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2008 Norwegian quality of supply survey - State of art and reported needs

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Abstract. This paper reports the findings in a national survey conducted in 2008/2009 on the quality of supply. The respondents are from distribution system operators (DSOs) and from the Norwegian Transmission system operator (TSO). The survey was implemented as a web based survey and covered all quality of supply phenomena defined in EN 50160 [1]. In addition some EMC issues also were included. The objective of the survey was to investigate which phenomena are the most important and what the utilities' needs to improve quality of supply management.

The phenomena causing most problems in Norway are:

1. Supply voltage variations
2. Short duration supply interruptions
3. Voltage dips

These phenomena are of highly ranked both by the Norwegian TSO and the DSOs responding to the survey.

The most important need for quality of supply improvement according to the DSOs is to get advice concerning measurements and measurement equipment:

The TSO sees basic technology transfer, national databases, advice concerning measurements/ measurement equipment and standardisation as important issues in general, but the needs are different for different phenomena.

Key words

Quality of supply, reliability, voltage quality, EMC

1. Introduction

In 2007 SINTEF Energy Research initiated a five year project to develop a new concept for power quality and reliability measurement and management, the PQM project (see project website at: **http://www.energy.sintef.no/prosjekt/PQM/** .

The motivation for the PQM project was mainly the following:

- Quality of supply problems in T&D systems increase both due to increased pollution in networks (increased emission) and due to increased use of electrical equipment that are sensitive to disturbances (reduced immunity).
- Customers quality of supply requirements with respect to reliability and voltage quality increase as electricity is more widely used in business critical work and industrial processes.
- Increased influx of distributed generation (i.e. small hydro power, small wind farms) and renewable technologies (for instance larger wind farms) in T&D systems is restricted by power quality and reliability aspects, giving new challenges both to grid operators (TSOs and DSOs) and to power plant operators.
- Trend towards increased customer protection in general both at the national and international arena (EU) and more strict quality of supply legislation (for instance the new Norwegian PQ Code and the work for Council of European Energy Regulators)
- Lack of knowledge on how to achieve the best balance between quality of supply and costs (methodology, decision tools).

- Lack of knowledge on how to optimally share responsibilities between quality of supply stakeholders.
- Limited observation of quality of supply delivered to customers due to expensive measurement equipment.
- An expected substantial growth in PQ data (reliability data, voltage quality data) to be managed by utilities stemming from new meters – two way communication schemes etc.

To improve the knowledge base in order to better target research to perceived needs, it was decided to perform a survey among DSOs and the Norwegian TSO.

2. Quality of the electricity supply

Quality of the electricity supply (QoS) is defined in [2] as:

Collective effect of all aspects of performance in the supply of electricity

NOTE: This includes security of supply as a prerequisite, and also reliability, power quality, pricing and customer relationships.

Thus, the definition is very broad covering both technical on non-technical issues. In the survey reported in this paper, the focus is on the technical issues i.e.. reliability and voltage quality.

Based on this definition a structured presentation of the overall domain of quality of supply is illustrated in Figure 1:

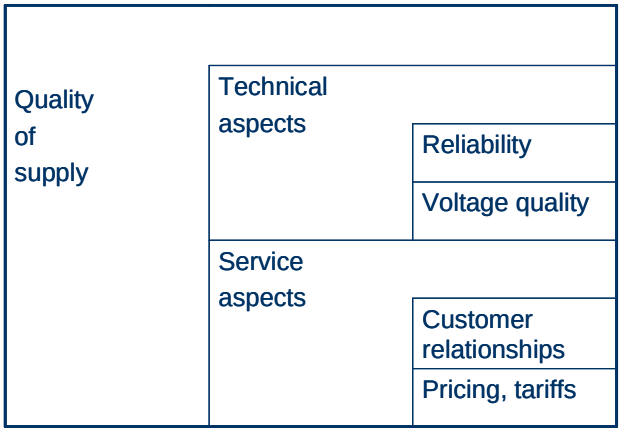

Fig.1 Quality of supply domain

The technical aspects of quality of supply comprise the following phenomena as specified in [1]:

Reliability
- Short interruptions of the supply voltage
- Long interruptions of the supply voltage

Voltage quality
- Power frequency
- Magnitude of the supply voltage
- Supply voltage variations
- Rapid voltage changes
  - Single rapid voltage change
  - Flicker severity
- Supply voltage dips
- Temporary power frequency overvoltages between live conductors and earth
- Transient overvoltages between live conductors and earth
- Supply voltage unbalance
- Harmonic voltage
- Interharmonic voltage
- Mains signalling voltage on the supply voltage

The survey covered all these aspects and in addition some EMC issues also were included:

- Electric fields
- Magnetic fields
- Electromagnetic pulse (EMP)
- Electromagnetic discharge (EMD)

3. Issues covered in the survey

A web based questionnaire was developed covering the following:
- Represents the different phenomena a problem for the utility and/or its network users?
- Are the problems considered to be large/medium/small?
- Is the problem increasing/stabile/decreasing
- What are the most important sources for causing the problem?

The survey also covered the utilities' needs with respect to management of the different quality of supply issues. The questions asked were related to the needs for:

- Basic technology transfer
- National databases
- Advice measurements/measurement equipment
- Better simulation/decision support tools
- New mitigation technologies
- Improved standardisation
- More assistance available for problem solving
- Creation of incentives in monopoly regulation

All findings in the survey are reported in [3].

4. Results

The survey received 36 responses from DSOs and 2 responses from the Norwegian TSO. The survey was sent to 131 DSOs. The DSO customers covered by the survey is about 60 % of all customers due to the fact that responses have been received from several of the larger DSOs in Norway.

The respondents' responsibilities within the companies were typically:

- Quality of supply responsible
- Distributions system manager
- Head of grid operations
- Distribution system planner

In total, the survey sample seems to be rather representative with respect to utility size and geographical area (North,/South, inland/costal, urban/rural …).

Figure 2 shows the response to the respondents' evaluation of the phenomena as a problem source:

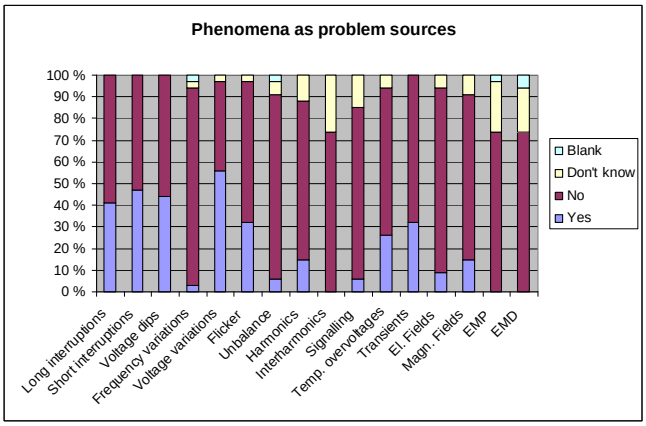

Fig. 2 Is the phenomenon a problem for the utility and/or its customers?

According to the respondents, the most important technical quality of supply issues are:

- Voltage variations (56%)
- Short duration supply interruptions (47%)
- Voltage dips (44%)
- Long duration supply interruptions (41%)

The response to a question concerning trends is given in figure 3:

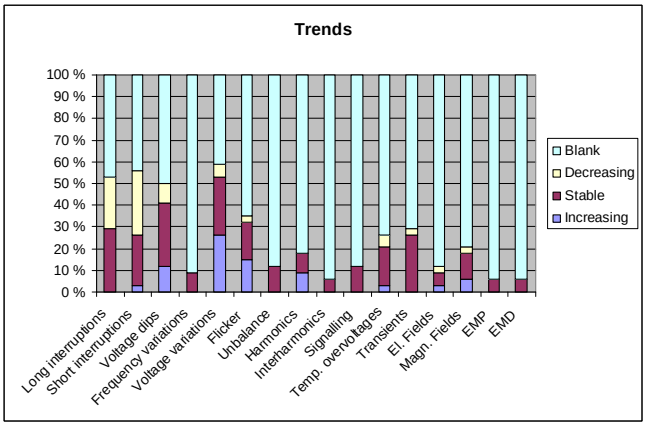

Fig. 3 Are the problems with the phenomenon increasing, stable or decreasing?

It is noteworthy that trend grading was difficult for the respondents as many entered "blank" as a response to this question. Supply voltage variations are a increasing or a stable problem for more than 50% of the respondents.

Also flicker shows a negative trend.

5. Problem sources

To manage quality of supply problems, it is necessary to identify the problem sources. In the questionnaire, the respondent invited to give free text input concerning the sources for problems with the different quality of supply phenomena. Below, the main input received for the most troublesome phenomena according to figure 2 is given:

Supply voltage variations

- Load growth existing loads (within present inlet fuse capacity)
- Stronger utilization of the grid
- Connection of new distributed generation in weak parts of the grid
- Long feeders with (large) variable loads connected at remote end with low short circuit levels
- Supply voltage variations in the supplying sub-transmission grid

Short duration supply interruptions

- Birds causing short circuits on overhead lines
- Vegetation/ trees in temporary contact with overhead lines
- Lightning

Voltage dips

- Switching operations
- Faults – short circuits
- Motor starts
- Long feeders with variable loads especially at the remote end
- Load switching, particularly on weak feeders (low short circuit level)
- Short circuits/faults in the supplying sub-transmission grid

Long duration supply interruptions

- Birds causing short circuits on overhead lines
- Vegetation/ trees contact with overhead lines often in combination with wind/snow
- Lightning
- Faults due to aging
- Environment/ climate conditions in general

Rapid voltage changes – flicker

- Motor loads (start/stop)
- Heat pumps with direct start
- Variable (special) loads connected in areas with low short circuit levels

Transient overvoltages

- Lightning
- Switching operations

Temporary power frequency overvoltages

- Load variations and operation switching (changes of operation topology) in heavily loaded grids
- Transformer tap-changer operations
- Network customer earth faults

6. Comparison with earlier surveys

The results from the survey were also compared with the findings in three earlier surveys or evaluations [4], [5] and [6]. The comparison was used to verify results and to investigate trends see table 1:

Table 1 Comparison with earlier surveys and evaluations

Phenomenon	Problem ranking according to survey			
	2008 [3]	1998 [4]	2003 [5]	2003 [6]
Short interruptions of the supply voltage	2	1	2	2
Long interruptions of the supply voltage	4	4	1	1
Power frequency.	11	10	N/A	10
Supply voltage variations	1	7	6	6
Rapid voltage changes - flicker	5	8	4	8
Supply voltage dips	3	3	3	3
Temporary power frequency overvoltages	7	6	5	5
Transient overvoltages	6	2	7	4
Supply voltage unbalance	9	9	9	9
Harmonic voltage	8	5	8	7
Interharmonic voltage	12	12	N/A	11
Mains signalling voltage on the supply voltage	10	11	N/A	12

Based on the findings given in table 1, the following conclusions and comments can be given:

- Long interruptions is ranked high by end-users and in terms of socio- economic costs [5],[6], but is ranked fourth as a DSO problem both in 2008 and in 1998 [3],[4].
- Short interruptions and voltage dips are ranked second and third in almost all evaluations
- Supply voltage variations were ranked sixth to seventh in the older evaluations, but are ranked as number one in the 2008 survey. Measurements carried out by SINTEF Energy Research have shown an increase in the LV voltage which might be due to stronger utilisation of the distribution systems compensated by higher tap-changer positions of the transformers. This might give problems with high voltage for customers close to the transformer and problems with low voltage in the far end of the feeders. Influx of distributed generation is also mentioned by the respondents as a problem source.
- Rapid voltage changes -flicker , temporary power frequency overvoltages, transient overvoltages, and harmonic voltages are mostly given a “medium” ranking
- Supply voltage unbalance, interharmonic voltage and mains signalling voltage on the supply voltage are the lowest ranked phenomena.

7. Quality of supply management needs

The survey also covered the utilities’ perceived needs with respect to improved management of the different quality of supply phenomena. The list of needs included the following items:

The need for:

- Basic technology transfer
- New National quality of supply databases
- Advice concerning how to do measurements/ selection of measurement equipment
- New Simulation/decision support tools
- New mitigation technology
- Improved standardisation
- Assistance in problem-solving

The following scale were used to grade the needs:

Large, *Medium Small* or *Blank*

To rank the needs for each phenomenon, the “Large” and “Medium” response were added and sorted for each response issue. In this way the priorities for the different issues are ranked, see example in figure 4:

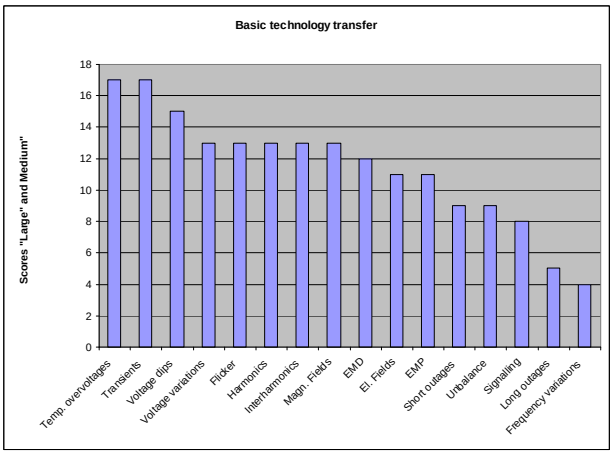

Fig. 4 Ranking of basic technology transfer needs (DSOs)

The main findings concerning DSO needs are summarized in Table 2:

Table 2 DSO needs

Phenomenon	**Type of need**	**Score large+medium (% of sample)**
Transients	Advice measurements/equipment	62
Flicker	Advice measurements/equipment	53
Short supply interruptions	New mitigation technology	53
Harmonics	Advice measurements/equipment	50
Interharmonics	Advice measurements/equipment	50
Temp. overvolt.	Advice measurements/equipment	50
El. Fields	Advice measurements/equipment	50
Magn. Fields	Advice measurements/equipment	50
Temp.overvolt.	Basic technology transfer	50
Transients	Basic technology transfer	50
Transients	New mitigation technology	50
Long supply interruptions	New mitigation technology	47
Voltage dips	New mitigation technology	47
Short supply interruptions	Standardization	47

The main findings concerning TSO needs are summarized in Table 3:

Table 3 Ranking of TSO needs:

Phenomenon	**Type of need**
Transients	Basic technology transfer
Transients	National databases
Transients	Simulation tools
Transients	Standardisation
Short supply interruptions	Basic technology transfer
Short supply interruptions	National databases
Short supply interruptions	Advice measurements/equipment
Short supply interruptions	Standardisation
Short supply interruptions	Assistance problem-solving
Voltage dips	Basic technology transfer
Voltage dips	National databases
Voltage dips	Advice measurements/equipment
Voltage dips	Assistance problem-solving

The ranking of needs for the DSOs are combined with the problem ranking given by figure 2 for the quality of supply phenomena (excluding EMC specific issues) The results are given in table 4:

Table 4 Ranking of DSO quality of supply needs and phenomena problem ranking

Phenomenon	**Type of need**	**Ranking of needs**	**Phenomena problem ranking**
Transients	Advice measurements	1	6
Flicker	Advice measurements	2	5
Harmonics	Advice measurements	3	8
Inter-harmonics	Advice measurements	4	14
Temp. overvolt.	Advice measurements	5	7
Temp. overvolt.	Basic technology transfer	6	7
Transients	Basic technology transfer	7	6
Short supply interruption	Standardisation	8	2
Voltage dips	Advice measurements/ equipment	9	3
Transients	Assistance problem solving	10	6
Voltage dips	Basic technology transfer	11	3
Voltage var.	Simulation/ decision support tools	12	1

As Table 4 shows, the ranking of needs is not the consistent with the ranking of which phenomena that is most important from a problem source point of view. This is not necessarily inconsistent. The ranking of needs could be related to what is required to better manage the issue, to increase the competence, to improve the documentation etc. while the problem ranking can be interpreted the as number of problems and complaint associated with the issue. Hence, both perspectives are of importance.

4. Conclusion

The most important quality of supply phenomena as sources for problems for the DSOs is given by the following ranking:

1. **Supply voltage variations**
2. **Short duration supply interruptions**
3. **Voltage dips**
4. Long duration supply interruptions
5. **Rapid voltage changes/flicker**
6. Transient overvoltages
7. **Temporary overvoltages**

The phenomena written in bold are the ones also prioritized by the TSO.

The most important need for quality of supply improvement according to the DSOs is to get advice concerning measurements and measurement equipment:

The TSO sees basic technology transfer, national databases, advice concerning measurements/ measurement equipment and standardisation as important issues in general, but the needs are different for different phenomena.
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- Powel (ICT company)
- Hafslund Nett
- Helgeland Kraftlag (DSO)
- Lyse Nett (DSO)
- Skagerak Nett (DSO)
- Istad Nett (DSO)
- NTE (DSO)

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