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TECHNICAL SPECIFICATION

colour inside

Microgrids –
Part 2: Guidelines for operation

IEC TS 62898-2:2018-09(en)

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Microgrids –
Part 2: Guidelines for operation

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MICROGRIDS –

Part 2: Guidelines for operation

FOREWORD

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62898-2, which is a technical specification, has been prepared by subcommittee 8B: Decentralized Electrical Energy Systems, of IEC technical committee 8: Systems aspects of electrical energy supply.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
8B/3/DTS	8B/13B/RVDTS

Full information on the voting for the approval of this technical specification 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.

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 publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Microgrids can serve different purposes depending on the primary objectives of their applications. They are usually seen as means to facilitate the management of grid contingency and the local optimization of energy supply by controlling distributed energy resources (DER). Microgrids also present a way to provide electricity supply in remote areas and to use clean and renewable energy as a systemic approach for rural electrification.

IEC TS 62898 series is intended to provide with comprehensive guidelines and requirements for microgrid projects.

IEC TS 62898-1 mainly covers the following issues:

1) determination of microgrid purposes and application;
2) preliminary study necessary for microgrid planning, including resource analysis, load forecast, DER planning and power system planning;
3) principles of microgrid technical requirements that should be specified during planning stage;
4) microgrid evaluation to select an optimal microgrid planning scheme.

IEC TS 62898-2 mainly covers the following issues:

a) response characteristic requirements of microgrids under different operation modes;
b) the basic control strategies and methods under different operation modes;
c) the requirements of electrical energy storage (EES), communication and monitoring under different operation modes;
d) the principle of relay protection under different operation modes;
e) basic requirements of synchronization and reclosing during mode transfer;
f) principle for power quality, EMC, maintenance and test of microgrid.

Microgrids can be stand-alone or be the sub-system of the smart grid. The technical requirements in this document are intended to be consistent and in line with:

- system requirements from IEC System Committee Smart Energy (e.g. Use Cases “microgrid” to come);
- IEC 62786 requirements for connection of generators intended to be operated in parallel with the grid;
- basic rules from IEC TC 64 and TC 99 for safety and quality of power distribution within installations (essentially through coordination of protective devices in the different operation modes);
- IEC TS 62257 series (IEC TC 82) with respect to rural electrification;
- IEC TS 62749 with respect to power quality.

MICROGRIDS –

Part 2: Guidelines for operation

1 Scope

The purpose of this document is to provide guidelines for operation of microgrids. Microgrids considered in this document are alternating current (AC) electrical systems with loads and distributed energy resources (DER) at low or medium voltage level. This document does not cover direct current (DC) microgrids.

Microgrids are classified into isolated microgrids and non-isolated microgrids.

Isolated microgrids have no electrical connection to a larger electric power system and operate in island mode only.

Non-isolated microgrids may act as controllable units to the electric power system and can operate in the following two modes:

- grid-connected mode;
- island mode.

The 62898 series is intended to provide guidelines and the basic technical requirements to ensure the security, reliability and stability of microgrids.

IEC TS 62898-2 applies to operation and control of microgrids, including:

- operation modes and mode transfer;
- energy management system (EMS) and control of microgrids;
- communication and monitoring procedures;
- electrical energy storage;
- protection principle covering: principle for non-isolated microgrid, isolated microgrid, anti-islanding, synchronization and reclosing, power quality;
- commissioning, maintenance and test.

NOTE 1 Safety for personnel is outside the scope of this document, and such information is referred to in IEC TC 64 and TC 99 publications.

NOTE 2 Local laws and regulations can overrule the requirements of this document.

NOTE 3 The principles for main types of protections in microgrid, fault analysis for converter type and rotating machines type, protection type selection, general technical requirements, setting value principles and so forth are intended to be developed in IEC TS 62898-3-1[1].

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.

1 Under preparation. Stage at the time of publication: IEC/CD TS 62898-3-1:2018.

IEC TR 61000-1-7:2016, *Electromagnetic compatibility (EMC) – Part 1-7: General – Power factor in single-phase systems under non-sinusoidal conditions*

IEC 61000-4-7:2002, *Electromagnetic compatibility (EMC) – Part 4-7: Testing and measurement techniques – General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*
IEC 61000-4-7:2002/AMD1:2008

IEC 61000-4-30:2008 [2], *Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement techniques*

IEC 61968-1, *Application integration at electric utilities – System interfaces for distribution management – Part 1: Interface architecture and general recommendations*

IEC 61850-3, *Communication networks and systems for power utility automation – Part 3: General requirements*

IEC 61850-4, *Communication networks and systems for power utility automation – Part 4: System and project management*

IEC 61850-5, *Communication networks and systems for power utility automation – Part 5: Communication requirements for functions and device models*

IEC TS 62749, *Assessment of power quality – Characteristics of electricity supplied by public networks*

IEC TS 62786, *Distributed energy resources connection with the grid*

IEC TS 62898-1, *Microgrids – Part 1: Guidelines for microgrid projects planning and specification*

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
anti-islanding protection
protection function(s) or combination of protection functions preventing distributed energy resources from supplying electricity to an unintentional island

Note 1 to entry: The protection function includes the detection of system characteristics which can lead to an unintentional island.

[SOURCE: IEC 60050-617:2017, 617-04-19, modified – "an unintentional island to be supplied with electrical energy by distributed energy resources" has been replaced by "distributed energy resources from supplying electricity to an unintentional island" and Note 1 to entry has been changed]

[2] This 2nd edition was replaced in 2015 by a 3rd Edition.

3.2
black start
start-up of an electric power system from a blackout through internal energy resources

[SOURCE: IEC 60050-617:2017, 617-04-24]

3.3
converter
device for changing one or more characteristics associated with electrical energy

Note 1 to entry: Characteristics associated with energy are for example voltage, number of phases and frequency including zero frequency.

[SOURCE: IEC 60050-151:2001, 151-13-36]

3.4
distributed energy resources
DER
generators, including loads having a generating mode (such as electrical energy storage systems), connected to the low or medium voltage network, with their auxiliaries, protection and connection equipment, if any

[SOURCE: IEC 60050-617:2017, 617-04-20, modified – "including loads having a generating mode" and "with their auxiliaries, protection and connection equipment, if any" have been added]

3.5
distributed generation
generation of electric energy by multiple sources which are connected to the low or medium voltage network

[SOURCE: IEC 60050-617:2009, 617-04-09, modified – "power distribution system" has been replaced by "low or medium voltage network"]

3.6
distribution network
electrical facility and its components including poles, transformers, disconnects, relays, isolators, cables and wires that are owned by an electrical utility for the purpose of distributing electrical energy from substations to customers

Note 1 to entry: Usually, the distribution network operates up to a nominal voltage of 35 kV.

3.7
distribution system operator
DSO
party operating a distribution system

[SOURCE: IEC 60050-617:2009, 617-02-10]

3.8
electrical energy storage
EES
installation that is able to absorb electrical energy, store it and release it for a certain amount of time during which energy conversion processes may be included

EXAMPLE A device that absorbs AC electrical energy to produce hydrogen by electrolysis, stores the hydrogen, and uses that gas to produce AC electrical energy is an EES.

Note 1 to entry: EES may be used also to indicate the activity of an apparatus described in the definition while performing its own functionality.

3.9
electromagnetic compatibility
EMC
ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

[SOURCE: IEC 60050-161:2017 161-01-07, modified – "apparatus or system" has been replaced by "equipment or system"]

3.10
electromagnetic disturbance
any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter

3.11
high voltage
HV
voltage having a value above a conventionally adopted limit

[SOURCE: IEC 60050-151:2001, 151-15-05]

3.12
intentional island
island resulted from planned action(s) of automatic protections, or from deliberate action(s) by the responsible network operator, or both, in order to keep supplying electrical energy to a section of an electric power system

[SOURCE: IEC 60050-617:2017, 617-04-17]

3.13
interconnection
<electric power systems> single or multiple transmission link between transmission systems enabling electric power and energy to be exchanged between these networks by means of electric circuits and/or transformers

[SOURCE: IEC 60050-617:2009, 617-03-08]

3.14
island
<electric power systems> part of an electric power system, that is disconnected from the remainder of the interconnected system, but remains energized

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

Note 2 to entry: The generation and loads can be any combination of customer-owned and utility-owned.

[SOURCE: IEC 60050-617:2017, 617-04-12, modified – "electrically disconnected" has been changed to "disconnected", "interconnected electric power system" has been changed to "interconnected system", "from the local electric power sources" has been deleted, Note 2 to entry has been changed]

3.15
isolated microgrid
group of interconnected loads and distributed energy resources forming a local electric power system at distribution voltage levels not currently capable of being connected to a wider electric power system

Note 1 to entry: Isolated microgrids are usually designed for geographical islands or for rural electrification.

Note 2 to entry: Microgrids capable of being connected to a wider electric power system are also called non-isolated microgrids.

[SOURCE: IEC 60050-617:2017, 617-04-23, modified – "with defined electrical boundaries" has been deleted, Note 2 to entry has been added]

3.16
low voltage
LV
a set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V for alternating current

[SOURCE: IEC 60050-601:1985, 601-01-26]

3.17
medium voltage
MV
any set of voltage levels lying between low and high voltage

Note 1 to entry: The term medium voltage is commonly used for distribution systems with voltages above 1 kV and generally applied up to and including 35 kV.

[SOURCE: IEC 60050-601:1985, 601-01-28, modified – Note 1 to entry has been changed]

3.18
microgrid
<electric power systems> group of interconnected loads and distributed energy resources with defined electrical boundaries that acts as a single controllable entity and is able to operate in both grid-connected and island mode

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

[SOURCE: IEC 60050-617:2017, 617-04-22, modified – "forming a local electric power system at distribution voltage levels" has been deleted]

3.19
microgrid energy management system
system operating and controlling energy resources and loads of the microgrid

[SOURCE: IEC 60050-617:2017, 617-04-25]

3.20
nominal value
value of a quantity used to designate and identify a component, device, equipment, or system

Note 1 to entry: The nominal value is generally a rounded value.

[SOURCE: IEC 60050-151:2001, 151-16-09]

3.21
point of connection
POC
reference point on the electric power system where the user's electrical facility is connected

Note 1 to entry: In this document, point of connection indicates the point where microgrid is connected to the utility grid.

[SOURCE: IEC 60050-617:2009, 617-04-01, modified – Note 1 to entry has been added]

3.22
power factor
under periodic conditions, ratio of the active power P to the apparent power S:

$$\lambda = \frac{P}{S}$$

Note 1 to entry: Under sinusoidal and symmetric conditions, the power factor λ is equal to cos φ.

Note 2 to entry: For the purpose of this document, the load power factor is determined assuming an ideal sinusoidal supply voltage. Where the load is non-linear, the load power factor includes harmonic power components.

Note 3 to entry: $\cos\varphi = \frac{P}{S}$ with positive and negative value.

[SOURCE: IEC 60050-131:2002, 131-11-46, modified – "ratio of the absolute value of the active power P" has been changed to "ratio of the active power P", Note 1 to entry has been changed and Notes 2 and 3 to entry have been added]

3.23
power quality
characteristics of the electric current, voltage and frequencies at a given point in an electric power 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 in an electric power system and the loads connected to that electric power system.

[SOURCE: IEC 60050-617:2009, 617-01-05]

3.24
reliability
probability that an electric power system can perform a required function under given conditions for a given time interval

Note 1 to entry: Reliability quantifies the ability of an electric power system to supply adequate electric service on a nearly continuous basis with few interruptions over an extended period of time.

Note 2 to entry: Reliability is the overall objective in electric power system design and operation.

[SOURCE: IEC 60050-617:2009, 617-01-01]

3.25
renewable energy
primary energy the source of which is constantly replenished and will not become depleted

Note 1 to entry: Examples of renewable energy are: wind, solar, geothermal, hydropower.

Note 2 to entry: Fossil fuels are non renewable.

[SOURCE: IEC 60050-617:2009, 617-04-11]

3.26
security
ability of an electric power system to operate in such a way that credible events do not give rise to loss of load, stresses of system components beyond their ratings, bus voltages or system frequency outside tolerances, instability, voltage collapse, or cascading

Note 1 to entry: This ability may be measured by one or several appropriate indices.

Note 2 to entry: This concept is normally applied to bulk power systems.

Note 3 to entry: In North America, this concept is usually defined with reference to instability, voltage collapse and cascading only.

[SOURCE: IEC 60050-617:2009, 617-01-02]

3.27
unintentional island
island that is not anticipated by the relevant network operator

[SOURCE: IEC 60050-617:2017, 617-04-18]

4 Operation modes

4.1 General

Microgrids can be designed to address different needs. Operation requirements are developed in accordance with the high level Use Cases (Business Use Cases or BUCs) already identified in IEC TS 62898-1.

Operation complements to Microgrids BUCs are given in Annex A to D.

4.2 Non-isolated microgrid

4.2.1 General

When a microgrid operates in island mode, the most important tasks are to ensure the normal operation of critical loads and not to impair the integrity or the safety of the utility grid. When the microgrid transfers between the two modes, the voltage and frequency should stay within acceptable limits and the protection system shall operate reliably.

4.2.2 Grid-connected mode

4.2.2.1 General

In grid-connected mode, DER as well as other connected components in the microgrid shall comply with the same requirements as required for connection to the utility grid. DER have to be able to operate in the operating range specified in IEC TS 62786, regardless of the topology and the settings of the interface for both microgrid POC and DER interface protection.

In grid-connected mode, the microgrid as a whole shall follow the same requirements as DER in microgrid.

4.2.2.2 Voltage response characteristics

The operating voltage requirement of this mode is specified in IEC TS 62786. DER with capacity exceeding a certain level, as defined by local requirements, shall be capable of withstanding voltage deviations.

4.2.2.3 Frequency response characteristics

The operating frequency requirement of this mode is specified in IEC TS 62786. DER with capacity exceeding a certain level, as defined by local requirements, shall provide capability of withstanding frequency deviations.

4.2.3 Island mode

4.2.3.1 Voltage response characteristics

Voltage control is essentially a local problem. Thus, there is no critical difference between the island mode and the grid-connected mode. In both cases, in order to limit the voltage deviation within a permissible range, the voltage is controlled by both active and reactive power generated by the DER in the microgrid. In the grid-connected mode, the voltage in microgrid is controlled by both utility grid and DER.

The DER shall respond accordingly when the voltage of the microgrid violates the operating limits defined by local requirements.

The following important issues should be considered when the non-isolated microgrid is operating in the island mode:

a) proper operation of auxiliary equipment, including capacitor banks, voltage regulators, reactors, protection equipment, capacity, and configuration of transformers;
b) the characteristics of loads in steady state;
c) the abnormal voltage withstanding capability;
d) the characteristics of the distribution network and microgrids, such as the earthing scheme, the short-circuit impendence of the equivalent source, the voltage regulators, configuration of the protection system, and automation scheme;
e) the measurement, information exchange, voltage control systems, and their requirements;
f) the permissible dynamic voltage stability limit and the reactive power capacity reserved for the future.

4.2.3.2 Frequency response characteristics

Non-isolated microgrids in island mode shall be able to perform load tracking. Load in this operation mode is supplied solely by DER and load management, and the sizing of DER should be large enough to ensure the normal operation of predetermined critical load.

In this operation mode, there shall be at least one (or one group of) controllable DER to provide frequency reference. The response characteristics of the converter control system shall be the same as those in grid-connected mode. Frequency regulation can be achieved by DER active power output adjustment through frequency droop control, storage devices response, and load shedding schemes in order to limit frequency deviation within a permissible range.

The microgrid in island mode needs to meet the following objectives:

a) active power balance between DER output and load;
b) frequency measurement and regulation;
c) load tracking, load management, and load shedding;
d) the ability to maintain transient stability when severe load swing, DER outage or other internal faults occur.

In the low voltage application area, sometimes $Q(U)$ and $P(f)$ are not decoupled, and this kind of situation should be considered.

4.2.4 Mode transfer of non-isolated microgrids

4.2.4.1 General

Mode transferring from grid-connected mode to island mode can be divided into two types: intentional islanding and unintentional islanding. The intentional islanding requires the microgrid to be disconnected from the utility grid seamlessly. When there is a fault in the utility grid which causes power quality to deteriorate beyond the predefined limit at POC, the microgrid is separated from the utility grid passively, and this is called unintentional islanding. A microgrid may have black start capability, which is needed if the mode transferring fails.

The microgrid may be able to maintain acceptable voltage continuity if enough DER operating in U/f operation mode are connected at the moment of the disconnection, associated to a fast shedding system to quickly adapt the load to the islanded generation capacity. Otherwise, the microgrid will stop operation and requires a black start sequence to restart.

4.2.4.2 Grid-connected mode to island mode

When DER can satisfy the critical loads in the non-isolated microgrid, the non-isolated microgrid may be disconnected from the utility grid and operate in island mode. For intentional islanding, the disconnecting time and duration need to be coordinated with all parties involved.

a) Voltage support

In order to prevent severe voltage fluctuation, the microgrid shall have enough devices to provide self-regulation of reactive power. The major DER operating in $Q(U)$-mode shall be used to provide voltage support.

b) Frequency support

In order to prevent severe frequency fluctuation, the microgrid shall provide self-regulation of active power. The major DER operating in $P(f)$-mode shall be used to provide frequency support.

4.2.4.3 Island mode to grid-connected mode

In island mode, the microgrid shall monitor the voltage amplitude and frequency of the utility grid plus the phase angle between the utility grid and the microgrid by a synchronization relay. Synchronization control shall be adopted for the transition from island mode to grid-connected mode by shifting voltage amplitude and frequency in a desired direction. When the voltage amplitude, frequency and phase angle differences between the utility grid and microgrid are within given ranges, the synchronization relay may close the interface switch to transfer the microgrid from island mode to grid-connected mode.

In case the microgrid does not have the capability to meet the requirements above, the synchronization control shall wait until the synchronization condition reappears. If synchronization is needed urgently, the synchronization control shall shut down connected DER, so that the microgrid is de-energized and then the interface switch can be closed. The interface switch can be closed without complete synchronization if the microgrid users have been requested to provide immunity for reclosing the interface switch outside the given ranges for resynchronization conditions and the relevant DSO has agreed. The DSO provides the synchronization conditions for frequency, voltage, and phase angle range.

4.3 Isolated microgrid

4.3.1 General

An isolated microgrid is a small local power system. It aims at providing a certain level of power quality and reliability even if large amounts of intermittent resources are present. It is physically independent of a utility grid.

4.3.2 Structure of the isolated microgrids

The isolated microgrid only contains DER, loads, and other control and monitoring devices. It has no connection with a larger utility grid. The structure of the isolated microgrid shall meet the following objectives:

a) ensure the safe, secure and steady operation of the system;
b) provide stable power supply to critical loads, if any;

c) improve the economy of the system if possible.

4.3.3 Voltage response characteristics

When the voltage of the isolated microgrid is outside the normal range, the DER shall respond timely to ensure the reliability of the power supply. The DER shall be designed to withstand abnormal voltage for certain durations. In this situation, the protecting devices shall not disconnect the DER from the microgrid, unless the voltage deviation exceeds the given range. The EES may also provide sufficient reactive power timely to reduce the voltage deviation.

4.3.4 Frequency response characteristics

Without active power support from the utility grid, the frequency response characteristics of DER are especially significant for the isolated microgrid. There shall be at least one controllable DER to provide frequency support. When the frequency is outside the normal range, the DER should respond accordingly to ensure the power quality and the reliability of power supply. The EES may also provide sufficient active power timely to reduce the frequency deviation.

5 Control of microgrids

5.1 General

The control structure may have several hierarchies. For example, the main control system of the microgrid is the primary control in each unit by local droop control, and this control may have a proportional characteristic (P control). The central controller is a secondary loop, and this control may have an integral characteristic (I control). The local control at each mode reacts on measured frequency and voltage locally. The central control is needed for coordinating and optimizing purposes, it is also needed to guarantee steady state accuracy prior to resynchronization. The microgrid gets access to the utility grid through the interface switch.

In isolated microgrids and island mode of non-isolated microgrids, the major function of energy management system (EMS) is to balance the loads and generation and manage the electrical energy storage capacities.

a) In the grid-connected mode, monitoring, information exchange, and control can be used to optimize the operation of the DER and to control the power flow between the microgrid and the utility grid.

b) In the island mode, DER should be sufficient to support the microgrid voltage, frequency and phase angle conditions. When the microgrid is reconnected to the distribution network, conditions of the microgrid and the utility grid at the POC shall be monitored for a certain observation time duration to check for synchronization conditions. The microgrid can reconnect only if all these conditions are met.

   NOTE The non-isolated microgrid that can work in grid-connected or island mode can or cannot have the black start capability, considering its importance and function to the utility grid.

c) In the isolated microgrid, several points should be considered:
   - active power and reactive power should be balanced;
   - voltage and frequency shall be adjusted within the permissible range;
   - some technical measures, such as load tracking, load management and load shedding should be adopted;
   - the dynamic response of the DER shall be provided;
   - the DER should have active and reactive power generation capacity and response characteristics to maintain power quality levels;
   - the isolated microgrid shall have its own black start capability.

Figure 1 and Figure 2 give examples for the structure of the non-isolated microgrid and isolated microgrid respectively.

The EMS mainly manages the power generation of the microgrid and its functions may include weather forecast, DER power generation forecast, load forecast, generation planning and dispatching, etc. It shall also manage data, and provide information to meet operation needs.

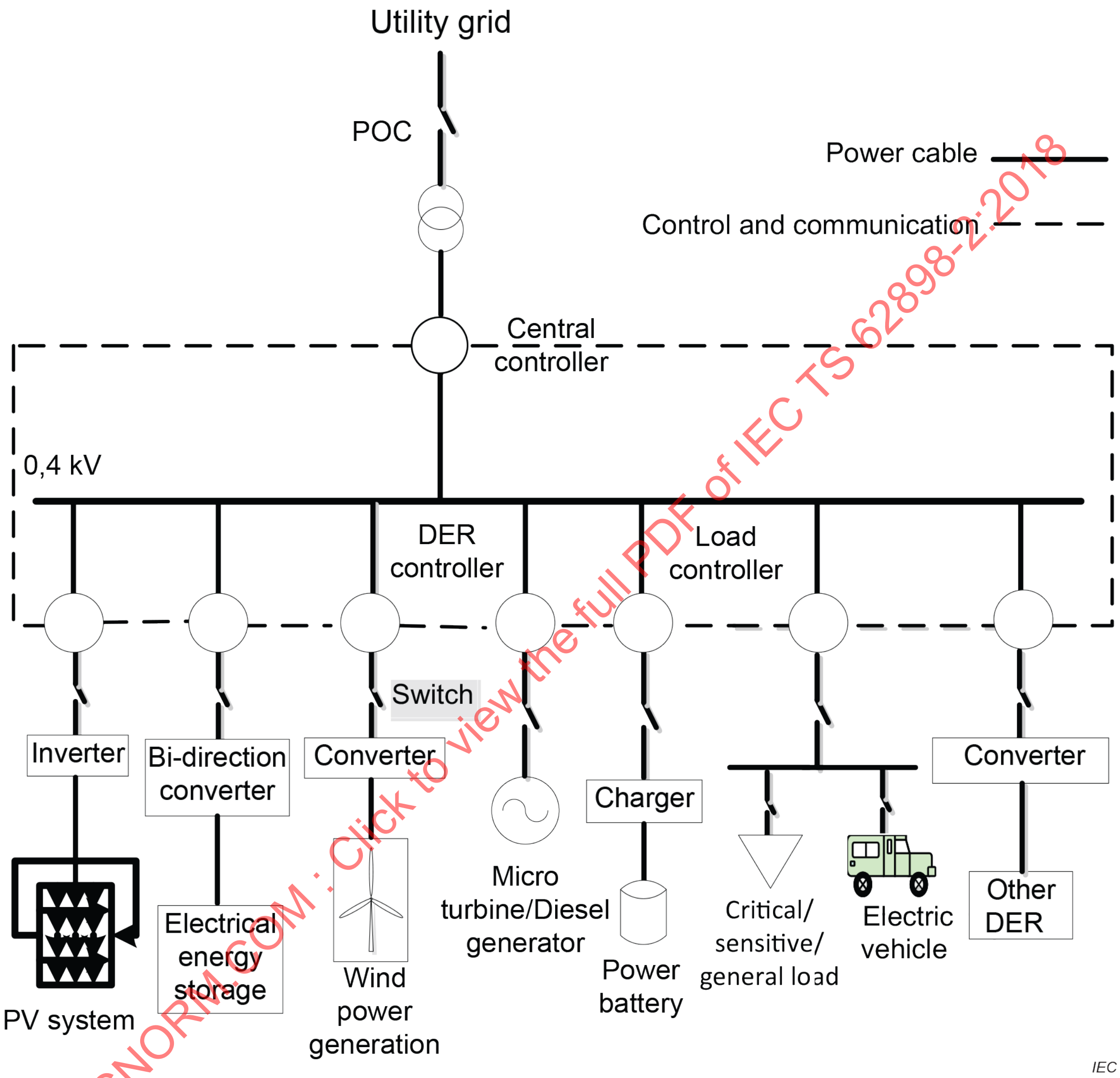

Figure 1 – Example for a non-isolated microgrid

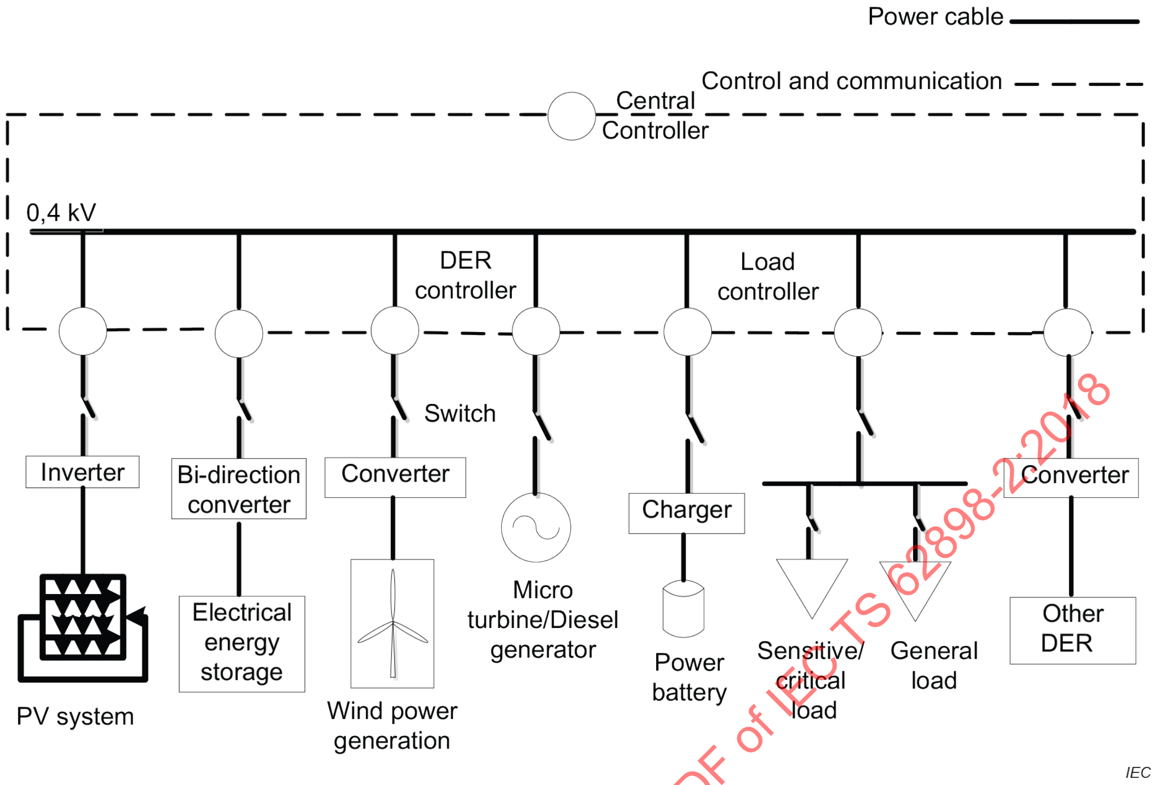

Figure 2 – Example for an isolated microgrid

5.2 Control of the non-isolated microgrid

5.2.1 Control of the grid-connected mode

5.2.1.1 Active power control and frequency regulation

The system frequency shall be regulated by the utility grid through active power control.

The microgrid in grid-connected mode is not required to regulate frequency unless the DSO has special requirements.

In this operation mode, the power flow at POC is bidirectional, meaning that the microgrid can export to or import active power from the utility grid. Combined with load shedding capabilities, the microgrid may also be able to provide auxiliary system services to the utility grid.

5.2.1.2 Reactive power control and voltage regulation

Power factor at POC can be adjusted by the utility grid and microgrid within a certain range for grid-connected mode, and can be out of the range for a specified time. For a small capacity microgrid, a Q/U approach may be useful, and when the microgrid is in island mode, the power factor is defined by load or power factor compensator (capacitor bank or active filter). Microgrids shall be capable of generating reactive power. In some cases, reactive power compensation equipment is required to adjust the utility grid voltage to the normal range. The power factor shall be adjusted within an allowable range, and the reference parameters are shown in Table E.1. When the utility grid operates in steady state, there are several reactive power control schemes that can be applied to the microgrid to provide static voltage support:

a) constant power factor λ;

b) reactive power as a function of active power $Q(P)$;

c) fixed reactive power Q_{fix};

d) reactive power as a function of voltage $Q(U)$;

e) reactive power as a function of active power and voltage at the same time $Q(P,U)$.

Under specific conditions of the utility grid shown in Table E.1, the dispatching mechanism of the microgrid is required to operate in either mode. This is to provide an operation curve or goal setting value, while ensuring the power factor is within the range specified in Table E.1.

The power provided by photovoltaic, wind and other kinds of DER fluctuates all the time. DSO can provide a characteristic curve which defines power factor as a function of active power $\lambda(P)$. For a constant active power output, DSO may require it to operate in fixed power factor, and in some situations compensation measures are needed. When the utility grid voltage is in variable state, DSO can provide a characteristic curve, which defines reactive power as a function of voltage characteristics.

The reactive power of the DER shall be adjustable within a required range. It needs to have the ability to change reactive power output within a range and specified time duration and as often as required. If a characteristic is specified by the DSO, reactive power value resulting from the characteristic shall be able to adjust automatically.

Under the permission of DSO, the microgrid may participate in voltage regulation at the POC as ancillary service. Power factor can be adjusted within the allowable range provided by the DSO.

The integration of the microgrid and the utility grid may have an impact on the voltage of the utility grid. Utility grid operators can change the voltage adjustment by the DER in low voltage distribution network with the need of utility grid operation.

In order to satisfy the requirements of the utility grid, microgrids may participate in the steady state voltage control of the medium voltage grid. DER of asynchronous machines and converter types in the medium voltage level shall be able to participate in the voltage regulation of the POC by reactive power control, especially for direct drive permanent magnetic wind turbine machines. The range of the power factor is related to the regulation ability of various DER. For power factor requirements, Annex E gives typical values cited in some standards

5.2.2 Control of the island mode

The operation control scheme of the island mode shall be consistent with the planned operating configuration of the island mode.

There are four alternative control schemes, as follows:

a) centralized control: in this control scheme, a central controller gives commands to the entire system through a master-slave control configuration between the central controller and the controllable distributed devices;

b) decentralized control: this control scheme is accomplished through independent controls communicating with each other. This strategy uses intelligent devices that are strategically located to detect the conditions and initiate the required actions;

c) hierarchical control: this control scheme combines the central and decentralized control;

d) autonomous control: this kind of control scheme is accomplished through independent controls without communication with other devices.

In the island mode of the microgrid, at least one of DER shall operate in U/f mode to maintain voltage and frequency, and other DER shall operate in P/Q mode. The DER voltage controller shall be coordinated with other regulating devices in the system. This will require some type of control that will coordinate the set points of different DER units and reactive power compensation equipment and voltage regulators to maintain the desired voltage profiles.

5.3 Control of the isolated microgrid

The steady state control of the isolated microgrid is different from the island mode of the non-isolated microgrid:

a) The ratio of electrical energy storage capacity to the total of other DER capacity in the isolated microgrid shall be much larger than that of the island mode;

b) The desired power quality of the isolated microgrid could be different from that of the island mode depending on the load demand requirements;

c) The isolated microgrid works currently in a self-sustained and independent way based on the load requirements, while the non-isolated microgrid only operates in island mode within limited time duration;

d) From the control point of view such as voltage and frequency control, strategies are different even though there are some common points;

e) The frequency and voltage of the non-isolated microgrid in island mode should be monitored all the time in order to reconnect back to the utility grid.

DER in isolated microgrid shall have frequency regulation ability. DER shall not adjust active power if the frequency is outside the regulated range according to Figure 3. With the required accuracy and at the required time, DER shall adjust active power versus frequency response as soon as possible. Once these requirements can no longer be met, this active power level is maintained constant.

In Figure 3, the frequency threshold values may be provided for the isolated microgrid according to load demand. For the frequency range between f_4 and f_H, the power of DER shall be decreased when the frequency is increasing. The overall effect of the regulation on frequency should emulate the right hand part of the droop curve given. Similarly, for the frequency range between f_3 and f_L, the power of DER shall be increased when the frequency is decreasing; even non-essential loads may be regulated or disconnected (load shedding), emulating the left hand part of the droop curve.

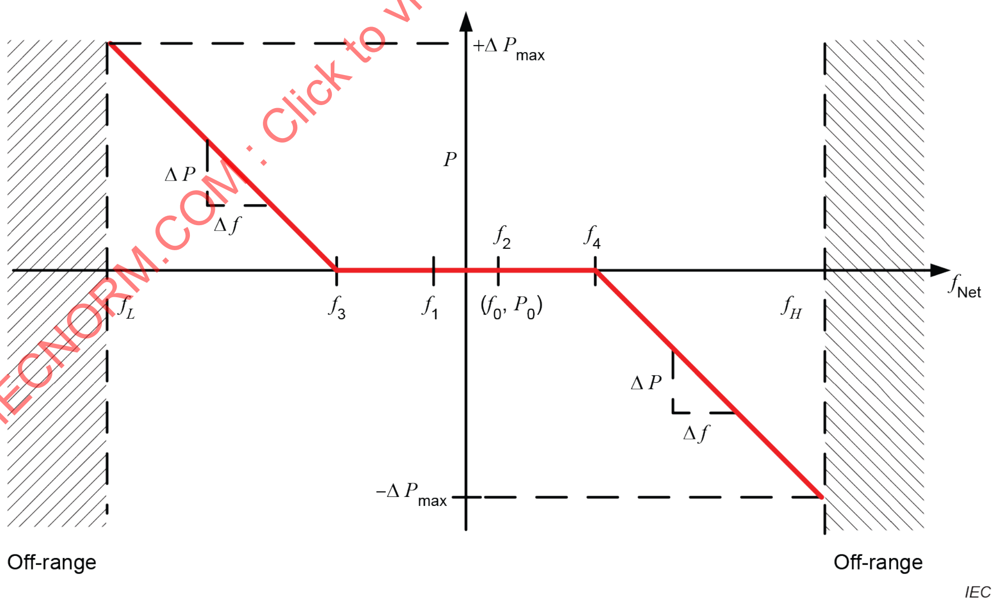

Figure 3 – The P-f control in isolated microgrid

f_{Net} refers to the system frequency axis, and the values of other parameters are shown in Table 1.

Table 1 – Example for the isolated microgrid frequency response of 50 Hz

Parameter	Value Hz
f_0	50,0
f_1	49,95
f_2	50,05
f_3	49,5
f_4	50,5
f_L	47,0
f_H	53,0

NOTE The values in Table 1 are examples (refer to [2][3]) applied to isolated microgrid.

The DER with capacity over, for example, 100 kVA, shall be able to limit its power output according to dispatch instructions. The step of DER active power output reduction under normal operation shall not exceed a given gradient (e.g. 10 % of the maximum power output per minute). When $f_{\text{Net}} < f_L$ or $f_{\text{Net}} > f_H$, the DER shall be disconnected from the microgrid. When $f_3 \leq f_{\text{Net}} \leq f_4$ within an isolated microgrid, there is no adjustment to the output power of the DER. When $f_L \leq f_{\text{Net}} < f_3$ within an isolated microgrid, the DER shall increase their output powers within their capacity in order to compensate the microgrid frequency drop. When $f_4 < f_{\text{Net}} \leq f_H$, the DER shall decrease active power output if frequency increases.

The setting values of an active power gradient and a step response maximum time are provided by the isolated microgrid. The microgrid users' requirements for the step response time depend on the technology. DER with fast response characteristic (e.g. converter based EES) shall react within a maximal step response time. If this is not technically feasible with slower reacting DER (e.g. gas turbines, combustion engines, hydro turbines), the DER shall be disconnected.

The active power change of DER shall meet the requirements for secure and stable operation of the isolated microgrid.

Without the support from utility grid, there shall be one or more (or one group of) DER of high reliability to work in *U*/*f* mode to maintain the stability of voltage and frequency for the isolated microgrid. There should be a transient control system to maintain stability for the isolated microgrid operating at the boundary of the unstable situation.

NOTE Wind power generators or photovoltaic arrays do not have the ability to work in *U*/*f* mode, considering their output fluctuation. A large enough capacity is one of the necessary conditions for the electrical energy storage device to be chosen.

6 Communication and monitoring

6.1 General

The DER in a microgrid should have the ability of data communication with the monitoring system, which can collect the electrical operating conditions of the microgrid and receive the instructions of control adjustment from the dispatching department in the utility grid. The microgrid shall monitor the system and record the operating conditions.

3 Figures in square brackets refer to the Bibliography.

In the grid-connected mode of the non-isolated microgrid, the communication methods and information transfer between the microgrid and the dispatching department including the telemetry, telecom and remote control, remote adjustment signal, shall comply with the relevant standards and DSO requirements.

6.2 Communications of microgrids

6.2.1 General

The microgrid communication system shall be responsible for retrieving information from the utility grid, microgrid field and equipment in the microgrid and vice versa. Despite their key functions, these communication protocols shall have incorporated security measures, including security against inadvertent errors, power system equipment malfunctions, communications equipment failures, or deliberate sabotage.

If different communication protocols are used, they shall be interoperable. To connect multiple components, a communication system shall reconcile network and protocol differences transparently to the components. The content of this subclause is based on existing or emerging standards and applications. IEC 61850-3, IEC 61850-4, IEC 61850-5 and IEC 61968-1 are recognized as the core standards for the smart grid and should be used for the microgrid applications.

6.2.2 Communications between non-isolated microgrids and the utility grid

a) In the normal operation mode, microgrids shall exchange information including voltage, current and power with the utility grid;

b) Microgrids shall be able to receive commands from the dispatching department of the utility grid when the utility grid needs support from microgrids;

c) For the mode transfer, microgrids may send signals to the utility grid when preparing to transfer from island mode to grid-connected mode or vice versa. Then the utility grid shall respond to it.

6.2.3 Communications inside the microgrids

Communication and data exchange are extremely important for the safe, secure and reliable operation of the microgrid. Data exchange may be realized among DER, essential loads and/or central controller.

NOTE Data exchange with electrical energy storage is important to manage the microgrid.

6.3 Monitoring the DER

The microgrid mainly monitors the following concerning DER:

a) the voltage and current of the DER in microgrids;

b) the active and reactive power exchanged between DER and microgrids;

c) the state of change or state of the electrical energy storage system in microgrids;

d) the fault states of DER in microgrids.

Besides the above contents, the microgrid also monitors the following concerning non-isolated microgrid:

1) the voltage and current of the POC;

2) the active and reactive power exchanged between microgrids and the utility grid.

6.4 Monitoring the switching devices for non-isolated microgrids

The monitoring system shall meet the requirements of electric power communication concerning relay protection, automatic safety devices, automation systems, dispatching devices and other services. The data of switching devices in the non-isolated microgrid to be monitored include:

a) the transformer tap changer position, the switching status of circuit breakers inside the non-isolated microgrid;
b) the main transformer tap changer position, the switching status of circuit breakers at the POC;
c) the switching status of DER.

6.5 Monitoring the switching devices for isolated microgrids

The monitoring system shall meet the requirements of electric power communication concerning relay protection, automatic safety devices, automation systems and other services. The data of switching devices in the isolated microgrid monitoring includes:

a) transformer tap changer position, the switching status of circuit breakers inside the microgrid;
b) the switching state of DER.

7 Electrical energy storage

7.1 General

EES is playing a very important role in microgrids, depending on what kind of EES is used. From the function point of view, they are classified as two types: power type and energy type. The power type is mostly used in isolated microgrids for transient or dynamic stability control. The energy type is mostly used for power balance. EES can work as load when it is charging and also as a generator when it is discharging. Converter control techniques are also essential when working with different EES.

7.2 EES in non-isolated microgrids

7.2.1 Requirements for EES in grid-connected mode

a) When the microgrid is in the grid-connected mode, the EES shall adopt the P/Q control mode. The setting power value of EES should aim to guarantee the power quality of the utility grid. In this way, EES can ensure that the output power of microgrid system to the utility grid is smooth.
b) EES shall absorb the active/reactive power from the power grid or output the active/reactive power to the utility grid based on the system demand (or EMS instructions) to ensure the stability of the power flow in the microgrid and the POC.
c) When in the grid-connected mode, the voltage and frequency of the microgrid could be supported by the utility grid and the EES could stop operation, especially in load smoothing state.

7.2.2 Requirements for EES in island mode

a) In island mode of non-isolated microgrid, the black start may or may not be necessary but the EES plays a major role for the black start. Among the energy storage converters, the one with the largest capacity shall adopt the control mode of U/f, to establish and maintain the system voltage and frequency, if there is no other major stable DER such as microturbines or diesel generators.
b) When the output power of the DER in the microgrid cannot meet the load demand, the EES shall start the power compensation working as generation. When the output power of the DER in the microgrid exceeds the load demand, the redundant power shall be absorbed by the EES working as load. If the EES works as generation and the load balance is still not met, then load shedding is inevitable depending on the load demand and the capacity of the EES, even some of the critical and sensitive load, cannot be supplied.

7.2.3 Requirements for EES in mode transfer

a) When the microgrids transfer from grid-connected mode to island mode, the transient action could cause stability problems. In the microgrid, energy storage converters and transient control systems shall promptly operate to ensure the system stability. Sufficient power energy storage capacity may be chosen to ensure the stable operation of the microgrid.

b) When the microgrids transfer from island mode to grid-connected mode, energy storage converters may timely detect the voltage amplitude, phase angle and frequency of the utility grid, and then adjust the voltage amplitude, phase angle and frequency of the converters to meet the synchronization requirements.

c) Fast and smooth mode transfer of microgrid can reduce the influence on the sensitive load and DER due to the mode transfer. The strict grid synchronization condition shall be set to reduce the surge current of the microgrid, through EES and ensure the stable operation of the microgrid and the utility grid.

d) If the EES act as the main resource in the island mode, when transferring from grid-connected to island mode, the control strategy mode shall transfer from P/Q control to U/f control, and the system shall have anti-islanding detection ability.

e) Low voltage and high voltage ride through (LVRT or HVRT) capability of the energy storage system shall match IEC TS 62898-1.

a) In an isolated microgrid, consideration for the capacity of the EES is totally different from that of the non-isolated microgrid in island mode. The capacity of EES is much larger than that of non-isolated microgrid in island mode, depending on what kind of EES is used and the load demand. In the isolated microgrid, there is at least a rotating machine such as microturbine or diesel generator that is set to operate in U/f mode. If more than one EES is used, a group of larger EES shall work in U/f mode to support the isolated microgrid in order to maintain the system voltage and frequency stability under the condition that the rotating machines are either not regulated fast enough, shut down or faulty. In the isolated microgrid, the black start is necessary and the EES can play a major role.

b) When the output power of the distributed generation in the isolated microgrid cannot meet the load demand, the lack of the power supply for the critical and sensitive loads shall be guaranteed by EES.

c) When the output power of the distributed generation in the isolated microgrid exceeds the load demand, the redundant power shall be absorbed by the EES.

7.3 EES management

The EES management shall:

a) detect the working state of each element of the EES dynamically, and the working state of the overall EES;

b) estimate the output capacity of each element among the EES and balance energy among EES; the state of charge for each element of the EES should be given, and the overall state of charge should be given as well;

c) prevent the EES from overcharging and over discharging;

d) increase the security and reliability of the EES;

e) extend the service life of the EES;

f) raise the utilization efficiency of EES.

8 Protection principle for microgrids

8.1 General

Non-isolated and isolated microgrids shall have the corresponding protective relaying functions to prevent equipment from being damaged and to guarantee secure operation. When a non-isolated microgrid transfers from grid-connected mode to island mode, the configuration, power flow, neutral earthing and short-circuit current values will change.

Therefore, the microgrid protection setting values shall be reconfigured accordingly. The microgrid protection should also take into account reliability, selectivity, sensitivity and speed.

8.2 Principle for protection in a non-isolated microgrid

Depending on the configuration, both the utility grid and the DER in the microgrid contribute to the short-circuit currents. The contribution to short-circuit currents from the microgrid depends on the configuration of the microgrid at any given time.

8.3 Reclosing with synchronization in a non-isolated microgrid

Before reclosing, synchronization should be achieved.

Synchronization requires that the microgrid components (mainly DER) are equal or close to the utility grid voltage, phase angle and frequency.

For the microgrid DER of synchronous machines, the parameter settings of synchronous interconnection are of great importance. The DER of asynchronous machines can be driven by the prime mover to connect the synchronous devices before close to the synchronous speed.

If the utility grid reclosing devices attempt to reclose before the microgrid is ready for reclosing, utility grid, the microgrid and DER equipment may be damaged.

If the DER cannot coordinate with the reclosing scheme of the utility grid, it may be necessary to alter the microgrid interconnection system or modify the reclosing POC breaker on the utility grid. Modification of utility grid reclosing may require the replacement of reclosing devices or the installation of supervisory relaying to inhibit reclosing if the DER have not been disconnected.

If the island resulted from the operation of a breaker because of a fault, it is unlikely that the DER are capable of synchronizing to the utility grid at that breaker. Sometimes the island is shut down before it can be reconnected to the utility grid, regardless of intentional or unintentional island. Both the microgrid and the utility grid will typically study the DER connection and determine whether the reclosing will impact the fluctuation of voltage and frequency.

8.4 Principle for protection in an isolated microgrid

The contribution to short-circuit currents from the microgrid depends on the configuration of the microgrid at any given time. Moreover, due to the solid state inverters or converters, small fault current values cannot guarantee the accurate action of the traditional protective relays, and specific algorithms sometimes are needed. In some cases, fiber-optic current differential protection should be used as the main protection, and directional or non-directional overcurrent protections should be used as the backup protection. Longitudinal differential protection and overcurrent protection should be installed on the DER side of the line.

9 Power quality and EMC of microgrids

9.1 Power quality in non-isolated microgrids

When the microgrid is connected to the utility grid, the microgrid operation shall not cause unacceptable disturbances to other network users.

The disturbance phenomena considered are:

- voltage fluctuations and flicker;
- harmonics up to and including the 40th harmonic;

- inter-harmonics up to the 40th harmonic;
- voltage distortions above 2 kHz;
- voltage dips and short supply interruptions;
- voltage unbalance;
- transient overvoltage;
- power frequency variation;
- DC components;
- mains signaling.

The power quality parameters at the POC should comply with IEC TS 62749.

Unless otherwise specified and mutually agreed, the power quality levels at IPCs (in-plant point of coupling) shall be the same in grid-connected and island modes.

9.2 Power quality in isolated microgrids

Unless otherwise specified and mutually agreed, the power quality levels shall be the same as in the grid connected microgrids.

9.3 EMC in microgrids

Microgrids shall be designed with consideration of electromagnetic emissions and for immunity to various electromagnetic phenomena.

The design and operation of a microgrid shall be consistent with the relevant EMC standards, which include compliance with IEC 61000-1-7, IEC 61000-4-7, IEC 61000-4-30, besides specific product standards.

10 Maintenance and test of microgrids

10.1 General

Microgrid operation and maintenance staff shall make maintenance and test plans both for isolated and non-isolated microgrids. When doing the above, the staff shall coordinate with the DSO.

As a part of the regular maintenance and test, the equipment of the microgrid shall be reassessed periodically, and be reassessed based on the equipment conditions.

10.2 Maintenance

The requirements for maintenance are as follows:

a) Microgrid operation and management department shall make the maintenance plan;
b) The personnel of operation and maintenance in the microgrid shall be professional staff;
c) The operators of the microgrid shall regularly supply the operation information for the maintenance plan: the status of the protection devices, grounding equipment, other security equipment and all the DER equipment. The microgrid shall have a specific maintenance cycle, and all the information shall be recorded.

10.3 Test

All equipment in the microgrid shall meet the test requirements specified below:

a) Implementation of test procedures shall be conducted in accordance with appropriate safety procedures, sequences and precautions;

b) The test environment shall be within the qualified manufacturer's specified environmental operating conditions;

c) The test results should coordinate with the requirements from the DSO, and should meet the requirements of all DER instruction manuals.

Annex A
(informative)

Business use case A: Improving reliability and securing the energy supply by islanding

Whole name: Microgrids that aim at improving reliability and securing the energy supply for all or part of their loads by islanding management.

This BUC is based on document IEC SyCSmartEnergy/32/CD, and is intended to be reviewed in view of keeping consistency with IEC TS 62913-2-1[4]*, Generic Smart Grid Requirements – Part 2-1: Domains – Grid related domains, these include transmission grid management, distribution grid management, microgrids and smart substation automation.*

<ins>*Operation and related technical issues:*</ins>

This Use Case can be decomposed in four steps, including a total of six scenarios:

- Step 1: Before islanding (scenario 1)
- Step 2: Starting the islanding with one of the following scenarios:
  - Preventive islanding if a supply interruption is planned, or a grid outage is expected (scenario 2);
  - Automated islanding in case of unplanned grid failure (scenario 3);
  - Black start recovery to re-supply loads after grid failure (scenario 4);
- Step 3: Maintaining the islanding (scenario 5);
- Step 4: Reconnection to the main grid (scenario 6).

Scenario 2 is only applicable for planned grid outages, which can be planned maintenance of upstream equipment, or anticipation of possible upcoming failure or constraints on the network (storms that could damage overhead lines, voltage limit reached locally due to PV injection, line congestion are non-exhaustive examples).

Scenarios 3 and 4 are applicable when an unplanned outage of the main grid occurs. The choice between both scenarios depends on the technical capabilities of the microgrid: automated islanding is better for the clients, as they do not sustain any outage, but is much more technically complicated to achieve, and thus needs more equipment and more investments.

The processes before and during the islanding, and for the re-connection to the main grid, are the same in every case.

<ins>Before islanding (scenario 1):</ins>

When the microgrid is connected to the main grid, in normal operating conditions, the microgrid manager monitors the state of the main grid and of the different generators, storage systems, controllable loads and other flexibilities inside the microgrid, to be able to island if an outage occurs, and to assess the possible duration of islanding. The microgrid manager informs in real time the MV/LV system operator about the microgrid's possibility to island. For distribution microgrids, the MV/LV system operator gives an authorization to island in case of outage.

[4] Under preparation. Stage at the time of publication: IEC/CD TS 62913-2-1:2018.

The microgrid manager also prepares the different generators, storage systems, controllable loads and other flexibilities, so that they are in the optimal state to start islanding if necessary, in coordination with the other use cases using them. For example, a certain percentage of a storage system's state of charge could be reserved to enable islanding, and not be used for other use cases. To prepare a generator, storage system or controllable loads, the microgrid manager can either have direct control, or pass through a system manager (DER operator or EES operator).

The preparation and the assessment of the islanding duration takes into account the forecasting of the consumption and production inside the microgrid.

Starting the islanding – Preventive islanding (scenario 2):

The preventive islanding can be triggered by one of the following events:

For distribution microgrids, the MV/LV system operator informs the microgrid manager that it should perform a preventive islanding due to:

- an operation on the network that will cause a supply interruption in the microgrid area; or
- an expected grid failure due to climatic events or constraints on the network.

The MV/LV system operator informs the microgrid manager about the starting time and the duration of this event.

For facility microgrids, the private network operator can decide to operate a preventive islanding if he receives one of the following information:

- The MV/LV system operator informs about an operation on the network that will cause a supply interruption in the facility area;
- The MV/LV system operator or a weather forecast provider informs about an expected grid failure due to climatic events;
- The MV/LV system operator informs about an expected grid failure due to grid constraints;
- The private network operator calculates from market prices that it will be less expensive to island for a given period of time.

In coordination with other use cases, the microgrid manager prepares the different generators, storage systems, controllable loads and other flexibilities, so that the system will be able to island during the entire event. The microgrid manager informs the MV/LV system operator about the microgrid's possibility to island.

Before the event starting time (real or expected), the microgrid manager takes control of the operation mode of the different generators, storage systems, controllable loads and other flexibilities, and starts the islanding by physically disconnecting the microgrid from the main grid and simultaneously switching the relevant resources to islanding mode.

Automated islanding (scenario 3):

At a given time, an unplanned outage occurs on the main grid, and is detected by the microgrid manager. If the conditions allow it, the microgrid manager takes control of the operation mode of the different generators, storage systems, controllable loads and other flexibilities, and starts the islanding by physically disconnecting the microgrid from the main grid and simultaneously switching the relevant resources to islanding mode.

The microgrid manager informs the MV/LV system operator about the microgrid's islanding state, and the possible duration of the islanding.

Black start recovery (scenario 4):

At a given time, an unplanned outage occurs on the main grid, and the microgrid is enabled to automatically island, and thus powered off. The microgrid manager evaluates the possibility to perform a black start recovery, and informs the MV/LV system operator about it.

If a black start is possible, the microgrid manager takes control of the operation mode of the different generators, storage systems, controllable loads and other flexibilities, physically disconnects the microgrid from the main grid and simultaneously switches the relevant resources to islanding mode, and performs a black start by managing the electrical energy resources and the other flexibilities. The microgrid manager assesses the duration that it will be able to maintain islanding, and informs the MV/LV system operator about it.

Maintaining the islanding (scenario 5):

Once the islanding is started, the microgrid operator has control over the different generators, storage systems, controllable loads and other flexibilities, and manages them to maintain the islanding for the targeted duration. If it is impossible to maintain all the loads supplied for the total duration, the microgrid manager optimizes the supply time of the loads, taking into account eventual priorities between the loads.

The microgrid manager regularly assesses the possible duration of the islanding, and informs the MV/LV system operator about it. This assessment takes into account the forecasting of the consumption and production inside the microgrid.

If, due to a lack of production, consumption or flexibility, the islanding becomes impossible to maintain, the microgrid manager safely powers out the microgrid area, or reconnects the microgrid to the main grid if it is possible.

Reconnection to the main grid (scenario 6):

When the power on the main grid is back to normal conditions, the MV/LV system operator informs the microgrid manager that it can reconnect the microgrid. The microgrid manager then manages the different generators, storage systems, controllable loads and other flexibilities to enable a reconnection without perturbation, and physically performs the reconnection. It informs the MV/LV system operator about the reconnection, and gives back the control of the different generators, storage systems, controllable loads and other flexibilities to the other use cases.

Annex B
(informative)

Business use case B: Electrifying remote areas and using renewable energy sources

Whole name: Electrifying remote areas, reducing conventional public distribution cost and using renewable energy sources.

This BUC is intended to be offered to IEC SyCSmartEnergy to initiate new development in IEC TS 62913-2-1, Generic Smart Grid Requirements – Part 2-1: Domains – Grid related domains, these include transmission grid management, distribution grid management, microgrids and smart substation automation.

This BUC implies that microgrid is one of the solutions to promote electrification for far rural areas or islands with integration of renewable energy resources (or distributed energy resources DERs). This BUC serves a community with weak transmission or distribution feeders.

Scope

This business use case (BUC) concerns isolated microgrids used for purposes such as electrification in far rural area or geographic islands.

Objective(s)

- local electrification in developing areas, eventually before the construction of large public distribution network;
- electricity supply in islands or areas where there is no possibility to have connection to large public distribution network;
- electricity supply in islands or areas where there is public distribution network but its power reliability and power quality are very poor.

Basic functions

Black-start, frequency and voltage regulation, guarantee necessary power reliability and power quality.

Advanced functions

Load shedding, load control forecast and power generation.

Figure B.1 shows one actual application case of this kind of microgrids built in China:

- The local area is far from existing public electric power distribution system.
- Low power reliability and high maintenance cost of the existing public distribution grid.
- Some critical loads in this area need high power reliability power supply.
- Local renewable energy resources are available.