

MONITORING AND REPORTING OF VOLTAGE DISTURBANCES – REGULATORY AND TECHNICAL CHALLENGES AND SOLUTIONS

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ABSTRACT

Voltage quality monitoring has a key role within quality regulation providing data on the real situation either by continuous monitoring or by monitoring upon customer complaints or requests. This paper describes the current requirements [1] on monitoring of voltage disturbances in Norway, during continuous monitoring and due to customer complaints or requests, and the motivation for these. Further, recommendations from a recent consultancy study [2] regarding the level of monitoring for achieving reliable statistics, and on a reporting system for voltage disturbances, will be presented.

INTRODUCTION

Results from continuous voltage quality monitoring systems are important in order for grid companies being able to fulfil their duty of informing customers about past and estimated future quality levels, giving customers the possibility to perform their own assessments on whether to install countermeasures, and in some cases even as a basis for handling customer complaints. For the latter, targeted measurements (trouble-shooting) based on the complaint are more common.

Some voltage disturbances occur stochastic over the year (e.g. voltage dips and swells); hence continuous monitoring is necessary to understand the real situation. For continuous voltage quality phenomena like e.g. slow supply voltage variations, harmonics and flicker, it is possible to get a rather good picture of the real situation in a given point of location by monitoring the voltage for minimum one week, but ensuring to include relevant operating conditions (working day vs weekend, seasonal differences, etc). Therefore, when the Norwegian regulator introduced mandatory monitoring of voltage disturbances, it was decided to focus on stochastic parameters, while all relevant parameters shall be measured upon a customer complaint.

Reliable statistics of voltage disturbances require a sufficient amount of measurement units installed in the power system. A key question relates to the number of instruments needed to be installed, still taking into account costs related to the monitoring scheme, parameters to monitor, presentation of data etc. The current regulation on continuous monitoring includes some degree of freedom for the grid companies, including the location of instruments (characteristic networks) and number of units. In general, the grid companies should be the ones with the best knowledge about their own grid, and therefore the best ones

to consider the optimal amount and location of possible voltage quality measurement units. It is important for the regulator to know whether the choices done by the companies still provide satisfactory number of measurement units installed at the appropriate points in the power system. Further, it is important to explore the possibilities for introducing a reporting system for results from voltage quality monitoring.

VOLTAGE QUALITY MONITORING

Historical review

There have been four voltage quality measurement campaigns in Norway. The first one was conducted by SINTEF Energy Research during late 80's and beginning of 90's with a very limited number of instruments Dranetz 646 and 606 located mainly in the medium voltage (MV) network but also in the distribution transformers on the low voltage (LV) side. This measurement campaign was limited to voltage rms variations including voltage dips and swells and fast transients/impulses. From 1993 to 2003 SINTEF performed a new measurement campaign with 44 BMI PQ Node instruments from the beginning and at the most 73 instruments. This was however mostly instruments owned by the Norwegian distribution system operators (DSOs), the transmission system operator (TSO) and a few industrial companies. Some of the instruments were moved to several measurement locations during these 10 years making a total number of measurement locations to over 700. The highest percentage of measurement locations was in the LV system (both in transformer and at customers) but a significant number of measurement locations was also in both MV and high voltage (HV) networks, and even a few in the extra-high voltage (EHV) network. These two measurement campaigns were voluntary for the involved parties.

A mandatory measurement campaign entered into force in 2006 by a regulatory order 30 November 2004 [1]. This will be described more detailed below. First, another voluntary campaign will be briefly described.

In parallel with the ongoing mandatory monitoring performed by the DSOs and the TSO, SINTEF Energy Research started a new measurement campaign in 2007 through 3 research projects. It is now installed units at 25 measurement locations (will increase to 28 in the very near future) with a "new generation" Power Quality instruments (Elspec G4XXX). Measurement locations are in LV, MV,

HV and EHV with a high percentage in conjunction with renewable energy production (wind, small hydro power). This measurement campaign is more profoundly described in another paper for this CIRED conference, paper no. 0942.

Regulatory requirements

From 1 January 2005 [1], the TSO and all DSOs are obliged to do measurements to verify the levels of all relevant voltage quality parameters upon complaints from any customer, including end-users, producers or other grid companies. The costs associated with the treatment of customer complaints and related measurements shall be covered by the TSO/DSOs. The measurements carried out shall at least have a duration of one week and shall as far as possible reflect the equivalent operating conditions referred to in the complaint. The TSO/DSOs are also obliged to carry out measurements of some parameters upon request from any customer, even if the customer experiences no problems (i.e. there is no complaint). For the latter case, the costs associated with the measurements may be transferred to the customer who requested the measurement.

From 1 January 2006, the TSO/DSOs have been obliged also to perform continuous monitoring of voltage dips, voltage swells and rapid voltage changes. The continuous monitoring applies for different characteristic networks within each grid company, and for voltage levels above 1 kV. The TSO/DSOs are responsible for the number of instruments needed to provide trustworthy statistics. The companies are obliged to group their network into characteristic networks and to perform measurements within each type of their characteristic network. The minimum requirement is at least one instrument, but this is applicable only for the smallest DSOs. Results from continuous monitoring shall be stored for at least ten years. Given the large amount of grid companies in Norway (157 DSOs regulated by revenue cap in addition to the TSO, in 2010), this scheme results in several hundred instruments installed.

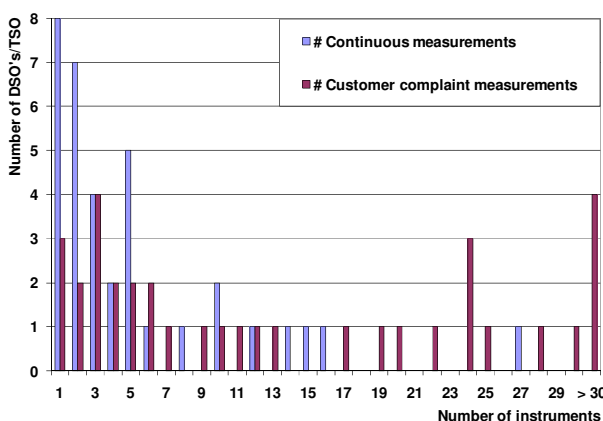


Figure 1 – Number of voltage quality measurement instruments installed by the surveyed grid companies. Status May 2009

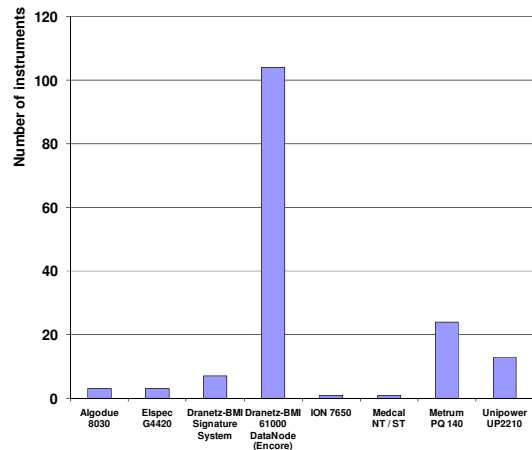


Figure 2 – Number of instruments of each type for continuous measurements, in use by the surveyed grid companies. Status May 2009

Further, the TSO/DSOs are obliged upon request to provide information on, *inter alia*, nominal voltages and existing voltage quality limits, results from reporting of interruptions and operation disturbances, results from continuous voltage quality monitoring systems, past and expected future frequency and duration of short and long interruptions, estimated past and expected future number of voltage dips and swells and calculated minimum and maximum levels of short circuit power.

According to the regulation, measurements of quality of supply shall be carried out in accordance with relevant standards prepared by the International Electrotechnical Commission (IEC) or the European Committee for Electrotechnical Standardization (CENELEC). The instruments used shall be calibrated in accordance with the instrument suppliers' specifications with respect to frequency and methodology. The calibration traceability for the individual measurement parameters shall be documented. The precision and limitations of the measuring equipment shall be stated in the documentation of the measurement results. The measurement results plus uncertainties shall be within the limits specified in the regulation.

CONSULTANCY STUDY

Task

NVE commissioned SINTEF Energy Research to perform a consultancy study [2], with the task of, *inter alia*, evaluate how grid companies have solved the current requirements on continuous monitoring of voltage disturbances, including number of instruments, voltage disturbances monitored, characteristic networks, location of measurement units etc. Further; to evaluate whether the current regulatory requirement is sufficient to ensure trustworthy statistics at national, regional and local level, and to recommend a suitable division of characteristic networks for a given number of companies. The assignment included recommendations on regulatory requirements to ensure the

mentioned trustworthy statistics. Finally, the assignment included recommendation on a reporting scheme of results from measurements of voltage disturbances through continuous monitoring, or monitoring related to customer complaints or requests. As part of the consultancy project [2], 35 grid companies were surveyed by a web and postal questionnaire (8 themes including 69 questions). In addition, 4 grid companies were analysed profoundly by the researchers who visited those particular companies. The number and types of instruments installed by the surveyed grid companies are presented in Figure 1 and Figure 2.

Recommendations

Measurement location

Monitoring voltage disturbances only in different characteristic networks is one way of reducing the amount of monitoring units. Instead of monitoring in all galvanic separated grids, the scope of occurrence of stochastic parameters may be similar in similar characteristic networks. Important elements when separating the grid into characteristic networks are voltage level, system earth, short circuit power, the amount of underground cable vs aerial line, geography (inland vs coast, valley vs mountain), climatic strain (snowy, icy, rainy, hot, cold, wet, dry), customer groups connected and age of networks.

The survey of grid companies showed that most companies only used one or few of these elements when grouping their grids into characteristic networks. In Norway, there are 158 TSO/DSOs (2010). Therefore, evaluating monitoring results from several companies, it is possible to provide reliable statistics at national, regional and sometimes local level. Even within each company, reliable statistics at regional levels are possible.

SINTEF believes that the current requirement on continuous monitoring in different characteristic networks should stay unchanged. SINTEF believes this to be a good and not very costly approach, and that the gains are quite few compared to increased costs by detailing the specific amount and location of measurement units.

Number of instruments

Huge differences exist between companies regarding number of measurement units for continuous monitoring. The survey shows that those companies that to a larger extent have been dealing with voltage quality in general due to local challenges also are the ones that have installed a relatively higher number of measurement units. However, based on the current installations of monitoring units, reliable statistics can be achieved at national, regional and local level. SINTEF recommends to continue allowing the companies to decide upon the exact number of instruments needed to achieve reliable statistics in their own grid. The number of different characteristic networks will also influence on the necessary number of instruments.

Voltage disturbances to monitor

The current regulation obliges the companies to continuously monitor voltage dips, voltage swells and rapid voltage changes, as these have a stochastic behaviour. However, all instruments installed by the companies to fulfil this obligation have the functionality to measure more or less all relevant voltage quality parameters. Based on this, SINTEF recommends to change the regulation so that the companies are obliged to monitor all relevant parameters, including supply voltage variations, voltage dips, voltage swells, rapid voltage changes, flicker, voltage unbalance, harmonics and transient overvoltages. However, requiring the companies to monitor all parameters could involve extra costs in administration and structuring of the data, and for example in voltage transformers in order to ensure reliable measurements. These concerns need to be taken into account as well. Regarding measurements due to customer complaints, there are no doubts, all relevant parameters shall be included in the mandatory measurements.

Reporting system

One of the main purposes of this project was to recommend possible solutions for a reporting system for measured voltage quality. In Norway, the 158 TSO/DSOs are using different types of measurement units from about 7 different vendors. This poses challenges on the design of a common reporting system. The choice of format to transfer measured data in the reporting system will be critical, regarding the type of software that can be used to analyse the reported data, the possible size of data to be transferred and the needed size of the database at the receiver's end, and the degree of advanced and comprehensive analysis possible to be performed on the reported data. SINTEF lists three important factors when considering how to perform a possible future reporting of voltage disturbances:

- 1) The possibilities for advanced and detailed analysis on the reported data;
- 2) Low resources needed for the companies to report data; and
- 3) Low resources, if any, needed for making new standards for data transfer.

SINTEF made a detailed evaluation of the following data formats: ASCII (American Standard Code for Information Interchange); XML (Extensible Markup Language); CSV (Comma Separated Values); Binary; PQDIF (Power Quality Data Interchange Format, IEEE Std. 1159.3-2003); and COMTRADE (COMmon TRAnsient Data Exchange, IEEE Std. C37.111-1999).

PQDIF is the only standardised format for exchange of voltage events and voltage quality trends (measurements over a given period of time). PQDIF is a binary format, still, the only one standardised and which many of the current measurement systems already support. Therefore, PQDIF can be considered as an interchange format of voltage

quality independent of type of measurement system. PQDIF makes possible transfer of voltage quality data between the grid companies themselves and to NVE without needing huge effort in advance regarding specifying the content of the data files.

The advantages of using PQDIF in the Norwegian case are:

- An international standard for data exchange exist, and most measurement instrument systems used in Norway already support this standard.
- A limited aggregation of data, meaning that the receiver may carry out detailed analysis and provide advanced statistics based on the data reported.

There exist some challenges as well if using PQDIF in the Norwegian case. The size of data to be reported will be higher than with some other formats, still, the size should be manageable. PQDIF does not include the parameter rapid voltage changes, which is an important parameter in the Norwegian power system and quality regulation. This parameter has been included in the scheme for continuous monitoring since its beginning. Either a change in the standard for PQDIF or an alternative solution should be sought to include rapid voltage changes in the reporting scheme.

SINTEF Recommends using PQDIF if introducing a reporting system in Norway for voltage disturbances. This will reduce to a minimum the required effort in advance of starting-up a reporting scheme, so that a scheme could be established in short term.

Frequency of reporting

SINTEF recommends the frequency of reporting to be considered based on the current measurement systems ability to automatically download measured data to a database for further transfer, see Figure 3. As long as some companies still rely on manual downloading, SINTEF recommends the reporting interval to not exceed a few times per year, or only annually.

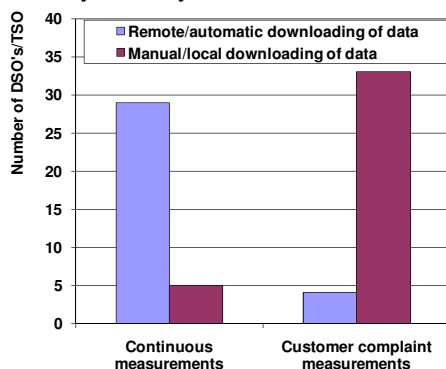


Figure 3 – Number of the surveyed grid companies who use automatic versus manual downloading, respectively. Status May 2009

For the far most companies and measurement units already installed, automatic downloading and transfer of data is possible. For the very few cases, where only manually downloading is possible, this will probably remain until there is a requirement stating frequently reporting, like monthly or quarterly. Regardless of any requirement on a reporting system, all companies are already obliged to collect the data, structure them and provide statistics upon request. Hence the additional burden for the companies regarding a reporting system, is the actual sending to the regulator, which in most cases can occur automatically.

CONCLUSIONS

The choices, regarding requirements on how to perform continuous monitoring of voltage disturbances, taken by NVE in 2004 prior to the introduction of the regulatory order “Reg No 1557 30 November 2004 on the quality of supply in the Norwegian power system” [1], seems still solid. The approach of requiring the TSO/DSOs to divide their own grid into characteristic networks and to perform monitoring with a sufficient amount of measurement units within each of these, have been concluded to provide satisfactory results. The final choice on the number of instrument and their exact locations are then determined by the companies themselves.

In addition, a recent consultancy study performed by SINTEF Energy Research [2] has provided recommendations to increase the amount of voltage quality parameters to be included when performing continuously voltage quality monitoring, and on a reporting system for results from voltage quality measurements. NVE will consider these recommendations and whether regulatory changes are deemed useful.

REFERENCES

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