FAULT AND INTERRUPTION STATISTICS: EXPERIENCES, UTILITARIAN VALUES, NEW REQUIREMENTS

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SUMMARY

The paper addresses several issues related to registration, reporting and use of fault and interruption statistics in the Norwegian transmission and distribution system. FASIT, a system for registration of faults and interruption, is presented together with experiences from the use of the system. An important reason for developing FASIT was requirements from the authorities related to reporting of customer interruptions. This is taken a step further next year in that the utilities are obliged to pay financial compensation for ENS to their customers.

INTRODUCTION

The Norwegian power system is characterised by a large number of small utilities. A total of 180 companies are operating the MV system, with a sum of 2 200 000 customers. As many as 45 % of these companies have less than 5 000 customers and only 5 % have more than 50 000 customers. This structure is due to geographical and historical reasons. In the HV system there is a different situation: Statnett, the system operator, is the owner of nearly 50 % of the main grid (> 110 kV).

After the deregulation in 1991 there has been an increased pressure for cost-effectiveness in the power system. This has lead to restructuring of the industry with concentration into larger units as the result. Thus, the number of utilities is constantly decreasing.

The transmission and distribution system is defined by the authorities as a natural monopoly with the Norwegian Water Resources and Energy Directorate (NVE) as the regulatory agency. NVE is requiring that the system should be optimised from a socio-economic point of view taking into account customers' interruption costs. These conditions have resulted in an increased need for reliable fault and interruption data as a basis for planning and operation of the networks. To deal with these challenges an extensive data basis is required. A collection and reporting system for power interruptions and component faults, denoted FASIT, was therefore developed and has been in use by Norwegian utilities since 1995. One of the challenges was to develop a system that stimulated as many companies as possible, large or small, to systemise the use of fault and interruption statistics.

THE FASIT SYSTEM

History/status

Since 1989 a system called FAS was used for reporting faults and interruptions in the MV system. After the deregulation the need for a more tailor-made system for registration of customer interruptions became evident. Thus, FASIT was developed as a part of The Norwegian Power Quality Programme [1]. The main objective was:

To establish a co-ordinated and standardised system for registration, reporting and analysis of fault and interruption data on all voltage levels, through preparation of:

- *Requirement specifications for registration of faults and interruptions*
- *A basis for calculation of key figures and statistics*
- *A specification for software tools for registration, reporting and statistics preparation*

Several software companies have developed FASIT programs based on these specifications, either as independent programs on a PC platform or as an integrated part of network/customer information systems (the dominant system being Netbas from Powel Data [2]). When FASIT was put into operation it was in the first phase mainly used in the MV system. So far, around 120 Norwegian utilities have purchased FASIT software and in addition an unknown number of (smaller) companies are using FASIT on a manual basis. The success of the FASIT system in Norway is to a great extent due to requirements on power quality stated by NVE. The following requirements were introduced in 1995:

The utilities are requested to report annual interruption indices based on registrations for each distribution transformer. Based on this documentation the utility must, when asked, inform their customers about the expected interruption level at their point of supply. Furthermore, the utilities are recommended to prepare fault and interruption statistics in FASIT.

Due to these requirements FASIT has in practice become the national standard for collection and reporting of fault and interruption data in the distribution system. From 1997 the operator in the Norwegian HV system, Statnett, has decided to use FASIT for collection of data on the 33-110 kV level as well. For registration of failures above 110 kV Statnett is using a self-developed system that is tailor-made for these voltage levels. This system is now co-ordinated with FASIT with respect to terminology etc.

New requirements

As a result of the experiences gained through 3 years with FASIT operation, together with new and stricter requirements from the authorities, it was decided to revise the system from 1999. The revision comprised the following main changes and extensions:

- Adoption of a new terminology standard developed in co-operation between NVE, The Norwegian Electricity Foundation (EnFO), Statnett and SINTEF Energy Research
- Some changes in the reporting scheme
- Development of a standardised method for estimation of energy not supplied (ENS)

The authorities have announced that all network utilities are obliged to pay financial compensation for energy not supplied (CENS) to their customers from the year 2000. FASIT is very important in providing the necessary documentation for this arrangement. The purpose is to get a long-term instrument to achieve a socio-economic optimal level in the quality of supply. The main issues in the arrangement the first years, will be as follows:

- A company causing a customer interruption (in their own or another network) is obliged to pay compensation to the affected customers according to the estimated amount of ENS. If the customers are connected to another network the compensation goes through the other network owner.
- Only interruptions exceeding 3 minutes shall be compensated.
- The customers should as a minimum be separated into two groups (household/agricultural and business/ industry) with different compensation fees. The fees for notified interruptions are lower.
- The companies are encouraged to establish agreements about other compensation fees with customers who want such contracts.
- A company is obliged to pay compensation for ENS caused by a third party.
- In a first phase only interruptions caused by the MV and HV network are compensated (due to practical reasons).

In addition to information about ENS for each load point or customer, FASIT software provides the ability to implement compensation fees for each customer group and for customers with individual arrangements. After registration of an interruption the FASIT software will calculate the amount of compensation to each customer, or at least the sum of compensation for each group of consumers connected to a load point. This calculation has to be done in close co-operation with the customer information system, especially since only very few utilities have modelled the low voltage network in their FASIT program. A practical way of dealing with this task will therefore be to let FASIT explore which distribution transformers that are affected by an interruption, and use the transformer names/references as tags in the customer information system and thereby identify the interrupted customers. The compensation fees should be stored together with other customer information in that system.

FASIT can further produce various interesting statistics connected to CENS, e.g. CENS caused by planned interruptions and outages, CENS caused by different components and fault types, CENS caused by own network and other networks, etc.

The financial compensation is based on the amount of ENS, and therefore it is necessary to have rules and guidelines for the estimation of this figure. The method consists of the following elements:

- General load profiles for each group of consumers
- Energy consumption last year
- Daily average temperatures from last year
- Time and duration of the interruption
- Average temperature the day the interruption occurred

General load profiles for 11 consumer groups have been developed from an extensive number of measurements performed at SINTEF Energy Research in the period 1981-1997. The database includes sufficient data for producing different profiles for working days, weekends, low load period (spring, summer, autumn) and high load period (winter). Based on these load profiles, together with temperatures and energy consumption from last year, ENS can be estimated for each of the year's 8760 hours for all relevant consumer groups. The average temperature from the day the interruption occurred is used to correct the amplitude of the profile. For customers / load points where hourly measuring are performed, the measurements can be used as a basis for producing the load profiles instead of the general profiles.

EXPERIENCES

The distribution system

FASIT is, as already mentioned, a follow-up system to FAS which was introduced in 1989. The four last years FASIT has been the foundation for preparing aggregated fault statistics for the whole Norwegian MV system. This national database is administrated by the Norwegian Electricity Foundation (EnFO). Reporting to the database is voluntary but the dissolution has nevertheless had a positive increase. Table 1 shows the dissolution compared to the whole MV system.

Table 1 Utility dissolution in the FASIT database

Year	% of utilities	% of MV network	% of customers	% of delivered energy	No of FASIT-reports
1995	20 %	35 %	42 %	40 %	8 400
1996	27 %	50 %	45 %	45 %	13 000
1997	38 %	65 %	70 %	70 %	19 000

The statistical content is of course to a certain extent influenced by what utilities have contributed each year, but all three years the quantity of data has been large enough to give significant statistics. Among many other aspects the statistics show that there are regional differences due to different climatic exposures between areas (and therefore different guidelines for construction), as well as differences between utilities with cable vs. overhead line systems.

Figure 1 gives an example from the above mentioned statistics put together with data from the former system (FAS), while figure 2 shows one result from the mandatory reporting of interruption indices to the regulator (NVE).

In 1997 about 113 000 distribution transformers were included in the Norwegian interruption statistics. These transformers had in average 3,1 interruptions with an annual interruption time of 6,4 hours. Energy not supplied was in average 0,366 ‰ of delivered energy.

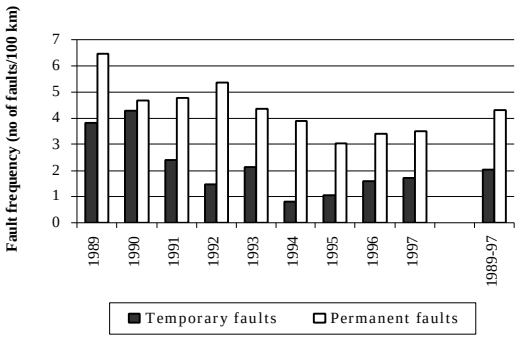

Figure 1 Fault frequency for overhead lines in the Norwegian MV system, 1989-1997.

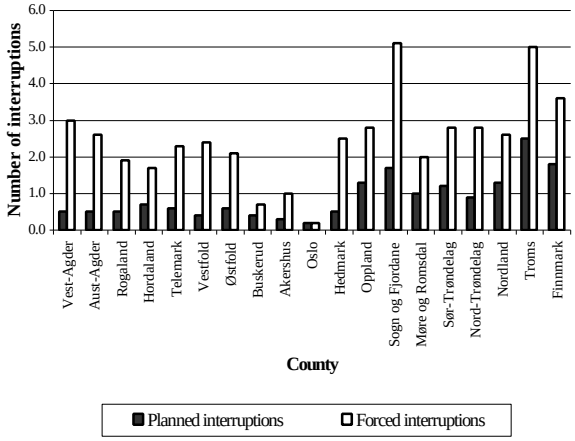

Figure 2 Number of planned and forced interruptions per distribution transformer in the 19 counties of Norway, 1997 (sorted from south to north starting from left)

The transmission system

Statnett is responsible for failure statistics for the voltage levels above 33 kV. This includes collection and publishing of data from the 33-110 kV networks, and analysis and registration of faults caused by disturbances in the main grid. In the period prior to 1996 the registration was based on information reported from the network owners in the HV system before further analysis by Statnett. The reporting practice during these years has varied and the statistics are therefore different in respect of extent and quality. The figures are most reliable for the highest voltage levels (110-420 kV) and more uncertain for the voltage levels below 110 kV. The main reason for this is that the reporting of faults in networks with voltage levels below 110 kV has been voluntary up to recently.

From 1997 the routines for reporting of faults were changed. The new routines can be summed up as follows:

- Faults in networks with voltage levels 132-420 kV, and generating units directly connected to these levels, shall be reported to Statnett. Statnett performs the fault analysis, stores the registered faults in a database and prepares statistics.
- The owners of the faulty equipment perform the fault analyses themselves in the 33-110 kV system. They register the faults in the FASIT system and send data files to Statnett twice a year, which prepares national statistics.

National statistics for the Norwegian transmission system is published annually. Two examples from the national statistics are shown in figure 3 and 4. In co-operation with the other Nordic countries a Nordic fault statistics is published annually as well.

There is about 30 000 km overhead line and 1 300 km cable length on the voltage levels above 33 kV in the Norwegian system.

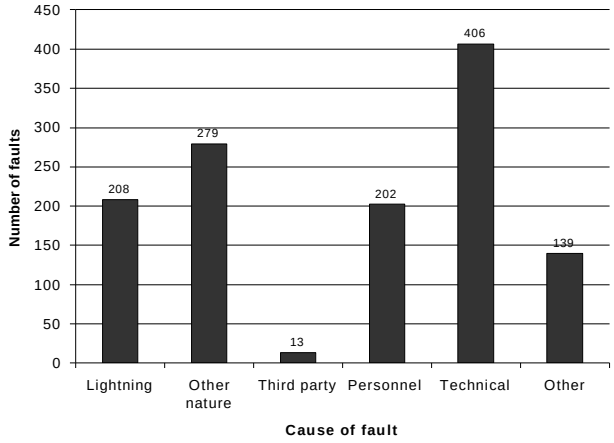

Figure 3 Number of faults sorted on different fault causes (voltage levels 33-420 kV, 1997)

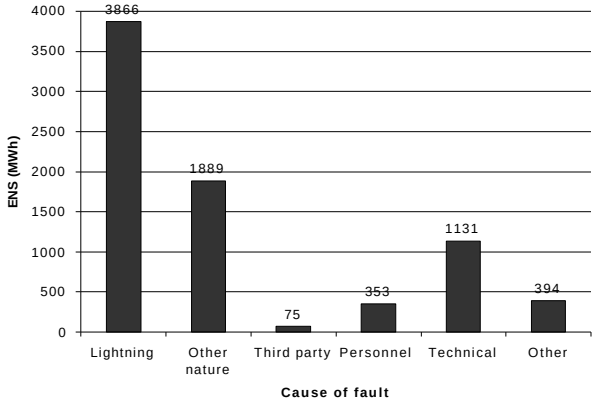

Figure 4 ENS (MWh) sorted on different fault causes (voltage levels 33-420 kV, 1997)

Full-scale use of FASIT

Various experiences are gained through the use of FASIT in practically the whole Norwegian network below 110 kV. The experiences have been reported during several courses in how to use FASIT, through sampling tests of reports submitted to the national database, via contact with users of the system and from developers of FASIT software programs.

Perhaps the most important feedback is the problems related to the large number of people involved, i.e. to get many persons to think the same way. How to get everyone involved in the FASIT work to understand and interpret the definitions and rules for registration of faults and interruptions uniformly? This is a major difficulty and a big challenge as long as there are as many as 180 utilities, with an average of three to five persons involved with FASIT. One must accept that the most complicated events are practically impossible to register the same way every time. In some cases there may even be more than one correct way of reporting a fault. However, these events represent the minority of the reports submitted during one year and the time and effort should first be focused on the more simple and vast majority of events. Controls of the reports submitted to the national database prove that there are much to gain by educating the involved persons in the basic rules and definitions.

The involvement from the regulator (NVE) has been very important with respect of getting the management in the utilities interested in such a work. NVE was deeply involved in the development of FASIT, both technically and financially, and later NVE has stated requirements and recommendations regarding reporting of key figures for interruptions. This has been an important contribution to the success of the system, and it is expected that next year's arrangement with financial compensation of ENS will further draw focus and resources towards FASIT (both locally and on a national level). This will undoubtedly further improve both the quality and the quantity of the data material.

Another important experience is that some kind of automation in the registration of interruptions for each load point / customer is necessary, at least for medium sized and larger utilities. Software tools are necessary for handling these tasks. The programs have also proven their strength through the connection between faults and items in the equipment database, making it possible to generate interesting statistics for individual items and load points (or groups of items / load points). Another benefit is of course the possibility of producing local statistics and the easy way reports can be exported to e.g. the national database. It is important that there is a close follow-up from the responsible actor (EnFO) with respect to checking the software programs towards the specification. With four different programs on the market that demands a lot of resources and effort.

UTILITARIAN VALUES

Many utilities have become very skilled FASIT users and have experienced that the more seriously they take the work the more benefit they get from the system. This section presents examples from two companies on how they utilise FASIT.

Vest-Agder Energiverk

The first report is from Vest-Agder Energiverk (VAE), a vertically integrated company in the south of Norway with 57 000 customers. The company was ISO 9001 certified in 1996 and has as a result of that process outlined a systematic scheme for documentation of faults and interruptions. One of the reports contains statistics over forced outages, planned interruptions, successful reconnections and the total interruption time for all distribution transformers. A monthly report for every distribution transformer larger than a stated limit is

written and commented by the responsible engineer. The report also contains a description of causes and effects of the deviation.

VAE has guaranteed their customers a quality of supply as follows:

All customers having more than 9 interruptions or 25 hours of interruption time during one year will be repaid some of the network charges (following specific rates and rules).

By the end of the year a balance is settled and customers exceeding the above mentioned limits are refunded up to 20 % of their tariff. As a result, the focus on customer interruptions has increased in all departments and levels in the organisation, from electricians to representatives of the board. The network manager's monthly reports are delivered to the board of VAE, where the owners and representatives of the local authorities are seated. Lately there has been a demand for better statistics concerning interruptions, as well as reliable explanations for high interruption frequencies in specific areas together with descriptions of the attempts done to improve the situation.

Figure 5 shows an example on the monthly statistic material presented to the local authorities and the board of VAE.

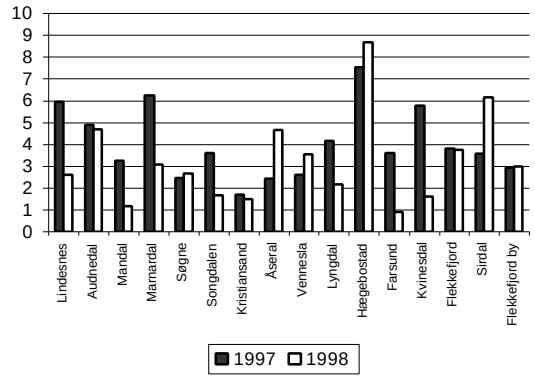

Figure 5 Average number of forced outages (exceeding 3 minutes) per transformer, in different areas of VAE's MV system

Fault statistics are used as an aid to find components that often cause outages. Fault statistics for distribution transformers combined with lightning registrations can give a strong indication of the necessity of over-voltage protection of the transformers. Fault statistics for distribution transformers indicate a growing demand for better protection in the last years.

As figure 6 shows there has been a falling tendency of transformer failures vs. the registered lightning strokes in the period 1988-1997. This may be taken as a validation of the decision of installing protection on the distribution transformers.

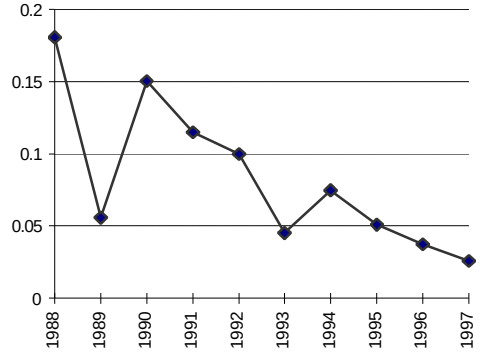

Figure 6 Number of distribution transformer accidents vs. number of lightning strokes in VAE's MV system

Hålogaland Kraft

The second report is from Hålogaland Kraft (HK), a vertically integrated company in the north of Norway with 21 000 customers. The company has registered faults and interruptions since 1985. These data have primarily been used to study what types and manufacturers of components that are most liable to fail.

In addition to inferior component quality, the causes behind many faults may be incorrect use under the climatic conditions in subarctic environments. Components that have shown to be particularly liable to fail have been replaced by components from other suppliers. Thus, the company has been able to replace components of inferior quality, or of types not suited for areas with such rough weather conditions.

There have also been sections of overhead lines with many short outages, mainly caused by birds. Changing the design of the distribution lines, e.g. by replacing triangular suspensions with horizontal suspensions has solved this problem. At specific line sections where grounding of cross-arms was used, the ground wire was moved from the topside to the underside of the cross-arm. This arrangement makes it more difficult for birds to cause a short circuit between phase and ground. Additionally, isolated cables between the overhead lines and the transformers are used and the flashgaps are mounted with birdguard rails.

The result of these efforts has, for several line sections, turned out to be very successful. The average number of interruptions has been reduced from 60 to 5 per year.

CONCLUSIONS

The paper deals with several issues related to registration, reporting and use of fault and interruption statistics in the Norwegian transmission and distribution system. The FASIT system was developed to provide necessary data basis for a number of purposes related to planning and operation of the power system. FASIT has during four years of operation proven its strength as a tool for the network planning, regulator's monopoly control, R&D purposes, etc.

Several experiences have been gained through the use of FASIT in practically the whole Norwegian network below 110 kV. The problems related to the large number of people involved in such work should not be underestimated. With several persons involved from each of 120 utilities using the system, it is a big challenge to get everyone to understand and interpret the definitions and rules for registration of faults and interruptions uniformly. Extensive training is therefore necessary.

Another important aspect has been the regulator's involvement in the development of the system, together with the stated requirements on documentation of interruptions. It is expected that next year's requirements on financial compensation of ENS to affected customers will further increase the interest and efforts related to fault and interruption statistics.

Several software companies have developed FASIT programs, either as independent software for PC or as an integrated part of network/customer information systems. Some kind of software tool is necessary for registration of interruptions for each load point / customer due to the large number of reporting points.

Many utilities have experienced that the more seriously they take the work related to fault and interruption statistics the more benefit they get from it. In the paper experiences from two companies are presented showing that this has become an important tool in the system management.

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