QUALITY OF SUPPLY REGULATION IN NORWAY
GOING BEYOND EN 50160

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INTRODUCTION

Regulation of quality of supply in its present form in Norway, has been introduced through a step-wise evolution. The most recent step is the introduction of a new set of regulations relating to the quality of supply in the Norwegian power system. The new Power Quality Directive (PQD) was put into force January 1st 2005. The paper gives an overview of the new directive, its intentions and its content. The PQD includes new requirements for Power Quality (PQ) documentation, PQ information and PQ service as well as limits for certain voltage quality phenomena. The phenomena dealt with are mainly the same as defined in EN 50160. In the paper a comparison with EN 50160 is given, as the PQD goes further than the EN 50160 on some phenomena.

BACKGROUND

Deregulation of the electricity sector and the introduction of Performance-Based-Regulation regimes pose a challenge to assure efficient provision of quality of supply. When undertaking such a change, it must be kept in mind that this business is vital in the sense that almost all other businesses and economic activity relies on its continuous output. Deregulation can weaken operations and the economic incentives for required investments and maintenance. Only a slight decrease in regularity or quality of power supply can reduce and even cancel the benefits of deregulation – hence quality of supply regulation, environmental standards and safety standards are important aspects in the regulation of DSOs.

The DSO regulation in Norway has largely been based on utilities costs. Both the early rate of return regulation and the present revenue cap regulation utilized utility costs as the basis for the regulation when entering a new five year regulatory period. Within the regulatory period utility costs and utility revenue are decoupled. A utility cost reduction will not affect the utilities allowed revenue. Hence, it is possible to generate short term profits by reducing utility operating costs which in turn might affect quality, health, safety and environmental issues (HSE). HSE are mainly dealt with through direct regulation. Absence of explicit regulatory framework for assuring quality of supply can create incentives to reduce quality of supply to obtain (short term) profit.

To counteract a possible negative development of power quality, the authorities for years have focused on these matters and the network companies in Norway are being increasingly subjected to regulatory regimes that explicitly take into account the quality of supply to the consumers. The new PQD is the latest development in this process that started in 1991.

REGULATION OF QUALITY OF SUPPLY IN NORWAY

Regulation of quality of supply in its present form in Norway, has been introduced through step-wise evolution as shown below:

1991
- A new Energy Act was put into force with, giving the authorities (NVE) the mandate to regulate power quality.
- Results from a large interruption cost survey drawing attention to cost issues relating to power quality.

1995
- FASIT – a standardized system for reporting of failures and interruptions was introduced. The system is used for mandatory reporting of interruptions to NVE.
- NVE requires interruption costs to be included in power system planning

1997
- Mandatory reporting of faults and disturbances in the 33 - 420 k networks.
- Revenue cap regulation introduced, but with no specific incentives for power quality management of network

2000
- Standardized method for estimation of Energy Not Supplied (ENS) introduced
- Mandatory reporting of ENS per customer category

2001
- Quality adjusted revenue caps introduced. Based on CENS – Costs of Energy Not Supplied.
- Giving incentives to balance utility costs and customer interruption costs.

2003
- New interruption cost survey giving new and increased ENS cost rates

2005
- New power quality directive on quality of supply introduced
The most important step in this process as regards quality of supply, was the introduction of the CENS-arrangement [1]. The arrangement regulates economically only long duration interruptions (> 3 min).

NVE gave the following evaluation of the CENS-arrangement at CIRED 2003:

- “The CENS arrangement has a positive effect on the network companies’ behavior and attitude related to the customers’ interruption costs.
- There is a need for additional regulation dealing with other quality parameters than long interruptions.
- Future development to extend the CENS arrangement is possible.”

The experience with the arrangement so far, has mostly been positive, taking into account the limitations of the arrangement; to impose economical incentives for long interruptions.

However, new research has shown that long interruptions only count for approx. half of the customers total costs related to interruptions and voltage dips [3]:

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<table>
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<tbody>
<tr>
<td>Long interruptions (&gt; 3 min)</td>
<td>850 MNOK/year</td>
</tr>
<tr>
<td>Short interruptions (≤ 3 min)</td>
<td>600 MNOK/year</td>
</tr>
<tr>
<td>Voltage dips</td>
<td>170-330 MNOK/year</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1 600-1 800 MNOK/year</strong></td>
</tr>
</tbody>
</table>

From the customers’ point of view, Table 1 show that in Norway the long interruptions alone contributes to approx. 50% of total costs related to interruptions and voltage dips.

These figures are compared to other utility costs - investments and cost of electrical losses (see figure 1).

The customers’ annual costs associated with interruptions and voltage dips exceed the annual costs of losses and amounts to approx. 65% of the annual investments.

Compared with the total annual revenue cap of approx. 15 billion NOK/year – the costs of interruptions and dips are in the order of 10% of overall costs which shows the sosio-economic importance of these power quality aspects.

**A NEW NORWEGIAN DIRECTIVE ON QUALITY OF SUPPLY**

NVE put into force a new Directive on quality of supply from January 1st 2005. NVE stated the following rationale for the new Directive:

- To ensure a satisfactory quality of supply in the Norwegian power system and a rational operation, development and construction of the power system.
- No intentions on general increase or decrease in the quality of supply from the existing level in the Norwegian power system, but local efforts might be necessary.
- To adapt to the present general quality of supply level in the Norwegian power system as customers and utilities have adapted to the existing level and it should not cause unreasonable costs to pursue this quality level.

NVE also draw the attention to the importance of compatibility between immunity levels for electric equipment (limits for damage in particular) and the power quality level.

The Directive defines requirements for:

- A minimum acceptable level of power quality at customers terminals
- Continuous measurements of power quality
- Information to the customers about what power quality is to be expected
- Time limits for handling and solving customer’s complaints related to power quality

The specified limits largely follow the structure and definitions specified in EN 50160 [4]. For some phenomena NVE has chosen not to introduce minimum limits:

- Supply voltage dips
- Short interruptions
- Long interruptions
- Temporary overvoltages live/earth
- Transient overvoltages
- Interharmonic voltages
- Mains signaling voltage on the supply voltage.

The reason for not introducing limits for these phenomena is partly due to difficulties in setting limits and monitoring them. Another aspect was the sosio-economic importance or weight of some of the phenomena. Interruptions and dips
are important aspects, and partly covered by the CENS arrangement giving incentives to avoid faults and disturbances. In the future NVE signals that the CENS arrangement might be further developed to take into account short interruptions and possibly voltage dips.

Responsibilities for Power Quality
Both Utilities and customers are subject to the Directive and might be economically responsible for insufficient power quality and hence may have to finance mitigation. The Directive points out the legal entity/person owning or using electrical equipment or plants causing violation of the limits to be responsible. Procedures to determine whether the supply system is too weak or emissions from the load are too high are not yet given. It is pointed out in the regulation that power quality shall be a part of the network contract between DSO’s and customers. Such a contract is an important instrument to limit emissions from customers so that the power quality requirements at all supply terminals can be managed.

Going beyond EN50160
There are some significant differences between EN50160 and the new Directive, where the Directive goes beyond the EN50160. A comparison is given in Table 2 below.

<table>
<thead>
<tr>
<th>Quality aspects</th>
<th>EN 50160</th>
<th>The new Norwegian directive on quality of supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main evaluation period for most phenomena</td>
<td>95%</td>
<td>100%</td>
</tr>
<tr>
<td>RMS-variation averaging time period</td>
<td>10 min</td>
<td>1 min</td>
</tr>
<tr>
<td>Flicker levels</td>
<td>95% value for Plt ≤ 1</td>
<td>100% value of Plt ≤ 1 and a 95% value for Pst ≤ 1.2</td>
</tr>
<tr>
<td>Voltage steps LV</td>
<td>Normally 5% and in special situation up to 10% a few times per day</td>
<td>Once per day for voltage steps up to 10%, 24 steps per day up to 5% and for steps that occur more than 24 times per day the change shall not exceed 3%</td>
</tr>
<tr>
<td>THD LV/MV</td>
<td>8% for the 10 minute average</td>
<td>8% for the 10 minute average and 5% weekly average</td>
</tr>
<tr>
<td>Higher order harmonics</td>
<td>No limits for harmonics above 25th order</td>
<td>General limits for higher order harmonics</td>
</tr>
<tr>
<td>HV/EHV</td>
<td>No limits for HV/EHV as customers connected to these voltage levels are expected to be covered by special contracts</td>
<td>Introducing some limits for HV and EHV: Rapid voltage changes, flicker, harmonics, voltage unbalance</td>
</tr>
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</table>

100% values versus 95% values
EN 50160 specifies limits for 95% of the time for some voltage disturbances. The PQD specifies limits for 100% of the time under normal operation conditions in the network for disturbances like unbalance, harmonic voltages and flicker.

1 minute averages for rms voltage variations
Voltage rms variations are the only voltage parameter to be measured as an average over 1 minute instead of 10 minutes as for most other parameters in the PQD and in EN 50160. NVE has chosen 1-minute average due to experiences with damage to equipment when 10 minute average values have been within +/-10% while the a number of rms values have been as high as above 270 V. These 50 Hz phase-to-phase overvoltages have occurred with durations from a few cycles up to more than 30 seconds.

An example of large voltage variations and overvoltages filtered out by 10-minute average are shown in Figure 2 and 3. A Norwegian Utility performed the shown measurements. Figure 2 shows only the 10 minute average voltage and the two major horizontal lines indicate 230 V +10% and –10% (253 and 207 V). In figure 3 the 10-minute average value is shown together with the maximum and minimum rms voltage for every 10-minute interval.
The proposed rms voltage values in the PQD also have a historical background:

The Norwegian Utilities have in their standard contract with customers for several decades specified +/- 10 % as limits for voltage rms variations 100 % of the time under normal operating conditions. Until the mid 90s it was common practice to consider voltage variations outside +/- 10 % on a much shorter time base than 10 minutes as insufficient power quality according to the contract. Implementing the 10 minutes average values from the EN 50160 actually makes it easier for the Utilities to comply than the with the previous application of the standard contract limits of +/-10% giving no indication of measurement interval.

**Pst limits in addition to Plt limits**

Flicker levels are another area where the PQD goes beyond EN 50160. While EN 50160 specifies a 95% value for Plt \(\leq 1\), the PQD specify a 100% value of Plt \(\leq 1\) and a 95% value for Pst \(\leq 1.2\). The introduction of Pst is based on several Norwegian customer complaints where Plt \(\leq 1\) where Pst have been much larger than 1.0. An example measured by a Norwegian Utility is shown in figure 4.

**Figure 4** High flicker levels (Pst to the right) when Plt \(\leq 1\) (left). Note that in addition to the horizontal lines at P=1, a line is added at Pst = 1.2 that is the limit in the PQD.

**Rapid voltage changes**

In EN50160 voltage steps are referred to normally be within 5% and in special situation up to 10% a few times pr day. The PQD limits the voltage steps to for LV:

- 10% for changes occurring less than once per day
- 5% for changes occurring less than 24 times per day
- 3% for changes occurring less than 24 times per day

These values are based on analysis of the correlation between actual voltage step levels measured and significant increases in customer complaints.

The limits for MV/HV/EHV are

- 6% for changes occurring less than once per day
- 4% for changes occurring less than 24 times per day
- 3% for changes occurring less than 24 times per day

**5% limit for THD as a week average in LV and MV**

In addition to the EN50160 limit of 8% for the 10 minute average the PQD introduces 5% as the limit for the weekly average. The average of all 10-minute values during a week should hence not exceed 5%. This value is mainly based on experiences with some problems with harmonic levels of THD between 6 and 8 % even though no individual harmonic component exceeded the limit values.

**Higher order harmonics**

Due to the problems of managing higher order harmonics (resonance phenomena etc), EN 50160 gives no limits for higher order harmonics, but NVE has chosen to introduce limits for higher order harmonics at levels to have some guidance also for higher order problem situations.

**HV/EHV**

These voltage levels also have customers directly connected an as the PQD is also intended to cover such situations, NVE has given limits for the voltage levels. In EN 50160 it was not found necessary to introduce limits as such customers was expected to be covered by contractual arrangements.

**OTHER IMPORTANT ASPECTS OF THE NORWEGIAN DIRECTIVE ON QUALITY OF SUPPLY**

Utilities and customers may agree on either better or poorer power quality than required in the PQD by individual contracts. Utilities may not make collective contracts with several customers, but may introduce poorer or better power quality to several customers as long as there is an individual agreement between the utility and all the involved customers.

The PQD gives Norwegian Customers a minimum protection in terms of time limits for utilities to handle customer complaints. The PQD sets a limit of 4 weeks for the utility to respond to a customer complaint with a solution or a plan for how the utility will investigate the reported situation. Within 4 months the utility must find the reason for the problem and who is responsible for solving the problem. In difficult cases with voltage disturbances occurring seldom, NVE have stated that the 4-month limit may be exceeded.

The PQD goes more thoroughly into the utilities obligation to inform customers about the power quality they can expect. The utilities are obliged to perform a minimum level of continuous monitoring of power quality in medium and high voltage systems. For small utilities this minimum level may however not involve more than a few measurement locations.
CONCLUSION-OUTLINE OF FUTURE CHALLENGES

The implementation of the PQD is expected to raise a number of challenges, of technical, economical as well as of legislative nature. Some of these issues are:

Technical-legislative issues:
- Development of procedures and methodology to manage violations of the restrictions given in the PQD, among others to determine who is the responsible party for a violation.
- Management of flicker levels in situations with disturbing loads running in such patterns that customers complain and high Pst values are measured when Plt ≤ 1.
- Management of overvoltages and slow voltage variations i.e. discussion on using 10-minute rms average in combination with limits for instantaneous rms voltage. An alternative to 1-minute averaging could have been limits for the instantaneous value of rms overvoltages. With such a limit to prevent damage of electrical equipment there would not be needs for reducing the averaging interval from 10 minutes to 1 minute.
- Coordination and adoption with the development in EU legislation and international standards mainly standardization within electricity as a product and EMC standards.

Technical-economical issues:
- Development of methods and concepts for overall evaluation, simulation, analysis and optimization of quality of supply in power networks with power quality restrictions.
- Development of measurement- and data collection systems for management and quality assurance of large amount of voltage quality data.
- Development of methods and novel concepts for analysis of these data, enabling the utilities and regulatory bodies with decision support.

An overall evaluation of the new Norwegian directive on quality of supply is that it follows the step-wise evolution in regulation of quality of supply. The new Directive is a complementary to the existing CENS-arrangement, putting emphasis on also other aspects of quality of supply than the long interruptions. However, the Directive raises new challenges and reveals needs for R&D in the technical disciplines, as well as questions raised on the regulatory framework as a whole, seen from a national as well as an international point-of-view.

Utilities mainly welcome a more transparent regulation of power quality. Limits are easier to relate to than inaccurate regulatory statements such as “reasonable power quality”. However, utilities question whether the PQD gives the optimal balance between utility and customer costs.

It is expected that the introduction of the Directive will accelerate an already increasing focus on the very important field of quality of supply, in all relevant disciplines (technical, economical and legislative). As this Directive is new both to the industry and the authorities, it is expected that the experience with the application of the Directive will be the source for modifications. Co-ordination with ongoing legislative customer protection work is also foreseen.

Many parties have shown concern for the deviation from international standards such as EN 50160. Eurelectric stated among others in connection with the European notification on the Norwegian Directive:

“With regard to EN 50160 representing a well-proven compromise in specifying the voltage characteristics of electricity supplied by public distribution systems, the implementation of such a national regulation would, from our point of view, result in:

- a contradiction to the New Approach principle, established by the Commission in 1985, regulating the creation of rules forming the detailed basis for their directives being assigned to the three recognized European standardization bodies;”

NVE has the opinion that EN 50160 does not fully cover the Regulator needs and hence has decided to go beyond EN 50160. In the future NVE foresees that with improved international standards that better cover the Regulator’s needs, it is desirable to revise the PQD in direction of a framework provision referring to international standards.

The authors hope that such a harmonization can be reached.

REFERENCES


