quality Standards E07-EQS-15-03 published in parallel with the present Evaluation of Comments Report in the ERGEG website www.ergeg.org.

- Low harmonic distortion levels necessary anyway, due to the danger of resonance phenomena in low load phases;
- Few technical measures for the improvement of power quality on the HV side, except for the construction of new transmission corridors.

One solution provider suggested that for harmonics, IEC 61000-3-6 and IEC 61000-3-7 recommendations should be followed by the TSO. One utility association explained that the Transmission Code in Czech Republic already included requirements on voltage quality, mostly taken from IEC 61000-3-6 and IEC 61000-3-7. However, results gained from permanent monitoring at 110 kV delivery points during last year showed that especially Plt is not suitable with those requirements. Plt was at many measured points higher than Pst and at some points the measured values of flicker in different weeks varied significantly. At 110 kV, limits of THD and harmonics according to IEC 61000-3-6 (lower comparing to EN50160 limits) are in some cases violated.

One utility proposed to base the expectations relative to higher voltage levels (as well) upon customers' demands. According to the utility, the impact of events on these voltage levels is considerably decreasing, which means less trouble for customers.

One respondent from academia stated that it would be very hard to directly correlate voltage quality limits established at HV and EHV with equipment performance (customers rarely connect their equipment at HV and EHV levels). Voltage quality limits for HV and EHV levels, therefore, could/should be defined more from the system performance point of view (e.g. for benchmarking purposes, when different HV and EHV systems, and their performances, should be compared). Additionally, HV and EHV limits and requirements should be carefully correlated with corresponding MV and LV limits and requirements (HV and EHV should be more stringent).

b) Two utility associations partly agreed with the proposal. They argued that EN 50160 philosophy cannot be directly copied to extra-high voltage, due to significant technical differences. However, for high voltage, there is a chance to develop an additional chapter within EN 50160.

c) One utility and one utility association **expressed their doubts** about the necessity of the work involved for that enlargement, as very few customers are connected to higher voltages and whose needs are normally thoroughly addressed by individual discussions.

Furthermore, according to the utility, in European countries where there are different systems operators for distribution and transmission systems, voltage quality standards for HV could have a role. Otherwise, voltage standards set for MV and LV levels will ensure an adequate voltage quality at HV. Lastly, as there are different network designs in place in different countries, it may prove difficult to set limits that will have a European wide application.

d) One utility association **totally disagreed with the ERGEG recommendation**, due to its national specific situation concerning voltage quality standards at HV and EHV voltage levels. The development and operation of the UK transmission network is currently specified in the Grid Code. This is drawn up by the TSOs through a consultative process involving generators, DSOs and major energy users, under the authority of the UK Energy Regulator. This system works well. For larger supplies, new connections are designed on a different basis from that used in a number of other European countries, taking account of the specific requirements of the new load and the specific electrical environment to which it will be connected. This approach has, over many years, proved to be cost-effective and very satisfactory in meeting the needs of users. The UK systems also use a different approach to the regulation of voltage and frequency within the transmission system from many other European Countries. There is real concern that adding TSO requirements to EN 50160 would lead ultimately to replacing the current system of UK standards and practices at TSO level, with no obvious benefits and many obvious disadvantages to energy users. Any such change needs to be undertaken with caution, with a recognition of these fundamental differences, involving a protracted transition period and only if economically justifiable.

4.5. Indicative values for voltage events

ERGEG recommendation:

Avoid ambiguous indicative values for voltage events[13]

In detail:

As seen in chapter 2.2 of the Consultation paper (voltage events), EN 50160 does not give binding limits but only indicative (non-binding) values. Especially for dips and interruptions, indicative values are given with rather vague formulas (e.g. "up to several hundreds") that are not useful for customers, neither for claiming damages when these occur nor even for designing their own protection systems in an economically sound manner, or for taking appropriate countermeasures. Indicative values for rapid voltage changes are only given with regard to the magnitude and not the frequency. Indicative values for voltage events are no longer acceptable if they are expressed in such an ambiguous manner.

Since EN 50160 was conceived, a vast knowledge about stochastic distribution of voltage events has been cumulated and it is now time to rethink the approach, specifying limits even for voltage events.

As a preliminary step, a classification of severity of voltage dips and swells is needed. This can be done through the definition of a "voltage dip table" that classifies dips by depth and duration, in order to distinguish groups of events having common severity characteristics. The same can be done for voltage swells by height and duration. The "voltage dip table" proposed by UNIPEDE some years ago proved not be effective and should be reviewed. It is important that such a classification table takes into account electrical equipments critical levels and the dips different causes. A Rationalized User Specification (NRS 048-2:2004) from South Africa, contains an interesting classification of voltage dips based upon inter alia customer plant immunity and possible causes of voltage dips. This user specification is however not a national or international standard (see Appendix 4 of the Consultation paper). ERGEG proposes to have an expert evaluation of a dip and swell classification table taking into account following items:

- Voltage depth and duration for voltage dips. Voltage height and duration for voltage swells.
- Electrical equipments critical levels (e.g. the ITIC curve), and different consequences (trip, malfunction, damage etc).

[13] Also see chapter 2.5 in the ERGEG Conclusions Paper on Voltage Quality Standards E07-EQS-15-03 published in parallel with the present Evaluation of Comments Report in the ERGEG website www.ergeg.org.

- Different typical causes; short circuits, earth faults, motor start-ups, transformer inrush currents etc. Zone 1, zone 2 clearance etc.
- Location of the incident; close or remote incident.
- Simplicity has to be evaluated against usefulness.

Such classification of voltage dips and swells should enable regulators to put measures into place were it is most cost-effective and will be useful for both monitoring and investigations. Moreover, it is a first step towards a possible future regulation of voltage dips and swells. The classification of voltage dips and swells is a very important change for EN 50160 that currently does not contain any dip or swell requirements or classification tables.

Respondents' views:

The consultation process collected 24 responses on the proposal of building a classification of severity of voltage dips and swells, following the objective of setting limits for those events.

a) Some of the respondents (from academia, research institute, utilities, utility association, solution provider and expert) clearly agreed with the need of a voltage dips and swells classification.

The respondent from academia suggested that a per-phase representation of dips and swells (and their combinations – dips in some phases and swells in the other) should be introduced; otherwise, there will be no distinction between, e.g. single-phase and three-phase dip/swell events.

The respondents from academia and from a research institute mentioned that effects of these events on equipment performance should be considered. In other words, those types of events that have different causes, but have the same or similar effects on equipment performance, should be put in the same event categories; classification of events only with respect to their causes may be helpful from the system point of view (e.g. it allows easier counting of events), but severity of events is not determined by their causes.

The utility association pointed out the importance of taking into account the causes of voltage dips in a classification, as they are often beyond the DSO's responsibility.

The respondent from a research institute pointed out that the duration of a voltage dip/swell is a very important parameter that should be set dynamically in accordance with the height of the event. Indeed, appliances can operate (i.e. will not shut down) when the voltage is 0%, as long as this lasts only a very short time. On the other hand, a voltage dip of 80% can cause a shutdown, if it persists for a longer time.

The solution provider suggested that a clear separation should be made between interruption indexes accounting for energy loss, based on energy lost * time and severity indexes accounting for dips and swells. For that purpose, 6-9 zones over an ITIC type curve or a simpler unique index counting the number of events outside an ITIC type curve weighted by the distance to that curve should be used.

The expert mentioned that in addition to the duration of the event, the extent of the voltage reduction should be considered. EN 50160 does not specify categories, but only provides indicative values for voltage dips with certain characteristics. A classification could be:

- Short (shorter than few seconds) and shallow (less than 60% of the nominal voltage) dips: this category contains the majority of all voltage dips and events. In this category are the least severe events for an electricity customer;
- Short (shorter than few seconds) and deep (more than 60% of the nominal voltage) dips: the severity of the events in this category is close to short interruptions with the same duration;
- Long (longer than few seconds) and shallow (less than 60% of the nominal voltage) dips: this category of dips is similar to slow voltage variations;
- Long (longer than few seconds) and deep (more than 60% of the nominal voltage): this category is very much related to short interruptions.

b) One respondent from a research institute, one respondent from academia and one utility noted that, according to the different characteristics of the networks in different countries and even in the different parts of the same country, it is **not feasible to define Europe-wide limits** on the number of voltage dips/swells. It would either lead to unacceptable levels of quality for most customers or to unacceptably high costs for most network operators. The respondent from a research institute suggested that reasonable limits on a number of voltage dips should be set in close cooperation with local network operators and affected customers taking into account local circumstances.

c) One respondent from a research institute, four utility associations and one utility mentioned that **limiting the number of voltage dips and swells would be very costly**, especially in well-designed and well-operated systems.

Among them, one utility association argued that regulation on voltage dips and swells would not be enforceable at realistic cost, as measurement at all user installations simultaneously is not possible in practice.

All respondents justified this position by the fact that tightening the limits would induce large investments for the DSOs. For instance, the utility explained that the regulation of the number of interruptions would imply a regulation of the number of voltage dips. The reduction of the number of interruptions is obtained by reducing the fault probability i.e. building underground distribution lines and reducing the length of the feeders. Both these solutions imply a reduction of the number of voltage dips but their depth slightly increases. Obviously the envisaged investments on the distribution networks are huge and would impact on the cost of electrical energy of all the customers, whereas only a few of them could have relative benefits on their production processes. In any case, the few customers who suffer voltage dips should anyway take countermeasures while those who are already satisfied with present voltage quality would pay more without reason. To give an idea, to reduce by 50% the number of interruptions and voltage dips, coming from MV network only, the utility should duplicate its HV/MV substations (about 2.000) with an indicative cost not lower than 3.500 million euros.

d) Two respondents from a research institute, two respondents from academia, three utility associations and three utilities mentioned the importance of the **weather influence on voltage dips and swells**.

For that reason, one utility association and one respondent from a research institute expressed their disagreement with any regulatory limits on those events, as any correlation to weather influence can only be retrospective as an indicator over time of the maintenance of the network (system level goals can be implemented but not individual limits).

The other respondents are more mitigated, saying that this influence should be taken into account while setting the limits.

One respondent from academia suggested considering year-by-year variations by a periodic revision of the limits in function of the actual network performances obtained by a large scale measurement in different European countries. For instance, starting from the results of annual reports on the actual voltage quality, limits of disturbances could be refreshed every fixed interval time (e.g. every 5 years).

Two utilities suggested considering weather influence using a 3 years average when specifying numerical thresholds for each class of voltage dips/swells.

One utility proposed allowing national regulators to monitor performance against specified targets with rules that allow adjustments for periods of exceptional weather.

One utility association evaluated that there is sufficient empirical knowledge based on past years to estimate the frequency of occurrence of voltage dips and swells.

e) One respondent from a research institute, five utility associations, one utility and one expert mentioned that **voltage dips and swells are not always under the grid operator's control**. This position is not only explained by weather influence as seen above, but also by faults on higher voltage levels networks according to the utility who estimated that voltage dips coming from HV network represent around 12% of the total. Two utility associations pointed out that voltage events are also caused by faults occurring in consumer's appliances. When setting limits, those responsibilities should be considered. The expert added that a reasonable limit should reflect both what could be expected from the network operator and the other connected customers, and the own responsibility of vulnerable customers.

f) One respondent from a research institute, five utility associations and one expert mentioned that **problems related to voltage dips and swells should be treated on a 'case by case' basis, at the customer's site**. The DSO and the customer should find an appropriate "immunisation" of the equipment or the use of a customer-specific decentralised power supply. One utility association noted that the investment of voltage quality starts at the customer installation and ends at the grid. The distributor must achieve a standard quality of a specific zone and if household or industrials needs better quality standards, they should install necessary measures to solve individually voltage quality problems, higher than the standards. An inverted situation is in comparison extremely expensive. For that purpose, the respondent from a research institute suggested that utilities should have the capability to describe expected performance for individual sites, by reporting historical performances.

g) 4.5.7 One expert **disagreed with the use of the ITIC curve in the EN 50160 standard**. ITIC curve addresses only a family of products and, additionally, should not be used without its application note. It is available at http://www.itic.org/technical/iticurv.pdf:

"The ITI (CBEMA) Curve and this Application Note describe an AC input voltage which typically can be tolerated (no interruption in function) by most Information Technology Equipment (ITE). The Curve and this Application Note comprise a single document and are not to be considered separately from each other. They are not intended to serve as a design specification for products or AC distribution systems. The Curve and this Application Note describe both steady-state and transitory conditions."

4.6. Duties and rights of involved parties

ERGEG recommendation:

Duties and rights of all parties involved should be defined

The revised EN 50160 should indicate responsibilities of all interested parties: network companies (both distribution and transmission grid operators), customers and equipment manufacturers. In this field, a sound coordination among technical standards (both system-related and product-related) is of paramount importance. Limits given in EN 50160 must not be in conflict with other technical standards, for instance product standards, emission and immunity standards. EN 50160 should not contain limits which will lead to severe costs if electrical equipments are to handle them.

Sharing responsibilities between the parties involved is of key importance from the regulators' viewpoint. The revision of EN 50160 should lead to a first milestone in the coordination between technical standards: this may be achieved by introducing suitable curves in the plan voltage/time. A possible approach is depicted in Figure 2.

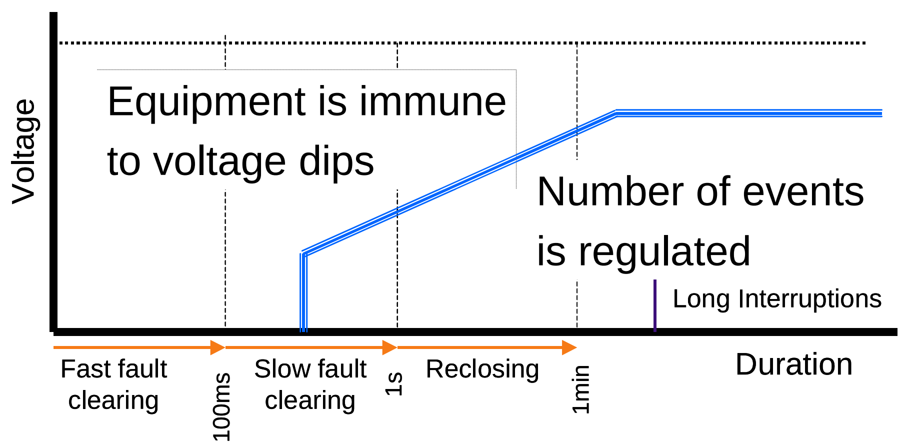


Figure 2 - Hypothetical curve for responsibility sharing.
(Courtesy of: prof. Matt Bollen, CEER workshop on Voltage quality standards, Milan September 29 2006)

The blue line in Figure 2 is a hypothetical border for discriminating network and equipment responsibility. The zone above this line represents the permitted behaviour of the network, and no action by the regulator is needed. Within this above-the-curve area, negative effects, like visual annoyance, related to rapid voltage changes are captured by flicker indices[14]. CE marked

[14] Another way of measuring network performances within the "shaded" area is to use steadiness indicators, like the ones in force in Hungary, discussed during the Milan workshop

equipment should also be able to operate satisfactory above the curve. The zone below the curve can be considered (in a further stage of the technical standardization) as a minimum immunity area for equipment (process). This immunity area will be even wider, depending on the class of equipment or type of process. As for the network performance, all the events falling below the curve might be subjected to regulation, with different limits (e.g., different number of events allowed in rural areas vs. urban areas) varying among different countries or among different network structures. Furthermore, network performances may vary significantly depending also on the protection systems put in place by both distributors and customers.

The approach followed in NRS-048-2 for voltage dips is a practical example of this framework (see appendix 4 of the Consultation paper), that can be enlarged to all voltage variations and events.

Duties and rights of all the parties should be taken into account. Characteristics of withdrawal (e.g. harmonics currents) should be explored, as well as minimum levels of short-circuit power provided by operators, in order to clearly identify responsibilities for voltage quality disturbances. To this aim, also the presence of “disturbing” customers has to be accounted for. The level of disturbance that customers are allowed to inject has to be compliant with the short circuit power at the connection point to achieve the prescribed voltage quality. If special network features are needed (e.g. high values of short circuit power) they should be arranged for by suitable contracts.

Measurements should be considered as well in order to simply obtain a non controversial measure of disturbances, and as far as possible, a meaningful one for detecting responsibilities.

Respondents’ views:

The consultation process collected 22 responses on the proposal of introducing limits for voltage events according to network characteristics.

***Note**: Measurement issues that have been described through comments on this proposal are not considered in this section as long as they were related to a general view on measurement methods. A special paragraph in the first section is dedicated to this issue.*

Several respondents (from utility associations, utilities, customers association, equipment manufacturer and expert) expressed clearly their wishes of obtaining a framework in order to **define rights and obligations for the different actors**: network operators, customers and equipment industry. Among them, three utility associations and the equipment manufacturer specified that power quality seen from the customer’s viewpoint depends on: a) interruptions, short circuit power and network capacity; b) the sum and the behaviour of equipment in all the customers’ installations; c) situations of force majeure. In consequence, the DSO can only be responsible for that part of power quality that is under his control. Equipment manufactures and customers have a role in the drive towards cost effective improvement in the functioning of electrical equipment and share the responsibility of the power quality. Three utilities and one utility association considered important to define customers’ duties in case of voltage quality disturbances. It could allow the DSOs to take action against consumers/producers operating inadequate equipment compromising quality, so as to make them to comply with the rules of cooperation. In that way, they could be requested to bear the costs of the solution. One utility

VLSI= (Umax-Umin)(3s)/Umean(10min).

Still the frequency of rapid voltage changes may have to be limited.

pointed out that it would be a tool to handle voltage complaints of customers in a legal way. Following this goal, two utilities encouraged the development of measuring tools, which are adaptable for **disturbance-source identification** (at simple meters: waveform-disturbance-registration option, besides examination of time-distribution of classified rapid voltage changes; in case of special measuring instrument: harmonic-contribution and flicker-contribution measurements).

One expert agreed with the limit described in the ERGEG recommendation, above which equipment should be immune and below which the number of events should be regulated. This is based on the distinction between power-quality variations and events. The voltage magnitude is treated as a power-quality variation: e.g. the voltage characteristic is the value that is not exceeded during 95% of time. Voltage dips are treated as an event: an objective would place a limit on the number of events per year. Nowadays, both voltage magnitude and voltage dips are quantified using the rms voltage, so that it becomes difficult to consider them as two completely different phenomena, without defining a strict border between them. The same problem occurs between voltage variations and voltage swells.

The first step is then to define a border between "*variations in voltage magnitude*" and "*voltage magnitude events*". The two borders (one for overvoltage events, one for undervoltage events) are shown in Figure 3.

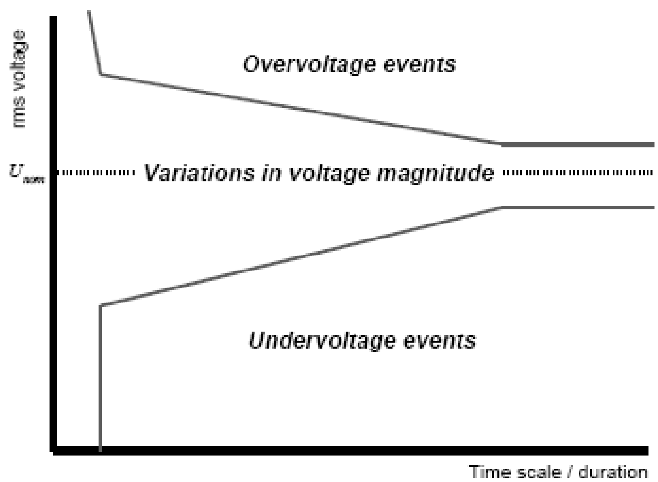


Figure 3: A framework covering slow and fast variations in voltage magnitude.

The next step is to use these borders as the "*responsibility-sharing curves*" between the network operator and the customer. The area in between the curves should be viewed as "*voltage supplied to the customer during normal operation of the network*" or simply "*normal operational voltage*". End-user equipment and industrial production processes should be immune against any voltage within the normal voltage range.

The expert mentioned that responsibility-sharing curves for <u>undervoltages</u> already exist in two national standards, although the term is not used. Under the contract with medium-voltage and high-voltage customers in France, the customer is responsible for dips shorter than 600 ms and for dips with residual voltage over 70% of the nominal voltage. The network operator is responsible for limiting the number of more severe dips. The power-quality standard in use in South Africa places the responsibility with the customer for dips with residual voltage over 70% with duration up to 150 ms; over 80% up to 600 ms and over 85% for longer dips. The number of events is limited for all other dips. It is proposed to use the tests prescribed in IEC 61000-4-

11 as a basis for the responsibility-sharing curve for undervoltage events. This document prescribes how to perform immunity tests against voltage dips for equipment; they shall be tested for the following combinations of residual voltage and duration: 0%, 10 ms; 0%, 20 ms; 40%, 200 ms; 70%, 500 ms; and 80%, 5 s. Both responsibility-sharing curves and the testing requirements under IEC 61000-4-11 are shown in Figure 4.

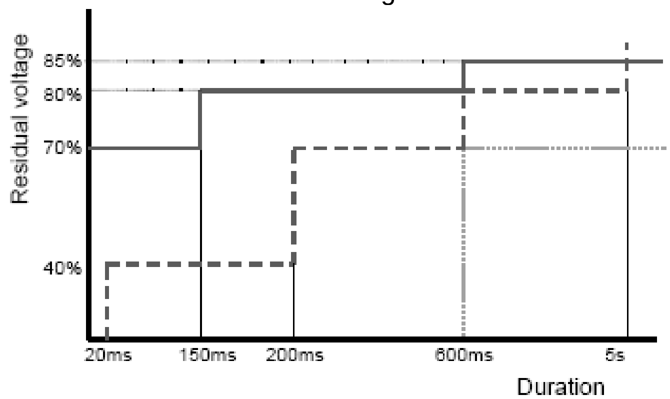


Figure 4: Responsibility-sharing curve according to the contracts with MV customers in France (dotted), according to South-African standard (solid), and based on tests prescribed by IEC 61000-4-11 (dashed).

IEC 61000-4-11 does not place any requirements on equipment but could be a good basis for discussion between network operators, industrial and domestic customers, and equipment manufacturers in order to define a responsibility sharing curve for undervoltage events. A suitable platform for such a discussion is formed by the various IEC working groups and similar organizations like CIGRE and IEEE Standards.

However, no international standard document exist that can be used as basis for a responsibility-sharing curve for overvoltages. The only widely used curves that give limits for overvoltage events are the CBEMA curve and the more recent ITIC curve. Both curves indicate which overvoltages equipment should tolerate. For long-duration overvoltages the requirement is 105% of nominal according to CBEMA and 110% according to ITIC. The CBEMA curve allows higher voltages for durations less than 200 ms, up to 115% for an overvoltage of 20-ms duration. The equipment requirement according to ITIC is 120% of nominal voltage up to 500 ms duration. The proposal for a responsibility-sharing curve in Figure 5 is based on the more recent ITIC curve.

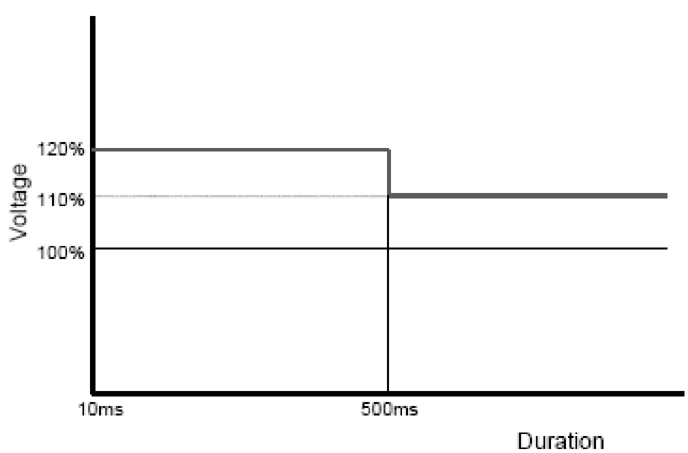


Figure 5: Responsibility-sharing curve for overvoltages based on the ITIC curve.

One expert pointed out that introducing limits for **flicker** severity and **harmonics** implies that network operators are becoming responsible for keeping those limits. Although network operators can influence flicker and harmonics, those disturbances are mainly caused or influenced by customers. However, since other customers do not have contractual agreements with these customers, it could only be the network operator dealing with reducing flicker or harmonic distortion if limits are exceeded. It is then acceptable to set limits for network operators. At the same time, they should have the possibility to make disturbing customers take measures in case their disturbance leads to a non-acceptable level of voltage quality. Unlike flicker or harmonics, **supply voltage variations** cannot be considered a shared responsibility between the network operator and customers. In principle, supply voltage levels should be considered being controllable by network operators under normal circumstances. Therefore, it is fair to attribute responsibility for a good voltage level to network operators alone.

Two utilities agreed that it is also important to **stipulate the minimum short circuit power** that has to be assured by the DSO to a consumer having a given available power. In case the DSO assured this prescribed short-circuit power, it has done the network action that was "legally required" from it. However, one respondent from academia pointed out that the minimum value of the network's short circuit power is not a sufficient measure for characterizing the main voltage distortion levels due to the harmonic currents absorbed by the load. The characterization of the network's frequency response at different harmonics is necessary. This measure highlights the possible critical situations linked with the network resonance. The resonance can occur in the presence of capacitors, not only used for power factor improvement, but also the ones of the lines.

Two respondents from academia and one from a research institute approved the fact to **introduce different "responsibility sharing curves" (RSC)**. The respondent from a research institute stated that those curves, as a minimum, should create a platform for information sharing between network operators and customers with equipment, processes and/or installations sensitive to voltage variations. One respondent from academia suggested defining RSCs not just at different voltage levels, or for different system configurations and topologies, but also for at least few general classes of equipment (e.g. those mentioned in IEC 61000 series, where different requirements apply for different classes of equipment). Extension of the RSC concept to different classes of equipment will also provide a good starting point in further negotiation of more specific power quality contracts between the customers and utilities. Finally, when several limits and voltage responsibility curves are defined and used, they should be carefully correlated, in order to provide information about the overall system/customer performance. The other respondent from academia specified that a curve should also cover overvoltages (swells and fundamental voltage amplitude).

One respondent from academia and one from a research institute suggested that the **RSC should be explained in more detail**. For its use in three-phase supply systems, clear explanation should be provided as to what voltage should be used for establishing border lines: minimum of all concerned, or their average, and how voltage measurement should be performed: phase-to-neutral or phase-to-phase. Indeed, sag types need to be defined: three phase sags are not the same as one phase sags.

Following this idea, one expert pointed out that a responsibility-sharing curve should be applicable to both single-phase and three-phase equipments and therefore considers the three-phase character of the grid. The standard for testing equipment against voltage dips, IEC 61000-4-11, prescribes that the voltage dip shall occur between one phase and neutral or between two phases. A dip shall be characterized by the lowest of the three residual voltages.

An alternative method results in a characteristic voltage that is independent of the connection of the measurement equipment (phase-to-neutral or phase-to-phase) and that does not change when a dip transfers through a transformer. The method requires dips to be classified into different types, as for instance:

- Type A: voltage drop in all three phases;
- Type B: voltage drop between two phases;
- Type C: voltage drop between phase and neutral.

Several respondents (from academia, research institute, expert, utilities and utility association) mentioned that it is necessary to take **existing national or international standards** into account. Among them, two respondents from academia, one from a research institute, one utility and one utility association recommended coordination with equipment immunity requirements as defined in national or international standards. One respondent from a research institute added that a liaison between ERGEG/CEER and IEC 77A WG 06 is highly advisable. The expert suggested that legal responsibilities of the parties should not be placed in a standard, mainly because they are already defined by the EMC Directive for disturbance and Low Voltage Directive for damage to LV equipment. One respondent from academia suggested also to explain what information on equipment immunity, among those available in international standards or equipment product specifications, should be used (and what should be not used) for the construction of the RSC, and why. In other words, the differences between the existing concepts for the assessment of equipment immunity (e.g. the ITIC curve) and the newly proposed RSC concept should be explained. On that purpose, one utility gave some elements of response; the ITIC curve was first developed in the 1970s when electronic equipment was powered via bridge rectified power supplies. As most equipment has switched mode type power supplies, it could work on a much wider range of voltage. According to the two other utilities, all equipments must be able to withstand dips lasting less than 40 ms, otherwise the equipment's interruption tolerance must comply with the ITIC curve. One respondent from a research institute suggested referring to IEC 61000-4-11 and IEC 61000-4-30 standards for the expected performance, as explained below.

One respondent from a research institute agreed that it would be good to provide an immunity curve defining a recommended dividing line where equipment should be immune and the performance of the system should not be a factor. EN 50160 could provide an **index for describing system performance** as the number of events outside of this curve for different types of sags. However, this index should not be a regulated limit but a way of describing expected performance.

One respondent from a research institute and two utility associations suggested **changing the title "responsibility sharing curve".** Indeed, the respondent from a research institute proposed "indicative compatibility curve" as an alternative, since protection against severe consequences, like fire, injury or emission of dangerous substances, remains the customer's responsibility, even for events beyond the responsibility-sharing curve. Following the same idea, one utility association argued that a "responsibility-sharing curve" makes only sense for normal operating conditions, as in such cases responsibilities are clearly assignable. Contrary to that, the proposed curve deals with phenomena which, first and foremost, occur under abnormal operating conditions. According to the other utility association, it is questionable if the term "responsibility" can be implemented in a standard as EN 50160.

One expert and one utility association totally **disagreed with this proposal**. First of all, they estimated that EN 50160 is not the place to define responsibilities. Secondly, the approach of defining a general immunity curve is completely impractical, different performance criteria should be define depending on the specificity of the product and the severity of the disturbance. Lastly, the utility association argued that within any particular product type there can be substantial differences in immunity level, reflecting the ways in which manufacturers have chosen to meet their customers' needs. It seems wrong to seek to establish legal or contractual responsibility within a public standard.

4.7. Voltage events

ERGEG recommendation:

Introduce limits for voltage events according to network characteristics

In detail:

The costs borne by customers for poor voltage quality require a new technical answer about reference levels applicable in the specific situation. The new approach to setting limits for voltage events must take into account that the present level of voltage quality may differ a lot both among the European countries and within the same country. Different countries may have different requirements or different network structures: e.g. neutral grounding is different among European countries and is very important for short interruptions and dips.

New limits for voltage events should be studied taking into account different network structures as far as possible in order to give realistic values. In this way, new limits should be differentiated according to main characteristics of the network (not only voltage level, but also: overhead/underground; neutral point configuration; short-circuit power; etc.). The availability of field data from the monitoring systems recently installed in some countries could be extremely helpful for this purpose.

New limits, differentiated according to network characteristics, should no longer have as reference the worse situation in Europe, as some indicative levels currently given in EN 50160 present. New limits for voltage events should specifically define voltage values as it is recommended for supply voltage variations.

Respondents' views:

The consultation process collected fourteen responses on the proposal of introducing limits for voltage events according to network characteristics.

Among the respondents, **nine of them totally agreed with the ERGEG position**.
Some of those respondents proposed some additional networks' characteristics to those already mentioned in the consultation paper in order to define better specific standards.

Several respondents (from academia, utility, solution provider and equipment manufacturer) suggested adding a differentiation according to the loads characteristics (rural or urban areas, industrial or domestic equipments). For that purpose, the respondent from academia suggested to refer to the IEC 61000-2-4 for equipment categorisation. This characteristic should be taken into account, as customers using equipment in public networks generally do not have necessary technical and engineering support for solving possible power quality problems (due to their own equipments), what is usually available in most of the industrial environments.

One utility association and one equipment manufacturer suggested taking also into account the climatic and geographic characteristics of the area. Those characteristics can be very different within Europe. Following this idea, an argument of one utility association who is not favourable to this proposal, is to say that the geography of the surrounding area is of paramount impact on the voltage quality of a grid and cannot be influenced by the network design.

Three utilities supported the recommendation, as it will help in the “acceptance” of voltage quality levels by the customers. Indeed, newly appearing customer will be aware of the supply characteristics of the specific type of network and the related power quality standards that apply. It could have a positive effect on customer contacts and avoid many voltage related complaints.

One utility and one equipment manufacturer insisted that collecting data is very important for that purpose. The utility specified that it will be important to allow sufficient time to gather historical data to establish the present status. The equipment manufacturer considered that it is indispensable to process the data coming from the monitoring system already operating or planned. It is essential to define a specification inherent to the network characteristics to relate the data with and the aggregation criteria to apply. Examples of aggregation criteria of power quality measurements can be retrieved visiting the website of the Italian MV power quality monitoring system (http://queen.ricercadisistema.it). Furthermore, the equipment manufacturer suggested to institute at EU level a super national body aimed to collect constantly aggregated data from the national monitoring systems in order to create a joined data bank. Such joined resource could become the source for ERGEG to monitor, identify and update the voltage quality levels.

Having a specified and unified system of network characteristics and aggregation criteria it is possible to make review comparing field data harmonized reports, also coming from different monitoring systems, avoiding the mixing-up of data not related to similar characteristics.

One utility and one respondent from a research institute made comments on the limits to be set. The utility specified that unrealistic demands could not be asked from the DSOs e.g. with regards to voltage dips on overhead line networks. The respondent from a research institute suggested that these system characteristics should not affect minimum requirements for steady state voltage quality that all systems should be able to meet.

The same respondent from a research institute agreed with the recommendation but only as a long term goal. Indeed, he considered that the impact of the main characteristics of networks are not adequately understood yet to come up with reasonable requirements, especially for voltage sags.

Two utility associations agreed with the necessity to describe events having in mind the different regional characteristics of the structure of supply and the existing grids. However, they raised the difficulty of setting limits for voltage events as they are rather unpredictable and mainly out of DSOs’ control.

Two utility associations considered that **any diversification of limits for voltage events for different classes of grids appears to be undesirable**, for different reasons. One utility association argued that the proposal is directly contrary to the needs of equipment manufacturers and users, both of which would generally prefer one product standard to be applicable at every likely point of use. The other utility association argued that many grids are mixed structures, containing cables and overhead lines, changing due to restructuring along time. For that reason, immunity classes for customers, if adopted to grid-specific requirements, may happen to be inappropriate after several years of operation, in case of regulatory voltage events limits getting changed. Furthermore, the proposed diversification will inevitably cause a different treatment of equal customers in different network segments, which is not desirable.

4.8. Power quality contracts

ERGEG recommendation:

Develop the concept of power quality contracts

In detail:

It is stated in EN 50160 that “this standard may be superseded in total or in part by the terms of a contract between the individual customer and the electricity supplier”. In 61000-4-30 the issue of power quality contracts is briefly presented in the informative Annex 6.

Power quality contracts are still at a starting phase but they can be useful for revealing customer preferences for quality, especially for customers with the greatest need for continuity and voltage quality. These contracts require that customers requesting better voltage quality have a clear willingness to pay for it. This is the reason why this type of contracts is not yet widely diffused. The concept of power quality contracts should be developed, taking into account experiences and regulations in some European countries (especially France).

Respondents’ views:

The consultation process collected fifteen responses on the subject of power quality contracts. Thirteen of the responses were favourable to the implementation or the development of power quality contracts. It is widely accepted that users seeking a higher level of quality than EN 50160 standard can negotiate this with their network operator.

One expert agreed that for cases where individual customers have more demanding quality needs than limits imposed by the EN 50160 or by a national regulation, power quality contracts can be considered. Such contracts allow the need for very high quality by individual customer to be addressed without having to increase the overall standard for the average customer beyond reasonable levels.

Four utility associations and two utilities reminded that power contracts with higher standards should imply a financial contribution from the customer in the form of a well calculated extra tariff or a yearly fee.

One utility association indicated that such contracts could be submitted to regulator’s control, if needed. One utility noted that regulators should be allowed to adjudicate in the event of dispute. However, according to one utility association, this issue seems to be outside of the scope of the regulator’s competence and should remain as well outside of EN 50160. Another utility association stated that the contracts’ procedure is already mentioned in EN 50160 and cannot be further regarded in EN 50160, as it is a bilateral agreement between the grid operator and the customer.

One utility association and one utility agreed that a form of “standard contract” should be avoided. One respondent from a research institute supported the publication of guidelines for composing individual power quality contracts including the setting of limits in reference to the power quality statistics of the consumer at the PCC. One utility association expressed its disappointment related to the lack of simple rules in order to develop and to use power quality contracts in Czech Republic, even if a regulator’s decree as well as the Distribution and Transmission Codes make them possible.

One respondent from a research institute pointed out that there will very seldom be any economic reason for power quality contracts in any area except voltage sags and interruptions. Those contracts would be requested from specific clients where the supplying utility could provide an option to investments within a facility for equipment protection from interruptions and voltage sags.

One utility argued that power quality contracts are extremely problematic, since it could be guaranteed only in very few cases that other customers will not profit of the advantages of a “good” network developed for a customer paying more expensive for a better quality.

Although favourable to the concept of developing power quality contracts, two utility associations addressed this issue. Firstly, it has been settled that connecting a new customer to the grid should not affect the rights of existing customers. The cost of preventing or correcting possible new disturbances must be supported by the new customer. Furthermore, in case of additional customers benefiting from the higher quality supply provided for the requestor, the respondent wondered whether the latter should pay all costs or if the other customers could be obliged to pay higher fees, following the idea of a proportionate financing.

4.9. Future of voltage quality regulation

Which are pros and cons of introducing national VQ limits and requirements by the national regulator? Do you believe that a “two level” option (definitions and measurement rules set homogeneously at EU level; limits set country by country by relevant authorities) can be a more effective way for improving or at least not deteriorating voltage quality? Twelve respondents expressed their opinion on these questions.

More than half of them (from academia, customers association, utilities and expert) **supported the option of introducing national voltage quality limits and requirements** by the national regulator and the two-level option.

The customers association argued that it is important to preserve better national standards where such are defined.

Two utilities mentioned that national limits would be more efficient, as the situation through Europe can be very different due to different local conditions. One of them suggested that analysing customer quality related complaints based on the nature and duration of the events and the costs incurred for the customers should be extended and applied as a general practice for the other CEER countries. Experiences should be assessed together and conclusions should be drawn while taking into consideration national characteristics.

One utility suggested that this option could be more appropriate for HV and EHV standards than extending the scope of EN 50160. Furthermore, it may prove difficult to set limits for voltage events according to networks' characteristics for European wide application. An alternative approach would be to harmonise classification of voltage events and for national regulators to set targets for each of its regulated network operators.

The expert mentioned that EN 50160 standard and IEC compatibility levels are both based on the principle that the objectives on power-quality disturbances are the same for all customers. This basic assumption has shown to work rather well for power-quality variations, but can no longer be maintained when more detailed objectives are to be set for the number of power-quality events. The widely varying requirements on number and duration of interruptions in different European countries confirm this. For power-quality events like overvoltages and undervoltages, local objectives are needed, either based on local characteristics of the supply network, or on a power-quality management process.

Four utility associations and one respondent from a research institute **rejected the option of setting limits at a national level**.

They all argued that a two level option seems fundamentally opposed to the EU concept of a single market. To establish national limits would be entirely contrary to the needs of equipment harmonisation for the manufacturing industry. One utility association added that equipment manufacturers would have to raise prices due to diversified immunity levels needed for their products.

Nevertheless, one utility association suggested that for transition countries, a timescale would be defined for any necessary improvement.