IMPLEMENTING A SYSTEMATIC APPROACH TOWARDS SOLVING POWER QUALITY COMPLAINTS – FROM A NETWORK OPERATOR'S PERSPECTIVE

Sharmistha BHATTACHARYYA
Endinet – The Netherlands
sharmirb@yahoo.com

Luc van den NIEUWENHOF
Endinet – The Netherlands
Luc.van.den.Nieuwenhof@endinet.nl

ABSTRACT

In Europe, the national regulators make strict regulations for a network operator to supply a voltage at a customer's point of connection (POC) that meets the EN50160 standard guidelines. However, voltage quality is highly influenced by current quality that customer's devices demand at a POC. Nowadays, these devices have become more sensitive than ten years ago. Also, customers have better understanding about supply quality issues and their own rights. Therefore, when a customer faces a power quality (PQ) disturbance at his installation, he immediately complains and asks the network operator to solve it. However, in many situations, the source of a PQ problem is within the customer's own installation. In the last three years, all the network operators of the Netherlands work together to find a systematic approach to handle PQ problems in efficient & effective ways. In this paper, first a brief summary is given on the national level activities. Further, some PQ problems in Endinet's service area and their handling procedures are described. It is observed that the national level guidelines have improved Endinet's complaint handling procedure significantly. As a network operator Endinet works with maximum transparency & is able to upkeep its image to the clients.

INTRODUCTION

The Dutch regulatory authority ACM ('Autoriteit Consument & Markt' in Dutch) has asked the network operators in the Netherlands to become more transparent about their supply voltage quality, performance of their networks and other related issues. A 'Voltage Quality (VQ)' workgroup is formed under the name of 'Netbeheer Nederland' (an organization representing all network operators of the Netherlands). ACM has asked to perform a sufficient amount of power quality monitoring (PQM) activities in different parts of the networks in the Netherlands. When large amount of PQ measurements are done, it is possible to understand the actual voltage quality performance of the Dutch network in comparison to other European or international networks. Also, ACM asked the network operators to define the source of various types of PQ problems in the network.

Endinet is registering an increasing number of power quality (PQ) complaints, mainly from low voltage (LV) clients, during the last ten years. Since last couple of years, understanding on this topic has increased largely among the network operators as well as the customers. The Dutch network operators, in approval of ACM, have taken a number of integrated measures to conduct PQM more efficiently. Also, knowledge and experience sharing among the group members help all network operators to build strong understanding regarding various PQ issues. Every network operator is spreading their knowledge too to their customers via internet and information brochures. This helps the customer to understand PQ issues in a better way.

In addition to the above, complaint registering method is improved significantly. Previously, when a customer complained about a voltage quality problem, it was often not easy to determine the best course of action because of the lack of PQ monitoring expertise. During the last two years, the understanding about PQ monitoring activities has been improved largely because of the knowledge sharing from the VQ workgroup. Nowadays, after analyzing a PQ problem, it is often possible to identify the cause of PQ problem and its originating point. It is also well understood that a customer's current quality can influence network's voltage quality and can enhance the network disturbance. Therefore, network operator is not alone responsible for the PQ level at a POC, as shown in Fig.1.

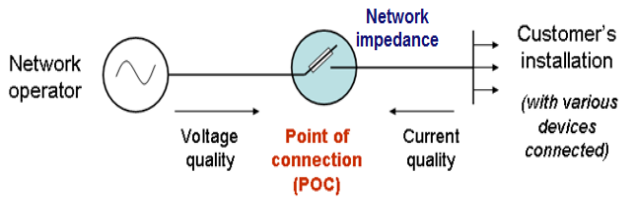

Fig. 1: PQ responsibilities at a POC

In this paper a brief description is given about various activities that Endinet participates with the national VQ workgroup. Within this group, a general approach is developed to handle a PQ complaint from the customers. Endinet follows almost a similar procedure to tackle a PQ complaint. In the latter part of this paper, some interesting PQ complaints and their handling procedures are discussed. Those were registered in Endinet's database over the last four years. It was observed that many customers complain mainly about harmonics related inconveniences, such as: misoperation of devices, damage of appliances and frequent blowing out of lamps, etc. Besides that, customers sometimes complain about light flicker and voltage variations too.

NATIONAL WORKGROUP ACTIVITIES

In 2013, the Dutch regulatory authority ACM asked the network operators in the Netherlands to take several measures to guarantee the voltage quality of the public network. It appeared from earlier surveys that there was not sufficient evidence (measurements) present for the Dutch grids by which ACM can accept that all networks in the Netherlands fulfil the minimum (voltage) quality standard level as per the European standard 50160 [1] and the Dutch Netcode [2]. Therefore, in 2013, ACM assigned the "voltage quality" project to all the network operators of the Netherlands, via Netbeheer Nederland. Therefore, the working group VQ was formed with the representatives of every network operator. Endinet is participating in this group as well. Following activities, as desired by ACM, are assigned for the regional network operators [3]:

- ***Activity 1***: Develop voltage dip standards for medium voltage (MV) networks. This requires continuous monitoring of HV/MV stations at MV busbar for a minimum period of 3 years.
- ***Activity 2***: Investigating the reasons / sources of harmonics in the network, specially for 15th and 21st harmonics. Also, to determine the optimum values of these harmonic voltages (to improve the present standard limits).
- ***Activity 3***: Perform increased number of PQ measurements for a week in the MV and LV network (250 measurements in each network level, instead of 60 until year 2014). Moreover, continuous monitoring needs to be done for all high voltage (HV) and extra high voltage (EHV) installations.
- ***Activity 4***: The week measurements should be done evenly throughout the year and should be spread among all different population densities (such as cities and townships, industrial and household customers).
- ***Activity 5***: Absolute transparency is needed from the network operators with the customers.
- ***Activity 6***: All PQ measured results should be submitted as a national PQ report, describing the maximum, average and minimum values for each PQ disturbance and event.
- ***Activity 7***: A dedicated reporting tool is to be developed to declare the above mentioned measurement results. This information should be publicly visible via the dedicated internet website.
- ***Activity 8***: Customers should be allowed to see the PQM results if a PQ meter is placed at his installation.
- ***Activity 9***: A uniform registration system is to be developed to register PQ complaints from the customers. This way, ACM can compare the performance of individual network operators.

Besides the activities mentioned here, there are some special projects going on in the networks of national transmission system operator 'TenneT' under the VQ work group. As Endinet is not directly involved in those special projects, these are not discussed in this paper.
The various activities of the VQ work group is officially coordinated by 'Movares Energy', the Netherlands. Every network operator is obliged to send their PQM data to them for further analysis and reporting purposes.

From 2014, all the network operators have started to implement those assignment activities in their networks. Adjustments need to be done in many MV stations to start continuous monitoring of voltage dips, as desired by ACM. Endinet does not own any HV/MV transformer stations. Therefore, no PQ meter is required in Endinet's MV station to perform continuous monitoring (for voltage dips). Besides that Endinet is obliged to carry out other activities. The PQ complaint registration system is improved and Endinet has started to follow a uniform registration method for registering various complaints from clients regarding voltage quality issues. This is described in detail in the following section of this paper. Also, new PQ monitoring devices (Fluke 435, class A) are bought, as recommended by the work group VQ. Endinet's technicians are trained to perform PQM activities in line with the national process. During a PQ measurement at a POC of a client's installation, Endinet sometimes performs an impedance measurement too. This is done to confirm that the impedance at that POC is within the specified range as per Endinet's own internal network design criteria. When a large value of impedance is measured at a POC, it is often found that connection cable is not appropriately connected or a cable joint is loose or defected. The measuring instruments that Endinet uses for PQM activity are shown in Fig. 2.

'Fluke' Power quality meter | 'Sonel' Impedance meter

Fig. 2: Measuring instruments for PQM

Besides the above PQM activities, Endinet actively works on improving its internet websites with useful information on voltage quality. Now, the clients are better informed about PQ problems and their solutions. Also, Endinet's network voltage quality performance is visible through the national website of Netbeheer Nederland.

COMPLAINT HANDLING PROCEDURE

When a customer complains to Endinet service desk about a voltage quality issue, firstly a telephonic discussion takes place to understand the severity of the problem. Next, the exact location of the customer in Endinet's network is found out from GIS (geographical information system) database. By doing that it is possible to estimate the approximate network impedance at that customer's connection point (POC). Further, when it is understood by our PQ experts that the customer's problem is serious and needs attention, a PQ measurement is done for a week at the customer's POC to record all voltage quality data, as indicated in Fig. 3.

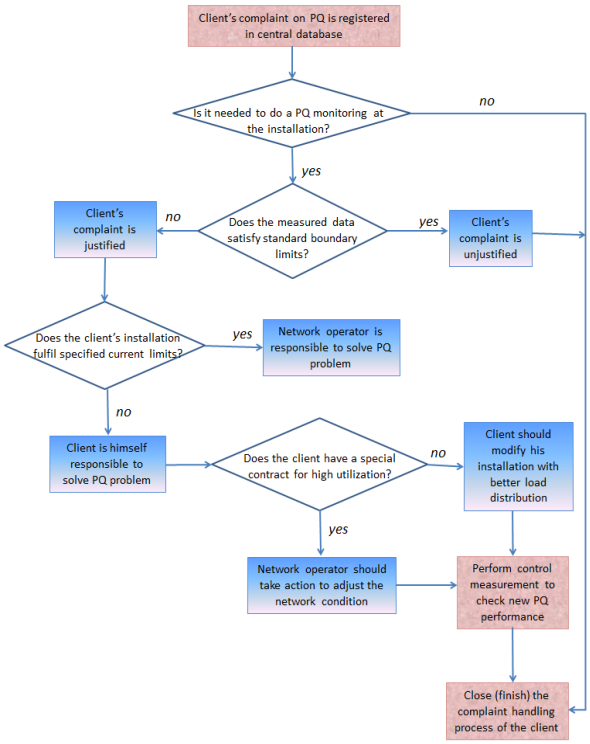

Fig. 3: Standard guidelines for PQ complaint handling

Afterwards, the measured data is analyzed thoroughly to find out any violation of voltage quality parameters with respect to the limiting values mentioned in the EN50160 standard or the Dutch Netcode. These standards boundary limits are considered as minimum requirements for a supply voltage.

From the data analysis, conclusions are made and communicated to the customer. If an action is needed from the network operator's side, a corrective measure is taken immediately. On the other hand, if it is concluded from the analysis that the problem source is located at the customer's installation, Endinet advices the client to take a corrective/ preventive measure to solve his PQ problem. In this way, by using a systematic approach, Endinet solves PQ related complaints of the customers efficiently. Also, this approach helps Endinet to understand the bottlenecks of its own network and the optimum solution possibilities. This systematic approach helps Endinet's asset management as well as operational activities immensely to meet the present challenges in the network. In the next sections some interesting PQ case studies in Endinet's network are discussed.

PQM ACTIVITIES IN ENDINET'S GRID

In the last three years, Endinet is actively working on building up expertise and knowledge within the organization regarding PQ issues and establishing efficient ways of solving customer PQ problems. Therefore, monitoring the grid and analyzing the data is found an effective way to understand the voltage quality of the network. Three types of PQM are conducted in Endinet's networks and described below:

PQM due to customer's complaint

Endinet provides electricity to more than 110.000 customers. On yearly basis Endinet's customer service desk gets approximately 30 complaints (telephonic calls) regarding various voltage supply related disturbances. It was observed that when there is 'no voltage' available at an installation of a customer, he considers it as a voltage related disturbance and calls Endinet to solve it immediately. However, this type of disturbance cannot be considered as PQ complaint. Most of the cases, this type of disturbance is because of a temporary power outage due to a local problem in the network (such as temporary short circuit in a feeder and nearby fuse of a local distribution box operates as a protective measure). It is observed from last four years measurements that there on average 30 complaints every year are registered as voltage disturbances whereas only on average 10 complaints/ year are real PQ related complaints where PQ monitoring was needed, as shown in Fig. 4.

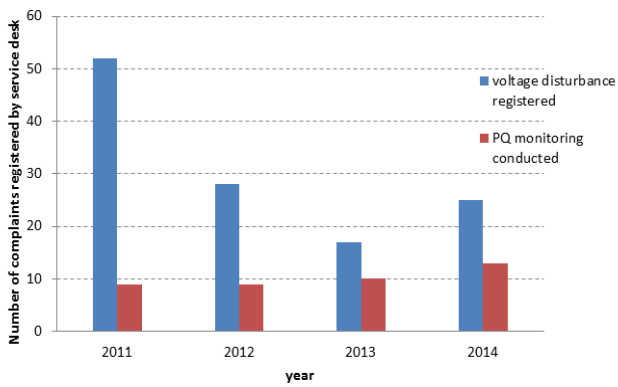

Fig. 4: Number of PQ complaints in Endinet's grid

The main PQ disturbances that are observed in Endinet's network are harmonics and flicker. Research shows that in 60% of the cases the PQ disturbance is due to a high amount of harmonic currents produced at the customer's POC itself. This increases the harmonic voltages at the POC of the specific customer and makes the supply voltage distorted.

As a result, customer's devices can malfunction and in extreme cases switch off or burnout. In 2014, around 13 PQ measurements were conducted at various complaining customer's installations. It was observed that only occasionally some of the PQ disturbances (such as 15th and 21st harmonic voltage values) have exceeded the standard limit boundaries. Last year, in two of such situations PQ parameters (for harmonics voltages) were above the standard boundary limits. However, it was noticed that impedances at those POCs were within Endinet's specified design limit. It was found that the harmonic currents are quite high at those installations in comparison to similar kind of typical installations. Here, it can be mentioned that the EN50160 standard specifies relatively lower limiting values for 15th and 21st harmonic voltages as compared to other adjacent harmonics. In the international levels, various standardization organizations are reconsidering about the valid reasoning of those low values. The VQ group has made a proposal and submitted it to the working group of the European standardization committee (CLC_TC8) regarding increment of the limiting values of 15th and 21st harmonic voltages [4]. From the national level PQM monitoring activities in the Netherlands, it is found that the number of measured LV installations have registered higher values for these two harmonic voltages, exceeding the standard limit (see Fig. 5 below). This high trend is observed from 2008 onwards. The similar trend is also noticed for other countries in Europe. It is worth to mention that the customers generally do not notice any inconvenience at their installations because of the (slightly) higher amount of harmonic voltages for 15th and 21st harmonics.

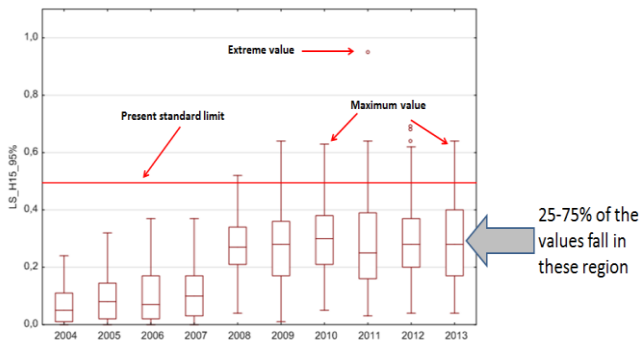

Fig. 5: 15th harmonic voltage trend in the Netherlands [4]

In Endinet's network, there was a PQ monitoring conducted at a LV business customer (travel agency). The customer complained that all types of lamps (halogen, energy savings CFLs) at their installation are burning out frequently. After Endinet registered the complaint, a PQM took place at this customer's POC. From PQM data, it was noticed that the customer had heavy capacitive loads at the installation which was making the power factor low (0,4), especially at night. Generally, it is expected that LV customers should have a power factor not lower than 0,9 at a POC. Seven days PQM results are shown in Fig. 6 and Table 1.

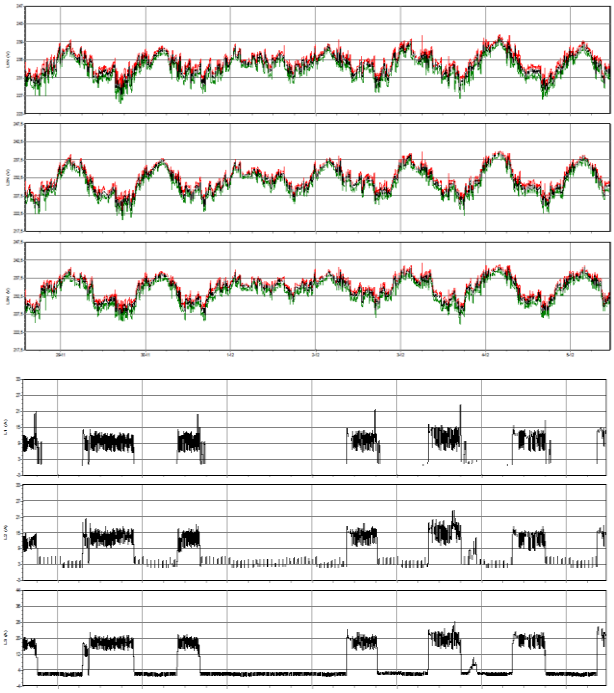

Fig. 6: Measured voltage & current profiles at POC

Table 1: PQ performance at a glance at that POC

PQ phenomena (nominal voltage 230V)- applicable std. EN50160/ Netcode	Satisfy std. limits	Max limit (95%)	Measured (95%)	Max limit (100 %)	Measured (100%)
Slow voltage variations (min- 207V, max- 253V)	yes	+/- 10%	237V	+ 10% -15%	240V 227V
Fast voltage variation (Plt, flicker)	yes	1	0,21	5	0,23
Unbalance	yes	2%	0,8%	3%	1,1%
Total harmonic distortion (THD)	yes	8%	2,9%	12%	3,0%
Presence of individual harmonic voltages at POC	2,3,5,7,9,11,13,15,21				
Any violation of standard limit?	No, all measured values are within limiting values of standards				

Table 1 shows that there is no violation of standard limiting values for various PQ parameters at the POC. However, large values of harmonic currents are measured at that POC. The measured current waveforms are found quite distorted. Moreover, loads in different phases are also not evenly distributed. It can be concluded from the measurement that customer's lamps are either very sensitive or are of poor quality (for a low price). Also, there is a chance that impedance matching is happening between network inductive impedance and customer's capacitive impedance. This might cause resonance and might lead to a sudden rise of voltage and damage the lamps. As the measured data are within limit values, the customer himself is responsible to solve the PQ problem at his installation.

PQM due to yearly sample survey

Until 2014, Endinet was selected by the VQ group of Netbeheer Nederland to perform annually 6 PQM in its grid (3 in MV and 3 in LV networks). From 2015, the ACM has asked Endinet to perform one more PQM to meet national target of 500 measurements per year. Therefore, this year onwards Endinet has to conduct annually 7 numbers of PQ monitoring - 4 in MV and 3 in LV networks. All the measured data is sent to Movares (as mentioned before) for analysis and national level reporting to the ACM. In Fig. 7, a sample PQ report is shown. This measurement is done for a LV customer's POC, located in the city where density of LV customers are high. The upper figure represents the voltage quality parameters, such as maximum and minimum voltage levels, flicker (Plt), asymmetry, harmonics voltage (5th, 7th, 15th) and total harmonic distortion (THD) values for 100% of the measured time. The figure below represents the same voltage quality parameters for 95% of the measured time.

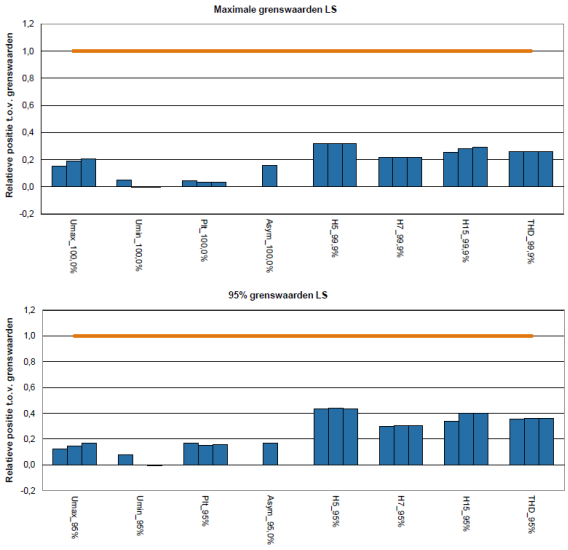

Fig. 7: PQM done for yearly sample survey

PQM for regular monitoring

Endinet conducts regular PQ monitoring in its network to access performance of the existing network for better future planning. One such measurement is conducted at a transformer's terminal to monitor loading patterns of it. In that neighbourhood, large scale photovoltaic (PV) panels will be installed at roof-tops of the houses. It can be observed from Fig. 8 that peak load is around 275A while the maximum loading during the lean period is as low as 75A only. The transformer has a capacity of 315kVA (equivalent to 454A). At present, this transformer is loaded by a maximum of 60% of its rated capacity to supply electricity to the neighbouring houses.

The measured voltage profile at the transformer terminal remains within the standard limit (230V±10%). From measurements it is found that average value of THD for voltage is around 2,8% (while the standard allows 8%). The average value of power factor remains within 0,9; occasionally becomes as low as 0,8. It was observed that flicker level is 0,25, when the standard boundary limit is 1,0. Hence, present voltage quality performance of the network is reasonably good. Also, it has sufficient capacity available to allow more load growths in future.

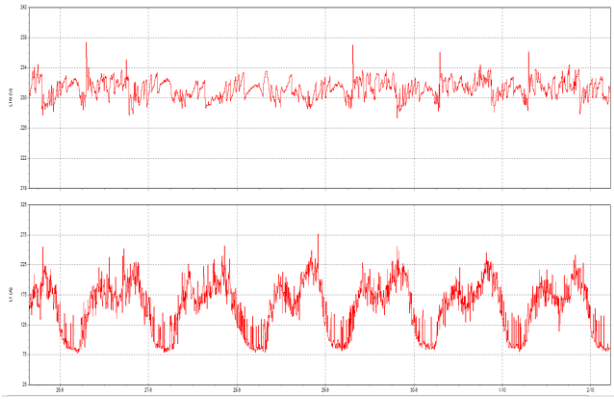

Fig. 7: Voltage (above) & current (below) profiles (for a week) at transformer terminal

CONCLUSION

In this paper various power quality monitoring activities in Endinet's network are described. From last year, PQ complaint handling process has become more systematic after implementing the national level recommended approach, developed by the VQ working group of Netbeheer Nederland. In addition to the process improvements there are better insights into the nature and causes of PQ problems. Often it is found that despite complaints from the customer, the measured values at POC are within the norm. An increased number of PQ monitoring activities has also improved Endinet's expertise level and insights into PQ problems. It is helping asset management activities too to assess the voltage quality performance of the present networks. As a result, Endinet's image as a transparent and cooperating network operator is improved immensely to its client.

Acknowledgments

Authors are thankful to technician Bart Smetsers for doing PQ measurements on their behalf, discussed in the paper.

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