CONTINUITY OF SUPPLY: BENCHMARKING FIVE URBAN ELECTRIC DISTRIBUTION UTILITIES IN SWITZERLAND

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ABSTRACT

Continuity indicators such as SAIDI, SAIFI and CAIDI are compared for unplanned interruptions among five urban electrical distribution networks in Switzerland. The influence of the largest event, the voltage level, the causes of interruptions and the density of a network (urban versus rural for one utility) are investigated. The average value of the five utilities is assumed to be representative for Switzerland and is compared with other countries in Europe, using information from CEER-benchmark reports. The question "what level of reliability is reasonable" is raised.

INTRODUCTION

The European Union's intention is to completely liberalise the electricity market per first July 2007. Regulators of the member countries define rules, concerning the continuity of supply. The utilities are not only benchmarked within a country but also compared between countries, as shown by the third benchmarking report of the Council of European Regulators (CEER) [1].

The Swiss parliament is debating a new law concerning the supply of electricity. In case of acceptance by the parliament and by the Swiss sovereign, a regulator would have to define minimum requirements for the continuity of supply. To determine the actual situation and for benchmarking purposes, five Swiss urban distribution utilities started to collect data about the reliability of their networks in a harmonised manner. The obtained information is used for network improvements and eventually to answer the question about “what level of continuity supply" is reasonable.

Among the five utilities data acquisition guidelines were determined (number of customers, begin, termination and duration of interruption, loss of power, handling of large interruptions, distinction of network density as urban or rural). Further aspects were additionally considered (but not discussed in this study): 1) topology of the network and future upgrading, 2) Step-restoration tracking 3) planned interruptions, 4) actual target values for reliability, 5) fault-clearance organization, 6) customer information policy and 7) treatment of emergency connections.

The paper presents comparisons of three continuity indicators: 1) **SAIDI** (System Average Interruption Duration Index), indicating the duration that energy is not supplied to a customer in a year; 2) **SAIFI** (System Average Interruption Frequency Index) revealing the number of times in a year energy is not delivered to a customer and 3) **CAIDI** (Customer Average Interruption Duration Index), representing the average time required to restore service to the average customer per interruption. The computations are made for all unplanned cases and without the "largest event".

Further voltage levels and responsibility (cause of interruption) as well as density analysis (urban, rural) are presented. Some results are compared with values obtained by the CEER-benchmarks [1, 2].

NETWORK, DATA AND DEFINITIONS

Reliability indices are usually compared between countries, regions or distribution companies as an average value over the whole network. In the following this approach is considered, comparing the 5 Swiss urban utilities. However, one has to be aware that within a company's network significant differences can be found since dynamical processes of ageing, maintenance, renewing and expanding of the grid can alter the network conditions, as shown in [3].

The size of the investigated distribution companies can be briefly described as follows: The utilities deliver power to 40'000 to 260'000 customers (= meters). The density of customers per hectare (0.01 km^2) build up area (buildings, industry, infrastructure) is about 50 to 75 and the number of customers per km LV-grid varies between 70 and 240.

For four of the utilities data from 4 years (2002-2005) are available, one joined recently the program and only data from 2005 can be used.

For an event a minimum duration of 1 sec is taken. The interruption ends at the moment when 100 % of the customers are again supplied with energy (step-restorations are not considered). The number of customer is actually the number of meters. Only unplanned interruptions are considered in the following.

The distinction between "urban" and "rural" network is given by the density of customers and is defined as follows: A community with at least 10'000 inhabitants and a population ratio of at least 58 inhabitants / hectare build up area is taken as "urban". For one utility (number 3, see below), which operates an urban and rural network, data allows the performance of a density analysis. The same utility experienced in 2005 a "blackout" of the whole network, caused by cascading shut-downs of overloaded transmission lines after lightning stroke on one of the lines during a winter storm [4]. If the case is excluded from the analysis it will be mentioned.

RESULTS OF THE BENCHMARK

Figure 1 shows the yearly and the average **SAIDI** for the 5 utilities (numbered 1 to 5) for the period 2002-2005. SUA (Swiss Urban Average) is the average of the five company values, which is thought to be representative for urban Switzerland. All outages > 1 sec are considered. The large column in the histogram of utility 3 includes the "blackout event" of the year 2005.

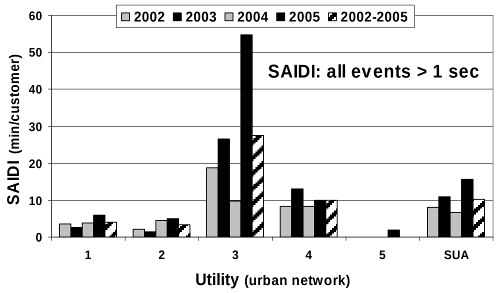

Figure 1: Yearly and average SAIDI for the period 2002-2005 and for 5 utilities. SUA means Swiss Urban Average and indicates the general average of unplanned interruptions within an urban networks. Data of utility 5 are only available for 2005.

From the values in Figure 1, computed from all events, the percent of SAIDI indicated in Figure 2 can be subtracted to obtain the yearly SAIDI without the largest value, resp. without the "blackout event" of company 3. That event comprises about 90 % of the total value of more than 50 min/customer. The second highest share amounts to about 70 % (utility 2, 2004).

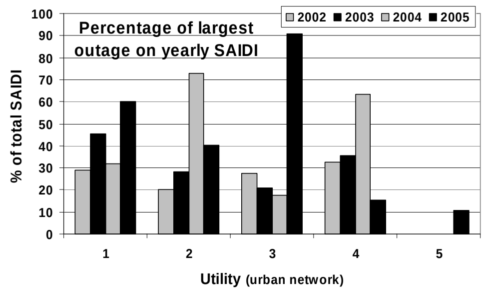

Figure 2: Percent of largest outage on total yearly SAIDI.

A comparison of the four year average SAIDI, computed with and without the largest value, is depicted in Figure 3. Seen over all companies the SAIDI - after reduction by the highest value - is roughly half of the original number.

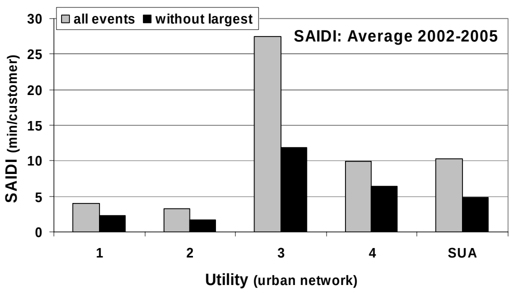

Figure 3: Comparison of average SAIDI computed from all events, resp. without the largest event for 4 companies and for the Swiss Urban Average (SUA).

The total SAIDI is stratified into three voltage levels (HV, MV, LV). Figure 4 depicts the percentage for the three categories as an average of the observational period 2002-2005. Utility 5 is not considered. For all utilities, the MV-level shows the largest fraction of the total SAIDI. On the Swiss average (SUA) MV interruptions contribute almost 60 % to the total SAIDI.

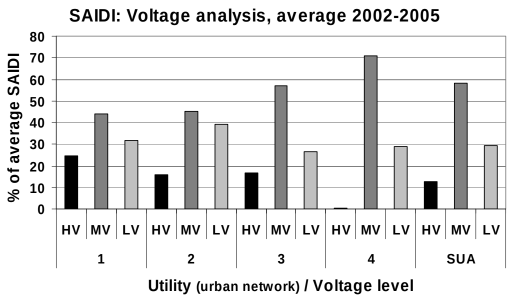

Figure 4: Percent of average SAIDI 2002-2005, stratified into three voltage level categories (HV, MV, LV). (percent of HV for utility 4 is 0.4, blackout case (3) not considered).

Another stratification is shown in Figure 5, according to the causes of interruption. Four categories are considered: 1) "Acts of God" (e.g. atmospheric hazards like storms and lightning), 2) "3rd parties" (e.g. construction work), 3) "utility caused" (e.g. component failures, network operations, human errors) and 4) "unknown". Again the average 2002-2005 is considered but given as a percentage on total SAIDI. On the Swiss-level (SUA) about 50 % of SAIDI is in the responsibility of the utilities (column 3).

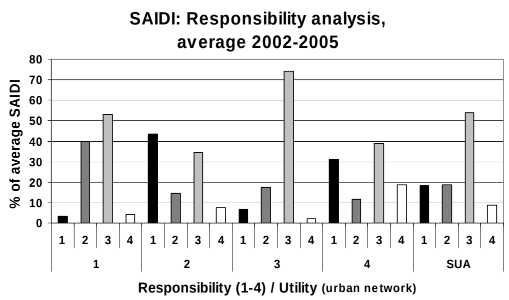

Figure 5: Percent of average SAIDI 2002-2005, stratified into four categories of causes: 1) "Act of God", 2) "3rd parties", 3) "utility caused", 4) "unknown". (Blackout case (3) not considered).

The yearly variation of **SAIFI**, the frequency of interruptions / customer and year, is depicted in Figure 6. The highest number of outages is recorded in the network of utility 3. The value of 2005 includes the "blackout case". One blackout, if all customers are out of power, results in a SAIFI of 1.0 for that event and network. Without that case, the SAIFI would be around 0.1, which is comparable to the other utilities.

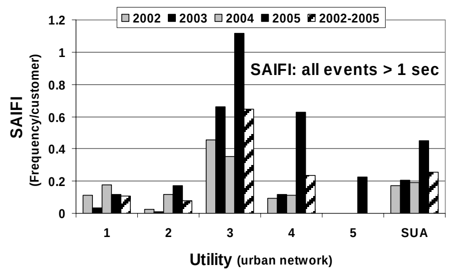

Figure 6: Yearly and average SAIFI for the period 2002-2005 and for 5 utilities. SUA means Swiss Urban Average.

So far all events > 1 sec were taken into consideration. Often a distinction between short and long (sustained) inter-

ruptions are made. VDN (Verband der Netzbetreiber) in Germany and EN50160 [5] defines outages > 3 min as sustained interruptions, IEEE (Institute of Electrical and Electronic Engineers in the US) for outages > 5 min [6]. Using the 5 min threshold, SAIDI shows almost no difference between short and long outages. The percentage of short durations varies between 0.1 and 3 % of total SAIDI for the observed utilities. If high voltage (HV) cases are of interest than short interruptions are more important.
The distinction in short and long interruptions is more important for SAIFI, which is shown in Figure 7. The percentage of the two categories are given and they look quite different from network to network.

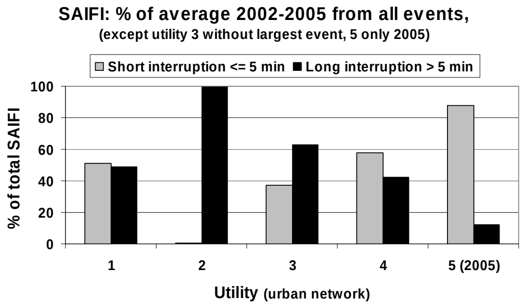

Figure 7: Percentage of short and long interruptions on total SAIFI. The threshold is taken as 5 min. The blackout case of utility 3 is not considered. (Percent of utility 2 short = 0.5).

If a customer experiences an outage the average duration of the interruption that has to be expected is the continuity index **CAIDI** (SAIDI / SAIFI). For completion of the indices set, Figure 8 indicates the variation of the yearly and average duration in min. The Swiss urban network average is about 40 - 50 min.

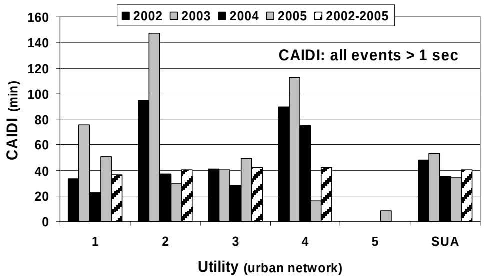

Figure 8: The same as Figure 6 but for the CAIDI.

RESULTS OF DENSITY ANALYSIS

Usually continuity indicators as SAIDI or SAIFI are given as an overall value for a particular utility's network or for an average value of the participating utilities in a country statistic. The indicator value is mostly comprised from outages happened in densely (e.g. centre areas) and less densely populated (city agglomeration, small villages) networks. Two of this study's utilities consist partly of urban and rural networks. Reasonable data is available from company 3 to be able to show possible differences in the continuity indicators between the "total" network and the "urban" or "rural" part of the network (criteria to distinguish between urban and rural part, see chapter "network, data and definitions").

The variation of SAIDI from year to year and between total, urban or rural network is shown in Figure 9. The average of the period 2002-2005 is represented by the three columns on the right of Figure 9. They reveal that the distinction between urban and rural must be considered.

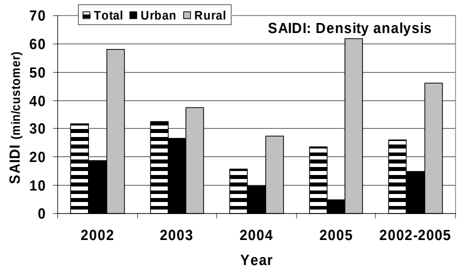

Figure 9: Comparison between yearly and average SAIDI for the "total", "urban" and "rural" network of utility 3. The blackout event is not considered.

If we compare the percentage of total SAIDI for the three voltage levels, no significant differences can be observed (Figure 10). Looking at the responsibility analysis (Figure 11) the percentage of "Act of God" causes is higher for rural areas, which can be expected because of a higher percentage of overhead lines. However, the percentage of "third party" and "utility caused" errors is higher in the urban network. The percentage of "unknown" cases is fortunately in both networks rather low.

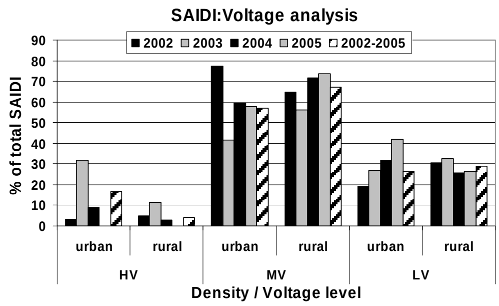

Figure 10: Voltage analysis for utility 3 and the period 2002-2005. The urban and rural percentages on total SAIDI is given for three voltage levels. The blackout event is not considered.

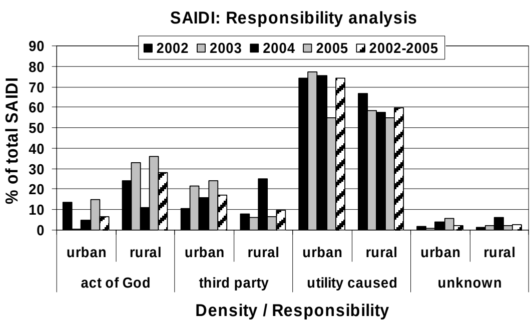

Figure 11: The same as Figure 10 but for the causes of interruption.

The comparison of SAIFI is depicted in Figure 12. Although the variation from year to year is considerable, the rural network always shows a higher frequency of interruptions per customer than for the urban grid.

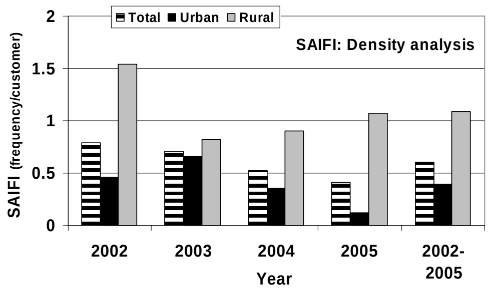

Figure 12: Same as Figure 9, but for SAIFI.

COMPARISON WITH OTHER COUNTRIES

CEER [2] obtained data from five countries which distinguished between "urban", "semi-urban" and "rural" networks. However, the definitions differ from country to country. To compare Swiss values with CEER-values, the average SAIDI, shown as SUA in Figure 1 is taken as representative for urban Switzerland. Figure 13 depicts a three year average urban SAIDI from 5 EU-countries in comparison with SUA-value.

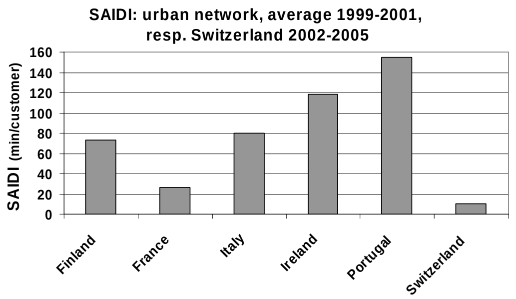

Figure 13: Comparison of SAIDI from unplanned interruptions in urban grids between CEER-countries (original data [2]) and Switzerland (SUA in Figure 1).

To get an idea about "semi-urban" or "rural" Switzerland, the following estimations in using the knowledge of Swiss utility 3 in combination with CEER-data are made:
The data of utility 3 reveal that the percentage of urban, resp. rural SAIDI on the total is on the average about 60, resp. 180 % (Figure 9). The CEER's 2nd benchmark [2] supports more or less this finding and shows an average of 45 (urban), resp. 160 % (rural) from the total SAIDI. CEER's report also shows some figures for "semi-urban" areas, which allows to estimate that contribution. It is about 90 % of the total value, indicating that the total SAIDI represents more or less a "semi-urban" area.
Unfortunately the CEER 3rd benchmark [1] listed no numerical values for the density analysis just a histogram, adding years after 2001. Therefore, to be able to compare more recent years, the above shown numbers can be used to estimate roughly urban or rural values from overall values. We use the average from unplanned interruptions for the years 2001-2004. About 50% of this average is assumed to be the percentage of "urban" interruptions. Figure 14 depicts for 10 EU-countries the estimated average country-wide SAIDI for urban grids. The value from Switzerland is the same as in Figure 13.

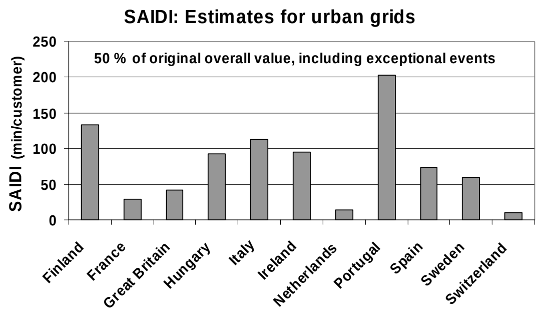

Figure 14: Estimates of urban SAIDI. Data are taken from CEER 3rd benchmark report. 50 % of the overall value is displayed from the average of the period 2001-2004. Switzerland is 2002-2005.

DISCUSSION AND CONCLUSIONS

Compared to other European countries, where regulators try to set targets for the reliability of networks, the standard of the investigated Swiss utilities is high (e.g. low SAIDI). In this context the question is raised about "what level of continuity of supply" is reasonable.
Several strategies can be chosen to determine the utilities reliability. An informative overview is given by Brown and Marshall in [7]. In the paper six possibilities are listed: 1) benchmark targets, 2) value-based targets, 3) performance-based rates, 4) reliability market-place, 5) differentiated services, 6) reliability guarantees. From a customer point of view strategy 5 and 6 might be of interest. Under 5) the utility offers a variation of reliabilities and prices. Approach 6) is simpler. Reliability plans are offered and if the chosen plan is not fulfilled, the customer will get a reduced bill.
The five Swiss utilities are considering the above mentioned possibilities. The results suggest that the benchmark targets "low indices" (a still lower SAIDI) are not being regarded further. Instead to increase in general the reliability, we try to improve the reliability of customers with critical processes. Services with costs (e.g. redundant connections, stand-by generator, operation-contracting) are offered.

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