### Course

**Power Quality - 1**

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### Introduction to Power Quality

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What is power quality - 1

- different definitions for power quality, depending on one’s frame of reference
- utilities may define power quality as reliability
- the manufacturer of load equipment may define power quality as those characteristics of the power supply that enable the equipment to work properly
- power quality is ultimately customer-driven issue

Any power problem manifested in voltage, current, or frequency deviations that results in failure or misoperation of customer equipment.

Equipment has become more sensitive

- electronic and power electronic equipment has become more sensitive to voltage disturbances
- companies have become more sensitive to loss of production time
- reduced profit margins
- electricity is considered a basic right, which should always be present
- the interruption will lead to complaints, even if there are no damages or costs related to it

Equipment causes voltage disturbances

- tripping of equipment due to disturbances in the supply voltage is described by customers as “bad power quality”
- utilities view disturbances due to end-user equipment
- modern electronic equipment is not only sensitive to voltage disturbances, it also causes disturbances for other customer
- converter-driven equipment, large number of small consumer electronics equipment, …
A growing need for standardization

- today the utilities have to treat the consumers as "customers"
- electricity is viewed as product with certain characteristics (beside price), which have to be measured, guaranteed, improved, … (quality)
- need for standardization and performance criteria
- privatization and deregulation of the electricity industry
- open competition
- who is responsible for reliability and quality

Utilities want to deliver good product

- many power quality developments are driven by the utilities
- most utilities want to deliver a good product and have been committed to that for many decades
- designing a system with high reliability of supply for a limited cost is a technical challenge

Power supply has become too good

- high quality of the supply voltage
- long interruptions have become rare in most industrialized countries
- wrong impression that electricity is something that is always available and always of high quality
- in countries where the electricity supply has a high unavailability, power quality does not appear to be such a big issue as in countries with availability well over 99.9%
Power quality can be measured

- availability of electronic devices to measure and show waveforms has contributed to the interest in power quality
- harmonic currents, voltage dips, flicker were hard to measure on a large scale in the past
- measurements were restricted to rms voltage, frequency and long interruptions

What is “Good Power Quality”

- if the voltage:
  - has a constant sine wave shape with fundamental frequency only
  - is supplied at constant frequency
  - forms a symmetrical three-phase power system
  - has a constant RMS value, unchanged over time
  - is unaffected by load changes
  - is reliable, i.e., energy available when required

Power quality, voltage quality - 1

- which term to use for utility-customer (system-load) interactions
- one cannot talk about the quality of a physical quantity like power
- the term “power quality” does not give perfect description of a phenomenon
- IEC in its standard documents uses the term electromagnetic compatibility, which is not the same as power quality
Power quality, voltage quality - 2

• the IEEE definition of power quality: *Power quality is the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment.*

• the IEC definition of electromagnetic compatibility: *Electromagnetic compatibility is the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.*

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Power quality, voltage quality - 3

• voltage quality
  – concerned with deviations of the voltage from the ideal – single-frequency sine wave of constant frequency and constant magnitude
  – it covers only technical aspects
  – current distortions are reflected in voltage distortion (impedance)
  – regularly used in European publications
  – interpreted as the quality of the product delivered by the utility to the customers

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Power quality, voltage quality - 4

• current quality
  – complementary definition
  – deviations of the current from the ideal
  – additional requirement, current is in phase with the supply voltage
  – current quality is concerned with what the consumer takes from the utility
  – if either current or voltage deviates from ideal it is hard for the other to be ideal

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• power quality
  – combination of voltage quality and current quality
  – deviations of voltage and/or current from the ideal
  – power quality has nothing to do with deviations of the product of voltage and current (the power) from any ideal shape

• quality of supply
  – includes technical part (voltage quality) plus a non-technical part sometimes referred to as “quality of service”
  – the latter covers the interaction between the customer and the utility
  – customer responsibilities are not included
  – European approach

• quality of consumption
  – complimentary term of quality of supply
  – would contain current quality
  – how accurate the customer is in paying the electricity bill
Power quality, voltage quality - 8

- electromagnetic compatibility (EMC)
  - used in IEC standards
  - mutual interactions between equipment and interactions between equipment and supply
  - two important terms are used
  - "emission" is electromagnetic pollution produced by a device
  - ...

Power quality, voltage quality - 9

- electromagnetic compatibility (EMC)
  - ...
  - "immunity" is device’s ability to withstand electromagnetic pollution
  - emission is related to the term current quality
  - immunity is related to the term voltage quality

Why are we concerned about PQ

- economic value
- economic impacts on utilities, their customers and suppliers of load equipment
- direct financial consequences for industrial customers and utilities
- utilities are interested in meeting customer expectations and maintaining confidence – indirect costs (competition between utilities)
- Load equipment suppliers
  - competitive market
  - features to the equipment to withstand common disturbances
Economic value - 1

- inadequate power quality costs
  - loss of production
  - lost materials
  - equipment malfunction
  - accelerated equipment ageing
  - additional power losses
- savings
  - unused materials
  - energy bill
  - savings are much smaller than costs

Economic value - 2

- losses per voltage dip for different industries

Economic value - 3

- estimated power interruption costs (USA, 1992, survey of 210 large industrial customers)
  - average cost per event:
    - 4h outage (accidental) 74.835 $
    - 1h outage (accidental) 39.459 $
    - 1h outage (prearranged) 22.973 $
    - voltage dip 7.694 $
    - momentary outage 11.027 $
Economic value - 4

- estimated costs per disturbance
  - 6 $ / kVA of load (Europe)
  - 40 $ / kVA of load (USA)
- estimated cost of a single dip (USA)
  - 50,000 $ – 1,000,000 $
- data companies: £1M/min interruption
- average cost of downtime
  - mobile communications 41,000 $/hour
  - airline reservations 99,000 $/hour
  - credit card operations 2,580,000 $/hour
  - brokerage operations 6,480,000 $/hour

Responsibilities - 1

- many misunderstandings regarding the causes of power quality problems
- the utility and customer perspectives are often much different

Responsibilities - 2

- survey of mid-size industries in the USA:
  - 87% utility is responsible for delivery of clean power to main service entrance
  - 11% utility is responsible for all problems
  - 2% plant is responsible for all problems
Responsibilities - 3

• Survey of mid-size industries in the USA:
  – weather
  – utility
  – equipment
  – plant infrastructure
  – usage of equipment

Responsibilities - 3

• standardization
• the utility is responsible for voltage quality
• customers are responsible for current quality
• allocation of disturbances
  – measurements
  – different methods
  – difficulties in some cases (harmonic distortion)
  – allocation of costs for mitigation measures

Basic terms and definitions
Basic terms

- definition of Council of European Energy Regulators (CEER)
- Working Group on Quality of Electricity Supply
- quality of electricity supply:
  - commercial quality
  - continuity of supply
  - voltage quality
Commercial Quality - 2

- guaranteed standards are usually associated to some kind of reimbursement to the user in the event of non-compliance
- standards can be defined, for example, in terms of the maximum time to provide supply, metering, reading and billing, information supply, telephone enquiry responses, appointments, customers' complaints, emergency services and others

Continuity of Supply - 1

- technical issue
- is characterized by the number and duration of interruptions
- several indicators are used to evaluate the continuity of supply in transmission and distribution networks
- regulation can aim to compensate customers for very long supply interruptions, keep restoration times under control and to create incentives to reduce the total number and duration of interruptions

Continuity of Supply - 2

- different methods and accuracies of measuring interruptions and in assigning liability for each of them create problems in regulating continuity of supply
Voltage Quality - 1

• technical issue
• is becoming an important issue for distributors and customers in some countries, both because of the sensitivity of end-user equipment and the increasing concern of some end-users.
• industrial equipment is claimed to have become more vulnerable to voltage distortion, while at the same time the use of electronic devices in homes and small businesses has increased the sensitivity of a greater number of users.

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Voltage Quality - 2

• the main parameters of voltage quality are
  – frequency
  – voltage magnitude and its variation
  – voltage dips
  – temporary or transient overvoltages and
  – harmonic distortion
• European Standard EN 50160 lists the main voltage characteristics in low and medium voltage networks, under normal operating conditions.

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The need for common PQ Terminology

• there is a need for common terminology in order to:
  – avoid confusion from many different terms that have similar meanings
  – develop standards for characterizing and categorizing monitoring and measurement results
  – permit statistical analysis of data obtained from different sources
  – facilitate communication when describing encountered problems

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Power Quality Categories

- two major categories of Power Quality variations
  - disturbances
    - transients
    - voltage dips
    - interruptions of supply
  - steady state variations
    - voltage regulation
    - harmonic distortion
    - voltage flicker

Basic definitions - PCC

- Point of Common Coupling (PCC) - the point in the interconnected power system where loads are connected to the network (point at which load interacts with other loads and the network itself)
  - IEC definition
  - for typical residential application PCC is at the distribution transformer secondary
  - for large industrial and commercial services, a distribution transformer supplies a single customer so the PCC is usually the transformer primary

Basic definitions - RMS

- root-mean-square (RMS) value of voltage or current over one cycle or half-cycle of the fundamental power frequency

$$X = \sqrt{\frac{1}{T} \int_{0}^{T} x^2(t) \, dt} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} x_i^2}$$

x - voltage (V) or current (I)
Basic definitions - voltage regulation

\[ V_R[\%] = 100 \left(1 - \frac{V_{\text{rated}} - V}{V_{\text{rated}}} \right) \]

- \( V_{\text{rated}} \) - rated circuit voltage
- \( V \) - measured RMS voltage

- the regulation of voltage is closely related to the "strength" of the bus, i.e., the ability of the bus to supply current without changing voltage amplitude

Basic definitions - SCR

\[ SCR = \frac{I_{\text{sc}}}{I_{\text{nom}}} \]

- short circuit ratio
- \( I_{\text{nom}} \) - circuit nominal (maximum) current measured and averaged in 15min intervals over one calendar year
- \( I_{\text{sc}} \) - short-circuit current of the bus, i.e. three-phase (or single phase if applicable) current due to a bolted short-circuit to ground
- typical values of SCR are between 20 and 100 for residential circuits and much higher (to 1000 or more) for industrial circuits
- it is often limited by the distribution transformer when the PCC is at the transformer secondary

Definitions (EN 50160) - 1

- customer – the purchaser of electricity from a supplier
- supplier – the party who provides electricity via a public distribution system
- supply terminals – point of connection of customer’s installation to the public system
- supply voltage – the rms value of the voltage at the given time at the supply terminals
- nominal voltage of a system \( U_n \) – the voltage by which a system is designated or identified
Definitions (EN 50160) - 2

- declared supply voltage \( U_c \) – if by agreement between the supplier and the customer a voltage different from the nominal voltage is applied to the terminal, that this voltage is declared supply voltage
- low voltage LV – a voltage used for the supply of electricity, whose upper limit of nominal rms value is 1 kV
- medium voltage MV – a voltage used for the supply of electricity, whose nominal rms value lies between 1 kV and 35 kV

Definitions (EN 50160) - 3

- normal operating conditions – the condition of meeting load demand, system switching and clearing faults by automatic system protection in the absence of exceptional conditions due to external influences or major events
- conducted disturbance – electromagnetic phenomena propagated along the line conductors of a distribution system
- frequency of the supply voltage – repetition rate of fundamental wave of the supply voltage
- voltage variation – an increase or decrease of voltage normally due to variations of the total load

Definitions (EN 50160) - 4

- rapid voltage change – a single rapid variation of the rms value of a voltage between two consecutive levels which are sustained for definite but unspecified durations
- voltage fluctuation – a series of voltage changes or a cyclic variation of the voltage envelope
- flicker – impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time
- flicker severity – intensity of flicker annoyance defined by the UIE-IEC flicker measuring method
Definitions (EN 50160) - 5

- **supply voltage dip** – a sudden reduction of the supply voltage to a value between 90 % and 1 % of the declared voltage $U_c$, followed by a voltage recovery after a short period of time
- **supply interruption** – a condition in which the voltage at the supply terminals is lower than 1 % of the declared voltage
- **temporary power frequency overvoltage** – an overvoltage at given location of relatively long duration

Definitions (EN 50160) - 6

- **transient overvoltage** – a short duration oscillatory or non-oscillatory overvoltage usually highly damped and with a duration of a few milliseconds or less
- **harmonic voltage** – a sinusoidal voltage with a frequency equal to an integer multiple of the fundamental frequency of the supply voltage
- **interharmonic voltage** – a sinusoidal voltage with a frequency between the harmonics, i.e. the frequency is not an integer multiple of the fundamental

Definitions (EN 50160) - 7

- **voltage unbalance** – a condition in a three-phase system in which the rms values of the phase voltages or the phase angles between consecutive phases are not equal
- **mains signaling voltage** – a signal superimposed on the supply voltage for the purpose of transmission of information in the public distribution system and customers' premises
Overview of PQ definitions

PQ standards

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European power quality standard

• EN 50160 – Voltage characteristics of electricity supplied by public distribution systems
• approved by CENELEC – European Committee for Electrotechnical Standardization
• gives the main characteristics of the voltage at the customer’s supply-terminals in public low voltage (LV) and medium voltage (MV) networks
• under normal operating conditions

IEC power quality standards

• IEC standards on Electromagnetic compatibility (EMC)
  – 61000-1-X - Definitions and methodology
  – 61000-2-X - Environment (e.g. 61000-2-4 is compatibility levels in industrial plants)
  – 61000-3-X - Limits (e.g. 61000-3-4 is limits on harmonics emissions)
  – 61000-4-X - Tests and measurements (e.g. 61000-4-30 is power quality measurements)
  – 61000-5-X - Installation and mitigation
  – 61000-6-X - Generic immunity & emissions standards

IEEE power quality standards

• IEEE 1159: Monitoring Electric Power Quality
• IEEE 1159.1: Guide for Recorder and Data Acquisition Requirements
• IEEE 1159.2: Power Quality Event Characterization
• IEEE 1159.3: Data File Format for Power Quality Data Interchange
• IEEE P1544: Voltage Sag Indices
• IEEE 1346: Power System Compatibility with Process Equipment
• IEEE P1100: Power and Grounding Electronic Equipment (Emerald Book)
• IEEE 5433: Power Quality Definitions
• IEEE P1453: Voltage flicker
• IEEE 519: Harmonic Control in Electrical Power Systems
• IEEE P519A: Guide for Applying Harmonic Limits on Power Systems
• supply voltage disturbances
  – power frequency
  • synchronous connection
  • island operation
  – magnitude of supply voltage
  • four-wire three phase system
  • three-wire three phase system

• supply voltage disturbances
  – supply voltage variations
  • load change

• supply voltage disturbances
  – rapid voltage changes – 1
  • switch-on of capacitor bank
EN 50160

• supply voltage disturbances
  – rapid voltage changes – 2
    • consequence of arc furnace operation

EN 50160

• supply voltage disturbances
  – rapid voltage changes – voltage fluctuation
    • short-term flicker

EN 50160

• supply voltage disturbances
  – rapid voltage changes – voltage fluctuation
    • long-term flicker
• supply voltage disturbances
  – supply voltage dips

• supply voltage disturabnces
  – short interruptions of the supply voltage

• supply voltage disturbances
  – supply interruption
    • the voltage at the supply-terminals is lower than 1 % of the declared voltage
    • prearranged interruption
    • accidental interruption
    • a short interruption (up to three minutes)
    • a long interruption (longer than three minutes)
EN 50160

- supply voltage disturbances
  - temporary power frequency overvoltages between live conductors and earth

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EN 50160

- supply voltage disturbances
  - transient overvoltages between live conductors and earth – lighting stroke current impulsive transient

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EN 50160

- supply voltage disturbances
  - supply voltage unbalance

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EN 50160

- supply voltage disturbances
  - harmonic voltage

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EN 50160

- supply voltage disturbances
  - harmonic voltage
  - distorted load current

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EN 50160

- supply voltage disturbances
  - harmonic voltage

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EN 50160

- Supply voltage disturbances
  - Interharmonic voltage
    - Sinusoidal voltage with the frequency between two harmonics
  - Mains signaling voltage on the supply voltage
    - Power line carrier signaling
    - Tone frequency control

EN 50160

- Voltage supply-characteristics
  - Power frequency
    - Measured over 10-second interval
    - Normal operating conditions
    - 50 Hz ±1 % during 99.5 % of a week (synchronous connection)
    - 50 Hz ±4 % -6 % during 100 % of a week (synchronous connection)
    - 50 Hz ±2 % during 99.5 % of a week (island operation)
    - 50 Hz ±15 % during 100 % of a week (island operation)

EN 50160

- Voltage supply-characteristics
  - Magnitude of the supply voltage
    - Standard nominal voltage for public LV network is 230 V between phase and neutral
    - Magnitude of the supply voltage for public MV network is given by the declared voltage $U_c$
  - Supply voltage variations
    - Normal operating conditions
    - 10-minute mean rms values
    - $U_c ± 10$ % for MV networks (95 % of a week)
    - $U_n ± 10$ % for LV networks (95 % of a week, may differ in accordance with HD 472 S1)
EN 50160

- **voltage supply-characteristics**
  - **rapid voltage changes**
    - magnitude of the rapid voltage changes for LV networks:
      - up to 5 % Un under normal operating conditions
      - up to 10 % Un with a short duration some times per day
    - magnitude of the rapid voltage changes for MV networks:
      - up to 4 % Uc under normal operating conditions
      - up to 6 % Uc with a short duration some times per day
  - **flicker severity**
    - long term flicker severity under normal operating conditions should be equal or less than 1 for 95 % of the time

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EN 50160

- **voltage supply-characteristics**
  - **supply voltage dips**
    - expected number in a year: up to a few tens to up to one thousand
    - the majority have a duration less than 1 second and a depth less than 60 %
    - voltage dips with greater depth and duration can occur infrequently
    - voltage dips with depths between 10 and 15 % can occur very frequently (switching of loads)

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EN 50160

- **voltage supply-characteristics**
  - **short interruptions of the supply voltage in LV and MV networks (up to 3 minutes)**
    - annual occurrence: from up to a few tens to up to several hundreds
    - approximately 70 % of short interruptions may be less than one second

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EN 50160

- Voltage supply-characteristics
  - Long interruptions of the supply voltage in LV and MV networks (longer than 3 minutes)
    - Indicative values: less than 10 or up to 50
    - Differences in system configurations and structures in various countries
    - Indicative values are not given for prearranged interruptions

EN 50160

- Voltage supply-characteristics
  - Temporary power frequency overvoltages between live conductors and earth
    - Temporary power frequency overvoltages in LV networks
      - May reach the value of the phase-to-phase voltage
      - Under certain circumstances up to 1.5 kV rms
    - Temporary power frequency overvoltages in MV networks
      - Depends on the type of earthing of the system
      - In solidly or impedance earthed systems up to 1.7 Uc
      - In isolated or resonant earthed systems up to 2 Uc

EN 50160

- Voltage supply-characteristics
  - Transient overvoltages between live conductors and earth
    - Generally will not exceed 6 kV in LV networks
    - Switching and lightning overvoltages
    - Supply voltage unbalance in LV and MV networks
      - 95% of the 10-minute mean rms values of the negative sequence component of the supply voltage shall be up to 2% of the positive sequence component
      - Unbalances up to about 3% occur
EN 50160

- voltage supply-characteristics
  - harmonic voltages in LV and MV networks
    - 95 % values are given in the table
    - the THD up to the order 40 shall be less than or equal to 8 %

<table>
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<td>&lt; 5</td>
<td>2</td>
<td>&lt; 5</td>
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<td>&lt; 3</td>
<td>5</td>
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<td>&lt; 2</td>
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<td>23</td>
<td>&lt; 1.5</td>
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- interharmonic voltages
  - the level of interharmonics is increasing
  - levels are under considerations

- mains signaling voltage in LV and MV networks
  - over 99 % of the day the 3-second mean of signal voltages shall be less or equal to the values given in the graph (from 0.1 to 100 kHz)
  - power line carrier signaling with frequencies in the range from 95 kHz to 148.5 kHz may be used in customers' installations

PQ monitoring
The role of Power Quality monitoring

- benchmark system performance levels (Enhanced power quality services)
- reliability (broader definition) reporting
- identify and solve problems
- prioritize system investment
- verify power conditioning equipment performance
- information service for customers

What needs to be evaluated

- transients and grounding
- wiring integrity
- power factor correction issues
- motor starting
- nonlinear loads – harmonic levels
- impacts of voltage sags and momentary interruptions
- steady state voltage regulation and unbalance
Monitoring requirements

- monitoring instruments
- data collection software/system (the Power Quality Data Interchange Format – PQDIF has been defined to allow sharing of PQ data between different applications)
- data characterizing
- database management
- analysis applications
- reporting/viewing of information

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Instruments requirements

- instruments requirements according to standard EN 61000-4-30 (based on EN 50160)
  - class-A instrument
    - class-A instrument is a reference instrument
    - measurement accuracy
    - data flagging
    - solving of conflicts
  - class-B instrument
    - indication of network conditions
    - solving of operational problems

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Monitoring requirements for different disturbances

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<td>Waveform plots showing position of impulse on power frequency sinusoid</td>
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Required background information

- before monitoring, gather essential information
  - nature of problem
  - characteristics of the affected equipment
  - when problem occurs
  - other coincident problems or known system operations.
  - existing power conditioning equipment
  - electrical system data

Disturbance recording form

- date and time of disturbance
- description of problems encountered
- equipment sensitivity
- cost of equipment failure or downtime
- other related incidents
- utility events

Monitoring locations

- substations
- service entrance
- load experiencing problems
Monitor installation - 1

- environmental concerns
- transient protection
- transducer connections
  - phase rotation
  - pairing, polarity, etc.
- instrument setup
  - set and verify transducer ratios
  - set and verify triggers and thresholds (if applicable)
- sanity check
  - ensure steady state data is correct

Monitor installation - 2

- measured parameters (SIST EN 50160, SIST EN 61000-4-30)
- recommendable measurement of currents
- selection of measurement location
- number of instruments
- voltage protection
- earthing of instrument
- disturbances

Transducer requirements

- signal levels
  - signal levels should use the full scale of the instrument without distorting or clipping the desired signal
- frequency response
  - this is particularly important for transient and harmonic distortion monitoring, where high frequency signals are particularly important
  - normal VT and CT used for metering and protection are usually good up to 3kHz - 4kHz
Monitoring duration

- power frequency at least one week
- magnitude of supply voltage at least one week
- flicker at least one week
- supply voltage dips at least one year
- interruptions at least one year
- supply voltage unbalance at least one week
- harmonic voltages at least one week
- interharmonic voltages at least one week
- signaling voltage at least one day

Types of instruments

- digital multimeters
- scope meter
- portable PQ analyzer
- industrial Monitoring Systems
- long term PQ Monitors

Example: True RMS digital multimeter

- key features
  - min-max-average recording
  - manual and automatic ranging
  - display hold and auto hold
  - true RMS measurements
- application
  - utilized for Handheld
  - voltage, current, and frequency measurements
Example: ScopeMeter

- portable scope
- frequency
  spectrum analysis
  using FFT
- waveform
  reference for visual
  comparisons and
  automatic pass/fail
  testing of
  waveforms

Example: Power quality analyzer

- three-phase Power
  Quality recorder
- fully class-A compliant
- GPS time
  synchronization
- flexible and fully
  configurable thresholds
  and scale factors
- 10 MHz, 6000 Vpk
  waveform capture
- comprehensive software

Permanent PQ monitoring

- same performance as portable analyzers
- high performance communications options
  - client-server architecture
  - modem or network interface
- functional as
  - standalone, portable applications
  - network, permanent installations
- windows PC software
Monitoring instruments for systems

- PQ Monitors
- digital fault recorders
- voltage recorders
- industrial monitoring systems
- meters
- http://www.pqmonitoring.com

Signature System - Web-based PQ monitoring

Database of PQ monitoring data
Data analysis - 1

• executive summary
• system description
• summary of monitoring results
• evaluation of problems
  – dips and interruptions
  – harmonics
  – power factor correction
  – capacitor switching transients
  – wiring and grounding problems
• disturbance recording form

Data analysis - 2

• analysis of measurement results
  – presentation of results according to SIST EN 50160
  – comparison of measurement results with limit values
    • graphical presentation

Data analysis - 3

• analysis of measurement results
  – comparison of measurement results with limit values
    • presentation in table
Data analysis - 4

• detailed analysis of critical measured values
  • correlations with current values
    - correlation of voltage dips and flicker with current values enables determination of disturbance origin
  • comparison of results from different locations
    - determination of harmonic sources
  • additional studies
    - mathematical analysis
    - simulation
  • main goal is to find origin/location of disturbance

What do we get from PQ Monitoring - 1

• information to evaluate impacts of power quality variations on production process
• information to optimize power conditioning investments
• information to develop better equipment specifications
• information for contracts with electric utility
• information to flag possible equipment problems (motors, transformers, breakers, filters, surge suppressors, UPS equipment, etc.)
What do we get from PQ Monitoring - 3

- change in customer perception of utility service quality
- utilities are trying to understand their own individual systems
- contracts which include power quality considerations include monitoring requirements
- accurate performance data is basis for economic evaluation of power quality improvement alternatives
  - system and customer side solutions