THE CHALLENGE OF REGULATING NATURAL MONOPOLIES IN ELECTRICAL DISTRIBUTION – EXPERIENCES FROM SWEDEN

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SUMMARY

In Sweden a new model for regulating the natural monopolies of electrical distribution is being implemented. This paper first presents the regulation at large and the model more thoroughly. Essentially, the model performs a valuation of distribution utilities and their reliability level based on data observable from outside the utilities as well as common assumptions regarding all utilities. Furthermore, some issues related to the regulatory authority’s use of the model is discussed. Implications on utilities are also addressed in three stages, starting with experiences of what is required from the utilities in order to be able to use the model and continuing with discussing implications of the fundamental principles in the regulation and the model. Finally some implications on the businesses of distribution utilities are indicated.

INTRODUCTION

When the Swedish electricity market was deregulated in 1996, as in other European markets during the 1990’s, energy sales were made a competitive market while transmission and distributions became natural monopolies. As a consequence the needs for efficient methods to regulate the natural monopolies were accentuated. Various methods for regulation have been suggested [1],[2] for example rate of return regulation, yardstick competition, performance based regulation and efficiency analysis based on Data Envelope Analysis [3]. One concern is that these methods are mostly applied to ex ante regulation while Sweden uses ex post regulation.

The Swedish regulatory authority (“Energimyndigheten”) has taken a new approach by implementing the Network Performance Assessment Model (NPAM) as the framework for regulating local electricity distribution. Two pilot test of the model have been performed during 2001 and 2002 with one more scheduled for 2003. The model is intended to be in operational use in 2004, concerning the network tariffs of 2003. A consultant firm, managed by one of the authors, has developed the model on the commission of the regulatory authority. While the model is primarily designed for ex post regulation it could as well be used for ex ante regulation. It is only a matter of selecting the type of input data.

When introducing a new regulation model it is important to create understanding for the model and its implications. This paper is a part of that effort and its purposes are both to present the model for a broader audience and to discuss some experiences and implications of the model. Besides the rich information on the model available in the study, due to one of the authors’ deep involvement in the development process, interviews have been made with responsible persons at the regulatory authority and a number of utilities. Data from utilities and the pilot tests have also been available.

THE NEW REGULATION

A change in the law. Following the deregulation of the electricity market, regulation of distribution utilities was based on the concepts of reasonable tariffs, consideration of consumer interests and an acceptable return on capital for the utilities [4]. However, the implementation in reality proved to be more problematic and a government investigation was launched [5], which eventually resulted in a new electricity act, in place as of July 2002. The new act is the juridical fundament for the regulation of electricity distribution and it basically states that revenues from a distribution network have to be reasonable compared to the so-called “objective prerequisites” of electricity distribution in general and the way the owner of the network distributes electricity [6]. This implies that the law focuses on the service delivered to the customer and the price for the service, while leaving the utility with no guaranteed return on capital. The change in policy can be illustrated by looking at how the regulatory authority determines the reasonableness of a utility’s tariff before and after the change in the law. Before the change the tariff was essentially the sum of the utility’s cost and a reasonable profit: $\text{Tariff} = \text{Cost} + \text{Profit}$. In the new regulation the tariff is determined independent of the utility’s costs. Hence, the profit is what is left when the utility’s costs are subtracted: $\text{Profit} = \text{Tariff} - \text{Cost}$

Objectives and goals. Two fundamental objectives and several other goals with the regulation reform and the NPAM have been identified. The first objective is to create a market situation resembling a competitive market as much as possible, since it was the general assumption of the deregulation in Sweden that competitive markets are better suited to handle the supply of electricity in the country [7]. A second objective is to create a situation where the utilities as much as possible are self-regulated. Limited resources of the authority is one reason for this but also the aspiration to create a stable regulatory situation.

Besides the fundamental objectives there are several more or less concrete goals for the new regulation and the NPAM. Reasonable network tariffs and a regulatory method that will be able to function for a longer period of time are more or less obvious goals. Efficient utilities, not only regarding costs, and the creation of incentives for efficient reliability levels are two other goals. Finally there is a more political oriented goal of equalizing the tariffs between rural and urban networks.
THE NETWORK PERFORMANCE ASSESSMENT MODEL

The following section describes the construction of the NPAM and is based on [8] and [9] along with the experiences of the authors. It should be noted that the model is still under development and even though the fundamentals are decided on, some minor adjustments concerning details are to be expected in the future.

Overview

The NPAM is used to evaluate one utility at time and consists of two main steps. First, a fictitious network is constructed, given the location and the energy consumption of the utility’s customers and the connections to other networks, usually a regional distribution network. The fictitious network is constructed from network components such as cables, wires and transformers, but does not consider the layout of the actual network in the utility. Second, a two-folded valuation is performed. The yearly cost of delivering electricity to the utility’s customers is valued given the fictitious network and the reliability level is valued based on outage data from the utility’s actual network. Adding the results of these two valuations gives the Network Performance, which is the main output of the model.

Input data

The input data to the model from the utility are:

- Each customer’s geographical position, energy consumption and revenues generated to the utility.
- The geographical positions of connections to other networks along with energy delivered to the network and voltage levels.
- Average outage frequency and duration separated into announced and unannounced outages.
- Local generation, if any. Revenues, energy delivered and voltage level.

The fictitious network

Given the customers’ locations and their loads the model constructs the fictitious radius network. The network is then connected to the so-called Boundary Points, which the connections to other networks are called in the model.

The fictitious network consists of multiple voltage levels, ranging from low voltage customers and up with transformers between the levels. At every voltage level customers are grouped and connected to a transformer. The grouping is determined by several conditions that has to be fulfilled at the same time, for example the expected voltage drop between a customer and the transformer has to be below a certain percentage and the maximum size of the transformer is limited. Connecting customers within a groups starts by connecting the customer nearest to the transformer, which is placed in the electrical gravity center. The customer second nearest is either connected to the transformer or to an already connected customer whichever is closest. This processes is then repeated for the third nearest customer and so on until every customer in the group is connected. Transformers are interconnected at the higher voltage level based on the same principles, meaning that they are grouped, along with any customers at the voltage level, based on the same conditions and interconnected in the same way as described above. Hence, the process of creating the fictitious network is the same for all voltage levels. When the process is completed for all voltage levels the Boundary Points are connected to the network on the same voltage level as they operate. Any local generation is connected on the corresponding voltage level and the energy delivered is assumed to be transported to the nearest Boundary Point before being available for usage.

Two further adjustments are made to the fictitious network. First, when dimensioning the transformers the so-called Aggregation Function is used. The function determines the transformers size and is based on empirical studies of usage data and the assumption that timing of peak loads for customers are reasonable randomly distributed. Hence, additional customers can be assigned to a transformer than if peak loads were used, which gives the network more realistic characteristics. Furthermore, since the basic principle in the network is to draw cables and wires in straight lines between two points the total length of the cables and wires need to be enlarged since it is not possible to draw them in straight lines in dense populated areas. This is accomplished by multiplying the length of cables and wires with a density depending compensation factor.

Valuing the network

The Network Performance consists of, as stated above, two major parts. First, the valuation of the yearly cost of delivering electricity to the customers in the fictitious network is called the Transport Labor and is made up of several subparts that are added together. The valuation of the reliability level in the actual network is called the Delivery Quality Supplement in the model.

![Figure 1. The Network Performance and its major subparts.](image-url)
The Network Utility. This is essentially the cost of running the fictitious network on yearly basis, which is the yearly cost of capital employed in the network and the cost of operations and maintenance. Each network component is valued and all the parts are aggregated into the Network Utility.

The yearly cost of capital for the network is calculated as a real annuity using a depreciation time and a yearly real discount rate. All the network components are assumed to have the same depreciation time and yearly real discount rate. Investment costs, on the other hand, varies both with type of component and the density of the network. The general assumption is that the denser the network the higher the investment cost, but for transformers the size is the determining factor. Costs are based on the so-called EBR\textsuperscript{2} catalog.

Added to the yearly cost of capital is the cost of operation and maintenance for each component, which is a percentage of the investment cost for the component.

The Customer Specific Utility. In the model it is assumed that there are costs associated with having a customer not related to the customer’s load. These are costs for reading the meter, cost of the meter including investments and depreciation, cost of handling the metering data and the cost of billing the customer. The aggregated costs of all the utility’s customers form the Customer Specific Utility.

Losses. The model compensates for losses in cables, wires and transformers. Losses are calculated as a percentage of transported energy in the fictitious network times the electricity price. It is important to notice that the losses are based on the fictitious network and not the utility’s actual network. Furthermore, it is also assumed that losses are higher the denser the network is.

The Delivery Quality Supplement. The supplement accounts for the reliability maintained in the actual network but it does not consider redundancy in the utility’s real network, only outages. Rather, the intention is to create incentives for an appropriate level of reliability. How this is achieved is external to the model.

The outage frequencies and durations are considered as costs for the customers and forms the so-called Cost of Quality. Unannounced outages are assumed to cost more than announced and outages in denser areas costs more than in sparse. Of course longer and more frequent outages implies higher costs. By dividing the total Cost of Quality for all the utility’s customers by the Network Utility the Relative Cost of Quality is reached, which is inputted into a function determining a Quality Factor and hence the Delivery Quality Supplement. The guiding principle is the higher reliability level, which means lower Relative Quality Cost, the higher

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\textsuperscript{2} The EBR catalog is developed by the Swedish industry to standardize construction and maintenance of electrical distribution. See for example www.ebr.nu
Support communication

The NPAM also provides a communication interface between the regulating authority and the distribution utilities. Its construction, the parameters in the model and the use as a regulatory tool provides a common platform for the authority and the utilities to base discussions on. Hence, the authority need to be aware of the various signals sent by the way the model and related issues are handled. Besides functioning as a communication interface with the utilities, the model and its results can also be, if handled properly, means to communicate with the customers and the general public. However, education about the model and its purposes probably needs to be a large and integrated part of the communication process.

IMPLICATIONS ON UTILITIES

While it is not possible to address all implications on utilities created by the NPAM and the regulation the issue will be addressed in three stages. First, the requirements on the utilities in order to be able to use the model are addressed. If these requirements were not met the model would not be feasible to use in reality. Second, some fundamental principles of the regulation and model are addressed. These are important principles that influence numerous areas related to the model and its implications. Finally, some issues concerning the businesses of distribution utilities are discussed since, in the end, the model and the regulation will influence the way utilities make money.

Requirements in order to use the model – input data

Basically, the only thing required from the utilities in order to be able to use the NPAM is the input data. Hence, the discussion focuses on this and relates to the experiences so far. Several of the input parameters, that is the geographical position, energy consumption and revenues generated to the utility, are reported on individual customer basis, which means that data has to be available for each customer connected to every local distribution network in Sweden. The pilot tests have shown that it is possible to manage in large scale with reasonable efforts and cost, although gathering and handling the data is a task not to be taken too lightly.

Availability of input data can be subdivided into several issues. First is the availability of data within utilities, that is if the utilities themselves have all necessary data either on paper or in information systems. Second is the integration of data from different information systems. Often the data is dispersed over several information systems and need to be aggregated into a single database. Third is issue of data quality.

Availability of input data. Data can either be stored on paper or in information systems, but in any case the reporting to the regulation authority has to be in an electronic format. The two basic types of information systems involved are GIS-systems (geographical information system) for retrieving the customers’ locations, and administrative systems for handling the energy consumptions and the billing of customers. While many utilities in Sweden have GIS systems and administrative systems there are still some concerns. First, not every utility have these systems. It could be manageable for very small utilities to manually transform their paper-based data to the electronic format the authority requires, but it is not practically possible for larger utilities. Even if utilities have the systems, due to various reasons, not all customers are represented in the systems and hence they need to be either included in the systems or at least in the report to the authority.

Integrating input data. The data from the systems also have to be integrated in the sense that the geographical position, billing and energy consumption has to be identified for each customer. However, this has shown not be a straightforward task since the identification of the customer in the systems differs. In some cases there have been a considerable effort put into coordinating data from different systems and a high degree of manual work means increased cost. Another issue is that the geographical positions of customers and Boundary Points have to be transformed from the local coordinate systems into a national system. This has in some cases proved to generate extra work and occasionally extra errors in the input data.

Input data quality. The importance of data quality is quite obvious since no matter how accurate the model is the accuracy of the result also depends on correct input data. Even though the model performs a number of quality checks when running the model it is mostly for checking reasonableness of data. Several areas are involved, concerning both the correctness of existing data and the lack of data. For example the lack of coordinates for some customers has been an issue and there have also been examples of customers where billing and energy consumptions do not match. All these questions have to be solved. However, the initial costs are higher since when data once has been collected and integrated it is only necessary to update changes. Another experience from the pilot tests is that the model has shown to be more sensitive to errors in the outage data than random errors in geographical positions.

Changed fundamental principles of regulation

The principles discussed here are of more general type and have implications on several areas related to the regulation and the NPAM. In the model there are no guaranteed return on capital, which is a considerable change since the previous Swedish regulation. Furthermore, the model is based on data observable from outside the utilities along with common assumptions for all utilities, which among other things implies that the authority should not interfere as long as the utility behaves in line with the results of the model. Moreover, the model does not consider the history of a utility’s network, which for example makes it more difficult to justify high tariffs with historical investment decisions.
No guaranteed return. In the introduction, the principle of the new regulation and the NPAM is illustrated by rearranging the equation for describing the profit to: profit = tariff – cost. This tries to illustrate the fact that when the model is used, the utilities are no longer guaranteed a return on capital and hence it is not possible to cover every cost by increasing the tariff. One obvious implication is that when the model is used, the utilities have to manage their costs compared to their income. Hence, this principle relates to the goal of resembling a competitive market in the sense that on a competitive market, companies with high costs compared to their incomes will not be able to make a profit.

Regulation from the outside. Furthermore, one of the basic principles of the regulation and NPAM is that the regulating authority should be able to perform regulation on data visible from outside the utilities and common assumptions for all utilities, without penetrating into internal structures. This in turn implies that, as long as the utilities live up to their commitments given by the law and the result of the model, the regulating authority should not interfere, which has at least two consequences. The first is that utilities managing their cost efficiently should be able to make a substantial profit with the approval of the regulating authority. However, this could turn into a potentially sensitive political issue and the practical implications are yet to be shown. Second, it should, at least to some extent, be possible to manage the regulatory risk. Utilities could choose if they want to challenge the authority by having high tariffs or minimize the risk of the authorities involvement by following the results of the model.

History not considered. A central characteristic of the NPAM is that it does not consider the history of the network since no properties of the actual network layout in the utility is used in the model. It is probably not sensational to claim that history matters for distribution utilities. For example historical investment decisions based on, what showed to be exaggerated growth estimates, influences operations and maintenances of the network today as well as investment options. One of the main reasons for not considering the history of a network in the model is the focus on services delivered to the customer. It is assumed that the customer is primarily interested in having electricity delivered as cheap as possible with a satisfactory quality of service. Hence, the customer should not care about any historical decisions as long as electricity is delivered at a reasonable price and reliability. Furthermore, historical investment decisions are considered internal to the utility and not an objective prerequisite since it was, at least at some point in time, possible for the utility to influence the decisions. It could of course be discussed to what extent this is true in reality. Including the history would also mean that the authority have to penetrate into the internal structures of the utilities and this would be contradictory to the above principle of regulation based on data observable from the outside.

There are several implications on utilities by not considering the history. First it will of course be difficult to claim historical investments as a reason for having high tariffs.

However, in special situations where the decisions were based on factors outside the control of the utility it could probably be considered as an acceptable reason for the tariff level. Furthermore, utilities with highly depreciated networks could benefit because their actual capital costs are lower than the model assumes. On the other hand, for utilities with relative recent investments the situation is the opposite. Hence it would be an opportunity for depreciated networks to be allowed to make money. The practical implications of this is not clear today and it will be interesting to follow the authority’s reactions since this also could turn into a potentially sensitive political issue.

Some implications on the businesses

Given that the utility is a profit-maximizing company the two ways to increase the profit when the NPAM is used are, quite naturally, to either do one or both of the following: increase the allowed incomes or decrease the costs. The costs of the utilities are, as stated above, external to the model and hence up to the utilities themselves to manage. Incomes, on the other hand, are basically determined by the model and the way to increase them is to increase the Network Performance. It could be discussed if all distribution utilities in Sweden are profit-maximizing companies, especially concerning smaller cooperatives and some municipally owned utilities, but it is most likely applicable to the majority.

Increase incomes. Returning to Figure 1, the Network Performance is broken down into two basic areas, the Transport Labor and the Delivery Quality Supplement. The factors determining the Transport Labor are mostly difficult to influence. Concerning input data, it is of course for example possible to experiment with Boundary Points’ positions or voltage levels, but given the models current construction the impacts are quite limited. Customers’ locations are more or less given while the customers’ energy consumptions are, at least in theory, possible to influence. However, the question is how great the practical possibilities are and to what extent they influence the Network Performance. Local generation could influence the Transport Labor slightly since it increases the loads in the fictitious network and hence the Network Utility. The construction of the model, which also influences the Transport Labor, is of course out of the individual utility’s control. Hence, the conclusion is that the possibilities of influencing the Transport Labor are fairly limited.

Turning the Delivery Quality Supplement the parts possible to influence is the outage frequencies and durations. The construction of the supplement is of course out of reach. Some outages are not controllable, such as extreme weather or damage to the network from third parties. Other outages are more controllable such as planned outages for maintenance, which could probably be decreased if performed in another way. In a longer perspective more outages are possible to influence through for example investments in reliability increasing technologies or by changed and improved work processes.
Evaluating investments. There is a more general implication concerning the evaluation of investments when the NPAM is used. Changes and investments in a utility can be evaluated against the model given that it is possible to determine their effects on the input data. It is of course a task of varying degree of difficulty to determine the effects, especially over longer periods of time since the uncertainties about the estimates, the future of the model, its construction and its parameters increases.

Decrease costs. As said above, utilities actual costs are external to the model and a profit-maximizing utility would want to decrease their costs as much as possible. However, any cost reductions need to be evaluated against their possible negative on the Network Performance for example through increased outages. Again, given the perhaps complicated issue of identifying the impact on input data, the changes can be evaluated in the model.

When comparing the costs of a utility, to the result of the NPAM, the costs can be categorized into two dimensions. The first dimension considers the size of the utility’s actual network compared to what the model suggests. A large and under-utilized network costs more to operate and maintain for an utility than the suggested fictitious network. Efficiency of operation and maintenances is the second dimension. If the network has an acceptable size compared to the model, high costs could be the result of inefficient operation and maintenances of the network. Figure 2 illustrates the two dimensions. If the utility have a relatively slim network and the costs of operating and maintaining are low compared to the model it could be classified as both cost and network efficient. On the other hand, if the utility has either excessive network size or high costs of operation and maintenances it could be characterized as either cost or network efficient, depending on which area is efficient.

![Network Size and Efficiency Matrix](image)

<table>
<thead>
<tr>
<th>Network size compared to NPAM</th>
<th>Cost and network efficient</th>
<th>Neither</th>
<th>Cost efficient</th>
</tr>
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<tbody>
<tr>
<td>Small</td>
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<td>Large</td>
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<td>Low</td>
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Figure 2. Two dimensions of actual costs compared to the NPAM.

A final observation is that a profit-maximizing utility would want to minimize the costs without jeopardizing the long-term survival. However, the practical realization of this is not elementary and in this lays a true challenge for many utilities.

CONCLUSIONS

Based on the description of the NPAM and the discussion several conclusions can be drawn. From the regulating authority’s point of view, the exact use of the model and the principles on how to use it as a communication interface need to be settled along with focusing attention to the effects and incentives created. Furthermore, the model would not be possible to implement in reality without the availability of input data for every individual customer. Even though it is some work to gather and integrate data it has shown to be possible with reasonable efforts. The model and the regulation also has general principles that brings interesting implications, for example that utilities will have to manage their costs related to their incomes and that it should be possible to make a substantial profit without the regulatory authority objecting. Turning to the implications on business, the most obvious way to influence the allowed income, the Network Performance, is through the outages. Costs, on the other hand, are external to the model and can be managed in numerous ways, which poses interesting challenges for the utilities.

REFERENCES