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Edition 2.0 2015-12

TECHNICAL SPECIFICATION

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

IEC TS 62257-4:2015-12(en)

International Electrotechnical Commission

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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RECOMMENDATIONS FOR RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

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FOREWORD

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

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.

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.

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.

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

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 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.

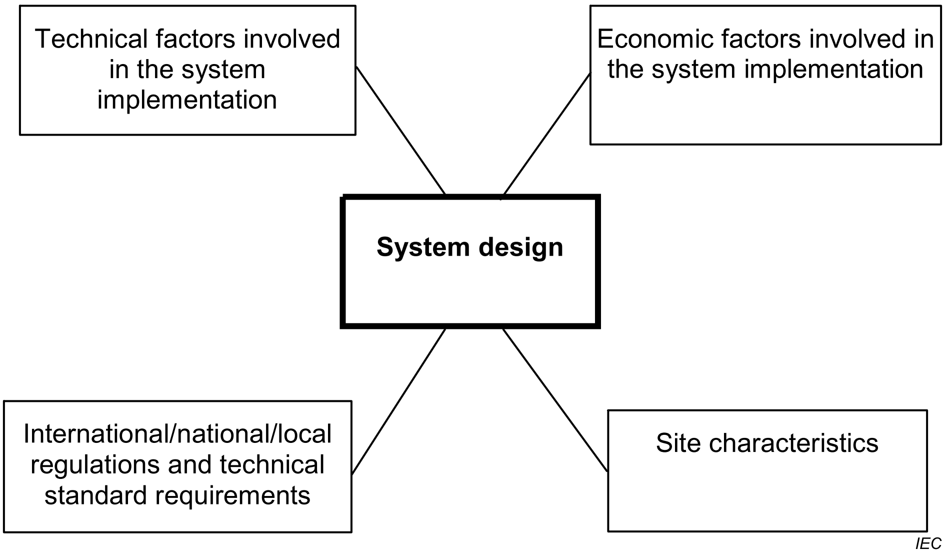

Figure 1 – Factors involved in the design of a system

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.

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.

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	

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:

- 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

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.

- 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;

- The mechanical constraints in the environment concerned.

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

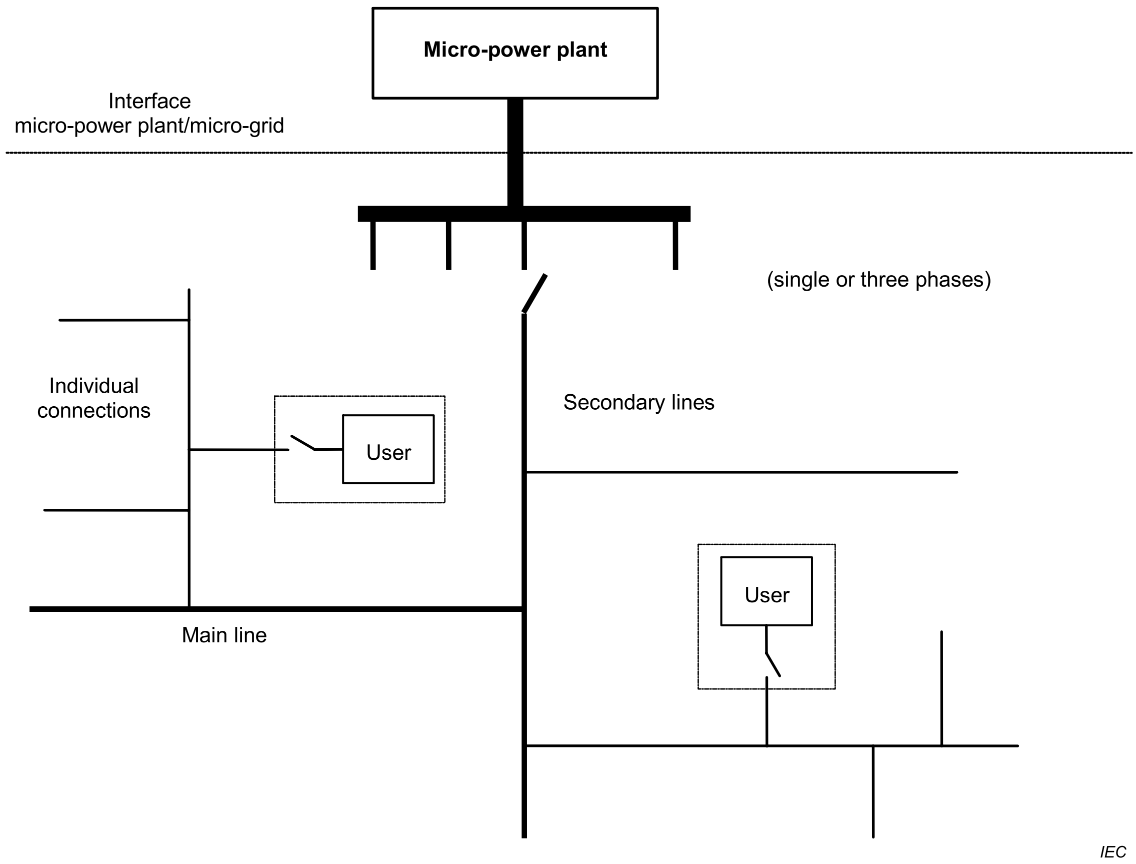

Figure 2 – Functional diagram of a radial structure for rural micro-grid

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

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.

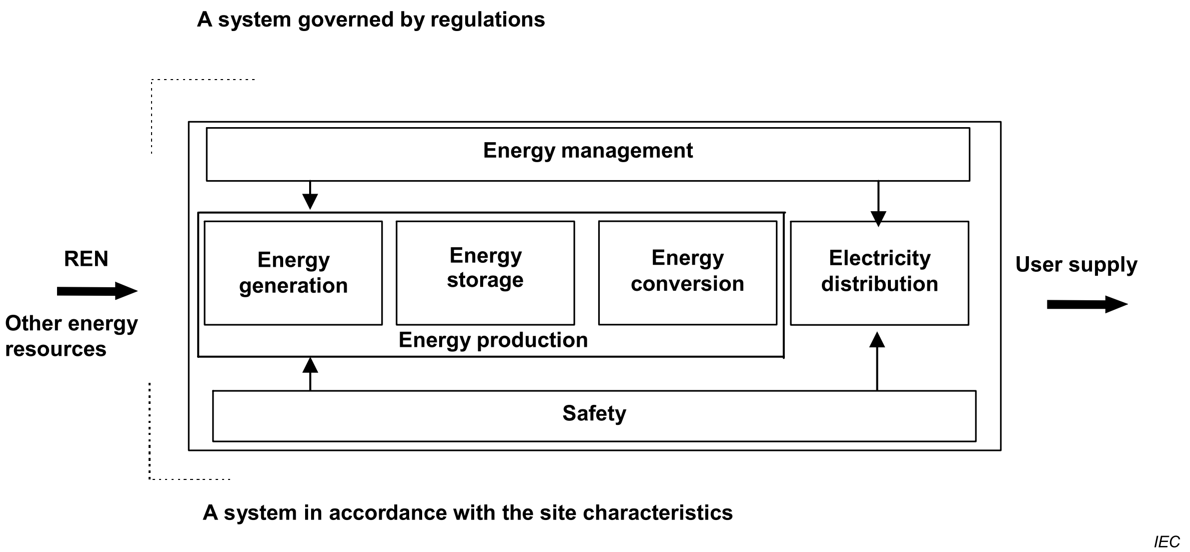

Figure 3 – Functional impact of energy management and safety

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

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.

The different design proposals should be compared on the basis of the following essential points:

- all assumptions used for preparing the design proposals;
- technical specification and energy predictions resulting from the sizing process;
- provisions made to reduce the risk of system outages;
- discounted costs of the proposed equipment;
- evidence, provided the designer of the credibility of the design calculations;
- system class identification;
- designer experience in the field;
- other criteria that may be specific to the project or the developer for example “environmental impact”.

6.4 Frameworks for proposal

6.4.1 General

Subclause 6.4.2 provides an outline for the types and quality of information that should be provided as part of the project development documentation.

The proposal should contain the following information:

- general commitment to supply the amount of energy required to meet the needs of the users;
- assumptions retaining to demand and renewable resource data;
- description of any severe weather events and previsions made to reduce the risk of outage;
- technical specification;
- energy outputs;
- costs including all economic assumptions used;
- documentation of design warranty.

6.4.2 General commitments to supply

These commitments are presented in IEC TS 62257-2, but can be summarized as major points in Table 7.

To size the production subsystems, the project implementer should consult with the project owner to determine a set of relevant indicators.

Some examples of these indicators are:

- users’ power “satisfaction factor"

  Plant sizing is committed to a probability of production versus available energy. At any time specified by the user, they will be supplied with a specified power and amount of energy time and whenever required, complying with predetermined assumptions of power requirements.
- A rate of forecast coverage of REN investments

  This rate of coverage is as follows:

$$\frac{\textit{Probable quantity of energy this plant can produce through RENs}^{1}}{\textit{Quantity of energy desired to be consumed}^{3}}$$

(month by month)

- Other criteria could also be considered, depending of the perspective of the different participants involved in the project, as suggested in Table 6.

Table 6 – Perspectives to be considered

Criteria	Perspective			
	Project developer	**Owner**	**Operator**	**User**
Technical	System provides request level of service	System operates for the desired equipment life	System is easy to operate and maintain	Power is available when wanted or specified in contract
Financial	Design is in accordance with financial resources	Positive cash flow will exist to cover replacement cost and operating cost in accordance with the business plan	System minimizes non technical losses and promotes easy service. To be able to operate in a given budget	Price of energy is affordable
Contractual	Power will be supplied through the design life	System is installed and operating correctly	Ownership and financial structure of the project is clear and secure	Power is supplied in accordance with agreements
Environmental	Project is environmentally sound	Project is environmentally sound	Low adverse system environmental impact	No long term negative environmental impact
Sociological	Project is sustainable	Social benefits: health, education,etc.	Acceptability of the system by the customers	Development of local activities Limited negative impact on quality of life

1 Measurements made from the same point.

Table 7 – Commitments indicators

Requirement	Proposed production subsystem			Electrification system		Proposals for contractual commitments between suppliers, operators and users (when applicable)
	REN	Storage	Genset	IES	CES	
User requests a given result of process over a given period; no quality requirement	X			T_1.I	N/A	Commitment to supply: • process result defined for a period of one month, one week, for a number of *n* months out of 12, *n* weeks out of 52 or *n* days out of 365
Every day, user would like to have multiple hour energy supply at constant voltages with several appliances on, simultaneously and accepts a lack of energy because of adverse climatic conditions	X	X		T_2.I	T_2.C	Commitment to supply: • the quantity of subscribed power/energy defined for a period of one month, one week, for a number of *n* months out of 12, *n* weeks out of 52 or *n* days out of 365
Every day, user would like to have multiple hour energy supply at constant voltages with several appliances on, simultaneously	X		X	T_3.I	T_3.C	Commitment to supply: • the quantity of subscribed power/energy defined for a period of one month, one week, for a number of *n* months out of 12, *n* weeks out of 52 or *n* days out of 365
and			X	T_5.I	T_5.C	
requires energy even in adverse climatic conditions	X	X	X	T_4.I	T_4.C	• service availability over fixed time periods
and		X	X	T_6.I	T_6.C	
accepts to have energy only during defined periods in the day						
Every day, user would like to have energy 24h/day	Same solutions, but different sizing and operating conditions					• same as above, but • 24 h service availability

6.4.3 Assumptions and classification of input

A presentation of the type and quality of the data used in the sizing process allows the project developer to assess the margin of uncertainty associated with this process. These, combined with the design assumptions allow a careful review of the designer’s work. The following tables provide a classification structure for the different data used in most system design and sizing processes. These data are relative to:

- site (Table 8);
- consumption (Table 9);
- resources (Tables 10, 11 and 12).

Different kinds of information are used to characterize these data.

For the site and consumption data, the designer shall be asked to detail the level of data used in the design process.

For the resource data, the designer shall be asked to detail the level, case and record of data used in the design process.

Level: the technical quality of the data used in the sizing process.

Case: the geographic relevance of the data for the specific site.

Record: the length of the data history used in the sizing process; records are the same for all technologies.

N is a number of years and M is a number of months that shall be specified. The length of the history of the data should be representative of the expected lifetime of the system.

Historical data are data of sufficient quality to assess inter years changes in weather patterns.

Weather statistics: only provides a multi-year average data.

Table 8 – Knowledge of site

Site topography	
Level 1	Exact location of site including but not limited to: • Topographical map with a resolution of at least a 1:24 000 of the surrounding area including 10 m elevation resolution. • Exact location of each of the load points through GIS plotting, detailed maps or aerial photos. • Specific understanding of the vegetation of the area around the site including but not limited to photos.
Level 2	Exact location of site including but not limited to: • Topographical map with a resolution of at least a 1:50 000 of the surrounding area including 25 m elevation resolution. • Spatial layout of the community based on measurements or informal mapping techniques. • General understanding of the vegetation of the area around the site.
Level 3	Exact location of site including but not limited to: • Topographical map with a resolution of at least a 1:100 000 of the surrounding area including 50 m elevation resolution. • No information of the spatial layout of the community and load centers. • No understanding of the vegetation of the area around the site.
Level 4	Very low resolution map with minor topographical information such as internationally available data sets with 1 km resolution.
Site climate	
Level 1	Monthly information on site temperature, humidity, rainfall, snowfall, days of ground fog and other environmental conditions. Data includes monthly averages as well as maximum and minimum values for all relevant parameters.
Level 2	Seasonal information on site temperature, humidity, rainfall, snowfall, days of ground fog and other environmental conditions. Data includes seasonal averages as well as maximum and minimum values for all relevant parameters.
Level 3	Yearly information on site temperature, humidity, rainfall, snowfall, days of ground fog and other environmental conditions. Data includes averages as well as maximum and minimum values for all relevant parameters.
Level 4	No specific or unconfirmed understanding or of site climatic information.
Site hazards	
Level 1	Detailed information on the yearly occurrences of hazards such as floods, lightning, hail, high wind events, tornados, tropical storms, hurricanes, typhoons, sandstorms, and icing events. Data would include number of events, seasonal characteristics and historical maximum values for threats present to the local area.
Level 2	Basic information on the yearly occurrences of hazards such as floods, lightning, hail, high wind events, tornados, tropical storms, hurricanes, typhoons, sandstorms, and icing events. Data would include average number of events per year.
Level 3	No specific or unconfirmed understanding or of site climatic information.

Table 9 – Knowledge of consumption data

Expected energy consumptions	
Level 1	Very accurate knowledge of the consumption and time domain including specific loads, frequency and duration of use on a daily level (complete detailed load profile).
Level 2	Daily consumption with at least the day/night portion distributed over the day.
Level 3	Daily consumption, with average of week days and average of weekend days.
Level 4	Daily consumption, monthly average.
Level 5	Daily consumption, yearly average.
Change in consumption	
Level 1	Historical change in load usage or community growth. Detailed understanding of planed load increases.
Level 2	Estimate of load or population increase.
Level 3	Basic understanding of load increase.

Table 10 – Knowledge of resources: data accuracy levels

Data				
	Sun	**Wind**	**Hydro**	**Biomass**
Level 1	Global,Direct and Diffuse Irradiation measured at a fine hourly frequency, over a horizontal surface, with ambient temperature, wind speed and direction.	• 15 min average wind speed measurements. • Measured at a height to provide unobstructed exposure to the windward direction. • Wind measurement at two heights recording maximum, minimum and standard deviation of readings. • 15 min average measurements of wind direction. • Measurement of ambient temperature and barometric pressure recommended.	**Run of river:** hourly records of flow rate, water depth, water turbidity. Seasonal description of water quality and debris. **Standard:** daily records of volumetric flow rate and water turbidity. Values for storage capacity, head height, pipe length. Seasonal description of water quality and debris.	Feedstock specification including BTU value, moisture content, bulk and specific stock density. Chemical/mineral makeup (proximate analysis), stock size and storability characteristics of biomass fuel. Quantity available per week.
Level 2	Daily global irradiation over a horizontal surface.	• 15 min average wind speed measurements at a height to provide unobstructed exposure to the windward direction. • 15 min average measurements of wind direction. • Measurement of ambient temperature and barometric pressure recommended.	**Run of river:** daily records of flow rate and water depth. Seasonal description of water quality and debris. **Standard:** monthly records of volumetric flow rate and water turbidity. Values for storage capacity, head height, pipe length.	Feedstock specification, quantity available per month.

Data				
	Sun	**Wind**	**Hydro**	**Biomass**
Level 3	Average daily global irradiation over a horizontal surface.	Hourly average wind speed measurements taken at 1 s intervals. • Measured at a height to provide unobstructed exposure to the windward direction. • Wind measurement at two heights recording maximum, minimum and standard deviation of readings. Hourly average measurements of wind direction.	**Run of river:** monthly records of flow rate, water depth, water turbidity. Seasonal description of water quality and debris. **Standard:** seasonal records of volumetric flow rate, water turbidity, general water quality and debris. Values for storage capacity, head height, pipe length.	Feedstock specification, Quantity available per season.
Level 4	Average monthly global irradiation over a horizontal surface.	Hourly average wind speed measurements at a height to provide unobstructed exposure to the windward direction. Hourly average measurements of wind direction.		
Level 5		Periodic sample of wind speed and direction throughout every day, such as on a 3 h basis. Common at most airports.		
Level 6		Periodic sample of wind speed and direction throughout the daylight hours of every day, such as three recordings per day. Also common at er airports.		
Level 7		Monthly average of wind speed.		
Level 8		Yearly average wind speed.		

Table 11 – Knowledge of resources: data retained for considered site

	Data			
	Sun	**Wind**	**Hydro**	**Biomass**
Case 1	At the approximate location for the system installation at the considered site.	At the approximate location for the system installation at the considered site.	At the approximate location for the system installation at the considered site.	At the approximate location for the system installation at the considered site.
Case 2	At a location in very close proximity to the considered site and with the same general characteristics.	At a location in very close proximity to the considered site and with the same general air flow characteristics.		
Case 3	At a location removed from the considered site but where correlations can be made to the considered site using either mathematical formulations or proven resource mapping techniques.	At a location removed from the considered site but where correlations can be made to the considered site using either mathematical formulations or proven resource mapping techniques.		
Case 4	At a location removed from the considered site but with similar solar irradiation characteristics is expected.	At a location removed from the considered site but with the same general air flow characteristics is expected.		
Case 5		At a location removed from the considered site and where accurate correlations can not be made		

Table 12 – Knowledge of resources: range of data history

	Data			
	Sun	**Wind**	**Hydro**	**Biomass**
Record 1	M consecutive months of data collected on site with N years of historical data what can be used in a general correlation.			
Record 2	M consecutive months of data collected on site with N years of weather statistics.			

6.4.4 Technical characteristics for the main equipment proposed

For each type of primary equipment (generators, batteries, converters), Tables 13 to 24 indicate the technical specifications that will lead the project implementer to recommend equipment types to the project developer. It is expected that this list is provided as a general guide, as different types of information will be needed for different sizing and analysis methods. The specified information would be provided to the project developer as part of the system design process.

6.4.5 Characteristics for a photovoltaic array

6.4.5.1 Photovoltaic modules

See Table 13.

Table 13 – Characteristics for photovoltaic modules

Information to be forwarded to the project developer
Quantity and type of modules (complying with the standard requirements of the general specification) Unit peak power: Module rated voltage: Surface of modules: Site constraints accounted for:
Technical characteristics leading to the final choice of panel modules
Total peak power: Generator rated voltage: Electrical characteristics $I = f(V)$: Site constraints accounted for:

6.4.5.2 Modules supporting structure

See Table 14.

Table 14 – Characteristics for modules supporting structure

Information to be forwarded to the project developer
Number of structures: Type of structure (roofing, etc.): Number of panels: Implementing the photovoltaic panel field: • Typical distance between arrays: • Minimum distance between array and ground:
Technical characteristics leading to the final choice of structures
Number of modules/structure: Material: Anchoring method: Incline of panels (°/horizon): Degree of incline variability: Orientation of panels (°/North): Degree of orientation variability: Site constraints accounted for: Surface to be reserved: Tracking axis if applicable: Snow loading (if applicable): Wind loading:

6.4.6 Characteristics for wind turbines

6.4.6.1 Wind turbine

See Table 15.

Table 15 – Characteristics for the wind turbine

Information to be forwarded to the project developer
Type of power output: Rated power: Rated voltage: Rated wind speed: Rated frequency: Manufacturer name and part number:
Technical characteristics leading to the final choice of wind turbines
Helix/rotor diameter: Number of blades: Power curve: Control system: Orientation system: Start up wind speed (rotation): Cut out wind speed: Destruction wind speed: Site constraints accounted for:

6.4.6.2 Wind turbine structure or tower support

See Table 16.

Table 16 – Characteristics for wind turbine structure

Information to be forwarded to the project developer
Type of tower: General plan: Overall site layout dimensions: Manufacturer certification:
Technical characteristics leading to the final choice of supporting structures
Means for access for maintenance: Anchoring method: Foundation design specification:

6.4.7 Characteristics for the generator set

This provides specification for any fossil fueled generator that is capable of starting at any time, either manually or in an automated fashion.

See Table 17.

Table 17 – Characteristics for the generator set

Information to be forwarded to the project developer
Generator type (brand and model number): Voltage and frequency: Start up method: Generator housing: Fuel type: Standby or prime power specification: Unit dimensions: Unit weight: Rated power (kW): Number of phases:
Technical characteristics leading to the final choice of the generator
Cost: Power (kVA): Operation voltage range: Nominal voltage: Operation frequency range: Nominal frequency: Fuel consumption at varying power levels: Speed: Power factor: Cooling type: Governor type: Environmental constraints and housing: Safety constraints including fault detection and safety measure specification: Operating constraints of unit: Installation constraints, characteristics and instructions: Specification of meters and controls included in unit: Overall dimensions and weight:

6.4.8 Characteristics for micro hydro turbines

See Table 18.

Table 18 – Characteristics for micro hydro turbines

Information to be forwarded to the project developer
Output power: Manufacture: Model number:
Technical characteristics leading to the final choice of hydro turbine
Nominal flow rate: Flow rate range: Unit power curve versus flow rate: Nominal output frequency: Maximum and minimum head requirements: Cost: Total harmonics distortion: Power factor allowed: Frequency regulation: Controller type: Safety features and fault protection: Input flow protection: Operating temperature range: Overall dimensions and weight: Installation constraints, characteristics and instructions: Connection and wire diagram:

6.4.9 Characteristics for biomass generators

See Table 19.

Table 19 – Characteristics for biomass generators

Information to be forwarded to the project developer
Fuel type: Startup/backup fossil fuel type: Output power (kW): Thermal output: Manufacture: Model number:
Technical characteristics leading to the final choice of biomass generator
Operation voltage range: Nominal voltage: Operation frequency range: Nominal frequency: Power factor: Minimum load: Startup fossil fuel fraction: Fuel curve, fuel conversion and required intake: Maximum biomass fuel moisture content: Maximum gas particulate count: Turndown ratio: Biomass cold startup time: Mixed fuel startup time: Environmental constraints and housing: Safety constraints including fault detection and safety measure specification: Operating constraints of unit: User interface/controls: Installation constraints, characteristics and instructions: Specification of meters and controls included in unit: Overall dimensions and weight:

6.4.10 Characteristics for power converters

Power converters allow power to be converter between a.c. and d.c. busses or busses at different voltages. Units that combine two or more component functions are expected to fulfil the functions called out for all devices. See Table 20.

Table 20 – Characteristics for power converters

Information to be forwarded to the project developer
Type of power conversion: Output power: Specification of control panel: Nominal frequency output (as appropriate): Manufacture: Model number:
Technical characteristics leading to the final choice of d.c./d.c. converters and transformers
Nominal input voltage: Input voltage range: Nominal output voltage: Output voltage range: Maximum current: Unit efficiency versus load or current: Energy consumption at zero load: Safety features and/or system protection: Existence and calibration of converter protection (against reverse polarity in particular): Conformity to applicable standards: Operating temperature range: Overall dimensions and weight: Installation constraints, characteristics and instructions: Connection and wire diagram
Technical characteristics leading to the final choice of d.c./a.c. inverter
Same as above, additionally: Operation frequency range: Nominal frequency: Unit efficiency by conversion power: Continuous a.c. output power: Maximum a.c. output power and time: Output signal waveform (pulse and shape): Voltage regulation: Peak efficiency: Total harmonics distortion: Power factor allowed: Frequency regulation: Maximum allowable pass through current from a.c. loads (if any): Power versus efficiency curve: Evolution of throughput versus load: Consumption at zero load: Inverter electrical protection: Output protection including short protection and breaker speed: d.c. disconnect breaker: Standby mode and standby power consumption:

Altitude limits Type of grounding: Ground fault protection:
Technical characteristics leading to the final choice of a.c./d.c. power rectifier
Same as above, additionally: Maximum input voltage: Input voltage: Unit efficiency versus conversion power curve: Input frequency range: Over voltage protection: Charge controller algorithm: Existence of temperature correction for charge control:

6.4.11 Characteristics for the load manager/meter

This device controls energy flow to different loads and allows control of different electrical loads. See Table 21.

Table 21 – Characteristics for load manager/meter

Information to be forwarded to the project developer
Measured parameters: Operations manual: System control features:
Technical characteristics leading to the final choice of energy managers
Control options: Voltage range: Current range: Load disconnect voltage range and number: Power requirements: Measurement accuracy: Safety features, disconnects and/or unit protection: Overall dimensions and weight: Installation constraints, characteristics and instructions: Connection and wire diagram:

6.4.12 Characteristics for system controllers

System controllers provide an over-riding structure that ensures that given proper operation, the power system operates smoothly and in a unified manner. Depending on system size and complexity, system controllers can be either relatively simple or very complex. See Table 22.

Table 22 – Characteristics for system controllers

Information to be forwarded to the project developer
Measured output and conditions:
Operations manual/user interface description:
Technical characteristics leading to the final choice of system controller
Control parameters:
Unit power:
User interface specification:
Control parameters and capabilities:
Fault detection capabilities:
System monitoring and logging capabilities:
Controller type (PLC manufacture and model):
Equipment communications requirements:
Remote access capabilities/description:
Operating temperature range:
Overall dimensions and weight:
Installation constraints, characteristics and instructions:
Connection and wire diagram:

6.4.13 Characteristics for batteries

See Table 23.

Table 23 – Characteristics for batteries

Information to be forwarded to the project developer
Battery classification (Lead Acid; Nickel Cadmium, etc.):
Maintenance classification (standard, low maintenance or maintenance free):
Storage capacity (Ah) at specified discharge current:
Nominal battery voltage:
Manufacturer:
Part number:
Expected replacement interval:
Technical characteristics leading to the final choice of battery
Cost:
Battery type (flooded, tubular, absorbed glass-mat, etc.):
Nominal battery capacity at different discharge currents:
Operational characteristics of battery at standard operating temperatures for the considered site:
Voltage charge and discharge characteristics for the battery:
Approximate battery internal resistance:
Cycles to failure information for various battery depth of discharges:
Battery terminal/lug type and location:
Casing material:
Battery dimensions and weight:

6.4.14 Characteristics for links and wiring

See Table 24.

Table 24 – Characteristics for links and wiring

Information to be forwarded to the project developer
Quantity and material specification Type approval Cost
Technical characteristics leading to the final choice of links
Cross section Insulation material Insulation level Wire material Temperature rating Multi stranded/solid Multi or single wire cable Cable type (armed, shielded, waterproof, etc.)

6.4.15 Energy outputs

See Tables 25 to 27.

Table 25 – Energy output from renewable energies

Energy source	**Associated electrical energy generator**	**Installed capacity**	**Energy type** (a.c. or d.c.)	**Voltage** V	**Frequency** Hz	**Expected energy output** kWh/year
Sun	Photovoltaic panels (PV)	kWc	To be defined for each project	To be defined for each project	To be defined for each project	To be defined for each project
Water	Microhydraulic power plant	kVA				
Biomass	Gas plant	kVA				
Wind	Wind turbine	kVA				

Table 26 – Energy output from fossil energies

Energy source	**Associated electrical energy generator**	**Installed capacity**	**Energy type**	**Voltage**	**Frequency**	**Expected energy output** kWh/year
Fuel (gas-oil, motor spirit, gas, etc.)	Generator set	kVA	a.c.	To be defined for each project	To be defined for each project	To be defined for each project

Table 27 – Energy output from storage

Storage	Type	Capacity	Power	Energy type	Voltage		
	Batteries						
	Hydrogen						
	Fly wheel						

An example system specification and data quality assessment is provided in Annex C.

6.4.16 Presentation of the costs

It is important that the costs associated with the project should be presented in a manner clearly understood by the parties involved. Costs will be broken down into four areas.

- initial investment cost (equipment, infrastructure and installation);
- operating costs (labour and expendable materials);
- replacement costs (equipment and installation);
- recovery and dismantling costs.

It should be noted that all cost calculations differ depending on the party for whom the cost calculations are being provided. A user who is leasing a specific system will not need to know the battery replacement cost as this may be the responsibility of the lease issuer and thus only the monthly service fee need be provide to the consumer. The purchaser of a complete system will however, want to understand all of the associated costs over the system life to compare this to other electrification options.

Costs supplied to the user should be provided in at least four formats:

- yearly cash flow;
- total life cycle cost;
- levelized cost of energy;
- annualized maintenance, operating, and replacement expense.

Formulas for each of these concepts, taken from the eye of the system owner, are provided in Annex D. Formulas for other important financial terms more applicable to the system from a business prospective are also provided in Annex D.

All these costs shall be considered in calculating the actualised discounted cost, depreciating not only the different costs mentioned above, but also the income from sale of energy throughout the life of the installation. This will enable the depreciated difference (income – cost) to be compared for the different technical solutions studied.

6.4.17 Design warranty

A warranty of the design of the power system is an important factor but unfortunately very hard to collect and validate. This is generally due to the structure of the project, the specific criteria that are used in the design process and the fact that the input to the design process (renewable resource information) is highly variable. Determining that the micro-power plant is operating is an easy assessment, knowing that it can produce the specified amount of energy in 10 years is almost impossible. Although obtaining a design warranty stating that the system was designed to provide a specified load given specified renewable input should be obtained, it is much more important to know that the organization doing the design has experience in the field of hybrid power systems. It would also be appropriate to have individuals with experience review any proposals or system designs provided by third party organizations. More information on tests for power systems is provided in Clause 6 of IEC TS 62257-3:2015.

6.4.18 Steps to reduce the impact of climatic hazards on system performance

Steps shall be taken to reduce the impact of climatic variability by detailing the level of resource and demand information available and their effect on the variability of the service delivered. An effort shall be made to ensure that appropriate data is used for the design. It is expected that the designer will provide a reference to the process used in the design and sizing of the system.

6.4.19 Presentation of the environmental and social impact

List of items concerning the environmental impact assessment will be produced.

6.4.20 Presentation of the socio- economic impact assessment

The final design shall be checked in the light of previous socio-economic studies.

6.5 Proposal for a sizing process

The design and component sizing of hybrid power systems require an understanding of many conflicting and overlapping criteria. In some cases the solution is quite easy, in others it is much more complicated. To add to the difficulties, usually there is not the time to complete detailed assessments for each individual system and so a basic methodology shall be adopted to simplify the process to allow for rapid implementation. In general, there are six basic technical criteria that have great impact on the design of systems:

- the load to be met in the community/household;
- the natural resources available close to the community/ household;
- the cost of diesel or alternative fuel;
- cost of the different technology options;
- if the system could be community based, the layout of the community and the cost of power distribution materials;
- finally, although not specifically technical, the level of technical ability available to facilitate service and repair of system and its components.

To discuss each of these items independently is beyond the scope of this part of IEC 62257, but clearly with the consideration of each of these interlocked issues, the problem can get quite complex. Of initial importance, and likely the hardest part of the whole process, is obtaining accurate data for the above criteria so that informed decisions can be made.

There are many tools that have been created to assist in the design and sizing of power systems. Some of these are software based, others, like the example shown in Annex E, describe a design philosophy that can be followed. There have also been a number of books written on the process as well as several periodicals that can be referenced. The only recommendation that can be made in this technical specification is that for any major project or implementation, a method for the design and sizing of the system be developed or adopted. This methodology should then be tested in a few initial locations and lessons incorporated before being put into general practice.

6.6 Impact of design assumptions on system sizing and cost

This subclause deals with design assumptions other than resources and demand data addressed in 6.4. These design assumptions cover different aspects such as level of service, equipment life, maintenance and replacement assumptions.

Table 28 summarizes the impact of energy management assumptions on the dimensions of an installation and the impact of level of service on the sizing of an installation.

Table 28 – Incidence of energy management assumptions on system sizing

Level of service assumptions	Incidence on sizing
Number of days without renewable energies	Battery autonomy Battery cycling choice Battery type REN generator dimensions for charging the batteries
Function of generator set • back-up (participation in the annual total energy) • emergency supply in the event of a component failing or an exceptional period without REN going beyond the design dimensioning assumptions	Power of the set Type of set: • motor spirit • diesel • normal or industrial quality
Rate of use of the set	Fuel storage capacity Dimensions of generator using REN Dimensions of batteries
Application or user load-shedding assumptions • load-shedding authorisation • load-shedding hierarchy	Capacity of batteries Power of set
Energy constraints set by certain applications: • operating time slots • power calls, etc.	Power of batteries Dimensions of inverter
Service life of equipment	Quality of components and equipment chosen Power management design

The outcome of sizing is to reach an acceptable compromise for each project, taking into consideration:

- initial investment/capital costs,
- operating and general maintenance costs,
- component replacement/renewal costs,
- recycling/dismantling costs.

Specific calculation methods are described in 6.4.16 and Annex D. The assumptions for calculating these costs and in particular the discount rate to be applied shall be determined by the project developer. Calculating the system costs is the responsibility of the project implementer in cooperation with system contractors.

Most of the technical choices shall follow from the cost targets set by the project developer.

The term “technical choices” represents the type and quality of the proposed system:

- system type and architecture:
  - the organisation and structure of the installation that is to generate and distribute the energy,
  - energy distribution in a.c. or d.c. form, and the quality of the supply (type, power, wave form; sinusoidal, square or other),
  - location of system operation break or isolating points and types of switchgear,
  - electrical protection systems (fuses, circuit-breakers);

- quality of the components and technical characteristics (photovoltaic modules, wind-powered generator, batteries, generator set) from amongst the equipment available on the market.

Several iterations may be necessary before arriving at the best compromise to be proposed to the project developer. The range of choice may also be restricted if the budget set by the project developer is too inflexible, in which case it will no longer be a matter of finding the best technical/economic compromise but of finding the best quality service rendered for a given target cost.

Table 29 summarises the main consequences of technical/economic choices in determining system sizing. This list is not comprehensive.

Table 29 – Incidence of cost management assumptions on system dimensions

Life span, maintenance and replacement assumptions	Impact on sizing
Intended equipment life span: • short (5 years) • normal (10 years) • long (15-20 years) **Equipment maintenance policy:** • setting up maintenance structures • training and capability of maintenance agents • type of maintenance (preventive, remedial) • stock of spares parts, etc. **Components and equipment replacement policy:** • installation take-over structure • replacement frequency, preventive maintenance, corrective maintenance, etc., policy	Quality of components Quality of electricity supplied Battery type Battery capacity Battery charging capacity of generator Quality of energy management and battery algorithms Type of generator set Type of equipment used (robustness/ reliability, energy consumption, etc.)

6.7 Guarantee of results

The designer shall be in a position to exhibit guaranteed results, hence the actual nature of steps he intends to make should a sizing or performance failure be evidenced.

7 Data acquisition rules for system management

7.1 Overview

Automatic or manual energy management requires information about the current operation of the power system. It is important to understand the information needed to manage the system operation, in other words, which power system parameters should be monitored to obtain information about current operation. Clause 7 describes the minimum requirements to perform this specific task. Complementary information may also be required for scientific or validation purposes.

This topic is of importance in the system design process as it relates specifically to the final power system configuration and performance.

7.2 General

In Clause 7, the specification describes the minimum set of measurements to be made by the data acquisition equipment installed in systems for electrification of remote sites by renewable energy based isolated electrification systems. Clause 7 describes first information required by the different components involved in operation of the system and then lists data that shall be collected to provide this information.

Without considering any specific technical solutions, system designs or where the data acquisition equipment shall be implemented, the document aims to list the different measurements that shall be obtained to manage the power system properly.

7.3 Levels of data acquisition and data necessity

7.3.1 General

Five types of information may be needed for the management of an autonomous installation intended to provide electric power to remote sites:

- information intended to ensure satisfactory operation of the installation and its energy management system,
- information intended to verify that the contracts between the different parties involved are complied with (see IEC TS 62257-3),
- information intended for the user to enable him/her to make good use of his/her installation,
- information intended for maintenance and troubleshooting of the power system,
- information for scientific analysis.

The recipients of this information are:

- the energy manager or system control circuitry,
- the operator of the installation,
- the user.

To meet these needs, monitoring systems aim to measure physical data or system states and, when collected, processes to provide status of the operating conditions. In certain cases, data may also be stored for the different recipients described above.

Different types of power systems use different data processing functions that can be located on a single or on several individual pieces of equipment, depending on the manufacturers design.

Generally, the control of hybrid power systems is quite simple, as most components of a power system are controlled independently and tied to the battery bank voltage for energy management. Hybrid power systems rarely have a single supervisory controller or energy manager that controls all aspects of the power system operation. Subclauses 7.3.2 to 7.3.5 introduce the detailed information needed and relevant data that are to be collected to elaborate this information.

7.3.2 Information to provide to the energy manager and relevant data to be collected

The functional specification of the energy managers and/or control systems indicates the detailed functions to be fulfilled.

The main function of this equipment is to automatically manage operating conditions of the electrification system; which means that it shall be able to manage:

- energy flows between "production" and "storage",
- energy flows between "storage" and "loads",
- energy flows between "production" and "loads",
- “on/off” orders for the genset (when applicable),

- information.

The main questions of interest for the energy manager are:

- How much energy is available from the power system?
- How much energy is needed by the user(s) of the system?
- How much of produced energy, in excess versus demand, can be stored in the battery bank?

The energy manager shall monitor the physical magnitudes involved in the operating status of the power system. This allows decisions concerning production and supply of energy while ensuring a long service life of the equipment.

Table 30 gives the information required by the energy manager to operate properly. Next to this list of information is the list of the data to be collected.

NOTE Because of the complexity of individual controlled components, this technical specification does not describe inter-component control mechanisms, only intra-component control parameters. Different combinations of the data above, either monitored directly or indirectly will give the energy managing system the ability to direct power flow in order to meet the load, if possible.

Table 30 – Information required by the energy manager and data to collect

Manager function No.	Name of function	Information needed by the energy manager	Information the monitoring system shall provide
1) Management of energy flows in production – storage			
1.1	Battery charging by REN sources or by the generator set (in case of diesel rural micro-plant)	Energy stored in batteries: E_{Bat}	Voltage across battery terminals: U_{Bat}
1.2	Non battery overload		Battery current: I_{Bat}
1.3	Optimization of the power of the PV generators as a function of irradiance		Voltage across genset terminals: U_{GR}
1.4	Equalization load (programmed day)		Current put out by the genset: I_{GR}
1.5	Control of direction of circulation of the current in the links sources-storage		Genset running time: T_{GR}
2) Management of energy flows in storage – loads			
2.1	Power supply for backed up a.c./d.c. loads	Energy stored in batteries: E_{Bat}	Voltage across loads terminals: U_{Util} Current in loads: I_{Util} Loads running time
2.2	Shedding of backed up a.c. or d.c. loads		Voltage across battery terminals: U_{Bat}
2.3	Maximum voltage limitation at terminals of backed up a.c. or d.c. loads	Voltage across loads terminals: U_{Util}	
2.4	Holding of minimum voltage at terminals of backed up a.c. users		
2.5	Power supply to non-backed up a.c. or d.c. loads	Energy stored in batteries: E_{Bat}	Voltage across loads terminals: U_{Util} Current in loads: I_{Util}
2.6	Shedding of non-backed up a.c. or d.c. loads		Loads running time
2.7	Maximum voltage limitation at terminals of non backed up a.c. or d.c. loads	Voltage across loads terminals: U_{Util}	Voltage across loads terminals: U_{Util}

Mana-ger func-tion No.	Name of function	Information needed by the energy manager	Information the monitoring system shall provide
2.8	Holding of minimum voltage at terminals of non-backed up a.c. loads		
3) Management of energy flows in production – loads			
3.1	Power supply to backed up a.c. loads from the generator set	Energy produced by the genset: E_{GR} Energy produced by all REN devices E_{REN}	Voltage across genset terminals: U_{GR} Current put out by the genset: I_{GR} Genset running time: T_{GR}
3.2	Break in power-supply to backed up a.c. loads from the generator set		
3.3	Power supply to battery-less loads	Energy stored in batteries: E_{Bat}	Voltage across REN generator: U_{REN}
3.4	Shedding of battery-less loads	Energy theoretically producible REN: E_{Th}	Output current of the REN source: I_{REN}
4) Management of genset on/off orders			
4.1	Start generator set	Energy stored in batteries: E_{Bat} Energy produced by all REN devices E_{REN}	All data for E_{Bat} as above I_{Util} (for management of high level power demand:
4.2	Stop generator set		
5) Information management			
5.1	Supplied by the instrumentation		
5.2	Supplied by the operator		
5.3	Return information to the actuators (information relating to the management decisions)	*(These management and communication functions are possible if original measured data are processed)*	
5.4	Return information to the operator (information relating to the management decisions)		
5.5	Return information to the user (information relating to the management decisions)		

7.3.3 Information to provide to the operator and relevant data to be collected

The operator of the installation needs several types of information, summarised in Table 31, which concerns compliance with the contract and assistance in troubleshooting and maintenance. The operator shall check that the performance capabilities of the installation are indeed those declared by the system design, equipment specification and commissioning documentation. The analysis of the system operating parameters may also allow the owner to assess system efficiency improvements and more effectively troubleshoot problems with system operation.

NOTE 1 Energy deficiency in the installation can have three main causes:

– failures of equipment,

– lack of production,

– over consumption by the user.

NOTE 2 The designer will have the opportunity to implement a data acquisition system that is either a fixed piece of equipment or a temporary system that can be removed after an initial break in period in the case of operational questions. In addition, a monitoring system that only addresses areas of concern, such as system power production, can be installed on a permanent basis.

Table 31 – Information required by the operator and data to collect

Requirement	Information to provide to the operator	Requisite data
Requested information: compliance with the contract		
Check that the performance capabilities of the installation comply with the system design	Theoretical energy production REN: E_{Th} Actual system energy production	Resource measurement at site: $V_{Avg.1}$, T_{Amb}, GT, V_{Flow} Production of specific generation components: E_{Wtg}, E_{GR}, E_{PV} E_{Hydro}, Gen Fuel, Genset running time: T_{GR}
Check that the energy consumption limits provided for by the equipment dimensioning and defined in operator/user "contract" are complied with	User energy consumption: E_{Util}	E_{Util}
Check that specific components meet initial requirements	Inverter and battery efficiencies are as specified Energy output of energy producers meet requirements for voltage and frequency	I_{Bat}, U_{Bat}: I_{Inv}, I_{Util}, U_{Util} U_{Util}, Freq, Power factor, harmonic distortion
Requested information: assistance in troubleshooting and maintenance		
Knowledge of the operating conditions of the installation before conducting any maintenance work	Fault identification	
	State of charge of the batteries: E_{Bat}	Voltage across battery terminals, U_{Bat} Battery current: I_{Bat} Battery temperature t_{Bat}
Troubleshooting in the event of failure	Past record of the production; logged data	Key system parameters: all above parameters
	Past record of the failures	System logbook

7.3.4 Information to provide to the user and relevant data to be collected

The installation user wishes to make the best possible use of his/her installation and will wish to receive prior warning in the event of a risk of lack of energy and any other event liable to counter his/her consumption. To do so, the user needs information as shown in Table 32, mainly the state of charge of the batteries.

Table 32 – Information required by the user and data to collect

Requirement	Information to provide to the user	Requisite data
Energy available	State of charge of the batteries: E_{Bat} Energy production; E_{REN}, E_{GEN}	Voltage measured across the terminals of the battery, U_{Bat} Battery current: I_{Bat} Battery temperature t_{Bat} Operation and production of specific generation component: U_{GR}, I_{GR}, U_{REN}, I_{REN}
Instantaneous energy available	Indication of instantaneous availability of energy	Same as above Current load: I_{Util}, U_{Util}
Knowledge of the risk not to have energy available	Predicted energy availability based on current conditions	Same as above

7.3.5 Summary of the information required

Table 33 summarises the list of the required information and the assigned destinations.

Table 33 – Summary of the needed information

Required information			Assigned destinations			
			Energy manager	Operator		User
				Compliance with contract	Troubleshooting/ maintenance	
Instantaneous information	U_{Util}	Voltage across loads terminals	(●)	●		
Records on running days		Quality of power output		●		
		Fault identification		●	●	
	E_{Bat}	Energy stored in the batteries	●		●	
	$E_{Ch\ bat}$	State of charge of the batteries			●	●
	E_{Tot}	Total energy production. E_{REN}, E_{Gen}	●			●
	E_{Real}	Energy produced by REN	(●)	●	●	
	E_{Th}	Energy theoretically producible from REN		●	●	
	E_{GR}	Energy produced by the genset	(●)	●		
	E_{Util}	Energy consumed by loads (d.c. and/or a.c.)		●		●
		Environmental conditions	(●)	●		
		Running time of the genset	(●)	●	●	
Past records		Past production from REN record		●	●	(●)
		Past possible production from REN record		●	●	(●)
		Past consumption record		●	●	(●)
		Past fault record				(●)
		Past state of charge of the batteries record			●	(●)
		Past production from genset record		●	●	(●)

● Information required as a minimum to allow the management of the system.

(●) Information required for a better comfort or a better accuracy in the management of the system.

7.3.6 Scientific data collection

Scientific data collection would require the collection of data from almost every parameter possible to allow the analysis of every system operating condition although this level of data analysis may be useful on a very limited basis for very large project implementation.

7.4 Data to be collected

In relation to the different needs of information as introduced above, Table 34 lists the minimum data that should be collected from the power system.

Table 34 – Minimum set of data to be collected

Data		
U_{Bat}	Voltage at battery terminals	●
I_{Bat}	Battery current (and direction)	●
θ_{Bat}	Battery temperature	(●)
U_{REN}	REN sources voltage	(●)
I_{REN}	REN sources current – for each renewable device is appropriate and desired.	●
U_{GR}	Generator set voltage	(●)
I_{GR}	Generator set current	●
U_{Util}	Applications supply voltage (d.c. and/or a.c.)	●
I_{Util}	d.c. and/or a.c. applications supply current	●
e'_{GR}	Genset starting status	(●)
e_{GR}	Genset operating status	(●)
$G_{En\ fuel}$	Genset fuel consumption	(●)
t_{Bat}	Battery temperature	(●)
t_{Amb}	Ambient temperature	(●)
T_{GR}	Generator set running time	●
● Information required as a minimum to allow the management of the system. (●) Information required for a better comfort or a better accuracy in the management of the system.		
NOTE This table introduces a list considered as a minimum. It is always possible to obtain more information (for example for a more accurate management, for scientific purpose, or validation). But, in a lot of situations, especially in developing countries, minimum cost is a key point to be considered.		

As shown in Table 35, the amount of useful information needed is in direct relation with the complexity of the system to be managed and thus the system classification.

This table encourages the system designer to adapt the sophistication of the data acquisition system to the sophistication of the power system.

(Identification of the systems refers to the classification defined in IEC TS 62257-2).

Table 35 – Relationship between required information and system architecture

		Required information	Systems T_1	T_2	T_3	T_4	T_5	T_6
Instantaneous information	U_{Util}	Applications supply voltage (d.c. and/or a.c.)	(●)	●	●	●	●	●
Records on running days		Fault identification	(●)	(●)	(●)	(●)	(●)	(●)
	E_{Bat}	Energy stored in the batteries		●		●		●
	$E_{Ch\ bat}$	State of charge of the batteries		●		●		
	E_{Real}	Energy produced by REN	(●)	●	●	●		
	E_{Th}	Energy theoretically producible from REN	(●)	●	●	●		
	E_{GR}	Energy produced by the genset			●	●	●	●
	E_{Util}	Energy consumed by loads (d.c. and/or a.c.)			●	●	●	●
		Running time of the genset			●	●	●	●
Past records		Past production from REN record	(●)	(●)	(●)	(●)		
		Past possible production from REN record	(●)	(●)	(●)	(●)		
		Past consumption record		(●)	(●)	(●)	(●)	(●)
		Past fault record	(●)	(●)	(●)	(●)	(●)	(●)
		Past state of charge of the batteries record		(●)	(●)	(●)	(●)	(●)
		Past production from genset record			(●)	(●)	(●)	(●)

7.5 Operating conditions, electrical and engineering requirements for data acquisition

For current and voltage measurements, it is advised to take averaged measurements over 10 min together with the minimum and maximum values throughout the day.

Protection performances (criteria IP) should be more strict.

The data acquisition system shall be powered by the electrification system as a load or by an independent power system. If supplied by the power system, the data acquisition system should not disturb any electrical characteristics of the system. Energy consumption of the DAS should be as low as possible:

Less than 5 % of the average daily produced energy, for power systems with $W_P < 500$ W.

Less than 2 % of the average daily produced energy, for power systems with $W_P > 500$ W.

Any faults of the data acquisition system shall have no influence on the monitored power system. Reliability of the installation shall be the same with or without operation of the data acquisition system.

Annex A
(informative)

Example for detailed performance criteria and levels for a production subsystem

Referring to the functional description list, each function shall be developed in order to express the objectives to be obtained for the sites studied.

The information presented should be in accordance with the following model as given in Table A.1 below.

Table A.1 – Detailed performance criteria and levels for a production subsystem

X. FUNCTION			
X.Y. sub-function	**Performance criteria**	**Performance levels**	**Remarks**
• Services rendered • Constraints complied with	Indicators selected to qualify the ability of a solution to render the services expected or to comply with the constraint	Quantitative requirements (within the criteria defined) guided by the “market” to be satisfied	

The following Table A.2 gives an example illustrating function 1.1 for a T3.C system (see IEC TS 62257-2):

Table A.2 – Typical example of Table A.1

1. GENERATION OF ELECTRIC POWER			
Sub-function	**Performance criteria**	**Performance levels**	**Remarks**
1.1 Production of electrical energy from primary energies	• d.c. energy to be produced per day	in Wh/ day	
1.1.1 from solar energy	• share of total energy to be provided • peak power • nominal voltage • direction of circulation of current in link • etc.	in Wh/day in Wc in d.c. V panels to battery: anti-return diode in each branch	
1.1.2 From fossil energy (generator set plus charger)	• share of total energy to be provided	in Wh/day (d.c.)	
1.1.2.1 Generating an a.c. voltage from the set 1.1.2.2 Converting the a.c. voltage of the set into d.c. voltage etc.	• power • voltage • frequency • fuel autonomy • characteristics • nominal current • charger efficiency • voltage • internal consumption • load management • etc.	in kVA, cos φ = 0,8 in a.c. V ± 10 % in Hz ± 2 Hz in month (0,25 l tank per kVAh) three-phase or single-phase in A ≥90 % in V ± 2 % in Wh/day etc.	

Annex B
(informative)

Example for detailed performance criteria and levels for a distribution subsystem

The information presented should be in accordance with the following model as given in Table B.1:

Table B.1 – Detailed performance criteria and levels for a distribution subsystem

X. FUNCTION			
X. Y. sub-function	**Performance criteria**	**Performance levels**	**Remarks**
• Services rendered • Constraints complied with	Indicators chosen to qualify the ability of a solution to render the service expected or to comply with the constraint	Quantitative requirements (in the criterion defined) guided by the "market" to be satisfied	

Hereinafter is an example of an element of the detailed functional specification for the following function: connecting the power plant to the application points, see Table B.2.

Table B.2 – Typical example of Table B.2

1. TO CONNECT THE PRODUCTION SOURCES TO THE APPLICATION POINTS			
sub-function	**Performance criteria**	**Performance levels**	**Remarks**
1.1. To connect to the rural micro-power plant	• Total transmission capacity		
1.2. To distribute the rural micro-power plant supply	• Number of off takes	(characteristics of site)	
1.3. To transmit the energy to the application points	• Transmission capacity of each main trunk line • Total length of network	(characteristics of site)	
1.4. To distribute the energy transmitted at local level	• Transmission capacity of each secondary trunk line • Number of secondary trunk lines • Number of customers per branch point	(characteristics of site)	
1.5. To enable energy transmission to be interrupted	• Number of cut-off/control points	(characteristics of site)	
1.6. To connect up to the application points	• Number of customers per offtake • Number of application points	(characteristics of site)	

Annex C
(informative)

Example framework for proposal specification[2]

Project name: Isla Tac

Project location: Island of Tac in the Chiloe Region of Southern Chile

C.1 Knowledge of site

(refer to Table 8 in the text)

Site topography	
Level 1	Exact location of site including but not limited to: • Topographical map with a resolution of at least a 1:24 000 of the surrounding area including 10 m elevation resolution. • Exact location of each of the load points through GIS plotting, detailed maps or aerial photos. • Specific understanding of the vegetation of the area around the site including but not limited to photos.
Site climate	
Level 2	Seasonal information on site temperature, humidity, rainfall, snowfall, days of ground fog and other environmental conditions. Data includes seasonal averages as well as maximum and minimum values for all relevant parameters.
Site hazards	
Level 2	Basic information on the yearly occurrences of hazards such as floods, lightning, hail, high wind events, tornados, tropical storms, hurricanes, typhoons, sandstorms, and icing events. Data would include average number of events per year.

C.2 Knowledge of consumption data

(refer to Table 9 in the text)

Expected energy consumptions	
Level 2	Daily consumption with at least the day/night portion distributed over the day
Change in consumption	
Level 2	Estimate of load or population increase

[2] This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the products named in this annex.

C.3 Knowledge of resources

(refer to Tables 10 to 12 in the text)

General data				
	Sun	**Wind**	**Hydro (not applicable)**	**Biomass (not applicable)**
Level 1				
Level 2	Daily global irradiation over a horizontal surface for a given site.			
Level 3				
Level 4		Hourly average wind speed measurements at a height to provide unobstructed exposure to the windward direction. Hourly average measurements of wind direction.		
Level 5				
Level 6				
Level 7				
Level 8				
Data retained for considered site				
Case 1				
Case 2	Climate wise, the site is similar to other sites whose general data are available (except level 4).			
Case 3		At a location removed from the considered site but where correlations can be made to the considered site using either mathematical formulations or proven resource mapping techniques.		
Case 4				
Case 5				
Range of data history				
Record 1	M consecutive months of data collected on site with N years of historical data what can be used in a general correlation.			
Record 2		6 months of data with 2 years of historical data what can be used in a general correlation.		

C.4 Technical characteristics for the main equipment proposed

C.4.1 Photovoltaic modules

(refer to Table 13)

Information to be forwarded to the project developer
PV determined to not be applicable for this application

C.4.2 Modules supporting structure

(refer to Table 14)

Information to be forwarded to the project developer
PV determined to not be applicable for this application

C.5 Characteristics for wind turbines

C.5.1 Wind turbine

(refer to Table 15)

Information to be forwarded to the project developer
Type of power output: Rectified d.c. Rated power: 7,5 kW Rated voltage: 48 V d.c. Rated wind speed: 13,8 m/s Rated frequency: N/A Manufacturer part number: Bergey Windpower – EXCEL-R
Technical characteristics leading to the final choice of wind turbines
Helix/Rotor diameter: 7 m Number of blades: 3 Power curve: (see attachment[3]) Control system: rectified controller Orientation system: passive yaw with tail boom Start up wind speed (rotation): 3,1 m/s Cut out wind speed: N/A Destruction wind speed: 54 m/s Site constraints accounted for

3 In this annex, the reference “see attachment” means that such an attachment (specific to each project) should be provided by the project implementer.

C.5.2 Structure support

(refer to Table 16)

Information to be forwarded to the project developer
Type of tower: guyed lattice tower General plan: see attached specifications Overall site layout dimensions: see attached specifications Manufacturer certification: Rohn Industries
Technical characteristics leading to the final choice of supporting structures
Means for access to maintenance: climbable tower, tower tilts down for major turbine maintenance Anchoring method: concrete anchors per manufacturer's specification Foundation design: concrete anchors per manufacturer's specification

C.6 Characteristics for the generator set

(refer to Table 17)

Information to be forwarded to the project developer
Generator type (brand and model number): F.G. Wilson Ltd. Voltage and frequency: 220 V a.c., 50 Hz Start up method: automatic Generator housing: none Fuel type: diesel Standby or prime power specification: prime Unit dimensions: Unit weight: Rated Power (kW): 14 kW number of phases: 3 phase
Technical characteristics leading to the final choice of the generator
Cost: $16 000 Power (kVA): 17,5 kVA Operation voltage range: 200 to 240 V a.c. Nominal voltage: 220 V a.c. Operation Frequency range: 46 to 54 Hz Nominal Frequency: 50 Hz Fuel consumption at varying power levels Speed: 1 500 RPM Power factor: 0,8 nominal Cooling type: water Governor type Environmental constraints and housing: indoor use only Safety constraints including fault detection and safety measure specification: over temperature and over speed Operating constraints of unit: none Installation constraints, characteristics and instructions: none Specification of meters and controls included in unit: none

C.7 Characteristics for micro hydro turbine

(refer to Table 18)

Information to be forwarded to the project developer
Micro hydro determined to not be applicable for this application

C.8 Characteristics for biomass generators

(refer to Table 19)

Information to be forwarded to the project developer
Biomass determined to not be applicable for this application

C.9 Characteristics for power converters

(refer to Table 20)

Information to be forwarded to the project developer
Type of power conversion: solid state power converter
Output power: 4,5 kW
Specification of control panel: see attachment
Nominal frequency output (as appropriate): 50 Hz
Manufacture: Trace Engineering
Model number: SW4548E
Technical characteristics leading to the final choice of d.c./a.c. inverter
Nominal input voltage: 48 V d.c.
Input voltage range: (42 to 56) V d.c.
Nominal output voltage: 220 V a.c.
Output voltage range: 220 V a.c.
Operation Frequency range: 50 Hz
Nominal Frequency: 50 Hz
Maximum current: 137 A d.c.
Unit efficiency versus load or current: Maximum 96 %, see attachment
Energy consumption at zero load: 17 W
Safety features and/or system protection: Over/under voltage, over temperature, over current
Existence and calibration of converter protection (against reverse polarity in particular): no
Conformity to applicable standards: yes – USA: UL designation
Operating temperature range: –40 °C to 60 °C
Overall dimensions and weight: 38 cm × 57 cm × 23 cm: 63 kg
Installation constraints, characteristics and instructions: see attachment
Connection and wire diagram: see attachment

Unit efficiency by conversion power: see attachment
Continuous a.c. output power: 14 A a.c.
Maximum a.c. output power and time: 34 A a.c., 1 min
Output signal waveform (pulse and shape): sine wave
Voltage regulation: yes
Peak Efficiency: 96 %
Total harmonics distortion: (3 to 5) %
Power Factor Allowed: –1 to 1
Frequency regulation: ±0,04 %
Maximum allowable pass through current from a.c. loads (if any): 60 A
Power versus efficiency curve: see attachment
Evolution of throughput versus load: see attachment
Inverter electrical protection: see attachment
Output protection including short protection and breaker speed: see attachment
d.c. disconnect breaker: no
Altitude limits: 5 000 m
Technical characteristics leading to the final choice of a.c./d.c. power rectifier
Same as above, additionally:
Maximum input voltage: 66 V d.c.
Input voltage: 220 V a.c.
Unit efficiency versus conversion power curve: see attachment
Input frequency: 50 Hz
Over voltage protection: yes
Charge controller algorithm: three stage
Existence of temperature correction for charge control: yes

C.10 Characteristics for load manager/meter

(refer to Table 21)

Information to be forwarded to the project developer
Not applicable for this application

C.11 Characteristics for system controllers

(refer to Table 22)

Information to be forwarded to the project developer
Incorporated into system power converter
Measured output and conditions: battery voltage
Operations manual/user interface description: see attachment
Technical characteristics leading to the final choice of system controller
Control parameters: see attachment
Unit power: not applicable
User interface specification: not applicable
Control parameters and capabilities
Fault detection capabilities
System monitoring and logging capabilities: none
Controller type (PLC manufacture and model): not applicable
Equipment communications requirements: not applicable
Remote access capabilities/description: none
Operating temperature range: see above
Overall dimensions and weight: not applicable
Installation constraints, characteristics and instructions: see attachment
Connection and wire diagram: not applicable

C.12 Characteristics for battery

(refer to Table 23)

Information to be forwarded to the project developer
Battery classification (Lead Acid; Nickel Cadmium, etc): flat plate lead acid
Maintenance classification (Standard, low maintenance or maintenance free): standard
Storage capacity (Ah) at specified discharge current: 1 024 Ah
Nominal battery voltage: 2 V d.c.
Manufacturer: SEC industrial
Part number: 6-M100-17
Expected replacement interval: 6 years
Technical characteristics leading to the final choice of batteries
Cost: $350 USD
Battery type (flooded, tubular, absorbed glass-mat, etc.): flooded
Nominal battery capacity at different discharge currents: see attachment
Operational characteristics of battery at standard operating temperatures for the considered site: see attachment
Voltage charge and discharge characteristics for the battery: see attachment
Approximate battery internal resistance: see attachment
Cycles to failure information for various battery depth of discharges: see attachment
Battery terminal/lug type and location: top, tab
Casing material: metal
Battery dimensions and weight: 13 cm × 15 cm × 66 cm

C.13 Energy outputs

C.13.1 From renewable energies

(refer to Table 25)

Energy source	Associated electrical energy generator	Installed capacity	Energy type	Voltage V	Frequency Hz	Expected energy output kWh/year
Sun	Not applicable	0				0,0
Water	Not applicable	0				0,0
Biomass	Not applicable	0				0,0
Wind	Wind turbines	2 × 7,5 kW	d.c.	48	N/A	32 560,0
Storage	Batteries	100,6 kWh	d.c.	48	N/A	N/A

C.13.2 From fossil energies

(refer to Table 26)

Energy source	Associated electrical energy generator	Installed capacity	Energy type	Voltage V	Frequency Hz	Expected energy output kWh/year
Diesel	Generator set	17,5 kVA	a.c.	240	50 Hz	16 065,0

Annex D
(informative)

Formula for costs calculations

D.1 Yearly cash flow

A yearly cash flow predicts the expenses that are expected each year of the project. This prediction will enable the user to determine what the yearly outlay of funds is to be expected. This is given for each year (n) by adding up the expected yearly expenses as shown in the following formula.

$$C(n) = Cs(n) + Co(n) + Cm(n) + Cr(n) + Cd - Cs(n) - Cr(n) \tag{D.1}$$

where

C is the system cost in year (n) and in the absence of income, is also the system cash flow.

Cs is any capital cost of the associated project billed in year (n). This may be paid in full in the first year of the project or spread out through financing of the equipment using loans over the life of the project. If financing is used, this cost should include both equity and debt payments as well as any initial down payments made in the first year of the project;

Co is the operational cost of the power system in the year (n). This would entail all consumable elements required for operation of the system such as fuel, oil, distilled water for batteries, replacement fuses, etc.;

Cm is the maintenance cost for any equipment in the power system incurred or expected to be incurred in year (n). Equipment maintenance differs from operation expense in that the expenses supply upkeep on equipment likely occur at least annually. Expenses can include personnel, major spare parts and system inspections;

Cr is the replacement cost for any components expected in year (n), generally for items that occur less frequently than every year such as wind turbine blades, batteries and diesel engines;

Cd is the recovery and dismantling costs associated with the project, usually only applicable in the final year of the project life;

Cs is any subsidy or grant for service received for a specific project in the year n;

Cr is any revenue received from the system through the sale of electricity or other means in year n.

D.2 Calculation of total life cycle cost

The total life cycle cost allows the determination of the whole project cost, independent of project life or the variation between initial expenses and operational expenses. It allows an even assessment of the costs of different energy options. The total life cycle cost is calculated by summing up the expected yearly expenses of the project, returned to the present value of the expense.

$$TLCC = \sum_{n=1}^{N} \frac{C(n)}{(1+d)^n} = \frac{C_1}{(1+d)^1} + \frac{C_2}{(1+d)^2} + \frac{C_3}{(1+d)^3} + ... + \frac{C_N}{(1+d)^N} \tag{D.2}$$

where

C is the cost in year n (Formula D.1);

N is the total number of years in the project;

d is the annual discount rate (based on the value for the specific country under consideration).

It should be noted that in recent years individuals have started using the term "total life cycle cost" in discussions referring to the total energy and resources used over the complete life of a component or device. Such as the resources needed to produce, operate and dispose of a PV module as compared to the energy generated by that device. This co-opting of terminology may in the future lead to confusion in the use of this term.

D.3 Calculation of the levelized cost of energy

The Levelized Cost of Energy (LCOE) provides the user(s) with a simple method to compare the total cost of energy for each specific electrification option. It should be noted that this number can cause some controversy as the cost of energy in rural areas is always higher than what will be found in urban areas. The method that governments want to use in rectifying this difference is one of governmental policy and is not addressed in this document. It is clear however, that although the cost of supplying rural consumers will be higher, the importance is the relative cost difference between the differing electrification options. The life cycle cost of energy can be calculated using the following formula.

$$LCOE = TLCC \Big/ \sum_{n=1}^{N}\left[\frac{Q(n)}{(1+d)^n}\right] \tag{D.3}$$

where

$TLCC$ is the total life cycle cost (Formula D.2);

N is the total number of years in the project;

d is the annual discount rate (based on the value for the specific country under consideration);

Q is the energy output of the power system in the specific year n.

D.4 Annualized maintenance, operating, and replacement expense

The final figure of merit is the annualized maintenance, operating, and replacement expense which allows a clear comparison to other energy options that are more dominated by operating costs then renewable based systems. It also demonstrates the expected cost of producing power once the initial capital of the equipment has been provided. This can be critical as many rural electrification programs subsidize the initial cost of generation equipment but do not subsidize operational costs, which are born by the system user. This calculation is in itself a two-step process, determination of the operational cash flow, similar to Formula D.1 and then the annualization of this expense.

The operational system expense is calculated by summing a subset of the yearly cash flow costs as shown in the following formula.

$$C_{op}(n) = Co(n) + Cm(n) + Cr(n) \tag{D.4}$$

where

C_{op} is the operational cost in year (n) and in the absence of income, is also the system cash flow;

Co is the operational cost of the power system in the specific year (n) including fuel, oil, distilled water for batteries, replacement fuses, etc.;

Cm is the maintenance cost for any equipment in the power system incurred or expected to be incurred in year *n* including filters, oil changes, system inspection;

Cr is the replacement cost for any components expected in year *n*.

It is possible from this value to determine the operational cost of energy, simply the cost of producing energy from the system in the absence of the initial capital cost. This can be done by following through Formulas D.2 and D.3 using the yearly operational expense (C_{op}) in place of the complete system cost (C).

The annualized expense provides a figure for the average yearly expenses that will be required to keep the system operational.

$$AVop = \left[\frac{d(1+d)^n}{(1+d)^n - 1}\right] \times \left[\sum_{n=1}^{N} \frac{Cop(n)}{(1+d)^n}\right] \quad \text{(D.5)}$$

where

Cop is the operational cost in year (n);

N is the total number of years in the project;

d is the annual discount rate (based on the value for the specific country under consideration).

D.5 Further economic calculations applicable to energy businesses

- Net Present Value (*NPV*):

  The Net Present Value of a project is one way of examining costs (cash outflows) and revenues (cash inflows) together. The basic principle it to associate all costs and revenues at the initial year of the project by discounting each expense back to the first year of the project. A *NPV* analysis can be composed of many different cost and revenue streams, each assessing costs or revenues at different years over the project life. The formula for the *NPV* can be expressed as:

$$NPV = \sum_{n=1}^{N} \frac{F(n)}{(1+d)^n} = \frac{F_1}{(1+d)^1} + \frac{F_2}{(1+d)^2} + \frac{F_3}{(1+d)^3} + ... + \frac{F_N}{(1+d)^N} \quad \text{(D.6)}$$

  where

  F is the summation of all of the cost and revenues (Formula D.1) in year *n;*

  N is the total number of years in the project;

  d is the annual discount rate (based on the value for the specific country under consideration). It should be noted that different expenses or revenues can be discounted using different rates as needed.

- Simple and discounted payback

  The calculation of payback periods allows a simple assessment of the time it will take to repay an investment based on the cost of the project, specifically specifying how many years a financiers money will be at risk. Because of its simplicity, it is commonly used to compare different project alternatives.

- Simple payback period

  The simple payback period, *SPP*, compares the initial capital cost of the system to the annualized yearly net profit from the system. It is calculated from the following formula:

$$SPP = \frac{Cs}{AV_{prof}} \quad \text{(D.7)}$$

where

Cs is any capital cost of the associated project, this is usually only assessed in or prior to the first year of the project;

AV_{prof} is the annualized profit of the system. This can be calculated by taking the operational system expense (Formula D.4) and adding any system profit received by the rental of the equipment or sale of the power produced. This value can then be substituted into Formula D.5 to return the annualized yearly profit from the system. A negative number would indicate that the system was not profitable and thus will never pay back the initial capital cost. In some cases, this term should also consider the savings associated with the retrofit of an existing system even if the there is no increase in revenues. For example, if retrofitting a diesel engine with renewable technology results in a net reduction in operational expenses, the profit associated with this reduction should be included as additional profit.

- Discounted payback period

  One of the disadvantages in using the simple payback rate is that it does not incorporate the time value of money, thus provides a lower payback period than if the initial capital investment was placed in an interest baring enterprise. The Discounted Payback Period, *DPP*, takes this into account and thus is a better indication of the systems worth. The *DPP* can be expressed as the est value of *DPP* (in years) for which:

$$\frac{Cs}{(1+d)^{DPP}} \leq \sum_{n=1}^{DPP} \frac{AV_{prof}(n)}{(1+d)^{n}} \tag{D.8}$$

where

d is the annual discount rate (based on the value for the specific country under consideration).

Annex E
(informative)

Proposal for a sizing process

E.1 General

The process recommended for defining the size of a power production plant using RENs is detailed in the following flow chart.

Each step in Figure E.1 is identified by an item number and forms the subject of comments shown in the following clauses/subclauses.

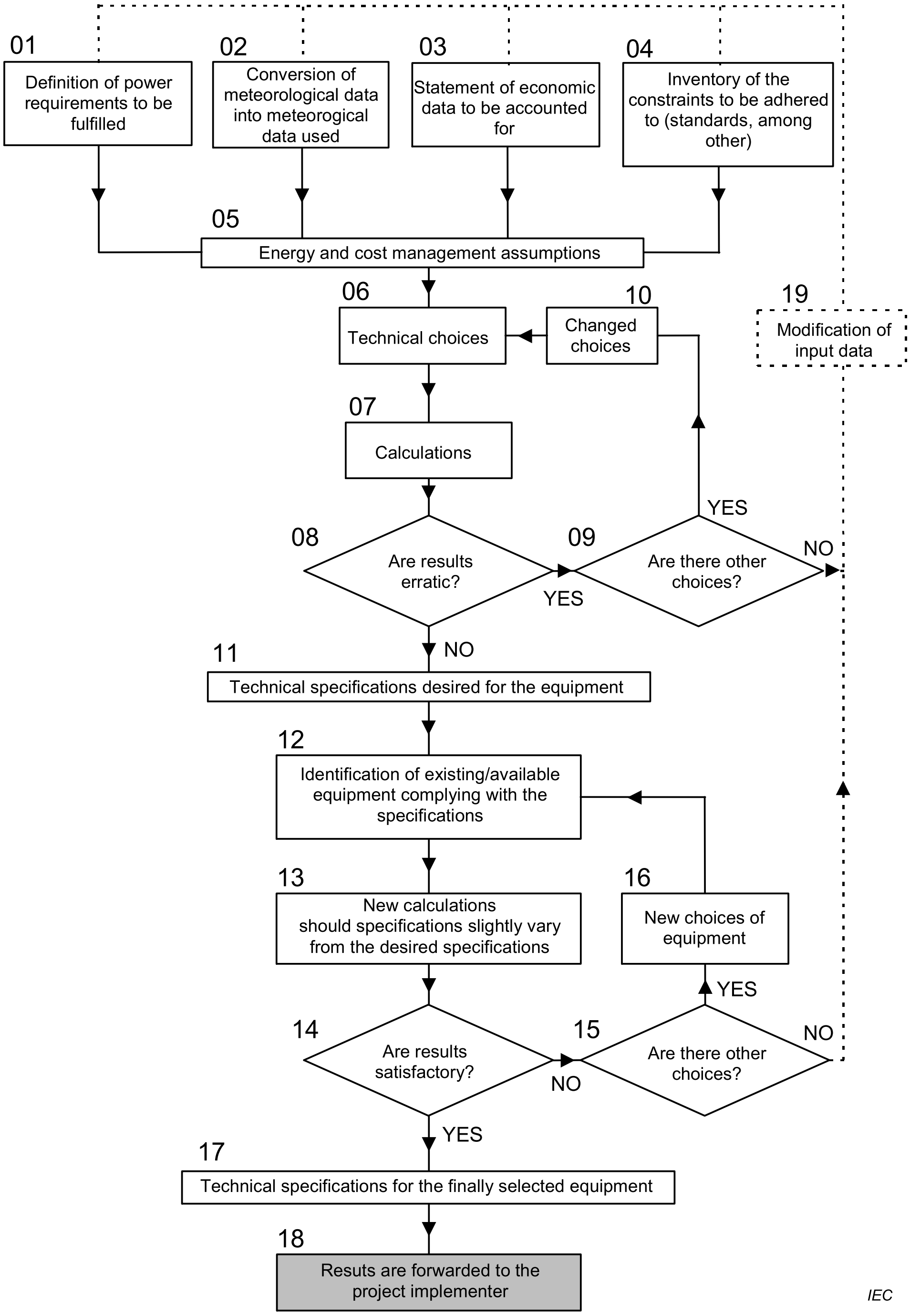

Figure E.1 – Sizing process flow chart

E.2 Comments on the proposed sizing process

E.2.1 General

Process steps 01 to 05 (data collection and determination of work assumptions) shall be preferably inspired by common, state of the art standards.

Process steps 06 to 16 are proposals for methodology: however, information sources and how this information should be processed is part of each designer’s know-how. No such detailed rules effective for everyone can be proposed herein.

The content and format of the results forwarded to the project developer on completion of the sizing process (steps 17 and 18) shall also be inspired by common, state of the art standards.

E.2.2 Step 01: Definition of power requirements to be fulfilled

Requirements to be fulfilled are characterized by:

a) Qualitative data:

   – **Type of consuming utilities** (type of receivers to be supplied with power):

   Table E.1 depicts how the inventory of the utilities accounted for should be preferably organized for this project.

Table E.1 – Description of utilities to be power supplied

Nature of existing or potential clients		Type of supplied receivers
Type 1	Individuals	Home used equipment (lighting, audiovisual, cold, etc.)
Type 2	Business activities	Professional equipment (motors, processes, etc.)
Type 3	Communities	Collective equipment (pumping, public lighting, etc.)

   – **Type of power** to be supplied (users receivers dependent):
   - direct current (d.c.);
   - and/or single-phase alternate current (a.c.);
   - and/or 3-phase alternate current (a.c.).

   – **Priority levels** to be assigned to the various types of utilization should the demand conflict with the global offer.

b) Quantitative data:

   – **Delivery characteristics**

   Number of delivery points per type of utilization.

   – **Supply commitment characteristics**

   Maximum level of power that can be connected to the delivery point, for each category of utilization.

   Maximum level of power consumable over a given period (for example, 24 h) for each delivery point.

   – **Consumption characteristics**

   Consumption profile (power and energy) for each delivery point over a given period.

   The hour is considered as a pertinent time unit for energy management.

   Ideally, the time unit used for acquiring consumption data should be as close as possible to the hour.

   Where it reveals impossible to know the true values at the h hour, then the known H-1 values shall be carried over.

   The time (over a given period) during which the supply shall be provided

   In regard to this point, the choices to be made will be of the type detailed in Table E.2.

Table E.2 – Consumption characteristics

Desired duration of global supply	Example of supply allocation
24 h/24 h	Supply to all clients
12 h/24 h	8 h supply (daytime) to business activities 4 h supply (evening time) to personal individuals
4 h/24 h	Supply to personal individuals

For the delivery point, the (forecast) power consumption will be assessed using:

- accurate evaluation of each appliance consumption (seen from the supply source side),
- determination (as accurate as possible) of the duration of use of the various appliances, as a function of the seasons as necessary,
- determination of the mean profile for power demand in the day: the day itself can be broken down into periods (for example, night/day on duty/off duty) or even into hours,
- determination of the profile of occupancy of premises: occupancy of the "continuous" or "occasional" type (with a known or unknown frequency of occupancy),
- definition of the peak or pulse consumption (possibly) characterized by power inrush calls over a very short time.

E.2.3 Step 02: Conversion of available weather data into relevant data

The nature of available weather data shall be carefully specified as close as possible to that of the site to be implemented and to a degree of fineness consistent with the refined knowledge of the power requirements.

In the absence of very detailed data and in order to provide clear information to all participants, corrections made to the available data shall be documented.

A sizing data sheet showing the data retained for the calculations shall be prepared to ensure sizing traceability. The format of this data sheet could be of the type shown in Table E.3.

Table E.3 – Meteorological data used for sizing

Equipment concerned	Data to be collected	Ideal data	Available data	Corrections made	Data used for calculations
Panels	Average sunshine on flat surface, in $kWh/m^2/d$ • Global • Direct • Diffuse	Average/h			
	Number of days per year without sun	Number of consecutive days			
	Masks	Status of panels/h			
	Albedo	Coefficient/period of the year			
Battery	Temperatures: night/day or min/max	Average/h			
Wind turbine	Wind speed (m/s) (and elevation of measuring point)	Average/month Average/day			
	Mean shape factor in Weibull distribution				
	Compass card	Year			

Equipment concerned	Data to be collected	Ideal data	Available data	Corrections made	Data used for calculations
	Number of calm days per month Site geography (obstacles, relief on an accurate plane, type of vegetation) Maximum wind speed	Number of consecutive days Average over 10 years			

E.2.4 Step 03: Statement of economic data to be accounted for

In order to permit to define the global cost of a plant over a given period, the cost elements detailed in Table E.4 will have to be assessed for each sizing scenario.

Table E.4 – Proposals for types of cost to be accounted for

Design cost		
Investment cost	Sources, batteries, converters, protection and management equipment	Cost of equipment and materials implemented on site (purchasing, transport, installation acceptance, civil work) Technical inspection Contractors cost
Operating cost	Exploitation operations, servicing, equipment maintenance, follow up	Cost of expandable materials on site (diesel fuel, demineralised water) Cost of services on site Assurances
Replacement cost	Equipment replacement for reasons of wear or expandability to new requirements	Portion of the initial cost assigned to "temporary milestones".
Dismantling cost		Cost of battery fallback

E.2.5 Step 04: Inventory of the constraints to account for

Table E.5 proposes a list of constraints which should be checked for existence on a case by case basis.

For each site, the list of the leading particulars should be taken into account in the sizing process.

Table E.5 – Site constraints inventory

	Type of constraints	Characteristics to be checked	Characteristics of the site which affect sizing
1	Geographical environment	Climatic aggressions (rain, salt, sand, frost, etc.)	
		Thermal and hygrometry extreme values	
		Accesses to site/time for access	
		Nature of terrain	
		Location of points to be supplied	
2	Biological environment	Animals	
		Plants	

	Type of constraints	Characteristics to be checked	Characteristics of the site which affect sizing
3	Technical environment	Type of existing grid (overhead, buried)	
		Civil work	
		Quality of existing structure	
		Local maintenance possible on site	
		Equipment imposed	
4	Sociological environment	Standard of living of supplied clients	
		Power consumption habits	
5	Economic environment	Existing business activities	
		Clients solvency	
		Various decrees	
		Budget not to be exceeded	
6	Local regulatory environment	Classified site	
		Specification for concession	
		Non nuisance constraints (noise, etc.)	

E.2.6 Step 05: Management assumptions

a) Energy management

Managing the energy is to observe the REN production/consumption balance and to react accordingly:

- For the benefit of the end user (in order to keep as close as possible to the commitments made to supply power).
- To assess the impact on the durability of the equipment (so that the investment is used throughout the life duration it was designed for).

Table E.6 indicates how plant sizing may be affected by management assumptions.

Table E.6 – Impact of energy management assumptions on plant sizing

Assumptions	Impact on sizing
Number of consecutive days without REN	Expected battery autonomy
Choices for cycling the battery	Type of battery
Role expected from the generator	Generator power
• Battery makeup charge (participating into the balance)	
• Emergency power supply source in cased of REN, battery or converter failures	
• Generate rate of use	Fuel storage capacity; battery autonomy
Authorized (or restricted) load shedding and in certain conditions, of a number of utilizations	Battery capacity and/or power of the generator set
Priority in load shedding	
Special constraints for some utilizations (for example significant power inrushes, hour based operating constraints, etc.)	Battery capacity
Constraints of equipment target durability	Choice of equipment types and battery capacity
Political will to use RENs	

b) Management of costs

For each project, an acceptable compromise should be searched for the set including "investment cost + operating cost + replacement costs".

Since this equilibrium has to be offset as a function of the client and his technical and financial capabilities and requirements, each project shall indicate the priority objectives which were sought for the client satisfaction using chosen technical solutions:

- minimum investment cost
- minimum operating cost
- minimum replacement cost

and shall specify the forecast part assigned to each cost.

Table E.7 indicates how plant sizing can be affected by cost management assumptions.

Table E.7 – Impact of cost management assumptions on plant sizing

Assumptions	Impact on sizing
Maximum/normal/minimum equipment life duration	Battery type, battery capacity, battery charge and discharge management, type of generator
Normal/minimum maintenance	
• number and level of difficulty of maintenance actions to be performed	Battery type, generator type
• maintenance operations frequency	Battery capacity and battery type Battery charge and discharge management Generator type
• generate rate of usage	Generator type
(this list is not exhaustive and should be further documented)	

E.2.7 Step 06: Technical choices

Technical choices denotes:

- architectural choices
  - schematic diagram to organize the plant designed to produce share and distribute power;
  - presence of converters or not. If so, quantity of converters, power produced and type of organization;
  - location and nature of disconnecting/protection points.
- choices technical characteristics for equipment (panels, wind turbine, generator set, batteries, etc.)
  - choices made among possible values corresponding to equipment existing on the market.

Several iterations will be undoubtedly required before concluding on the choice(s) to be recommended to the project developer.

The first choices will be initial choices based upon the designer's experience.

The liberty of choices might be very limited, in particular when equipment reuse constraints exist or when a number of brands or types have to be reused; see constraints defined in step 04.

According to the conclusions drawn from the analysis of the calculation results, or with a view to testing the sensitivity of performances for this plant to other choices than the initial choices, several "data sets" should be used.

Recommendations:

- single phase production if power < 5 kVA
- 3-phase production if power > 10 kVA
- continuous distribution if peak power (photovoltaic) < 1 kWc
- for business activities:
  - if business activities are marginal, the 3-phase supply problem (specific make up generator) will be preferably solved instead of impairing the network investment as a whole,
  - if business activities are developing or if it is desired to encourage them, the opportunity of a 3-phase distribution should be envisioned (throughout the whole network or via a separate network).

E.2.8 Step 07: Calculations

Considering the technical and economic assumptions accounted for, calculations consist in preparing power balance sheets and assessing the cost of the plant resulting in the said balance sheets.

The designers may freely choose the models for plant operation as well as the initial data processing algorithms.

Calculations shall be established with an accuracy consistent with a refined knowledge of the power requirements and producible REN.

Whichever tools used, assumptions specified in process steps 01 to 06 should allow to identify specific values as:

- plant average forecast coverage rate (this value is accounted for failing any better value);
- plant forecast service rate (to be reserved for a future version since this rate cannot be determined using the current tools);
- budget required for achieving these characteristics;
- sensitivity of the budget to the variation of these characteristics.

E.2.9 Step 08: Analysis of the results

The analysis of the results shall define the ability of the technical choices to meet technical requirements desired for this plant.

It is agreed that results will be regarded as "erratic" provided one of the following proposals is not adhered to:

- one element among steps 01 to 06 of the sizing process flowchart is not adhered to,
- recommendations are not adhered to,
- the investment cost exceeds the (provided or estimated) budget.

E.2.10 Step 09: Examination of the opportunity of other choices

When calculation results are unfavourable, new technical choices should be checked other than those considered in step 06.

If yes (unfavorable), proceed to step 10 for iteration of the technical choices; if no (favorable), proceed to step 19 for negotiating initial data (if possible).

E.2.11 Step 10: Change in technical choices

This step consists of modifying the architectural characteristics or preliminary sizing characteristics for the equipment in order to introduce a new set of data into the calculations.

E.2.12 Step 11: Definition of desired equipment characteristics

Depending on the algorithms used, the calculations have led to an acceptable techno-economic balance between the different equipment characteristics.

E.2.13 Step 12: Identification of existing/available equipment complying with the characteristics

From the expected characteristics, a list is prepared specifying the equipment that can be actually used in the plant, with due consideration for both equipment availability from the market and lead time for delivery as required to complete the project.

E.2.14 Step 13: New calculations

In reference to the list of equipment prepared in step 12, this step may be necessary provided an opportunity is possibly detected to use similar equipment which could be suddenly available for all kinds of reasons or at an interesting cost. Then, it would be valuable to reiterate the calculations to ascertain the deviation in the results in relation to those discrepancies in the characteristics between the equipment selected in step 12 and that newly identified equipment.

E.2.15 Step 14: Analysis of the results

The nature of this step is similar to that of step 08:

The analysis of the results shall state the ability of the technical choices to satisfy technical and economic objectives desired for this plant.

It is agreed that results will be regarded as "erratic" provided one of the following proposals is not adhered to:

- one element among steps 01 to 06 of the sizing process flowchart is not adhered to;
- recommendations are not adhered to;
- standards are not adhered to;
- the investment cost exceeds the (provided or estimated) budget;
- the actualized cost is not a minimum cost (in relation to other solutions envisioned).

E.2.16 Step 15: Examining the opportunity of other choices

The nature of this step is similar to that of step 09.

E.2.17 Step 16: New choices of equipment

The nature of this step is similar to that of step 10.

E.2.18 Step 17: Technical characteristics for the finally chosen equipment

These characteristics are those of the equipment finally retained in a scenario proposed to the project developer.

E.2.19 Step 18: Forwarding the results to the project implementer

If the results are satisfactory they are forwarded to the project implementer.

E.2.20 Step 19: Modification of the input data

If the results are unsatisfactory and if other technical choices are possible, new input data are used for a new complete sizing process.

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