CUSTOMER'S IMPACT ON THE DISTRIBUTION GRID

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ABSTRACT

This paper describes the problems occurring due to customers' impact on the distribution grid. The most common power quality (PQ) disturbances in the distribution grid, caused by customers' usage, are voltage dips due to rapid load changes, e.g. motor starting (in-rush currents), and flickers. Problems with poor compensation are also very common. Current regulations for the Croatian Distribution System Operator regarding power quality are defined on the basis of the EN 50160 standard [1].

INTRODUCTION

Some factors that influence power supply conditions in the distribution network are:
a) deviation due to significant change in loads,
b) nonlinear loads that cause higher current harmonics,
c) loads that vary rapidly and repeatedly in time (flickers),
d) different faults in the network,
e) faults transmitted from the transmission network.

The number of customer's complaints about power quality, has increased in past years. However, power disturbances are largely caused by the customers themselves. The most common complaints are about "outages" or brief voltage dips that cause tripping or restarting of the equipment. Utility companies and customers usually differ in their view of the origins of PQ problems. Customers, usually blame the utility company and believe that voltage disturbances originate from the supply network.

COMMON VOLTAGE AND POWER QUALITY DISTURBANCES

Voltage dips

Customers' complaints about voltage dips frequently come from small manufacturing plants, such as plastic processing plants and others that use heaters, mills, asynchronous machines and large fans. When a complaint is filed, it is typically followed by a measurement of the voltage conditions at the point of common coupling (PCC) and in the substation. Currents in the feeder at the MV/LV substation, which supplies customers in question are also measured. Upon request, all PQ parameters are monitored for a period of one week according to the EN 50160 standard. Comparison with data from permanently installed PQ monitors in HV/MV substations can show if the disturbance was transmitted from the transmission network or if it originated from the MV network. Conducted PQ measurements have shown in most cases a large ratio between medium and maximum rms current values in 10 min intervals. In some cases, the maximum values of inrush currents which occur during motor starting are 4 to 8 fold higher than the medium. These high currents cause voltage dips in the substation. Figure 1. shows a typical case with voltage dips from 10 to 14% corresponding to the time intervals with the maximal current loads.

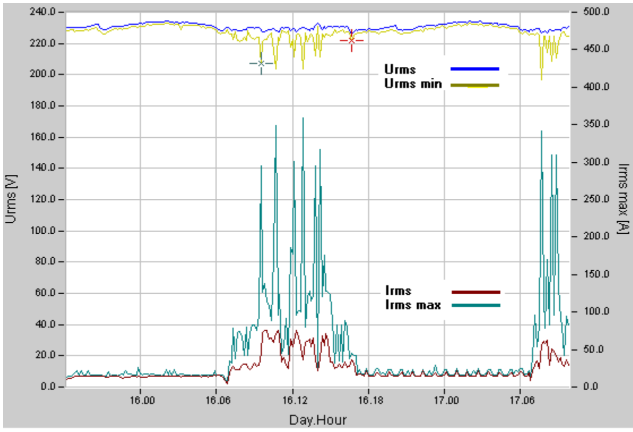

Fig.1. Voltage dips corresponding to maximal current loads

Figure 2. shows a voltage dip caused due to motor startup. A voltage dip below the allowed value lasted 90 ms, and effective voltage dipped down to 195 V, which represents 85% of the nominal value.

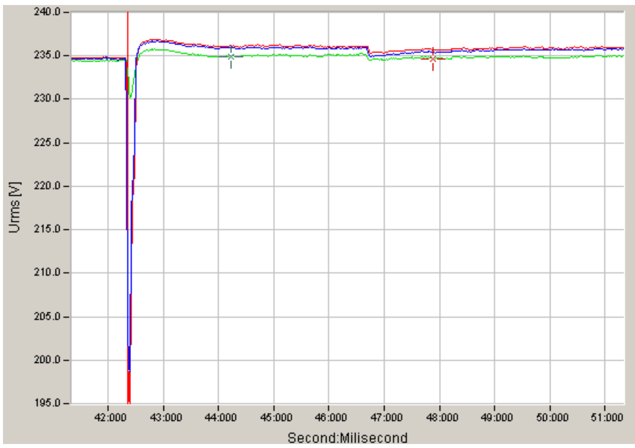

Fig. 2. Voltage dip due to motor start (rms values)

Rapid voltage changes

Figure 3. compares medium and maximum rms current values of an 1000 kVA, 10/0,4 kV transformer that supplies a commercial building. The customer complained about frequent power supply disruptions. However, records from the utility company show only a couple of operations with a substation breaker. The largest load on the power supply are two large fans with rated power of 196 kW and elevator drives with rated power of 112 kW, which cause spikes in the current upon startup, as shown in Fig. 3.

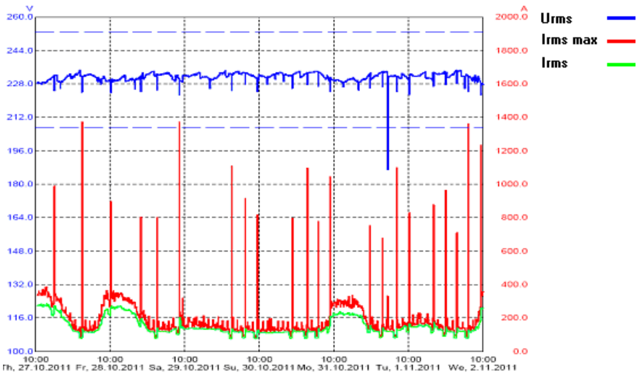

Fig. 3. Maximum rms current values and minimal voltage values measured on the transformer LV side

Inrush currents with maximal values of 1400 A cause rapid voltage changes of 9-10 V measured on the transformer busbars, which is a ~4% of the nominal value. The highest contractual real power for a single customer in a building supplied from discussed substation is 228 kW. Rapid voltage changes shown on the figure can not cause damage to the electrical equipment, but are detectable in light intensity fluctuations. Rapid voltage changes of 10 % (e.g. from motor startups) result in 34% reduction of light intensity of a 60 W incandescent lamp [2].

There are a number of solutions that would ensure a more gradual start-up of asynchronous machines. Soft starter devices reduce in-rush currents, and therefore reduce electricity consumption. Above all, they protect the machine system and the mains supply.

Such devices are advised for milling machines with DC braking, hydraulic pumps, escalators, elevators, conveyor belts and pumps, presses, large fans, saws, and crushers. Soft motor starting can also be accomplished with a frequency converter. However, this would only be cost effective if the motor's speed is also affected during the operation and not just at the startup.[3].

Flickers

In addition to voltage dips, changes in the customers' load, if frequent over short time periods, can also cause voltage fluctuations. These voltage fluctuations then cause light intensity fluctuations.

Fig. 4 below shows maximal loads and short and long term flicker severity as measured at the point of common coupling in a plastic manufacturers. Only one phase is depicted for the sake of clarity.

Fig. 4. Maximal loads, short and long term flicker

According to EN 50160 long term flicker severity is limited to 1. It is evident from the graph that the short term flicker severity is in direct connection with maximal loads. Disturbances caused by this customer were also visible in the installations of the neighboring users.

Poor compensation

Figure 5. shows an example of poorly designed compensation. According to regulations, the allowed power factor is between 0.95 and 1, unless otherwise contracted. following the customer's complaint about voltage dips, power quality has been assessed according to the norm EN 50160 and the load had been measured.

Delivery of apparent power is a matter of agreement between network users and the distribution system operator. In this case, the largest portion of the customer's bill was for reactive power, which amounts to 15% of the total electrical energy bill. According to the "Electricity distribution tariff system" charges are placed on the amount of reactive power surpassing 33% of real power which correspondents to a power factor of 0.95.

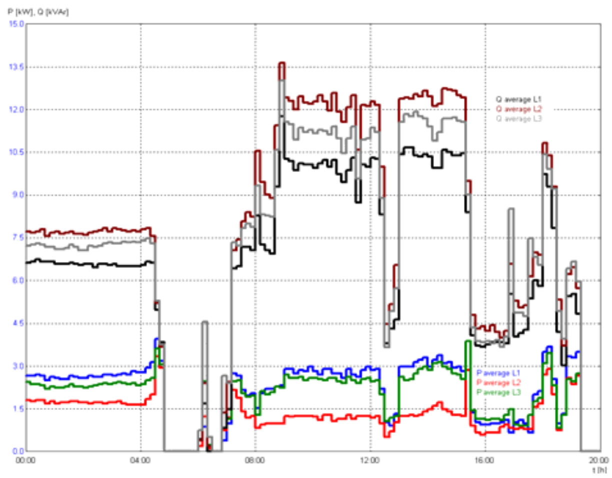

Fig. 5. Real and reactive power (10 min average)

Results have shown that the reactive power was two fold higher than the real power (Fig.5.). The connecting cable was dimensioned according to the requested real power. But the apparent power during normal operation of this small manufacturer was two times greater than the contracted power thus causing a considerable voltage drop across the connecting cable.

NEW USERS' CONNECTION TO THE DISTRIBUTION GRID

Terms and requirements for new users' connection to the distribution grid are regulated in the „Electricity System Grid Code". In order to insure satisfying power quality according to the EN 50160 standard to all customers, the impact of a new user should be estimated before issuing a preliminary permit. The procedure for issuing a preliminary permit and for the establishment of optimal conditions for the connection to the power grid is described in "General requirements for electrical energy supply".

Usually, when assessing a new user's request, only the requested real power is taken into consideration, while estimating whether power grid supply will be sufficient and determining the dimensions of the connection cables/lines and available capacity of the transformer.

In order to ensure good power quality, when issuing a permit, more attention should be given to the type of activity (e.g. households, offices, computer centers, medical and dental practices, building sites), as well as type of electrical equipment (welding machines, pumps, saws, electrical arc furnaces, presses, concrete mixers, photovoltaics, air conditioners, x-ray and CT apparatus), and rated power. Also estimates of a single customer's impact on the grid and load characteristics should be provided, especially when connecting larger loads.

A fair estimate of the customer's impact on the distribution grid and on power quality can be made in the case of smaller loads and lower content of nonlinear loads if the customer's rated power is compared to the short circuit power at the point of common coupling. The following condition should be met:

$$\frac{S_k}{S_p} \geq 150 \tag{1}$$

where S_k represents customer's rated power and S_p short-circuit power at the PCC.

The voltage drop is proportional to the ratio of the instantaneous power variations on the customer side and short circuit power at the point of common coupling.

It would be useful to establish some correlation between rapid voltage changes and customer's rated power, correlated to the different types of customer's characteristic loads. Some correlation factors have been proposed in [4] and [5].

When connecting new users with larger loads to the grid, measurements during the trial period should not exceed the prescribed power quality limits.

In order to guarantee a satisfying level of power quality according to the EN 50160 standard to all customers, we propose that the impact of a single customer (regarding the voltage drop in the substation) should not rise above 4%, and this limit should be imposed by regulations.

Currently, there are no penalties imposed to the operator or the customer for poor power quality, nor for any violations on the distribution grid.

How to improve power quality?

Common technical solutions that could improve power quality at the point of common coupling are increase of the cross-section of existing LV connection cables/overhead lines, replacement/increase of nominal power of the supply transformer, redistribution of load of a single LV feeder, reconnection of a customer to another MV/LV substations, interpolation of new MV/LV substations, replacement of the LV overhead lines either with LV isolated overhead lines or cables. Most of these solutions require considerable investments in the grid.

Mitigation

Voltage dips are the most common and costly power disturbances. Installation of equipment that could mitigate voltage dips, e.g. uninterruptible power supplies (UPS), voltage stabilizers, ferroresonant transformers also known as constant voltage transformers (CVT), tap switchers, dynamic voltage restorers as well as other protection devices is recommended for users with sensitive devices. All this mitigation equipment is connected between the utility grid and the sensitive load. Equipment design that tolerates voltage dips, will be more cost effective in the long run [6].

CONCLUSION

In many cases power quality problems, especially voltage dips were caused by customers' installations. Short circuits, overload, poor compensation, cable failures or motor starting phenomena caused the malfunctioning of their own sensitive equipment or of the equipment of other customers connected to the same power source. This problem is commonly misunderstood. The supply network is typically blamed for such disturbances. As the usage of equipment more sensitive to power quality variations (e.g. microprocessor-based controls and power electronic devices) has increased, customers have become more intolerant of power supply interruptions and their expectations of power quality are growing higher, and are increasingly demanding uninterruptible (continuous) supply. Some of customers' complaints are unjustified, because equipment should to some extent be immune to voltage dips (e.g. as defined by CBEMA curve). The power utility should therefore provide expertise and measurements that clearly explain the origin of the problem and advise customers about finding feasible technical solutions. The point of common coupling is seen as the bordering point (in some cases it can be a MV busbar in a substation), and responsibility between the customer and the utility are divided at that point as well. Power quality disturbances are qualified as downstream or upstream from that point. If the source of power quality disturbance is found downstream from the PPC, it is the responsibility of the customer to remedy to the problem at hand.

Power quality can be improved, either with modifications to the grid, which usually requires considerable monetary investments and is not always possible, or with modifications to the equipment itself in a way that makes it more immune to disturbances. However such equipment is not always commercially available and these decisions have to be made during the design stage. Generally, protective devices which can mitigate PQ problems can be installed between the utility grid and the sensitive load. However, if not properly chosen, they can also create additional problems (e.g. cheap UPS systems).

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