IMPACTS OF RIPPLE CONTROL SIGNALS AT LOW VOLTAGE CUSTOMER'S INSTALLATIONS

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ABSTRACT

Network operators in different countries of the world use the public networks to send control signals for managing various system operations and for controlling certain loads at different customers' installations. This signal is called 'ripple control signal' when its control frequency is between 110 Hz and 3000 Hz. In Endinet's network, ripple control signals are sent at a frequency of 1042 Hz and several times in a day. In the recent years, some customers complained about light flicker incidents at their installations that are observed without any definite known reason. However, in some cases, the times of light flicker incidents happen to synchronise with the time slots of sending of ripple control signals. Hence, it is suspected that the ripple signals might have some influence on light flicker incidents. To investigate the problem, a theoretical analysis is done by simulating the same part of the network and observing the influence of a ripple control signal from its broadcasting point up to the receiving terminal (at customer's installation).

INTRODUCTION

In Europe, the network operators (utilities) provide electricity to their customers at a supply frequency of 50Hz. Many utilities use the same public network to transmit various control signals for system management purposes and controlling certain types of loads such as: switching on and off street lights, tariff control, remote load switching, etc. Those control signals are superimposed on the supply voltage and transmit information in the public supply network and at the customer's premises. The European standard EN50160 [1] gives limit values regarding the mains signaling voltages and is classified in three groups:

- Ripple control signal: superimposed sinusoidal voltage signal in the frequency range of 110 Hz to 3000 Hz.
- Power-line carrier signal: superimposed sinusoidal voltage signal in the frequency range of 3 kHz to 148,5 kHz.
- Mains marking signals: superimposed short time alterations (transients) at selected points of the voltage waveform.

According to the EN50160 standard, for 99% of a day 3s mean value of signal voltages shall be less than or equal to the values given in Fig. 1.

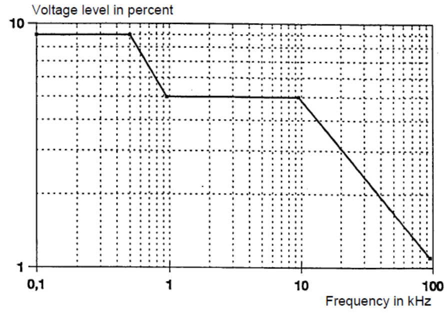

Fig. 1: Limits on mains signalling voltage magnitude as per EN50160 standard

The electricity demand varies throughout the day. For household customers, the energy demand generally reaches peak values in the evening; whereas many industries demand large amounts of electricity during the day-time. To optimize electricity production and network's transmission capacity requirement, utilities introduce variable electricity tariff (e.g. high tariff during peak load and low tariff during off-peak period) to motivate the customers to restrict their electricity demand during the peak hours. Therefore, utilities connect and disconnect various electrical loads (as agreed with the customers beforehand) based on network's real-time loading situation. Also, the time of switching of public lighting is sometimes controlled depending on network's loading conditions. Ripple control is a way to control electricity demand by sending a frequency signal in the network (in the range of 110Hz to 3000Hz, as specified in EN50160 standard), that is superimposed on the standard 50Hz power supply. They are generally sent for a duration of 0.5-2s and are repeated over a period of 6-180s, as shown in Fig. 2.

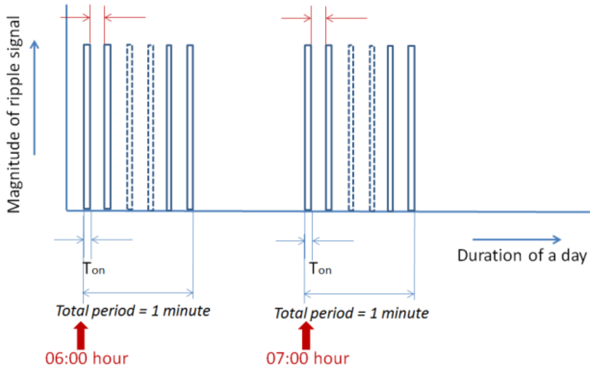

Fig. 2: Typical ripple control signal used by utilities

It was observed from literature study that the most common customer's complaints arising from ripple control are light flicker and noise from electrical appliances (probably due to resonance effects) [2]. The noise is generally intermittent depending on when ripple control signals are being transmitted. In this paper, a part of the Endinet's network is simulated to analyze the transfer characteristic of ripple control signal through the network, from the broadcasting point to the customer's installation. Furthermore, power quality measurements are carried out at some specified locations and the results are discussed briefly. Finally, recommendations are proposed to solve the problem.

USE OF MAINS SIGNALLING FREQUENCY IN ENDINET'S NETWORK

In Endinet's service area, ripple control signal is sent at a frequency of 1042Hz for approximately 21 times per day (e.g. 15 times for controlling various loads and 6 times for switching on and off street lights). The ripple control signals are sent from nine main distribution stations, located at different parts of the network. There are three groups of signal train: a) test group, b) double tariff control group, c) street light control group. In each case, the pulse-train is sent for a total period of 60s (see Fig. 3), with each pulse having a duration of 1,9s and a period of 3,8s. The sending signal voltage varies between 1-2.5% (in the three phases), and is sent from a 10kV station. The limit value of voltage should be within 5% as per the EN50160 standard. Before 2011, the ripple control signals sent from different sending stations were not synchronized. This sometimes used to have a negative impact on the control signal strength (because of mutual damping effect due to phase differences between the signals). Nowadays, control signals sent from different stations are synchronized which has made the ripple controlling more efficient and effective. However, the supply voltage waveform becomes slightly deformed from its clean sinusoidal waveform because of the superimposed ripple control signal.

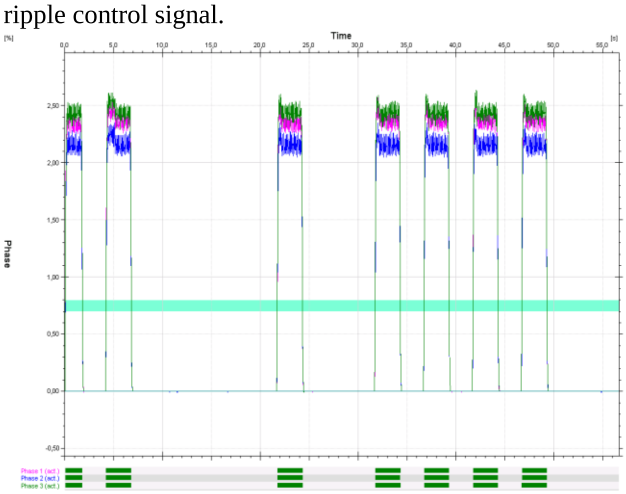

Fig. 3: Typical form and duration of ripple control signals sent in Endinet's network

CUSTOMER'S COMPLAINTS RELATED TO RIPPLE CONTROL SIGNALS

In the recent years, Endinet has registered some power quality (PQ) complaints from the customers, such as light flicker, that are (most likely) related to mains controlling signals. Also, some complaints are related to the operation of double tariff meter (for controlling day or peak tariff meter and night or dal tariff meter), that are not operating properly. Approximately 10% of Endinet's customers (both small and large category users) have double tariff meter. The customers with a connection capacity of <80A are called as 'small user'; while customers with a connection capacity >80A are named as 'large user'. The customers need to pay extra energy bills when the double tariff meter does not operate properly; while they could profit when the meter is stuck on low tariff meter. During year 2004-2011, there are more than 30 complaints registered because of incorrect operation of tariff meter. Sometimes customers also complain when the street lights do not switch on and off properly (for example: street lights are on during the day time, while are off at night). Endinet gets an average of around 5 complaints in a year that are related to the incorrect operation of street lights. All these complaints have impact on company's service and image to the society. Hence, the complaints are treated with full attention to solve them at the earliest and also to prevent them happening repeatedly in the future.

From a technical point of view, ripple signals are a potential source of interharmonics. Modern customers use various power electronics devices, energy savings lamps and LED lamps, dimmer controlled lamps and assimilation lighting. All those devices demand nonlinear current and cause current pollutions in the network. It is anticipated that the current pollutions produced by the power electronic devices might be enhanced when a supply voltage contains ripple control signals. One of the commercial customers has reported light flicker problem and some issues related to the noise in the sound system in the installation. From the initial PQ measurement at that installation, it was found that flicker levels are within the limits as specified in EN50160 standard. However, the 15th, 21st and some other harmonic voltages are found to be quite large, exceeding the standard limiting values. It was also noticed that the occurrence of the customer's reported problems approximately coincide with the time slots of sending the ripple control signals. It is suspected that there might be some resonance occurring in the network which is aggravating the PQ problems at the installation. In the literature [2], similar kind of problem was also reported.

TEST NETWORK FOR SIMULATION

A part of the Endinet's medium voltage network is simulated in which the above mentioned customer's installation is located. The test network is shown in Fig. 4.

Endinet's 10kV network is connected to the external grid provided by another network operator. The 10kV cables are connected to the main distribution board via coils (reactors) to restrict the short circuit current in the local stations. Also, there are four capacitor banks (each of 5,5kvar) connected at the main distribution station. From the main distribution station, several rings are connected. Each ring consists of several MV/LV transformers to supply electricity to various customers. The mains signalling voltage is fed from the main distribution station to send ripple control signals to the customers located in these rings.

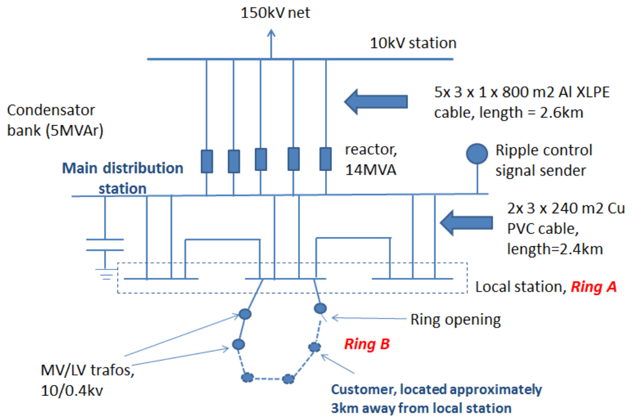

Fig. 4: Test network used for simulation

The customer has a MV/LV transformer at his installation. The transformer supplies to lighting loads (mostly energy saving lamps and halogen lamps), dimmers and sound systems. Therefore, the connected loads have mainly nonlinear characteristics. Also, it can be remarked here that customer loads are of capacitive in nature and sometimes exports reactive power in to the network (found from the measurement). The test network is modelled in Vision (a software developed by 'Phase to Phase BV', the Netherlands).

SIMULATION RESULTS

Three simulations are done by using Vision simulation tool:

a) Impedance-frequency spectrum: to check the sensitivity of the network with frequency and to find resonance points
b) Mains signalling frequency transfer characteristic through the network: to investigate the increase/ decrease of ripple control signal magnitude from the sending end up to the customer's installation
c) Harmonics spectrum at the customer's installation: can indicate the amount of current pollutions injected by the devices in to the network

Impedance-frequency spectrum

Fig. 5 shows the impedance-frequency response of the test network. It shows that there exists a parallel resonance in the network at in the frequency range of about 950Hz-1300Hz, depending on the loading condition of the network. This frequency is close to the mains signalling frequency.

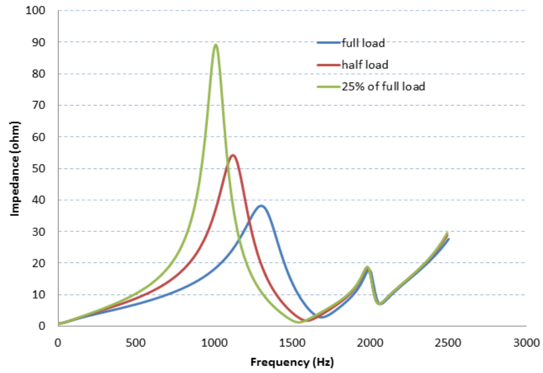

Fig. 5: Impedance spectrum with existing capacitors (4x 5,5kvar)

This resonance point can be shifted to a lower or higher frequency range by adding tunning capacitor or an inductor, as shown in Fig. 6. However, this type of modification needs detail analysis to understand its impact on different network conditions.

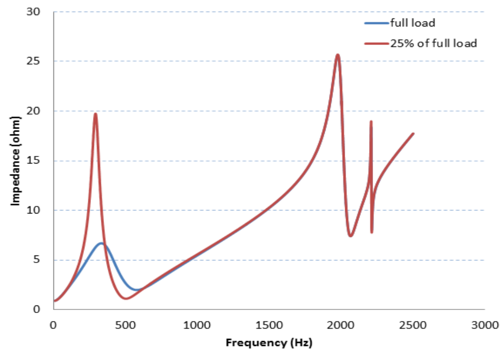

Fig. 6: Impedance spectrum with large tunning capacitor added to the main distribution board (5Mvar)

Mains signalling frequency transfer

The transfer of ripple control voltage signal at different points of the network is noted from simulation and is shown in Table 1. It can be noticed that ripple signal voltage magnitude gets amplified when it reaches at the customer's installation, especially when the customer has some capacitive loads at his installation.

Table 1: Ripple signal voltage magnitude at different points in test network of Fig. 4

Observation point	Ripple signal voltage magnitude (%)
Main distribution board (sending end of ripple signal)	2,55
Local station	2,71
Customer's point of connection (10kV side)	2,79
Customer's installation (LV side with capacitive loads)	3,63
10kV station g(upper grid)	2,2

Harmonic spectrum at the customer's installation

Harmonic analysis is done considering various nonlinear loads (such as rectifiers) at the customer's installation. From simulation, it is found that 15th and 21st order harmonic voltages exceed the standard limit values, as shown in Fig. 7. The same observation was also made in the power quality measurement at the installation, mentioned below.

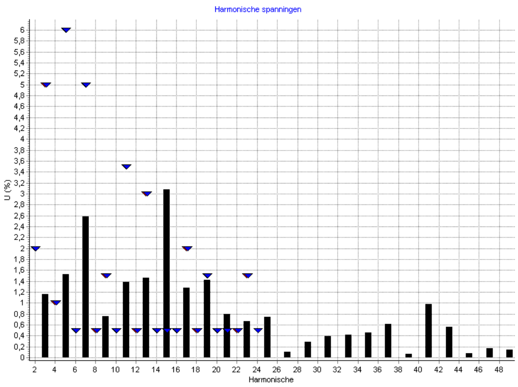

Fig. 7: Harmonic voltage spectrum at customer's installation (compared with standard limits)

POWER QUALITY MEASUREMENTS AT CUSTOMER'S INSTALLATION

Power quality measurements were done at the LV side of the transformer as well as next to the dimmer to check various voltage quality indicators. It was noticed that flicker level are quite low (average 0,4) and meets the EN 50160 standard limits of 1 (for all the 10 minutes data for 95% of the measured time). However, it was noticed that harmonic currents are quite high and some occasions harmonic voltages exceed the standard limits (especially for 15th and 21st harmonics). The current snapshot is shown in Fig. 8.

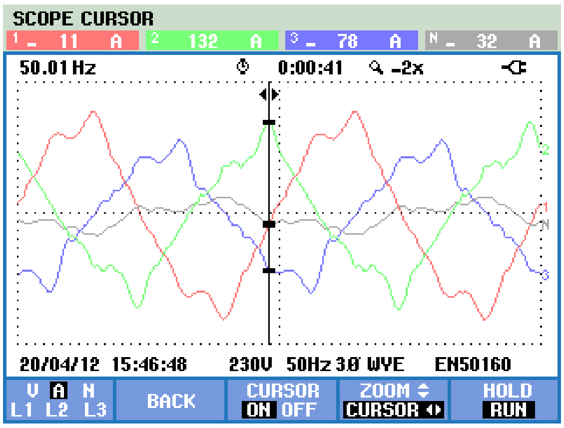

Fig. 8: Current waveforms measured at the installation

From the measurement, it was also observed that mains signalling voltage (3s average values) sometimes exceed 5% limit value at the installation. However, it is not fully confirmed whether it is due to the effect of ripple control signals or other nose signals / harmonics related issues. In the coming period, a number of synchronised measurements are planned: one at the sending station, second one at a middle point in the feeder and third one at the entrance of the installation. It is expected that this type of synchronised measurement can give some more insight about the problem (whether the ripple signal magnitude gets enhanced or not while passing through the network).

MITIGATION OPTION

The specific customer's installation under consideration is quite sensitive to the probable effects of ripple control signals. The dimmers used in the installation is sensitive to the additional zero crossing points in the voltage signal and cause flicker. This customer does not use double tariff meter and hence does not need to receive ripple control signal at his premise. Therefore, to solve the light flicker and noise disturbances at this installation, it is probably wise to block the ripple control signals at the point of connection of this installation. A ripple blocking filter can be used to stop ripple signals entering into the installation. The cost of such type of filter can vary between 1500-4000 euros depending on the required capacity of the filter.

CONCLUSION

Endinet registers some customer's complaints related to disturbances caused by ripple control signal. It is noticed that ripple control signal strength at the sending station is quite small as compared to the limits specified in EN50160 standard. However, due to some specific network's configuration and customer's loads characteristics, these can have a negative impact on ripple control signal at the customer's receiving end. In an extreme situation, ripple signals may cause light flicker and noise problem. It was found from network analysis that in the considered case, ripple control signal is indeed getting enhanced at the customer's installation to some extent. The considered customer has many nonlinear loads that are quite sensitive to voltage signal waveform (and its zero-crossing point). In this specific case, a ripple blocking filter can probably be the best solution to stop ripple signal related problem. Further, a detailed analysis based on synchronised measurements at different parts of the network is recommended to get an insight to the problem.

REFERENCES

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[2] European Standard, 2010, "Voltage characteristics of electricity supplied by public distribution system", *EN50160*, CENELEC, Brussels, Belgium.