REGULATORY GUIDELINES IN SETTING UP A VOLTAGE QUALITY MONITORING FRAMEWORK

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ABSTRACT

When setting up a voltage quality regulation framework, there are a number of basic issues that need to be considered. It is important to clearly define voltage quality and develop suitable indicators thereof. This paper addresses the issue of what regulators need to consider whenever establishing a voltage quality regulatory framework for distribution networks. It presents a general set of guidelines that regulators can consider in introducing and developing voltage quality regulation. Furthermore, a description of mitigation measures is provided.

INTRODUCTION

Voltage quality, sometimes power quality, covers a variety of disturbances in a power system. It is mainly determined by the physical quality of the voltage waveform. The relevant technical phenomena are: frequency variations, voltage magnitude fluctuations, short-duration voltage variations (dips, swells, short interruptions), long-duration voltage variations (over-/under-voltages), transients (transient over-voltages), and waveform distortion.

This paper addresses the regulator's issue what to consider when establishing a voltage quality regulatory framework for distribution networks (i.e. ≤35 kV). It presents a set of guidelines that regulators can consider in introducing and developing voltage quality regulation.

COSTS OF POOR VOLTAGE QUALITY

There is a growing interest throughout Europe for cost-estimation studies giving insight into costs due to deviations in voltage quality.

Types of costs

It is not obvious / easy to measure costs related to voltage quality. In order to get a clear view on lack of quality costs, all cost types are divided in two major categories: private customer costs and net costs to the rest of society [4].

Within these two major categories, several types of costs can be distinguished. Costs in each category can be divided into monetary costs (e.g. loss of production) and non-monetary costs (inconvenience, annoyance) and further subdivided into direct (e.g. destroyed equipment) and indirect costs (e.g. long term decision to increase stock). This categorization is summarized in Figure 1.

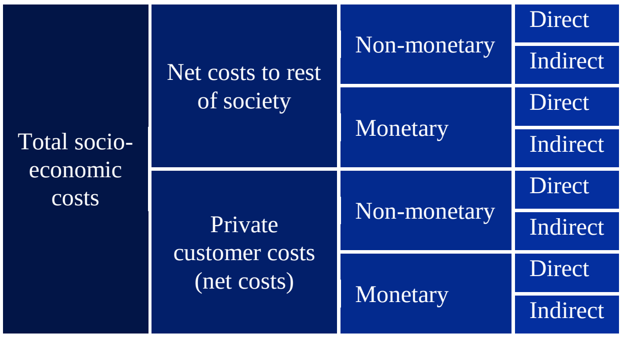

Figure 1: Categorization of different costs

Complementary to costs for society, network operators also bear costs. These costs can be categorized as follows:

- costs incurred to mitigate voltage quality issues (technical measures in distribution networks: sectionalizing, undergrounding, insulating, animal guards, lightning protection, fast switching)
- costs improving reliability but not voltage quality: reclosing schemes, redundant feeders, loops
- costs for responding to voltage quality issues: call centers, responding crew, inspection, monitoring, consultations, mitigation
- maintenance: tree trimming, equipment maintenance.

Valuation methods [3]

Cost estimation methods for both interruptions and voltage disturbances may be categorized in different ways. One is the bottom-up versus top-down approach. Most studies take a bottom-up approach, implying that they collect cost data on a detailed level (for example through surveys) and then add up. To uncover a cost function by specifying how the cost depends on a range of explanatory variables, a bottom-up approach is probably necessary. Methods based on a top-down approach make approximations based on available data on a macro-economic level.

Furthermore, cost investigations may be an ex-post analysis of real interruption events or based on hypothetical scenarios. Case studies of interruptions, studying price changes or asking people for incurred costs, are often thought to give more certain and realistic cost numbers, but on the other hand the results are not necessarily transferable to other situations.

Another dimension is direct versus indirect methods. Direct methods focus explicitly on costs (or willingness to pay or accept), either by surveys or by studying markets. Indirect methods uncover preferences and priorities (by surveys or by studying markets) without explicitly focusing on the cost of quality problem. The cost must be estimated in a separate step through the use of econometric models.

Cost figures

As discussed, different methods for cost calculation of poor voltage quality can be applied. It is shown that due to the complexity of measuring these costs, obtaining the total numbers is rather difficult. Experiences in several countries show that voltage dips, swells, transients, harmonics and supply voltage variations cause the highest costs for customers [3]. From a European survey in 2007 [5], the costs per event were analyzed. An overview of the results is given in Figure 2. Following this survey, it was estimated that the total costs of poor quality are around 150 billion euro per year for the European industry.

Surge or transient	€120,000 - €180,000
Long interruption	€90,000
Short interruption, service sectors	€18,000 - €36,000
Short interruption, industry	€7,000 - €14,000
Voltage dip	€2,000 - €4,000

Figure 2: Estimation of different costs [5]

MITIGATION MEASURES

An interesting problem arises when the market fails to offer products that meet the customers' power quality needs. If customers cannot find equipment that is designed to tolerate momentary power interruptions, for example, they may pressure the DNO and the regulator to increase the power quality of the overall distribution system. Also, if voltage quality standards are not met, the DNO may be pressed. Below, several technical and non-technical mitigation measures for lacking voltage quality are discussed.

Technical mitigation

Since most of the power quality problems are cost related this justifies the investments in mitigation technologies by the power company or the customer. In general, technical solutions that increase the voltage quality can be at four levels, as shown in Figure 3.

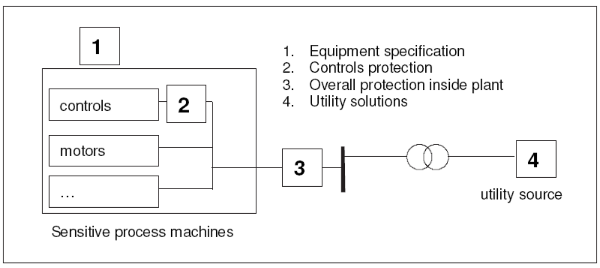

Figure 3: Levels of voltage quality improvement [6]

The choice for a mitigation method depends on [7]:

1. The nature of the disturbance generated and / or to be prevented,
2. The required level of performance,
3. The financial consequences of malfunction,
4. The time required for a return on the investment,
5. Practices, regulation and limits on disturbance set at the grid operator.

Non-technical mitigation

Two important non-technical mitigation measures are labeling and entering into premium contracts.

Premium contracts

Some utility companies have set up premium voltage quality contracts for customers who wish premium power. The distribution company can charge the additional costs for providing this premium service (often by grid modification) to the customer. On the other hand, some price sensitive customers can be interested in reduced costs and may be willing to accept lower levels of voltage quality. These customers can "sell" interruption rights. The distribution company can then interrupt these customers when the system is stressed; avoiding interruption of other customers.

Labeling

Another approach is labeling the voltage quality at the point of common coupling. An example of a transparent classification system for the delivered voltage quality is shown in Figure 4. In case the label turns out to be below the minimum required level, it can be used by the customers to force the DNO to improve voltage quality.

Figure 4: Classification of Voltage Quality [8]

GENERAL GUIDELINES FOR INTRODUCTION OF VOLTAGE QUALITY REGULATION

There are a number of basic issues that need to be considered and understood to make the right choices to get to an effective voltage quality regulatory system. In this section, the main issues to be considered during this process are identified. First, develop a good understanding of what voltage quality is and how it can be measured. Second, clearly define the objective one would like to pursue with respect to the voltage quality and third, choose the appropriate quality control in order to achieve the defined objectives. These three issues are discussed below.

Quality definition and measurement

The ability to measure voltage quality clearly is a precondition for setting up an effective voltage quality regulatory framework. But before measuring, of even more importance is the need to clearly define “voltage quality” and develop suitable indicators. Accurate measurement of these indicators is of utmost importance and the fundament for any quality regulation system. These data form the input of the regulatory process. Clearly, if the underlying data is wrong, so will be the outcome.

The objective of voltage quality regulation

Once a clear measure of voltage quality has been defined, the next step is to establish what the quality objective is. First, the existing level of performance should be quantified and possibly, compared in the light of international best practice. Second, the quality level that one ideally would like to achieve needs to be defined. From an economic point of view, the quality level the regulator aims at should be the quality level that provides highest net economic benefits. The regulatory objective should then be to bridge the gap between the targeted quality level and the existing level.

To achieve a higher quality level, one will need to invest more in the network. Clearly, increasing quality only makes sense if the additional benefits (cost reduction) are higher than the investment costs. At some point, benefits and costs will be equal at the margin. This point can be defined as the optimal quality level–as net economic benefits will be maximized–and is the theoretical objective that one should pursue to achieve. This optimum is visualized in Figure 5.

Measuring the benefits of increased quality is hard and therefore often approximated by the costs customers experience due to the voltage quality being less than perfect.

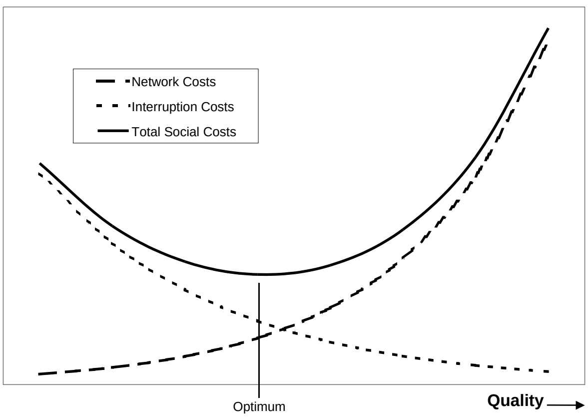

Figure 5: Optimal total social costs

Overview of quality controls

Once the regulator has identified the appropriate quality indicator, is able to measure it, and has an idea about the target performance level, the next step is to choose a suitable regulatory control to help achieve that objective. Generally speaking three quality control types can be distinguished, which are explained in the next sections.

Performance Monitoring

The basic idea of performance monitoring is to require the DNOs to report on their voltage quality performance to the regulator. The regulator can then decide to make this information available to the public, so the DNOs can be compared to each other. This “naming and shaming” is thought to provide strong incentives to outperform others as there is a reputational concern involved in the comparison.

Performance monitoring is the weakest form of quality control as it only provides indirect incentives to the utility. However, it is also the simplest to implement as it requires relatively little effort by the regulator. Also, in terms of data requirements, performance monitoring can be limited to a number of strategic locations within the network, eliminating the need for measuring extensively throughout the network.

Minimum Standards

Minimum standards dictate a minimum level to be achieved for a certain performance aspect. In case of not meeting this standard, the utility may be penalized. Sometimes the minimum standard is only indicative. However, the regulator could bring the fact that the utility did not meet a certain standard to the attention of the public. This has an indirect effect which can be substantial as it affects the utility’s public image.

Minimum standards provide clear guidelines about what voltage quality DNOs should aim at. They set quantitative targets for the companies to achieve. Combined with financial incentives for not meeting the standards, minimum standards can be very effective quality controls.

The minimum standard can be derived directly from standards which are already adopted and used within the power sector industry. For example, in Europe, the European standard EN 50160 has been generally considered as a reasonable starting point to establish voltage quality regulation systems.

Incentive Schemes

An incentive scheme can be considered as an extended minimum standard. Under an incentive scheme, a more continuous relation is imposed between price and quality. The better the DNO performs in terms of reducing the difference between actual performance and voltage quality targets, the better this is financially. By basing the incentive level (being the penalty or reward) on the costs that customers incur as a result of quality not being perfect, incentives can be provided to provide an optimal level of quality. If the regulatory objective is to maintain or improve quality, then an incentive scheme is most suitable and appealing as the relationship between performance and incentive is more continuous.

But even though theoretically superior, incentive schemes have serious practical limitations. These mainly arise from two sources. First of all, an incentive scheme is built on the idea that the regulator has good information about actual levels of quality performance. If actual performance is not known to a high degree of accuracy, the scheme may not be effective as the resulting financial incentive will be flawed. Secondly, it is difficult to exactly measure customer costs due to lack of quality. The heterogeneous nature of the customer base needs to be properly discounted into determining the incentive. Several countries performed surveys in the past to determine costs of quality aspects [3]. The reason why survey results are not directly translated into regulation can be explained by the fact that it can be debated how much a network operator can influence the occurrence and severity of these aspects.

VOLTAGE QUALITY IN SEVERAL COUNTRIES

This section assesses the considerations and progress made in several countries with regard to voltage quality regulation. This information helps to obtain more practical insights into how this issue is dealt with in Europe.

Ukraine

Electrical energy supply in Ukraine is carried out according to the supply agreement between the supplier and consumer. The main document dealing with requirements concerning the supplier's side is standard GOST 13109-97. GOST 13109-97 gives the main voltage parameters and their permissible deviation ranges at the customer's point of common coupling in public low and medium voltage electricity distribution systems, under normal operating conditions. Where the available voltage quality is not sufficient for the user's needs, improvement measures are needed and a cost-benefit analysis has to be carried out.

Norway

The power industry regulator in Norway NVE has put into force a new Directive on quality of supply as of 1st January 2005. The voltage quality regulations are set up in the form of minimum standards and are supplemented by rules for handling enquiries from connected parties to the network companies regarding quality of supply. Moreover NVE has included a provision about deviations from the standard voltage quality regulations providing for the option of bilateral agreements on voltage quality that allows for a voltage quality deviating from the minimum requirements stipulated by NVE.

The set of regulations imposed by NVE go further than the requirements on the EN 50160.

The Netherlands

Similar to Norway, the Dutch regulator NMa regulates different dimensions of voltage quality. Flicker is under regulatory control by imposing a minimum standard. For both medium voltage and low voltage networks flicker limits are defined. Since network operators are obviously not the only parties who can influence flicker, the Grid Code also defines requirements on flicker for the customers connected to low voltage networks. In addition to these requirements Dutch Grid Code refers to requirements for 'producers' of harmonic disturbance. At the moment, the Dutch regulator is working on regulation of transients.

CONCLUSIONS

The definition of the voltage quality objective follows logically from the perceived difference between current and desired levels of voltage quality. There are different controls that regulators could employ to achieve their voltage quality objectives. A distinction can be made between performance monitoring, minimum standards, and incentive schemes. In theory, an incentive scheme is the most effective control as it imposes a direct link between performance and financial incentives. However, at present time, it seems that implementation of incentive schemes is severely limited by practical concerns. On the other hand, performance monitoring is practically simple to implement but lacks true incentives for high voltage quality.

Minimum standards seem to strike a good balance between performance monitoring and incentive schemes. The degree of measurement data is more restricted than under incentive schemes. At the same time, minimum standards also provide financial incentives for good voltage quality. They dictate a minimum performance and set a clear boundary of what is acceptable quality and what is not. Typically, the European standard EN 50160 is used as the basis for setting minimum standards.

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