BENCHMARKING DANISH NETWORK OPERATORS ON QUALITY OF SUPPLY

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ABSTRACT

This paper presents the Danish quality of supply reporting requirements, which came into force 1st January 2006. The requirements are entirely related to the continuity of supply since no voltage quality issues are yet included in the guidelines. The paper gives a short description of the background and development of the scheme and how quality parameters will be implemented in the regulation. In addition the special problems related to interruptions to supply in meshed LV networks will be addressed.

INTRODUCTION

Like regulators in many other countries, the Danish Regulatory Authority (DERA) pays great attention to the quality of supply and the potential negative consequences caused by inappropriate incentives in the regulation. During the first years of deregulation, the regulator focused on efficiency and cost reduction without any considerations to the quality of supply. However the authorities seem to have reconsidered this position and quality of supply will thus be a part of the future benchmarking.

In order to keep the imposed scheme simple in the beginning, it was decided to include continuity of supply as the only quality parameter. This attitude may change over time, though.

DERA 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 mentioned below:

- All voltage levels (i.e. 0.4, 10-20, 30-60, 132-150 and 400 kV) are to be included.
- The continuity of supply key figures will 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 one minute or longer are to be recorded.
- Interruptions to supply have to be recorded as from 1st of January 2006.
- Due to the costs of implementation electricity not supplied (ENS) and end user costs, will not be considered.

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 principles are 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 made.

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 apply 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 of the interruption
- Number of disconnected customers
- Disconnected HV reporting points (in case of incidents in the high voltage grid only)
- Voltage level
- Whether the interruption was a planned outage or caused by a fault
- Cause of the fault, from a predefined list of 6 causes

A customer is considered to be interrupted if one or more phases are disconnected.

At present there are 102 DNO's in Denmark. Some of them operate low voltage networks only; others operate high voltage networks at one or several levels and others again both in high and low voltage networks. The statistics must reflect this fact in order to make the collected data comparable. It has therefore been chosen to divide the statistics into several groups, each representing one of the high voltage levels of the single company. The low voltage network will be handled along with the 10-20 kV network in accordance to the principles described below.

High voltage networks

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 of supply, must be recorded at 132-150 kV as well as at 30-60 kV and 10-20 kV. In addition the number of affected customers must be recorded at each voltage level.

It is important to notice that every single HV reporting point must be designated with a unique identification, whereas the individual end users do not need to be identifiable. This makes it possible to keep accurate track of the supply interruptions for every single reporting point and by this process to some extend also the number of interruptions to supply caused by high voltage incidents for the customers connected to the grid by this reporting point.

The counting of customers connected to every 10-20 kV reporting point is 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 fair estimation of the overall consequences for the customers.

Radial low voltage networks

In theory the principle used at high voltage level could apply at low voltage too, and a reporting point could hence be designated to every single end user. However it is rather difficult for most companies to keep accurate track of the connectivity of the individual end users.

The minimum requirement is therefore set at feeder level. In case of a fault that results in disconnection of the low voltage feeder or a part of this, the feeder designation, the outage duration and the number of customers must be recorded. Every customer connected to the feeder is assumed to be cut off so 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.

In order to make it possible to estimate the interruption frequency at end user level, the designation of the feeding reporting point must also 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 connected at low voltage.

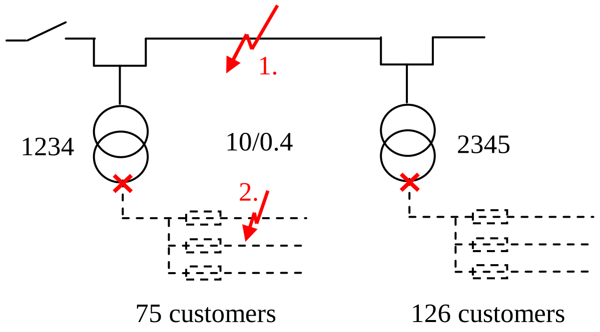

Figure 1: High and low voltage faults causing interruptions to supply. The faults are assumed to be non-simultaneous and the customers are assumed to be equally distributed on the LV-feeders.

Figure 1 shows a part of a 10 and 0.4 kV network and two faults causing interruptions to supply. The first fault which is on the 10 kV network, trips the substation protection and causes in this way interruption of supply to the 201 customers. The low voltage fault causes interruptions to supply for the 25 customers connected to LV-feeder 1 from secondary substation 1234. If it is assumed that the network also has been interrupted once due to a fault at transmission level, it is obvious that 25 customers have been interrupted 3 times, while the remaining 176 customers have been interrupted twice.

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

Meshed low voltage networks

In some Danish cities the DNO's operate meshed low voltage networks. End user connectivity in these networks is not as unambiguous as in radial networks, and the principles described above are therefore not necessarily applicable. The best solution seems to be voltage measurements at each end user, but since this would require installation of e.g. automatic metering and in this way impose more rigorous demands on a small part of the DNO's, another method had to be suggested.

Figure 2 illustrates a simplified meshed low voltage network. The network is fed by two separate 10 kV feeders and each low voltage section is protected by fuses. Several customers are usually connected to each low voltage section.

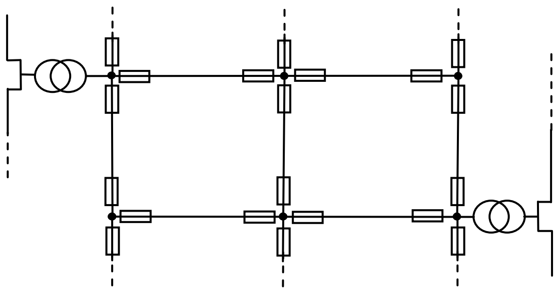

Figure 2: Simplified meshed low voltage network.

In case of interruptions to supply caused by incidents in the low voltage network, the DNO must register the unique designations of the disconnected low voltage sections, the number of customers connected to each section and the designation of the nearest reporting point. It is not very important whether the designated reporting point is in fact the nearest as long as the sections are always referred to the same reporting point.

Due to the interconnectivity most faults at 10-20 kV level will not cause interruptions to supply for end users connected at low voltage. In situations where interruptions to supply is nevertheless caused by faults in the high voltage network, great parts of the low voltage net will be disconnected and the circumstances are not that different from faults in 10-20 kV network supplying radial low voltage networks. In these situations the DNO must hence register the designations of the relevant reporting points as well as the duration, the number of affected end users for each reporting point.

In principle this methodology makes it possible to estimate the interruption frequency for a group of end users, using the method suggested for radial networks i.e. combining knowledge of the number of interruptions caused by incidents at high and low voltage level and the connection between high voltage reporting points and low voltage sections.

The accuracy depends indeed on the definitions of low voltage sections. Ideally a section should only include customers that can be disconnected simultaneously, this will typically be customers connected between two sets of fuses. In the extreme case each section can be defined to include only one single end user and the registration will thus be very accurate. For practical purposes the defined sections are assumed to include greater areas in order to reduce the work load.

BENCHMARKING

The regulator intention is to keep the benchmark quality of supply simple without losing the ability to ensure a proper level of supply for all customers.

The benchmark will thus be based on end user interruption frequencies and durations at system level (SAIFI and SAIDI respectively) as well as at end user level. As a first step the regulator intends to:

- Benchmark the individual DNO's against their previous performance in order to secure the preservation of an appropriate level of continuity of supply.
- Impose minimum requirements for the continuity of supply at system level.
- Impose minimum requirements for the continuity of supply at end user level.
- Include only interruptions caused by incidents in the DNO's own network.

Benchmarking of the DNO's against previous performance is in principle easy as long as there is no major changes in the registration principles, but due to the stochastic nature of interruptions to supply, data for several years is required. This is especially important when comparing small companies who may experience only one or two 10 kV faults each year, to larger companies with several hundreds of faults per year. The regulator has recognized this and the financial incentives will thus be limited in the first couple of years.

It may be more complicated to impose fair and effective requirements at system and end user level. Despite the fact that Danish DNO's are subject to rather similar operational conditions, available statistical material indicates that quite significant differences must be expected in the continuity of supply indices. Customers in rural areas must therefore expect 2-3 times as many interruptions to supply as customers residing in the city. Since these differences cannot be explained by good or poor performance only, the regulator faces the challenge of developing a simple benchmark model which accounts for the differences in operating conditions.

Most Danish DNO's have reported faults and outages on voluntary basis to DEFU for more than 30 years. By means of these statistics, DEFU has made a preliminary investigation of the problem. The work is far from complete, but it can be ascertained that some of the disparities might be reduced by referring the continuity of supply level to network or customer volume.

Figure 3 shows estimated SAIFI and a key figure representing the estimated number of end user interruptions per unit 10-20 kV network for urban and rural based companies respectively. Relevant data have only been available for half of the companies reporting to the statistical survey but additional data are assumed to be available in the very near future.

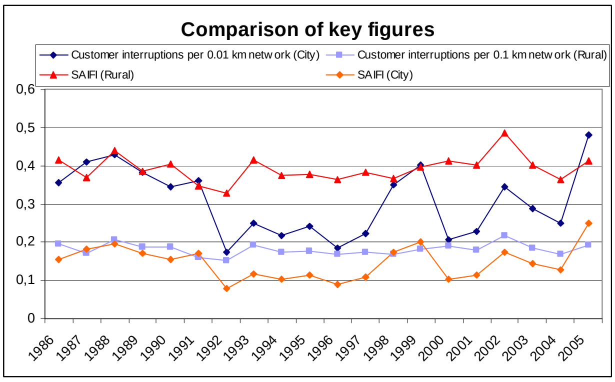

Figure 3: Comparison of continuity of supply in companies serving rural and urban areas using two different key figures (SAIFI and customer interruptions pr. 0.01 km 10 kV network respectively).

The figure above suggests that the differences between rural and urban based DNO's are slightly reduced when the number of customer interruptions is referred to the network proportions. The method tends to overcompensate companies operating networks in rural areas, though.

It is obvious that more work has to be done, but it is expected that a regression analysis of a greater set of data can lead to a simple model which can express a relation between network volume and customer interruptions.

Financial implications

The exact financial implications are yet not known, but it has been decided that the incentives will be a part of the price cap regulation and affected customers will therefore not receive separate payment. This is in line with the intentions of the registration guidelines, since these do not leave the possibility of keeping accurate track of the interruptions to supply for each single end user. As long as the statistics provide a true and fair view of the continuity of supply and end users do not receive any payment, it is not necessary to keep accurate track.

Since only interruptions due to fault in the companies' own network are included in the regulation, the risk of disputes between companies are minimized. This is hard to achieve if payment must be made to the affected end users, since these cannot be expected to distinguish between interruptions caused by faults in different parts of the network and will for this reason expect compensation regardless of the responsibilities of the different DNO's.

PROSPECTS

Some significant changes to the proposed scheme can be anticipated in the future. DERA 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, DERA conclude 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 have 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 Authorities have noted that such parameters can be relevant for customers and may 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 survey has ever been carried out. It is therefore not probable that voltage quality will be a part of the benchmarking in the years to come.

CONCLUSIONS

The Danish Regulatory Authority pays great attention to the quality of supply and has thus implemented a simple reporting scheme in order to facilitate benchmarking of the Danish DNO's on continuity of supply. The regulator intends to benchmark the companies against their previous performance and the regulator will add requirements for the continuity of supply at system and end user level respectively.

In order to achieve the overall objectives a special methodology has been developed. All customer interruptions caused by incidents at high voltage level are registered down to and including 10 kV. This information can be combined with similar information for the low voltage network and hence make it possible to estimate e.g. the maximum interruption frequency for small groups of end users. The suggested methodology can also to some extend be used in meshed low voltage networks.

REFERENCES

[1] Danish Energy Regulatory Authority, 2005, "Rapport om registrering af leveringssikkerhed", Copenhagen, Denmark (in Danish):

[2] Jensen M. M., 2005 "Indsamling af leverings-sikkerhedsdata", Danish Energy Regulatory Authority, Copenhagen, Denmark (in Danish).