

## DEALING WITH CUSTOMER'S COMPLAINTS REGARDING PQ ISSUES - FROM DNO PERSPECTIVE

Sharmistha BHATTACHARYYA  
 Enexis – The Netherlands  
 sharmirb@yahoo.com

Sjef COBBEN  
 TU/Eindhoven – The Netherlands  
 j.f.g.cobben@tue.nl

### ABSTRACT

*During the last two decades the customers have become more aware about the voltage quality that they receive from the grid and its possible (negative) impacts on their household apparatus and on the living environment. The modern customers use sophisticated devices in their day to day life and do not want to compromise on their comfort level. Therefore, any inconvenience that might be caused by the electricity utility service are immediately reported as a "complaint" to the network operators. When the operational people are convinced that it is voltage quality related complaint, a week-long power quality monitoring (PQM) is generally done at the customer's point of connection (POC). If the measured PQ parameters violate the standard limits of the EN50160 and the Dutch Netcode, an appropriate measure is taken/ advised at that installation or in the network to improve voltage quality at the POC. In this paper customer's complaints related to some specific PQ problems are discussed. Furthermore, a PQ complaint handling methodology is discussed briefly that gives guidelines to tackle customer complaints efficiently. Some national level activities are highlighted at the end of this paper.*

### INTRODUCTION

In the Netherlands, the network operators are obliged to provide a supply voltage at a customer's point of connection (POC) that should strictly meet the guidelines of the European standard EN50160 standard [1] and the Dutch Netcode [2]. However, voltage quality is highly influenced by the current quality that customer's devices demand from or inject into the network, as indicated in Fig. 1. The customer's devices, on the other hand, must follow the IEC 61000 series guidelines regarding their emission and immunity issues. Nowadays, these devices have become more sensitive than twenty years ago because of the usage of more complicated functionalities of various power electronics and digital technologies.

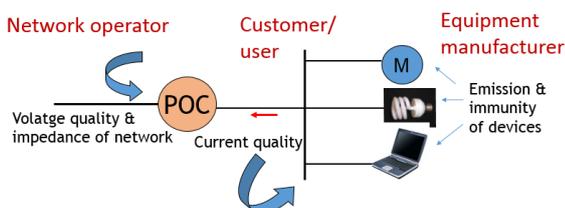


Fig. 1: Interaction between voltage and current qualities at POC

The customers have also become more aware about the issues related to the supply voltage quality. 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 origin of a PQ problem is within the customer's own installation. In this paper, a number of practical customer's complaint cases are discussed briefly. Further, a short description is given about the complaint handling methodology which is developed following the national level guidelines. In this approach, the operational activities are done efficiently together with maximum transparency; and at the same time satisfy the customer with the possible best services.

### TYPICAL PQ PROBLEMS

In this paper, a specific city in the Netherlands is considered where more than 110,000 low voltage (LV) electricity users are connected. Yearly around 60 voltage quality related complaints are received from this area; while PQ measurements are required to be done at around 8-10 locations. Majority of the cases, a telephonic advise is often helpful enough for the complaining customer to handle his PQ problem. Hence, no PQ measurement is done for those customers.

The main complaints that are received from the LV customers are related to damaged devices, improper functioning of apparatus, frequent blowing off lamps and fuses, etc. The customers also complain about unwanted switching-off of their inverter system connected with the photovoltaic (PV) panels and other related disturbances that are probably caused by poor quality of the supply voltage. Another type of complaint is due to the flickering of (dimmer controlled) lamps that occurs at some fixed time periods of the day. This problem is mainly caused by the ripple control signals that are sent by a network operator to control the street lights and customer's tariff meters. From network monitoring, it is found that sometimes the load distribution among the three phases in a network cable is not properly balanced that cause voltage asymmetry in the network. Customers also complain about occasional high voltage (on sunny days) at their POCs, when many customers in the same neighbourhood have PV panels at their installations. On contrary, low voltage problems are sometimes reported too for long length isolated feeders mainly connected in the rural areas. Nowadays, harmonic related problems are also quite visible in the network.

From various measurements, it is often found that the harmonic currents at some of the LV customer's terminals are quite high and sometimes some specific harmonic voltages exceed the standard boundary limits. A nearby medium voltage industrial customer can produce harmonic currents and inject the polluting currents in the LV networks due to which customer can suffer significant inconveniences too.

When customer complains about a PQ problem that needs serious attention, the network operator generally conducts a week-long PQ measurement at that customer's POC. It is noticed from internal monitoring database that around 25% of those PQ measurements at customer's installations have often one or more PQ parameters that exceed the standard limits. From further investigation, it is found that 60% of them are related to light flicker issues, 25% are about high- or low voltage problem at the customer's connect point and the rest 15% is related to inconveniences because of high harmonic currents/voltages at the installation.

## RESPONSIBILITY SHARING ISSUES

Power quality problems are quite complicated in nature. It is often not possible to clearly identify the actual origin of the problem because of their interactive nature. The customers use power electronics based apparatus at their installations that demand nonlinear current, which in return can distort the supply voltage. Also, these type of devices mutually interact with each other and can increase the distortion level in the network. Therefore, the device manufacturer should make the apparatus in such a way so that the individual distortion level and mutual interactions with each other should be restricted to a minimum level. When a customer uses many of such type of devices, then the customer is also responsible for the PQ problem at his premises.

Many electronic devices are quite sensitive to voltage wave-shapes and do not operate properly with a distorted voltage condition. Sometimes those devices malfunction and get damaged under a distorted voltage condition; sometimes they operate erroneously or occasionally they do not work at all. The voltage quality of a supply waveform can also be significantly distorted because of many polluting loads from different customers located in the same neighbourhood. Then, the group of customers are responsible for the PQ problem in the network, but the network operator should solve the problem. Occasionally, it is also found that the installation has some design defects or connection errors that may lead to some PQ problems at the POC. In this case, the customer himself is solely responsible to solve his problem.

While designing a new network, the network operator should follow standard guidelines and keep tolerances in the design, considering future demand growth in the network. Maximum value of network impedance at a LV connection point is determined by the main cable type, its length and protection device characteristic in the feeder.

Table 1 gives the technical rules that are commonly followed during design [3].

Table 1: Maximum network impedance for different LV feeders

Main fuse rating at the main LV feeder	Minimum cross-section of main LV cable	Maximum circuit impedance
100A gG	4x50 Al	371 mΩ
125A gG	4x95 Al	288 mΩ
160A gG	4x95 Al	231 mΩ
200A gG	4x150 Al	166 mΩ

It is often noticed that as network impedance at various connection points increases, exceeding the design values, the PQ problems are expected to occur more frequently, as shown in Fig. 2.

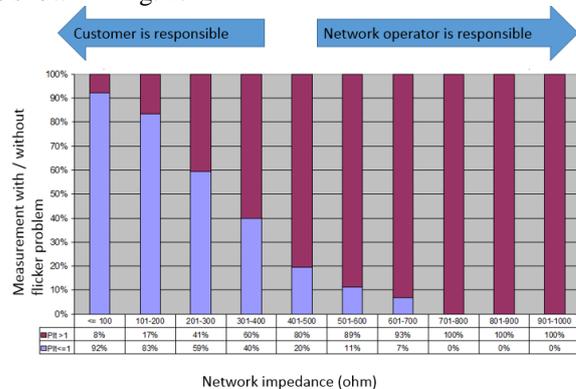


Fig. 2: Influence of network impedance on PQ problem & mutual responsibility sharing among different parties [3]

When a customer complains about a PQ problem, it is needed first to check about the location of the customer in the network. If it is found that the customer is located in a prime location where network impedance is high, a PQM along with network impedance measurement is done at the customer's POC. If the PQ parameters at that POC violates the standard limits, a thorough investigation is done before taking a mitigation measure. As network renovation/ modification is a costly affair, hence a cost-benefit analysis is done to reach an optimal discussion.

## COMPLAINT HANDLING PROCEDURE

When a customer complains about a voltage quality related issue, firstly a telephonic discussion takes place to understand the severity and frequency of the problem. Next, the exact location of the customer is found out from the network's assets database. By doing that it is possible to estimate the approximate network impedance at that customer's connection point (POC). Further, if it is understood that the customer's problem is serious and needs attention, the customer is asked to lodge his complaint in an official manner such as: sending an email to the client administration, or writing an letter to the company officials to give the needed information about the complaint.

After receiving the official complaint, the process starts by opening a dossier for the complaining customer. A date is planned with the customer to begin a week-long PQ monitoring at his POC to record all voltage quality data, as indicated in Fig. 3 [4]. Additionally, real-time network impedance measurement is also carried out at the connection point to measure the actual impedances of all the three phases and neutral conductor up to the complaining customer's POC.

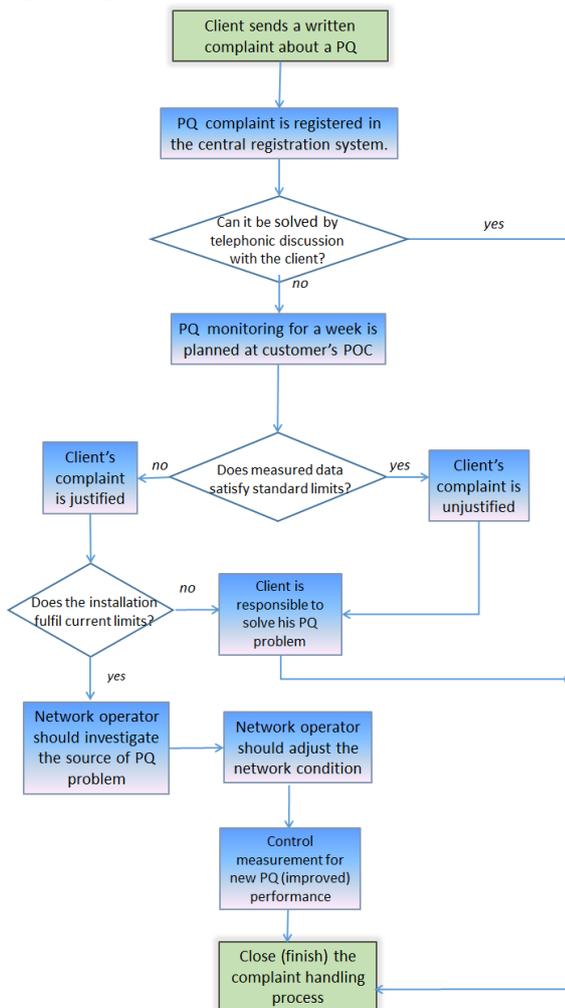


Fig. 3: Internal guidelines for handling a PQ complaint

Afterwards, the measured data of the PQ parameters are collected from the customer's POC and is sent to the operational department to analyze them thoroughly and to find out any violation of those parameters with respect to the limiting values mentioned in the EN50160 standard or the Dutch Netcode. As discussed in the previous section of this paper, majority of the cases if the network impedance is high (more than the values advised in table 1), the chance of a PQ parameter exceeding the standard limit values is found high. From the data analysis, conclusions are made and is communicated to the customer in the form of an advice (report). If an action is needed from the network operator's side, a corrective

measure is taken immediately. When it is found that the origin of the problem source is located at the customer's installation, the customer is advised to take a corrective measure to solve his PQ problem. After the mitigation measure (if needed) takes place, the case is considered to be solved and the customer's dossier is closed. As per the Dutch energy law, the whole process should be finished within 8 weeks of time for the LV customers (with an installation capacity  $\leq 80A$ ).

## ANALYSIS OF RECEIVED COMPLAINTS

In this paper, some typical PQ complaints of LV customers that are handled in the last two years are discussed. Mainly four different categories of PQ problems are reported:

- Light flicker in the installation
- Failure of motor starts
- Burning out lamps and damaged devices
- Spontaneous switching-off PV inverter system

All these above problems and analysis results are discussed separately in the following section.

### Light flicker in the installation

This type of complaints are received more frequently from this region of the network. The customers who use dimmer controlled LED lamps (of specific brands) often face this type of inconveniences. After investigation it is found that most of these incidents occur at a fixed time period of the day and continue for a maximum of two minutes. It is suspected that this problem is linked to the ripple control signals (at 1042 Hz frequency) that are sent via the normal 50Hz power lines. The network operator sends ripple control signals via the power lines to operate street lighting and day-night tariff meters of the customer's electricity meters. The dimmer controllers have power electronics that interact with the 1042 Hz signal and produce distortion in the network voltage, causing flickering of light bulbs. From measurement, it is found that the ripple control signal strength has much lower amplitude than the standard limits. However, as the dimmer controlled lamps are quite sensitive, light flickers are visible sharply by the customers. In this case, the customer is advised to change the dimmer type as a possible solution. The customer can also install a ripple blocking filter if he does not want this signal to enter at his installation.

Some other situations, light flicker is caused by the internal wiring fault of the installation, sometimes due to the broken neutral or loose connection joints of the supply cables. These types of problems are not a voltage quality problem, but considered as defects in the network.

### Failure of motor starts

In LV installations, it is sometimes noticed that motor-pump system fails to start because of too low voltage at the POC during start-up condition.

If an installation is located far from the MV/LV transformer station, its network impedance would be relatively high. Hence, the starting current of the pump system is to be restricted to a low value to limit the initial voltage drop at the installation. As a rule of thumb, the starting current is generally limited to the maximum connection capacity of the POC. The maximum voltage drop is limited to 3% to restrict fast voltage variations at the POC [2]. The customer is often advised to use a soft starter for his motor to meet the above requirements.

### **Frequent burning out lamps & damaged devices**

Few customers also complaint about frequent burn-outs of lamps and occasional damage of apparatus (such a music system). From measurements, it is sometimes noticed that these specific installations have faced high voltage around 248-250V, which is below the maximum allowable limit 253V of the standard 50160. If a number of customers from the same neighborhood have the same complaint (of high supply voltage), the tap setting of the local MV/LV transformer is also adjusted to satisfy the group demand. Generally, this situation occurs when many of the customers in the same neighborhood have PV panels at their installations and sends back electricity to the grid.

Sometimes, high neutral voltage (>10V) is also measured at the installation which is because of improper design of the internal earthing system of the customer's installation. This can cause unpleasant situation (occasional voltage spikes) in the installation.

Nowadays, it is noticed that the harmonic current levels are quite high at many LV customers installations. It is because of the increased use of power electronic based devices by the household customers. These are, in majority of the cases, the sources of harmonic currents. Therefore, these currents contribute to extra network losses, additional temperature rise of the connection wires and damage of the connected devices.

### **Spontaneous switching-off of PV inverters**

In the last years, more number of complaints have been registered by the network operators about spontaneous switching-off inverters of the PV panels at the customer's installations. Presently, it has become a national news and gets more attention in the media. The local government of the Netherlands is also encouraging the customers by giving subsidy to install PV panels at their installations. In some regions, large scale implementation of PV panels is already taken place. However, unfortunately many PQ complaints related to spontaneous switching-off of the PV inverters are reported from those regions too.

From the investigation, it is found that the inverters are often imported from different countries (such as China, Germany, Belgium, etc.) and are used in the Netherlands. The problem is that the PV inverter's specification for over- and under voltage limits are not harmonized in different countries of the world. The standard EN50438 is commonly used by the PV inverter manufacturers.

In this standard, the maximum limit for over voltage tolerance varies between 6-20% in different countries of the world. Moreover, the German manufacturers follow the German standard VDE 126-1-1. In this standard, the term "grid-plant protection" is used to prevent island operation. The inverter manufacturers (such as SMA) follow two overvoltage conditional limits:  $U > 253V$  and  $U \gg 264.5V$ . Hence, an inverter which is manufactured in one country and is being used in a different country, should be properly adjusted following the applicable regulatory guidelines of that particular country before putting into operation. Otherwise, unnecessary interruption may take place and the device will not perform optimally. The design guidelines for PV inverter connection for a LV installation in the Netherlands can be found in the Dutch Netcode and is showed in Table 2.

Table 2: Connection rules for PV inverters for LV customers as per the Dutch Netcode [2]

Design requirement	Category $\leq 3 \times 16A$	Category $> 3 \times 16A$
<i>Obligation of the customer to inform network operator about PV connection</i>	Later (within one month after installation) / can also be informed beforehand	Must be informed before the installation takes place
<i>Overvoltage protection</i>	110% (253V) with in 2 sec	110% (253V) with in 2 sec
<i>Under-voltage protection</i>	80% (184V) with in 2 sec	80% (184V) with in 2 sec; 70% (161V) with in 0.2 sec
<i>Maximum current protection</i>	Not needed	Overload protection needed
<i>Frequency protection</i>	Should be switched off when $f < 48Hz$ or $f > 51Hz$ with in 2sec	Should be switched off when $f < 48Hz$ or $f > 51Hz$ with in 2 sec
<i>Symmetrical distribution of inverters among three phases</i>	Desired	Obligatory

When a PQ complaint comes from a customer with PV system, he is often advised to consult with the installation company regarding the PV inverter setting issues and the requirements of table 2. During designing of the PV installation, the customer must follow the LV installation guidelines of NEN 1010 (2015). The connection rules for PV installation is available in a dedicated chapter of this norm (in part 712) [5]. It is advised that the inverter must isolate the AC side from the DC side of the supply for maximize the safety of the installation. If the AC side supply fails for some reason, the inverter must switch off within 0.2 sec. The voltage rise within the installation has to be estimated carefully. Finally, the inverter setting is to be adjusted in line with the applicable standard requirements of the country.

When many customers with PV installations from a same neighbourhood complain about a specific PQ problem such as high voltage at their POC, the network operator may take a remedial action at the station level or at feeder level. He might then adjust the tap setting of the MV/LV transformer present at that area. Also, an option is to implement a LV voltage regulator (MPV, as shown in Fig. 4) at an individual customer's POC, or at LV feeder level or at local transformer station level to lower the voltage rise within the specified limits.

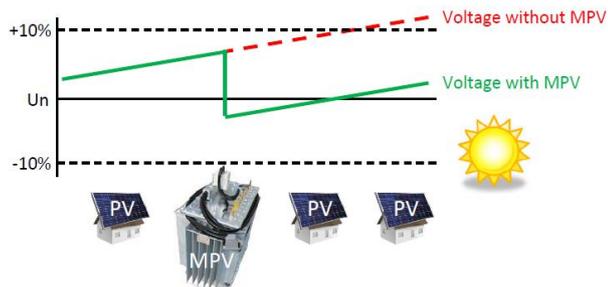


Fig. 4: Installing a LV regulator to control voltage rise in feeder

As the simultaneous load factor for the LV network with PV installations can be high (above 80%) in comparison to normal network without PV (which is less than 30%), the LV cables rating and the MV/LV transformer capacity have to be selected carefully (based on their over current protection features). It is also recommended (as problems could occur) to restrict the size of a customer's PV installation by reducing 30% of the peak production so that the network investment cost can be optimized. This results in only a total loss of 2% energy production annually. In these various ways the voltage quality and capacity issues because of large scale implementation of PV in the network can be handled efficiently while maximizing the societal benefits.

### ACTIVITIES AT NATIONAL LEVEL

In 2013, the Dutch regulator (ACM) has asked various network operators in the Netherlands to take necessary actions (such as increased monitoring activities) for better understanding of the present voltage quality level of the networks. Also, the network operators are asked to be more transparent about the voltage quality issues in the network. The PQ complaint handling procedure has to be more systematic and the customer should be informed about the actual voltage quality information with full transparency. ACM wants to get clear information about all the incidents where voltage quality parameters of the networks at different voltage levels exceed the standard boundary limits. Also, ACM would like to receive all information about the number of yearly complaints from various customer's groups, types of PQ problems and the handling procedures, and the average time needed to solve those problems. The network operators in the Netherlands are implementing those measures in their networks and their operational processes.

The best available practices developed by the European voltage quality group is applied by the Dutch network operators to operate and maintain their networks. During the last three years, various PQ monitoring programmes are started too to understand the actual voltage quality of the networks. The information is also published in the national website for maximize transparency of services. Furthermore, tentative voltage dip tables are developed for the HV and MV networks based on continuous dip monitoring data. From the PQ data of the past four years measurements, the national trend analysis is done for various voltage quality parameters. It is found that the harmonic voltage levels are slowly increasing in the LV networks while the 15<sup>th</sup> and 21<sup>st</sup> harmonic voltage levels are regularly exceeding the EN50160 standard boundary limits. However, the effects of high penetration of a specific harmonic voltage is not always immediately visible, but can have long-term indirect effects on the customer's devices. The new values of 15<sup>th</sup> and 21<sup>st</sup> harmonic voltage level values are suggested to the Dutch standardization committee and also discussed in international committees. A proposal is made for changing these limits in the standard EN50160.

The PQ complaint handling procedure is improved too for individual network operator. The customers are informed more systematically and are helped with their problem more efficiently. However, as the responsibility sharing of PQ problems are not clearly defined yet, these are the issues where further improvement is needed.

### REFERENCES

- [1] European Standard EN50160, 2010 - "Voltage characteristics of electricity supplied by public electricity networks", *CENELEC, Brussels, Belgium*, July, 2010
- [2] Dutch Grid Code Legislation: "Netcode Elektriciteit per 18 december 2015", *DTE (Dutch office for Energy Regulation)*, 2015, (available in Dutch language only).
- [3] Various design guidelines for LV networks of Enexis, "Ontwerp richtlijnen voor LS-net", *Copyright Assement management, Enexis Netbeheer*, 2015. (Internal documents, not available publicly).
- [4] S. Bhattacharyya, L. v. d. Nieuwenhof, 2015, "Implementing a systematic approach towards solving power quality complaints – from a network operator's perspective", *Proceedings of CIRED conference*, Paper no. 382, Lyon.
- [5] The Dutch LV installation standard guidelines NEN 1010:2015 (similar to the International standard IEC 60364 series) "Elektrische installaties voor laagspanning", *NEN 1010*, (available in Dutch language only).