



PQSoft Case Study

General Reference Power Quality Assessment Procedure

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Power Quality Category	General Interest		
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Problem Cause	Sags/Interruptions	Harmonics	Transients
Load Type	Power Electronic	Industrial	Commercial
Customer Type	Utility		
Miscellaneous1	Voltage Sags	Interruptions	Capacitor Switching
Miscellaneous2	Harmonic Resonance	Voltage Swells	Voltage Variations
References			

Abstract:

Power quality is a frequently used term that means different things to different people. Common power quality problems include all of the issues that arise from the incompatibility between a utility's power and the customer's energy-using equipment that result in impaired operation. These include transients, sags and swells, harmonics, and short- and long-term voltage variations and outages. Also included under this broad area are issues of power reliability.

This case describes a general procedure for performing on-site case studies of power quality concerns.

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RELATED STANDARDS

IEEE Std. 1159
IEEE Std. 1346
IEEE Std. 1250
IEEE Std. 1036
IEEE Std. 519

GLOSSARY AND ACRONYMS

ASD	Adjustable-Speed Drive
CVT	Constant Voltage Transformer
GPR	Ground Potential Rise
IEEE	Institute of Electrical and Electronics Engineers
MOV	Metal Oxide Varistor
PWM	Pulse Width Modulation
TVSS	Transient Voltage Surge Suppressors
UPS	Uninterruptible Power Supply
VCR	Video Cassette Recorder

POWER QUALITY ASSESSMENT PROCEDURE

This case describes a general procedure for performing on-site case studies of power quality concerns. The power quality assessment procedure is based on the variety of different power quality concerns that can exist and focuses on a combination of monitoring and analysis to characterize these concerns. Once the power quality concerns are characterized, the analysis procedures developed can be used to evaluate possible solutions to the power quality problems. These solutions must then be evaluated from both a technical and an economic perspective. There are a number of important areas that must be addressed in the power quality assessment procedure. These include:

- Data collection requirements
- Important power quality concerns as a function of the type of customer
- Equipment sensitivity
- Important parameters of the power quality concern
- Roles of measurements and simulations in evaluating the concern
- Implementation of possible solutions to solve the problem
- Technical considerations
- Economics
- Politics

The procedure presented here, along with the information included in the previous sections, provides the framework for performing case studies in a variety of customer categories. It is worthwhile to group customers in categories that involve the application of similar equipment and have similar electrical system designs. With this in mind, the following list of customer categories is provided as an example of possible customer segments:

- Office Buildings
- Hospitals
- Semiconductor Manufacturers
- Data Processing/Banking
- Telecommunications
- Computer Manufacturers
- Point of Sale Retail Operations
- Food Processing
- Pulp and Paper Mills
- Refinery and Chemicals
- Automotive Plants
- Printing/Publishing
- Steel Mills
- Rubber/Plastics Plants

Besides classifying the case studies by the type of customer involved, it is also possible to categorize the studies by the type of sensitive equipment involved or the specific type of power quality variation of concern. The results of multiple case studies can be combined to develop descriptions of general power quality concerns for various classes of customer equipment. Some of the most important equipment categories to consider include:

- Adjustable speed drives - harmonic distortion concerns
- Adjustable speed drives - sensitivity to transient voltages
- Electronic controls, ASDs, robotics, and PLCs - sensitivity to voltage sags
- Switch-mode power supplies - harmonic current generation and neutral current concerns
- Fluorescent lighting (especially with electronic ballasts) - harmonic generation
- Power factor correction capacitors - switching transients and magnification
- Power factor correction capacitors - harmonic distortion concerns (resonance)
- Motor contactors - sensitivity to voltage sags
- Power conditioning equipment selection - matching to requirements of protected equipment
- Data processing equipment - UPS system specification
- Electronic equipment - sensitivity to high frequency transients
- Transformers - harmonic heating
- Motors - voltage imbalances and harmonic heating

The power quality assessment procedure provides a general framework that contains all the possible elements that may be needed in a power quality case study. Each case study will have unique requirements, depending on the type of customer, equipment sensitivity, and other factors. These unique requirements will influence the level of effort needed for each step or may even permit bypassing a particular step of the overall procedure. The following sections summarize the general steps involved in the procedure.

Identify Power Quality Concerns

The specific power quality concerns that need to be evaluated will be different from customer to customer. A review of the types of equipment used by the customer, process requirements, and economic impacts of problems will lead to a list of concerns that need to be studied. The concerns can include possible problems with both the utility distribution system and the customer facilities. Possible power quality problem categories to be evaluated include the following:

- Voltage transients caused by circuit switching and load switching within the customer facility.
- Harmonic distortion from adjustable speed drives or other nonlinear loads.
- Transformer heating caused by harmonic current levels.
- Transient magnification at low voltage capacitor banks.
- Sensitivity of adjustable speed drives and control systems to utility capacitor switching transients.
- Transients and notching associated with power electronics equipment operation.
- Neutral conductor overloading due to harmonic producing loads in commercial installations.
- Voltage flicker from arc furnace loads and arc welding loads.
- Voltage sags due to faults on parallel circuits on the same distribution system or faults on the transmission system.

- Momentary interruptions at industrial and commercial installations due to recloser operations on feeder circuit breakers.
- Coupled voltages at customer facilities due to lightning transients on the primary distribution systems.

Identification of the particular concerns involved for an installation provides a focus for the study. Development of a model for analysis of the problem is dependent on the frequency range of the power quality variations that need to be studied. The model can be for computer simulations, hand calculations, or application of simple rules. Analysis of voltage sags often requires modeling all the way up to the utility transmission system. Analysis of high frequency transients might only require a model for a local part of the customer facility.

Monitoring requirements are also based on the particular concern involved. If harmonic distortion is a concern, monitoring of steady state conditions with a harmonic analyzer is required. Analysis of disturbances requires a disturbance monitor. The duration of monitoring depends on how often the problems occur. Some problems with voltage sags or momentary interruptions might only occur a few times per year due to faults on the transmission system while problems caused by capacitor switching might occur every day. Other voltage variations of interest probably fall somewhere between these extremes.

Collect Data/Develop Initial Models

A representation of the customer system and important parts of the utility system should be developed for preliminary analysis. This model can be used for preliminary simulations or analysis to predict power quality problems and evaluate possible solutions to problems. In cooperation with the customer, the data for the model is collected and compiled into a database for convenient reference during the analysis.

Important information includes:

1. Load characteristics
 - Motors
 - Power electronics
 - Process controls
 - Computers
 - Adjustable speed drives
 - Lighting
2. Transformer sizes/ratings
3. Conductor lengths, characteristics
4. Customer capacitor sizes, locations, switching procedures
5. Customer equipment and circuit switching
6. Power conditioning equipment
 - Surge suppressors (arresters, varistors, etc.)
 - Isolation transformers
 - Constant voltage transformers
 - Voltage regulators
 - Power conditioners
 - UPS systems
 - Harmonic filters

7. Distribution system characteristics
 - Primary Voltage
 - Underground/Overhead
 - Protection practices, switching procedures
 - Capacitor applications (locations, sizes, switching)

Perform Simulations

Simulations provide a convenient means to characterize power quality problems, predict disturbance characteristics, and evaluate possible solutions to problems. They should be performed in conjunction with monitoring efforts and measurements for verification of models and identification of important power quality concerns. The models required for the simulations depend on the system characteristics and the power quality variations being evaluated. The simulations fall into three major categories:

1. **Transients.** Transient simulations can be performed with the Electromagnetic Transients Program (EMTP). This is a valuable tool for analysis of circuit switching operations, capacitor switching, lightning transients, and transients associated with power electronic equipment operation.
2. **Harmonics.** Harmonic PLCs is usually performed using steady state analysis techniques at the individual harmonic frequencies. The SuperHarm program can be used for these simulations. Harmonic producing loads can be modeled as harmonic current sources and the simulations used to predict harmonic voltages and currents throughout the customer and utility systems.

Overloading of neutral conductors, transformer heating considerations, resonances caused by capacitor applications, and harmonic currents injected onto the utility system can be evaluated in the simulations.

3. **60 Hz Voltage Variations.** Variations in the fundamental frequency voltage can be evaluated with conventional analysis tools. Load flow programs give system voltages as a function of load levels on the system. Fault programs can calculate system voltage profiles during fault conditions for analysis of voltage sag concerns.

The models being developed during the case studies in the second phase of this project will serve as templates for future case studies by utility personnel. The models will be verified and refined using the results of monitoring at customer sites.

Develop Monitoring Program

The utility and customer systems being evaluated should be monitored to characterize the power quality variations and to verify the analytical models developed for simulations. The measurement program should be designed based on initial simulation results and on the particular sensitive loads existing at the customer facilities. Monitoring will typically be performed at the customer service entrance and close to particular sensitive loads in order to characterize disturbances coming from the utility system and disturbances that are localized at the sensitive loads. A measurement program plan should be developed which specifies:

- quantities to monitor
- monitoring durations
- threshold levels which will trigger recording of disturbances
- waveform sampling and data storage requirements
- analysis procedures and data presentation formats

Available monitoring instruments should be evaluated for the measurements required. The problem of obtaining adequate representation of both harmonic and transient conditions must be addressed in particular if both of these concerns exist at a facility.

A customer site survey should be part of the measurement program design. The site survey should characterize the wiring and distribution system integrity and provide basic information about circuit and equipment loading. The data collection forms provided in Chapter 8 can be used to assist with this data collection effort. The site survey should also include discussions with facility personnel regarding characteristics of equipment problems and known customer system conditions at the time power quality variations have occurred.

The actual monitoring effort requires close cooperation between the customer and utility personnel. Monitoring sites and instrumentation should be selected based on the particular concerns being characterized. The duration of monitoring will depend on the parameters that can affect the power quality concerns. It is likely that the customer will need to be responsible for making sure the monitor is operating properly on a day-to-day basis. The monitoring results should be compiled and analyzed for verification of analytical models and to provide a concise description of the possible concerns. The customer should participate in the monitoring effort by keeping a log of equipment problems during the monitoring period. It is very important to correlate actual equipment problems with power quality variations and with operations on the customer system or the utility system.

Evaluate Measurements Results

The measurement results are analyzed along with the results of simulations to correlate customer problems with the utility system power quality levels. The initial measurements and the site survey are used to identify the phenomena involved and the important parameters. The subsequent measurement results are used to verify the model and characterize the actual power quality variations. Using this information, the model can then be used for more detailed simulations of possible solutions to the power quality problem. The simulations provide the means to evaluate a range of possible solutions from a technical point of view.

Once the range of technical solutions is identified, economic analyses need to be performed to evaluate the possible alternatives for solving customer power quality problems. These alternatives will generally include the following options:

- Power conditioning and/or filtering at the sensitive loads.
- Central power conditioning and/or filtering at the customer service entrance.
- Changing operating procedures or system design on the utility distribution system.
- Modification to the design of loads to make them less sensitive to power quality variations.

The requirements for each of these options will be developed from the simulation effort and the analysis of measurement results. Power conditioning in this case includes surge suppression, voltage regulation, and possibly backup for momentary interruptions. Harmonic filtering to solve harmonic problems can be applied either at individual loads or at the main service for a facility. Customer system design modifications, such as changing power factor correction procedures and equipment, can have an important impact on power quality variations. If particular loads are much more sensitive than other loads in the facility, either power conditioning at the particular load or design changes to the load equipment should be considered.

Momentary interruptions and voltage sags deserve careful consideration. Distribution system modifications could include implementation of switching procedures to minimize transients associated with capacitor switching events or addition of current limiting devices to minimize the voltage sags that occur during faults on parallel feeders. The impact of protection practices on power quality levels experienced by customers should be evaluated carefully using both the analytical and measurement results. Conclusions will be developed from this effort regarding optimum locations for power quality improvement and the impact of distribution system design practices on customer power quality levels.

SUMMARY

The procedure described in the previous sections is summarized by the block diagram in Figure 1.

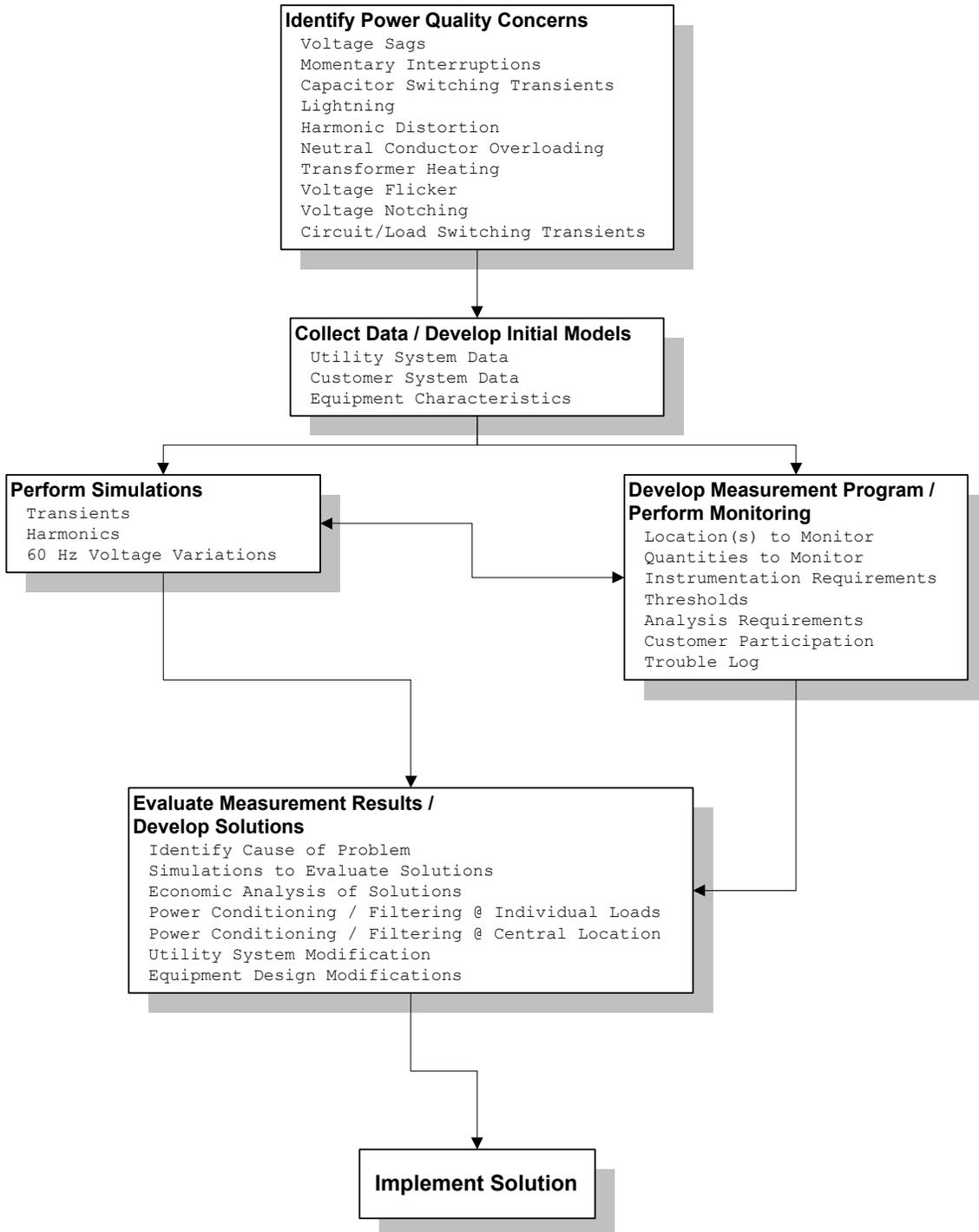


Figure 1 - Assessment Procedure for Power Quality Evaluations

REFERENCES

IEEE Standard 100. Terms and Definitions

IEEE Standard 1100. IEEE Recommended Practice for Powering and Grounding Sensitive Equipment (The Emerald Book).

IEEE Standard 1159. IEEE Recommended Practice on Monitoring Electric Power Quality.