INTRODUCTION

A critical parameter in implementation of a credible quality regulation scheme is information about customers’ interruption costs associated with alternative levels of quality of supply.

In Norway, a research project was undertaken during 2002, involving development of methodology and estimation of interruption costs which reflect consumer valuation of the quality of supply. This paper presents the main findings in this project.

BACKGROUND

Recent deregulation of electricity markets around the world and subjectation of electricity networks to economic Performance-Based-Regulation regimes pose a challenge to assure efficient provision of quality of supply by the regulated network monopolies. Absence of explicit regulatory framework for assuring quality of supply creates perverse incentives for the regulated network monopolies to reduce quality to meet the budgetary constraints implicit in the performance based regulatory regimes. This can over time lead to declined quality of supply.

To counteract such consequences, the network companies are being increasingly subjected to regulatory regimes that explicitly take into account the quality of supply to the consumers. One example is the Norwegian regulation scheme CENS (‘Cost of Energy Not Supplied’ - Quality adjusted revenue caps), where the network companies’ revenue caps are adjusted in accordance with the customers’ interruption costs [1]. A critical parameter in implementation of a credible quality regulation scheme is information about customers’ interruption costs associated with alternative levels of quality of supply.

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RESEARCH PROJECT

The project entitled “Customers’ costs associated with interruptions and voltage disturbances - control signals for optimal quality of supply”, involves developing methodology and estimating interruption costs, which reflect customers valuation for the quality of supply. The objective is to generate quantitative indicators which can be used for designing compensation schemes to enable effective regulation of quality of supply provided by electricity networks. The data generated is also useful for planning optimal network capacity and designing efficient rationing (load-shedding) or priority-pricing schemes to meet energy or network capacity shortages in the liberalised Norwegian electricity market.

PROJECT DESCRIPTION AND STATUS

The project focuses on development of theory and empirical estimation of interruption costs which reflect consumer valuation of quality of supply in a market-based power system. The study was organised into two phases. Phase I of the study developed and outlined a methodology for estimating consumer valuation of quality of supply. In principle, there are two measurement techniques used in estimating interruption costs; market-based methods (valuation is inferred using data related to observed consumer behaviour), and contingent valuation methods (involves use of survey and experimental settings to reveal consumer valuation). An extensive comparative review of literature can be found in [2-3], and [4] provides a discussion of the different issues related to the subject and also some recent international estimates. Phase I of the study was completed during 2001 under a grant from a consortium consisting of The Norwegian Water Resources and Energy Directorate (NVE), The Research Council of Norway (NFR) and diverse firms in the Norwegian electricity industry.

The objective of Phase II was to develop and carry out a national survey to analyse the estimates for interruption costs in Norway. Given the national expanse of the study, questionnaire-based postal-survey was considered as the most cost-effective instrument for collection of the information in the study. However, where found necessary, telephone interviews were also used to complement the postal survey. The information collected in the survey focussed on contingent valuation methods to obtain specific interruption cost estimates for residential, industrial, commercial, public-sector and agricultural consumers in Norway.

The project has been jointly implemented by the two reputed Norwegian university based research and development institutions; SINTEF Energy Research and Institute For Research In Economics And Business Administration (SNF) with a track record of policy research related to the development and implementation issues associated with the deregulation of the power markets.

SURVEY DESIGN
The national survey undertaken in the study covers the customer groups shown in Table 1.

<table>
<thead>
<tr>
<th>Customer group</th>
<th>Residential</th>
<th>Industry</th>
<th>Commercial</th>
<th>Agriculture</th>
<th>Public sector</th>
<th>Large industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>1000</td>
<td>2400</td>
<td>1800</td>
<td>800</td>
<td>800</td>
<td>220</td>
</tr>
<tr>
<td>Repeal</td>
<td>56</td>
<td>141</td>
<td>122</td>
<td>53</td>
<td>31</td>
<td>44</td>
</tr>
<tr>
<td>Real sample</td>
<td>944</td>
<td>2259</td>
<td>1678</td>
<td>747</td>
<td>769</td>
<td>176</td>
</tr>
<tr>
<td>Response rate</td>
<td>45%</td>
<td>27%</td>
<td>25%</td>
<td>43%</td>
<td>45%</td>
<td>45%</td>
</tr>
<tr>
<td>Incentive (lottery tickets)</td>
<td>40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1 – Survey sample size

An important part of a survey is the questionnaire used for collection of information from the respondents. In the current study questionnaires specific for each customer group were developed to obtain information about customer interruption costs in Norway. Design of questionnaire involves making trade-offs between details on one hand, and response rates to questionnaires on the other. The final set of questionnaires used in the study were chosen through an iterative process which included a pilot-survey involving two customer groups.

For all customer groups, the following data was collected; costs associated with:

- Long interruptions > 3 min (notified outages/not notified outages)
- Short interruptions ≤ 3 min
- Voltage disturbances (only dips are reported here)
- Disconnection of loads/partial loads

**STRATEGIC RESPONSE**

Particular attention was given to build in triangulation techniques to increase the credibility of information collected in the questionnaire. Triangulation is the combining of methods, data sources and other factors to obtain information about the unit of analysis. In the context of analysis of interruption costs in a market-based power system, respondents may have an incentive to indulge in strategic response to influence the final estimates from the survey. In the current survey both direct-worth estimates and information about actual customer actions (undertaken to avoid the consequences of interruptions) was collected in the questionnaire. Both direct-worth (DW) and willingness-to-pay (WTP) estimates were obtained and both these estimates were used to reveal consumer valuation of the interruption costs in Norway.

With DW/WTP means:
The respondent is faced a specific interruption/disturbance scenario, and is asked to estimate:

- how much is he/she willing to pay in order to avoid the scenario (WTP)
- economic (and other) impacts caused by the scenario (DW)

Previous attempts to estimate interruption costs have been primarily based on either DW or WTP estimates. The methodology in this study makes use of an average of these two estimates wherever information was available. To understand the logic behind this choice it is important to emphasise that the main objective of the study is to reveal consumer valuation of a commodity; in this case the commodity being quality of supply. Valuation of a commodity in a market is characterised by three factors; market environment, market institution and behaviour of the market participants. Market environment is defined by the individual values and costs of the market participants. Market institutions define rules for trade. In case there existed a specific market for quality of supply, a credible single proxy of the customer valuation would have been the equilibrium price in this market.

In the absence of such markets, questionnaire surveys provide a practical alternative. If we choose to interpret survey methodology as a simulation of a market we can draw some implications regarding use of information obtained in the survey.

Information in a questionnaire is a proxy for respondents valuations; in other words the market environment. Respondents in the current study provided information about their valuations for different interruptions of increasing duration which can be interpreted as the demand and supply curves for quality of supply in the market simulated by the survey. Secondly, information supplied through the questionnaires was confidential and the respondents were aware of the fact that the information supplied in the questionnaire will form a basis of a single estimate of interruption costs irrespective valuation reported by the individual.

In the jargon of market institutions the survey methodology resembles closely a sealed-bid single-price auction. Such auctions have been a subject of analysis in the field of economics.

The main results both from theory and in particular from the field of experimental economics [5] confirm that market participants in such auctions will resort to strategic bidding by underreporting willingness to pay and overstating their costs. In the current survey WTP estimates were well below the DW estimates; an outcome which is expected keeping in view the survey methodology used in the study. The outcome is also supported by the results obtained in other cases where markets do not exist, such as in case of surveys for valuation of quality of environmental resources.

Divergence between WTP and DW is quite expected and has important implications for use of information obtained in the survey. Exclusive use of any one of these estimates would introduce a systematic bias in the valuation of quality of supply and in the effectiveness of regulation, investments and tariffs based on such estimates. There is a need to account for...
this bias. In the present study, as a first approximation, wherever information was available for both DW and WTP we chose to estimate interruption costs as an average of the DW and WTP information reported by the respondents. All estimates were finally reported as specific interruption costs, in Norwegian kroner (NOK) per kWh of Energy Not Supplied (ENS) for long interruptions, and per kW of interrupted power for short interruptions and voltage dips.

WHAT’S THE PROBLEM?

Considering the situation in Norway, what are the customers’ costs associated with long interruptions (> 3 min), short interruptions (≤ 3 min) and voltage dips respectively?

From the survey data a weighted average specific interruption cost can be achieved: 32.4 NOK/kWh ENS for non-notified interruptions and 23.4 NOK/kWh ENS for notified interruptions.

On average, Norway as a whole has experienced 29 155 MWh Energy Not Supplied (ENS) on average for the years 1996-2001, due to long interruptions. Approx. 37 % of this is due to notified interruptions, and 63% due to non-notified interruptions. This gives a total cost for the Norwegian customers of approx. 850 MNOK/year.

Now, consider the short interruptions (≤ 3 min): From the survey data a weighted average specific interruption cost can be achieved: 7 NOK/kW.

From [6] we find that delivery points in the distribution network experience approx. 13 short interruptions/year. Considering only business customers, this gives a total cost for the Norwegian customers of 600 MNOK/year.

At last, consider the voltage dips: From the survey data a weighted average specific interruption cost can be achieved: 5 NOK/kW.

Total number of voltage dips/year in the distribution network and in the regional network are in Norway 63 and 13 respectively [6]. However, not all of these voltage dips are comparable to the voltage dip-scenario mapped in the survey (50% reduced voltage in 1 sec). From [6] we find that delivery points in the distribution network experience 5-10 such voltage dips/year. Considering only business customers and using the current estimates for voltage dips this gives a total cost for the Norwegian customers in the range of 170-330 MNOK/year.

Summing up, costs of interruptions and voltage dips for Norwegian customers amounts to a total of:

| Long interruptions (> 3 min) | 850 MNOK/year |
| Short interruptions (≤ 3 min) | 600 MNOK/year |
| Voltage dips | 170-330 MNOK/year |

These figures are compared to the network companies’ internal costs related to investments, operation and maintenance and electrical losses in figure 1. The customers’ costs associated with interruptions and voltage dips actually exceed the total costs that the Norwegian network companies in sum has on operation and maintenance on a yearly basis.

So, what’s the problem? From the customers’ point of view, Table 2 show that in Norway the long interruptions alone only stand for approx. 50% of total costs related to interruptions and voltage dips. As of today, only the long interruptions are being subject for regulation from the NVE, and the results from the research project described in this paper will be important in the evaluation of which power quality issues are to be regulated through incentive mechanisms, and which are to be regulated by means of standards.

CONCLUSIONS

A critical parameter in implementation of a credible quality regulation scheme for network companies subject to Performance Based Regulation is the information about customers’ interruption costs associated with alternative levels of quality of supply. In case there existed a specific market for quality of supply, a credible single proxy of the customer valuation of interruptions would have been the equilibrium price in this market. In the absence of such markets, questionnaire surveys provide a practical alternative. Credibility of the estimates based on survey methods calls for careful examination of strategic response from the respondents. Neglect of such issues can result in biased estimates, which would introduce a systematic bias in the valuation of quality of supply, and in the effectiveness of regulation, investments and tariffs based on such estimates.

This paper reports both methodological issues and some recent estimates for costs associated with various interruption scenarios in the Norwegian power system. Results are relevant for design of regulatory regimes for the network companies. As of today, only long interruptions (> 3 min) are being regulated in the CENS-arrangement in Norway. From 2004 NVE is to put into force a new set of regulations, covering also other power quality aspects than long interruptions. The results from the research project described
in this paper will be important in the evaluation of which power quality issues are to be regulated through incentive mechanisms, and which are to be regulated by means of standards.

REFERENCES


