THE SWEDISH BENCHMARKING REPORT ON CONTINUITY OF SUPPLY

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ABSTRACT

This paper presents the results of the annual evaluation of the reliability in local electricity networks in Sweden. A distinction is made in SAIFI and SAIDI for rural, suburban and urban networks. The values are significantly higher for rural than for urban networks; also the spread between network operators is higher for rural networks. Data is also presented on the number of very-long interruptions and on the investment and running costs by the network operators. Whereas the running costs remain constant, the investments have increased almost three-fold since 2004.

INTRODUCTION

A reliable electricity supply is essential for the functioning and developing of the modern society and the economy. Developments towards a more technically advanced and integrated society also increase the dependence on a reliable electricity supply. It is one of the roles of the Energy Markets Inspectorate (the Swedish energy regulator) to ensure that the electricity networks develop in accordance with their fundamental aims of reliability of supply and long-term cost-effectiveness. The interest of the general public in reliability of supply, and therewith the pressure on the regulator, has increased significantly in Sweden due to two storms that resulted in wide-spread interruptions: the storm Gudrun resulted in supply interruptions for 600 000 customers (12% of all customers in the country) in 2005; two years later the storm named Per caused the supply to be interrupted for 275 000 customers. It took many days before the supply to all customers was restored, which was seen as unacceptable. Partly as a result of this, a new paragraph was introduced in the Electricity Act that, from 2011, no interruption shall last longer than 24 hours.

THE SWEDISH ELECTRICITY NETWORKS

Swedish is a large country in area, with a relatively small population (9.4 million people, 5.2 million electricity customers spread over an area of 450 000 km^2). The transmission system operator, Svenska Kraftnät, owns and operates the 220 and 400-kV networks. The largest production units (nuclear and large hydro) are connected directly to the transmission system. The end-customers are supplied by about 170 local network operators that are connected to the so-called "regional networks" at voltage levels between 6 kV and 130 kV. Five different network operators own and operate these regional networks that form the link between the local networks, large industrial customers, most of the hydro power, and the largest wind-power installations, and the transmission system. The geographical extent of the local networks is shown in Figure 1. The figure shows a large variation in geographical size between the network operators.

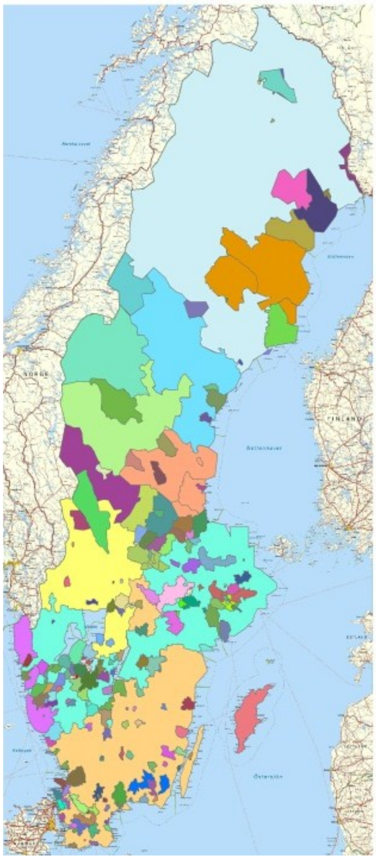

Figure 1, the local electricity networks in Sweden.

The annual benchmarking report (see next section) presents the continuity of supply for local as well as regional networks. In this paper we focus on the continuity of supply for the local networks.

THE BENCHMARKING REPORT

The Swedish energy regulator, the Energy Markets Inspectorate, annually publishes a benchmarking report on continuity of supply for the Swedish electricity network. The aim of the benchmarking report is to follow, analyse and present to all stakeholders the development of continuity of supply in different regions of the country, and to make comparisons between different transmission and distribution network areas. Furthermore, a league table of the most vulnerable network areas in Sweden is presented as well as the identification and presentation of distribution network areas with many very-long interruptions (longer than 12 or 24 hours). The report is therefore also an informative means of regulation regarding continuity of supply. The indicators being considered for the continuity of supply are SAIDI and SAIFI for distribution networks and energy not-supplied (ENS) at higher voltage levels. These indicators are analysed over a period of approximately ten years.

CONTINUITY OF SUPPLY AT SYSTEM AND CUSTOMER LEVEL

Continuity of supply concerns the likelihood that electricity can be transported to the consumer without interruption. In this paper we only present data on non-planned long interruptions (longer than 3 minutes) due to incidents in the local network. It should be noted that this does not give a complete picture of the reliability as experienced by the customers.

To analyse the development of the continuity of supply, a macro or system perspective and a micro or customer perspective are used. For the system perspective the aggregated interruption indices (SAIFI and CAIDI) are used. These values have to be provided by the network operators as part of their annual report to the regulator. At customer level, the network operators have to report details about all interruptions that last longer than 12 or 24 hours.

RESULTS

In this paper we present the contribution of the local networks to SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index), as defined among others in IEEE Std.1366 [2] and in the fourth benchmarking report on quality of supply published by the European energy regulators [3].

As was mentioned before, there is a huge difference in geographical extent and therefore in customer density, between different local networks. To be able to compare the results, the local networks are divided in three groups based on the customer density, the ratio between the number of customers and the total length of all lines and cables:

- ✓ Rural network: less than 10 customers per km;
- ✓ Suburban network: between 10 and 20 customers per km;
- ✓ Urban network: more than 20 customers per km.

The interruption frequency (SAIFI) and the unavailability (SAIDI) are shown in Figure 2 and Figure 3, respectively, for the period 1998 through 2008.

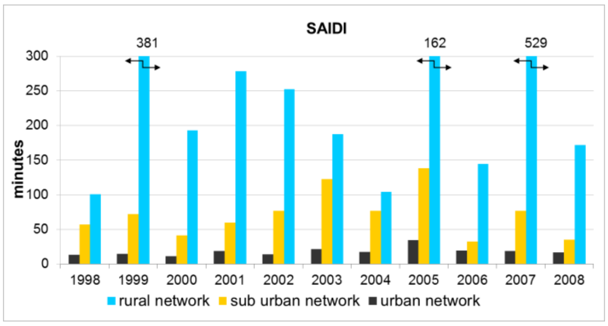

Figure 2, SAIDI (interrupted minutes per year) due to local networks.

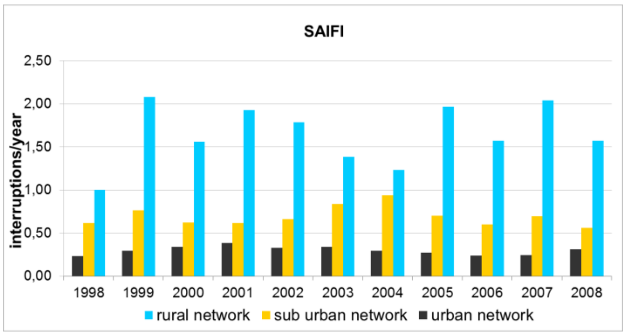

Figure 3. SAIFI (number of interruptions per year) due to local networks.

Unavailability

The following average and extreme values for unavailability have been reported:

- ✓ For rural networks, the unavailability was on average 6 hours per year, with the highest annual value (1620 minutes in 2005) being 16 times the lowest value (101 minutes in 1998).
- ✓ For suburban networks, the unavailability was on average 72 minutes per year, with the highest annual value (138 minutes in 2005) being four times the lowest value (32 minutes in 2006).
- ✓ For urban networks, the unavailability was on average 18 minutes per year, with the highest value (35 minutes in 2005) three times the lowest value (11 minutes in 2000).

The unavailability for rural networks is, as expected, much longer than for urban networks and it also shows much larger year-to-year variations. The highest values were reported during 2005, when the storm Gudrun affected large parts of the country, for all types of network. The storm Per in 2007 caused an increase in unavailability only for rural networks.

No further trends are visible in the values. Using least-square analysis shows an increase with a few percent per year for urban and rural networks. This increase can be explained completely by the high values during 2005.

Interruption frequency

The following average and extreme values for interruption frequency have been reported for the three types of local network:

- ✓ For rural networks, the interruption frequency was on average 1.65 interruptions per year, with the highest annual value (2.08 in 1999) being twice the lowest value (1.00 in 1998).
- ✓ For suburban networks, the interruption frequency was on average 0.69 per year, with the highest annual value (0.94 in 2004) being 1.7 times the lowest value (0.56 in 2008).
- ✓ For urban networks, the interruption frequency was on average 0.30 per year, with the highest value (0.39 in 2001) 1.7 times the lowest value (0.23 in 1998).

Also the interruption frequency is higher for urban networks than for rural networks, but the difference is significantly less for the interruption frequency (a factor 5.5) than for the unavailability (a factor 20).

Applying the least-square method did not show any significant trend in interruption frequency during the 11-year period over which statistics were available.

Spread between local networks

Both unavailability and interruption frequency vary a lot between local networks. To get a better impression of this variation, the standard deviation has been calculated for each year over the different local areas within each of the three types of network. The results are shown in Figure 4 and Figure 5 for interruption frequency and unavailability, respectively.

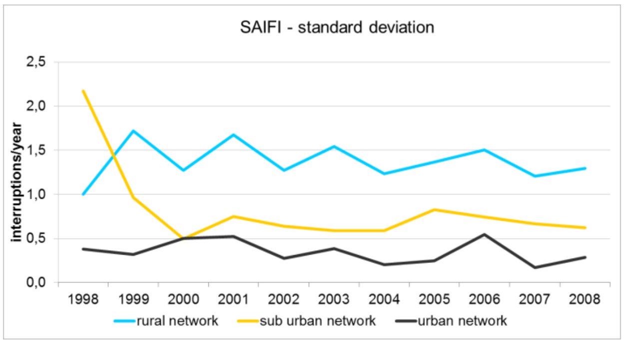

Figure 4. Standard deviation of the interruption frequency between local networks.

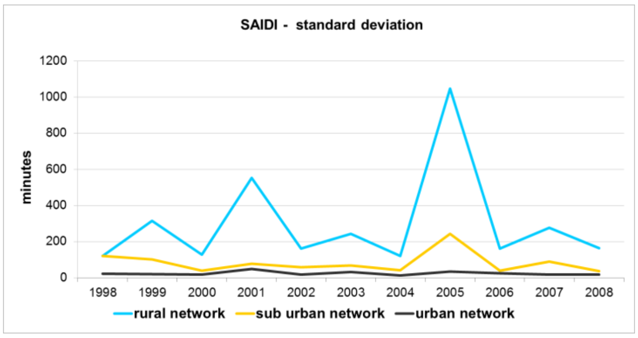

Figure 5. Standard deviation of the unavailability between local networks.

The standard deviation is bigger for rural than for suburban and urban networks. The spread (standard deviation) in the interruption frequency does not show any large variations and no trend, with the exception of a fast decrease for suburban networks during the first three years. The spread in unavailability shows high values during 2001 and 2005 for rural networks and only during 2005 for suburban networks.

Note that what is shown in the figures is the absolute spread in minutes and in number of interruptions. When calculating the relative spread (ratio between standard deviation and average) a higher relative spread in the interruption frequency is observed for suburban networks than for rural networks.

Very-long interruptions

Since 2007, network operators in Sweden have to annually report the number of customers that experience an interruption longer than 24 hours and the number of customers that experience an interruption between 12 and 24 hours in duration.

- ✓ During 2007, about 225 000 customers (4.3% of all customers) experienced an interruption longer than 24 hours. This high number is mainly due to the storm Per.
- ✓ During 2008, about 25 000 customers (0.5%) experienced an interruption longer than 24 hours.

As data has only been available over two years, it is not possible to extract any trends.

To identify in which local networks there remain serious problems with very-long interruptions, the ten network operators with the highest number of customers experiencing an interruption longer than 24 hours during 2008, have been identified in the benchmarking report.

- ✓ E.On Elnät Sverige AB: 15 602
- ✓ Vattenfall Eldistribution AB, Norrnät: 4 129
- ✓ Vattenfall Eldistribution AB, Södra: 3 854
- ✓ Luleå Energi Elnät AB: 634
- ✓ Skellefteå Kraft Elnät AB: 619
- ✓ Bodens Energi Nät AB: 188
- ✓ Göteborg Energi Nät AB: 88

- ✓ Mälarenergi Elnät AB: 76
- ✓ Jönköping Energinät AB: 60
- ✓ Björklinge Energi ek för: 39

From the list it follows that problems with long restoration times are limited to a small number of network operators. Only three network operators had more than 1000 customers that experienced a very-long interruption. It should however be noted that even for these network operators this only concerned a small part of the customers.

INVESTMENTS AND MAINTENANCE

After the storm Gudrun in 2005 the regulation towards continuity of supply has been strengthened. This regulation is especially directed towards limiting the number of very-long interruptions, less towards limiting overall performance indices like SAIFI and SAIDI. This is likely to impact the investments and running costs of the network operators.

Trends considering investments and running costs are presented in Figure 6 and Figure 7. The figures show a constant annual investment up to 2004 followed by a linearly-increasing investment since then. Note that the investment during 2008 is almost three times the annual amount up 2004. It should be noted that this includes all investments, not only investments aimed at reducing the number of very-long interruptions. But the Energy Market Inspectorate still sees the link between this increased investment and the strengthened regulation since 2005.

Interestingly, the running costs do not show any increasing trend. Instead they show strong year-to-year variations correlated with the storms Gudrun (in 2005) and Per (in 2007). The strong pressure to reduce the number of very-long interruption has thus apparently not resulted in noticeably-higher running costs.

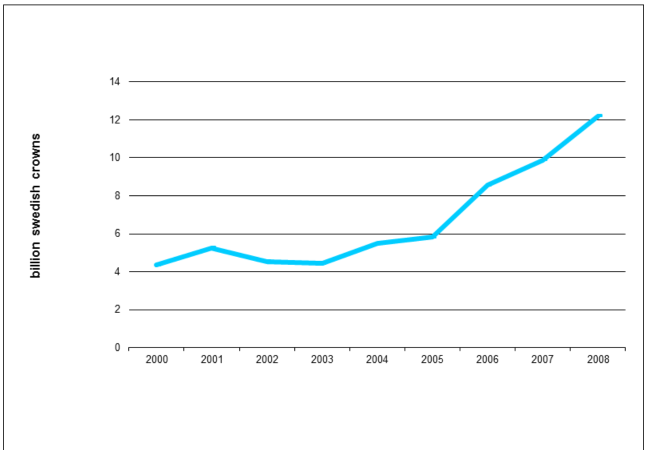

Figure 6. Investments by network operators, 2000-2008 in nominal prices.

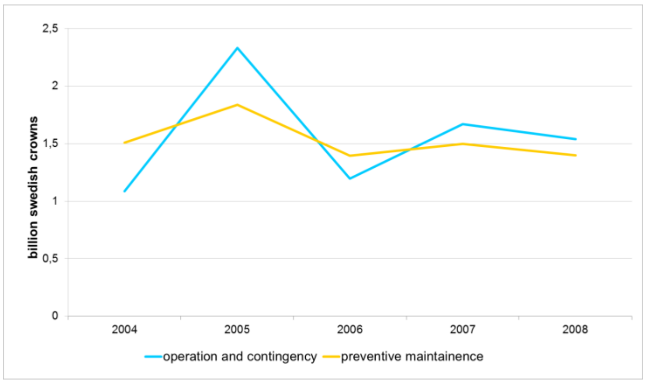

Figure 7. Nominal running costs by the network operators, 2004-2008.

Note also the difference in vertical scale between the two figures; during 2008 the investment was about 12 billion crowns versus about 3 billion crowns in total running costs.

CONCLUSIONS

The continuity of supply is shown to be relatively high in urban networks (0.3 interruptions, 16 min. per year) but significantly less in rural networks (1.3 interruptions and 110 min.). The spread between network operators is also larger in rural areas. No trends have been identified from the statistics over the 10 years for which data is available.

Problems with very-long interruptions were, during 2008, limited to a few network operators.

The total running costs for the network operators do not show any upward or downward trend whereas the investments have increased almost by a factor of three since 2004.

Work has started on the next benchmarking report on continuity of supply in Sweden, including the data over 2009. Continuity of supply statistics published by Swedish Energy (representing among others the network operators in Sweden) indicate an improvement during 2009 compared to earlier years [4].

REFERENCES

[1] Leveranssäkerhet i elnäten - Statistik och analys av elavbrotten i de svenska elnäten 1998-2008 (in Swedish), Energy Markets Inspectorate, EIR 2010:05, 15 April 2010. http://www.ei.se

[2] IEEE Std.1366, Guide for electric power distribution reliability indices.

[3] Fourth benchmarking report on quality of electricity supply, CEER, 2008.

[4] Svensk Energi, Drifthändelsestatistik (DARWin), http://www.svenskenergi.se, in Swedish.