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TECHNICAL REPORT

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Power quality management –
Part 100: Impact of power quality issues on electric equipment and power system

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POWER QUALITY MANAGEMENT –

Part 100: Impact of power quality issues on electrical equipment and power system

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IEC TR 63222-100 has been prepared by IEC technical committee 8: System aspects of electrical energy supply. It is a Technical Report.

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

Draft	Report on voting
8/1648/DTR	8/1660/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 63222 series, published under the general title *Power quality management*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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INTRODUCTION

The impacts of power quality issues increasingly attract much attention with modern industrial development. The integration of nonlinear loads, such as power-electronic based equipment, electric arc furnace, electric locomotive, etc., and faults or other events such as short-circuit and lightning strikes directly or indirectly cause power quality issues.

If public supply system power quality is not within the reasonable range defined in IEC TS 62749, and/or the demand-side power quality is not appropriately managed (e.g. IEC TR 63191) and/or the equipment immunity does not accommodate the expected environment, the performance of equipment may be impacted, likely causing malfunction, maloperation, or damage, and likewise the power system itself.

On the other hand, the quality of power is not absolute. Regarding the levels of power quality, the situation differs. So called “poor” power quality level for one grid may be acceptable or good for another internal application depending on the system configuration, the transfer characteristics between the different voltage levels (attenuation or amplification), the immunity of the equipment /installations/appliances, the actual disturbance levels on the system, etc.

In terms of power quality, the situation in micro-grid on islanding mode, off grid, mini-grid or weak grid may differ from that in public supply system. The level of power quality may worsen even far outside the recommended values defined by IEC TS 62749. In those forementioned grids, appliances may need to be better designed for immunity to power quality issues.

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This document, which is a Technical Report, collects relevant information on power quality impact from, e.g., CIGRE reports, case study, research findings, etc., in order to uncover the mechanism of how electrical equipment/installations are impacted under specific power quality condition, as well as to fully understand the reasons of power quality management.

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This document focuses on the public supply system. Notionally, the mechanisms of how electrical equipment/installations/system are impacted by power quality disturbances are applicable for so-called weak grids.

The contents of this document can help network users and equipment suppliers make rational investments and actively cooperate with network operators to take specific measures to improve power quality.

The contents of this document can also support IEC TR 63222-101, namely, power quality management-power quality data applications.

POWER QUALITY MANAGEMENT –

Part 100: Impact of power quality issues on electrical equipment and power system

1 Scope

This part of IEC 63222, which is a Technical Report, collects relevant information on power quality impacts from, e.g., CIGRE reports, case studies, research findings, etc., in order to uncover the mechanisms of how electrical equipment/installations/system are impacted by power quality disturbances, as well as to fully understand the guidelines for power quality management.

The contents of this document aim to help network operators, network users and equipment suppliers make rational investments and actively cooperate to manage power quality and keep it consistent with relevant EMC standards.

NOTE 1 The boundaries between the various voltage levels may be different for different countries/regions. In the context of this document, the following terms for system voltage are used:

- low voltage (LV) refers to $U_N \leq 1$ kV
- medium voltage (MV) refers to 1 kV < $U_N \leq 35$ kV
- high voltage (HV) refers to 35 kV < $U_N \leq 230$ kV

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NOTE 2 Because of existing network structures, in some countries/regions, the boundary between medium and high voltage can be different.

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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 terminology databases for use in standardization at the following addresses:

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

3.1
electricity
set of phenomena associated with electric charges and electric currents

Note 1 to entry: In the context of electric power systems, electricity is often described as a product with particular characteristics.

[SOURCE: IEC 60050-121:1998, 121-11-76]

3.2
flicker
impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time

[SOURCE: IEC 60050-161:1990, 161-08-13]

3.3
frequency deviation
difference between power supply frequency ($f_{h,1}$) and nominal frequency (f_n)

[SOURCE: IEC 60050-614:1990, 614-01-10, modified]

3.4
harmonic frequency
$f_{H,h}$ (abbreviation)
the frequency which is an integer multiple of the power supply (fundamental) frequency

[SOURCE: IEC 61000-4-7:2009, 3.2.1, modified (removal of formula and Note to entry)]

3.5
Harmonic order
h (abbreviation)
(Integer) the ratio of a harmonic frequency ($f_{H,h}$) to the power supply frequency ($f_{H,1}$)

[SOURCE: IEC 60050-161:1990, 161-02-19, modified]

3.6
System operator
network operator
the party responsible for safe and reliable operation of a part of the electric power system in a certain area and for connection to other parts of the electric power system

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[SOURCE: IEC 60050-617:2009, 617-02-09]

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3.7
nominal frequency
f_N (abbreviation)
value of frequency used to designate or identify a system

3.8
nominal voltage (of a system)
U_N (abbreviation)
value of voltage used to designate or identify a system

[SOURCE: IEC 60050-601:1985, 601-01-21, modified (addition of abbreviation, removal of "suitable approximate" from the beginning of definition)]

3.9
point of common coupling
PCC (abbreviation)
point in a public power supply network, electrically nearest to a particular load, at which other loads are or may be connected

Note 1 to entry: These loads can be either device, equipment or systems, or distinct network user's installations.

[SOURCE: IEC 60050-161:1990, 161-07-15, modified ("consumer's installation" replaced by "load")]

3.10
supply terminals
point of supply
point in a distribution network designated as such and contractually fixed, at which electric energy is exchanged between contractual partners

Note 1 to entry: Supply terminals may be different from the boundary between the electricity supply system and the user's own installation or from the metering point.

[SOURCE: IEC 60050-617:2009, 617-04-02, modified Note 1 to entry]

3.11
(power) network user
party supplying electric power and energy to, or being supplied with electric power and energy from, a transmission system or a distribution system

[SOURCE: IEC 60050-617:2009, 617-02-07]

3.12
power quality
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.

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Note 2 to entry: In the context of this Technical Specification, power quality refers to supply terminals and focuses on defining the characteristics of the voltage and frequency.

[SOURCE: IEC 60050-617:2009, 617-01-05, modified ("electric current, voltage and frequencies" replaced by "electricity" and Note 2 to entry added)]

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3.13
rapid voltage change
RVC (abbreviation)
quick transition (that may last more than several cycles) in RMS voltage between two steady-state conditions while the voltage stays in-between the thresholds defined for voltage swells and dips (otherwise, it would be considered as a swell or a dip)

Note 1 to entry: For more information, see IEC 61000-4-30.

3.14
transient over-voltage
voltage surge
transient voltage wave propagating along a line or a circuit and characterized by a rapid increase followed by a slighter decrease of the voltage

[SOURCE: IEC 60050-161:1990, 161-08-11]

3.15
voltage deviation
difference between supply voltage (U) and nominal voltage (U_N), often expressed by relative value

Note 1 to entry: In some circumstance, U_N may be replaced by U_C by contract or agreement.

3.16
voltage dip
sudden reduction of the voltage at a point in an electrical system followed by voltage recovery after a short period of time, usually from a few cycles to a few seconds

Note 1 to entry: The starting threshold of voltage dip generally is 90 % of the reference voltage.

[SOURCE: IEC 60050-161:1990, 161-08-10, modified (addition of Note 1 to entry)]

3.17
voltage fluctuation
series of voltage changes or a cyclic variation of the supply voltage envelope

Note 1 to entry: For the purpose of this document, the reference voltage is the nominal or declared voltage of the supply system.

[SOURCE: IEC 60050-161:1990, 161-08-05, modified (addition of "supply voltage" and Note 1 to entry)]

3.18
voltage swell
sudden increase of the voltage at a point in an electrical system followed by voltage recovery after a short period of time, usually from a few cycles to a few seconds

Note 1 to entry: The starting threshold of voltage swell generally is 110 % of reference voltage.

3.19
voltage unbalance
in a poly-phase system, a condition in which the magnitudes of the phase voltages or the phase angles between consecutive phases are not all equal (fundamental component)

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[SOURCE: IEC 60050-161:1990, 161-08-09, modified ("RMS values" replaced by "magnitudes")]

3.20
voltage unbalance factor
in a three-phase system, the degree of unbalance is expressed by the ratio (in per cent) between the RMS values of the negative sequence (or, rarely, of the zero-sequence) component and the positive sequence component of voltage

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[SOURCE: IEC 60050-604:1987, 604-01-30, modified (addition of "voltage" to term)]

4 General impacts of power quality issues

4.1 General

Generally, for electrical equipment exposing under continuous power quality phenomenon disturbances, the impacts of long-time accumulated effects may be the key aspect, while immediate impact may arise in case of events of discontinuous power quality phenomenon, e.g., voltage dip/swell/short time interruption.

IEC TS 62749:2020, Annex C describes the general impacts of power quality issues. This clause refers to IEC TS 62749:2020, Annex C.

4.2 Harmonic distortion

Generally, harmonic impacts due to long-time accumulated effects are often of concern , but harmonic resonance will lead to harmonic over-voltage which will lead to harmonic over-voltage which produces dielectric stress of electrical equipment, and even causes dielectric breakdown.

- Capacitors for power factor correction often act as sinks for a particular order of harmonic currents. In this case, it can lead to capacitor over current if no forethought is given at the designing stage.
- Non-sinusoidal power supplies result in the reduction of torque of induction motors.

- Harmonics will increase interference with telephone, communicating and analogue circuits.
- Excessive levels of harmonics can cause errors in the reading of induction type energy meters which are calibrated for pure sinusoidal AC power.
- High-order harmonics cause voltage stresses.
- Harmonic currents flowing through power system networks can cause additional losses.

It is reported that the level of inter-harmonics in power supply systems is increasing due to the development of frequency converters and similar electronically controlled equipment. Harmonic voltages and inter-harmonic voltages, if not controlled, might lead (among other effects) to overloading or disturbance of equipment on the supply networks and in electricity users 'installations.

In some cases, inter-harmonic voltages, even at low levels, can give rise to flicker or cause interference in ripple control systems.

4.3 Voltage unbalance

Voltage unbalance is always a concern as it affects the transformers, electrical motors, electrical generators, transmission losses and relay protection.

- Voltage unbalance degrades the performance and shortens the life of a three-phase motor.
- Current unbalance caused by voltage unbalance essentially creates counter-torque (resisting torque). That is, it tries to make the motor turn in the opposite direction. This may create heating.
- Voltage unbalance may also reduce the capacity of equipment such as motors or generators if not properly taken into consideration at the design stage (equipment is normally designed and rated to account for some degree of voltage unbalance normally present in any power system).
- Voltage unbalance causes distance protection and negative-sequence protection to malfunction, which may result in abnormal starting or even tripping of relay protection.
- Current unbalance caused by voltage unbalance may cause additional losses of distribution lines and cable lines. It may also lead to the shift of neutral point of high voltage side of the transformer.
- Voltage unbalance may increase non-characteristics harmonics produced by converters.
- Voltage unbalance may transfer triple harmonic currents in the transmission system, normally blocked by delta-connected transformer windings.

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4.4 Voltage deviation

Large voltage deviations from the nominal values may shorten the life of electrical equipment, lower the stable limit of the power system, increase the cost of network operation and reduce the output of reactive power compensation. Electrical equipment operating under this condition may malfunction, break down or be damaged.

4.5 Frequency deviation

Frequency deviation will endanger the reliability and stability of power system operation and production efficiency of end-users. The rapid change of frequency will bring great harm to the normal operation of the equipment of units, such as induction motor or feed water pump. The accuracy of the energy meter may be impacted by the frequency deviation. Frequency disturbances in the main network causing local electrical resonance may lead to a large-scale off-grid accident of renewable energy, e.g. sub-synchronous resonance.

If frequency deviation exceeds the limit, motors are usually protected by means of stopping their operation. Sustained operation will alter the speed of motors and potentially create unsafe conditions for the processes in which they function.