TRENDS IN QUALITY OF SUPPLY IN A LIBERALIZED ELECTRICITY MARKET

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ABSTRACT

It is a question of concern if - and how - the vulnerability of the electric power grid and probability of interruptions is increasing as assets are ageing and components are being utilized closer to their limits. These aspects may have severe long-term consequences which it is of vital importance to know more about. The comprehensive data basis in Norway on component faults and end-user interruptions has been explored to reveal trends in the level of quality of supply and the technical condition of the network. The study shows that there has been a considerable reduction in energy not supplied while the number of delivery point interruptions is almost unchanged. However, in the same period there has been a significant increase in the fault rate for temporary faults for overhead lines. This is mainly due to increased focus on registration of automatic breaker re-closure and short interruptions.

INTRODUCTION

In countries with liberalized electricity markets and a steadily tightening regulation of network companies, the increasing efficiency requirements and demand for cost reductions has led to less investments, reduced maintenance and work force reductions. To counteract that cost reductions will lead to a declined quality of supply, regulatory steps are taken in many countries e.g. in the form of quality requirements and penalty schemes [1 - 3]. Some countries have even adopted regulations for a maximum duration of interruptions [4].

The emerging quality of supply regulation in different countries has led to a need for more versatile and reliable interruption statistics and even more detailed supply quality data (e.g. voltage quality) is gradually being used for regulation purposes. In an ongoing co-operation at European regulatory level, needs for definitions, harmonisation and standardisation within this field are identified [5].

REGULATION OF QUALITY OF SUPPLY

Quality of supply (QoS) regulation was introduced in Norway in general terms by the energy act in 1991. Since then the Norwegian Water Resources and Energy Directorate (NVE) has taken various steps concerning the quality of supply. In 1995 it became mandatory for the network companies to report interruptions (> 3 minutes), for end-users at all voltage levels > 1 kV. In 1997 the revenue regulation of the network companies was put into force, and the cost of energy not supplied arrangement (CENS) in 2001 [7, 8]. CENS is based on a mandatory interruption reporting that follows FASIT specifications [9].

The QoS regulation was extended in 2005 by the inclusion of different voltage quality aspects as well as certain regulations regarding customer services such as information, monitoring etc. [10]. From this year it also became mandatory to register and report short interruptions (≤ 3 minutes). In 2007 a new revenue regulation period has started and from this year compensation for interruptions of duration > 12 hours is introduced. The regulator (NVE) furthermore plans for inclusion of short interruptions in the CENS arrangement from 2009. The Norwegian QoS regulation is discussed in [11].

STUDY MOTIVATION AND ANALYSIS

An important basis for the quality of supply regulation and management is the documentation of existing quality levels. In Norway a comprehensive data basis on component faults and end-user interruptions has been established since the deregulation in 1991. As mentioned reporting of delivery point (end-user) interruptions has been mandatory since 1995 while a voluntary reporting of distribution component faults has been going on since 1989. In addition there has been a national voltage quality measurement program going on since 1992. Results from these measurements and interruption statistics up to 2000 are reported in [6].

The interruption data is used by NVE to follow-up the development of quality of supply and as a basis for performance indicators and decision-making in network operation. Utilization of interruption statistics in this context is a common topic of interest in the Nordic countries and co-operation is going on to harmonise and standardise the systems for collection and reporting of data [12].

It is a question of concern if - and how - the vulnerability of the electric power grid and probability of interruptions is increasing as assets are ageing and components are being utilized closer to their limits. These aspects may have severe long-term consequences which it is of vital importance to know more about.

This paper reports results from a study of continuous fault and interruption data for the period 1989 – 2005. The data basis has been explored to reveal trends in the level of quality of supply and the technical condition of the network. The study addresses trends in number of interruptions, interruption duration and energy not supplied for delivery points in overhead and cable networks, as well as fault causes and fault rates for the main network components.

The main findings in the study are shown in the following.

FAULT AND INTERRUPTION DATA

The data analysed are from three different sources; the Norwegian electricity regulator (NVE), the Electricity Industry Association (EBL) and the Transmission System Operator (Statnett). Put together, these data cover all voltage levels ≥ 1 kV. Reporting of disturbances and component faults has been voluntary for the distribution system operators up to now. However, from 2007 it is mandatory to report disturbances and faults at all network levels. The distribution fault statistics cover 50 - 80 % of the network in the period 1989 - 2005. In the analysis shown the data has been scaled to be representative at the national level.

Fault analysis and reporting shall be in accordance with the FASIT specification [9]. FASIT makes it possible to record information about faults on electrical equipment and delivery point interruptions. The following data are registered:

- Information about the event (date, type etc.)
- Consequences (affected network parts, ENS etc.)
- Description of the fault (component, cause etc.)

Some general trends are observed regarding data quality and extent over the period 1989 - 2005;

Reporting extent: There is a significant increase in reported cases. This is mainly due to the QoS regulations regarding interruption statistics as well as increased voluntary reporting (fault statistics).

Data Quality: The data quality has improved considerably. The main reasons for this development lie in standardisation (definitions, registration principles etc.), regulatory requirements as well as an extensive increase in competence within the sector (through education, courses and seminars).

OVERVIEW 1989 - 2005

The total numbers of faults (temporary and permanent) and planned disconnections have been relatively stable over the period as shown in Figure 1 for all network levels 1 – 420 kV. We have found that > 90% of all events occur in the distribution network (1 – 22 kV). Closer examination of these data have shown that the number of permanent faults are relatively stable while the temporary faults had a decreasing trend in the period 1989-1995, and has increased since at the distribution level. This is due to a shift in focus on registration of automatic breaker re-closure and short interruptions. At the higher voltage levels (33 – 420 kV) there is observed a decrease in disturbances over the period.

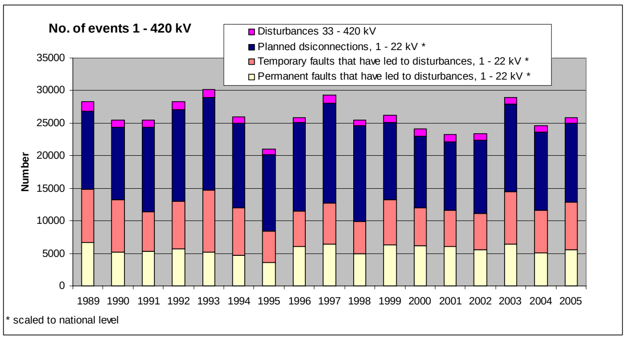

Figure 1 Number of events 1 – 420 kV. National level.

Trend analysis of energy not supplied (ENS) is shown in Figure 2. A considerable reduction has taken place, mainly due to a significant reduction in interruption duration. This is assumed to be caused by increased utilization of automation and remote control, as well as reserve supply and to some extent live line working. The figure shows that the larger part of ENS occurs due to events at the distribution level (74% in the period 2000 – 2005). Some of the peaks that can be observed from Fig. 1 and 2 in number of events and ENS are caused by heavy storms (1992, 1993 and 2003). Wind and icing led to a peak in 1989 while a breakdown of a 420 kV transformer caused the major portion of ENS at 33 – 420 kV in 1997.

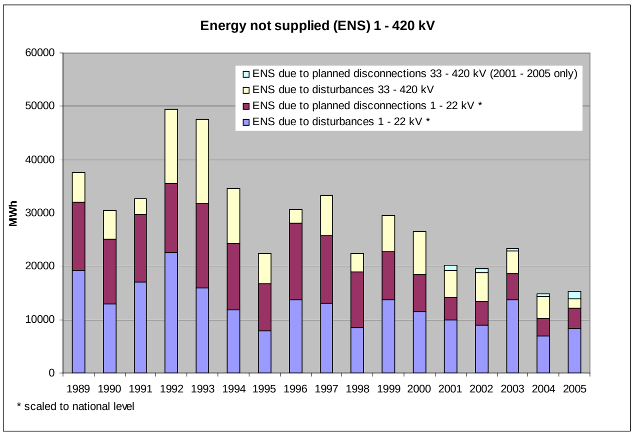

Figure 2 Energy not supplied 1 – 420 kV. National level.

FAULT CAUSES AND FAULTY COMPONENTS

The fault analysis provides information about the triggering fault causes and the faulty components. The fault causes are grouped in the following (from 1999):

- Environmental
- Technical
- Operational stress
- Human
- Design/maintenance etc.
- Other, unknown

Figure 3 shows the distribution of the triggering fault causes for the period 1989 – 2005 at the network levels 1 – 22 kV. The dominant fault causes are environmental (lightning, wind, vegetation, snow/ice, birds/animals etc.), followed by cause "unknown" (35 % on average). At the highest voltage levels (33 – 420 kV) "technical" is the second largest group of fault causes. The distribution of causes is slightly changed over the period 1989 – 2005. There is a trend that the portion of faults with cause "unknown" is decreasing while the portion of environmental faults is increasing. This is assumed to be a result of the continuous competence building regarding fault analysis and registration.

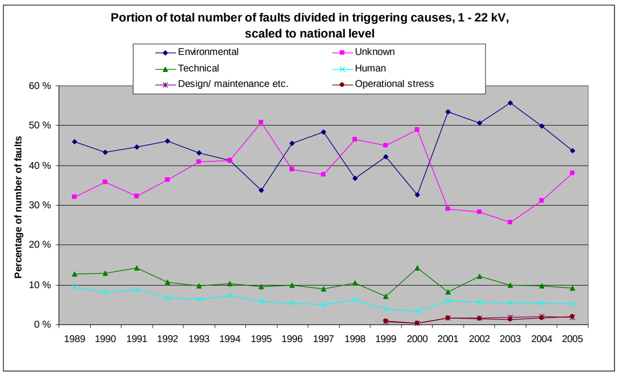

Figure 3 Triggering fault causes 1 – 22 kV, 1989 - 2005.

Overhead lines are the dominating faulty components and main contributors to ENS at all levels, followed by cables at the distribution level. Protection and control equipment is the second largest contributor to ENS at the highest voltage levels (33 – 420 kV), as outlined in [13].

Fault rates have been monitored where possible over the period under study and trends are analysed. By and large, developments are positive, but with one exception, namely overhead lines at distribution level. A significant increase in the fault rate for temporary faults is observed since 1998, see Figure 4. One reason is that there are larger portions of faults registered on overhead lines instead of "component not identified". The main reason is however assumed to be the increased focus on registration of automatic breaker re-closure and short interruptions.

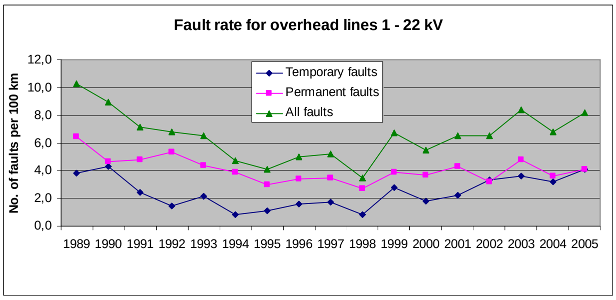

Figure 4 Fault rate for overhead lines 1-22 kV.

PLANNED DISCONNECTIONS

Trends in planned disconnections are investigated at the distribution level. The number of disconnections divided in different causes is shown in Figure 5 for the period 1999 - 2005. Preventive maintenance and new building/ reconstruction are found to be the dominant reasons for planned disconnections. The total number per year is about 12000 and has been rather stable over the period. There was however a top in disconnections in 2003 due to need for repair after a storm that year.

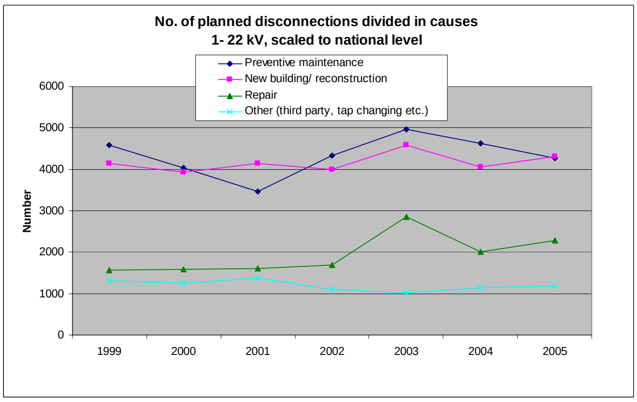

Figure 5 Planned disconnections 1-22 kV, 1999 - 2005.

END-USER INTERRUPTIONS

This section gives an overview of end-user interruptions. Only aggregated numbers covering all network types and voltage levels are given. Figure 6 and Figure 7 show the number of interruptions per delivery point1 (DP) and the average interruption duration respectively.

Figure 6 shows that there has been a slight increase in non-notified interruptions (13 %) while the notified interruptions are reduced by 45 % over the period 1996 – 2005. The major reason for this reduction is assumed to be that the planned disconnections affect fewer end-users than in previous years. For the same reason the average interruption duration (per interruption and DP) for notified interruptions has been reduced by 31% over the period 1996 – 2005.

1 Delivery point = Secondary side of distribution transformer or high voltage customer

Another reason is the increased use of reserve supply.

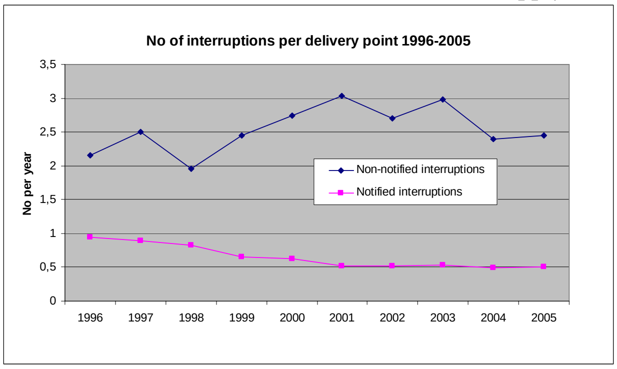

Figure 6 # interruptions (average) per DP.

The duration of non-notified interruptions has remained relatively stable. See Figure 7. A closer look at the distribution of interruption duration shows that for the 10 % longest lasting non-notified interruptions there has been an increase in average duration. This is expected to be due to a reduction in repair capacity over the period.

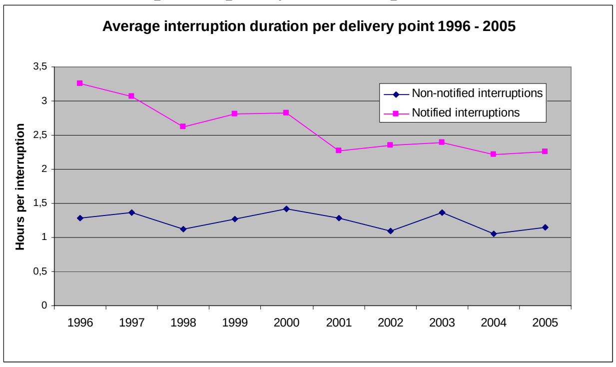

Figure 7 Average interruption duration per DP.

CONCLUSIONS

The results from the study reported in this paper show that in general the level of quality of supply has been relatively stable or even improving. There has been a considerable reduction in energy not supplied for end-users, while the number of delivery point interruptions is almost unchanged. In the same period the fault rate for temporary failures has increased for overhead lines. This is expected to mainly be a result of an increased focus on registration of automatic breaker re-closure and short interruptions. Generally the study has not identified any alarming trends regarding the technical condition of the network. However these conclusions are based on highly aggregated information. The study has also revealed that as a consequence of QoS regulations, standardisation and competence building the quality and extent of fault analysis and reporting has been considerably improved over the time period (1989 – 2005). Increasing interest from regulators in Europe towards regulating QoS increases the need for a harmonised and standardised statistics to perform benchmarking and to monitor trends.

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