FASIT – A TOOL FOR COLLECTION, CALCULATION AND REPORTING OF RELIABILITY DATA

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ABSTRACT

The paper describes the FASIT standard for reliability data collection, and reliability indices calculation and reporting. Such standards are necessary as a basis in quality of supply regulation, particularly for the documentation of existing levels of reliability of supply, and for providing input data to the value-based reliability planning. The structure and specification of FASIT is thoroughly described in the paper.

INTRODUCTION

Balancing cost-effectiveness and quality of supply is one of the most important and challenging tasks for network companies in the deregulated environment. There is a trend that transmission and distribution systems are subjected to performance-based economic regulation, giving incentives for cost reductions and a risk for deteriorating the quality over time. To counteract such possible consequences the economic regulation is gradually extended and complemented by some kind of quality regulation. Different mechanisms are being used, discussed in e.g. [1, 2]. Examples are yardstick competition, performance standards and economic penalties. The regulatory mechanisms in use typically cover the reliability of supply characterised by number and duration of interruptions. An example is the Norwegian quality of supply regulation [3, 4].

Quality of supply regulation including documentation and penalty schemes calls for standardised systems for collection, calculation and reporting of interruption data. To meet the quality requirements in Norway a concept for national collection and reporting of component fault and delivery point interruption data was developed in the 1990's. This concept is denoted FASIT (Fault And Supply Interruption information Tool) and has been in use by the Norwegian network companies since 1995 [5-7]. After gaining experience for three years (primarily in the MV network) the system went through a major revision in 1998, and has over the years been revised regularly to satisfy new requirements from the regulator. The version presented in this paper has become a national standard for collection, calculation and reporting of reliability data for all voltage levels above 1 kV, regulated through the Norwegian quality of supply regulation [3]. The standard is in use by all network companies (about 150) including the transmission system operator. FASIT is based on international terms and standards, e.g. IEEE Std. 859 - 1987.

FASIT REQUIREMENT SPECIFICATION

Overview of the FASIT system

An overview of the FASIT system is given in Figure 1. FASIT consists of basic requirements, guidelines for data collection (including examples), and reporting schemes divided in three voltage levels: < 1 kV, 1-22 kV and $\geq$ 33 kV. In addition there is a requirement specification for the software. At present there are six FASIT software vendors.

While the FASIT specification[1] is a public access report, the vendors are authorised to implement the FASIT tool as a module in their own software by paying an annual license fee. FASIT is typically implemented as a module in the network information system (NIS).
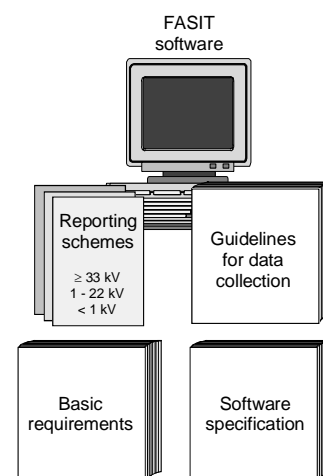

Figure 1 Overview of the FASIT system

The FASIT system makes it possible for network companies to record information about:
- Faults on equipment (components)
- Delivery point interruptions
- Restoration and repair times

A delivery point (DP) in FASIT is a load point, representing a MV or HV end-user, or a MV/LV transformer. Faults are registered in the FASIT software by pointing and clicking on the faulty component in a single-line diagram, and afterwards adding complementary information describing

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the fault. Delivery point interruptions are recorded by simulation of breaker operations. After the simulation FASIT calculates and allocates information about interruption duration, energy not supplied (ENS), interruption costs etc. for each affected delivery point.

Data classes in FASIT

The main data classes in FASIT are:
- Information about the event (date, type etc.)
- Description of the fault (component, cause etc.)
- Consequences (affected delivery points, ENS etc.)

All information about interruptions is linked to the affected delivery points, while information about faults is linked to the faulty components. An overview of the data categories is given in Table 1. The table gives a compact description of the content of the FASIT schemes, showing the information collected about the event, the consequences and the fault.

In order to generate useful reports and statistics there are logic connections in the database between the FASIT report, the faulty equipment and the affected delivery points. This is illustrated in Figure 2.
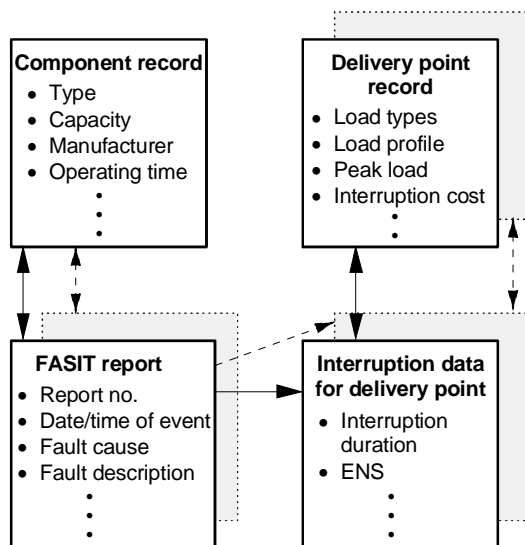

Figure 2 Linking component faults and DP data

Input data to the FASIT registration

For the purpose of determining the consequences of an outage FASIT needs information about the affected customers. The customer information consists of the following data categories:
- Customer identity and location
- Type of customer (NACE-code [10] etc.)
- Connection (location etc.)
- Load (consumption, load profile, tariff)

A standardised format is prepared for transferring these data from Customer Information Systems (CIS) to FASIT. This

standard ensures that any combination of FASIT software and CIS is possible for data exchange.

To identify which parts of the network are affected by switching operations, FASIT needs updated information about the network topology, breaker positions and customer locations, at the time of occurrence of the outage.

Knowledge about type of the faulty component and some details about the specific component is important information for the registration of component faults. This information is typically obtained from the NIS database.

Calculation of outage consequences

The consequences of the outage are presented in terms of interruption duration, interrupted power, ENS and interruption cost. The standardised method for calculation of ENS is based on the expected load curve in the interruption time period [11]. Hence, expected ENS for customer category K connected to the delivery point (DP) is determined according to (1) for an interruption lasting from T1 to T2. For this purpose the customer and topology information described above should be available.

$$ENS_{DP,K} = \int_{T1}^{T2} P_{DP,K}(t)dt \approx \sum_{h=i}^{h=i+n} P_{DP,K,h} \quad [\text{kWh}] \quad (1)$$

where
n = number of intervals (hours) included in the outage
$P_{DP,K,h}$ = average load for customer category K at the delivery point DP in any hour h [kWh/h]

The following data is needed for the calculation of ENS:
- Breaker operations during the event (see Table 1)
- Load measurements for calibration
- Standardised load profiles for different load categories and climate [kWh/h]
- Individual load profiles for certain DPs [kWh/h]
- Local temperature series for previous years [$^{\circ}$C]
- Daily mean temperature(s) for the day(s) of the interruption [$^{\circ}$C]

The procedure for using load profiles to estimate hourly loads for a given customer category for a given temperature is described in detail in [11]. The cost of an interruption (C_j) at any time j for customer category K connected to the delivery point (DP) is calculated according to (2) [13]:

$$C_{DP,K,j} = c_{DP,K,ref}(r) \cdot f_{Ch} \cdot f_{Cd} \cdot f_{Cm} \cdot P_{DP,K,ref} \quad (2)$$

where
$C_{DP,K,j}$ = Cost of an interruption in DP at time j (NOK)
$c_{DP,K,ref}$ (r) = Cost rate in NOK/kW at reference time for customer category K and duration r at time j
$P_{DP,K,ref}$ = Interrupted power in kW at reference time
f_{Ch}, f_{Cd}, f_{Cm} = Correction factors for cost (in monetary terms) at time j, i.e. in hour h, on weekday d and in month m

Table 1   Data Categories used in FASIT

Information about the event	
General information	commentary/description (free text format), report number, reference to other report, internal reference, name of company, department, date/time of event, registered/controlled by
Type of event	forced outage, planned disconnection (notified / not notified and reason for), no disconnection
Network where event occurred	own installation, other network owner's installation, customer's installation, production unit
System voltage and netw. level	kV, main grid, regional, distribution
Sectioning method	manual local, remote control, automatic, no sectioning
Breaker operations	operation ID, date/time for operation, breaker status after operation, tripping, remote control etc.
Protection	type, setting (3-phase, 1 + 3 phase), response (correct, early, delayed, missing), ref. to primary fault
Time consumption	minutes (turn-out time, sectioning time, fault localisation time, repair time, technical delay etc)
Consequences	
Affected network parts	(predefined choices for each company)
Lost production	MWh, MW, affected power production unit(s)
Energy not supplied (ENS)	kWh (for each customer category under each delivery point, plus various aggregated values)
Interrupted power	kW (for each customer category under each delivery point, plus various aggregated values)
Interruption duration	minutes (for each delivery point)
Interruption costs	currency (for each customer category under each DP, plus various aggregated values etc.
Supply restoration method	repair, reconnection, provisional reserve, provisional repair, changing of fuses etc.
Description of the fault(s)	
Faulty component	generator, busbar, breaker, transformer, overhead line, cable, reactor, capacitor, protection, control equipment, etc. Faulty sub-component: specified choices for each component
Misc. info about component	location, function, type, manufacturer, capacity, year of installation, etc.
Common mode fault	yes, no
Fault detection method	tripping, casual observation, condition monitoring, maintenance work, third person message etc.
Fault character	permanent, temporary, intermittent
Repair	repair type (component/sub-component exchanged, temporary repair, permanent repair), repair time
Fault description	(specific choices grouped under material, mechanical, electric and other faults)
Triggering fault cause, main	environment, human, operational stress, techn. equipm., construction/maintenance, unknown etc.
Triggering fault cause, detailed	lightning, wind, snow/ice, vegetation, animals/birds, work/testing, tree cutting, digging, sabotage, overloading, vibration, ageing, wear, corrosion, incorrect setting, imperfect maintenance, etc.
Underlying fault cause	(same choices as for Triggering fault cause, except previous fault)

The interruption cost is calculated as a function of the duration and time of occurrence of the interruption as shown in (2). The latter aspect is handled using correction factors. Cost rates ($c_{K,ref}$ (r)) and correction factors are given for six customer categories [13]. The interruption cost is calculated for notified and non-notified interruptions separately.

Software certification

The software is undergoing continuous development and quality assurance. Since reliability data collection and reporting is an important part of the network company regulation the development and sale of the software is subjected to a license agreement. Every time a new version of the specification is released the software has to pass a certification test. For these purposes a test network is developed, shown in Figure 3.

The necessary data described in the previous sections are represented in the test network as well as the interfaces between different utilities, marked with the letters A to E in the figure. In addition, the test consists of a number of events that should be registered in the FASIT tool.
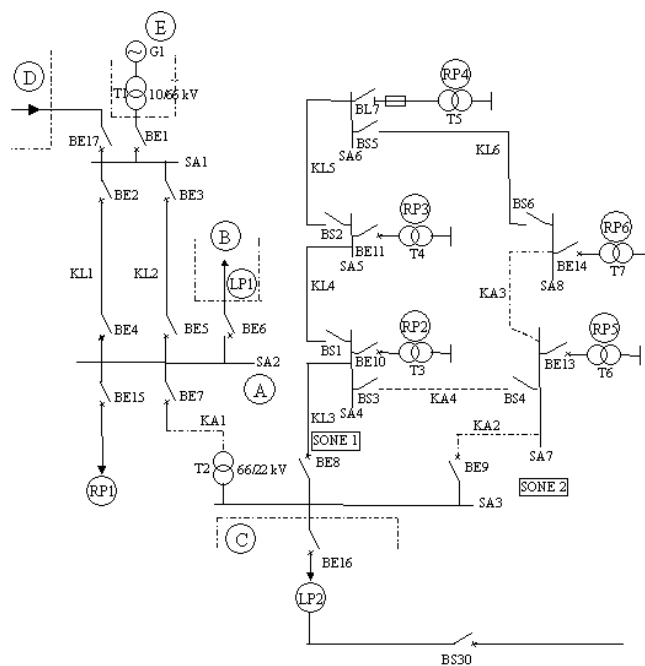

Figure 3 FASIT test network

REPORTS GENERATED BY FASIT

According to the quality of supply regulations it is mandatory for the network companies to deliver annual interruption reports to the energy regulator (Norwegian Water Resources and Energy Directorate) and fault reports to the transmission system operator (Statnett). These reports constitute the basis for providing annual statistics.

The interruption report consists of delivery point interruption data. In addition the following indices are calculated and reported: SAIFI, CAIFI, SAIDI, CTAIDI, and CAIDI. For each fault in the network a fault report should be registered in FASIT. Information is collected for each individual fault, e.g. if there are two faults involved in one event, both faults are reported individually. An example of information that can be provided is given in Figure 4, showing the development of the average fault rate for MV overhead lines (OH) in Norway in the period 1989 – 2006. (Data before 1995 was collected in the preceding system.)
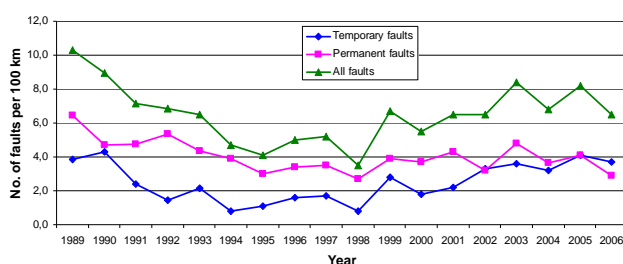

Figure 4 Fault rate OH lines (1 – 22 kV) in Norway

Figure 5 shows the total energy not supplied in Norway for the period 1997 – 2006, for notified and non-notified interruptions. There has been a considerable reduction in ENS over the period, particularly for notified interruptions.
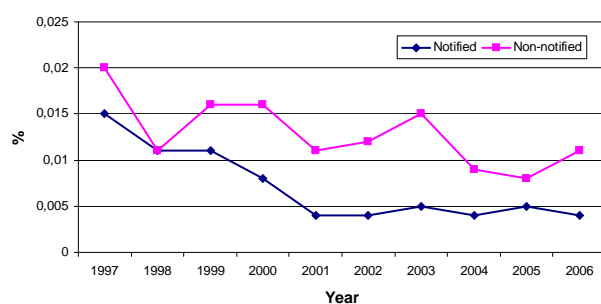

Figure 5 ENS in % of energy supplied in Norway 97– 06

CONCLUSION

In Norway a comprehensive data basis on component faults and delivery point interruptions is established continuously over the years from 1989 for all network levels >1 kV. There have been different systems in use before FASIT became the standard for all voltage levels in 2000. The study published in [12] revealed that as a consequence of quality of supply regulations, standardisation and competence building the quality and extent of fault analysis

and reporting has been considerably improved in Norway over the studied time period 1989 – 2005. A growing interest from regulators around the world towards regulating quality of supply increases the need for harmonised and standardised statistics to perform benchmarking and to monitor trends. In the Nordic countries there has been a co-operation on the transmission level for many years to standardise fault statistics and there is work going on to standardise the collection and reporting on the distribution level as well [8, 9]. This is an important basis for the future development of FASIT.

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