POWER QUALITY EARLY WARNING SYSTEM

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INTRODUCTION

Power quality disturbances, which most frequently create problems for industrial plants, are caused by short voltage dips or power outages. These disturbances occur randomly which means measurements must be done continuously with registration during a certain period to be able to detect them for further analysis. Instruments used so far have been rather complicated and expensive and thus not suitable for use on long-term basis. This has limited the possibilities of effective measurement and follow up of power disturbances at an industrial customer.

POWER QUALITY DISTURBANCES

The increasing number of sensitive electronic equipment in utilities network are often an irritating and unnecessary cause of bad relations between the network owner and the consumers. Many disturbances are related to switching not only in the utility network but also to switching in the customers own plants, e.g. of motors, capacitors etc. The most common power quality disturbances, which have the worst economic effect on the industrial production, are voltage dips and momentary interruptions. They are to the customer the most unpredictable disturbances since they often depend on actions taking place outside the industrial plant and their impact also often depend on the network layout, e.g. if the network is radial or meshed, the short circuit current, earthing, protection system etc.

The most common causes of voltage dips and momentary interruptions are insulation failures in the power system and operation of protective devices. Other causes are related to the installation itself such as rapidly varying loads or equipment with very high inrush current.

The insulation failures can be caused by failure in the components in the network or by external influence such as lightning, storm, accidental contact of branches of trees, damage of cables by excavating machines etc.

Photo: Bengt Ekman/N

Many disturbances in the plant operation do not even relate to failures in the electrical power system.

Since many disturbances are related to weather conditions and other in time unpredictable causes the monitoring equipment for data capture of important background information must monitor all parameters continuously. This actually means that the monitoring system for identifying power quality problems, especially coming from the network, need not only record any disturbance but also to alarm the plant maintenance personnel so they immediately can relate any breakdown to disturbances cause by faults in the network.

CHARACTERISATION OF A VOLTAGE DIP

A voltage reduction of more than 10% of the reference voltage with duration between 10 ms and 60 s (180 s) is characterised as a voltage dip. In this application it is acceptable to prolong the lower time limit to 20 ms (50 Hz net).

A voltage dip, measured in a medium voltage system, is plotted in figure 1. The depth of the voltage dip is about 20 %, which means that the minimum voltage U_{min} is 80% and the duration is 170 ms. Voltage dips can be much more complex than this one especially when the customer is connected to a meshed net. A fault far away from the connection point (point of common coupling, PCC) will have several steps in the descending and returning voltage resulting from protective disconnections and failed re-closing of the lines circuit breakers close to the fault (usually). When the relay protection system have identified and isolated the faulty transmission line or the fault has cleared itself the voltage will increase in steps depending of the involved circuit breakers closing times. These changes do not effect the determination of the length of the dip, still the time is measured from the point when the voltage suddenly decreases (under –10% of reference voltage) till the final restoration of the voltage (above 90% of reference voltage).

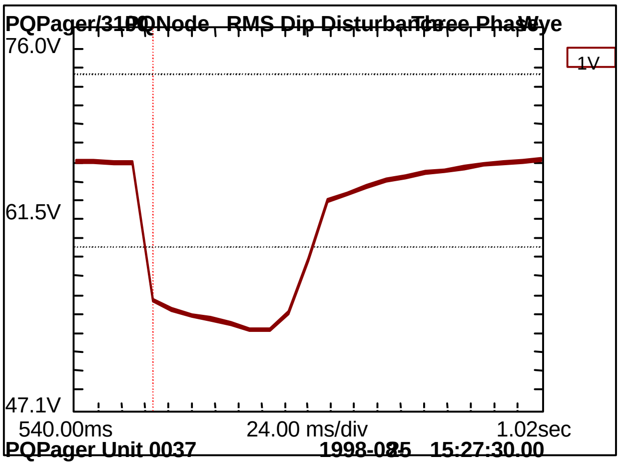

Figure 1: Typical voltage dip

MEASURING SYSTEM

During one year we have tested a simple power quality indicator (PQPager), modified it and demonstrated it at various industrial plants i.e. car manufacturers, mining industry, chemical plant, hospital etc. Our experiences are so far very good and an extension of the number of measurement locations up to a larger number is planned in the near future.

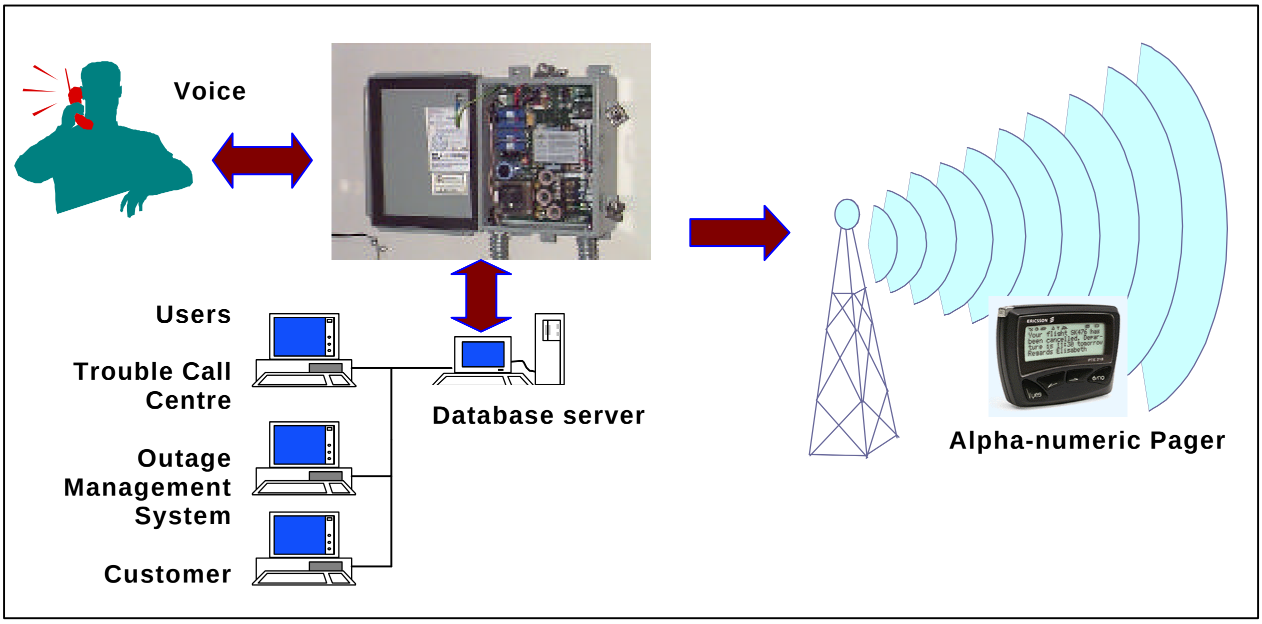

Figure 2: Measuring system showing the PQPager

The power quality indicator is usually installed at the customer service entrances or close to sensitive equipment. The indicator is connected on 3-phase voltages (Wye or delta) directly on low voltage or with PT:s for higher voltages. The measuring module is connected to an internal modem operating on the regular telecom net. The indicator measures all three-phase voltages continuously and with a very sophisticated trigger module saves any voltage dip disturbance in its internal memory.

Retrieving data from the PQPager can be done in three different ways (see figure 2). Whenever a disturbance occurs the instrument calls directly to the pager service provider and a message is sent to pagers, usually as an alphanumeric message (number-only pagers are supported but we have not used them so far). Another way of getting data is through the voice-mail-like telephone interface, which means it is possible to check for power quality disturbances and other events from anywhere using the telephone at home, a pay phone, a cellular phone or from the office. It is even possible to change the PQPager parameter settings using this interface. The third way is using a modem connection and a regular PC (usually operating as a server) with a software package. In this case not only the information of the voltage dip is transferred but also the waveform of the power disturbances. These recordings are also stored and available, via internet/intranet together with our analysis of the disturbances.

In PC mode the indicator also acts as a three-channel oscilloscope, a vector scope or as a simple spectrum analyser.

The pager message is a short description of the type of voltage disturbance that occurred. In case of a voltage dip the message sent is the site name, the lowest voltage during the dip and the total duration of the dip for all three phases.

The power quality indicator is an important part of the complete power quality analysing system. First of all, the eminent pager mode gives very fast response to responsible personnel like the Key Customer Manager, a Trouble Call Centre and can also be connected to a Outage Management System etc. This means that utilities are aware of a local power quality problem even before the customers complains and therefore prepare an answer or even contact the customer. However the most common use of the pager is by the customer maintenance personnel.

Very often the key customer engineer receives complaints about momentary voltage interruptions from customers maintenance personnel which can not be related to any failure in the utilities network. In the past the utilities had to mount very expensive special power quality measuring instrument and as in most cases nothing happens under this rather short registration period. And as always no reason for this disturbance is found. Now, with this rather inexpensive watchdog, disturbances can easily be recorded, as soon something happens the plant personnel can easily relate any disturbance in production to failure on the service entrance. In fact most disturbances that before have been characterised as short interruptions have been found to be voltage dips which easily could be solved at a rather low cost.

The power quality indicator not only operates as a watchdog it also function as a rather qualified disturbance recorder showing the waveform (with sampling frequency not much less then the most common disturbance recorders).

Example of database data

Measurements taken by the measuring equipment are classified and collected in a database system. This is a great advantage since data now easily can be displayed and tabulated in various ways so that patterns, earlier difficult to recognise, now easily can be presented. If we for instance want to study voltage dips in the feeders to some specific paper industries. The dips could easily be selected and plotted. In this example, figure 3, the duration of the voltage dip (in milliseconds) is plotted versus the minimum voltage in percent. Every single event (voltage dip) could easily be investigated thanks to the fast transmission from the measurement equipment to the staff of the plants and the personnel operating the distribution net. So now data with a certain background could be selected and displayed etc.

In figure 4 the percentage number of voltage dips versus their duration is shown.

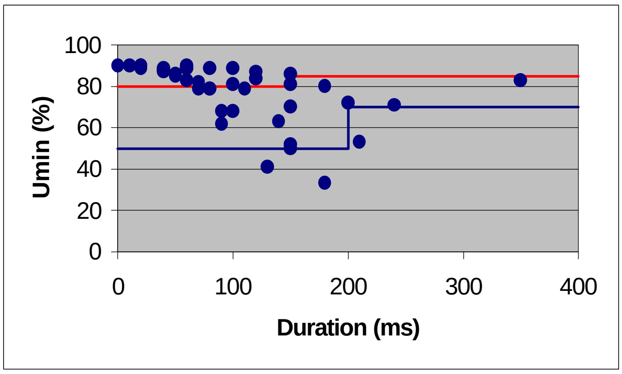

Figure 3: Plotted data from the database showing the magnitude of voltage dips as a function of the duration

CONSEQUENCES FOR INDUSTRIAL PLANTS

The effects of power quality disturbances on large industrial plants may be severe. Of special concern are the voltage sags to voltage levels lower than 80-85 % of operating voltage and with duration of 100 ms or longer.

Although the voltage variations do not last very long they may cause interruptions of plant production for hours. The consequences of such events have been reported not only to cause loss of production but also damage to plant equipment and high clean up costs. Some paper mills have reported a total annual cost of about 250 000 ECU each due to loss of production only from voltage dips. From semiconductor plants costs of production up to 1 MECU are reported.

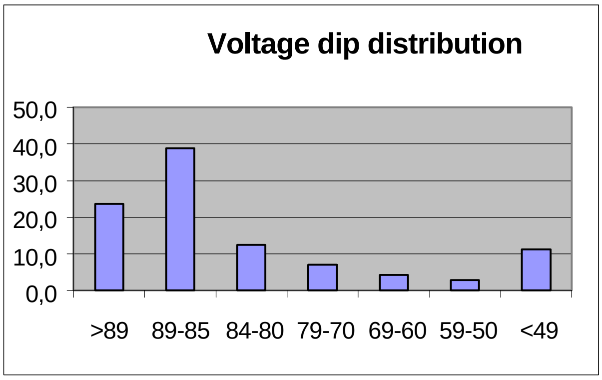

Figure 4: Relative distribution of voltage dips of various depth customers in southern Sweden

Case studies

Measurements during about one year at some Swedish paper mills are showing a certain pattern of voltage dips plotted in figure 3. A single dip is shown as a dot indicating its minimum voltage level and duration. Each of these measured values has been recorded and transmitted to the plant operating staff pager at the instant of the event recorded by the fast responding measuring equipment.

The upper line in figure 3 indicates the immunity level to voltage dips met today by most industrial plants. However it is obvious that this is insufficient in many cases. An improvement of the immunity to comply with the lower line would considerably reduce the frequency of plant outages.

Another example with measurements at a Swedish cement plant is shown in figures 5 and 6 with two different events recorded. We found out that the plant operation was not affected by voltage dips above 85 % as recorded in figure 5. However at dips lower than 80 % plant shutdown occurs. Thus the immunity level of that plant is shown to be between 80-85 % of operating voltage level. At the same plant our measurements show that most of the voltage dips have a level exceeding 70 % and plant shut-down mostly occurs from the tripping of the most essential single variable speed drive unit. Thus improving the immunity of that single unit would essentially improve the annual plant outage time.

To find out the occurrence of voltage dips in southern Sweden the database was used to plot the voltage dips versus their duration at some industrial plants. The result shown in figure 4 tells us that if we can make the plants accept dips down to 80% of operating voltage we will manage 75 % of all voltage sags without disturbing the operation of the plants.

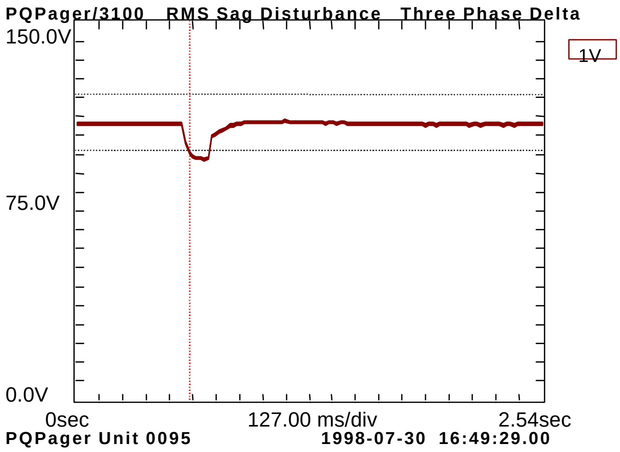

Figure 5: Voltage dip of 85% measured on the feeder to a cement plant

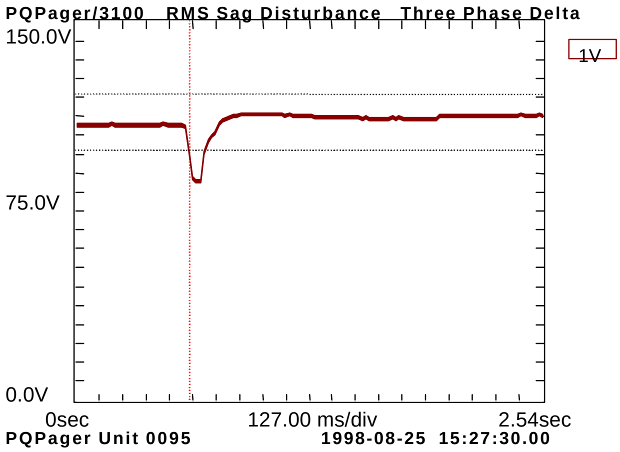

Figure 6: Voltage dip of 80% measured on the same site as in figure 5

CONCLUSIONS

The described newly developed and tested measuring system offers great possibilities to handle large amounts of power quality disturbance data for single plant analysis or statistical analysis of electrical networks performance. The measuring instrument settings and data capture is remotely controlled from a centrally located measuring central enabling fast and accurate response to power disturbance events. The described system is now ready for expansion and use for customer related services at a large scale with direct communication between the power supplier and its customer. This reduces the fault finding time for the plant owner and gives the power company a possibility to assist the customer finding the cause of the disturbance as well as means to reduce its influence on plant performance.

REFERENCES

[1] ELECTRIC POWER RESEARCH INSTITUTE, PQPager-based Power Quality Early Warning Network, *Innovators, April 1998, IN-110009*

[2] ELECTRIC POWER RESEARCH INSTITUTE, Impact of Voltage Sags on Customer Loads

[3] Dranetz/BMI, PQPager, User’s Guide, 1998