A SCORECARD APPROACH TO TRACK RELIABILITY PERFORMANCE OF DISTRIBUTION SYSTEM OPERATORS

Jan Henning JÜRGENSEN
KTH – Sweden
jhjur@kth.se

Lars NORDSTRÖM
KTH – Sweden
larsn@ics.kth.se

Patrik HILBER
KTH – Sweden
hilber@kth.se

ABSTRACT

Firstly, this paper reviews the current process of reporting reliability data in Sweden. Limitations of reliability indices such as SAIDI and SAIFI are discussed and the need for more reliability measures is stated. The paper suggests the introduction of a reliability performance scorecard to analyse reliability measures in an organized system under different aspects. Furthermore, a set of measurements is provided that can be used to assess a utility's reliability performance. The use of the scorecard is discussed and its applicability for implementing and tracking regulations. This would result in a better policy-making and a decreased pressure on electric utilities due to a higher understanding of what companies invest to achieve a reliable supply of energy.

INTRODUCTION

The continuous technological progress of industry and modern society demands reliable and uninterrupted electricity supply even in rural areas. Major power blackouts as in Canada and the USA in 2003 or in Sweden due to the storms Gudrun and Per, 2005 and 2007, demonstrated the vulnerability of an ageing power grid and drew high public and political pressure towards a mostly deregulated area. Electric utilities faced challenges due to new regulations and reliability indices such as SAIDI, SAIFI, and MAIFI were introduced for an assessment of reliability on a national basis [1]. However, more data and an increased information flow between utilities and regulators would facilitate performance tracking and the impact of new regulations will become more visible [2]. [3] suggests more and precise data and reports about energy outages for the American sector. The goal is that a higher information flow will lead to an improved analysis and a more accurate policy-making.

This paper describes the current reliability reporting in Sweden and discusses the limitations of SAIDI and SAIFI as reporting indices and the need for more reliability performance measures to improve the existing reporting process. We suggest a set of reliability performance measures and use the scorecard approach to organize these measures under different aspects. This would enable an improved overview and analysis of a utility's reliability performance.

REPORTING RELIABILITY DATA IN SWEDEN

The Swedish Energy Markets Inspectorate (Ei) as an independent organisation was founded in 2008 from the regulating authority Swedish Energy Agency. The main responsibility is the regulation of electrical distribution system tariff levels [4]. Another responsibility is the supervision of the delivery of energy and its quality. The Ei has established the reporting of outage times for every distribution system operator (DSO) in 2008 to strengthen the position of the customer and to enable the possibility to assess the quality of electricity supply. Every DSO must report the number of outages and the outage times of their electricity network every year latest the 31st of March. Ei provides a regulatory framework [5] that specifies the criteria for reporting planned or unplanned outages. Planned outages must be reported according to the criteria:

- Number and total time in minutes of planned outages in the DSOs electricity grid
- Number and total time in minutes of planned outages caused by the overlaying electricity grid

The reporting of unplanned outages is divided into short and long outages, where short outages are defined as outages from 100 milliseconds to three minutes and long outages as outages above three minutes. The criteria for long unplanned outages are defined as:

- Number and total time in minutes of planned outages up to 12 hours in the DSOs electricity grid
- Number and total time in minutes of planned outages with or above 12 hours in the DSOs electricity grid
- Number and total time in minutes of planned outages up to 12 hours caused by the overlaying electricity grid
- Number and total time in minutes of planned outages with or above 12 hours caused by the overlaying electricity grid

Short outages are reported as total number for the own and overlaying grid. In addition, every load point has to be classified with respect to the type of customer. This data is used to publish a report which is named "Security of supply in the power system" that analyses the gathered data from the DSOs. Five reliability indices are mainly used to compare the quality of supply: System Average Interruption Frequency Index (SAIFI), Customer Average Interruption Frequency Index (CAIFI), System Average Interruption Duration Index (SAIDI), Customer Total

Average Interruption Duration Index (CAIDI), and Momentary Average Interruption Event Frequency Index (MAIFIE). Moreover, Swedish DSOs are obliged to execute a risk analysis on a yearly basis and report it to the Ei [6]. The goal is the identification of risks to plan and prepare actions for failure scenarios. Due to security concerns, the conducted risk analyses are not publicly available. A benchmark study, which used reliability information, was conducted by the consultant firm Rejlers, and compared 12 Swedish DSO in terms of operational effectiveness [7]. The study focused on investments and maintenance costs related to quality of electricity supply defined as SAIDI and CAIDI.

The new tariff regulation system introduced 2012 in Sweden utilizes the reliability indices SAIFI and SAIDI as a measurement of the reliability of the local distribution system divided in planned and unplanned outages [8]. If the reliability has decreased over a four year period, the return on capital will decrease. The aim is to create incentives for an increase in quality of electricity supply [8].

Limitations of SAIFI and SAIDI

All outages regardless the reason must be reported in Sweden [5]. Thus, the reported reliability data becomes vulnerable to unpredictable external factors such as weather events. Analysing the reliability indices SAIDI and SAIFI in Figure 1 and 2 for the complete Swedish distribution grid, it is observable that when the storms Gudrun (2005), Per (2007), and Dagmar (2011) occurred, the indices have a significant increase compared to years without severe weather events. Even if the weather event years would be excluded from the analysis, still no clear trend is visible over time, see Figure 1 and 2.

Another limitation is the difficulty of assessing the impact of investments into a more reliable grid while evaluating SAIDI or SAIFI. For example, the investments in cables and smart meters might only be seen over a longer period of time [9]. Therefore, the direct impact of investments into a more reliable grid could almost not be determined with reliability indices. Analysing the SAIDI and SAIFI values from Figures 1 and 2 as a representative on a company level, there is no evidence that there is a trend towards better or worse reliability and we can conclude that many unknown external factors influence SAIDI and SAIFI. As a result, even if Swedish DSOs respond to the incentives with a higher effort towards a higher quality of electricity supply, it is difficult to show improvements to the Ei based on these indices.

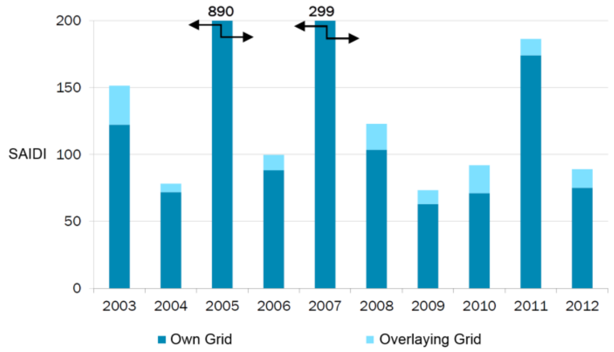

Figure 1: SAIDI in [minutes per customer and year] for the complete Swedish distribution grid [4]

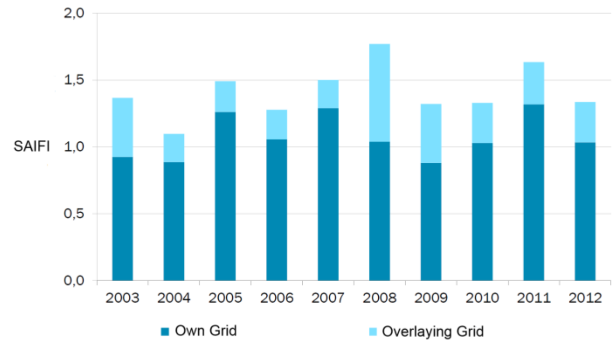

Figure 2: SAIFI in [interruptions per customer and year] for the complete Swedish distribution grid [4]

RELIABILITY PERFORMANCE SCORECARD

In March 2014, the Ontario Energy Board presented a renewed regulatory framework that assesses DSOs using a performance-based scorecard approach with focus on the creation of better transparency for existing and future customers [10]. The scorecard is divided into four performance outcomes: customer focus, operational effectiveness, public policy responsiveness, and financial performance. These performance outcomes reflect the overall performance of Canadian DSOs to create better customer satisfaction and align interest under all parties. The Canadian scorecard approach addresses under operational effectiveness the categories: safety, system reliability, asset management, and cost control. System reliability is measured as SAIDI, SAIFI, and asset management as distribution system plan implementation progress.

Inspired by the Canadian scorecard approach, we propose a reliability performance scorecard (RPS) to improve the Swedish reliability reporting. The RPS focuses on reliability instead of evaluating the overall DSO performance. A scorecard as performance evaluation tool was selected because the regulator and the customer should gain an overview about the company's reliability

System Reliability Perspectives	Criteria	Existent	Measures	Data Analysis
Transparency Reflection of how reliability data and results are communicated to the regulator and the customer	Reporting	✓ •	Reported information to the regulator Available Information for the customer	Organised overview of reliability performance measures Long term view of the performance Setting targets Comparing results to: • company targets • regulator specifications • industry standards Benchmarking of DSOs Transformation of regulations into specific measures Tracking the implementation process of regulations
Operation Operation of the assets and how they are maintained to reflect the improvement of system reliability	System	✓ ✓ ✓ ✓ ✓	System Average Interruption Duration Index in [min per customer per year] System Average Interruption Frequency Index in [interruptions per customer per year] Momentary Average Interruption Event Frequency Index in [interruptions per customer per year] Customer Average Interruption Duration Index in [min per customer and year] Customers Experiencing Multiple Interruptions in [customers experiencing more than n interruptions]	
	Equipment	✓ ✓ • • • ✓ ✓	Level of primary equipment documentation in [%] Age level of the primary equipment Percentage of feeders with automated feeder switching Number of monitored equipment Condition/Risk estimation of monitored equipment New investments in [SEK per kilometre line] Reinvestments in [SEK per kilometre line]	
	Maintenance	✓ ✓ ✓ ✓	Planned maintenance tasks Unplanned maintenance tasks Ratio of planned or unplanned maintenance to total maintenance tasks Maintenance strategy implemented in the utility	
Evaluation and Improvement Support and objective analysis from external experts to gain objective feedback for implemented and planned projects	Implemented Standards	✓	Implemented asset management standard	
	Knowledge Exchange	• •	Number of projects in collaboration with universities Number of collaborations with industry partners	

Table 1: Reliability performance scorecard for the evaluation of DSOs with suggested reliability measures

performance rather than doing an interpretation of a single index. The illustration of performance measures on a scorecard results in a better understanding and presents a better overall picture when measurements are organised and grouped into different aspects. This enables evaluation of utilities and facilitates the comparison between DSOs. The scorecard can also support the transformation of new policies into specific terms and support the following tracking of the implementation [11]. In sum, the RPS reflects the utilities reliability performance and reveals its capability to communicate it to the regulator and customer.

The scorecard is organized in a bottom-up structure. This enables cause-and-effect chains between the perspectives and measurements. The evaluation and improvement perspective describes the DSO's ability for continuous improvement and acquiring knowledge. This has an impact on the operation perspective in terms of better maintenance or optimized investments in equipment. Improved maintenance and equipment would influence the system indices. This has a positive effect on the communication with the regulator and increase customer satisfaction. The structure is schematically illustrated in Table 1 and the following subsections are describing the proposed performance measures.

Measures

Evaluation and Improvement

This section represents the utilities performance of internal improvement, external evaluation, and knowledge exchange.

1. The *implemented asset management standards* defined by the regulator can be measured by stating the level of implementation progress in percentage. For example, the implementation of ISO 55000 demonstrates that an asset management system is implemented and progress is intended.
2. The evaluation of knowledge exchange can be represented by the *number of university collaborations* established or conducted research projects with universities per year. Likewise, *number of collaborations with industry partners* is a representative for ongoing information exchange.

This can also be measured as ratio of invested value into collaborations to company turnover. Evaluating utility concepts indicates the ability of adapting to new concepts and creates an environment of objective feedback for own projects.

Operation

The operation perspective is subdivided into the aspects: maintenance, equipment, and system. The suggested reliability measures for the three aspects are:

3. *Planned maintenance tasks* (preventive maintenance) are quantified as number of planned maintenance tasks [12].
4. *Unplanned maintenance tasks* (corrective maintenance) are quantified as number of unplanned maintenance tasks [12].
5. *The ratio of planned or unplanned maintenance to total maintenance tasks* makes maintenance comparable to other DSOs. Alternatively, the ratio of maintenance costs to total turnover could be used.
6. The implemented *maintenance strategy* in the company demonstrates the impact of utilized maintenance frameworks on reliability and effectiveness. This is a non-quantitative measure.
7. *Level of documented primary equipment* is the ratio of documented equipment to the overall installed equipment. Documented equipment must be defined as, for example, equipment where attributes such as production year, installation year, serial number, producer, location, etc. are known. A sufficient set of attributes needs to be defined.
8. *Age level of the primary equipment* is an indicator that describes the overall condition of the grid. It can be determined by the ratio of the actual equipment age to the estimated technical or economical lifetime. The calculation of this indicator might be challenging if the equipment age is not documented. The regulator and DSOs have to agree on an estimation method. This is included in the new Swedish regulation period 2016 to 2019 [13].
9. *Percentage of feeders with automated feeder switching* is an indicator of the degree of automation of the distribution system. [14] presents initial results of reliability improvements of automated feeder switching in 4 of 42 smart grid projects in the US. The range of percent change of the reliability indices is -11% to -49% for SAIFI and +4% to -56 % for SAIDI after installation of automated feeder switching. The negative change shows reliability improvement while the positive change shows a decline. The high improvement can be explained by the fact that the projects installed automated feeder switching on the worst performing feeders [14].
10. *Number of monitored equipment* illustrates the ability to predict failures of equipment. This results in less unplanned outages. It should be defined beforehand which equipment is important to monitor because it is not reasonable to control all equipment.
11. *Condition/Risk estimation of the monitored equipment* reflects the actual condition and the impact of maintenance might become visible. An estimation of the risk could be calculated by the information gained from the monitored equipment.
12. *New investments and re-investments in [SEK per kilometre line]* are measures that reflect the efficiency of the DSO and make the performance comparable to other DSOs.
13. The reliability indices *SAIDI, SAIFI, and MAIFIE* illustrate the overall system perspective and keep the comparability between DSOs.
14. The indices *CAIDI and Customers Experiencing Multiple Interruptions* ($CEMI_n$) reflect the outage duration for customers and the frequency of interruptions for customers.

Transparency

The establishment of a conversation between the utility and the regulator or customer is an important instrument to achieve high transparency. This creates trust among all parties. To assess the transparency, two measures are suggested:

15. The *reported information to the regulator* can be stated as ratio of what has been reported to what should be reported. Thereby, the customer and the regulator gain an overview if the DSO fulfilled the reporting obligations in time.
16. *Available information to the customer* can be assessed by conducting surveys in form of questionnaires.

Availability of performance measures

The measurements are selected under the constraint of availability of data. We tried to select measures that are obtainable or already existing for Swedish DSOs. The proposed measurements 3 to 6 could be gathered from maintenance work orders, 7, 13, and 14 have been used in reports [5, 6], 12 in [7], and 8 will be used according to [13]. All other information might be acquired from internal DSO data bases or must be collected. The suggested measures should be seen as a starting point of discussion between the DSOs and the Ei and depending on the aim adjusted or replaced.

Discussion of RPS

The RPS enables the opportunity of a wide range of data evaluations. It is possible to extend and customize the scorecard which makes it flexible for implementation. New measures can be included or insufficient be removed regarding their significance. The data can be presented over time to assess trends. Likewise the balanced scorecard [15], objectives can be set and later analysis could show if they have been achieved. Performance measures can be compared to company targets, regulator specifications, and industry standards in an efficient way.

When introducing measures, the challenge will be to define and select measures that are significant. Measures should be related to goals or to track the implementation of policies and therefore be built on one another to create cause-and-effect chains. Furthermore, the processes of setting targets could be difficult due to a lack of knowledge and experience [16]. [10] does not set any performance targets until sufficient experience was gained from new measures. This demonstrates that the choice of measurements combined with the limitation of data will be an obstacle during the introduction of scorecards. [16] solved the challenge by a creative determination of measures during workshops and later selected the measures which are most relevant and easy to gather. A successful implementation of an RPS also requires the willingness of utilities to gather measurements. However, the RPS can be utilized internally, as a benchmarking tool, or to present the reliability performance to the regulator. When using it as a benchmarking tool, the measurements must be comparable and independent of utility specific characteristics.

Furthermore, the RPS requires a higher amount of manpower capacity due to defining and gathering the necessary data, setting targets, monitoring of the measures, and the later analysis and benchmarking. Nevertheless, the scorecard approach can be easily understood by all parties, enables a structured overview, keeps the regulator informed about the reliability performance, and supports the understanding of how to implement and track new policies.

CONCULSION

This paper describes the current reliability reporting process of DSOs to the energy market regulator in Sweden. Limitations of expressing the reliability performance simply with reliability indices such as SAIDI and SAIFI have been identified and the need for more reliability performance measures was shown. A reliability performance scorecard that illustrates different performance measures to provide an organized overview was suggested. This organized structure also facilitates the benchmarking between DSOs, the identification of the impact of new regulations, and the assessment of reliability for the customer. Furthermore, a set of measures that focus on the Swedish reliability reporting was also recommended as a foundation for evaluation. The presented scorecard approach and the measures should be seen as a basis to encourage discussion between DSOs and the energy market regulator to improve the present reporting process.

REFERENCES

[1] K. H. LaCommare and J. H. Eto, 2006, "Cost of power interruptions to electricity consumers in the United States (US)", *Energy*, vol. 31, pp. 1845-1855.

[2] K. H. LaCommare, 2008, "Tracking the Reliability of the U.S. Electric Power System: An Assessment of Publicly Available Information Reported to State Public Utility Commissions", Lawrence Berkeley National Laboratory.

[3] E. Fisher; J.H. Eto; K.H. LaCommare, 2012, "Understanding Bulk Power Reliability: The Importance of Good Data and a Critical Review of Existing Sources", *45th Hawaii International Conference on System Science (HICSS)*, 2159-2168.

[4] Swedish Energy Markets Inspectorate, 2014, http://www.ei.se

[5] Swedish Energy Markets Inspectorate, 2013, "Energimarknadsinspektionens föreskrifter och allmänna råd om skyldighet att rapportera elavbrott för bedömning av leveranskvaliteten i elnäten".

[6] Swedish Energy Markets Inspectorate, 2013, "De svenska elnätsföretagens redovisning av risk- och sårbarhetsanalyser och åtgärdsplaner 2012".

[7] L. Wikman, 2013, "Bäst i klassen Elnät – En jämförande studie i operativ effektivitet", Underhåll och investeringar i elnät.

[8] S. Stenberg; C.J. Wallnerström; P. Hilber; O. Hansson, 2012, "The new Swedish regulation of power distribution system tariffs – a description and an initial evaluation on its risk and asset management incentives", *Proceedings NORDAC Conference*, Espoo.

[9] E.ON SE: Charts Investor Relations, 2014 "E.ON's European distribution business – Powering the energy system transformation", *Business Deep Drive Distribution in London*.

[10] Ontario Energy Board, 2014, "EB-2010-0379 Report of the Board – Performance Measurement for Electricity Distributors: A Scorecard Approach".

[11] B. Frost; "Measuring Performance: Seven Good Reasons to Use a Scorecard", *Performance Perspectives Series*, http://www.measurementinternational.com.

[12] A. Parida and G. Chattopadhyay, 2007, "Development of a multi-criteria hierarchical framework for maintenance performance measurement (MPM)," *Journal of Quality in Maintenance Engineering*, vol. 13, pp. 241-258.

[13] Svensk Energi AB, 2014, "Stort interesse för elnätsregleringen 2016-2019", http://www.svenskenergi.se/Pressrum/Nyheter/Elnatsregleringen-2016-2019/

[14] U.S. Department of Energy, 2012, "Reliability Improvements from the Application of Distribution Automation Technologies – Initial Results".

[15] R. Kaplan and D. Norton, 1996, *The balanced scorecard: translating strategy into action*. Harvard Business Press.

[16] H. Ahn, 2001, "Applying the Balanced Scorecard Concept: An Experience Report", *Long Range Planning*, Volume 34, Issue 4, Pages 441-461.