PD IEC/TS 62257-4:2015

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Recommendations for renewable energy and hybrid systems for rural electrification

Part 4: System selection and design

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee GEL/82, Photovoltaic Energy Systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

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TECHNICAL SPECIFICATION

Recommendations for renewable energy and hybrid systems for rural electrification –
Part 4: System selection and design

INTERNATIONAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

RECOMMENDATIONS FOR RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 4: System selection and design

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 62257-4, which is a technical specification, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

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This second edition cancels and replaces the first edition issued in 2005. It constitutes a technical revision.

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

– redefine the maximum AC voltage from 500 V to 1 000 V, the maximum DC voltage from 750 V to 1 500 V;
– removal of the limitation of 100 kVA system size. Hence the removal of the word “small” in the title and related references in this technical specification.

This technical specification is to be used in conjunction with the IEC 62257 series.

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

Enquiry draft	Report on voting
82/949/DTS	82/1000A/RVC

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 publication 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.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

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.

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INTRODUCTION

The IEC 62257 series 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 rural electrification concentrating on but not specific to developing countries. They should not be 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 mechanisms developments 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 aiming at the lowest life cycle cost as 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.

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RECOMMENDATIONS FOR RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 4: System selection and design

1 Scope

This part of IEC 62257 provides a method for describing the results to be achieved by the electrification system independently of the technical solutions that could be implemented.

The purpose of this part of IEC 62257 is to provide a method to assist project contractors and project developers to select and design the electrification system for isolated sites while matching the identified needs, such as those described in IEC TS 62257-2. IEC TS 62257-2 assesses the needs of the users and the different power system architectures which can be used for meeting these needs. In relation to the needs of the different participants to the project, functional requirements that shall be achieved by the production and distribution subsystems are listed.

In Clause 5, energy management rules to be considered are described. These are key issues as they have a great influence on the sizing of the electrification system.

In Clause 6, the informations provided by the system sizing process to allow the participants to select the equipment or component able to fulfil the functional requirements are listed.

To allow and facilitate the management of the micro-power plant and the maintenance of the whole electrification system, some information is collected and monitored.

Clause 7 is dedicated to defining the parameters and specifying rules for data acquisition.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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 62257-3:2015, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 3: Project development and management*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
renewable energy
RE
energy from a source that is not depleted when used

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3.2
hybrid system
multi-sources system with at least two different kind of technologies

3.3
dispatchable power system
power system considered dispatchable if delivered power is available at any specified time, e.g diesel generator

3.4
non-dispatchable power system
power system considered non-dispatchable system when it is resource dependent and whose power might not be available at a specified time, e.g solar grid connected system

3.5
storage
storage of energy produced by one of the generators of the system and which can be reconverted through the system into electricity

3.6
rural mini-power plant
power plant that produces less than 100 kVA through the use of a single resource or hybrid system

3.7
rural mini-grid
grid that transfers a capacity level less than 100 kVA and powered by a micro-power plant

3.8
individual electrification system
IES
micro-power plant system that supplies electricity to one consumption point usually with a single energy resource point

3.9
collective electrification system
CES
micro-power plant and micro-grid that supplies electricity to multiple consumption points using a single or multiple energy resource points

3.10
isolated site
electric characteristic to define a specific location not currently connected to a national/ regional grid

3.11
remote site
remote area
geographic characteristic to define a specific location far from developed infrastructures, specifically energy distribution

4 Functional requirements of production and distribution subsystems

4.1 General

The purpose of Clause 4 is to provide a method for describing the results to be achieved by electrification systems for isolated sites as defined in IEC TS 62257-2. It describes the

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characteristics expected from these installations based on production of electricity from renewable and/or fossil energy sources.

This stage of defining the expected results of production precedes the technical dimensioning and details engineering stages.

4.2 Overall needs to be satisfied

4.2.1 Main factors to be considered

Figure 1 illustrates the main factors influencing the design of the micro-power plant.

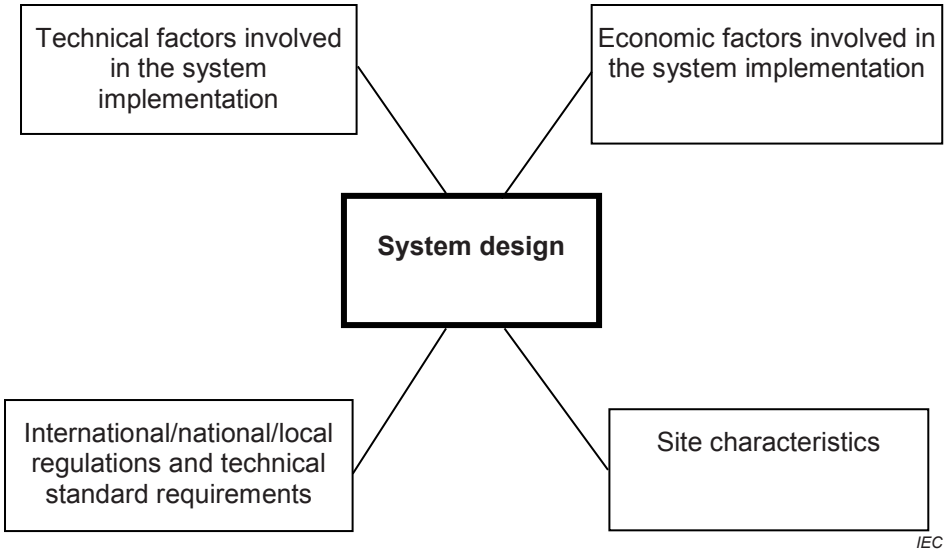

Figure 1 – Factors involved in the design of a system

4.2.2 Needs and characteristics to be considered

For each of the factors depicted in Figure 1, detailed needs or characteristics to be considered shall be identified. These needs and characteristics are defined in Tables 1 to 4.

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Table 1 – Technical factors – needs or characteristics to be considered

Nature of participant	Needs or characteristics
Project developer/owner	Compliance with the general specification and relevant standards. Efficient use of energy (demand side management).
Project implementer/subcontractor	Easiest possible implementation: limited constraints in terms of transportation means and lifting apparatus. Technology compatible with limited skills of local manpower. Limited installation work duration on field. Standardized equipment.
Operator	Simple operational rules to cope with possible limited skills of local operating agents. Simple mounting tools. Reliable equipment. Simple management rules. Clear and unambiguous contractual rules not liable to lead to situations of dispute or litigation. Relevant technical choices/customer management. Limited spare parts variety.
Maintenance contractor	Reliable and easy-to replace on site equipment. Limited spare parts variety.
Different users/loads	Types of energy services (see IEC TS 62257-2:2015, Annex B).

Table 2 – Economic factors – needs and characteristics to be considered

Nature of participant	Needs or characteristics
Project developer/owner	Balance between initial capital costs and operational costs to make the project profitable and sustainable.
Project implementer	Balance between equipment cost (purchase and installation) and specified level of reliability.
Subcontractor	To make a correct living while fulfilling the project implementer's requirements.
Operator	Operational costs as low as possible.
Maintenance contractor	To have an economically viable activity while fulfilling the operator's requirements.
The different users/loads	Available services promised (lighting, TV, etc.) at the contractual level of quality, for the agreed price.

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Table 3 – Site characteristics

General characteristics of site	Detailed characteristics	Comments
Geographical environment	Weather statistics (T°, humidity, wind, precipitation, etc.)	General information about the standard conditions at the site.
	Climate and severe weather or other local hazards	The characteristics of the climate at the site will affect the design of the system and the nature of its constituent equipment. One may mention: • temperature differences; • hygrometry differences; • rainfall and snowfall; • superimposed loads on structures (caused by wind, cyclones, frost, etc.); • pollution (sand, salt, dust, other pollutant wastes).
	Energy resources	Definition of local energy resources. See Table 4 for further details.
	Means of access to and around the site	General access to the site, bridges road conditions and ease of access around the site (streets, rivers, etc.) will affect the difficulty in crossing obstacles and anticipating changes in the micro distribution network, etc.
	Nature of soil (geological environment)	This affects the type of structure (overhead or buried power lines) to be set up and the execution of certain installations (for example grounding system depending on the resistively characteristics of the ground and system foundations).
	Geographical distribution of the user points	This is a major factor in the cost of the distribution infrastructures. The scatter or concentration of the user points, their probable evolution (near or remote) time-wise and space-wise, will affect choices concerning the topology of the distribution network.
Human environment	Distance to/between homes / loads – production system	
	Type of homes /loads	
	Acceptable noise level	
	Acceptable waste disposal level	
	Type of building to house the rural micro-power plant	
Biological environment	Fauna	
	Flora	
	Type of tree cover	
Technical environment	Type of grid in place, if any (overhead, buried)	
	Civil engineering	
	Quality of existing building	This may be either an ally or an enemy as regards to certain solutions for providing supports for conductors (the physical quality of the building, its height, etc.)
	Possible local maintenance at site	
	Available telecommunication facilities	
	Equipment restrictions	
	Local technical skills level	
	Soil resistivity	

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General characteristics of site	Detailed characteristics	Comments
Sociological environment	Energy needs of customers	How much energy will consumers need and be willing to pay for.
	Energy consumption habits	Load profiles for the community.
	Type of clientele	Distribution by a grid will take place on the basis of: • Sociological criteria (rules of society, living habits). • Economic criteria combining the grid and the rural micro-power plant shall cost less than the sum of isolated individual production/distribution facilities whilst providing the same service. • Technical criteria (a guaranteed level of service, security, etc.).
Economic environment	Cost of fuel delivered to site	
	Cost of technical services	
	Economic environments in place	
	Solvability of customers	
	Tariff basis for service	

Table 4 – Regulations and requirements to be considered

Regulatory area		References
Procurement quality		To be filled for each project
Electrical safety		
Distribution conditions		
Buildings	Generation/distribution	
Fuel storage		
Fuel transport		
Local environmental impact		
Classified site		
Miscellaneous decrees		
Possibility of recycling equipment		
Production/distribution specification		
Import duties		
Regulatory authorities		
Local labor requirements		

4.3 Introduction to subsystems

An electrification system shall be considered as a subsystem if it fulfills the following functions:

a) ensuring a power supply service (production subsystem);

and

b) providing an electric power distribution service (distribution subsystem);

and

c) providing a service to the user (demand subsystem);

whilst at the same time complying with constraints (acting on all subsystems);

1) individual Electrification Systems (IES) for single users/loads incorporate two subsystems:

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- an electrical power production subsystem,
- a demand subsystem for utilizing this electrical power.

2) collective Electrification Systems (CES) for multiple users incorporate three subsystems:
   - an electrical power production subsystem (rural micro-power plant);
   - a distribution grid for sharing this power to individual users (rural micro-grid);
   - a demand subsystem including home wiring and user's electrical appliances for all individual users.

These subsystems may correspond to systems operated and maintained by different persons or bodies. In certain cases, the entire system may be owned, operated and used by the same person.

4.4 Functional description of a production subsystem

4.4.1 General

The function of a production subsystem is to supply electric power and energy to an individual customer or a combination of permanent customers. This generating subsystem shall be capable of fulfilling its mission, despite contingencies of availability of the renewable and/or fossil energy sources supplying it and by managing the consumption patterns of the customers.

The technical objectives assigned to such an installation can be summarised in the following essential points:

- to produce and store the energy in a cost effective manner,
- if "REN" sources are used:
  - to give precedence to use of REN where they are locally available,
  - to store energy from the REN sources whenever they are available,
  - to use the back-up energy sources (generator sets) to meet the specified level of service when REN are not available or sufficient.

4.4.2 Detailed functions to be achieved by a production subsystem

From a functional view point, a production subsystem is a system capable of:

Ensuring a power supply service consisting of:

a) Generating electric power

   The different sources and architectures are described in IEC TS 62257-2.

   This function embodies everything needed to produce electric power corresponding to the necessary characteristics of voltage, frequency, harmonics, power and consumption of the customers, according to the needed quality of service (IEC TS 62257-2).

   This function covers:

   - energy conversion from primary energies;
   - energy storage (when applicable);
   - electric conversion from d.c. to a.c. (if necessary);
   - energy measurement.

   Given proper supply and maintenance of the system, it can be designed to meet all of the loads and electrical needs required by the community in an affordable manner.

b) Providing electric power to the distribution subsystem

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Following the production of energy, this function ensures that the energy is provided to the interface with the collective or individual distribution system with respect to the contractual requirements.

c) Managing energy

In principle, the quantity of energy that can be consumed by the users is not unlimited owing to the very existence and contingencies of availability of primary energy (solar radiation, fuel, etc.) and the storage capacities of this energy.

Accordingly, it is important to manage the use of resources provided in order:

- to optimise the use of the available energy,
- to preserve the energy stored in the best way (minimum losses),
- to control energy flows available to the best interest of the customers (immediate energy needs) and equipment (long service life of the installation),
- to minimise the use of fossil resources, when applicable.

This requires:

- management of the energy production/storage;
- management of the energy storage/distribution;
- management of the energy production/distribution;
- management of the genset operation “on/off” (when applicable).

d) Providing information on the operating condition of the installation

The installation is required to provide the users and operators with the information they need to control energy production and consumption in their own interests, and where applicable, that of the community.

4.4.3 Detailed performances criteria to be achieved by a production subsystem

Each criterion shall be developed in order to express the quantitative objectives to be obtained for the sites studied.

The information should be presented in accordance with the general model given in Annex A.

4.5 Functional description of a distribution subsystem

4.5.1 Detailed functions to be achieved by a distribution subsystem (or rural micro-grid)

Providing an electric power distribution service consisting of:

a) Connecting the rural micro-power plant to the application points

This function groups together everything needed to ensure that the terminal application points are supplied from the rural micro-power plant energy supply point, whilst adapting to the energy requirements of the different types of customer (individuals, economic activities, local collective authorities, public lighting, etc.).

Methods should be put in place to account for and monitor rural micro-grid distribution losses.

b) Not degrading the level of quality

The availability and supply quality objectives shall be taken in to consideration when designing the rural micro-grid.

c) Including protection to the micro-power plant as needed to ensure safe operation

Protection should be added to:

- Protect the micro-power plant from a harmful short circuit or other electrical impacts to the extent possible.

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- Localize the impact of short circuits or system overloads so that the whole micro-power plant and all other clients are not interrupted.

d) Executing the decisions of the rural micro-grid manager (load-shedding)

This function describes what the rural micro-grid shall do to comply with the management rules adopted when the rural micro-grid management system also includes an automatic function, in order to guarantee that energy is provided to the users. This shall be completed while ensuring the long service of the production subsystem equipment.

The design of the rural micro-grid shall permit modification of its configuration according to decisions based on information given by the energy management system.

That means:

- allow any agreed changes;
- switch on/off circuits connected to the genset (when applicable);
- switch off circuits according to priority rules;
- provide information to the operator.

e) Managing compliance with the user's contract

It shall be possible to apply commercial rules in conjunction with the technical service of making electricity available (connect/disconnect the users under contractual rules).

The use of advanced monitoring and accounting devices can greatly assist in forcing the compliance of contract.

4.5.2 Detailed performances criteria to be achieved by a distribution subsystem

It is impossible here to recommend any general quantitative objectives (performance levels).

The essential task will hence be to define qualitative objectives (performance criteria) in a functional specification before determining the technical dimensions of the system.

Each criterion shall be developed to express the results to be obtained for the system type studied.

A typical tool for describing functional characteristics of a rural micro-grid is indicated in Annex B in the form of functions/performance sheet concerning how to connect the rural micro-power plant to the application points.

Each rural micro-grid entails aspects specific to the site concerned.

Depending on the characteristics of the needs to be satisfied, the architecture of a rural micro-grid will be constructed on the basis of the following criteria:

- The number of energy delivery points;

  The number of principal and secondary trunk feeders determined in the light of the distribution of the users at the site, the maximum dimensions of the lines, and system losses.

- The possibility of having a certain number of opening points available, enabling all or part of the rural micro-power plant rural micro-grid to be isolated.

As for dimensioning, this will be determined on the basis of such characteristics as:

- The quality level (IEC TS 62257-2) of energy to be distributed;
- The apparent predictable maximum power of the receivers to be supplied at each delivery point (peak power);
- The service quality agreed with the users, in particular the maximum voltage drop, which should not exceed a certain value between the interface with the rural micro-power plant and the customers;

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- The mechanical constraints in the environment concerned.

Figure 2 is a functional diagram of a radial structure for a rural micro-grid.

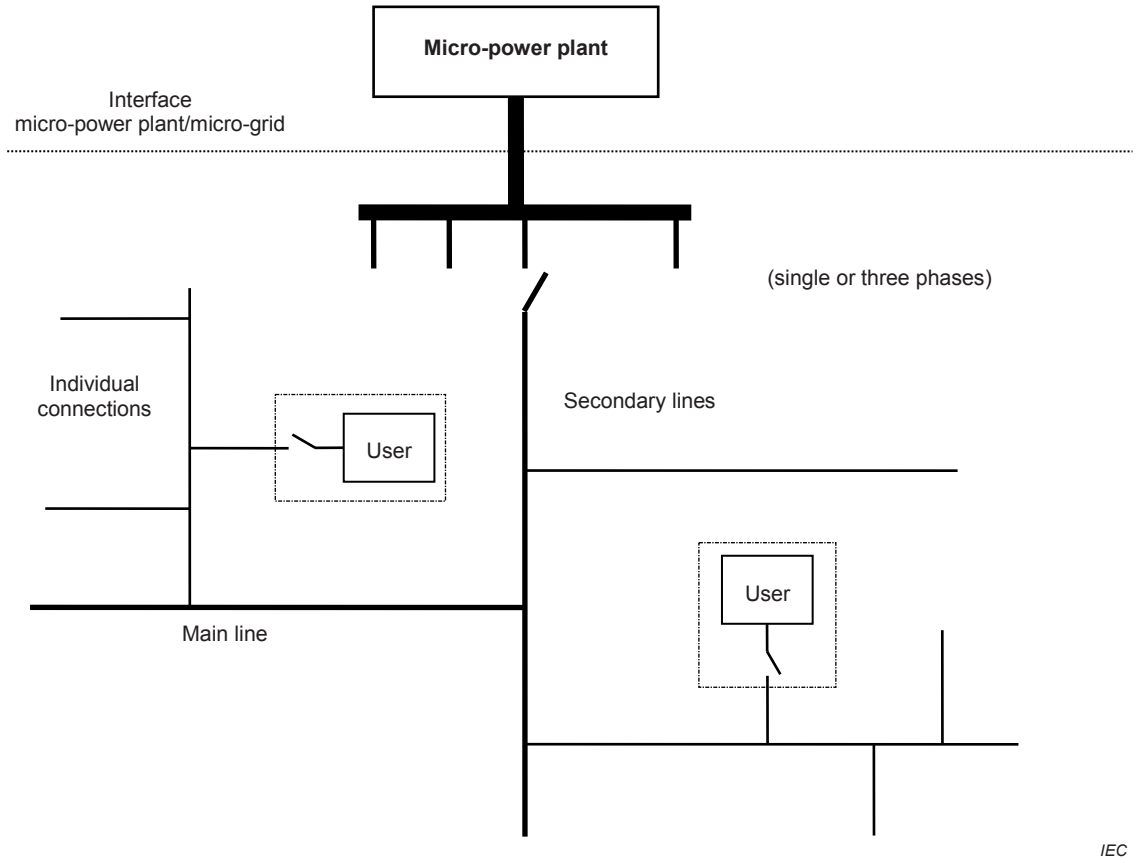

Figure 2 – Functional diagram of a radial structure for rural micro-grid

4.6 Functional description of a demand subsystem

Detailed functions to be achieved by a demand subsystem (or rural micro-grid):

Providing an electric power to applications consisting of:

a) Interfacing with the distribution system

This function groups everything needed to ensure that the user installation is supplied from the distribution system, including functions relevant with the contractual commitment such as payment or metering system.

b) Distributing energy to the appliances

Here are included all the electric functions able to provide, switch on/off electricity from the distribution system interface to the final user's application.

NOTE In some projects, this function could include the supply of the appliances (such as lamps for example).

4.7 Constraints to be complied with by production distribution and demand subsystems

a) Matching the characteristics of the site

This function signifies all constraints, such as geographical, technical, economic or sociological, as well as human factors specific to the site that the design and performance of the facilities to be set up will have to satisfy.

b) Ensuring protection of persons and assets

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The equipment shall be designed to control risks to individuals, operators or third parties. In addition, they shall be protected from the faults that may occur on the different parts of the installation.

c) Minimizing special maintenance to make energy available

That means:

- making easy installation;
- facilitating operating conditions;
- facilitating maintenance;
- facilitating dismantling;
- facilitating expansion.

For reasons of cost, it is imperative that the installation can continue to operate without requiring frequent intervention by specialists.

d) Complying with regulations

This function groups together all the technical and legal constraints to which the installation shall comply to be usable.

e) Complying with the operator and user duties

This specification stipulates the rights and obligations of the operator and users. It is generally drawn up by the national and/or regional institutional authority.

5 Energy management rules

5.1 General

In REN powered systems, the availability of resource can vary considerably. Energy management is particularly vital in providing the service promised to the user under the best possible conditions without jeopardising the operating life of the equipment.

This Clause 5 describes the impact of energy management assumptions and the technical choices that they imply on system sizing.

Figure 3 illustrates the role of energy management and safety as transverse functions in the operation of the system.

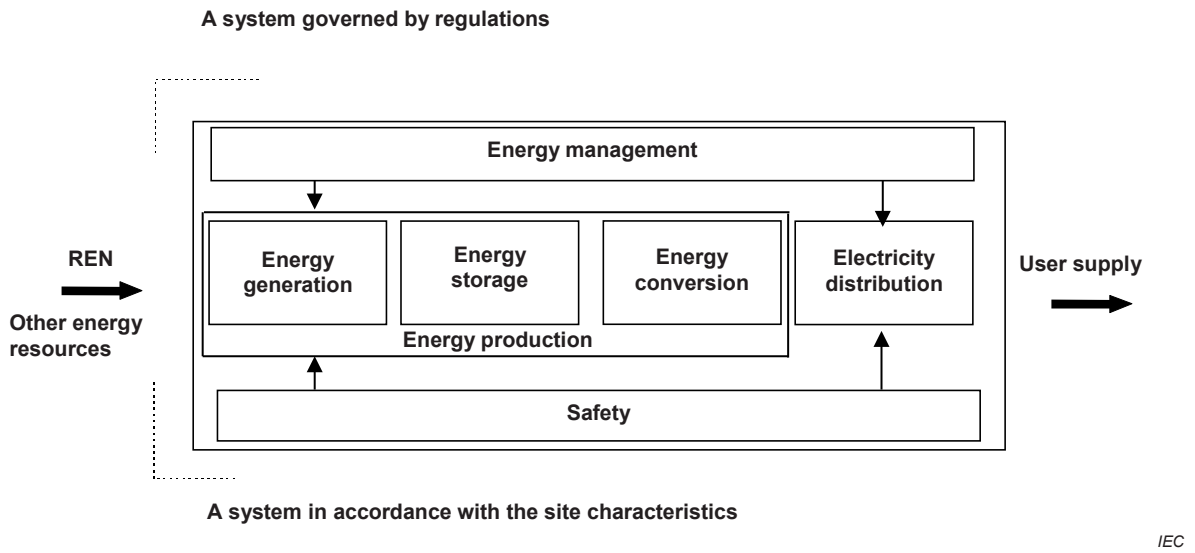

Figure 3 – Functional impact of energy management and safety

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5.2 Functional description for an energy management of an isolated system

To manage energy in REN systems, a number of functions shall be considered, as described below:

a) Adequate management of resources and needs

To manage energy in an isolated system, consideration shall be given to the overall production from renewable energy sources and energy consumption, ensuring that the resources match the demand for energy, then taking the appropriate action. This management is necessary in order to comply as closely as possible with the commitments of the entity providing the services (the project developer and operator). This task should be completed in the best interest of the user.

b) Giving precedence to the use of renewable energies

Energy management in an isolated system is to give precedence to generation from renewable energies in order to reduce consumption of fossil energy and lower system operating cost.

c) Maximising service life and performance of equipment

Managing energy in an isolated system also involves ensuring a long service life for the equipment. This entails giving precedence to equipment protection in relation to supply, so that the capital investment is used correctly throughout the service life for which the equipment has been designed.

d) Managing the storage system

Quality of battery management has a very high impact on battery life, on the system's level of performance, and life cycle cost.

e) Managing the available quantity of energy

Managing energy in an isolated REN system consists in:

- maximising the use of the available REN, which is generally limited,
- optimising the sharing of the available quantity of electrical energy produced from the REN, amongst the different users or appliances.

In a single-user system, over-consumption will interrupt supply. The user quickly learns how to use the energy of the system correctly.

In a multi-user system (for example, a rural micro-power plant associated to a rural micro-grid), steps shall be taken to preserve the store of energy to the benefit of the greatest number and avoid jeopardising the common installation. Clearly, several solutions are possible, for example:

- The grid is live only during a certain time periods and the power of each user is limited; in this case, it is the time the network is live that limits the quantity of energy distributed.
- The grid is live for a considerable period during the day, resulting in better service quality, but requiring both the power available to each user and the quantity of energy the user can consume to be limited during a certain period of time. Depending on the dimensions of the installation, this quantity of energy can be managed over one or several days.
- An appropriate tariff structure is implemented to limit energy consumption or allow for the expansion of the system from revenues of large energy consumers. A step or graduated tariff is recommended to provide low cost power to customers but charge higher consumers for further system expansion.

In systems comprising electrochemical storage, energy management also entails taking the necessary steps to replenish the energy stored. In systems powered by running exposure to renewable energy resources, sometimes referred to as direct drive devices, storage is generally in the form of the energy product, water in pumping application or ice in ice production systems.

f) Managing the quality of the electricity produced

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The final factor in energy management is that of controlling the quality of the electricity delivered to the user. The following are the criteria defining this quality:

- voltage level and its variation range,
- d.c. voltage ripple,
- a.c. frequency and its voltage variation range,
- harmonic ratio for an a.c. voltage, which depends directly on the quality of the inverter (pseudo-sine wave or sine wave) or generator used and shall be appropriate for the devices used. Accordingly, the designer of the system shall check this condition.

Clause 6 describes the impact of the energy management assumptions on system sizing.

5.3 Demand side management

According to the limited quantity of energy produced by any micro-power system generating electricity from REN, it is mandatory to use high efficiency, low consumption appliances and make use of all energy demand control resources readily available.

6 Expected results from the sizing process

6.1 Overview

Clause 6 presents recommendations relative to the information to be provided in a sizing data report.

While each designer may freely choose the specific method used for sizing a system, the objective is to define a framework of assumptions within which sizing can be described, including the type of documentation to be forwarded to the project developer.

Common rules for the presentation of results should be applied by plant designers, so that any project developer can objectively compare the various offers related to this specification.

Clause 6 gives transparent technical and economic criteria for "suitable" sizing, thus making it possible for the offers to be easily compared.

6.2 Participants in the sizing process

A plant sizing process requires a number of active participants, see Table 5.

Special attention shall be exercised in order to request these participants to provide the project with information/decisions they hold or are responsible for.

Table 5 – Participants in the sizing process

Nature of participants	Liabilities of the participants along the sizing process
User	Expresses electricity demand needs
Project developer	Defines the requirements to be fulfilled
Engineering consultant	Assists the project developer in specifying the project and reviewing design proposals
Project implementer	Establishes proper design and sizing

6.3 Elements for comparing various design proposals

All design proposals should be based on the same general specifications.

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