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TECHNICAL SPECIFICATION

colour inside

Microgrids –
Part 1: Guidelines for microgrid projects planning and specification

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MICROGRIDS –

Part 1: Guidelines for microgrid projects planning and specification

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, which is a Technical Specification, has been prepared by IEC technical committee 8: Systems aspects for electrical energy supply.

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

Enquiry draft	Report on voting
8/1445/DTS	8/1460/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 document will remain unchanged until the stability date indicated on the IEC website under "http://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- withdrawn,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.

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

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INTRODUCTION

Microgrids can serve different purposes depending on the primary objectives of their applications. They are usually seen as means to manage reliability of supply in a grid contingency and 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.

This part of IEC 62898 defines the guidelines for the general planning and design of microgrids, and IEC TS 62898-2 [1] defines the general technical requirements for operation and control of microgrids.

This document mainly covers the following issues:

- determination of microgrid purpose and application;
- preliminary study used for microgrid planning, including resource analysis, load forecast, DER planning and microgrid power system planning;
- principles of microgrid technical requirements that should be specified during planning stage;
- microgrid evaluation to select an optimal planning scheme for a microgrid project.

IEC TS 62898-2 mainly covers the following issues:

- operation requirements and control targets of microgrids under different operation modes;
- basic control strategies and methods under different operation modes;
- requirements of energy storage, monitoring and communication under different operation modes;
- power quality.

Microgrids can be stand-alone or be a sub-system of the smart grid. The technical requirements in this document and in IEC TS 62898-2 are intended to be consistent and in line with:

- system requirements from IEC System Committee Smart Energy,
- technical requirements from IEC 62786 for connection of generators intended to be operated in parallel with the microgrid,
- basic rules from IEC TC 64 and TC 99 for safety and quality of power distribution (essentially selectivity, through coordination of protective devices) in installations,
- basic rules from IEC TC 77/SC 77A for electromagnetic compatibility (EMC) issues,
- IEC TS 62257 (all parts) with respect to rural electrification,
- IEC TS 62749 with respect to power quality.

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

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1 Under preparation. Stage at the time of publication: IEC CD 62898-2:2017.

MICROGRIDS –

Part 1: Guidelines for microgrid projects planning and specification

1 Scope

The purpose of this part of IEC 62898, which is a Technical Specification, is to provide guidelines for microgrid projects planning and specification. 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 wider electric power system. Non-isolated microgrids can act as controllable units to the electric power system and can operate in the following two modes:

- grid-connected mode;
- island mode.

This document will cover the following areas:

- microgrid application, resource analysis, generation forecast, and load forecast;
- DER planning and microgrid power system planning;
- high level technical requirements for DER in microgrids, for microgrid connection to the distribution system, and for control, protection and communication systems;
- evaluation of microgrid projects.

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.

IEC 60038, *IEC standard voltages*

IEC 60364 (all parts), *Low voltage electrical installations*

IEC 61936 (all parts), *Power installations exceeding 1 kV AC*

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

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

[SOURCE: IEC 60050-617:2009, 617-04-24]

3.2
busbar
low-impedance conductor to which several electric circuits can be connected at separate points

Note 1 to entry: In many cases, the busbar consists of a bar.

[SOURCE: IEC 60050-151:2001, 151-12-30]

3.3
converter
device for changing one or more characteristics associated with electric 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, modified – The words "electric energy" have been removed from the term]

3.4
combined heat and power
CHP
production of heat which is used for non-electrical purposes and also for the generation of electric energy

Note 1 to entry: Conventional power plants emit the heat produced as a useless byproduct of the generation of electric energy into the environment. With combined heat and power, the excess heat is captured for domestic or industrial heating purposes.

[SOURCE: IEC 60050-602:1983, 602-01-24, modified – The abbreviated term "CHP" has been added, as well as the note to entry. The definition has been rephrased]

3.5
earth
ground
part of the earth which is in electric contact with an earth electrode and whose electric potential is not necessarily equal to zero

[SOURCE: IEC 60050-195:1998, 195-01-03, modified – The adjective "local" has been removed from the term]

3.6
earthing arrangement
grounding arrangement
electric connections and devices involved in the earthing of a system, an installation and equipment

[SOURCE: IEC 60050-195:1998, 195-02-20, modified – The deprecated term has been removed]

3.7
earthing conductor
grounding conductor
conductor which provides a conductive path, or part of the conductive path, between a given point in a system or in an installation or in equipment and an earth electrode

[SOURCE: IEC 60050-195:1998, 195-02-03, modified – The deprecated term has been removed]

3.8
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 60050-161:1990, 161-01-07]

3.9
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

3.10
distributed generation
generation of electric energy by multiple sources which are connected to the power distribution system

[SOURCE: IEC 60050-617:2009, 617-04-09, modified – The other preferred terms "embedded generation" and "dispersed generation" have been deleted]

3.11
distribution network
electrical facility and its components including poles, transformers, disconnects, relays, isolators, and wires that are owned or operated 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.

3.12
in-plant point of coupling
IPC
point on a network inside a system or an installation, electrically nearest to a particular load, at which other loads are, or could be, connected

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

[SOURCE: IEC 61000-2-4:2002, 3.1.7]

3.13
interface switch
switch (circuit breaker, switch or contactor) installed in the microgrid, for separating the part(s) of the microgrid containing at least one generation unit from the distribution network

3.14
interruptible load
load of particular consumers which, according to contract, can be disconnected by the supply undertaking for a limited period of time

[SOURCE: IEC 60050-603:1986, 603-04-41]

3.15
island
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 60050-617:2009, 617-04-12, modified – "in an electric power system" has been deleted. The second note to entry has been added]

3.16
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: Microgrid capable of being connected to a wider electric power system is also called non-isolated microgrid.

3.17
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]

3.18
load forecast
estimate of the expected load of a network at a given future date

[SOURCE: IEC 60050-603:1986, 603-01-04]

3.19
load profile
curve representing supplied electric power against time of occurrence to illustrate the variance in a load during a given time interval

[SOURCE: IEC 60050-617:2009, 617-04-05]

3.20
main switch
switch installed as close as possible to the point of connection, for protection against internal faults and disconnection of the microgrid from the distribution network

3.21
medium voltage
MV
set of voltage levels lying between low and high voltage

Note 1 to entry: The boundaries between medium- and high-voltage levels overlap and depend on local circumstances and history or common usage. Nevertheless the band 30 kV to 100 kV frequently contains the accepted boundary.

[SOURCE: IEC 60050-601:1985, 601-01-28 – The information about the use of this term has been deleted]

3.22
microgrid
<electric power system> 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.

3.23
microgrid energy management system
system operating and controlling energy resources and loads of the microgrid

3.24
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 distribution network.

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

3.25
generation forecast
forecast of the expected production of the DER in the microgrid

3.26
power quality
characteristics of the electric current, voltage and frequencies at a given point in an electric power system, evaluate 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]

3.27
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]

3.28
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]

3.29
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]

3.30
switch
device for changing the electric connections among its terminals

[SOURCE: IEC 60050-151:2001, 151-12-22]

3.31
under-frequency load shedding
UFLS
process of deliberately disconnecting preselected loads from a power system in response to under-frequency condition in order to maintain the active power balance of the remainder of the system

3.32
under-voltage load shedding
UVLS
process of deliberately disconnecting preselected loads from a power system in response to under-voltage condition in order to maintain the active power balance of the remainder of the system

4 General principles

4.1 General

The objective of non-isolated microgrids is to improve the supply reliability and optimize the use of local generation, while the primary objective of isolated microgrids is to supply users in remote areas where a wider electric power system is not available. Accordingly, identification of the objective and customer requirements is an essential part of the microgrid planning and design process.

The main task of the microgrid planning and design is to evaluate the local energy resources, and to determine the configuration and connecting requirements of distributed energy resources (DER). As many microgrids may not be built from scratch, when planning, grid planners should take into consideration the local load profile, energy demand and existing power supply units. The result of the microgrid planning should be flexible enough to satisfy the immediate need along with the future demand growth.

It is necessary to first determine the application that the system is intended for. The use case methodology may provide guidance to determine the optimal design of the microgrid system.

This document provides a procedure for planning and design of a microgrid, specifying the requirements for the microgrid internal design and external connection.

4.2 Preliminary study

Before a microgrid is planned, it is recommended to carry out a preliminary study to understand the local needs and perform a technical assessment, which includes the following:

a) energy resource analysis, including local renewable energy resources, energy storage, fuel sources, existing energy supply and its dispatchability;
b) load profile, load characteristics including dispatchability, and projected future demand growth;
c) a site survey, including location, size, and configuration of reactive power compensation, voltage regulation equipment, reactors, transformers, protective and sectionalizing equipment;
d) local distribution system parameters;
e) provisions for network expansion and future development.

4.3 Overall microgrid planning and design process

Figure 1 is the illustration of the main topics that should be investigated in the microgrid planning and design process.

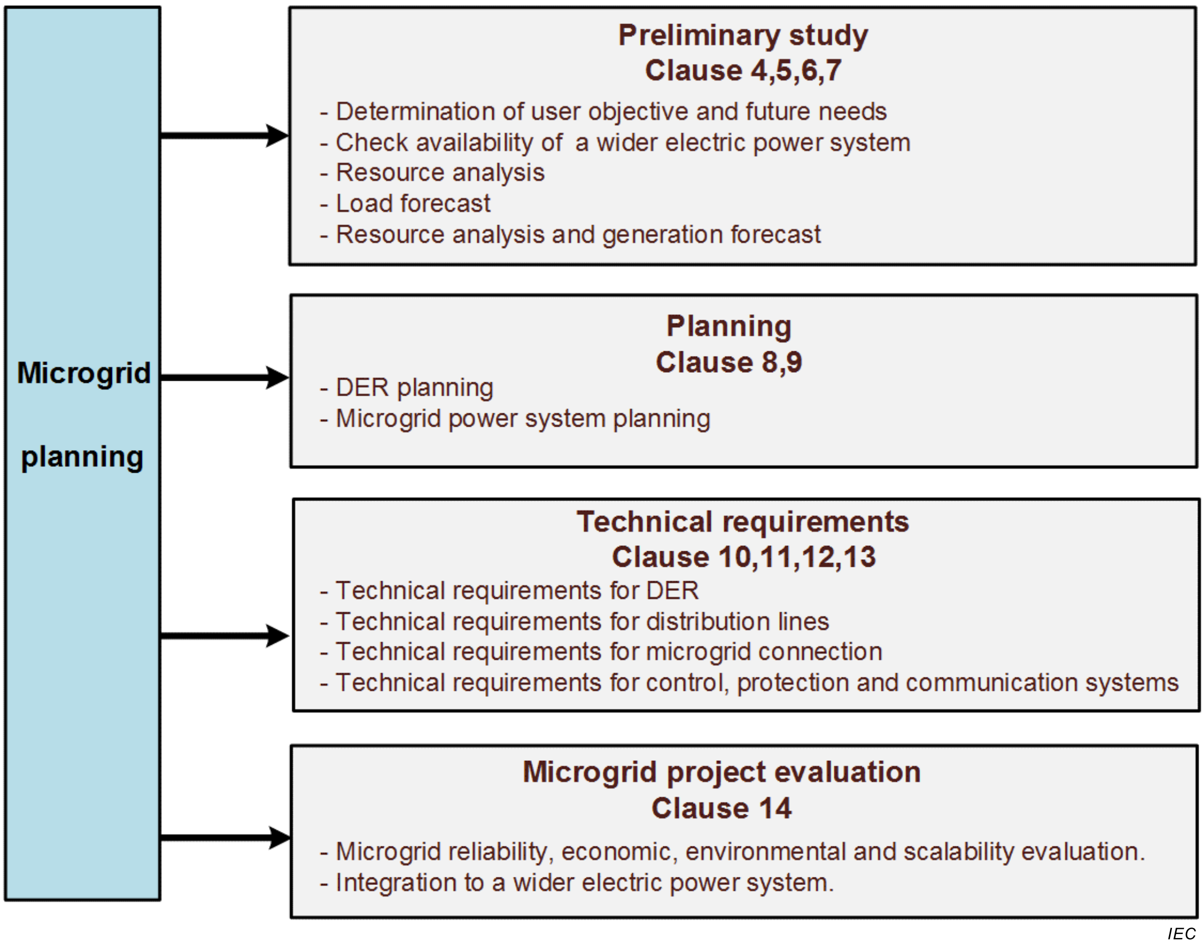

Figure 1 – Overall microgrid planning and design process

5 Purpose and application of microgrids

5.1 Application classification

Different purposes or a combination may be expected for a microgrid, including improved reliability, economy, and disaster preparedness. The following are use case scenarios for microgrids (coordinated with IEC TS 62913-2-1 developed by SyC Smart energy; see also Annexes A to D for details).

a) Microgrids that aim at improving reliability, and securing the energy supply for all or part of their loads by islanding:
   1) Distribution microgrid, for example part of utility grid, campus, activity zone;
   2) Facility microgrid, for example microgrids in a customer installation, a military base, a hospital.
b) Microgrids that aim at providing power to remote areas with lower cost, for example isolated microgrids in rural electrification, oceanic islands;
c) Microgrids that aim at reducing energy costs for microgrid users in the grid-connected mode by optimizing the assets such as energy storage, dispatchable loads and generators, providing ancillary services to the grid;
d) Microgrids that aim at providing disaster-preparedness by optimizing the assets such as energy storage, dispatchable loads and generators. This kind of microgrids may be built in natural disaster prone areas, designed for the zone where enhanced power supply is required for some critical loads, etc.

At the planning stage, the microgrids shall be classified into "non-isolated microgrids" or "isolated microgrids", considering the availability of a wider electric power system, the characteristics of the local DER and load pattern. The determining factors also include requirements of customers for environmental benefit, power quality, reliability and economy in the microgrid.

The classification should be recognized as an essential step because different purposes, and requirements envisioned by microgrid planners will lead to different planning schemes. However, both types of microgrids should abide by the technical requirements in this document.

5.2 Application of non-isolated microgrids

The non-isolated microgrid is connected to the distribution system through the point of connection (POC), and can operate in grid-connected mode or island mode. Such a microgrid should be equipped with necessary energy storage facilities and/or dispatchable generating units. The non-isolated microgrid emphasizes the use of local resources, including renewable energy resources, with enough energy storage capacity that can sustain the critical load for a predetermined period of time in island mode.

In the non-isolated microgrid, the microgrid energy management system (EMS) should be able to keep track of the operation cost by local generation and prices of energy imported from the utility grid, in order to reach the optimal operation objectives.

Urban electrification should provide the critical load with energy of a specific power quality and reliability level. To do so, the non-isolated microgrid shall be able to transfer from one operation mode to another seamlessly and safely, while having the ability to supply the critical load in island mode. Certain equipment to improve power quality and reliability, harmonics filters and reactive power compensators should be installed in the microgrid.

5.3 Application of isolated microgrids

The isolated microgrid is not connected to the distribution system and thus is permanently operating in island mode. Such a microgrid is mainly used in areas remote from a wider electric power system. The isolated microgrid aims at continuous and reliable energy supply with or without sufficient renewable energy. Therefore, such a microgrid should contain sufficient energy storage capacity and dispatchable DER.

The isolated microgrid shall keep the power balance by managing generators, energy storage system as well as demand response.

The microgrid planners should make the economic decision between installing large electric energy storage versus paying for periodic delivery of fuel.

Scalability of isolated microgrids should be envisaged from the beginning, through enlargement of the microgrid and/or connectivity of microgrids.

6 Resource analysis and generation forecast

6.1 Resource analysis

6.1.1 General

The proper understanding of the generation potential and other characteristic of the local energy resources is the first step in microgrid planning. The resource analysis should be carried out by first considering the non-dispatchable resources and then dispatchable resources. The non-dispatchable resources are mostly renewable energy, including solar energy and wind energy; dispatchable resources include biomass, combined heat and power (CHP), combustion unit, storage, etc. During the preliminary study stage, historical meteorological data, geographical features, and availability of construction site should be collected. Modern site assessment techniques should also be utilized to predict the possible energy generation potential.

6.1.2 Non-dispatchable resource analysis

6.1.2.1 Solar energy resource analysis

Solar energy resources should be assessed based on monthly and yearly solar radiation and sunshine intensity data, combined with the regional climate conditions, annual change patterns of solar radiation and sunshine intensity. Indices used in the solar evaluation should indicate richness and consistency of solar energy.

For photovoltaic generation, the total solar radiation should be taken as an index to assess the richness of solar energy resources. For solar-thermal power generation, direct radiation perpendicular to the incident light of the sun should be taken as an index to assess the richness of solar energy resources.

The analysis and design of solar energy resources and photovoltaic generating units should abide by the requirements of IEC 60904 (all parts).

6.1.2.2 Wind resource analysis

Wind energy resources should be assessed at possible wind turbine installation sites based on monthly and yearly wind data, combined with wind power density, wind speed, wind direction, fluctuation of wind speed, wind turbulence intensity and other meteorological factors.

6.1.2.3 Other non-dispatchable resource analysis

Other non-dispatchable resources, such as tidal energy and wave energy, should be assessed based on related standards and procedure.

6.1.2.4 Selection of non-dispatchable energy units

Non-dispatchable energy units should be selected according to the local natural environment, engineering geological conditions, site utilization condition, equipment availability and other factors, on the basis of technology advancement and operation reliability. The maximum available capacity of non-dispatchable energy power generation should be calculated.

6.1.3 Dispatchable resource analysis

For dispatchable renewable energy (e.g. biomass, hydro and geothermal), the analysis is similar to that of non-dispatchable energy. For example, to use biomass DER, microgrid planners should evaluate the amount of the raw material available on a daily, monthly, and yearly basis. In the thermal dispatchable DER planning, availability of raw material, fuel cost, transportation cost, and environmental impact should be assessed.

6.2 Generation forecast

6.2.1 General

Forecasting of the DER generation is the basis of microgrid planning and operation. With historical meteorological data and numerical weather prediction as input, generation forecast models can yield generation forecasts in different timescale.

NOTE Generation forecast can be generally classified into ultra-short term (in seconds to a few minutes), short-term (in hours, up to 72 hours ahead) and long term (in days, weeks, and years ahead). The exact definition of different timescale is up to the forecast service providers, microgrid planners and operators to decide.

Information to be collected should include, but not be limited to the following:

a) scope of the generator installation region, installed capacity, generator type, inverter type;
b) size and the number of generators;
c) characteristics curve of generators, etc.;
d) longitude, latitude, altitude and installation location of the meteorological station.

Historical monitoring information to be collected should include, but not be limited to the following:

e) horizontal radiation, direct radiation, diffused radiation, ambient temperature, relative humidity, barometric pressure, wind speed and direction;
f) output power of generators, working conditions of the inverters, and the record of generator faults.

Weather prediction data to be collected generally include the following:

g) direct horizontal solar radiation, diffuse horizontal solar radiation, direct solar radiation perpendicular to the incident light;
h) wind velocity, wind direction, temperature, relative humidity, air pressure, cloud thickness, and precipitation.

6.2.2 Technical requirements

More than one generation forecasting schemes should be put forward. The scheme with the best fit should be selected to forecast power generation.

In data processing, elimination of inconsistent data should be allowed. Forecasting error of the forecast curve should be estimated, and an error range for a given confidence level should be provided.

6.2.3 Data processing

6.2.3.1 Data feasibility test

Data feasibility test should include the following:

a) test of power generation forecast and measurement systems with respective confidence level – the confidence level may be manually set;
b) test of change rate of power generation, the limit of which may be reset;
c) test of mean and standard deviation of power;
d) correlation test between previous forecasted data and real power output.

6.2.3.2 Missing or bad data

Consideration should be given to missing or bad data. For example, missing or bad data should be processed in the following ways:

a) replaced by the latest power measurement data;
b) replaced by the installed capacity of the generating unit;
c) data less than zero replaced by zero;
d) missing or bad data can be reset manually; after correction, these data should be marked.

7 Load forecast

7.1 General

Load forecast, including energy demand forecast and power demand forecast, lays the foundation for microgrid planning and energy scheduling activities, such as generation scheduling, fuel purchasing scheduling, maintenance scheduling and investment scheduling.

Load forecast is based on the assessment of the local load data, history of infrastructure construction and industry development, etc. In addition, social, environmental and economic factors related with load variation should be investigated.

The required data for load forecast are the following:

a) demographical and geographical data;
b) economic, social and meteorological data;
c) information on electric power and energy balancing;
d) peak load, typical daily load profile;
e) historical energy consumption, load, capacity of contract by large customers;
f) development projects underway in the area;
g) potential load shedding capacity;
h) analysis of changes in load characteristics and the influence of DER integration on load forecast.

The expected load growth should be considered and evaluated in the system planning annually.

7.2 Load analysis

For a non-isolated microgrid in grid-connected mode, if the generation within the microgrid is lower than demand, electricity can be purchased from the distribution system and transmitted through the POC; for a non-isolated microgrid in island mode, and for an isolated microgrid, the demand-supply balance should be achieved by DER output, load priority, controllable load as well as demand response.

It will be critical to understand the priority of various loads and to distinguish critical load and load that can be curtailed or shed. One common response in times of constrained supply is to shed low-priority loads in order to maintain supply to the critical load. Low-priority load can also participate in demand response where a facility owner is paid to shed loads at times of peak system demand. Demand side management can participate in the balance of energy and act as spinning reserve. Such service should be designed to be fully responsive and nondisruptive. Plug-in electric vehicles and thermostatically controlled loads, such as refrigerators, air conditioners, and electric water heaters, are examples of controllable loads where energy balancing does not interfere much with their end-use functions.

7.3 Classification of load forecast

Load forecast is divided into long term, medium term and short term forecast.

NOTE Long term forecast starts from 1 year and above. Medium term forecast is from months to 1 year. Short term forecast covers hourly, daily, weekly forecast. The exact definition of different timescale is up to the forecast service providers, microgrid planners and operators to decide.

Long/medium term forecast is primarily intended for capacity expansion, capital investment, revenue analysis and corporate budgeting. Long-term energy sales, total energy and peak load demand forecast are several of the critical items for microgrid planners to make effective resource planning decisions.

The basic quantity of interest in short term load forecast (STLF) is, typically, the hourly total system load. The primary application of the STLF is to assist the scheduling functions to determine the most economical commitment of DER consistently with reliability requirements, operational constraints and physical, environmental, and equipment limitations. In addition to the forecast of the hourly values of the system load, STLF is also concerned with the forecasting of the following:

a) daily peak system load;
b) values of system load at certain time of the day;
c) hourly or half-hourly values of system load;
d) daily and weekly system energy.

If historical measurement data are not available, load forecast can be used instead.

7.4 Technical requirements

In order to improve forecasting precision, the forecasting results can be cross checked with the results in areas domestic and abroad with similar size and features. Besides, the planning of a microgrid shall leave enough margin for future expansion.

It is recommended that load forecast should be put forward using two or more methods and cross checked with each other. After forecasts for high, medium and low load schemes are carried out, a recommended forecast result should be given for microgrid planning.

Inconsistent data in historical load power and energy records should be discarded or replaced in a logical manner.

For load forecast, the energy demand should be evaluated first and then power demand. Usually, the energy demand forecast for one year is studied. After that, the expected maximum power demand is calculated based on the utilization hours per year. It is also possible to estimate loads of different times according to typical load profiles.

8 Distributed energy resource planning

8.1 Ratio of renewable energy

The ratio of renewable energy in a microgrid is determined by the purpose of the microgrid, availability of local renewable resources, evaluation of investment and economy consideration, as well as the construction condition.

NOTE Ratio of renewable energy indicates the ratio of the installed capacity of renewable energy to the total installed capacity in the microgrid.

8.2 Renewable generation configuration

After the ratio of renewable energy is determined, the types and capacity of the distributed generation sources are determined on the basis of economic analysis and reliability analysis.

8.3 Energy storage

Microgrids may install energy storage to mitigate the volatility of renewable energy and fluctuating load pattern, provide load management, improve microgrid reliability, and supply demand in isolated microgrids and island mode of non-isolated microgrids. Energy storage may be in the form of electrochemical storage systems, mechanical energy storage, chemical energy storage, electromagnetic energy storage, thermal storage, etc. The types, energy capacity and installed power of energy storage systems should be determined based on the reliability requirements, power quality requirements, and available investment of the microgrid. A spectral analysis of fluctuating load patterns and renewable energy resources for electricity is also helpful to assess the amount of storage needed.

NOTE In TC 120, standards related to electrical energy storage system are currently being developed, which are expected to be helpful for dimensioning the storage size in a microgrid.

8.4 Electric power and energy balancing

Microgrid planners should ensure the balance of generation and consumption in all possible unit commitment schemes.

The analysis of electric power and energy balancing should be carried out periodically and reviewed annually. The influence of renewable energy, electric vehicles, and storage devices should also be counted.

The microgrid should be able to regulate voltage, especially in island mode for secure operation. Accordingly, reactive power balance should also be maintained in the microgrid.

Electric power and energy balancing should first be carried out using load forecast and maximum capacity of renewable energy. Then the amount of non-renewable generation (e.g. diesel generators, natural gas engines, micro turbine, storage) can be determined.

Electric power and energy balancing is a prerequisite for isolated microgrids, but may not be so for non-isolated microgrids.

8.5 Dispatchable generation configuration

According to the result of electric power and energy balancing, the final dispatchable generation configuration is established while considering the uncertainty of renewable energy. The final decision aims at maximizing reliability and economy.

With the criteria of reliability, cost efficiency, available construction site, fossil fuel transportation, and controllable load, the types and capacity of dispatchable generation units can be decided.

9 Microgrid power system planning

9.1 Voltage level

Voltage levels within the microgrid shall be chosen according to IEC 60038.

A non-isolated microgrid should be designed at a voltage level to achieve the optimal power exchange with the distribution system. The maximum power exchange in each direction at the POC is specified by the relevant network operator.

9.2 Typical topology of a microgrid

9.2.1 Typical topology for a non-isolated microgrid

9.2.1.1 Single bus structure

The single bus topology shown in Figure 2 can be used for both a low voltage and a medium voltage network.

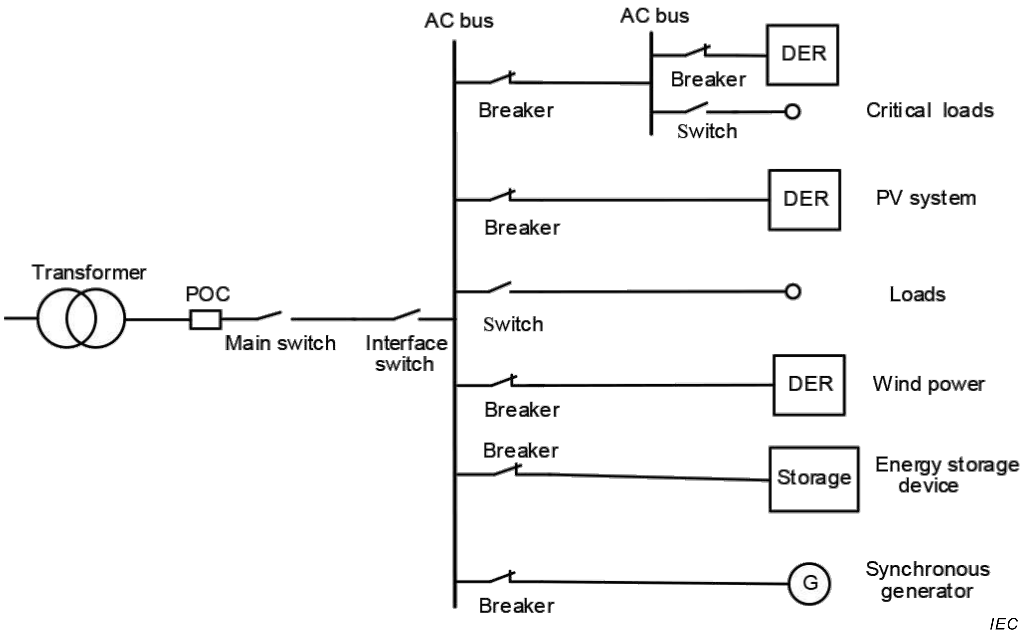

Figure 2 – Single bus structure microgrid

9.2.1.2 Multiple bus structure

The multiple bus topology shown in Figure 3 can be used for a microgrid that aims at high reliability on a large oceanic island or an urban community.

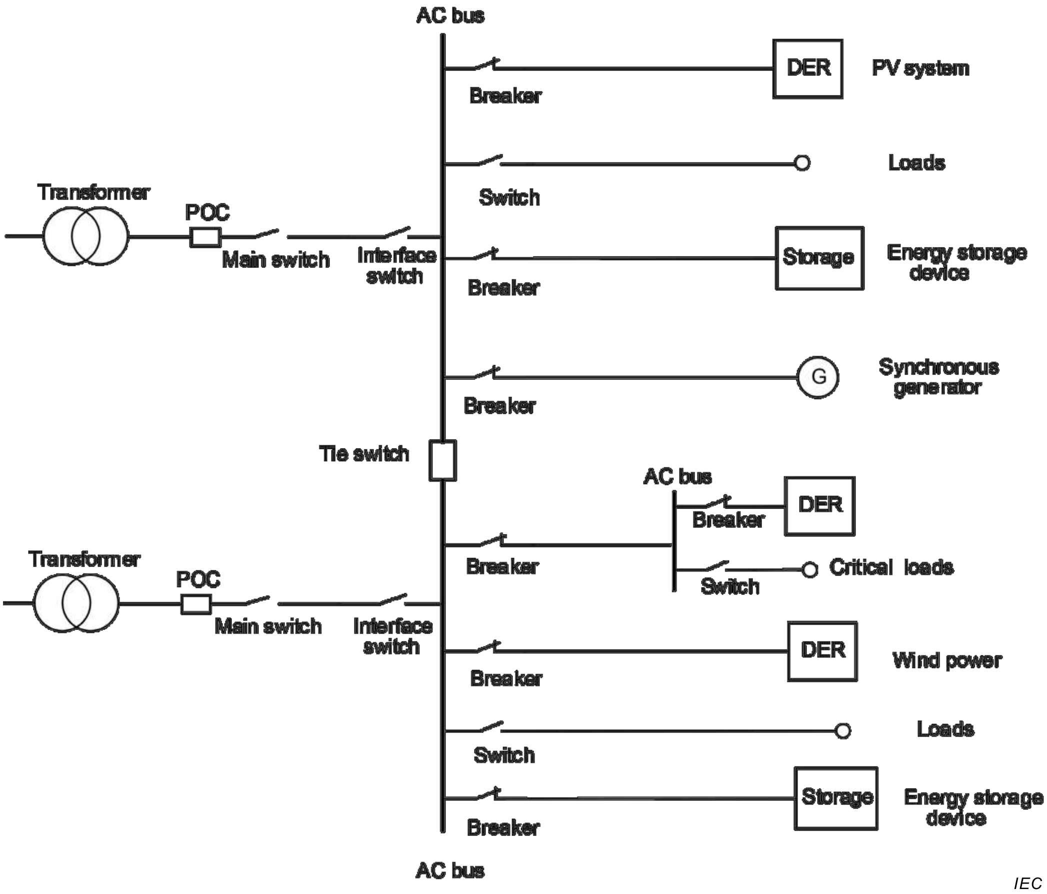

Figure 3 – Multiple bus structure microgrid

9.2.1.3 Multilevel structure

The multilevel topology shown in Figure 4 is mainly used for large-scale microgrid with dispersed DER.

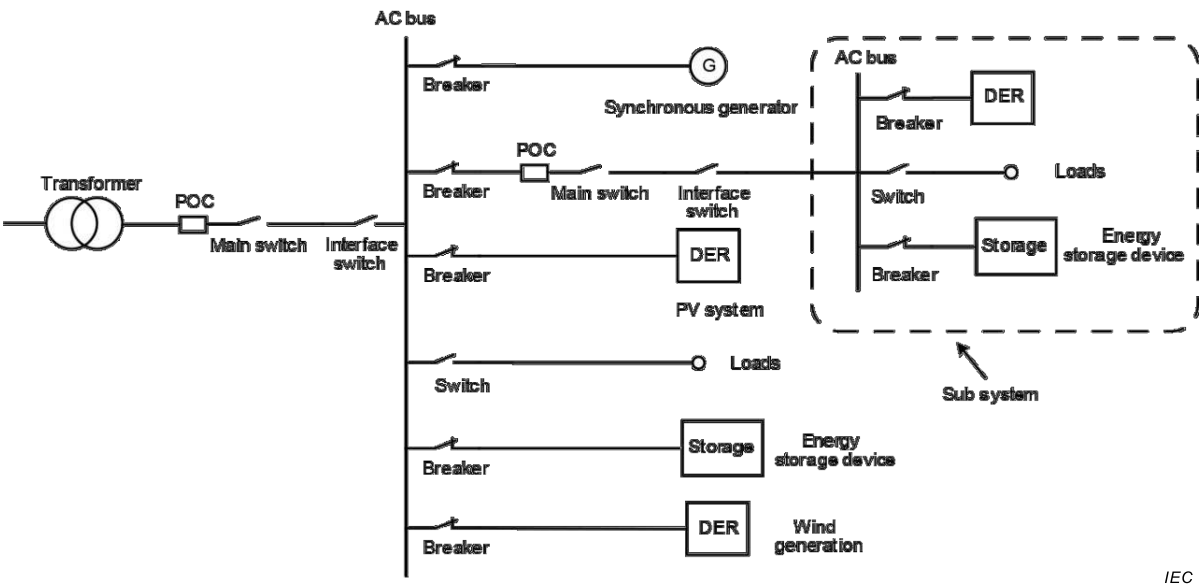

Figure 4 – Multilevel structure microgrid

9.2.2 Typical topology for an isolated microgrid

The typical topology for an isolated microgrid (see Figure 5) is similar to that of a non-isolated microgrid without POC.

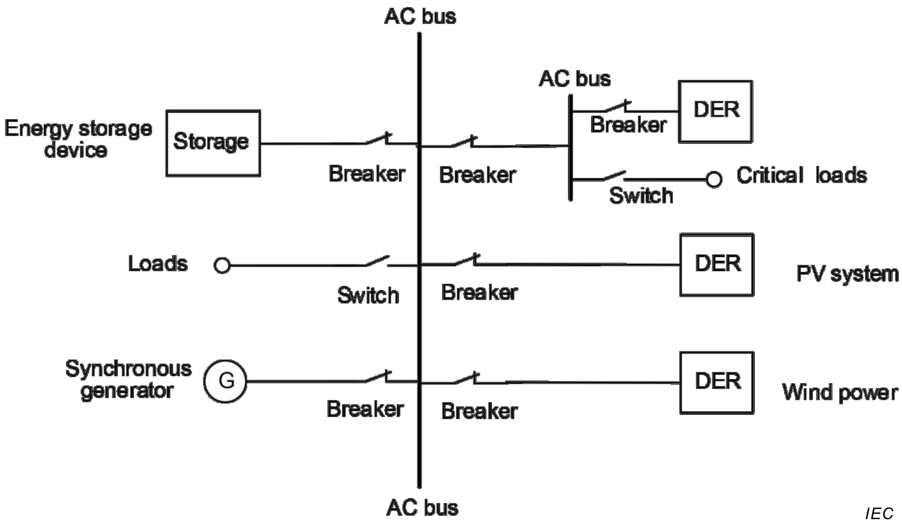

Figure 5 – Typical topology for an isolated microgrid

9.3 Electrical parameter calculations

Electrical parameter calculation that should be carried out includes:

a) power flow: power flow calculation of typical operation modes;
b) short-circuit current calculation: three phases and single phase short circuit current calculation;
c) stability calculation as required case by case;
d) fault ride through capability verification by numerical simulation or theoretical analysis.

10 Technical requirements for DER in microgrids

10.1 General

Clause 10 intends to provide the baseline technical requirements for DER in microgrids. The principles and technical requirements for DER connected to the distribution system have been specified in IEC TS 62786, and the content within it applies to DER in microgrids in grid-connected mode. Specific DER requirements from a perspective of overall microgrid management in different microgrid operation modes are given in IEC TS 62898-2. Different countries may also have local or national grid codes or other requirements for DER.

DER in microgrids can be synchronous generators, asynchronous generators, or converter-based generators. Synchronous generators can be directly coupled to a microgrid, they have rotating inertia and usually work in the droop mode.

The usual control methods for converter-based DER are the control of injected active and reactive power, the control of voltage and frequency and droop mode (P-f, Q-V).

According to IEC TS 62786, the common functions of DER control include the following:

a) voltage and frequency control capabilities;
b) active and reactive power output regulation;
c) disconnection and reconnection to the microgrid;

d) immunity to frequency change;

e) fault ride through capability.

DER in microgrids should adapt to possible stringent operation environment in isolated microgrids, in island mode and/or during microgrid mode transferring.

10.2 Technical requirements for DER in grid-connected mode

When the microgrid is in grid-connected mode, microgrid frequency and voltage can be regulated by the connected distribution system. In addition to local or regional grid codes, DER should comply with relevant technical requirements in IEC TS 62786.

10.3 Technical requirements for DER in isolated microgrids and island mode of non-isolated microgrids

In isolated microgrids and the island mode of non-isolated microgrids, microgrids shall be self-sustained either for a limited duration or permanently. Load in these operation modes is satisfied solely by DER and load management, and the sizing of DER should be large enough to ensure the normal operation of predetermined critical loads.

Without support from the connected distribution system, microgrids in these modes might experience a degradation of power quality. The DER protective setting may be relaxed by microgrid operators in order to provide stable power supply.

In these operation modes, there shall be at least one (or one group of) controllable DER to provide frequency and voltage reference.

For the island mode of non-isolated microgrids, the microgrid shall monitor the voltage, frequency and phase angle of the distribution system. When the voltage and frequency of the distribution system are normal, the microgrid is allowed to transfer to grid-connected mode. Synchronization control shall be adopted for the transition from island mode to grid-connection mode.

11 Technical requirements for distribution lines in microgrids

Selection and erection of distribution lines in a microgrid shall comply with IEC 60364 (all parts), IEC 61936 (all parts) or local rules for public distribution systems.

12 Technical requirements for microgrid connection to distribution networks

12.1 General

Clause 12 applies to non-isolated microgrids. Connection of the microgrid to the distribution network should not risk the safe and reliable operation of the distribution network. After the microgrid is connected, the power quality at the POC should meet the specific requirements by IEC standards.

12.2 Interface protection

The main switch at the POC shall be easily operated manually or automatically and should be able to latch. At the POC, an interface switch with visual breakpoint also shall be installed.

Interface devices should meet the corresponding electric equipment voltage withstanding level.

The breaking capacity of main switch at POC should be determined by the larger one of the two values: maximum short circuit current at POC, when the microgrid is in island mode or maximum short circuit current of the distribution network at POC.

12.3 Microgrid earthing

12.3.1 General

The choice of the microgrid earthing strongly influences the reliability of the microgrid operation and the safety of persons, livestock and property. 12.3 intends to provide the basic guidelines for earthing arrangement design in non-isolated microgrids. The earthing arrangement for isolated microgrid may be designed according to local requirements (if any), and IEC TS 62257-5.

12.3.2 Technical requirements for microgrid earthing

In the earthing arrangement, the choice of earthing conductors should be made based on the mechanical strength, thermal stability and anti-corrosive property of the conductor materials.

The earthing of DER, transformers and other electrical installation in microgrids shall be compatible with the earthing system of the distribution network that the microgrid is connected to. The safe operation should be ensured in grid-connected mode, island mode and during mode transferring.

In microgrid electrical installation, exposed conductive parts in microgrid electrical installations shall be connected to a protective conductor under the specific conditions for each type of system earthing. Simultaneously accessible exposed-conductive-parts shall be connected to the same earthing system individually, in groups or collectively.

In medium-voltage microgrids (nominal voltage above 1 kV AC), the earthing system of the microgrid should also abide by requirements in IEC 61936 (all parts).

In low voltage microgrids (nominal voltage at or below 1 kV AC), the earthing system of the microgrid should also abide by the requirement in IEC 60364 (all parts).

Important parts of the microgrid installations, such as DER switchgears, conductors, busbar systems, including safety warnings and instructions should be clearly and durably labelled.

12.4 Power quality at POC

12.4.1 General

The power quality parameters are used to demonstrate reliable operation of microgrids and should not be outside the allowed operating range for all components in the microgrid.

Power quality levels shall be specified in accordance with the business use case specified in Clause 5.

For a non-isolated microgrid, unless otherwise specified, the power quality levels at in-plant point of coupling (IPC) shall be the same in grid-connected and island mode.

When a microgrid is connected to a distribution system, it shall not cause unacceptable disturbances to the other system users.

The microgrid shall parallel with the distribution system without causing a voltage fluctuation at the distribution system or resulting in flicker and rapid voltage changes greater than the ranges defined in the IEC TS 62749.

12.4.2 Power quality monitoring

Non-isolated microgrids should support to monitor power quality parameters at the POC, if needed.

13 Technical requirements for control, protection and communication systems

13.1 Microgrid control

13.1.1 General

The function of the control system in microgrids should include power balance, demand side management and economic dispatch. The optimal operation is achieved by analyzing DER types, energy cost, unit maintenance schedule, and environmental impacts. The non-isolated microgrid should be able to transfer from grid-connected mode to island mode smoothly. There should also exist emergency plans to prevent fluctuation and contingency inside the microgrid from affecting the distribution system. The non-isolated microgrid should be able to exchange information with the distribution system which it connects to.

13.1.2 Control scheme

The control scheme of a microgrid should be consistent with its planned operation. Usually, two kinds of control schemes are used in a microgrid.

1) Centralized control: this kind of control is performed by a single central controller, which requires an extensive communication system between the central controller and controlled units. All control decisions and signals are made by the central controller. Under centralized control, one (or a group of) master DER can act as a synchronous generator with adjustable capacity for voltage and frequency regulation.
2) Decentralized control: this kind of control is accomplished by the local controller at each individual controllable unit, which only receives information from locally measured data, such as system parameters (e.g. voltage and frequency), and uses the principle of self-regulation.

A hierarchical control scheme that combines the centralized and decentralized control can be used according to the size of the microgrid.

13.2 Protection relays and automatic protection devices

13.2.1 General

Protection systems in microgrids may be different from that in traditional distribution systems, as the contribution of fault currents from the distribution transformer is lacking. In the case of DER only consisting of the converter-based type and not of synchronous machines, a fault current calculation needs to be done to determine if protection settings trigger or not (also see IEC 62040-1).

In non-isolated microgrids, the fault current differs between the grid-connected mode and the island mode. In the grid-connected mode, the fault current is larger because it is contributed both from the distribution system and the DER in microgrid; in island mode, the fault current is only produced by DER. While the output current of converter-based DER is usually confined to 1,5 to 2 times rated current, in this way the fault current is much smaller. The two operating modes should have different relay settings.

Connection of the microgrid to the distribution system shall not interfere with the safe, secure and reliable operation of the connected distribution system. When the protection for microgrid POC to distribution system is being designed, the envisioned protection schemes should be coordinated with the existing protections in the distribution system. The non-isolated microgrid can either act as load or energy resource, so when the microgrid is connected through dedicated line to the distribution system, protection of the dedicated connection line should be set according to the principle of bilateral power protection configuration. If the microgrid is connected by T connection to the distribution system, microgrids should be equipped with directional current protection; for the microgrid that is directly connected to a low voltage bus, the microgrid should be equipped with over-current protection system.

13.2.2 DER component protection

In microgrids, the transformers and rotating distributed generators should be equipped with reliable protection devices. DER protection should be able to detect short-circuit fault (including single-phase ground fault) on the distribution system and stator phase failure, and cut the DER off fast enough under these conditions.

DER should also be equipped with under-voltage and over-voltage protection to ensure the safety of operating staff as well as the devices.

13.2.3 Component protection for all users in a microgrid

All equipment that may be connected to a microgrid in the grid-connected and island mode shall be fitted with protection that will operate at the fault levels of both modes, which are expected to be significantly different. This should require relays with at least two switchable protection settings.

13.2.4 Load shedding in a microgrid

Under-frequency as well as under-voltage voltage protection for interruptible loads shall be considered. The relay settings for the under-frequency load shedding and under-voltage load shedding should be chosen in a staged or randomised way so that a droop like reaction is emulated.

13.3 Microgrid communication

13.3.1 Communication within microgrid subsystem

In microgrids, there should be fast and reliable ways for DER to exchange information with microgrid EMS, if needed. Communication protocol of microgrids should abide by IEC 61850 (all parts). Communication between microgrid EMS and the distribution system should abide by the requirements of IEC 61968 (all parts) and IEC 61970 (all parts). Communication services within microgrids should abide by the requirements and/or regulations in the specific country and jurisdictions.

Construction of communication network can be divided into different phases according to microgrid construction plan.

13.3.2 Microgrid communication with connected distribution system

As there may be existing communication systems, the relevant system operator is tasked to choose the appropriate communication system. When choosing communication with the distribution system, fibre optic communication is the first choice, and if it is not available, wireless communication, or carrier communication can be used.

It is recommended that the non-isolated microgrid updates the telecontrol information using dedicated private communication network, preferably power dispatch data network. Public wireless network can be used by a microgrid that has no specific control requirements, when measures are taken for information security.

13.4 Information exchange

Under normal operation, the non-isolated microgrid should provide data as required by the relevant system operator, for example the following:

a) status of POC interface switch;
b) voltage, frequency, current at the POC;
c) active and reactive power at the POC;
d) state of Charge (SOC) of the storage facilities.

14 Evaluation of microgrid projects

14.1 General

With the goal of technical innovation, efficient energy supply and socio-economic feasibility in mind, a number of applicable proposals should be put forward for discussion. The suggested proposals should be evaluted to make the final decision.

The optimal microgrid planning and design scheme is chosen based on the expected application of the microgrid.

14.2 Reliability of power supply

Reliability evaluation can be carried out from the perpective of the distribution system, which regards the microgrid as an entity at one of its nodes that acts as load or power resource. Reliability evaluation can be carried out within the microgrid too. The distribution system reliability evaluation methods can be applied to microgrids. The expected reliability level is determined by the application of the microgrid and related local requirements.

Complete reliability studies should take account of the possible failures of the communication and IT systems of the microgrid and their consequences, the possible black start capabilities of microgrids for restoration and/or a black start service to the connected distribution system.

14.3 Economic benefits

In the economic evaluation, microgrid planners should assess the economic feasibility of a microgrid by calculating the financial costs, benefits, and customer paying ability.

The socio-economic feasibility of a planning scheme or an existing microgrid can be carried out by performance simulation by commercial softwares.

14.4 Environmental benefits

It is necessary to assess the influence of the microgrid construction on environment, to prove its feasibility, and later to use the assessment to guide the environmental protection schemes in the microgrid.

The microgrid contractors should also recognize their responsibility for environmental protection, and provide necessary information for environmental management.

14.5 Scalability

Scalability should be considered if a microgrid system is to expand or to be networked with other microgrid systems. There should be periodically evaluation as to assess the availability of nearby microgrids, protocol compatibility, communication and control complexity, etc.

14.6 Integration to the wider electric power system

For isolated microgrid, during the planning stage, the connection to the wider electric power system in the future should be considered. When conditions are met (e.g. wider electric power system is constructed, supply capacity is adequate), the isolated microgrid can be integrated to the wider electric power system through a POC.

Annex A
(informative)

Business use case A
Guarantee a continuity in load service by islanding with microgrids

A.1 General

This business use case (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[2].

A.2 Purpose

This BUC concerns non-isolated microgrids only (distribution microgrids or facility microgrids). It describes how microgrids can guarantee a continuity in load service by islanding, i.e. by operating disconnected from the overlay grid.

A.3 Objectives

This BUC reaches thus several objectives on the services to microgrid users:

- improve resiliency of the grid toward blackouts;
- facilitate maintenance of network assets, by enabling downwards customers to stay supplied during an intervention;
- maintain critical loads supplied during blackouts;
- improve continuity of electricity supply for customers of the microgrid area;
- reduce the outage time for customers of the microgrid area.

Three kinds of islanding start are possible:

- preventive islanding if a supply interruption is planned (e.g. due to maintenance), or a grid outage is expected (examples include storms that could damage overhead lines, overvoltage due to PV injection and line congestion);
- automated islanding in case of unplanned grid failure;
- black start recovery to re-supply loads after grid failure, if the microgrid is technically not capable to automatically island without any blackout.

After starting the islanding, the microgrid will continue to operate in island mode as long as the power is not back to normal on the overlay grid. Afterwards, it can reconnect to the grid, and work again in grid-connected mode.

2 Under preparation. Stage at the time of publication: IEC CD 62913-2-1:2017.

Annex B
(informative)

Business use case B
Optimize local resources to provide services to customers inside the microgrid

B.1 General

This business use case (BUC) is intended to be offered to IEC SyC SmartEnergy to complement IEC TS 62913-2-1.

B.2 Purpose

This BUC concerns non-isolated microgrids. It describes how microgrids can be used to provide services to their customers, by optimizing the assets such as energy storage, dispatchable loads and generators. The services provided can be the reduction of the energy cost, the increase of local energy consumption, the decrease of greenhouse gas emissions, etc.

B.3 Objectives

- Reduce the energy cost for microgrid users.
- Promote local consumption.
- Facilitate renewable energy integration.
- Services to the grid.

Annex C
(informative)

Business use case C
Electrify remote areas using renewable energy sources

C.1 General

This business use case (BUC) is intended to be offered to IEC SyC SmartEnergy to complement IEC TS 62913-2-1.

C.2 Purpose

This BUC concerns isolated microgrids used for purposes such as electrification in far rural area or geographic islands.

C.3 Objectives

- Local electrification in developing areas, eventually before the construction of large public distribution networks.
- Electricity supply in islands or areas where there is no possibility to have connection to large public distribution networks.

This BUC implies that microgrid is one of the solution to promote electrification for far rural areas or islands with integration of renewable energy resources (or distributed energy resources DER).

C.4 Basic functions

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

C.5 Advanced functions

Load shedding, load control, forecast of load and power generation.

Annex D
(informative)

Business use case D
Optimize local resources to provide services to the grid/disaster preparedness

D.1 General

This business use case (BUC) is intended to be offered to IEC SyC SmartEnergy to complement future IEC/TS 62913-2-1*: Generic Smart Grid Requirements – Part 2-1: Grid related Domains,* to come.

D.2 Scope

This BUC concerns microgrids or DER used for system services such as frequency regulation, voltage control, robust smart grid and electric power grid recovery from disasters.

D.3 Objectives

- Ancillary services for electric power system such as frequency regulation and voltage control.
- Post-disasters of electric power system (enhance black start capacity, help to start local wind turbine or HVDC link, etc.).

This BUC implies that microgrids or DER are one of the solutions to perform electric power system services.

D.4 Basic functions

Black start, VAR control, frequency and voltage regulation.

D.5 Advanced functions

Management of priority of load supply.

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[3] Under preparation. Stage at the time of publication: IEC CD 62898-2:2017.

[4] Under preparation. Stage at the time of publication: IEC CD 62913-2-1:2017.

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