DANISH QUALITY OF SUPPLY REPORTING REQUIREMENTS

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ABSTRACT

The paper presents the Danish quality of supply reporting requirements, which came into force on 1st January 2006. The requirements are entirely related to the continuity of supply since no voltage quality issues are included in the guidelines. The paper gives a short description of the background and development of the scheme, of the anticipated benchmarking model and of how the quality parameters might be implemented in the regulation. The main part of the paper describes the general principles for registration of interruptions of the supply. Finally a few future prospects are described.

INTRODUCTION

Up to now the regulation of the Danish distribution network operators (DNO's) has focused on efficiency and cost reduction without any considerations for the quality of supply. The Danish authorities seem to have reconsidered this attitude and the quality of supply will thus be a parameter in the future benchmarking of the companies.

Including the quality of supply in the future benchmarking requires reliable data, but so far the authorities have never collected such data. During the last 30-35 years DEFU has recorded interruption statistics based on data from most of the larger Danish network operators, but since these data do not cover the entire sector and not necessarily honour all of the authority's requirements, an alternative system had to be developed.

The Danish Energy Regulatory Authority has considered different approaches to the subject as described in their report about monitoring the continuity of supply [1]. The continuity of supply in Denmark is considered to be at a satisfactory level, so the overall objective is to maintain the present quality level. Some of the conclusions in the report, which outlines the requirements, are as follows:

- All voltage levels are to be included.
- The continuity of supply key figures are to be based on the number of affected end users. Incidents that affect a large number of end users add thus more to the key figures than incidents that only affect a few.
- Interruptions to supply lasting 1 minute or longer are to be recorded.
- Interruptions to supply have to be recorded as from 1st of January 2006.
- Due to implementation costs electricity not supplied (ENS) and end user costs will not be considered.

The Danish Energy Regulatory Authority has subsequent postponed the commencement of the registration related to the low voltage network. Registration of incidents at low voltage level will thus be optional during the first year.

In addition to the conclusions listed above, the report concluded that it was necessary to prepare a set of guidelines for the registration. DEFU was subsequent commissioned to develop these guidelines [2]. The main content is described below.

REGISTRATION OF INCIDENTS

The objective of the requirements is to make it possible to present a true and fair view of the companies' continuity of supply without imposing too rigorous demands. This is not easily obtained since a high degree of justice also requires a very detailed reporting and therefore some compromises have to be reached.

Based on the high voltage statistics and rules of thumb it was estimated that approximately 5-10 % of the interruptions are caused by low voltage incidents, 65-70 % by 10-20 kV incidents and the remaining 20-25 % by incidents at higher voltage levels. Assuming that this can be trusted it is reasonable to spend most of the resources at high voltage level, which is also reflected in the guidelines.

The guidelines are to be considered as minimum requirements and the DNO's can therefore choose to implement more accurate reporting schemes if they find this appropriate. In the following the most important minimum requirements will be described.

For each incident that causes an interruption of the supply to one or more customers for one minute or longer the DNO has as a minimum to register e.g.:

- Date and time
- Duration
- Number of disconnected customers
- Disconnected HV reporting points (in case of incidents in the high voltage grid)
- Voltage level
- Whether the interruption was a planned outage or caused by a fault
- Cause of the fault

It is important to notice that every HV reporting point must be designated with a unique identification, whereas the individual end users do not need to be identifiable.

At present there are 106 DNO's in Denmark. Some operates low voltage networks only; some operates high voltage networks at one or several levels and some both high voltage and low voltage networks. The statistics must reflect this fact in order to make the collected data comparable. It has been chosen to divide the statistics into several groups, each representing one voltage level as illustrated below.

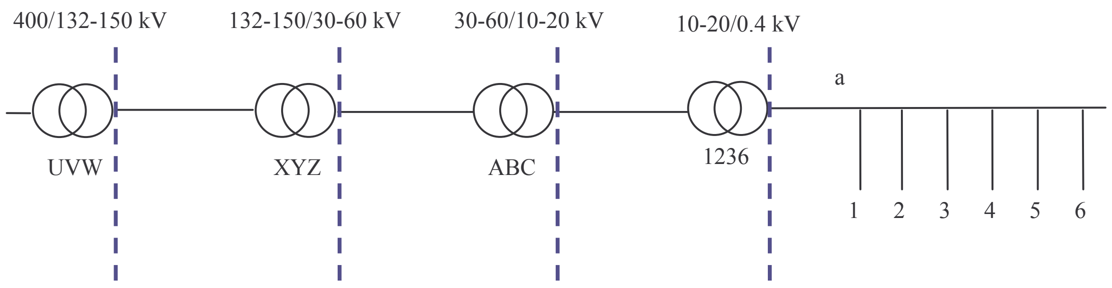

Figure 1. Division by voltage levels.

A reporting point must be defined at the lower voltage side of each transformer as well as at every boundary between companies or between company and customers connected at high voltage. Every time one or more of these reporting points are disconnected it must be recorded. This means that a fault at e.g. 132-150 kV, which causes interruption to supply, must be recorded at 132-150 kV as well as at 50-60 kV and 10-20 kV. In addition the relevant number of affected customers must be recorded at each voltage level.

Two types of reporting points have been defined at 10-20 kV in order to make it possible to distinguish ordinary distribution transformer points from transformers connecting wind turbines to the grid. Wind turbines are usually connected to the grid through collection feeders, which are designed exclusively for connection of decentralised power producing units. Most often these have only one-sided connectivity to the grid. Long lasting incidents such as planned outages in one of the secondary substations can therefore result in long interruption durations for several other secondary substations at a feeder, which leads to some unnecessary distortion in the continuity of supply key figures.

The main principles in the guidelines will be described below using a few examples. For simplicity, there is no distinction between the types of reporting points and not all required information is included in the examples.

Example 1:
While excavating a contractor damages a 10 kV cable which causes interruption to supply for three 10 kV reporting points (1234, 2345 and 3456) and 375 low voltage customers:

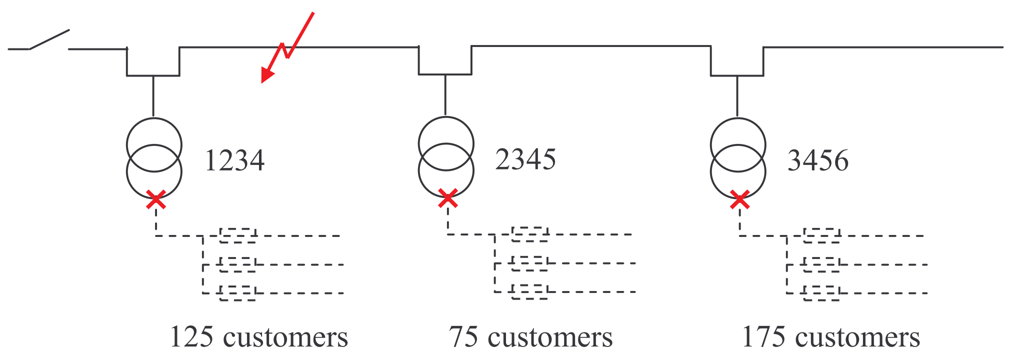

Figure 2. High voltage fault resulting in disconnection of 3 reporting points and 375 customers.

The duration is 1 hour for the customers connected to 1234 and 2 hours for the remaining customers. The company must then register the following information about the disconnected reporting points and customers:

Reporting point	Duration (hh:mm)	Affected customers
1234	01:00	125
2345	02:00	75
3456	02:00	175

Table 1. Outage information.

In addition information about date and time, cause of fault etc. must be recorded. This information is not important for the discussions in this paper and is therefore omitted.

In theory this principle could apply at low voltage too, and a reporting point could hence be allocated to every end user. In practise it is not possible for most companies to keep accurate track of the connectivity of the individual end user. In addition it would demand a high degree of automation to handle the great amount of data produced by an interruption at e.g. transmission level.

The count of customers connected to every 10-20 kV reporting point as shown above was considered to be a cost effective way to handle the low voltage customer interruptions. In case of a high voltage interruption the low voltage customers are expected to be interrupted in the same period of time as the feeding transformer. Due to the accurate monitoring of the designated reporting point, it is also possible to get a good estimation of the overall consequences for the customers.

Outages caused by faults and planned outages at low voltage level are handled in a likewise manner. The minimum requirement is registration at feeder level. In case of a fault that results in disconnection of the low voltage feeder, the feeder designation, the outage duration and the number of customers must be recorded. Every customer connected to the feeder is counted as being cut off as long as just one customer is without supply. The company can choose to make a more accurate registration, but this might not be worth the effort assuming that only 5-10 % of the end user interruptions are related to faults and planned outages at low voltage level.

Example 2:
A fault at the low voltage feeder causes the fuse in the substation to blow which subsequent causes interruption of 50 customers.

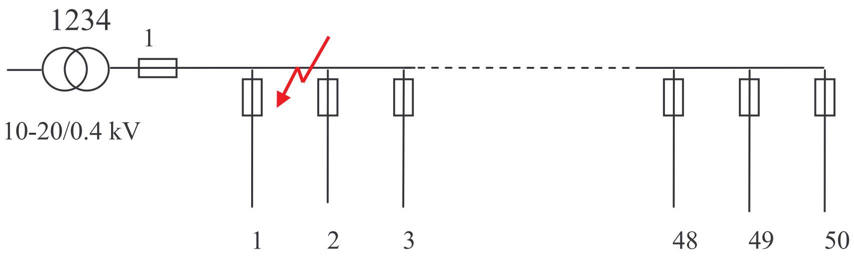

Figure 3. Low voltage fault resulting in disconnection of feeder 1(feeders 2 and 3 are not shown) and 50 customers.

Assuming duration of 45 minutes, the following must be recorded:

Feeding reporting point	Feeder	Duration (hh:mm)	No. of interrupted customers	Total no. of customers
1234	1	00:45	50	50

Table 2. Outage information.

In order to make it possible to estimate the interruption frequency at end user level, the designation of the feeding reporting point must be recorded. Combining the knowledge of interruptions at high and low voltage levels makes it possible to make a fair estimation of the interruption frequency and durations for a particular end user. Assuming that the customers have been interrupted as described in examples 1 and 2 only and also assuming that the connectivity has been unchanged, it is obvious that customer 1 through 50 have been interrupted twice while the remaining 325 customers have been interrupted only once.

The suggested estimation will of course not be very accurate over a long period of time since the low voltage connectivity often changes, but the only alternative seems to be a full registration at end user level.

It is worth mentioning that a few companies operate meshed low voltage networks, which complicates the matter a great deal. A solution to this problem is suggested in the guidelines [2].

In accordance with the outlines in the Danish Energy Regulatory Authority's report, the number of interrupted customers must also be recorded in case of faults at higher voltage level e.g. 30-60 kV. This is not as unambiguous as at distribution level while the connectivity may not be as simple. In addition the ownership boundaries seem to be determined in various ways throughout the country which makes it even more difficult to make clear-cut registration principles. Experience learned so far also indicates that the guidelines might need some improvements in this area.

The network operator must record information about every fault that causes interruption to supply. With a few minor exceptions the registration principles are as for the 10-20 kV level. The disconnected customers must be counted as the sum of customers at the actual voltage level and the total number of disconnected customers at lower voltage levels (including low voltage). If a fault is causing disconnections of costumers in a neighbouring company (including customers connected at lower voltages) these are to be registered in the neighbouring company. This is to avoid that a fault is reported to cause disconnection of more customers than the company are supplying under normal conditions.

Interruptions caused by faults at other voltage levels or in neighbouring companies have to be registered in every company involved in the incident (excluding low voltage). The companies have to analyse the incident in co-operation and the companies not responsible will record this fact in their report.

Example 3:
A fault at 60 kV causes disconnection of one 60/10 kV transformer (ABC), three 10/0.4 kV transformers (1234, 2345 and 3456) and 375 customers (all connected at low voltage):

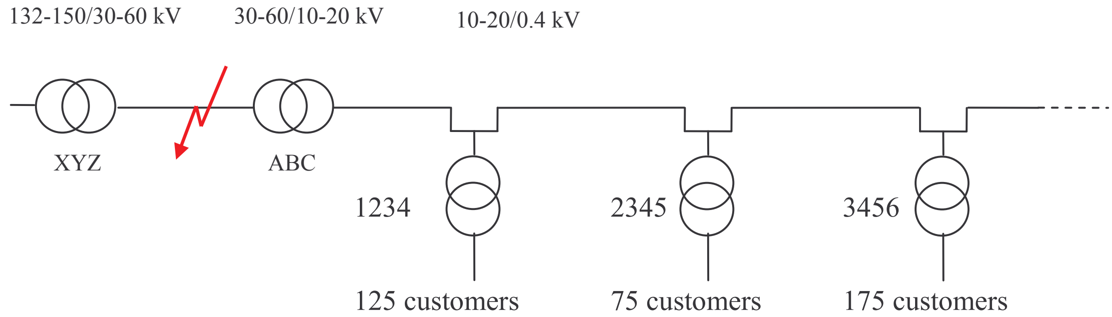

Figure 4. A 60 kV fault causing interruption to supply at 10 and 0.4 kV level.

In this situation the company which operates the 60 kV network must register the following information about the disconnected reporting point and the disconnected customers:

Reporting point	Duration (hh:mm)	Affected customers
ABC	00:10	325

Table 3. 60 kV outage information.

A customer connected at 60 kV would have been designated with a reporting point, and also registered with the relevant outage duration.

The company operating the 10 kV network must also register the outages. Like a disconnection at 10 kV level, every single disconnected reporting point must be recorded:

Reporting point	Duration (hh:mm)	Affected customers
1234	00:10	125
2345	00:10	75
3456	00:10	175

Table 4. 10 kV outage information.

In principle this approach makes it possible to get an overview at the continuity of supply at each high voltage level.

OUTPUT REPORTING REQUIREMENTS

The Authority does not collect detailed information about the occurring incidents. The DNO's are trusted with this job and are merely requested annually to report some selected key figures to the Authority. In addition to the key figures each company shall make a short description of the continuity of supply in the year that went by. This makes it possible for the company to describe extraordinary events during the previous year e.g. severe weather incidents or other relevant information.

In the beginning the companies must report SAIFI[1], SAIDI[2] and CAIDI[3] and similar figures for the reporting points. The key figures have to be calculated separately for both types of reporting points as well as for the company as a whole.

The suggested key figures are useful for an assessment of the general continuity of supply level in each company. It is at present not certain if this will be considered sufficient, since some customers in a well performing company in principle can experience frequent interruptions to supply. It is quite probable that the key figures will have to be supplemented by e.g. frequency and duration distributions, to get an overview of the continuity of supply also in its extremities. The principles in the guidelines should allow for such extensions to the output reporting requirements as described above.

BENCHMARKING

It is still uncertain how the Danish Energy Regulatory Authority intents to benchmark the DNO's. So far it is decided that the benchmarking shall take effect from the 1st of January 2007 and that economic parameters as well as quality of supply shall be included. The meaning of the term 'quality of supply' is not specified in the departmental order, but in the first instance the interpretation suggests that the quality can be described by continuity of supply only. In the future it is quite possible that additional parameters such as voltage quality or commercial quality will be included.

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[1] System Average Interruption Frequency Index = Number of interruptions/Total number of customers [5].
[2] System Average Interruption Duration Index = ∑ Duration of all interruptions/total number of customers [5].
[3] Costumer Average Interruption Duration Index = ∑ Duration of all interruptions/number of interruptions [5].

It has not been decided yet exactly how the companies shall be benchmarked, but considering the available time frame, it seems almost certain that the benchmarking will be based on the 'grid volume model' developed by PA Consulting Group for the Danish Energy Regulatory Authority [3]. The model uses physical components as cost drivers such as:

- Number of transformers at different voltage levels
- Number of contact bays at different voltage levels
- km cable and overhead line at different voltage levels
- Number of customers

Each cost driver is assigned a cost equivalent and the grid volume sums up the expected operating costs:

$$\text{Grid Volume} = \sum n_i \cdot \boldsymbol{e_i}$$, where:

n_i is the number of grid components i
e_i is the cost equivalent of a component I in an average company.

The relative efficiency of a company can then be determined:

$$\text{Relative efficiency} = \frac{\sum \text{Grid volume}}{\sum \text{Operating costs}}$$

It is acknowledged that the original cost equivalents need to be updated, which should be possible in due time though. The Authority has already done some of this work, but the details of this work are not published yet.

Continuity of supply issues are not considered in the grid volume model, and it is therefore necessary to include the relevant parameters or develop a supplementary model which makes it possible to rank the companies by these parameters. The model must reflect the differences between companies operating in different environments. DEFU's interruptions statistics shows that the average interruption frequency in rural areas is 2-3 times the average interruption frequency in urban areas at 10-20 kV level [4]. The average outage duration is roughly speaking the same in the two types of areas. This implies that the average interruption duration is also 2-3 times higher in rural areas.

There is no exact knowledge about the consequences for the customer based key figures, which probably will be basis for the benchmarking, since the number of customer interruptions has never been recorded nationwide. Assuming homogeneous customer distribution in the individual companies, the proportions will of course be the same, but since most companies operate in both urban and rural areas this may not be a very accurate estimation. Regardless of this aspect there are definitely some significant differences that must be taken into account in the benchmark model.

It is possible that some of the principles in the grid volume model can be used in the development of a continuity of supply benchmarking model. Intuitive there must be a connection between e.g. the number of interruptions and the extension of the grid. Rough calculations based on the 10-20 kV statistics and assumptions of homogeneous customer distribution also indicate that the differences between urban and rural based companies can be reduced if the number of interruptions is related to the grid extension. Despite the improvements gained by using this approach, there are still some differences that cannot be explained by poor or good performance only. It is likely that some of the differences are due to a very inhomogeneous customer distribution in some companies, and this introduces too large errors in the estimations. This will be apparent when the first key figures are published in the spring 2007. It is also probable that more parameters are needed in order to achieve a fair benchmark.

It is notoriously difficult to collect comparable statistical data from a great number of sources because of differences in the interpretation of guidelines, differences in company routines etc. Usually it takes a couple of iterations to get things right which implies that it cannot be anticipated that the collected data are flawless the first couple of years. The Authority seems to have recognized this, and it is therefore likely that the initial economic consequences of a continuity of supply benchmarking will be very limited.

FUTURE PROSPECTS

Some significant changes to the proposed scheme can be anticipated in the future. The Authority has chosen not to include ENS due to the expected implementation costs as estimation of ENS at especially low voltage level is rather time consuming without metering. However the Authority concludes that they consider the ENS key figure to be more accurate than interruption frequency and duration indices [1], and it is therefore not impossible to imagine ENS in a future Danish benchmarking.

Even though the regulation of the DNO's seems to be based entirely on the benchmark in the first instance it can be interesting to consider alternative solutions. In some of our neighbouring countries compensation schemes has already been implemented and it is possible that the Danish regulation to some extend will take this direction too. At present several Danish companies are implementing remote metering of every single end user, and besides other advantages remote metering can make it easier and more cost effective to keep track of interrupted end users. This facilitates more accurate key figures but also the possibility to implement a fair compensation scheme in the future.

There has not yet been a significant focus on voltage quality parameters as benchmarks, but it is likely to come. The Authority has noticed that such parameters can be relevant for customers and might wish to include them in a future benchmark. However the empirical basis for this kind of benchmark is not sufficient at the moment, since no nationwide metering schemes have ever been implemented. It is therefore not probable that voltage quality will be a part of the benchmarking in the years to come.

CONCLUSIONS

The paper has presented the background and the general principles in the most recent Danish guidelines for recording interruptions to supply. Every DNO must record information about interruptions to supply lasting 1 minute or longer. As from 1st of January 2006 every incident in the high voltage grid must be recorded, and this is extended to include the low voltage grid as from 1st of January 2007. Once a year the DNO's must report CAIDI, SAIFI and SAIDI key figures to the Danish Regulatory Authority.

It is anticipated that the grid volume model will be basis for the efficiency benchmark, but it is still not decided how the quality are to be implemented. Financial implications due to interruptions to supply are still not known, but it seems unlikely that the Authority will impose severe financial incentives on the companies in the next couple of years. This is due to the fact that fair ranking of the companies seems to require a thorough analysis and that the necessary data for this have not been collected yet.

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