Power Quality recording and evaluation in an industrial area (chemical park)

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ABSTRACT

It is not new that the quality of electrical power supply pretty much influences connected loads and processes and it is also well known that power quality issues causes huge financial losses to connected industry customers.
It is a matter of fact that industry processes are becoming more sensitive on power supply quality fluctuation and that even the processes and connected loads e.g. big drives have a negative impact on the supply itself.
But by knowing that the real challenge is to detect these power quality issues before they result in a decrease of the industry process quality or even stronger in an outage of a process.
The paper highlights the concept and result of a power quality recording and assessment project for a large industrial plant,

INTRODUCTION

The goal was a continuous registration and documentation of the power supply quality as an evidence for all connected customers inside an industry park area that the provided power is of a quality as specified in their energy purchase contracts. For that purpose power quality recorders have been utilized at interesting points in the power supply network and connected to superior evaluation software installed at a central control room. All data from the individual recorders are assessed against European standard grid codes as well as against the specific customer grid codes.

EXISTING MACHINES AND PROTECTION

This chapter describes the already installed primary and secondary technique and gives an impression about the installed loads inside the industry park as well as the already existing protection hard- and software systems.

Energy equipments

The industry park is connected to a 2x 110 kV power transmission system of the local utility. The common point of coupling has a short-circuit power of 5GVA. This gives an impression about the dimensions of the loads inside the park.

Voltage levels and corresponding transformers
In summary 10 transformers are installed in the industry park. At the two connection points to the 110 kV utility grid, two 110 kV/30 kV transformers with 63 MVA are placed. Four 20 MVA step down transformers have the task to transform the 30 kV medium voltage level to 10 kV. Last but not least the 400V low voltage level is supplied by 2x 630kVA, 1x 800kVA and one 1.6 MVA transformer.

Bus bars
Three 10 kV bus bars and one 30 kV bus bar are installed in the substation. The 30 kV bus bar is rated for a short circuit power of 2 GVA.

Emergency Generators
The emergency power supply is done by two generators with an output of 2,5 MVA and 5 MVA.

VAR compensators
Two static VAR compensation units with 2 and 3 MVAR are installed to increase the voltage stability.

Customers / consumer profile
The six customers companies which are located inside the park have quite different needs for their power supply.

For example the hydrogen chloride electrolysis plant has an overall power demand of 65MVA distributed to 5 transformers. Huge influence on power quality has the connected rectifier system to ensure a current of 1000 Ampere on the DC side.

There are converter driven pumps with speed control a rated power between 470 kW and up to 3 MW. Some of these pumps are running permanently while others are operated sporadically.

Protection devices

A wide range of protection hardware is already installed inside the 30kV substation.

- 6x Bay control unit; controls and monitors switch gear activities as well as monitoring the position of switching elements.
- 7x Multifunction protection relay with synchronization
- 4x Transient earth-fault protection relay
- 2x Differential protection relay for transformers, generators, motors and bus bars
- Differential protection relay for 2 line ends

Substation automation system

All protection relays are already integrated in a redundant SICAM PAS substation automation system since several years (Figure 1).

Two functionally identical automation systems are available in the substation. Both systems are using the same configuration.

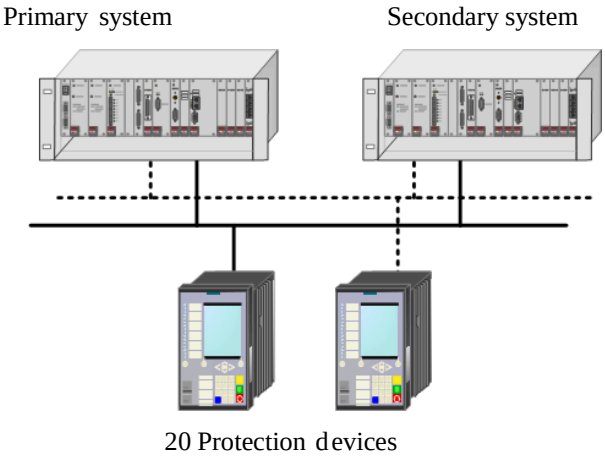

Figure1: Redundant substation automation system

POWER QUALITY ENHANCEMENTS

The chemical processes with their machines and the liquid pumps are mainly responsible for power quality issues. This issues needs to be detected in an early phase to avoid a disturbance or in the worst case an outage of the processes, production losses and high sequential costs.

To reach the goal and to have a continuous registration and documentation of the power supply quality as an evidence for all connected customers inside the industry park area that the provided power is of a quality as specified in their energy purchase contracts a Power Quality monitoring and evaluation system was installed parallel to the existing substation automation system.

This additional system has the focus only on Power Quality measurement, evaluation and reporting. This means this system has the task to gather and save all power quality relevant data from the 12 PQ recorders. Afterwards software is carrying out the evaluation against different Grid-Codes and provides a gap less reporting of all power quality of the entire power supply system of the plant.

Power quality recorder

The installed power quality recorders SICAM Q 80 are class A according to IEC 61000-4-30 [1]. These PQ recorder implement the “complete recording” measurement philosophy.
This means that all measured quantities are available for subsequent analysis even after the comparison with standards.

Voltage characteristics like Harmonics, THD and symmetry are recorded with 10 minutes mean values, frequency based on 10 second mean values and long term flicker with a mean time of 2 hours.

Power quality system

The runtime and evaluation is done by the power quality system SICAM PQS which allows all fault records and power quality data to be analyzed in one single system. The protection of power distribution equipment is a crucial part of assuring a reliable power supply. The connected customers inside the industry park are expecting maximum availability of electric power with a consistently high standard of quality at any point of time.

The core elements of the PQ system

The principle setup of the PQ system is given in figure 2.

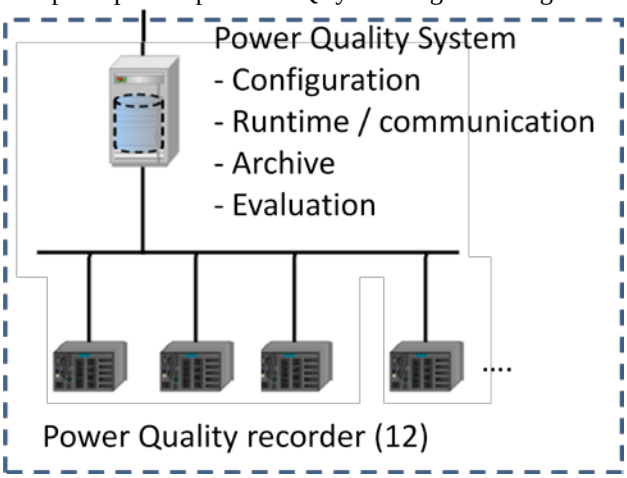

Figure2: PQ system setup

Inside the PQ system there are five core elements.

Evaluation engine & PQ Index

The grid power quality is evaluated in the power quality system on the basis of the assigned Grid Codes and represented in the visualization HMI.

The PQ index is a simple and clear way of representing the grid quality. It is calculated from the operational limits and the period limits of the assigned Grid Codes. The PQ index allows the user to compare and evaluate deviations of different characteristics from the defined upper and lower limits.

The PQ index can more than only give a violated or not violated statement; the PQ index shows the operator an exact level of power quality and answers the question how close the operation is to violate the grid code limit.
An example is given in figure 3.

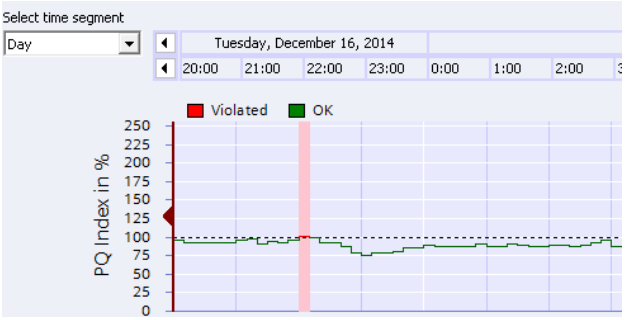

Figure 3: Zoomed PQ index with time line

This gives the possibility to detect critical time ranges as well as to detect special process scenarios inside the park. Weak spots and potentially disturbing sources can be identified and suitable mitigation measures carefully selected in balancing operational requirements of the power supply system as well as process parameters.

Up to 4 Grid Codes can be assigned to a measurement point.

Archive
The archive is the central location to store:

- Measured data
- Fault records
- Power quality violation reports
- Scheduled reports
- Evaluation results (PQ Indexes)
- Topology information
- Grid Codes e.g. EN50160 [2]

Grid Code violation reporting
Automatic analysis and reporting of power quality violations. PQ Violation Reports provide a quick and comprehensive overview of all limit value violations.

Notification service
This service informs the control center operator as well for power quality responsible operator via email and SMS immediately after detecting a grid code violation. The mail contains a PQ violation report generated by the evaluation engine. This report informs the receiver about topology path, time stamp, event type (voltage sag or swell) and the violated characteristic limit.

Scheduled Reporting
The scheduled reports engine provides an overview of the evaluation results of measured data during a selectable time period e.g. every day, every week.

Visualization and analysis application

The HMI to bring the information on PQ to the control center level is the SICAM PQ Analyzer.
The visualization application for power quality and substation automation data in the industry park control center provides comprehensive evaluation options of archived PQ measuring data and fault records from the substation automation system. The analyzer supports the control center operator to establish a report for root cause detection.
The main display views are:

Incident Explorer

In the view Incident Explorer (figure 4) the control center operator gets a list of all recorded fault records from protection relays with their corresponding topology and the selected time range.

The listed fault records can be displayed with the installed Comtrade viewer application. After taking a look inside the record of the incident can be acknowledged.

Side by side the fault records from protection relays or fault recorders also the just in time generated PQ Violation reports are listed in the Incident Explorer view.
The control center operator has one location for fault record and PQ evaluation because mostly this two kind of scenarios belonging together.

Figure 4: Zoomed Incident Explorer

PQ Inspector

The essential view for power quality observation is the PQ Inspector view (figure 5). Measurement points on consumer common point of coupling are grouped and assigned to traffic lights. Depending of the selection of measurement groups the PQ Index will be cumulated.

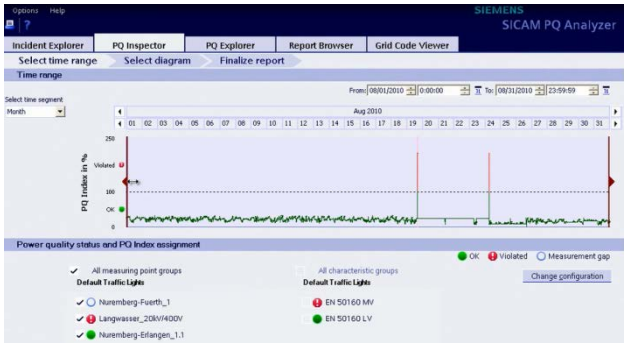

Figure 5: PQ Inspector

This is the big advantage of the PQ Inspector, the control center operator can see on one view very quickly if a Grid Code violation happens on customer side and how far the industry park is away from a Grid Code violation. The information is supported by color coding in which the red color highlights a violation.

Report Browser

A chronological overview of all generated scheduled reports can be found in the view report browser (figure 6). Each individual customer inside the industry park has its specific measurement point; the scheduled reporting engine generates for each measurement point a daily report. This daily report includes timeline diagrams as well as tables, event lists and PQ Indices. In this view the goal was like in all other analyzer views to give the operator a very fast overview about the power quality performance on customer side.

The scheduled reports will be displayed in red (Grid-Code limit was violated), green (all limits are kept), yellow (no limit violated however an event recorded) and grey (no evaluation statement can be given due to a measurement gap)

Figure 6: Report Browser

Conclusion

A proper quality of the electrical power supply is inevitable for an efficient and economic operation of industrial processes. The continuous measurement and monitoring of relevant power quality characteristics is a step towards a quality assessment in order to recognize possible discrepancies in the supply quality thus enables the operators to localize the problem in a fast to early define appropriate mitigation measures.

In case an energy consumer inside the industry park complains that equipment was damaged or a production process was disturbed or even interrupted and causes financial losses. It is very easy for the energy provider to take a look in the scheduled reporter user interface to check how have the power quality been during a specific time range in the past. The result is mostly, that the electrical energy was not the cause for the damage because the quality was in the given limits.

The enhancement of the existing SCADA system with a dedicated PQ system which fits seamless provides the electricity provider of the large industrial park with many sensitive loads as well as disturbing loads with the necessary evidence for power quality. It verifies the grid code requirements are kept and allows identification of root causes in case of problems. This is statement can is supported by more than one year of successful operation.

References

[1] IEC 61000-4-30 Power Quality Measurement Methods

[2] EUROPEAN STANDARD EN 50160 Voltage characteristics of electricity supplied by public electricity networks.

Final system architecture in the industry park

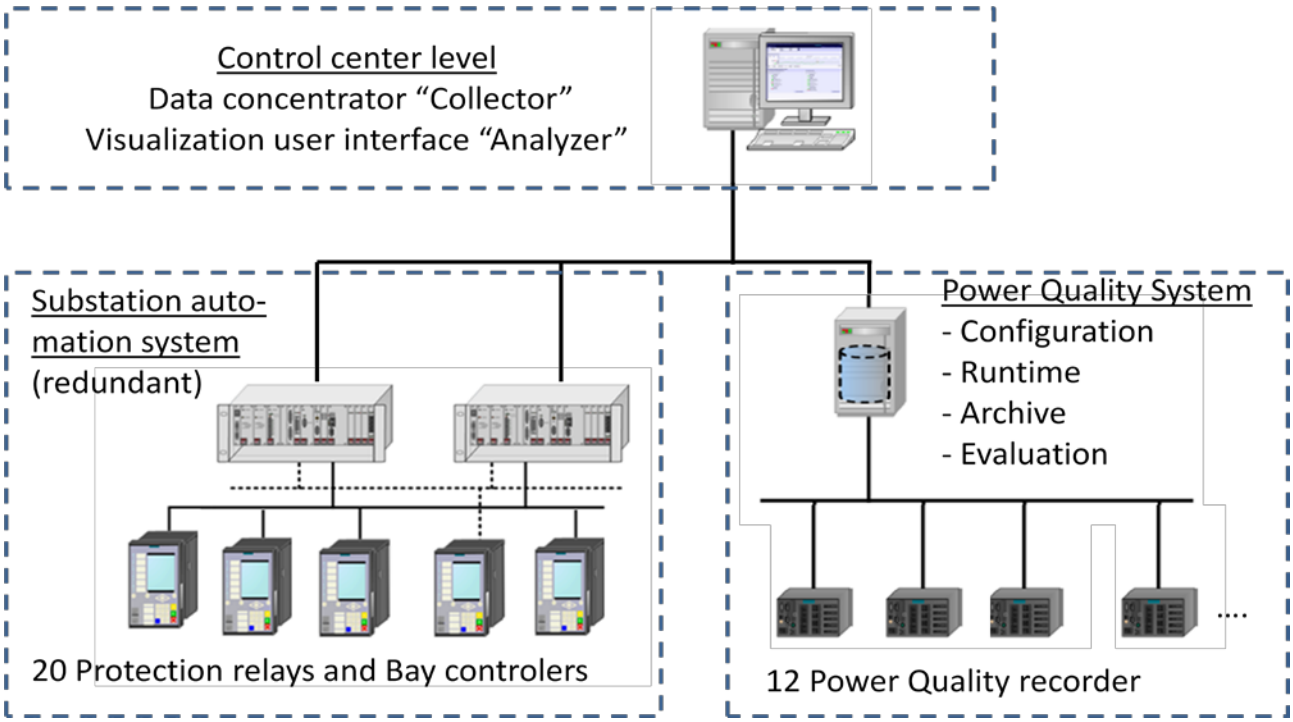

Figure: Protection and Power Quality system topology