IMPLEMENTATION OF THE NEW GERMAN STATISTIC ON OUTAGES AND SUPPLY AVAILABILITY

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SUMMARY

Detailed information on the quality performance of networks, considering both the reliability of the network components and of course customer supply availability, is becoming even more important in liberalised markets. It is necessary to find the optimal balance between cost effectiveness and quality of supply for network planning and operation. The information is gathered in suitable statistics and expressed in appropriate indices. This paper presents the new German statistic on outages and supply interruptions, which is also focusing on the DISQUAL indices for supply availability. Examples for the implementation of the outage recording process with two German distribution network operators, as well as examples for the analysis of the statistic demonstrate its usage.

INTRODUCTION

In the liberalised energy markets, network operators have to find the optimal balance between cost effectiveness and quality of supply. These are contradicting requirements, as measures to reduce costs will in general have negative effects on the quality of supply [1].

In this context, it is important to have quantitative and detailed information not only on costs, but also on the technical quality of supply. This is a prerequisite for the objective discussion of the dependencies between costs and quality both internally within the network operators as well as externally with politics and the general public. For the area of supply reliability, such figures can be derived from suitable statistics on the outage and availability performance of the networks.

In most liberalised markets, the regulators force network operators to maintain statistical records on supply interruptions. These records are combined into availability statistics for the system under consideration. Figure 1 gives an example for different European countries [2].

Further information, e.g. on the outage performance of network equipment, is typically not required by the regulator but in some cases gathered by the network operators themselves or their associations. Also in Germany VDN (Verband der Netzbetreiber, association of network operators) maintained a statistic on outages for many years. But this statistic did not completely fulfil the requirements of liberalised markets. Therefore the statistic was updated in 2004 [3].

The motivation for the update as well as the new recording scheme are presented after a short description of supply availability indices.

However, even having a well-defined recording scheme at hand, the actual implementation of the data recording processes to fill outages and availability statistics is a challenging task on its own. A detailed definition and effective integration of the recording processes into the internal workflow, as well as optimal software support of the recording, administration and analysis of the data is important to reduce the overall effort.

Depending on network size, IT infrastructure and other parameters, the actual requirements differ significantly between network operators. Solutions for two different distribution network operators are presented.

With the new recording scheme, several detailed analyses are possible. Different examples are presented.

SUPPLY AVAILABILITY INDICES

General

Supply availability is a complex aspect. As a matter of fact, supply availability cannot be expressed comprehensively in a single index, because it is made up of three generally independent dimensions:

- frequency of interruptions,
- duration of interruptions,
- extent of interruptions.

Nevertheless, there exists a multitude of different availability indices. But each index only describes certain aspects of supply availability, and the details of the exact definitions are of high importance for their correct interpretation.
In the end, the user of such indices has to keep in mind that any availability index represents an abstract description of the supply reliability according to the given models and definitions.

**DISQUAL Indices**

As explained above, there exists a multitude of different availability indices. However, in Europe the so called DISQUAL indices have evolved into a commonly used definition. In 1997, the UNIPEDE Distribution Study Committee Quality of Supply published its report on Availability of Supply Indices [4]. In this report, a set of three indices is presented, together with three different methods to calculate the indices:

- **Interruption Frequency** $F_i$: This index gives the average number of interruptions per customer in a year. It is calculated as follows:
  \[
  F_i = \frac{\sum j x_j}{X_{\text{total}}} \tag{1}
  \]

- **Supply Unavailability** $Q_i$: This index gives the average time without supply per customer in a year. It is calculated as follows:
  \[
  Q_i = \frac{\sum j x_j \cdot t_j}{X_{\text{total}}} \tag{2}
  \]

- **Interruption Duration** $T_i$: This index gives the average duration of a supply interruption. It is calculated as follows:
  \[
  T_i = \frac{\sum j x_j \cdot t_j}{\sum j x_j} \tag{3}
  \]

In the equations, $x_j$ is the measure for the extent of the $j$th supply interruption, and $X_{\text{total}}$ is the measure for the size of the system. $t_j$ is the duration of the $j$th supply interruption. The actual variables for $x$ and $X$ differ in the three calculation methods:

- In method (1), $x$ is the number of interrupted customers and $X$ is the total number of customers supplied by the system.
- In method (2), $x$ is the installed (or declared) kVA affected by an interruption and $X$ is the total installed (or declared) kVA supplied by the system.
- In method (3), $x$ is the number of interrupted medium voltage (MV) / low voltage (LV) stations and $X$ is the total number of MV/LV stations supplied by the system. Instead of MV/LV stations, also MV/LV transformers can be used.

It has to be noticed that the DISQUAL indices describe supply availability from the customer-perspective, but nevertheless they are system indices that can only be calculated for the total system, and not for individual stations.

**NEW GERMAN STATISTIC ON OUTAGES AND SUPPLY AVAILABILITY**

**Motivation for the Update**

The former German VDN statistic on outages, with the latest recording scheme in operation between 1994 and 2003, had a strong focus on the description and analysis of the failure occurrences in the system. It did not include the description of the supply availability in distribution networks. Also, it was required to re-optimise the trade-off between the effort for recording the data and the benefits of the statistical analysis.

So, the statistic was re-designed and put in operation in 2004 as the VDN statistic on outages and supply availability [3]. Especially the data on distribution systems was significantly extended. The statistic covers MV to extra high voltage (EHV) networks in a consistent way, as well as LV networks in a simplified way. Special attention was paid to the possibility to derive DISQUAL indices on supply availability separate for LV and MV networks, considering also planned interruptions, and to calculate component reliability data to be used in probabilistic reliability calculations for MV to EHV networks.

**New Recording Schemes**

In the new statistic on outages and supply availability, two different recording schemes are defined:

- **Recording scheme for the availability statistic**: This is a reduced recording scheme, considering on supply interruptions for calculating availability of supply indices. LV interruptions are always recorded under this scheme.
- **Recording scheme for the outage and availability statistic**: This is the actual update of the former outage statistic, focusing on both the outage occurrences affecting the network equipment, and on supply availability. High voltage (HV) and EHV outages are always recorded under this scheme.

The separate data items recorded in the statistic are grouped as follows:

- **Organisational information**: Certain information is recorded in order to identify the different events and to allocate the events to the affected networks.
- **Data on outage occurrences**: The following data items are recorded once per event:
  - Date and time of outage occurrence,
  - Occasion of outage occurrence, e.g. atmospheric or third party influences, planned interruption etc.,
  - Effect of outage occurrence, e.g. classification of protection operation or of manual switching-off etc.,
  - Failure type, e.g. earth fault, three phase fault, faulty equipment etc.,
  - Voltage level of the network causing the event, if the original failure is not located in the network under consideration.
- **Data on failure locations**: There may be multiple failure locations affected in a complex event. For each failure location the following data is recorded:
• **Data on supply interruptions:** The process of supply interruptions and supply restoration with different customers can be very complex for large outages. Software tools allow the recording of multiple, separate supply interruptions. From these data, the overall values for the complete event are calculated and transferred to VDN for the availability statistic. For each individual interruption, the following data is recorded:
  - Begin and end of supply interruptions,
  - Interrupted power (in MV and HV/EHV),_interrupted customers (in LV),
  - Energy not delivered (in MV and HV/EHV), Interrupted power (in MV and HV/EHV), Customer minutes lost (in LV).

• **Quantitative network data:** In order to be able to calculate failure rates of component types, availability indices and other comparable indices, certain information on the networks under consideration have to be recorded. This information includes e.g. circuit lengths, number of stations, number of customers, total installed power, etc.

Apart from these data fields defined in the official VDN statistic, certain additional information may be recorded by network operators. For example, the VDN statistic does not consider the individual failure affected components (e.g. line no. 123 between stations A and B), nor the individual stations affected by supply interruptions, as this is not relevant for Germany-wide statistical analysis. However, especially information on individual components and stations is highly important for the internal use of the statistic by the network operators.

**OUTAGE RECORDING PROCESS WITH DISTRIBUTION NETWORK OPERATORS**

**General**

Practical experiences have shown that the exact definition of the outage recording process is of great importance for achieving an overall effective workflow. This is especially important for the new VDN statistic on outages and supply availability, as the focus on supply interruptions in distribution and even LV networks requires that regional and local control centres or service groups are included in the recording process.

Also, each network operator has to clearly define the requirements and the resulting scope of the statistic. Typically, this leads to the definition of data items which are additional to the standard VDN statistic. In many cases, especially the individual failure locations and interrupted stations are of interest. Finally, the actual implementation of suitable software tools also has to consider the existing IT architecture. If possible, data already existing in other systems should be made available for the recording of outages and supply interruptions in order to reduce the effort.

**The Süwag Energie AG Solution**

Süwag Energie AG, Frankfurt am Main, is a distribution network operator with several network-regions in the German states Hessen, Rheinland-Pfalz, Baden-Württemberg and Bayern. Süwag supplies electricity and gas to 860,000 customers in its 5,000 km² supply area.

Süwag Energie’s electrical distribution networks are controlled by two control centres, with the main centre being located in Frankfurt. Süwag has chosen the INTERASS software tool by FGH e.V. for the recording, maintenance and analysis of outage and supply availability data. The control centres are responsible for the documentation of all relevant events in the central INTERASS database. The HV and MV outage-events are on-line recorded by the central SCADA-systems and exported to INTERASS. LV supply interruptions are recorded in a different system (SAP-PM) for practical reasons from the local working-groups, and then imported into INTERASS in fixed time intervals.

In the Süwag Energie software solution, several Süwag specific data fields are added to the recording scheme, and the functionality is extended to import report files from the network control system. In case of outages and supply interruptions, the operators can use special reporting tools of the control system to compile information on the individual failure affected component and on the interrupted stations, together with other organisational information. When a new event in the statistic tool is created using this report file, a large part of the relevant data fields is already filled. The manual effort thus is significantly reduced. **Figure 2** shows an example for the recording of the individual failure affected component, as well as the dialogue for creating a new event with the import of the control centre report file.

**The EnBW Regional AG Solution**

EnBW Regional AG, Stuttgart, operates the electrical distribution network in most of the federal state of Baden Württemberg, including several large cities like the state capital Stuttgart. The total supply area covers 21,000 km² with 3 Mio. customers.

Also EnBW Regional has chosen the INTERASS software tool. The recording scheme was extended to meet the EnBW specific requirements, focusing especially on the recording of
individual failure locations and interrupted stations. With EnBW, the regional control centres are responsible for MV outages and interruptions, while LV events are maintained by local service groups. This results in a total of approximately 200 different users in 50 locations, working on one company-wide database. The implemented administration of user rights ensures that local teams can only access the networks and events they are responsible for.

In the EnBW software solution, an interface to the Network Information System (NIS) is included. From the NIS, certain views of the installed components and the supplied stations per network can be exported. These lists are hierarchically structured according to the feeding HV/MV substation and the outgoing feeders. The staff entering data on outages and supply interruptions thus can easily encode the individual failure affected components and the interrupted stations. Figure 3 shows an example for the recording of individual interrupted stations, together with the dialogue for choosing interrupted stations. The stations are listed with their installed (or declared) kVA, and both begin and end of interruptions can be entered in the dialogue, so that all relevant information is included. Stations for which an interruption already is recorded are marked red in the list.

As an example, Table 1 shows the supply unavailability separated for the different occasions of failure occurrence and different failure locations. Please note that these are fictive numbers, as the results for the first reporting year under the new VDN statistic, which is 2004, will be available in spring 2005.

Table 1: DISQUAL supply unavailability in min/a for different occasions of outage occurrences and for different failure locations (fictive example)

<table>
<thead>
<tr>
<th>Occasion of outage occurrence</th>
<th>Overhead line</th>
<th>Cable</th>
<th>HV/MV substation</th>
<th>HV/LV station</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No recognisable occasion</td>
<td>0.17</td>
<td>1.76</td>
<td>0.07</td>
<td>0.86</td>
<td>2.06</td>
<td></td>
</tr>
<tr>
<td>Atmospheric influence</td>
<td>0.56</td>
<td>0.07</td>
<td>0.11</td>
<td>0.11</td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td>Third party influence</td>
<td>0.06</td>
<td>0.18</td>
<td>0.17</td>
<td>0.13</td>
<td>0.89</td>
<td></td>
</tr>
<tr>
<td>Other influence</td>
<td>0.42</td>
<td>0.79</td>
<td>0.04</td>
<td>1.22</td>
<td>1.97</td>
<td></td>
</tr>
<tr>
<td>Secondary equipment</td>
<td>0.06</td>
<td>0.91</td>
<td>0.05</td>
<td>0.42</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>Affected by failure in HV networks</td>
<td>0.08</td>
<td>0.98</td>
<td>0.08</td>
<td>0.08</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Affected by failure in EHV networks</td>
<td>0.91</td>
<td>0.09</td>
<td>0.91</td>
<td>0.01</td>
<td>0.98</td>
<td></td>
</tr>
<tr>
<td>Affected by failures in other system/equipment</td>
<td>0.03</td>
<td>0.00</td>
<td>0.03</td>
<td>0.03</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Total stochastic outages</td>
<td>5.29</td>
<td>5.11</td>
<td>0.22</td>
<td>0.68</td>
<td>11.59</td>
<td></td>
</tr>
<tr>
<td>Planned interruptions</td>
<td>2.06</td>
<td>1.76</td>
<td>0.07</td>
<td>0.86</td>
<td>4.71</td>
<td></td>
</tr>
<tr>
<td>Total interruptions</td>
<td>18.46</td>
<td>16.87</td>
<td>0.29</td>
<td>1.54</td>
<td>20.90</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3: Example for the recording of individual interrupted stations

**EXAMPLES FOR ANALYSING THE STATISTIC**

**Analysis of Supply Availability**

The analysis of the supply availability statistic for Germany, respectively the calculation of the DISQUAL indices, is awaited with special interest. Because in the former statistic only supply interruptions in HV and EHV systems were recorded, there is very little information available up to now about the details of the availability level in Germany. The layout of the future supply availability statistic is already defined. Besides calculating the overall availability indices, also the composition of the described unreliability with regard to different failure occasions, failure locations and responsible system levels will be presented.

However, the analysis of supply availability is not only restricted to calculating DISQUAL indices. Network operators that also record the individual interrupted stations may perform analysis in much greater detail, calculating the actual number of interruptions, average time of interruptions, interrupted power or other indices for each separate station. This information can be used for various processes in network planning and for the information of customers.

**Analysis of System Performance**

The analysis of the system performance is the classical field of the German VDN statistic. Especially, the reliability performance of different equipment types and the general description of the occurring outage events are under consideration. For these aspects, data is available also from the former recording scheme, which was in operation since 1994 for HV and EHV systems. The new recording scheme will provide the same level of detail for all networks from MV up to EHV.

Also for the outage statistic, the layout of the future analysis is already defined. It will provide more details and a clearer structure than the former analysis. Basically, the results for each recorded data field will be included in the standard analysis, and additional certain indices will also be separated for e.g. occasion of failure occurrence and failure location, as shown above for the supply unavailability.

Of course, part of the new standard analysis will be similar to the former scheme. As an example, Table 2 lists the number of outages per 100 km circuit length for different effects of outage occurrence in the separate MV voltage levels for the year 2002 [5]. It is not at all possible to publish any result of interest in a standard analysis of the statistic. The database of the statistic is also used for special investigations according to the given requirements on request of network operators, academic institutions or other interested parties. However, with all analyses, strict anonymity of the results is guaranteed.
Analysis of Component Reliability Data

For probabilistic reliability analysis, which gain more and more importance in network planning today, suitable input data on the reliability of network equipment is required. This so-called component reliability data can be derived from suitable statistics. The German VDN statistic already focused on this goal in its former scheme for HV and EHV networks. The new recording scheme will provide the same level of detail for all networks from MV to EHV. For this aspect, it is very important to collect data of several network operators, as some failure events occur very rarely.

In a recent analysis, the data from 1994 to 2001 was used for the calculation of component reliability analysis [6]. Although this analysis was performed on data in the former recording scheme, the process was already changed to the requirements of the new recording scheme.

As an example, Table 3 gives the component reliability data for different cable types in 20 kV networks with compensated neutral.

### Table 3: Component reliability data for different cable types in 20 kV networks with compensated neutral

<table>
<thead>
<tr>
<th>Failure mode</th>
<th>Cable type</th>
<th>20 kV compensated neutral H in 1/(km a)</th>
<th>0.1% point failure in 1/km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent single failure</td>
<td>All</td>
<td>6228</td>
<td>0.01198</td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>2242</td>
<td>0.01490</td>
</tr>
<tr>
<td></td>
<td>Oil</td>
<td>52</td>
<td>0.12572</td>
</tr>
<tr>
<td></td>
<td>PE</td>
<td>1240</td>
<td>0.03112</td>
</tr>
<tr>
<td></td>
<td>PVC</td>
<td>104</td>
<td>0.29966</td>
</tr>
<tr>
<td></td>
<td>VPE</td>
<td>1103</td>
<td>0.00552</td>
</tr>
<tr>
<td>Delayed manual switching-off</td>
<td>All</td>
<td>4099</td>
<td>0.007867</td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>1340</td>
<td>0.008911</td>
</tr>
<tr>
<td></td>
<td>Oil</td>
<td>75</td>
<td>0.18134</td>
</tr>
<tr>
<td></td>
<td>PE</td>
<td>856</td>
<td>0.02148</td>
</tr>
<tr>
<td></td>
<td>PVC</td>
<td>61</td>
<td>0.17567</td>
</tr>
<tr>
<td></td>
<td>VPE</td>
<td>925</td>
<td>0.004525</td>
</tr>
<tr>
<td>Failure of protection operation</td>
<td>All</td>
<td>182</td>
<td>0.005107</td>
</tr>
<tr>
<td>Permanent earth fault</td>
<td>All</td>
<td>8804</td>
<td>0.013059</td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>2409</td>
<td>0.018020</td>
</tr>
<tr>
<td></td>
<td>Oil</td>
<td>124</td>
<td>0.299814</td>
</tr>
<tr>
<td></td>
<td>PE</td>
<td>1335</td>
<td>0.033510</td>
</tr>
<tr>
<td></td>
<td>PVC</td>
<td>93</td>
<td>0.287972</td>
</tr>
<tr>
<td></td>
<td>VPE</td>
<td>1454</td>
<td>0.007113</td>
</tr>
<tr>
<td>Multiple earth fault with multiple outages</td>
<td>All</td>
<td>2114</td>
<td>0.0030</td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>464</td>
<td>0.0018</td>
</tr>
<tr>
<td></td>
<td>Oil</td>
<td>25</td>
<td>0.0343</td>
</tr>
<tr>
<td></td>
<td>PE</td>
<td>279</td>
<td>0.0040</td>
</tr>
<tr>
<td></td>
<td>PVC</td>
<td>19</td>
<td>0.0311</td>
</tr>
<tr>
<td></td>
<td>VPE</td>
<td>715</td>
<td>0.0020</td>
</tr>
</tbody>
</table>

### REFERENCES