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TECHNICAL SPECIFICATION

Microgrids –
Part 3-3: Technical requirements – Self-regulation of dispatchable loads

colour inside

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IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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IEC TS 62898-3-3 has been prepared by subcommittee SC 8B: Decentralized electrical energy systems, of IEC technical committee TC 8: System aspects of electrical energy supply. It is a Technical Specification.

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

Draft	Report on voting
8B/155/DTS	8B/172/RVDTS

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 Specification 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/standardsdev/publications.

A list of all parts in the IEC 62898 series, published under the general title *Microgrids*, 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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

Self-regulation of loads is a phenomenon known very well to transmission system operators, see Annex A. This effect historically emerged from the dynamic behaviour of electric motors that were used to directly power mechanical drivetrains, for example for pumps or air blowers. The higher the rotational speed of the drive, the more active power is used and vice versa. This effect automatically contributes to frequency stabilization without a supervisory control.

There is also a self-regulation effect on the voltage due to resistive loads. At higher voltages, the current through a resistive load increases and therefore the active power consumption increases as well. This increased current also flows through the impedance of the upstream supply network, resulting in a voltage reduction at the load's point of connection and vice versa. This effect helps to stabilise the voltage and is also used indirectly with power system stabilisers (PSS). Modulated system voltage at transmission level is translated to corresponding changes of active power consumption of loads at distribution level which dampen low frequency power oscillations.

This document intends to emulate the above explained beneficial behaviours with dispatchable loads, which do not affect the functionality with regard to the end user, and to make this effect available for frequency and voltage stabilization in microgrids. Dispatchable loads can modify the active power consumption while maintaining their functionality by keeping system parameters within acceptable ranges. This is usually achieved by the use of an internal energy storage, for example thermal energy storage in refrigerators, freezers, air conditioners, water heaters, or electrical energy storage units such as batteries. As the loads respond to the frequency and voltage they experience, no communication channels or complex control systems are necessary to include small loads in the common task of keeping the electric system stable.

MICROGRIDS –

Part 3-3: Technical requirements – Self-regulation of dispatchable loads

1 Scope

This part of IEC 62898 deals with frequency and voltage stabilization of AC microgrids by dispatchable loads, which react autonomously on variations of frequency and voltage with a change in active power consumption. Both 50 Hz and 60 Hz electric power systems are covered. This document gives requirements to emulate the self-regulation effect of loads including synthetic inertia.

The loads recommended for this approach are noncritical loads, this means their power modulation will not significantly affect the user as some kind of energy storage is involved which effectively decouples end energy use from the electricity supply by the electric network. The self-regulation of loads is beneficial both in island mode and grid-connected mode. This document gives the details of the self-regulation behaviour but does not stipulate which loads shall participate in this approach as an optional function.

This document covers both continuously controllable loads with droop control and ON/OFF-switchable loads with staged settings. The scope of this document is limited to loads connected to the voltage level up to 35 kV. Reactive power for voltage stabilization and DC microgrids are excluded in this document.

NOTE 1 If agreed between system operator and grid user, the self-regulating principles outlined in this document can also be applied to loads in other electricity networks, see IEC/ISO Directives, Part 1:2023, C.4.3.2, Example 1.

NOTE 2 According to 3.1.7, critical loads with an electrical energy storage system such as an uninterruptable power supply are considered as noncritical and therefore dispatchable.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Terms, definitions, abbreviated terms and symbols

For the purposes of this document, the following terms, definitions and abbreviated 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 Terms and definitions

3.1.1
accuracy
<of a measuring instrument> quality which characterizes the ability of a measuring instrument to provide an indicated value close to a true value of the measurand

Note 1 to entry: This term is used in the "true value" approach. An updated term using the "uncertainty" approach is in preparation for edition 2 of this document.

Note 2 to entry: Accuracy is all the better when the indicated value is closer to the corresponding true value.

[SOURCE: IEC 60050-311:2001, 311-06-08, modified – Note 1 to entry has been expanded.]

3.1.2
closed-loop control
process whereby one variable quantity, namely the controlled variable is continuously or sequentially measured, compared with another variable quantity, namely the reference variable, and influenced in such a manner as to adjust to the reference variable

Note 1 to entry: Characteristic for closed-loop control is the closed action in which the controlled variable continuously or sequentially influences itself in the action path of the closed loop.

[SOURCE: IEC 60050-351:2013, 351-47-01, modified – Note 2 to entry has been deleted.]

3.1.3
control loop
set of elements or systems incorporated in the closed action of a closed-loop control

[SOURCE: IEC 60050-351:2013, 351-47-11, modified – Note 1 to entry has been deleted.]

3.1.4
damping coefficient
δ
positive quantity δ in the expression $A_0 \mathrm{e}^{-\delta t} f(x)$ of an exponentially damped oscillation, where $f(x)$ is a periodic function

[SOURCE: IEC 60050-103:2009, 103-05-24]

3.1.5
damping ratio
for a linear time-invariant system described by the second order differential equation

$$\frac{\mathrm{d}^2 x}{\mathrm{d}t^2} + 2 \cdot \vartheta \cdot \omega_0 \cdot \frac{\mathrm{d}x}{\mathrm{d}t} + \omega_0^2 \cdot x = 0$$

the value of the coefficient ϑ,

where

t is the time;

x is a state variable of the system;

ω_0 is the characteristic angular frequency of the system

Note 1 to entry: When $\vartheta<1$, $\omega_\mathrm{d} = \omega_0 \cdot \sqrt{1-\vartheta^2}$ is the eigen angular frequency of the system.

[SOURCE: IEC 60050-351:2013, 351-45-19, modified – Note 2 to entry has been deleted.]

3.1.6
dead band
dead zone
finite range of values of the input variable within which a variation of the input variable does not produce any measurable change in the output variable

Note 1 to entry: When this type of characteristic is intentional, it is sometimes called neutral zone.

[SOURCE: IEC 60050-351:2013, 351-45-15, modified – Note 2 to entry has been deleted.]

3.1.7
dispatchable load
noncritical load
load for which the active power consumption can be modified while maintaining the functionality of that load within an acceptable range of parameters

Note 1 to entry: Maintaining the load's functionality is often achieved by use of an internal energy storage.

Note 2 to entry: The use of dispatchability depends on an agreement between grid user and grid operator.

Note 3 to entry: The feature of dispatchability can be made accessible either by self-regulation or remote control.

Note 4 to entry: The reference point for the conformity assessment is the terminal of the load.

3.1.8
droop control
<of dispatchable loads> control loop to control dispatchable loads in such a way that the active power consumption is a function of system frequency, voltage, or both

3.1.9
(electric) island
part of an electric power system that is electrically disconnected from the remainder of the interconnected electric power system but remains energized from the local electric power sources

Note 1 to entry: An electric island can be either the result of the action of automatic protections or the result of a deliberate action.

Note 2 to entry: An electric island can be stable or unstable.

Note 3 to entry: Electric islands can be nested.

[SOURCE: IEC 60050-692:2017, 692-02-11, modified – Note 3 to entry has been added.]

3.1.10
fault ride through
FRT
ability of a load to stay connected during specified faults in the electric power system

3.1.11
(frequency) droop
ratio of the per-unit changes in frequency $(\Delta f)/f_n$ (where f_n is the nominal frequency) to the per-unit change in power $(\Delta P)/P_{ref}$ (where P_{ref} is the reference active power):

$$\sigma = (\Delta f/f_n) / (\Delta P/P_{ref})$$

Note 1 to entry: Frequency droop is f-by-P, whereas the often used characteristic curve is $P(f)$.

Note 2 to entry: The reference active power P_{ref} is either the nominal active power or the present active power.

Note 3 to entry: The same principle can be applied for a voltage droop.

Note 4 to entry: The frequency gradient of a characteristic curve, which describes the power response to frequency, is the active power change per frequency change. In a 50 Hz system, a droop of σ % can be transformed into a gradient g % (in P_n/Hz) by the formula $g = 200/\sigma$; in a 60 Hz system $g = 166,7/\sigma$.

[SOURCE: IEC 60050-603:1986, 603-04-08, modified – The notes have been added, the nominal power has been replaced with reference power, and the specific use <of a set> has been deleted in the term.]

3.1.12
frequency response
for a linear time-invariant system with a sinusoidal input variable in steady state of the output variable the ratio of the phasor of the output variable to the phasor of the corresponding input variable, represented as a function of the angular frequency ω

Note 1 to entry: The frequency response coincides with the transfer function taken on the imaginary axis of the complex plane.

[SOURCE: IEC 60050-351:2013, 351-45-41, modified – Figure 9, Figure 10 and Note 2 to entry have been deleted.]

3.1.13
functional diagram
symbolic representation of the actions in a system by functional blocks, summing points and branching points linked by action lines

Note 1 to entry: The action lines do not necessarily represent physical connections, like electrical wires.

Note 2 to entry: Functional blocks, action lines, summing points, and branching points are elements of the functional diagram.

[SOURCE: IEC 60050-351:2013, 351-44-01, modified – Figure 1, Figure 2 and Note 3 to entry have been deleted.]

3.1.14
hysteresis
phenomenon represented by a characteristic curve which has a branch, called ascending branch, for increasing values of the input variable, and a different branch, called descending branch, for decreasing values of the input variable

SEE: Figure 1.

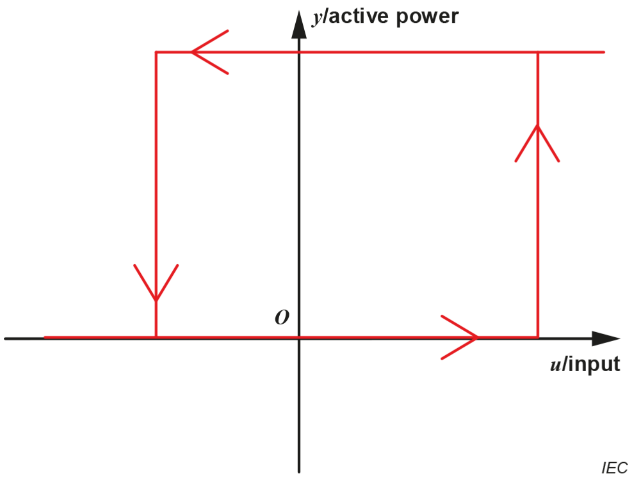


Figure 1 – Hysteresis curve of a switchable load

[SOURCE: IEC 60050-351:2013, 351-45-16, modified – The figure has been added and Note 1 to entry has been deleted.]

3.1.15
hysteresis control
two-state control
control scheme where a device is switched ON when an input variable crosses a threshold value in a given direction, and is switched OFF when the input variable crosses another threshold value in the opposite direction

3.1.16
(hysteresis) width
<of hysteresis control> difference of the input variable between the ON and OFF switching states

3.1.17
immunity
<to a disturbance> ability of a device, equipment or system to perform without degradation in the presence of a voltage or frequency disturbance

3.1.18
inertia,
<in an electric power system> property of a rotating rigid body according to which it maintains its angular velocity in an inertial frame in the absence of an external torque

[SOURCE: IEC 60050-113:2011, 113-03-02, modified –The definition has been modified for the purpose of rotating reference system.]

3.1.19
inertia constant, <of a rotational energy storage>
H
ratio of rotational energy stored at nominal frequency and the nominal power

$H = E_{max} / P_n$

Note 1 to entry: The inertia constant H is half the mechanical starting time T_m.

3.1.20
low-pass filter
filter having a single pass band below a cut-off frequency and a stop band for higher frequencies

[SOURCE: IEC 60050-561:2014, 561-02-26, modified – Note 1 to entry has been deleted.]

3.1.21
measurand
particular quantity subject to measurement

[SOURCE: IEC 60050-311:2001, 311-01-03]

3.1.22
mechanical starting time, <of a rotating electric machine>
T_m
time of a rotating mass from standstill to nominal frequency while being accelerated with nominal torque

Note 1 to entry: The mechanical starting time T_m is twice the inertia constant H.

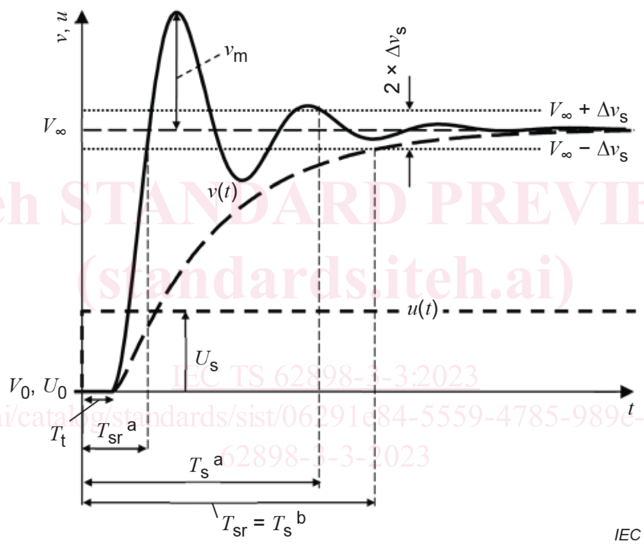
3.1.23
microgrid
<in an electric power system> group of interconnected loads and distributed energy resources with defined electrical boundaries forming a local electric power system at distribution voltage levels, that acts as a single controllable entity and is able to operate in island mode

Note 1 to entry: This definition covers both (utility) distribution microgrids and (customer owned) facility microgrids.

[SOURCE: IEC 60050-617:2017, 617-04-22, modified – Reworded to avoid redundancy.]

3.1.24
overshoot
v_m
for a step response of a transfer element the maximum transient deviation from the final steady-state value of the output variable, mostly used in the form of overshoot ratio

SEE Figure 2 (v_m)



u	Input variable
U_0	Initial value of the input variable
U_s	Step height of the input variable
v	Output variable
V_0, V_∞	Steady-state value before and after application of the step
v_m	Overshoot (maximum transient deviation from the final steady-state value)
$2 \cdot \Delta v_s$	Specified tolerance limit
T_{sr}	Step response time
T_s	Settling time
T_t	Dead time

Figure 2 – Typical step response of a system

[SOURCE: IEC 60050-351:2013, 351-45-38, modified – The second part of the definition has been simplified and adapted to the purpose of this document.]

3.1.25
overshoot ratio
ratio between the overshoot and the difference of steady-state values before and after the application of the step

$$v_{\mathrm{m}} / (V_{\infty} - V_0)$$

3.1.26
over-voltage ride through
OVRT
ability of a load to stay connected during a limited duration rise of system voltage

3.1.27
power system stability
capability of a power system to regain a steady state, characterized by the synchronous operation of the generators after a disturbance due, for example, to variation of power or impedance

[SOURCE: IEC 60050-603:1986, 603-03-01]

3.1.28
primary control
<for active power> control of generators or loads by their individual controllers which ensures that the active power flow is a function of the power frequency or network voltage

3.1.29
rebound effect
aggregated increase or decrease of power consumption after synchronised demand response deactivation

Note 1 to entry: The risk of oscillating rebound effects is small when there is a high diversity in the time constants of the relevant dispatchable loads, which define the need to switch from on to off and vice versa.

3.1.30
resolution
smallest change in the measurand, or quantity supplied, which causes a perceptible change in the indication

[SOURCE: IEC 60050-311:2001, 311-03-10]

3.1.31
rate of change of frequency
ROCOF
first-order derivative in time of the frequency

$$\mathrm{d}f/\mathrm{d}t$$

3.1.32
secondary control
<of active power in a system> coordinated control of the active power supplied to the network by particular generators

Note 1 to entry: The secondary control usually has an integrative component to ensure steady state accuracy of the controlled variable.

[SOURCE: IEC 60050-603:1986, 603-04-05, modified – Note 1 to entry has been added.]