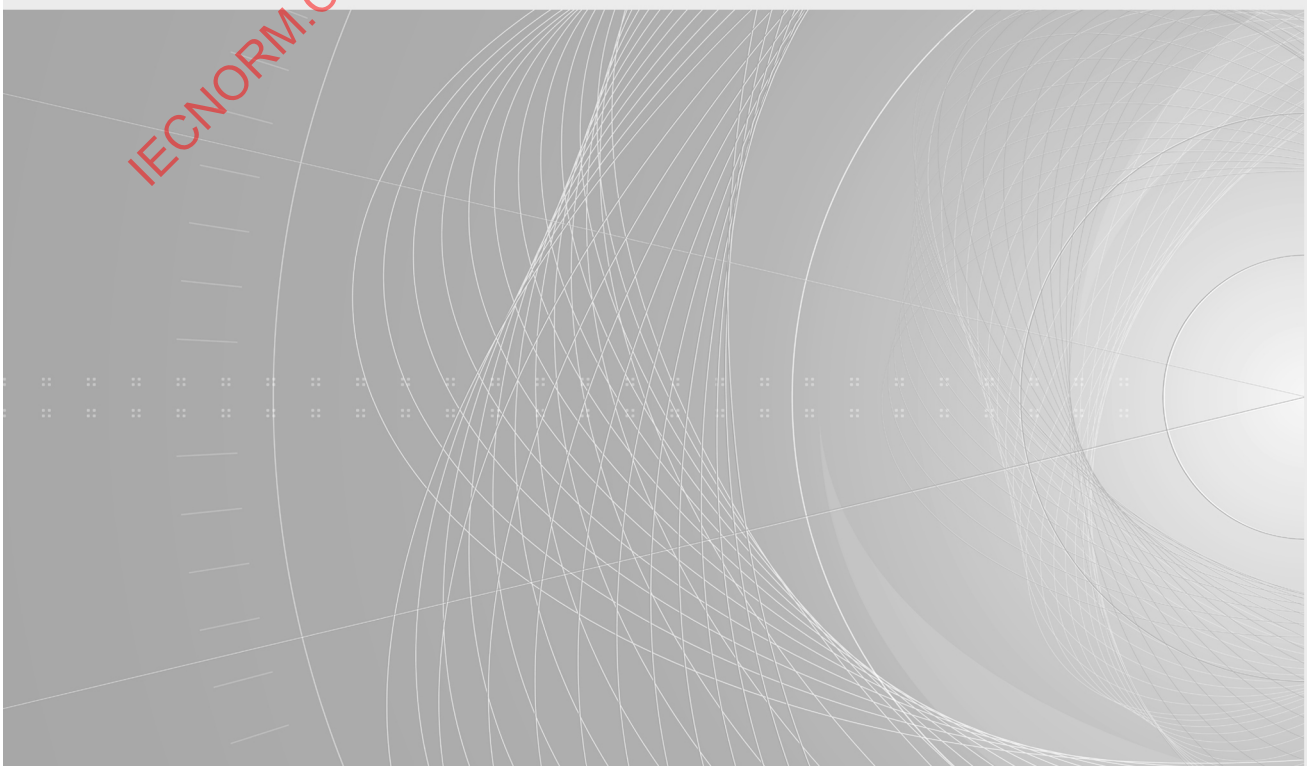
IEC TS 62257-7-3

Edition 2.0 2018-03

TECHNICAL SPECIFICATION

Recommendations for renewable energy and hybrid systems for rural electrification –
Part 7-3: Generator set – Selection of generator sets for rural electrification systems



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INTERNATIONAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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RECOMMENDATIONS FOR RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 7-3: Generator set – Selection of generator sets for rural electrification systems

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 62257-7-3, which is a technical specification, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This second edition cancels and replaces the first edition, issued in 2008. It constitutes a technical revision.

The main technical changes with regard to the previous edition are as follows:

- Increased the voltage and power levels to which this TS applies.
- Added descriptions of four different types of micropower systems and their relevant requirements.

This technical specification is to be used in conjunction with other parts of this series or future parts as and when they are published.

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

Enquiry draft	Report on voting
82/1329/DTS	82/1383A/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 62257 series, published under the general title: *Recommendations for renewable energy and hybrid systems for rural electrification*, 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.

INTRODUCTION

The IEC 62257 series of documents intends to provide to different players involved in rural electrification projects (such as project implementers, project contractors, project supervisors, installers, etc.) documents for the setting up of renewable energy and hybrid systems with AC voltage below 1 000 V, and DC voltage below 1 500 V.

These documents are recommendations:

– to choose the right system for the right place;

– to design the system;

– to operate and maintain the system.

These documents are focused only on off-grid rural electrification concentrating on, but not specific to, developing countries. They are not considered as all-inclusive to rural electrification. The documents try to promote the use of renewable energies in rural electrification; they do not deal with clean development mechanisms at this time (CO_2 emission, carbon credit, etc.). Further developments in this field could be introduced in future steps.

This consistent set of documents is best considered as a whole with different parts corresponding to items for safety, sustainability of systems and at the lowest life-cycle cost possible. One of the main objectives is to provide the minimum sufficient requirements, relevant to the field of application, that is, renewable energy and hybrid off-grid systems.

RECOMMENDATIONS FOR RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 7-3: Generator set – Selection of generator sets for rural electrification systems

1 Scope

This part of IEC 62257 specifies the general requirements for the selection, sizing, erection and operation of generator sets in decentralized rural electrification systems.

It applies to all low voltage combustion engine electricity generator sets energized by renewable energy such as biomass gasifier or biogas, or fossil fuel such as gasoline or diesel fuel, and designed for supplying electrical power to isolated sites used in systems as described in IEC TS 62257-2.

This document is not an exhaustive resource for the design, installation, operation or maintenance of generator sets, but is more focused on recommendations to provide strategies on selection and criteria which may affect the use of such generation systems in a rural electrification project.

Four cases of micropower plant will be considered as illustrated by Figure 1 to power a collective electrification system (microgrid) or an individual electrification system.

– the micropower plant is composed of one generator set;
– the micropower plant is composed of multiple generator sets, which may have a single energy source or multiple energy sources;
– the micropower plant which is a hybrid energy system between one generator set and a Power Conditioning Sub-system (PCS) which is powered by other energy source including renewable energy source or energy storage;
– the micropower plant which is a hybrid energy system between multiple generator sets and multiple Power Conditioning Sub-systems (PCSs) which are powered by other energy sources including renewable energy sources or energy storage systems.

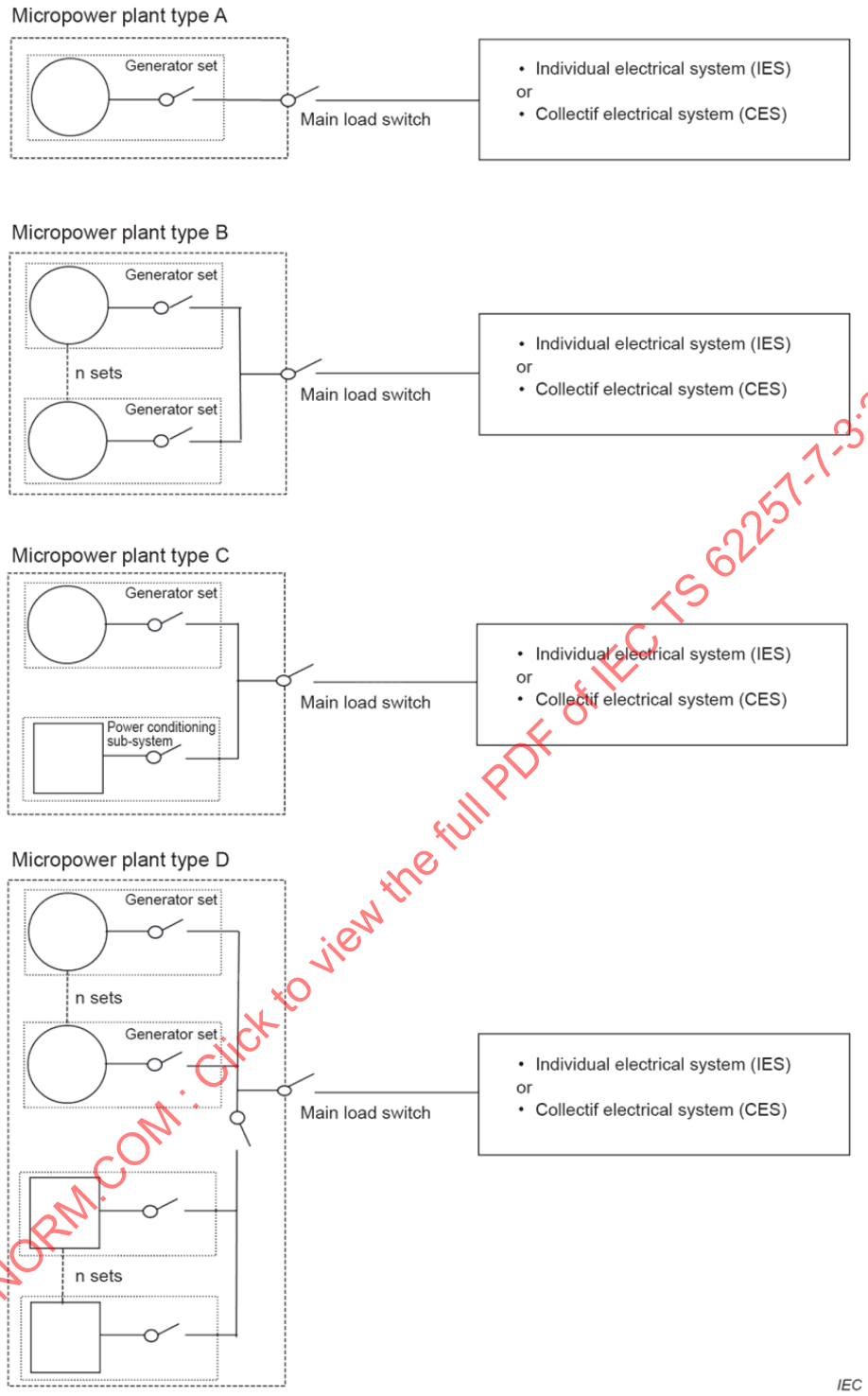

Figure 1 – General functional configuration of micropower plant in micropower system

The aim of this document is to provide users with the appropriate guide to select generator sets for using in micropower plant with different configurations and levels of reliability and safety of the equipment during its estimated service lifespan.

It describes the minimum requirement of generator set functionality and safety requirements and does not claim to be an exhaustive instruction manual or design specification.

Compliance with this document does not exempt any person, organization or corporation from the responsibility to comply with all other relevant requirements including what is indicated in maker user manuals and local electrical regulations.

This document gives recommendations for the following types of generator sets:

a) single phase;

b) three phase;

c) LV range up to 500 V – 50/60 Hz (see IEC TS 62257-9-2).

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 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-9, *Rotating electrical machines – Part 9: Noise limits*

IEC 60034-22, *Rotating electrical machines – Part 22: AC generators for reciprocating internal combustion (RIC) engine driven generating sets*

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

IEC 60529, *Degrees of protection provided by enclosures (IP code)*

IEC 61009-1, *Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) – Part 1: General rules*

IEC TS 62257-2:2015, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 2: From requirements to a range of electrification systems*

IEC TS 62257-5, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 5: Protection against electrical hazards*

IEC TS 62257-6, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 6: Acceptance, operation, maintenance and replacement*

IEC TS 62257-9-2, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 9-2: Microgrid*

IEC TS 62257-9-4, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 9-4: Integrated systems – User installation*

ISO 8528-1, *Reciprocating internal combustion engine driven alternating current generating sets – Part 1: Application, ratings and performance*

ISO 8528-5, *Reciprocating internal combustion engine driven alternating current generating sets – Part 5: Generating sets*

ISO 8528-7, *Reciprocating internal combustion engine driven alternating current generating sets – Part 7: Technical declarations for specification and design*

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
environmental conditions
environment characteristics (altitude, temperature, humidity, etc.) which may affect the performance

3.2
generator set
equipment producing electricity from a fossil fuel; it consists basically of an internal combustion engine producing mechanical energy and a generator which converts the mechanical energy into electrical energy and mechanical transmission, support and assembly components

3.3
identification file
IF
document provided by the manufacturer which guarantees the conformity of the equipment supplied with that which has undergone the type tests

3.4
lifespan
effective period of functioning taking into account the probability of a catastrophic failure

3.5
non-routine maintenance
maintenance necessary in addition to that pre-planned

3.6
rated frequency
frequency at which the generator set is designed to operate

3.7
routine maintenance
preventive maintenance carried out to an established plan

3.8
rated electrical power
nominal power
rated capacity
maximum continuous power supplied by a generator set in compliance with its specifications, and under standard operating conditions

Note 1 to entry: This is expressed in VA (volt-ampere), or more usually in kVA.

3.9
rated rotation speed
alternator rotation speed necessary to produce the voltage at the rated frequency

3.10
rated voltage
voltage between phases on the alternator terminals at the rated frequency and rated power

3.11
extra low voltage
ELV
voltage not exceeding a limit which is generally accepted to be 50 V a.c. and 120 V d.c. ripple free

3.12
safety extra-low voltage
SELV
extra-low voltage system which is electrically separated from earth and from other systems in such a way that a single fault cannot give rise to the risk of electric shock

3.13
protected extra-low voltage
PELV
extra-low voltage system which is not electrically separated from earth, but which otherwise satisfies all the requirements for SELV

3.14
live conductive part
conductor or conductive part intended to be energized in normal operation, including a neutral conductor, but by convention not a PE or a PEN conductor

3.15
power factor
ratio of real power to apparent power in an a.c. circuit

3.16
real power
for a.c. circuits, the product of voltage, current and power factor, also equal to the rate of flow of electrical energy

Note 1 to entry: Real power is measured in watts (W).

3.17
apparent power
for a.c. circuits, the product of voltage by current

Note 1 to entry: Measured in volt-amperes (VA).

3.18
nominal power of the generator set
maximum apparent power that can be provided by the generator set according to the manufacturer's specification

3.19
minor fuel storage
fuel storage located in the generator set room

3.20
main fuel storage
fuel storage located outside the generator set room and able to provide fuel filling the minor fuel storage

3.21
voltage
differences of potential normally existing between conductors and between conductors and earth as follows:

a) Extra-low voltage: not exceeding 50 V a.c. or 120 V ripple-free d.c.

b) Low voltage: exceeding upper limits of extra-low voltage, but not exceeding 1 000 V a.c. or 1 500 V d.c.

c) High voltage: exceeding upper limits of low voltage

3.22
protective conductor
(identification: PE)
conductor provided for purposes of safety, for example protection against electric shock

[SOURCE: IEC 60050-195:1998, 195-02-09]

3.23
PEN conductor
conductor combining the functions of both a protective earthing conductor and a neutral conductor

[SOURCE: IEC 60050-195:1998, 195-02-12]

3.24
generator power plant
multiple generator sets operate together to provide higher power than single generator set operation or provide higher reliability of electrical power generation

3.25
individual electrification system
IES
micropower plant system that supplies electricity to one consumption point usually with a single energy resource point

3.26
collective electrification system
CES
micropower plant and micro-grid that supplies electricity to multiple consumption points using a single or multiple energy resource points

3.27
power conditioning sub-system
component(s) that convert(s) electricity from one form into another form that is suitable for the intended application. Such a sub-system could include the charge regulator that converts d.c. to d.c., the inverter that converts d.c. to a.c., or the charger or rectifier that converts a.c. to d.c.

3.28
micropower system
electrical power system that consists of micropower plant, distribution network and load which is not part of national utility grid network

3.29
micropower plant
electrical power generator plant that supplies stable voltage and frequency to micropower system

4 Introduction to generator sets

4.1 Generator set system

In the present document a generator set system includes the installed generator set itself, the related civil works or prefabricated enclosure if any and all relative ancillaries, such as fuel tank, pipes, earthing systems, etc., necessary for the operation of the generator set.

4.2 Generator set application in rural electrification systems

4.2.1 General

The usage of generator sets in rural electrification systems application, are described in IEC TS 62257-2 for T3, T4, T5 and T6 categories of systems.

In these system categories the generator sets are used to supply a.c power with stable voltage and frequency to distribution system, recharge batteries and/or provide a backup power supply to all or part of the a.c. distribution system, or to supply a.c. dedicated equipment.

The type of use of the generator set shall be identified by the project developer and notified to the supplier.

For rural electrification the generator set can be operated as a single unit or can be operated in multiple units. Multiple generator sets known collectively as the generator power plant are operated in order to increase total power or increase reliability of micropower plant. The generator set or generator power plant can also operate with other power conditioning sub-system(s) to form hybrid power/energy system in micropower plant.

Power generation in micropower plant with generator set(s) can be in one of the following configurations.

4.2.2 Single generator set (micropower plant Type A)

This type of micropower plant (refer to Figure 2) has one generator to supply power to user whether it is IES or CES.

- The selection of generator set is based on peak load of IES or CES. The starting/stopping of the generator is set by manual or an automatic control device.

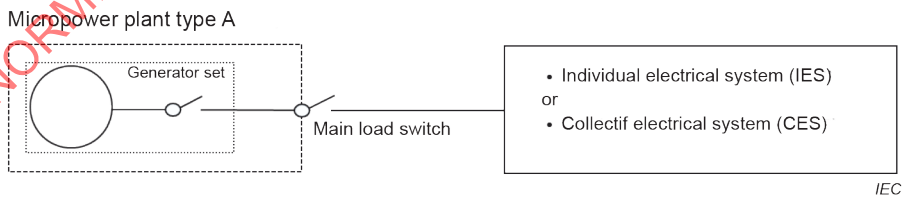

Figure 2 – Micropower plant Type A: single generator set

4.2.3 Multiple generator sets (micropower plant Type B)

This type of micropower plant (refer to Figure 3) has more than one generator set in micropower plant and the generator sets can operate as follows:

- One generator set is put to operate at any time. The selection of generator set is based on peak load of IES or CES. The starting/stopping of the generator is set by manual or an automatic control device.

- Parallel a.c. operation of more than one generator set to supply larger load of IES or CES. The micropower plant shall have measuring instruments to indicate that electrical a.c. output of the running generators are synchronized before they enter into parallel operation together. The combination of a.c. output can be done by manual or automatic control devices.

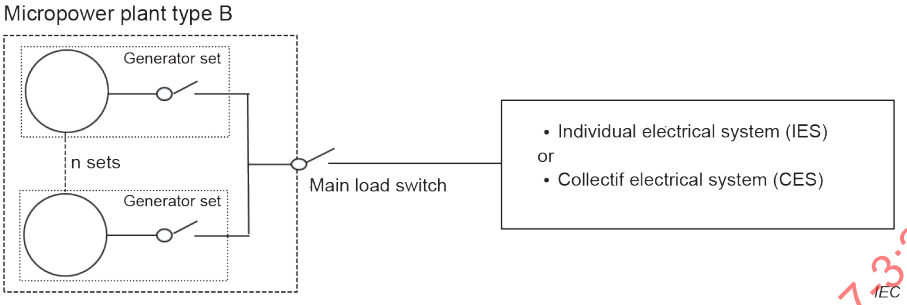

Figure 3 – Micropower plant Type B: multiple generator sets in micropower plant

4.2.4 Single generator set with a power conditioning sub-system (micropower plant Type C)

This type of micropower plant (refer to Figure 4) has a generator set operating with a power conditioning sub-system which can be a.c power source such as PV converter, converter with energy storage system (ESS), wind turbine, hydro turbine or other energy sources with converter to condition a.c. at output. The micropower plant can operate as follows:

- The generator set or power conditioning sub-system with ESS is alternately operated by manual or an automatic control device. When the generator set is operating it may charge the ESS through the power conditioning sub-system..
- The generator set and power conditioning sub-system are operated in parallel on a.c. output by manual or an automatic control device. To operate in parallel the generator set and the power conditioning sub-system need to have capability to synchronize their a.c. output together. The power conditioning sub-system may have power sources such as PV, wind turbine, ESS, or energy sources. To operate in this mode the micropower plant shall be capable of preventing electrical current back feed to the alternator of the generator set.

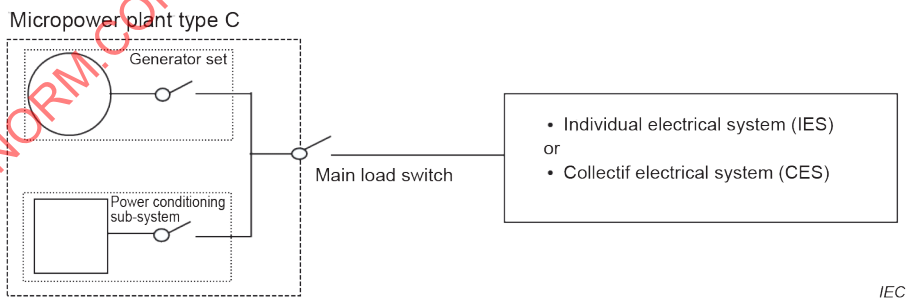

Figure 4 – Micropower plant Type C: single generator set with a power conditioning sub-system in micropower plant

4.2.5 Multiple generator sets with multiple power conditioning sub-systems (micropower plant Type D)

This type of micropower plant (refer to Figure 5) has more than one generator set operating with more than one power conditioning sub-system. It also covers the cases where single generator set works with multiple power conditioning sub-systems, or where multiple generator sets are working with a single power conditioning sub-system. The power conditioning sub-system may be AC power sources such as PV converters, converters with

energy storage systems (ESS), wind turbines, hydro turbines or other energy sources with converters to condition a.c. at output. The micropower plant can operate as follows:

- One or multiple generator sets and one or multiple power conditioning sub-systems are either operated by manual or an automatic control devices.

In this operation a bus tie switch is not required.

- One or multiple generator sets and one or multiple power conditioning sub-systems are operated in parallel on a.c. output by manual or an automatic control device. In this operation the bus tie switch is required when a group of multiple generator sets synchronized together before it is tied with the bus which has a group of multiple power conditioning sub-systems that are synchronized together.

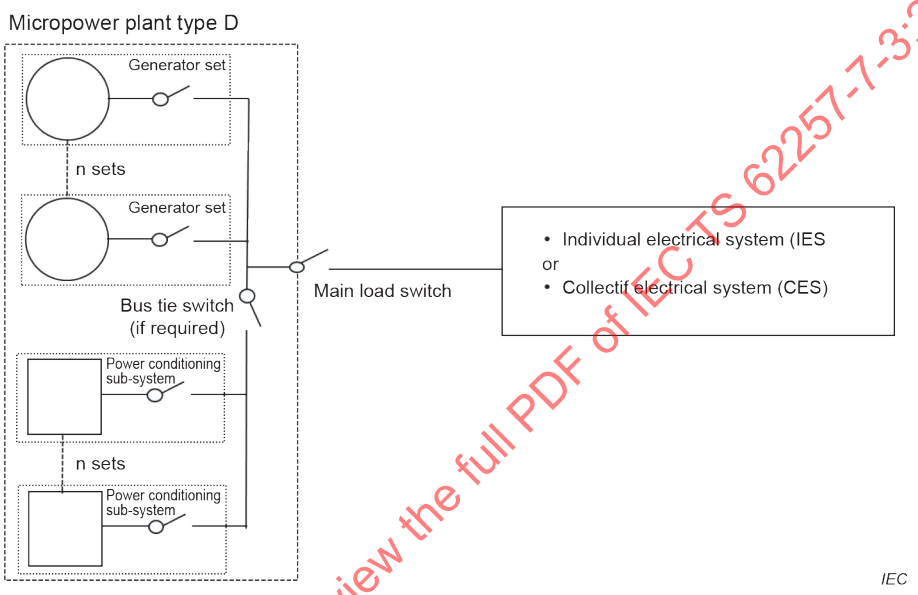

Figure 5 – Micropower plant Type D: Multiple generator sets with multiple power conditioning sub-systems micropower plant

4.3 Resource assessment

Before choosing a generator set as the generator in an electrification system, it is important to check the availability of the fuel supply on the installation site and whether it is possible to be supplied throughout the year. For example in some countries it could be impossible to deliver fuel to the site during the rainy season.

The project implementer also shall take into account that the cost of fuel may vary with the price of the oil market and also with changes in local subsidies.

5 Selection and erection

5.1 General

A lot of technologies are available on the market for engines, from the most simple to the most sophisticated.

For small size (~below 5 kVA) the most commonly used technology is gasoline engines.

For larger size, the most commonly used technology is diesel engines while the biofuel engine and biomass gasification engine in the range of lower than 1 000 kVA are also used.

Other fuels can be used, such as fuel oil, or ethanol.

The engines are designed either for 3 000 rpm (generally for small machines) or 1 500 rpm (generally for larger machines) at 50 Hz and 3 600 rpm or 1 800 rpm for 60 Hz.

Other technologies like small fuel turbines may also be available.

The project implementer shall select the appropriate technology corresponding to the required level of quality of the service, the skill of the maintenance staff, the level of equipment available at the maintenance centre, the spare parts than can be easily sourced, and all specific constraints of the project. Annex A provides some information about the classification of different types of generator sets as they are available on the market.

5.2 Selection requirements

5.2.1 Power quality

Type and configuration of generator set shall be selected in relation with the requirements of the power supply to the end user as given in the General Specification (GS) of the project.

These requirements shall refer to the different figures expressed in IEC TS 62257-2:2015, Annex C.

The control system of the generator set shall be able to provide information necessary to assess that the level of quality of service provided is in accordance with the requirements of the generator set (at least voltage, current and frequency).

5.2.2 Generator set sizing

Generator set sizing has two primary requirements:

a) that the alternator is capable of supplying the continuous and surge load apparent power (VA);

b) that the engine is capable of providing the power requirements of the alternator and the mechanical losses of the whole system (alternator + coupling system).

It is for the project developer to precisely define the generator set minimum operating conditions:

- the environmental conditions;
- the maximum nominal outputs, the corresponding durations and load factor;
- the electrical load characteristics (power factor, permitted voltage range, current harmonic content, high starting currents, etc.).

The selection and sizing of generator set should be done with consideration of the supplied electrical load and the structure of the microgrid (single phase / three phase, see IEC TS 62257-9-2).

Important rating of the generator set shall be considered:

- rated voltage;
- rated frequency;
- rated power and corresponding operating speed in conformity with ISO 8528-1;
- the application class, as defined in ISO 8528-1(see Annex A);
- rated current;
- rated power factor.

NOTE When considering the power rating it is important to consider the application class and the service to be provided. Refer to Annex A.

Care needs to be taken with respect to application classes defined in ISO 8528-1 as these classes of operation take into account only predominantly linear loads. In many microgrid and hybrid system applications, considerable harmonic current flows (particularly in battery charger loads) may cause excessive voltage distortion if not taken into account early in the design and specification.

The sizing of the generator set shall be made such as the engine works between 50 % and 80 % of its maximum nominal power in normal operating conditions. Functioning at maximum nominal power shall not exceed manufacturer's recommendations as well as overload periods of functioning.

The project implementer shall draw the daily load curve and its variation along the year in order to determine the maximum and minimum power. This makes it possible to determine the nominal power of the engine to ensure that it operates between 50 % and 80 % of its maximum nominal power.

The project implementer shall also assess if there is any peak power or very low power period during the year whose duration may affect the generator set lifespan. A solution could be to install multiple generator sets (micropower plant Type B or Type D) and operate them in two options:

– Single generator set operation.
– Multiple generator set operation.

In single generator set operation, from all generator sets in micropower plant a generation set which has alternator power rating and engine power rating in the range to supply load between 50 % and 80 % of maximum nominal power shall be selected to supply load. The selection and starting the selected generator set can be done by manual or automatic control.

Multiple generator sets may be operated in parallel in order to increase electrical power generation during moments of peak demand. In multiple generator set operation, generator sets whose combined output can supply the loads should be switched in and out of the AC bus, in such a way that each individual generator set is working between 50 % and 80 % of its power rating. This switching operation may be either by manual or automatic control. The generator sets can all be of the same power rating or they may be different power ratings. Local conditions shall be taken into account to size the generator set (altitude, humidity, temperature, etc.) according to 5.2.3.

The local conditions shall be checked by the project developer and indicated in the call for tender to manufacturers.

Technical declarations for the specification and design of the generator sets recommended by ISO 8528-7 are to be carried out as follows:

– the project implementer expresses his requirements in a technical questionnaire in conformity with ISO 8528-7;
– the specifications approved by the generator set manufacturer and the project implementer shall be set out in a technical form as per ISO 8528-7.

5.2.3 Generator set type

There are different kinds of generator sets available on the market. Annex A gives the main guidelines to choose the right type of generator set according to the type of use which is expected, in conformity with ISO 8528-1:

– indoor or outdoor use;
– service duration;

– noise level;
– etc.

5.2.4 Derating factors

The site conditions under which the generator set is called upon to operate, whatever its mode of installation, may affect certain of its characteristics. They shall be taken into account by the project implementer and the manufacturer.

When the site conditions are unknown and unless otherwise specified, the following nominal conditions shall be used according to ISO 8528-1.

– total barometric pressure 89,9 kPa;
– air temperature 25 °C;
– relative humidity 30 %;
– temperature coolant for the supercharging air 25 °C.

As the generator set magnitudes are usually defined for the standard reference conditions, it is therefore necessary to clearly define and to take into account climatic conditions at the intended site.

The generator set shall be rated to operate over:

– the range of expected temperatures, and
– humidity conditions, and
– altitude prevailing at the application site.

Table 1 provides some examples of derating factors taking into account local conditions.

Table 1 – Examples of derating factors for generator sets

Air temperature		Derate 2,5 % for every 5 °C above 25 °C
Altitude		Derate 3 % for every additional 300 m above 300 m altitude
Humidity	Air temperature between 30 °C and 40 °C	Derate 0,5 % for every 10 % above 60 % humidity
	Air temperature between 40 °C and 50 °C	Derate 1,0 % for every 10 % above 60 % humidity
	Air temperature above 50 °C	Derate 1,5 % for every 10 % above 60 % humidity

When performing generator set sizing calculations, the derating factors should be added to the required size specification.

In particular, it should be noted that beyond the reference conditions (temperature 25 °C and pressure < 89,9 kPa) engine power oversizing should be considered. Special attention shall be paid to the cooling system in relation with the environmental conditions.

5.2.5 Starting system

The generator set maker shall define the starting system of the generator set: manual or automatic, remote or local. The choice of the starting system impacts the design of the generator set site and the operating conditions.

The starting battery shall be installed as close as possible to the engine. The cables shall be sized according to the starting current but also according to the distance between the battery and the engine.

Where the generator set is seldom used (back-up systems) attention shall be paid that the starting battery is kept at an acceptable state of charge. The batteries should be suitable for continuous float charging and of suitable voltage and current rating (Ah) for starting duty of the generator set.

The charging of engine starting battery can be done when:

a) the generator set is operating; or

b) auxiliary power supply with rectifier when the generator set is not operating.

Suitable battery types include lead-acid and nickel-cadmium batteries.

In the micropower plants Type B, C and D which have multiple generator sets or hybrid with power conditioning sub-systems, the a.c. input power to the battery charger of each engine starting battery should be connected to main a.c. bus to maintain reliable electrical supply to the battery, even when the generator sets are not called to operate for long time.

5.2.6 Control systems

The generator set maker shall define the parameters to be surveyed during operation; voltage, frequency, output power, temperature of air, water, engine, etc.

Frequency and voltage adjustments can be either automatic or manual. This shall be defined by the generator set maker.

5.2.7 Noise issues

The generator set shall be rated appropriately taking into consideration the noise level produced under worst case operating conditions.

The generator sets shall be in conformity, with regard to noise emitted, with the airborne noise level limits as set out in Table 2.

Table 2 – Generator set permitted noise levels

Generator electrical output P	**Permitted noise level** dBA
$P \leq 2$ kVA	102
2 kVA < P < 240 kVA	100

Compliance with these limits may require the use of a soundproofing casing.

The generator set alternator noise levels shall be in conformity with IEC 60034-9, depending on its cooling methods and its rated rotation speed.

5.2.8 Environmental issues

The project implementer shall inform the manufacturer of the environmental conditions that may affect the design and maintenance of the generator set:

– presence of sand, dust or other physical pollutants of the atmosphere of the generator set;

– marine environment (generator set operating on costal sites);

– shock and vibrations (earth tremors, presence of another rotating machine, etc.);
– presence of chemical pollution.

5.3 Erection

5.3.1 Shipping

Shipping to the site, installation and commissioning of the generator set are carried out in conformity with the generator set supplier's recommendations.

Access and transport to the site shall be taken into consideration:

– quality of roads;
– maximum size for trucks;
– local available handling devices;
– on-board-the-truck handling devices.

Attention shall be paid to the fact that it is sometimes necessary to move the generator set to another site when heavy maintenance is required. It is thus sometimes more efficient to install several smaller generator sets than a single large generator set.

Before handling, the attachment points and handling devices shall be inspected to ensure that they are adequate for the weight and size of the generator set to be handled. Built-in attachment points and handling gear of the generator set shall be used wherever possible for this purpose.

Position and angle of slings shall conform to correct handling rules. Special attention shall be paid to the condition of the slings.

5.3.2 Design of the erection site

5.3.2.1 General

The generator set can be installed either in the open air or in a dedicated building.

In case of use as an individual electrification system (see IEC TS 62257-2), the generator set shall be installed outside the house to avoid noise and exhurst.

In all situations, the floor of the site shall allow the generator sets to be restrained from movement during normal operation.

5.3.2.2 Civil works (if any)

The civil works may be conventional masonry work, or pre-fabricated. Their lifespan shall be at least equal to the generator set lifespan.

– The floor shall be able to bear the weight of the generator set and its accessories.
– Provision shall be made to avoid any pollution of the soil by oil or fuel leaks.
– It shall enable easy installation and removal of the equipment.
– The wiring trays (cables) and mechanical trays (fluids) shall be separate.
– Metal frameworks shall be connected to the earth.
– A water supply point and drain shall be provided if necessary.
– The generator set premises shall not be used for storage of fuel or spare parts.

5.3.2.3 Safety provisions

5.3.2.3.1 Access space for generator sets

Adequate space shall be provided around a generator set on all sides where persons are to pass, to enable all equipment to be safely and effectively operated and adjusted.

NOTE Attention is drawn to additional requirements that may be specified by relevant regulatory authorities.

5.3.2.3.2 Setting up of the generator set

All generator sets shall be restrained from movement during normal operation.

5.3.2.3.3 Automatic starting

Where a generator set is capable of automatic or remote manual starting, a warning notice shall be clearly visible on approach to, and located within 1 m of the generator set, bearing the words “danger; this equipment starts automatically”. The generator engine shall be provided with a device to prevent the starting of the generator when inspection, repair or maintenance is carried out.

5.3.2.3.4 Exit from generator set area

5.3.2.3.4.1 Number of openings

At least one door or opening shall be provided to enable a person to leave the vicinity of a generator set. However, where any generator set:

a) has a rated power exceeding 25 kVA; or

b) is driven by a petrol engine;

not less than two generator set openings or doorways, spaced well apart, shall be provided.

5.3.2.3.4.2 Opening and locking of doors

All barriers or doors provided to prevent the entry of unauthorized persons to any room or enclosure containing a generator set shall open outwards away from the generator set without the use of a key or tool on the generator set side of the door, and shall be capable of being locked from the outside.

5.3.2.3.4.3 Size of doors and openings

Doors and openings providing entrance to and exit from a generator set area shall have a height of not less than 1,98 m from the floor or walked-on surface and a width of not less than 0,75 m.

5.3.2.3.5 Lighting

Adequate lighting shall be provided to enable equipment and controls to be effectively and safely operated.

5.3.2.3.6 Earthing

The earth connection shall be in conformity with the requirements of IEC TS 62257-5.

All metal assemblies are to be connected to the installation earthing terminal:

– the generator set;

– its cabinet, if any;

– the tanks and piping;

– the cable trays, metal roof decking;
– hardware.

5.3.3 Installation requirements

5.3.3.1 General

Means shall be provided to prevent the entrance of, or interference by, unauthorized (see IEC TS 62257-6) persons by the erection of suitable fences, screens, partitions, walls or similar barriers. Such barriers shall not impede the access required for authorized persons for maintenance, testing or inspection.

This shall not preclude the installation of a generator set in an enclosure or room with other equipment for which access is similarly restricted to authorized persons.

5.3.3.2 Ventilation

Ventilation shall be as far as possible from the gas exhaust of the engine, especially the fresh air admission. The extraction of hot air shall be made through the upper ventilation and the fresh air admission through the lower one.

Ventilation grates shall be kept clean.

For a generator set installed in an enclosed and soundproofed room, the room should enable proper supply to the engine of combustion and cooling air and also maintain the generator set within the ambient temperature limits for which it was specified.

The generator set air consumption is notified by the manufacturer. If not, the following values may be used as a reference.

The air intake cross-section shall be the same as that of delivery and determined as follows:

– radiator or air cooler 80 m^3/h per kVA,
– additional fan 40 m^3/h per kVA,
– speed in ducting 4 m s^{-1}.

EXAMPLE Generator set of 30 kVA: flow 30 × 80 = 2 400 m^3/h = 0,67 $m^3 s^{-1}$, cross-section = 0,67 $m^3 s^{-1}$ / 4 m s^{-1} = 0,17 m^2.

Ventilation of the generator set installation room shall be dimensioned in order to comply with the limit ambient temperatures permitted by the generator set, engine and alternator, under the specified operating and environment conditions.

For this, the generator set supplier shall provide the project implementer with all of the information necessary for dimensioning the room housing the generator set:

– exhaust losses (in spite of lagging);
– engine losses removed by the radiator or radiation;
– losses emitted directly into atmosphere (alternator and engine convection).

Any room or enclosure containing a permanently connected generator set shall be adequately ventilated so that the room or enclosure temperature rise, associated with the running of the generator set, is limited to 10 °C.

5.3.3.3 Water cooling

For water cooled generator sets, the exhaust of hot water shall be made in the upper part of the water tank and the intake of fresh water shall be made in the lower part of the tank. The water tank shall be level with the generator set.

The water level in the tank shall be checked regularly. Only clean water shall be used for cooling the engine.

5.3.3.4 Combustion gas exhaust

Combustion gases shall be expelled directly to the outside of the room.

The cross-section of the combustion gases exhaust pipe may be dimensioned using the following formula:

$$D = \sqrt{P \times 1{,}2}$$

Where

D is the diameter in cm;

P is the power in kVA.

The diameter chosen shall be as close as possible to a standard diameter.

This piping may be lagged or not and be in stainless steel or mild steel.

The minimum diameter of the bends of the pipes shall be two times the diameters.

To reduce the noise, a silencer shall be installed on the exhaust pipe.

5.3.3.5 Fuel storage

The capacity of the minor fuel storage installed in the generator set room shall be sufficient for two or three days of autonomy of the generator set. The main fuel storage shall be made in another building or tank located at least three metres away from the generator set room.

The capacity of the main tank shall be able to provide the necessary autonomy according to the size of the generator set, the duration of the service and the local possibilities of refuelling. For example in some locations it is impossible to refuel during the rainy season. The capacity of the main tank shall be calculated accordingly.

The fuel storage shall comply with the local regulations if any. If no local regulation exists, the following requirements shall be complied with:

- The quantity of diesel fuel stored in the generator set room shall not exceed 500 l. If the quantity stored is over 500 l, storage shall be in a special room or in a separated area.
- The quantity of petrol stored in the generator set room shall not exceed 25 l according to the fact that the recommended maximum power of such generator set is limited to 5 kVA.

For a capacity of C l of the minor fuel storage, a drip tray with a capacity of (C + 20 %) litres shall be installed in the generator set room which means a 600 l tray for a 500 l storage.

The main fuel storage tank shall comply with the following:

– double-sided if the tank is buried;
– storage site ground shall be hydrocarbon leak proofed (coating, sheet, etc.);
– vent at top point;
– generator set fuel supply cut-off equipment located outside the room;
– generator set fuel supply by electric or manual pump;
– pump and alarm trigger switch (if electrically-powered);

– tank earthed and equipotentially bonded with the exposed-conductive parts of the generator set room.

Both minor and main fuel storage tanks shall be at least 1 m away from any heat source or equipment that may emit arcs sparks or hot particles. The position of the tanks shall be such as to avoid any spilling or leakage of fuel on hot parts.

In case of gravity supply of fuel to the engine, the minor fuel storage tank shall be installed in an elevated position to ensure the right supply pressure.

Refueling of the minor fuel tank shall be made with appropriate pipes (according to the manufacturer's recommendations) and provisions shall be made to avoid any spilling of fuel and any pollution of the soil during the refueling operation.

6 Safety

6.1 General

The safety issues that shall be addressed by the project implementer are notably related to electrical, mechanical, thermal and fire risks.

6.2 Electrical issues

6.2.1 General requirements

The requirements of IEC 60364 and IEC TS 62257-5 shall be applied, and local regulations shall be complied with.

To ensure the safety of workers, the following provisions shall be made:

– protection of persons against direct contacts;
– protection of persons against indirect contacts.

The main problems to be addressed are:

– the design of the neutral system;
– the design of the earthing system;
– the connection of all the exposed conductive parts to the earthing system.

The good condition of all these devices shall be checked regularly (see IEC TS 62257-6). Additionally, the following provisions shall also be made:

– Keep all accessible parts clean.
– Replace defective or damaged parts.
– Detect abnormal heating parts.
– Detect defective connection.

Adequate means shall be provided to ensure the safe starting, running and shutting down of the generator set. They can be either an automatic starting device or a detailed operation instruction sheet.

6.2.2 Connection system to the application

Two kinds of connection systems can be used to connect the generator set either to the micropower plant or to the utilization system:

– plugs and sockets;

– hardwired connection.

Plugs and sockets present several disadvantages and introduce questions such as:

– Is the socket on the generator set side or on the application side?
– Are there several kinds of voltages and so risks of misconnections?
– Are there both a.c. and d.c. currents in the micropower plant and so risks of misconnections?

For all these reasons, hardwired connections are recommended, especially in cases where the generator set is part of a hybrid micropower plant.

As far as possible the generator set shall be shipped pre-hardwired so a simple connection of the generator set to the main power circuit and a connection of the exposed conductive part to the earthing system is all that is required on site.

6.2.3 Power cables

Power cables shall be thermally dimensioned (the short-circuit power of a generator set is only three times its nominal power) in accordance with Table 3, which shows the cross-section of connecting cables for a three-phase 230/400 V generator set, a cable length of 10 m and an ambient temperature of 40 °C.

Table 3 – Cross-section of power cables

Power kVA	**Cross-section / phase** mm^2
20 and 30	6
40	16
50	16
60	25
80	35
100	35

6.2.4 Neutral system

The generator set neutral mode shall be that of the installation it supplies. Refer to IEC TS 62257-9-2 for the recommended neutral system for microgrids.

6.2.5 Earthing

The following parts of the generator set shall be electrically bonded together to form the generator set bonding system:

– the engine frame;
– the alternator frame;
– all exposed conductive parts enclosing electrical equipment or wiring;
– the earth terminals of any connecting devices;
– all the metallic parts of the housing of the generator set including metallic doors.

The connection of the generator set to the exposed conductive parts circuits shall be identified by the following symbol (marked  or ‘FRAME’).

All these provisions are made in order to create an equipotential bond between all exposed conductive parts listed above.

6.2.6 Overcurrent protection

All outgoing circuits from a generator set shall be provided with overcurrent protection devices located as close as possible to the alternator output.

The alternator electrical protection system shall be sized to be able to interrupt the short circuit current of the application circuit.

6.2.7 Residual Current Protection Device (RCD)

IEC TS 62257-9-2 recommends the use of TNC system for the earthing of the neutral wire of the microgrid. IEC TS 62257-9-4 recommends the use of TNC-S system for the earthing of the neutral wire of the user's installation.

This allows the use of a 30 mA RCD in order to protect the user against electric shocks.

A combined 500 mA residual current protection device and overcurrent circuit-breaker shall be installed on the main switch between the generator set (or the micropower plant) and the application circuit in order to protect the generator set (or the micropower plant) against an insulation fault on the application side or microgrid side (see Figure 1). These devices comply with IEC 61009-1.

6.2.8 Isolating devices

Every engine shall be provided with an isolating device, which may be a shutdown device, to prevent the starting of the generator set when inspection, repair or maintenance is being carried out. An emergency shutdown device may also be necessary under certain conditions.

The isolating device shall prevent the generator set from being started by any automatic device or remote control mechanism. Where a switch located in a control or starting circuit is used for this purpose, it shall disconnect all live conductors of the circuit.

The isolating device shall be readily accessible to maintenance or other authorized personnel and be:

a) installed adjacent to or on the generator set so that a person operating the device has a clear view of any person working on the machine; or

b) provided with a means of securing the device in the isolated position that requires a deliberate action to engage or disengage it.

6.3 Mechanical issues

6.3.1 Vibration

The whole system (engine – coupling – generator – chassis – exhaust) when installed shall not exceed the vibration level as defined in the GS.

If the vibration level may be a problem for the immediate environment of the generator set provisions shall be made to ensure a correct absorption.

6.3.2 Protection from mechanical damage

All components of a generator set including mechanical parts, fuel systems, wiring, switches, instruments and controls shall be adequately protected against mechanical damage.

6.3.3 Protection from moving parts

All moving parts that may cause injury to persons shall be protected by barriers to prevent unintentional personal contact with such parts. The protection shall be provided by guards, enclosures, railing or fences.

6.4 Thermal issues

All hot parts of a generator set which operate at temperatures exceeding 80 °C shall be out of reach or lagged so as to prevent accidental personal contact.

6.5 Fire risk

Fire-fighting equipment (at least a sand bin and preferably extinguishers) shall be provided.

The room doors shall open outwards and be fitted with anti-panic devices.

7 Acceptance

7.1 General

The acceptance procedure comprises:

– verification of the supplied generator set with the identification file;
– examination of the conformity of the whole installation with the GS (housing, generator set, fuel storage, etc.);
– execution of the acceptance tests.

Sanctions: Any difference between the required and the measured performances shall be corrected.

7.2 Conformity of the generator set to the identification file

The equipment supplied by the manufacturer shall be checked to verify its conformity to the identification file (see Annex B).

IMPORTANT: This conformity shall be verified before shipping the generator set to the operation site.

7.3 Conformity of the generator set system to the generator set specification (GS)

The generator set system shall be checked to verify its conformity to the GS. It includes the generator set installation and all the ancillaries (civil works, fuel tank, pipes, safety issues, etc.).

Attention shall be paid to the conformity of earthing arrangements.

7.4 Acceptance process

7.4.1 Preparation of the generator set for commissioning

Before starting the generator set and according to the manufacturer's specification pre-operation actions shall be performed in order to prepare the generator set for operation.

– Fill the fuel tank.
– Fill the engine lubricant tank.
– Verify that the starting battery is fully charged.

– Perform all the preliminary actions specified by the manufacturer.
– Etc.

7.4.2 Commissioning inspection of the generator set system

According to the GS, the following controls shall be performed on the civil works, ancillaries and electrical installation:

– Mechanical: Visual inspection on civil works and equipment (fuel tank, exhaust pipes, etc.).
– Electrical (power off):
  - visual control of the electrical installation and wirings;
  - IP codes (for all parts);
  - control of connections;
  - test of the equipotential bonding;
  - measure of the earth resistance;
  - test of the mechanical operation of the switches (main and secondary if any, see Figure 1).

All non-conformity to the identification file or the requirements of the GS shall be fixed.

7.4.3 Commissioning tests of the generator set system

7.4.3.1 General

These tests are performed with the generator set running.

Perform the operation procedure as recommended by the manufacturer.

If loads of the application circuit can be connected, perform the procedure completely (see 7.4.3.1 and 7.4.3.2). If not, stop the procedure temporarily. The final part of the procedure shall be performed when the application circuit is ready to be powered.

7.4.3.2 Main switch off

The generator set overall tests are to be performed in conformity with ISO 8528-5.

The basic operating parameters to be checked are:

– voltage and frequency stability in stable operation;
– alternator overheating;
– engine fuel consumption;
– engine, alternator and chassis vibration.

The operating tests shall also be carried out in order to check the correct functioning of the protection and monitoring systems.

If possible, tests are to be performed at the limits of the environment conditions specified for the generator set.

Check according to the GS:

– ventilation;
– leakages in the exhaust pipes;
– leakage of fuel, oil;

– temperature (engine and ambient air in the housing);
– noise emission level of the generator set system;
– etc.

7.4.3.3 Main switch on

The generator set overall tests are to be performed in conformity with ISO 8528-5.

The basic operating parameters to be checked are:

– voltage and frequency stability for different load conditions in stable operation;
– voltage and frequency for different load conditions in transient operation;
– alternator overheating;
– engine fuel consumption;
– engine, alternator and chassis vibration.

The operating tests shall also be carried out in order to check the correct functioning of the protection and monitoring systems.

If possible, tests are to be performed at the limits of the environment conditions specified for the generator set.

Check according to the GS:

– ventilation;
– leakages in the exhaust pipes;
– leakage of fuel, oil;
– temperature (engine and ambient air in the housing);
– noise emission level of the generator set system;
– etc.

7.4.4 Test file

Measures and observations shall be recorded.

Relevant actions shall be performed to fix all the disfunctioning modes.

8 Operation and maintenance

8.1 Access to the generator set

The generator set can be installed in open air or in a classical masonry work or in a pre-fabricated civil work. In any case access to the generator set shall be restricted to qualified and authorized skilled personnel.

8.2 Operation process

The actions that shall be performed by the operator during the normal operation of a generator set are:

– starting;
– monitoring;
– adjustment of voltage and frequency;
– switching;

– shutdown.

These may be fully or partly manual or automatic.

8.3 Monitoring

The parameters that have to be monitored shall be identified in the GS according to the manufacturer's recommendations and also according to the quality of service to be provided to the end user.

To allow the operator to perform all necessary corrective actions in order to keep the parameters within the specified limits, the following measurement shall be made as a minimum:

– output voltage;
– frequency;
– output current;
– temperature of the engine;
– operation duration.

The occurrence and the level of automation of the measurement shall be adapted to the size of the installation, and to the daily and yearly duration of service.

8.4 Maintenance schedule

Programmed maintenance operations (type and interval) are defined by the generator set suppliers and notified to the operator.

The skill of the maintenance staff shall be adapted to the technology that has been chosen. Part of the maintenance operation may be performed on site. For some heavy maintenance operation it may be necessary to move the generator set to an operation centre.

A maintenance file shall be designed by the operator according to the maintenance handbook provided by the generator set manufacturer. All maintenance operation shall be recorded on this file.

For maintenance purpose overall running time and running time period shall be recorded. If possible these records will be correlated to load profiles on the same periods.

An example of maintenance schedule is given in Annex D.

9 Replacement

Every generator set is specified for a given lifespan under given operation conditions, according to its manufacturer. The operator shall survey and record the operating conditions and also check the condition of the generator set and also of all its components in order to assess that the specified lifespan will be reached. For this purpose the main data to be collected are:

– operation duration;
– output power;
– voltage;
– current.

According to these operating conditions, the lifespan may be shortened or lengthened. The operator shall be able to gather all the necessary data to assess correctly the real lifespan and plan the replacement in time to avoid any blackout.

According to the size and the budget of the project, it could be necessary or useful to keep spare generator sets locally or in the maintenance centre in order to maintain the service during the maintenance or repair operations.

It could also be necessary to replace the generator set because of the increase of the subscribed power. Different strategies can be implemented such as:

– replace the existing generator set by a more powerful one (and reinforce the microgrid);
– add more generator sets to work in parallel with existing generator set;
– split the existing microgrid or rearrange the existing ones and create a new one powered by a new generator set .

Close attention shall be paid to the recycling of dead generator set. Provisions shall be made to store safely the latter and avoid any pollution before sending for scrap.

10 Marking

10.1 General

All generator sets shall be fitted with the following identification plates, in conformity with ISO 8528-5.

10.2 Generator set

– the wording: "Generator set in conformity with standard, etc.";
– the manufacturer's name or brand name;
– the product number and name;
– the serial number, date and place of manufacture;
– the rated power of the generator set in kW giving the corresponding type of operating mode;
– the application class in conformity with ISO 8528-1;
– the rated power factor;
– the maximum operating altitude;
– the maximum ambient temperature;
– the rated voltage per phase;
– the rated frequency;
– the rated current;
– the weight.

10.3 Engine

– the brand name and serial number;
– the date and place of manufacture;
– the rotation speed;
– the type of fuel;
– the type of lubricant.

10.4 Alternator

The alternator shall have an identification plate in conformity with IEC 60034-1 and IEC 60034-22 carrying at least the following information:

– manufacturer's name or brand name;
– machine serial number and code;
– year of manufacture;
– reference standard;
– casing protection rating (IP code)(see IEC 60529);
– thermal classification or overheating limit;
– rated power;
– rated voltage;
– rated frequency;
– rated current;
– rated rotation speed;
– rated power factor;
– maximum operating altitude;
– maximum ambient temperature;
– rotation direction (if single).

10.5 Shutdown apparatus

– electrical characteristics.

11 Documentation

11.1 General

The generator set manufacturer shall provide with each machine:

– the identification file (see Annex B);
– the operator instructions manual;
– the maintenance manual which sets out the maintenance requirements;
– the documents which include the general drawings, wiring diagrams, specifications and instructions for assembly and installation, list of components used and their origin, spare parts list and their location drawings.

The manuals shall be in a language which can be read and understood by the local operators.

The documentation shall include information relative to the following situations:

11.2 Installation

– details of the specific tooling, apparatus and anchoring devices and other equipment to enable installation in complete safety;
– the instructions to enable proper lubrication and the conditions prior to putting into service all of the components;
– the assembly procedures recommended by the manufacturer;
– identification of critical attachment points and procedures relating to tightening torques and other recommendations;
– a set of drawings for final assembly on site and installation;
– a complete wiring and connection diagram.

The installation project implementer shall supply the operator with the technical documents relating to installation of the generator set:

– room drawing;
– generator set installation drawing (chassis, ventilation ducting, etc.);
– generator set connection wiring diagrams;
– installation servicing and maintenance manual (cleaning and replacement of room filters, if necessary, servicing of accumulator batteries, etc.).

11.3 Operation

– the safe operating limits and descriptions, including the starting and shutdown procedures;
– the procedure for functional checking of all the protection subsystems;
– a description of the generator set system, of all its parts and their functioning.

11.4 Inspection and maintenance

– the maintenance and inspection intervals and procedures;
– the lubrication intervals, giving the frequency, types of oil and other special fluids to be used;
– non-routine and emergency maintenance procedures;
– diagnostic procedures and a troubleshooting guide.

Annex A
(informative)

Generator set classification criteria

A.1 General

Selection of the appropriate type of generator set for the right project shall be made according to a list of criteria. The main ones are described in the following clauses.

A.2 Functioning mode

Several generator set functioning modes could be considered, in conformity with ISO 8528-1:

- stand-alone: the generator set operates without direct connection to another power source;
- coupled (sets in parallel): in this operating mode, two or more generator sets are connected electrically.

A.3 Services provided

The generator sets are classified on the basis of the service they provide. These services define a permitted power output for operating hours per year. These are set out in Table A.1.

Table A.1 – Classification of generator set services

Service	A	B	C	D
Power	continuous max.	continuous variable	variable	variable
Operating hours/year (up to)	(unlimited)	4 000	2 000	500
Overload	no	10 % single hour	10 % single hour	no
Operating hours/day	24	24	12	[a]

[a] To be studied case by case (backup, peaking, etc.).

A.4 Application classes

The application classes are defined in ISO 8528-1.

Class G1: uses in which the equipment powered is such that only minor voltage or frequency constraints need to be specified. General use (lighting, and other simple electrical loads).

Class G2: uses in which the voltage characteristic requirements are more or less the same as those of the public grid. When load variations occur, temporary voltage and frequency fluctuations may be accepted. Lighting systems, pumps, fans and lifting apparatus.

Class G3: uses in which the equipment powered may necessitate strict frequency, voltage and wave form requirements. Telecommunications and thyristor regulated loads (battery chargers).

NOTE Class G4, the most stringent applicable to computer systems, is not included.

For rural electrification projects the application classes G1 or G2 are most appropriate.

The choice of the generator set according to the kind of service that the project implementer intends to provide to the customer depends on:

- nominal power (to be maintained between 50 % to 80 % level to optimize the lifetime of the generator set);
- quality of supply:
  - targeted THD on the supply system;
  - stability of the frequency;
  - voltage stability.

A.5 Lifespan

The lifespan of a generator set depends on:

- the generator set technology (e.g.: rotation speed);
- environmental conditions;
- operating and servicing conditions;
- the fuel and oil characteristics.

Examples of common lifespan values are given in Table A.2.

Table A.2 – Common lifespan values

Class of power of the generator set kVA	Common lifespan h
< 5	1 000 up to 4 000
5 up to 10	4 000 to 10 000
> 10	> 10 000

A.6 Generator set components design

A.6.1 Engine

A.6.1.1 General design

There are 2 types of reciprocating internal combustion engines:

– compression ignition engines;
– spark ignition engines.

The type of engine may be specified by the project implementer, for example, on the basis of technical-economic criteria.

A.6.1.2 Fuel

The type of fuel to be used is specified by the generator set supplier.

If the project developer wishes to impose or exclude a particular type of fuel, he shall inform the generator set supplier.

NOTE ISO 8528-7 covers fuels used by generator sets.