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Demand side power quality management

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National foreword

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TECHNICAL REPORT

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Demand side power quality management

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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DEMAND SIDE POWER QUALITY MANAGEMENT

FOREWORD

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IEC TR 63191, which is a Technical Report, has been prepared by IEC technical committee 85: Measuring equipment for electrical and electromagnetic quantities.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
85/640/DTR	85/647/RVDTR

Full information on the voting for the approval of this Technical Report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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INTRODUCTION

The effective management of power quality on the demand side (power consumer) is an essential activity to ensure the proper operation of the electrical equipment operating on the consumer site.

While the level of power quality present at the point of supply is generally monitored, and managed by the power provider (utility), the actual level of power disturbances present on the consumer site could be significantly worse and may negatively impact the operation of the electrical equipment. The interaction between these loads and the voltage supply is often the cause of degraded power quality on the demand side.

One effective step in the prevention of the hindrances caused by power quality is the assessment of the level of power quality disturbance present on the demand side. However, proper measurements require adequate planning and understanding of the measurement systems and their results.

This document provides guidance on how to establish, implement, exploit, maintain and improve a demand side power quality monitoring system. This document will also facilitate the tailoring of power quality monitoring concepts to the specific site where it will be deployed.

Disturbances in the electrical energy can have an important impact on the equipment, processes, organization's activities and environment. Some electrical installations (industrial sites, data centres, hospitals, etc.) are particularly impacted by the poor quality of electrical energy.

The quality of the electrical energy has different origins, impacts and measurement indicators on the supply side and on the demand side – see Figure 1 presenting an overview of the electrical network from generation (supply side) to consumer (demand side).

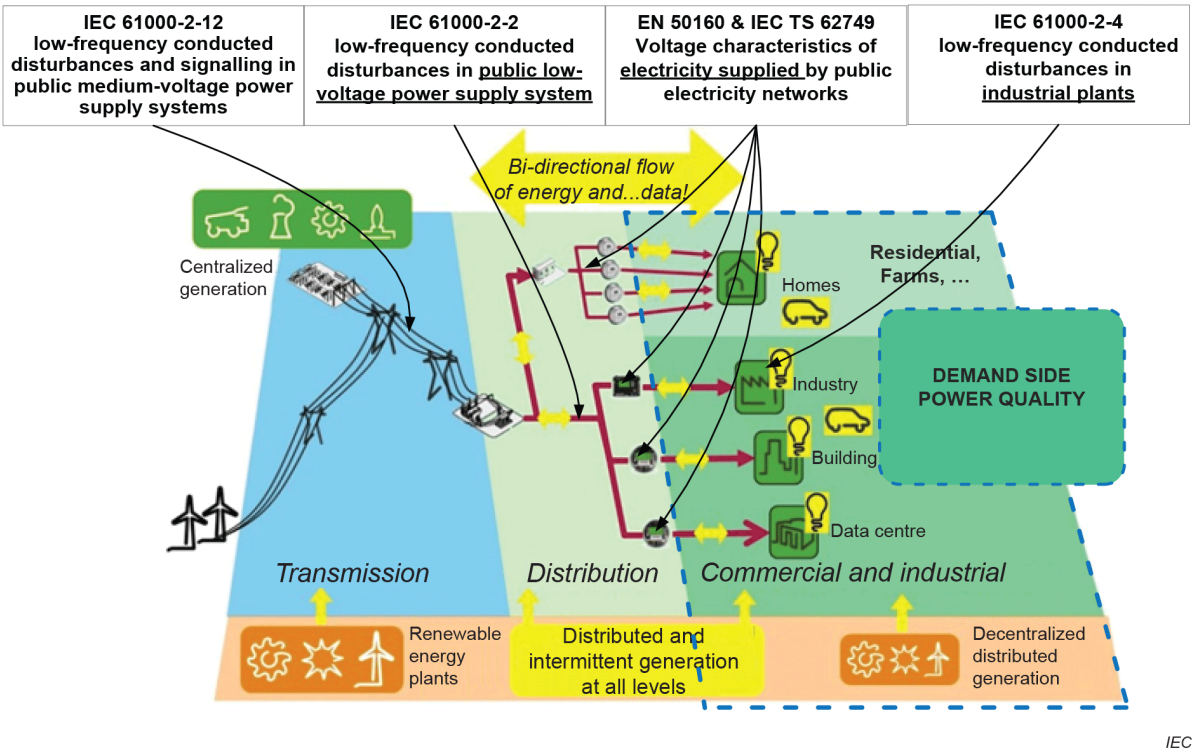

Figure 1 – Overview of electrical distribution system from supply side to demand side

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While documents such as IEC TS 62749 or EN 50160 define the voltage characteristics provided by a public network (called power quality of the grid), this document gives guidance for qualifying the electrical quality of internal networks including voltage and current disturbances (called demand side power quality).

In this document, power quality on the demand side, related to buildings, industrial and data centres applications is referred to as demand side power quality (DSPQ).

See Annex D for a general statement on demand side power quality.

See Annex E for a discussion about grid evolution.

See Annex F for a list of standards related to demand side power quality.

See Annex G for definition of electrical parameters.

It is recommended that readers possess a minimum knowledge of power quality phenomena.

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DEMAND SIDE POWER QUALITY MANAGEMENT

1 Scope

This document specifies recommendations about power quality measurement and assessment within installations.

NOTE 1 Most standards take care of power quality at the delivery point between energy providers and customers.

This document outlines the various phases needed for the establishment of a demand side power quality measurement plan for buildings and industry installations.

NOTE 2 The demand side is defined as the electrical installation, beyond the PCC (point of common coupling), which is under the jurisdiction of facility managers.

Such a power quality measurement plan will enable the optimization of the energy availability and efficiency, improve the assets lifetime and facilitate the resolutions of power quality problems. A power quality measurement plan encompasses the following stages:

- definition of the context, objectives and constraints;
- assessment of the initial power quality situation;
- definition of an action plan for the improvement of the power quality situation;
- implementation of the power quality measuring system;
- exploitation of the measurement system for the improvement of the power quality situation;
- maintenance of the measurement system.

This document will also help facility managers to tailor their measurement plan to the specific needs of the electrical system under their control. It addresses all the disturbances present in such networks, but does not cover the disturbances present in public electrical distribution networks (supply side) as they are governed by specific documents such as EN 50160 and IEC TS 62749.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
demand side
part of the grid where electric energy is consumed by end-use customers within their electric distribution system

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3.2
DSPQ
demand side power quality
characteristics of the electric current, voltage and frequencies at a given point in an electric distribution system located on the demand side, evaluated against a set of reference technical parameters

3.3
IPC
in-plant point of coupling
point on a network inside a system or an installation, electrically nearest to a particular load, at which other loads are, or could be, connected

Note 1 to entry: The IPC is usually the point for which electromagnetic compatibility is to be considered.

3.4
PCC
point of common coupling
point of a power supply network, electrically nearest to a particular load, at which other loads are, or may be, connected

3.5
flicker
impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time

3.6
interruption
reduction of the voltage at a point in the electrical system below the interruption threshold

3.7
interruption threshold
voltage magnitude specified for the purpose of detecting the start and the end of a voltage interruption

3.8
voltage dip
voltage sag
temporary reduction of the voltage magnitude at a point in the electrical system below a threshold

Note 1 to entry: Interruptions are a special case of a voltage dip. Post-processing may be used to distinguish between voltage dips and interruptions.

Note 2 to entry: A voltage dip is also referred to as voltage sag. The two terms are considered as interchangeable; however, this document uses only the term "voltage dip".

3.9
voltage swell
temporary increase of the voltage magnitude at a point in the electrical system above a threshold

3.10
voltage unbalance
condition in a polyphase system in which the RMS values of the line voltages (fundamental component), and/or the phase angles between consecutive line voltages, are not all equal

Note 1 to entry: The degree of the inequality is usually expressed as the ratios of the negative- and zero-sequence components to the positive-sequence component.

Note 2 to entry: In this document, voltage unbalance is considered in relation to 3-phase systems.

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[SOURCE: IEC 60050-161:1990, 161-08-09, modified – "phase voltages" has been replaced with "line voltages (fundamental component)", "consecutive phases" has been replaced with "consecutive line voltages" and the notes have been added.]

3.11
transient overvoltage
short-duration overvoltage of few milliseconds or less, oscillatory or non-oscillatory, usually highly damped

3.12
power quality
PQ
characteristics of the electricity at a given point on an electrical system, evaluated against a set of reference technical parameters

Note 1 to entry: These parameters might, in some cases, relate to the compatibility between electricity supplied on a network and the loads connected to that network.

3.13
mesh
group of electrical equipment powered from one or more circuits of the electrical installation for one or more zones including one or more services for the purpose of electrical energy efficiency or demand side power quality

[SOURCE: IEC 60364-8-1:2014, 3.1.8, modified – "or demand side power quality" has been added.]

3.14
supraharmonics
disturbances in the range 2 kHz to 150 kHz

3.15
power metering and monitoring device
PMD
combination in one or more devices of several functional modules dedicated to metering and monitoring electrical parameters in energy distribution systems or electrical installations, used for applications such as energy efficiency, power monitoring and network performance

Note 1 to entry: Under the generic term “monitoring” are also included functions of recording, alarm management, etc.

Note 2 to entry: These devices may include demand side quality functions for monitoring inside commercial/industrial installations.

[SOURCE: IEC 61557-12:2007, modified – In the term and definition, "measuring" has been replaced with "metering".]

3.16
power quality instrument
PQI
instrument whose main function is to measure, record and possibly monitor power quality parameters in power supply systems, and whose measuring methods (class A or class S) are defined in IEC 61000-4-30

[SOURCE: IEC 62586-1:2017, 3.1.1]

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3.17
total harmonic ratio
total harmonic distortion
THD
ratio of the RMS value of the harmonic content to the RMS value of the fundamental component or the reference fundamental component of an alternating quantity

Note 1 to entry: The total harmonic ratio depends on the choice of the fundamental component. If it is not clear from the context which one is used an indication should be given.

Note 2 to entry: The total harmonic ratio may be restricted to a certain harmonic order. This is to be stated.

[SOURCE: IEC 60050-551:2001, 551-20-13]

4 Phases of a measurement plan

4.1 Six-phase measurement plan

Clause 4 defines the recommendations for the design and implementation of a demand side power quality measurement plan for an organization.

The plan describes the methodology to put in place a measurement system to monitor the installation from defining the context to maintaining the measurement system (see Figure 2).

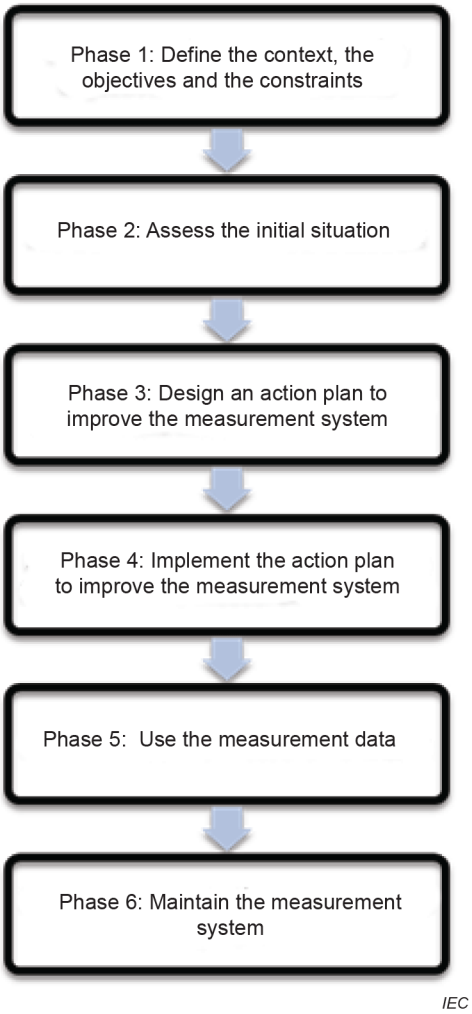

Figure 2 – Six-phase measurement plan

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4.2 Phase 1: Define the context, the objectives and the constraints

4.2.1 Goal of phase 1

- Ensure that the motivations, implications and objectives of the organization are clearly defined.
- Ensure that the organizational, technical and financial context will allow the creation and maintenance of a demand side power quality (DSPQ) improvement plan.

4.2.2 Context of the DSPQ improvement plan

Today, an organization wishing to deploy a DSPQ improvement plan faces a number of obstacles, including:

- the design of the plan, defining its content and its boundaries according to the needs and targeted objective;
- the evaluation of the cost/benefits of implementing the plan, supporting the decision;
- the technical difficulties associated with the implementation of the plan.

4.2.3 Motivations of the organization

Mainly to increase its economic competitiveness, quality of services and data security, the organization may design its DSPQ improvement plan according to its objectives, for example:

- ensure the energy availability by minimizing the risk of unwanted tripping and black out;
- avoid supplier penalties;
- avoid deterioration of materials and reduction of their lifetime;
- improve the energy efficiency of installations.

4.2.4 Boundaries of the DSPQ improvement plan

The organization defines the boundaries of the DSPQ improvement plan, and more specifically the sites, the zones, the relevant sources and loads.

See Annex A.

4.2.5 Stakeholders of the plan

The organization may identify the specific needs of each type of user of a DSPQ improvement plan which are as follows.

- Senior management: defines the organization objectives relative to energy management in general and energy measurement in particular, including the budget and priorities.
- Technical director: allocates the resources within the facility and reports on the results. The technical director is capable of evaluating the targeted objectives and those actually achieved, in both energy performance and financial terms.
- Operating and maintenance personnel: tasked with using the measurement system to check and ensure efficient operation by taking corrective measures in the event of deviations in energy performance, by eliminating waste and performing preventive maintenance to reduce deterioration in energy performance. The operating and maintenance personnel can use the measurement system for the process or the equipment under their responsibility.
- Energy manager: provides expertise related to energy management, at site or organizational level. The DSPQ improvement plan is one of the tools the energy manager uses to implement an efficient energy management system. The energy manager is responsible for making sure the scope of measured data is consistent with energy management objectives.

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- Installers and system integrators: are responsible for the setup of the measurement and monitoring system. They need to make sure the measurement system is working as expected by the DSPQ improvement plan. They may be internal or external.
- Other external stakeholders: these users can include regulating organizations, service providers, customers, suppliers, architects, facility managers or other organizations.

4.2.6 Budget

The organization defines the budget allocated to the DSPQ improvement plan according to its objectives.

4.2.7 Planning

The DSPQ improvement plan may be implemented in phases according to priorities in order to meet the organization's budgetary constraints.

The organization puts in place a schedule for the implementation of the DSPQ improvement plan. It may indicate the most important milestones of the project.

4.2.8 Resources

The organization identifies the human and material resources necessary for the various phases in the implementation of the DSPQ improvement plan:

- study;
- installation;
- measurement;
- acquisition system or resources necessary for manual reading if necessary;
- processing and interpretation of power quality data consolidation and presentation of data;

  NOTE An external service provider can be necessary to achieve this task.
- maintenance.

The organization clearly identifies a person responsible for the DSPQ improvement plan and ensures that the person is competent and available.

The organization should identify and verify the skills necessary for the application of the DSPQ improvement plan by its personnel or its service providers.

4.2.9 Levels of the measurement system

The organization assesses the appropriateness of its measurement system linked to the DSPQ improvement plan with respect to its needs. The six assessment criteria are:

- the ability to quantify the energy quality by site, by zone or by source and relevant loads;
- the ability to take readings from the quality points at regular intervals;
- the ability to quantify the influencing factors that affect the DSPQ;
- the ability to monitor the installation;
- the ability to view, understand and analyse the DSPQ.

4.2.10 Deliverables for phase 1

The organization provides a note summarizing its objectives and its constraints, the organizational structure adopted and the implementation schedule and budgets allocated to the DSPQ improvement plan.

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4.3 Phase 2: Assess the initial situation

4.3.1 Goal of phase 2

- Gather the needs and identify the data to be collected.
- Establish a technical inventory (the available data and equipment).

4.3.2 Preliminary analysis

The organization defines the initial level of power quality by analysing:

- its existing measurement system;
- the energy invoices (for supplier penalties) and contracts;
- the deliverables of a power quality or energy audit;
- electrical mapping and characteristics of the installation and equipment;
- site specifications (use, architecture, neighbourhood, etc.).

4.3.3 Critical and disruptive loads

The organization identifies the critical and disruptive loads relating to power quality, such as:

- power conversion equipment;
- motors starters;
- IT equipment;
- welders;
- switching equipment.

4.3.4 Zones

The organization determines the relevant zones relating to disruptive loads:

- workshops, production lines;
- offices, IT rooms.

4.3.5 Relevant variables

The organization identifies the factors influencing the DSPQ:

- quantity of disruptive equipment;
- quality of the energy delivered by utilities;

  NOTE In Europe, utilities deliver electrical energy according to the quality level defined in EN 50160.
- type of system used (TT, TN, etc.);
- local production of energy;
- disruptive neighbourhoods sites.

According to these factors, the organization has to monitor and analyse the relevant variable. Power quality variables and their impact are defined in Clause 5, especially under the different “Key parameters to measure” subclauses.

4.3.6 Existing measuring devices

The organization draws up an inventory of the existing measuring devices for each installation.

Equipment should comply with their product standard, such as:

- power quality instruments (PQI): IEC 62586-1;

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- power metering and monitoring devices (PMD): IEC 61557-12.

NOTE Devices providing measuring functions which comply with IEC 61000-4-30 and tested in accordance with IEC 62586-2 provide matching results (class A or class S).

4.3.7 Data reading and storage

For each quantity measured, the organization determines the reading (automatic or manual) and storage aids already used by the installation. The organization should analyse the appropriateness of the acquisition system (choice and coherence of reading frequencies between the measuring devices) and of storage in relation to its objectives, in accordance with Table 1.

Table 1 – Example of overview of the readings and storage carried out

Measuring point	Location	Measured parameter	Reading method (manual / automatic)	Measurement frequency	For PQI class: class A or class S For PMD type: performance class	Repository system (e.g. spreadsheet, database)
PQI N°1						
PQI N°2						
PMD N°1						
…						

The organization should pay attention to the quality of the data and establish criteria to evaluate the quality of the data.

4.3.8 Deliverables for phase 2

The organization should establish a mapping of the existing installations within the analysis perimeter, identifying the data acquisition and utilization systems. The organization should provide an analysis of the defective elements on the DSPQ or elements that needs supplementing with respect to its objectives.

4.4 Phase 3: Design an action plan to improve the measurement system

4.4.1 Goal of phase 3

Define the actions to undertake under the DSPQ improvement plan to achieve the organization's objectives.

4.4.2 Proposal of improvement actions

To achieve its objectives, the organization implements actions aiming to improve the DSPQ.

To measure the relevant variables, power quality events need long term analysis, so it is recommended to use fixed installed equipment. However, for short periods of time on a targeted zone, portative equipment can be used to analyse the power quality.

Equipment should comply with their product standard, such as:

- power quality instruments (PQI): IEC 62586-1 and IEC 62586-2;
- performance measuring and monitoring devices (PMD): IEC 61557-12.

NOTE Devices providing measuring functions which comply with IEC 61000-4-30 and tested in accordance with IEC 62586-2 provide matching results (class A or class S).

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Some guidance to improve DSPQ is given in Clause 5.

4.4.3 Prioritize the actions

One of the proposed actions is to prioritize the installation of measuring equipment on disruptive equipment (if requested by mitigation measures defined in Clause 5).

Annex B provides the state of the art related to disturbance levels on the DSPQ. The organization should use Annex B to define, on the relevant identified variables, the different levels of quality (low disturbance, medium disturbance or high disturbance).

According to these levels, Annex B provides the state of the art related to disturbance levels according to profiles. Thus, it is possible to determine which variables and factors are the most important to treat and prioritize actions accordingly.

4.4.4 Periodic review of the action plan

The organization can, depending on its objectives, priorities and overall budget, define a plan of actions that is graduated over time.

The organization conducts a periodic review of its plan of actions and readjusts it according to the objectives and the results obtained. This review can be carried out as part of the energy management system review.

4.4.5 Deliverables for phase 3

The organization establishes a DSPQ improvement plan with identified actions, implementation priorities, time-frame and agenda.

4.5 Phase 4: Implement the action plan to improve the measurement system

4.5.1 Goal of phase 4

- Ensure the implementation of actions according to the planning and dedicated resources.
- Respect the state of the art regarding equipment installation.

4.5.2 Documentation related to measurement equipment implementation

Manufacturer's documentation has to be read, followed and stored for further use.

Certificates for measurement equipment and for periodical verification are recommended.

4.5.3 Installation and commissioning of measurement equipment

Installations rules in the manufacturer's documentation and installation standards should be followed.

Some equipment needs to be installed and commissioned by the installer or the manufacturer. In this case, the cost of installation has to be taken into account in the budget allocation (in case mitigation measures defined in Clause 5 request installation of devices).

4.5.4 Deliverables for phase 4

Report on the installation (wiring, sensors implementation, etc.) and functioning (sensor ratio configuration, phases ordering, etc.) of the measuring equipment.

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4.6 Phase 5: Use the measurement data

4.6.1 Goal of phase 5

- Check the relevance of the implemented actions aiming to improve the DSPQ.
- Identify new actions of DSPQ improvement.
- Identify new factors or sources of disturbance of the DSPQ.

4.6.2 Storage of power quality data

The measurement data should be stored, so that it can be retrieved and used easily. The frequency and method of uploading to the database (manual or automatic) should be appropriate for the users' needs (including performance) and the targets of the organization.

The organization should define a minimum retention period for the data, in accordance with legal or other requirements. The organization should define a maximum retention period, a backup strategy and an aggregation strategy for the data, to ensure the long-term usability of the system.

The organization should check the quality of the measurement data provided by the measurement system. When corrections are made to the measurements, the organization should identify that they have undergone a retrospective modification (date and nature of change, possibly the modification originator).

4.6.3 Analysis of power quality data

Classify the power quality measurements according to Annex B.

It is important to determine relevant indicators between initial and measured data in order to define the relevance of implemented actions.

It is important to ensure that the analysis of power quality data is achieved by competent people.

If no internal competencies exist, power quality data could be analysed by external experts or by the equipment manufacturers.

4.6.4 Dissemination and protection of power quality data

This data has to be shared with interested and skilled people inside the organization.

4.6.5 Deliverables for phase 5

Report power quality measurement in order to establish an improvement plan.

4.7 Phase 6: Maintain the measurement system

4.7.1 Goal of phase 6

Ensure the sustainability and the accuracy of the measurement system.

4.7.2 Verification of the measurement system

The measurement system should be verified in accordance with the recommendations given by the manufacturer of the equipment.

4.7.3 Metrological maintenance and monitoring

Instruments need to be verified according to the manufacturer's specifications.

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4.7.4 Deliverables for phase 6

Maintenance planning for the measurement devices and maintenance report.

Devices firmwares and softwares can be updated.

The system has to stay operational and calibrated to ensure the power quality data collected are reliable.

5 Demand side power quality disturbances and their impact

5.1 General

Clause 5 intends to provide origin, effect, mitigation and key parameters related to power quality disturbances, in AC distribution networks, on the demand side.

Further information is provided in Annex C.

See Table 2, Table 3 and Table 4.

An attempt to provide similar information for DC networks is provided in Annex H.

Table 2 – Classification of PQ phenomena

Continuous phenomena
• Long-term frequency variations
• Long-term voltage variations
• Voltage/current unbalance
• Flicker
• Voltage/current harmonics and interharmonics, including supraharmonics
Events
• Supply voltage dips and interruptions
• Supply voltage swells
• Transient overvoltage
• Rapid voltage changes

Table 3 – Origins of PQ problems

Supply side	Demand side
Frequency variations	Current harmonics and interharmonics
Voltage variations	Current unbalance
Voltage harmonics and interharmonics	Reactive power
Voltage unbalance	Neutral currents
	Rapid voltage changes
Supply voltage dips, swells, interruptions	
Flicker	
Voltage transients	

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Table 4 – Impacts of PQ problems on consumers, manufacturers and utilities

Financial losses due to	Interruption of processes
	Equipment damage and/or aging
	Production loss
	Waste of raw material
	Loss of data
	Increased losses in electrical equipment and distribution system
	Disturbance and interference to electronics appliances and communication networks
	Malfunctioning of protection relays

5.2 Frequency deviation

5.2.1 Origins

Frequency deviation is caused by an unbalance between the generated capacity and the connected loads.

Frequency deviations are limited in amplitude in stable interconnected utility grid.

However, it is possible to experience significant frequency deviations in case of poor power infrastructure or when the sites have their own local power production and operate independently from the grid.

The frequency deviation results from the source (generator or inverter in case of renewable energy production) and its control system.

5.2.2 Effects

5.2.2.1 Effects on motors

Three-phase induction motors are designed to operate most efficiently at their rated frequency. A significant frequency drift may cause a motor to run faster or slower to match the frequency of the input power. This would cause the motor to run inefficiently and/or lead to overheating and motor attrition.

5.2.2.2 Effects on IT equipment

IT equipment is frequency tolerant, and generally not affected by minor frequency shifts. However, significant frequency deviation may lead to erratic operation, data loss and system crashes.

5.2.2.3 Effects on other equipment

Important frequency variations may affect the operation of other equipment within the installation such as transformers, capacitors and active filters.

5.2.3 Possible mitigation measures

To mitigate frequency deviation, all power sources and their control systems should be assessed, and then corrected.

5.2.4 Key parameters to measure

Power frequency.

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5.3 Magnitude of supply voltage: deviation, underdeviations, overdeviations

5.3.1 Origins

The values of nominal voltage specified in IEC 60038 are mainly based on the historical development of electrical supply systems throughout the world, since these values turned out to be the most common ones, and have achieved worldwide recognition. The voltage ranges mentioned in IEC 60038 have been recognized to be the most appropriate ones as a basis for design and testing of electrical equipment and systems. As part of the energy transition, there is an increasing supply of renewable energy at all voltage levels. When feeding at the highest voltage level (e.g. by large wind farms), this occasionally caused bottlenecks of network capacity, but voltage control is more difficult in particular by feed-in medium and low voltage networks. These networks have been designed as pure distribution networks and essential feeds were not provided. The main problem is the fluctuating nature of the feeds of wind turbines. Each country has requirements on nominal values and tolerances. IEC 61010-1:2010, Annex I provides relevant information on most common mains systems.

5.3.2 Effects

5.3.2.1 General effects

In general, the lifetime of products will decrease with voltage overdeviations.

5.3.2.2 Effects on motors

Deviations above or below a motor's rated nameplate voltage will have a detrimental effect on induction motors. Figure 3 illustrates the effects of typical motor characteristics as a motor's terminal voltage is increased or decreased from its rated voltage.

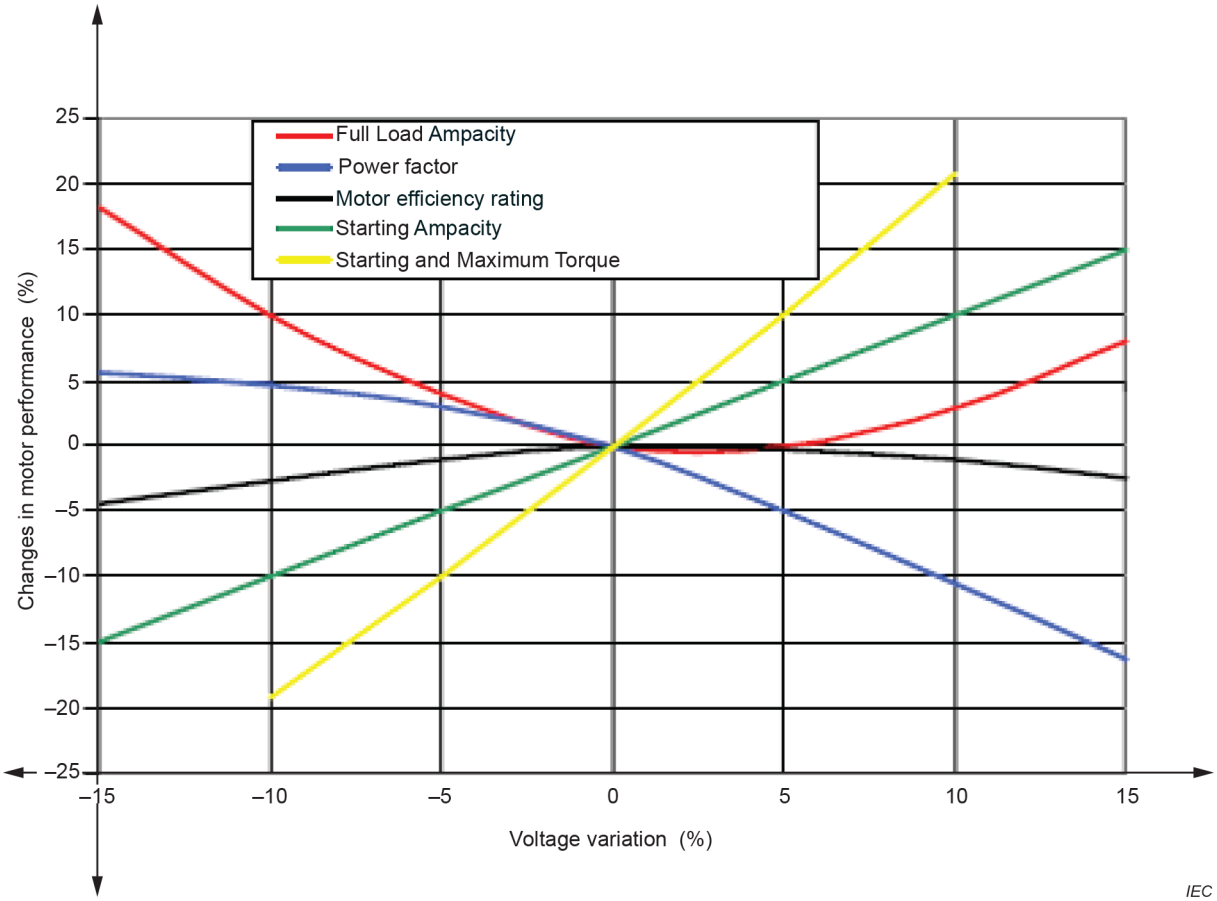

Figure 3 – Effects of voltage deviation on a motor

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