LAWS AND REGULATIONS OF SWEDISH POWER DISTRIBUTION SYSTEMS 1996-2012

-learning from novel approaches such as less good experiences

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ABSTRACT

This paper gives an overview of a turbulent time for the regulator and distribution system operators (DSO) in Sweden since the de-regulation of the electricity market in 1996. A performance based ex-post model was introduced 2003 as a tool to judge distribution system tariffs. This model is since 2009 formally abandoned and a new ex-ante regulation will be introduced in 2012. The aim of this paper is to learn from both unique and novel approaches such as less good experiences. The paper describes the history, the current situation and planed future regulations and describes additional relevant laws.

INTRODUCTION

The electrical power system is one of the fundamental infrastructures in a modern society. Its overarching aims are to produce and provide customers with electrical energy of a certain voltage quality and level of reliability at a reasonable cost and with regard for the environment. The issues of cost and environment first came into focus at the end of the last century [1], [2]. A paradigm shift took place when market conditions were introduced [3].

From the perspective of the distribution system operators (DSOs), there are costs for operation and maintenance to balance against the requirements for system reliability and the profit for the stakeholders. In a perfect market environment, a balance would be reached when customers select the DSO with the best price for the required customer value. However, the infrastructures are natural monopolies. It is the task of the authorities to judge if this tariff is reasonable. In Sweden, the electricity market was de-regulated in 1996 and a unique and innovative regulatory tool was introduced in 2003, referred to as the Network Performance Assessment Model (NPAM) [1].

The regulation of network tariffs using the NPAM was strongly criticized by stakeholders followed by legal processes [4], [5]. In late 2008 the parties made an agreement concerning 2003-2007 and in January 2009 the regulator decided to formally abandon the NPAM. From 2012 Sweden will according to an EU directive, implement an ex-ante regulation [6]. Ex-ante is when the regulator judges the level of customer tariffs before they are applied by the DSO. The new regulation will continue to focus on similar objectives as the NPAM such as cost efficiency, reliability and customer values. Moreover, more laws have and will be implemented.

A law, introduced in Sweden 2006, dictates that every DSO annually have to report result from a risk- and vulnerability analysis regarding the reliability. The risk analysis has to include an action plan of how the reliability shall be improved [7]. The tariff regulation will take 0.05-12 hour outages into consideration. However, additional legalization has been introduced for long term outages and regulation on short will also be applied. The customers are compensated with 12.5 % of the annual tariff after 12 hours of outage (minimum ~ 100 €). This compensation increases with the outage time, to a maximum of 300 % of the annual tariff [8]. Furthermore, a functional requirement states that no customer outages ≥24 hours are allowed from 2011 [9]. Hence, 12 and 24 hours are important limits for the Swedish DSOs and. give incentives to introduce more advanced planning methods [10].

SWEDISH TARIFF REGULATION

De-regulation with implications

The Swedish electricity market was de-regulated in 1996 and a new regulating authority, the Swedish Energy Agency (STEM), was established in 1998. The distribution was however still operated as regional natural monopolies, with responsibilities as well as privileges for the DSOs [2]. Earlier, the DSOs were more or less allowed to compensate for all their costs by settle tariff levels regardless the effectively and quality. Following the de-regulation, STEM identified a problem with increased tariff levels. Despite several attempts by STEM to keep the tariffs down, e.g. through price freezing, no solution was found. There was therefore needed to find a new regulation paradigm [2].

In 1998, a project [1] was initiated by STEM to propose a new regulation model. The model was to be based on self-regulation and was to give incentives to increase the cost efficiency and maintain a reasonable quality. Moreover, the model should be accepted by the customers and different DSOs. Finally, there should be full insight into the model. The first approach was to use an existing model adjusted to Swedish conditions. However, when no model was suitable enough according to SETM's requirements of customer focus and cost efficiently incentives, it was decided to develop a new model. [2]. The proposed regulation model meant a change in perspective from a company to a consumer focus, with performance-based regulation. From the consumer perspective, the cost is based on the value to the consumer, in contrast to the cost for the DSO. As a result of this new customer perspective the law was changed [9].

The rise and fall of the NPAM

Overview of the tariff regulation with the NPAM

From an international perspective, the NPAM was a unique and innovative regulatory tool. The model evaluated tariffs ex-post by enter several system data to a computer program which produce a fictive network with the aim of having the same objective conditions as the real system [1], [4]. Followed by the use of this regulatory tool, STEM demanded repayments from several DSOs each year from the tariffs of 2003, based on strong indications of too high tariff levels according to results from the NPAM. The Energy Markets Inspectorate (EI), a division of STEM, becomes an independent authority in 2008 with responsibilities of e.g. regulate electrical distribution system tariff levels [6].

The tariff regulation using NPAM as the primary tool was however strongly criticized by stakeholders followed legal processes. For example the NPAM was criticized to not taking historical circumstances (such as investments to areas with decreasing need of electricity) into consideration and not be robust enough to fulfill the criteria of objectiveness [4], [5]. These legal presences would have taken sevaral years and cost a lot of time and recourses only to treat 2003, while new legal processes was added for each year. In late 2008 the parties made an agreement for 2003-2007, that includes fewer DSOs and, compared with the original demand, low levels of repayments. In January 2009 the regulator decided to abandon the NPAM although the model [6] theoretically can be used in an ex-ante regulation as well [10].

The Network Performance Assessment Model

This section provides a summary of the NPAM (more information in [10]), which overall structure is illustrated by Fig. 1. The NPAM have a unique complexity, which includes technical assumptions based on years of discussions, performed Monte Carlo simulations, reliability analyses etc. The model is abandoned, but is however still useful as reference material.

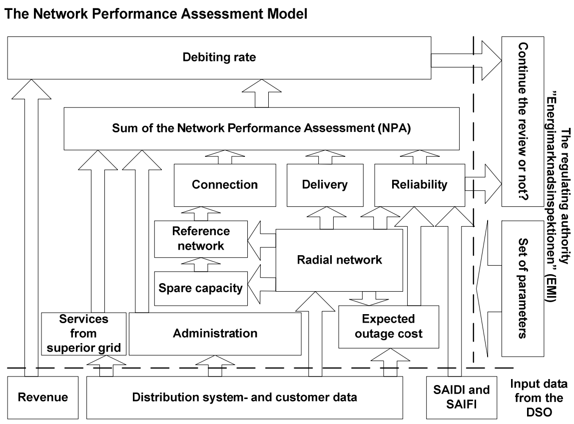

Fig. 1 Overview of the NPAM

The model builds up a radial fictive reference network, based on annual reported data from the DSO. The data aim to representing the objective conditions, i.e. that the DSO not can influence. The fictive network is radial and results in a cost referred to as C_{Radial}, which includes capital costs and template compensations for e.g. maintenance. Power distribution systems often include redundancy to improve system reliability [11]. The amount of spare capacity aims to correspond with what the customers are willing to pay for. The model estimates this amount and the resulting required cost referred to as C_{Spare}. Not effectible costs are fully compensated $C_{Service}$, while administration C_{Admin} and energy losses C_{Deliv} are estimated by template functions. Finally, this total cost can be reduced, if the reliability is lower than expected C_{Rel}. The resulting total cost is referred to as the Network Performance Assessment (NPA), summarized by equation 1 [10].

$$NPA = C_{Connect} + C_{Admin} + C_{Deliv} + C_{Service} - C_{Rel},$$
$$\text{where: } C_{Connect} = C_{Spare} + C_{Radial} \qquad (1)$$

The reliability function is calculated by equation 2:

$$C_{Rel} = \begin{cases} 0 & if\ C_{Outage} - C_{Expect} \le 0 \\ C_{Outage} - C_{Expect} & if\ 0 \le C_{Outage} - C_{Expect} \le C_{Max} \\ C_{Max} \Leftrightarrow C_{Spare} & if\ C_{Outage} - C_{Expect} \ge C_{Max} \end{cases}, \text{ where:}$$
$$C_{Outage} = \frac{E}{8760} \cdot \sum_{i=a,b} (x_i \cdot SAIFI_i + y_i \cdot SAIDI_i) \qquad (2)$$

E [kWh/yr] is the total annual energy consumption, 8760 is hours in a year [h/yr], index i indicates if the interruptions are announced (lower cost) or not, $SAIFI_i$ [number of outages/year] and $SAIDI_i$ [hours/year] are system reliability indices [11], x_i [SEK/kW, int.] and y_i [SEK/kWh] are customer interruption costs determinate by a template considering the customer density [10].

The NPA is an assessment of the customer values of a power distribution system. The fundamental idea of the NPAM is that DSOs will be allowed to collect *revenue* that corresponds to the NPA. The *debiting rate* for a DSO is defined by the quotient of the revenue and the NPA, as shown in equation 3. The first year the NPAM was used in practice, a debiting rate of 1.3 was considered as an highest accepted performance, a level that was gradually decreased over the following years [10]. The results from NPAM was considered to be the primary tool for the regulator to judge the tariffs level to decide if a DSO should be monitored for further review [10].

$$Debiting\ Rate = \frac{Revenue}{NPA} \qquad (3)$$

Mid-term regulation

During these years, much of the focus is on the preparedness of the new ex-ante regulation from 2012. The regulator has the difficult task to both avoid relapsing into great conflicts and legal processes and on the other hand to fulfill their task to protect electricity customers, while the regulation has to be fair and motivate right incentives. In some way the tariff levels are self regulated during the period. The DSOs have the incentive to be careful, because too high increments of the tariffs could affect the regulator in the process of defining the details of the regulation, i.e. motivate harder regulation.

An official mid time regulation however exists. By the law the regulator has the mandate to review the fairness of the tariff levels and provide sanctions if needed although without quantitative results from the NPAM. The mid-term regulation has similar overall principles as the upcoming regulation such as review several years at time and EI aims to create some sort of tariff levels before 2012. DSOs with suspected high tariffs regarding its quality are manually reviewed and have the possibility of "self-regulate" until 2012. Any tariff adjustments concerning 2008-2011 are then settled in connection with the decisions of tariff levels of 2012-2015 [6].

Introduction of an ex-ante regulation

The major parts of the new regulation are settled, but details remains to determine and everything will not be included in the first version. The new regulation aims to give a stable prediction of the revenue which hopefully will facilitate investment- and maintenance planning performed by the DSOs. Historical data from recent years gives a preliminary revenue framework for a period of four years. Changes in conditions compared with the forecast can be later adjusted [6].

The revenue framework is based on following parts:

- **Capital costs:** The capital cost of a component consists of depreciations and the cost of restricted capital. The regulator intends to apply capacity conservation principles by using real annuity. A constant annuity is calculated based on the estimated net present value and economical lifetime. The constant annuity value is used despite actual age, which makes it easier for both parties. If a component is older than its estimated economical lifetime, the compensation will be the same (DSOs who maintain their components well are thus rewarded). The required rate of return is calculated with the WACC method (weighted average cost of capital) [6].
- The operating costs is divided into:
  - **Effectible costs**: During the first regulatory period, a general efficiency requirement will be imposed.
  - **Not effectible costs**, such as taxes, are fully compensated.
- **Quality function**: The quality function could unlike the NPAM, both be negative and positive. All costumers may collectively obtain revised tariff levels regardless the individual reliability. In order to not "punish" a DSO twice, outages ≥12 hours are excluded. The quality function is limited to affect the compensation for cost of restricted capital (part of the capital cost) [6].

EI has by law the ability to integrate more quality aspects in upcoming regulation, but these will probably not be included in the first phase. However, EI has already the possibility to impose sanctions on DSOs to correct major weaknesses. The additional quality aspects that will be considered in the future are [6]:

- **Administrative deficiencies**: Customer service, information etc. Customer services could be overloaded during large disturbance.
- **Voltage Quality**: transients, waveform, deviation from the normal voltage value etc.
- **Very short interruptions (<0.05 h)**: These have traditionally not been included in the Swedish Even short outages can cause high impact on certain categories of customers.

ADDITIONAL LAWS

Outage compensation and functional requirement

Sweden has legalization for outages above12 hours and a functional requirement from 2011 that interruptions above 24 hours are not tolerated [9]. Consequently, 12 and 24 hours are important limits for Swedish DSOs in maintenance and investment planning [7]. TABLE I [8] summarize the model for determining customer outage compensation and damages to affected customers. Note that outages ≥24 hours could both lead to compensation according to the customer compensation model and to additional consequences.

TABLE I Consequences of outages ≥12 hours

Length of interruption	Compensation to customer	Minimum compensation[1]
12-24 hours	12.5 % of α	2 % of β
24-48 hours	37.5 % of α	4 % of β
Following 24 hour periods	+ 25 % of α + γ	+ 2 % of β
…	…	…
Max	300 % of α + γ	-

α = Individual customer's annual network tariff, β = Yearly set base amount (42 400 SEK 2010), γ = Risk of further consequences of breaking the law. [1]Is always set to even 100 SEK values, rounded up → 2 % of β is rounded to 900 SEK (~100 € / ~130$)

Compulsory risk- and vulnerability analysis

A law [9] introduced in Sweden 2006 dictates that every DSO annually have to report result from a risk- and vulnerability analysis regarding the reliability. The risk analysis has to include an action plan of how the reliability shall be improved [10]. An initial problem was the Swedish principle that authorities' records are open and available to the public. Hence, analysis results are potential “terrorist manuals”. That lead to revision of the law, so the regulator receives information that the analysis had been done, and if needed, read the results at the DSO without collect documents [6].

Reporting of severe outages

From 2008, information about extensive outages has to be reported to EI within 14 days. The aim is to make it possible to assess the quality of electricity supply. Outages are defined to be extensive if any of following criteria is fulfilled [6]:

- Longer than 24 hours and involves more than 1 000 customers or 25 % of the customers.
- Longer than 12 hours and involves more than 10 000 customers or 50 % of the customers.
- Longer than 2 hours and involves more than 100 000 customers.

CLOSURE

The Swedish regulation of power distribution tariffs between 1996 and 2012 are described. Furthermore some complementary laws such as customer compensation for long outages are presented. The aim is to learn from both unique and novel approaches such as less good experiences as reference when developing regulations and laws affecting the operation of power distribution systems.

The regulator has the rule to provide incentives of cost efficient operation with acceptable reliability and reasonable tariff levels. Because the Swedish power distribution systems consist of several (~180) natural monopolies, with different operators, the regulation has also to be objective and fair, i.e. not favors some DSO.

The experiences from Sweden show on the importance of having a constructive dialogue with the DSOs without being to compliance. Another difficult task for the regulator is to settle the complexity, i.e. the balance between consider many details and the manageableness

REFERENCES

[1] M. Larsson, February 2005, *The Network Performance Assessment Model*, Licentiate Thesis, KTH, Stockholm, Sweden, TRITA-ICS-0501.
[2] L. Bertling, M. Larsson and C. J. Wallnerström, June 2005, “Evaluation of the customer value of component redundancy in electrical distribution systems”, *IEEE PowerTech*, St. Petersburg, Russia.
[3] T. Solver, 2005, *Reliability in performance-based regulation*, Licentiate Thesis, KTH, Sweden
[4] C. J. Wallnerström, L. Bertling, 2008, *Investigation of the Robustness of the Swedish Network Performance Assessment Model*, IEEE Transactions on Power Systems, Volume 23, No. 2
[5] C. J. Wallnerström, L. Bertling, 2007, *A Sensitivity Study of the Swedish Network Performance Assessment Model Investigating the Effects of Changes in Input Data*, CIRED, Vienna
[6] Energy Markets Inspectorate, http://www.energimarknadsinspektionen.se
[7] C. J. Wallnerström, L. Bertling, 2009, *Risk Management Applied to Electrical Distribution Systems,* CIRED, Prague
[8] J. Setréus, C. J. Wallnerström, L. Bertling, 2007, *A Comparative Study of Regulation Policies for Interruption of Supply of Electrical Distribution Systems in Sweden and UK*, CIRED, Vienna
[9] The Swedish Law for the Electric Power System, Chapter 4, “*Ellag (1997:857)*”, including updates until 2009
[10] C.J. Wallnerström, 2008, *On Risk Management of Electrical Distribution Systems and the Impact of Regulations*, Licentiate Thesis, KTH, Sweden
[11] R. Billinton, R. Allan, 1996, *Reliability Evaluation of Power Systems*, New York, US (2nd Edition)