QUALITY REGULATION IN ELECTRICITY DISTRIBUTION BUSINESS

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ABSTRACT

Regulatory bodies in electricity sector are trying to find suitable methods to compensate the effects of cost reductions emerged from regulatory models used to control electricity distribution monopolies. Quality aspects have to be recognised also due to growing interest stemming from the customers. This paper describes the regulatory measures taken by several European regulators in order to implement quality regulation in electricity distribution business. Planned regulatory measures in Finland are described in detail.

INTRODUCTION

Quality demands for electricity have risen. There are industrial processes that would suffer greatly due to disruptions. Besides the requirement needed by the industry, also the level of service in which the residential customers have accustomed has risen. This has forced energy sector regulators to consider quality aspects when deciding proper regulatory measures for electricity distribution monopoly.

On the other hand the methods used for price regulation can create a need for a specific quality regulation. The liberalisation process of energy markets has changed the need to regulate electricity distribution and transmission that have remained as natural monopolies. Performance based regulation methods, i.e. price or revenue cap regulation, have been popular among European regulatory bodies. These methods create strong incentives to cost reductions. Cost reductions can have a negative impact on the quality of electricity. This represents a challenge for the regulatory bodies to find a suitable method to compensate the effects of cost reductions to the quality of electricity supply. Power quality issues have to be recognised in other regulation methods as well. The regulator cannot rely on the engineering rationale of the companies in e.g. rate-of-return regulation where companies usually define their own investment and quality levels. In this case there is a strong incentive to over-invest and this does not lead to socio-economic optimum level concerning quality and efficiency. High quality level requires high costs and hence high tariffs for electricity.

The European Commission has appointed monitoring responsibilities to the national regulatory body relating to quality of supply. In addition the regulator has to provide adequate economic incentives for the maintenance and construction of the necessary network infrastructure (2003/54/EC). Quality of electricity supply regulation can take many forms. In most countries quality standards are in place. There can be financial penalties if these standards are not met. Financial consequences can also be more severe. Mostly in price or revenue cap regulation the incentive to improve quality can be focused on the allowed revenue.

QUALITY REGULATION

The purpose of quality regulation is to ensure that the development of the networks is focused on the most rational targets from social-economic point of view. This requires that quality issues are dealt with extensively, so that every perspective is considered. Regulators face a challenging task when deciding proper solutions for the implementation of quality incentive schemes. Different interest groups in electricity distribution business have different needs and therefore they value quality variously.

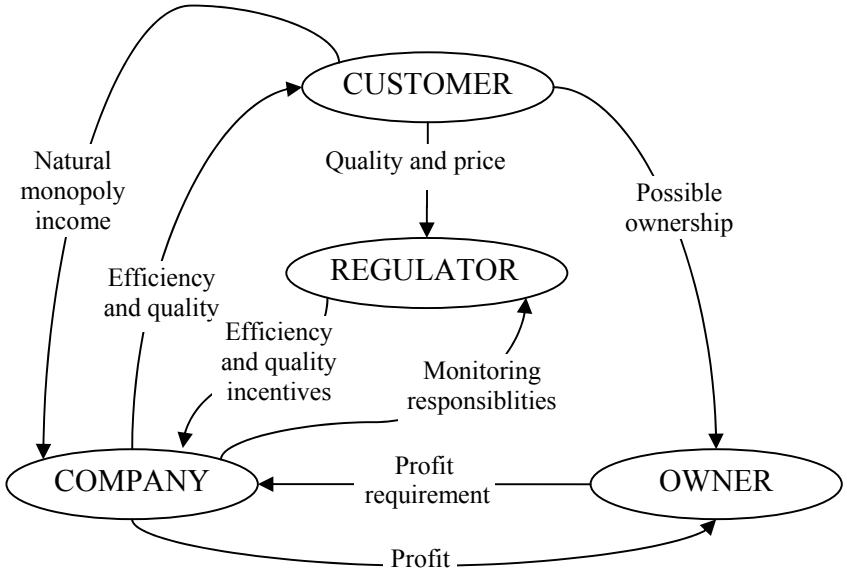

Figure 1. Expectations of different interest groups in electricity distribution business.

As seen in the figure 1 there is four major interest groups in electricity distribution business, the customers, companies, owners and the regulator. The companies operate their businesses according to profit requirements from company's owners as well as various requirements from the customers and the regulator. In some cases companies are owned by the customers i.e. municipals and therefore do not require any specific profit. The customers are confined to a certain monopoly company which supplies them with electricity and receives a certain income from the customers. Customers in return expect a certain quality to the delivery as well as reasonable prices. The regulator works on behalf of these customers.

The regulator aims to ensure reasonable tariffs and sufficient quality of supply for the monopoly customers by setting regulations to the companies. These regulations usually contain objectives for efficiency improvements in order to decrease costs and hence reduce tariffs. Sufficient quality level is obtained through necessary investments in the network. According to the Directive issued by the European Council "…Member States may impose on undertakings operating in the electricity sector, in the general economic interest, public service obligations which may relate to security, including security of supply, regularity, quality and price of supplies and environmental protection… Such obligations must be clearly defined, transparent, non-discriminatory,

verifiable…" (2003/54/EC). The regulator first has to determine the desired level of quality performance and thereby give the companies incentives to invest in order to meet this level.

Based on the expectations described above, quality of supply regulation should focus on parameters that are important to the customers and at the same time are such that companies can control them. This way a socio-economic optimum is reached. The regulation also has to be feasible i.e. the performance level has to be measurable by the regulator. Regulator has many opportunities to determine by which way it wishes to approach quality issues. Generally regulation is considered to build up from three different aspects: commercial relations between the company and the customer, continuity of supply and voltage quality. There are several ways for determining standards against which the distribution companies' performance is measured. In the next paragraphs some are mentioned.

Quality of service

Quality of service relates to the nature and quality of customer service provided to the customers by the distribution companies. Quality of service is generally monitored through standards. Standards can be Overall or Guaranteed standards. Guaranteed standards set the minimum service level which must be met in each individual case. If the company does not meet these standards, compensation at fixed rates must be paid. Guaranteed standards include:

- Service covered (e.g. estimating charges)
- Required performance level - usually with a response time (e.g. certain number of working days)
- Penalty payment to be paid to a customer who fails to receive this level of service (e.g. specific amount of euros) (CEER 2001)

Overall standards cover areas of service where it may not be possible to give individual guarantees but where companies are expected to deliver predetermined levels of service. Overall standards do not carry penalty payments but are used for monitoring purposes and for promoting quality of service. Overall standards are defined as followed:

- Service covered (e.g. connecting new customers to the grid)
- Minimum performance level to be achieved over a defined period of time. (CEER 2001)

Voltage quality

Voltage quality covers a variety of concepts such as frequency, voltage magnitude, voltage dips and harmonic distortion. There are several technical standards for voltage quality criteria, but in the end the quality is directly or indirectly determined by the ability of customer equipment to perform properly. Therefore the definition of voltage quality should contain the impact of voltage disturbances on the customers. This is included in continuity of supply review. Parts of the standard EN-50160 is generally used as a guideline for low and medium voltage networks. This standard does not give exact levels for voltage quality, so it is difficult to discover the real performance level. Also because voltage quality is difficult to measure reliably and economically, there are hardly ever penalties if criteria are not met. (CEER 2001)

Continuity of supply

Continuity of supply measures the networks ability to supply the customers with electricity. It is generally characterised as the number and duration of interruptions in supply. There are, however a number of considerations to be taken into account. The regulator has to select the aspects of continuity of supply it wishes to focus on in the regulation. The main features are:

- Type of interruption; planned or unplanned.
- The duration of interruption; short or long interruptions. Standard EN-50160 defines interruptions over 3 minutes as long interruptions and others as short interruptions.
- The voltage levels of faults.
- The type of continuity factors; number and durations of interruptions. Possible factors are for instance System Average Interruption Duration Index (SAIDI) that indicates how long energy is not supplied during a year, System Average Interruption Frequency Index (SAIFI) that indicates how many outages customers have in a year. Also yearly duration of interruptions for each customer (CML, Customer Minutes Lost) is used. (CEER 2001)

As the regulator has set target levels for the companies, there are several ways in which they can be given incentives to improve the quality of supply. The main economic impacts to the distribution companies can be penalty payments to the customers. Generally penalty payments are attached to the individual customer standards. Some special recovery plans are also possible for the companies to reach a desired level of quality. There can also be a link between tariff and continuity of supply level. This is discussed below.

Quality incentive schemes

Quality incentive schemes link the performance levels of the company to its earnings. The regulator has to first decide the parameters, on which it wishes to determine the current as well as the optimal level of quality. The performance level can be measured at different levels ranging from system level to the performance delivered to the individual customers. Based on company performance against this optimal level, there is a reward or a penalty. The penalties or rewards financial impact can be given as a percentage from the company's revenue or profit. In figure 2, case (1) depicts a case where a fixed penalty is given when a minimum standard is breached. Case (2) makes revenue fully depended on performance. In case (3) there is a maximum fixed limit for penalty or a reward in addition to case (2). In case (4) there is a dead band in a certain area. Penalties are usually carried out as price reductions to the customers. (Ajodhia 2002)

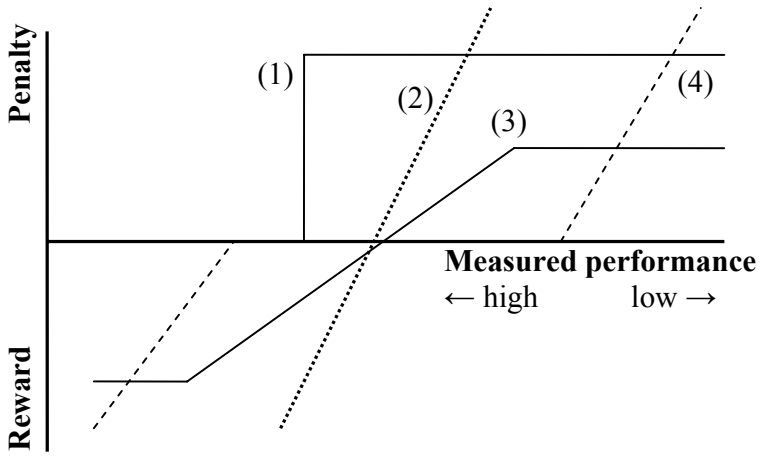

Figure 2. Examples of penalty or reward systems. (Ajodhia 2002)

The role of quality component in efficiency studies

The role of efficiency studies can have a significant effect on the quality of electricity. Method shortly described here is Data Envelopment Analysis (DEA). DEA-model is a non-parametric method that uses linear programming to determine relative efficiency of distribution companies. It can be used to measure technical as well as cost efficiency. DEA-model is not usually designed to take account quality aspects. Still there are quality parameters implemented in the models applied by European regulators. By doing so, the regulators can create further incentives to the companies concerning quality aspects while promoting efficiency. These incentives are therefore used to create socio-economic optimum level for network investments and operation.

The DEA-model uses a set of inputs and outputs for each company, assigns them with a set of weights in order to maximise the ratio of weighted outputs to inputs. An efficient company can produce more of all the outputs using less of any input. Hence the goal is to reduce inputs to the level of the efficient company operating in efficiency frontier. DEA-model can be specified as input- or output-oriented i.e. either minimising inputs for a given level of outputs or maximising output for a given level of input. In the analysis the factors that companies can not affect are taken into account as environmental factors. (CEPA 2003)

CURRENT REGULATION IN SOME EUROPEAN COUNTRIES

In this chapter there is a short presentation of the regulatory models used for regulating the electricity distribution business in some European countries. The main focus is the quality regulation process.

Finland

Finland is currently applying rate-of-return regulation. The allowed profit of the company is compared to the calculatory profit. The investigations are launched based on Energy Market Authority's own initiative or complaints made by customers. From 2005 on the investigations will apply to all of the companies and the parameters of the regulation will be published beforehand.

There is no electricity quality regulation in Finland at the moment. However the interruption time has been an output factor in DEA efficiency analysis from 2000. The efficiency analysis is used to determine a supplement to the efficient companies. The supplement has a maximum 10 % value of the company's operational expenses. The poorly performing companies are not penalised. There were plans to introduce full scale operation of the efficiency benchmarking, but finally in 2002 the Finnish Energy Market Authority decided to hold off these plans due to forthcoming regulation model in 2005. At the same time the Authority has continued the development work concerning DEA models quality parameter. This process is discussed later.

Great Britain

The regulator in Great Britain (Ofgem) defines the allowed revenue of the distribution companies. Ofgem set up a Quality of Service Incentive Scheme in 2002 to provide financial incentives to quality improvements. Companies' allowed revenue is adjusted according to company performance based on the difference between target levels for interruption time and frequency and customer service. The maximum level in incentive for the continuity of supply is ± 1,75 % and for the quality of service ± 0,125 %. The interruption time includes both planned and unplanned interruptions, interruptions over 1 min. are included in the study. The quality of service is measured as monthly investigations concerning service received through customer telephone calls. (Grenard & Strbac 2003)

Netherlands

The regulator in Netherlands, DTe, regulates the distribution companies by means of price-cap regulation. The individual X-factor in RPI-X regulation is determined using DEA-model. Starting from 2005 companies are planned to be given a target for interruption time and frequency. If the company fails this target, revenue will be reduced and increased in case company beats the target. (Ahodhia et al. 2003)

Norway

The distribution companies in Norway are regulated through revenue cap, set by the regulator NVE. Norway uses DEA-model in the determination of individual efficiency requirement for the company's revenue. In the model there is an actual number of minutes lost as an input factor and a normalised interruption time as an environmental factor.

The actual quality incentive scheme is called CENS arrangement, Compensations for Energy Not Supplied. It has been in place from 2001. Based on estimates of energy not supplied and average specific interruption costs for each customer groups, interruption costs are calculated for each company annually. If the company fails the expected level, the allowed revenue will be reduced and increased in case company beats the target. The regulator uses regression analysis in order to calculate the expected level of energy not supplied. In the analysis historical data of non-delivered energy and other structural variables such as energy supplied, network extension and weather conditions are taken into account. In theory there is no specific boundary limit for quality reduction or increase, but the regulator ensures a minimum profit for the companies. The cost of interruption is determined for two customer groups, residential/agriculture and industry/commercial, as a three year average figure. The planned and unplanned interruptions are treated separately and only long interruptions are taken into account. (Tengereid 2003)

Sweden

The Swedish distribution companies' revenue cap compiles out of standard costs generated based on fictitious network. This Network Performance Assessment Model is however apparently used as a selection tool for more detailed analysis of the companies' performance.

One of the elements comprising the allowed revenue in the model is reserve capacity. The amount of reserve capacity is reduced according to the performance of the company against target level. The performance is measured from real interruptions, but the target level refers to the interruption costs obtained from fictitious network. Interruption data are reported for the network company as a hole, not for the individual customers or customer groups. (Larsson 2003)

Comparison of certain European experiences

Of those countries studied here all but Finland have quality incentive schemes in place in order to take the effects of efficiency incentives into account. The incentive for quality improvement is quite high in Norway, where there is no upper limit to the penalty for failing the target. However the regulator assures 2 % profit for the companies. Similar model is planned in the Netherlands. In Great Britain there is also an upper limit for continuity of supply. By doing so the regulator sets a balance between quality improvements and sufficient return to the companies.

The quality of service regulation through incentive schemes is only applied in Great Britain. The use of such method is very problematic due to measurement issues. In Great Britain it is done through customer surveys that tend to subjective.

Finland and Norway have a quality component in the DEA efficiency study. In Norway the interruption time is used as an input factor, hence there is an incentive to reduce it. In Finland interruption time is an output factor, but there are plans to change it.

Table 1. Comparison of country practices.

	Incentive system	**Efficiency benchmarking**
Finland		**DEA**: **Input:** Operational expenses **Output:** interruption time, energy distributed **Environmental factors:** customer volume, network length
Great Britain	Allowed revenue is adjusted according to company performance based on the difference between target levels for interruption time and frequency (max ±1,75 % of the revenue) and customer service (max ± 0,125 %)	**COLS**[2]: **Input:** Opex **Output:** Composite variable (50 % customer volume, 25 % electricity distributed, 25 % network length)
Netherlands	Starting 2005 companies are provided a target for interruption time and frequency. Allowed revenue will be adjusted according to whether the company exceeds or fails target.	**DEA**: **Input:** Total costs (operational + capital expenses) **Output:** electricity distributed, peak demand, customer volume **Environmental factor:** Number of transformers, network length
Norway	Companies are provided with a target for interruption costs. The allowed revenue will be adjusted according to whether the company exceeds or fails this target.	**DEA**: **Input:** network assets (book value or replacement value), number of man-labor years, interruption time, network losses, operational expenses **Output:** customer volume, energy delivered **Environmental factor:** network length, normalised interruption time
Sweden	Companies allowed revenue is reduced according to its performance against target levels for interruption time and frequency.	**Network performance model**: geographical location of customers, electricity distributed, voltage levels, billing, number and length of interruptions

[2] Corrected Ordinary Least Square method (COLS)

THE PLANNED QUALITY REGULATION IN FINLAND

The new regulation model in Finland will continue to focus on rate of return. There is a general efficiency requirement of 1,3 % annually but no individual efficiency requirements during the regulatory period 2005-2007. There are plans to implement both general and individual efficiency requirements for the second regulatory period. The Energy Market Authority will probably go on using DEA model for the determination of individual efficiency requirement. The data for future efficiency calculations will be produced during the first regulatory period.

The DEA model

There has never been a specific quality regulation scheme in place in Finland, but DEA-scores containing quality parameter, are used as rewards for the efficient companies, the inefficient ones are not penalised. Generally the quality of supply has, however, been in good condition, while weather and geographical issues are demanding.

There have been several problems that have delayed the full use of DEA-scores. In the DEA model there are some problems concerning the definition of the quality parameter as well as the functioning of the model (Lassila et al. 2003). Closing the inefficiency gap would have been impossible for many companies to achieve and there have been large annual variations in DEA-scores. This led to situation where distribution companies were treated unequally and thus the use of the model could not be continued.

Quality parameter used is total interruption time and it is used as uncontrolled output factor in the analysis. Total interruption time is measured in each transforming district yearly for each customer. This created an incentive to reduce interruption time in districts, where customer numbers were low. Hence companies operating in different environments were not treated equally. Also the quality parameter was an insignificant factor in the DEA model for a large number of companies (even for 40 % of the companies). These companies do not benefit from additional investments to improve quality of supply. On another hand power quality has a great influence on the efficiency score for a few companies. The directing effects of the model were thereby random for the development of quality issues in the distribution companies.

The proposed development of quality regulation

Process for developing quality regulation in Finland has taken place in a project concerning the electricity quality in electricity distribution business evaluation carried out by Lappeenranta University of Technology and Tampere University of Technology (EMV 2003). The planned model will focus on monitoring the planned and unplanned interruption times and frequencies for medium voltage networks, number of autoreclosings and the number of low-voltage faults. These figures are used to calculate the weighted interruption costs in each transformer district. These interruption costs will affect the company's return through DEA analysis. In practise this would mean that in order to improve efficiency score that affects the allowed return, the company has to improve quality of supply. Company has therefore an incentive to make quality related enhancements in the network concerning parameters included in the efficiency study. The quality parameter should describe the basic components reflecting the damage caused by interruption in order to reach the desired outcome.

The baseline for the development work in DEA model is that the number of parameters will not rise, because then the model's ability to detect differences among the companies would deteriorate. This means that the quality parameter would have to remain as one figure. The future parameter would have to include the following factors:

- fault interruption time and number
- maintenance interruption time and number
- instant autoreclosing number
- delayed autoreclosing number

In DEA analysis these factors are conjoined as a single parameter. Weighting coefficient is used to reflect the damage caused by each interruption type. The weighting coefficients would be cost of interruption in €/kW and €/kWh. Even though quality parameter used in DEA calculations would be more versatile, there still is a problem with unequal treatment of the companies. The quality parameter could be insignificant to some and have major impact to others. This could be solved by introducing cost of interruption to the operational expenses (Lassila et al. 2003). These total expenses would be treated as controllable output factor. The calculation of quality factor parameters would be done in a transformer district level.

CONCLUSIONS

The regulator of the electricity sector has to ensure that the distribution companies operate in efficient manner. Efficient operation often means reducing costs. The regulator then has to ensure that the quality of electricity does not decrease. This can be done by implementing quality regulation.

There are different aspects of quality regulation. It can comprise from quality of service, quality of voltage or continuity of supply aspects. Continuity of supply can be perceived as an important aspect, because the need to secure the continuity of electricity distribution is vital to the modern life. This can be done through various incentive systems. The regulator can set a penalty or a reward to the companies according to their performance against the desired performance level. Performance is usually measured as electricity distribution interruption time and frequency. Usually the incentive is focused on the revenues that companies can collect. The quality aspect in regulation can also be implemented in efficiency benchmarking. By doing so, the efficiency requirement also includes incentives of some kind to quality improvements.

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