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TECHNICAL SPECIFICATION

Recommendations for small renewable energy and hybrid systems for rural electrification –
Part 9-6: Integrated system – Selection of Photovoltaic Individual Electrification Systems (PV-IES)

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RECOMMENDATIONS FOR SMALL RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 9-6: Integrated system – Selection of Photovoltaic Individual Electrification Systems (PV-IES)

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

IEC 62257-9-6, which is a technical specification, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This document is based on IEC/PAS 62111 (1999); it cancels and replaces the relevant parts of IEC/PAS 62111.

This part of IEC 62257 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
82/510/DTS	82/532/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 of IEC 62257 series, under the general title: *Recommendations for small renewable energy and hybrid systems for rural electrification,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

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

INTRODUCTION

The IEC 62257 series of documents intends to provide to different players involved in rural electrification projects (such as project implementers, project contractors, project supervisors, installers, etc.) documents for the setting up of renewable energy and hybrid systems with a.c. voltage below 500 V, d.c. voltage below 750 V and power below 100 kVA.

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 must 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 and 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: small renewable energy and hybrid off-grid systems.

This document and the others of the IEC 62257 series are only guidance and so cannot be International Standards. Additionally their subject is still under technical development and so they shall be published as Technical Specifications.

RECOMMENDATIONS FOR SMALL RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 9-6: Integrated system – Selection of Photovoltaic Individual Electrification Systems (PV-IES)

1 Scope

The purpose of this part of IEC 62257 is to propose simple selection procedure and cheap, comparative tests which can be performed in laboratories of developing countries, in order to identify the most suitable model of small Photovoltaic Individual Electrification Systems (PV-IES) up to 500 Wp for a particular rural electrification project from a number of products submitted for test.

It is different of the scope of IEC 62124, *Photovoltaic (PV) stand alone systems – Design verification*, which provides guidance for verifying the design of stand-alone PV systems and indoor and outdoor tests in order to evaluate the performance of PV systems including PV generator, battery storage and loads such as lights, TV sets, and refrigerators.

The tests provided in IEC 62257-9-6 allow assessment of the performance of a PV-IES according to the requirement of the General Specification (GS) of the project (see IEC/TS 62257-2) and to verify their ability to provide the required service. They should be performed locally, as close as possible to the real site operating conditions.

This document is not a type approval standard. It is a technical specification to be used as guidelines and does not replace any existing IEC standard on PV systems.

2 Normative references

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

IEC 61215, *Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval*

IEC 61646, *Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval*

IEC 61730-1, *Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction*

IEC 61730-2, *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*

IEC/TS 62257-2:2004, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 2: From requirements to a range of electrification systems*

IEC/TS 62257-4, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 4: System selection and design*

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

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

IEC/TS 62257-7-1, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 7-1: Generators – Photovoltaic arrays*

IEC/TS 62257-8-1:2007, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 8-1: Selection of batteries and battery management systems for stand-alone electrification systems – Specific case of automotive flooded lead-acid batteries available in developing countries*

IEC/TS 62257-9-3, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 9-3: Integrated system – User interface*

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

IEC/TS 62257-12-1, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 12-1: Selection of self-ballasted lamps (CFL) for rural electrification systems and recommendations for household lighting equipment*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

3.1.1
cycle
sequence of a discharge followed by a charge or a charge followed by a discharge of a battery under specified conditions

3.1.2
duration of service
number of hours when a load is powered

3.1.3
fulfilment of service
ratio of a measured provided service to a required service

3.1.4
initial charge
commissioning charge given to a new battery to bring it to the fully charged state

3.1.5
period of service
part of the day when a load is powered

3.1.6
reference irradiation
value of irradiation taken in consideration for the design of the system, approved by the project implementer and specified in the GS of the project

3.1.7
service ratio
extent in which the service required by the GS is fulfilled by the system

3.2 Abbreviated terms

3.2.1
GS
general specification for the project

3.2.2
QI
quality of service index

3.2.3
$TWQI_T$
total weighted quality of service

3.2.4
$DWQI_T$
daily weighted quality of service

3.2.5
S_{good}, S_{bad} and S_d
S_{good}: service ratio under favourable conditions;
S_{bad}: service ratio under unfavourable conditions;
S_d: daily service ratio

4 System boundaries

A PV-IES comprises the following elements:

- a PV generator including PV modules and support structure;
- a charge controller;
- a storage system (including battery and associated casing);
- adequate wiring, switches and protective devices (see IEC/TS 62257-9-3 and IEC/TS 62257-9-4);
- loads relevant for the required service (such as lamps, TV set, radio set, and refrigerators).

5 System pre-selection

5.1 Services to be provided by the system

The preliminary socio-economic studies shall provide the project developer with information on the ability of the customers who will benefit from the project to pay for the service provided. Then, the project developer shall define within the GS the range of services to be provided as described in IEC/TS 62257-2 as well as the relative priority of the services to be provided (TV, lighting, etc.)

5.2 Specification of a model

5.2.1 General operating conditions

The project implementer shall define the operating conditions to which the PV-IES can be subjected. Examples of such conditions are given in Table 1.

Table 1 – Climatic conditions (example)

	Nominal operating range	Storage - Transport
Temperature	–10 °C to +50 °C	–40 °C to +80 °C
Humidity at 28 °C	5 % to 95 %	
Atmospheric pressure	860 hPa to 1 060 hPa	

5.2.2 Design

For the part of the project which will be implemented through Individual Electrification Systems, the project developer shall size a range of PV IES able to provide the required service under the specified operating conditions (see IEC/TS 62257-2). The project implementer could either:

- specify complete integrated systems, or
- specify the different components for PV-IES in order to realize the integration of these components through its own system design.

In addition, the project developer shall set up the requirements for the loads relevant for the service to be provided (such as lamps, TV set, radio set, and refrigerator).

5.2.3 Components requirements

The components of the PV-IES shall comply with the relevant IEC standards and/or the relevant local regulations if any.

For the selection of batteries, tests recommended in IEC/TS 62257-8-1 shall apply and for the selection of lamps, tests recommended in IEC/TS 62257-12-1 shall apply.

5.2.4 Safety issues

The project developer shall define the IP degree and IK code of the expected products.

Table 2 gives some values that could be considered as a minimum.

Table 2 – Suggested minimum values for IP and IK

Protection degree	Minimum suggested value
IP	34
IK	8

Safety rules shall comply with IEC/TS 62257-5.

5.2.5 Installation rules

The complete installation shall comply with IEC/TS 62257-7-1 and IEC/TS 62257-9-4 and any local wiring codes.

5.2.6 Operation and maintenance rules

The systems shall be designed in order that operation and maintenance may be performed in accordance with the specifications given in IEC/TS 62257-6.

5.2.7 Documentation and marking

A manual shall also be provided including PV-IES installation and operating guidelines such as:

- initial operations before first use;
- instructions to use the PV-IES properly;
- mounting the PV module;
- charging instructions;
- maintenance and troubleshooting instructions.

5.3 Pre-selection process

5.3.1 Elements of the GS to be provided to potential suppliers

The project implementer shall supply the annual locally available solar irradiation curve.

NOTE This information could be provided through available laboratory data or through local measurements performed with a reference cell that will be used afterwards for the comparative tests.

This information as well as the requirements defined in 5.1 and 5.2 shall be provided to potential suppliers in order to receive proposals for relevant products.

The project implementer could:

- provide load requirements and let the suppliers provide systems to supply the load, or
- provide a complete PV-IES system specification, in order to source complete integrated PV-IES, or
- provide components requirements in order to source separately the different components of a PV-IES and realize the integration of these components.

5.3.2 Answers to be provided by potential suppliers

The supplier of the PV-IES and/or of the components shall prove that the PV-IES and/or the components comply with the relevant IEC standards and IEC 62257 technical specifications.

A technical sheet shall be provided by the supplier in order to demonstrate the ability of its product to match the requirements defined in 5.1 and 5.2.

5.3.3 Pre-selection criteria

The performances claimed by the manufacturer shall be compared to the performances required by the GS in order to make a pre-selection of available products.

The following general criteria can be used as an initial help for product pre-selection:

- services characteristics claimed by the manufacturer (duration of service and fulfillment of service);
- conformity of the modules with the following IEC standards: IEC 61215, IEC 61646, IEC 61730-1 and IEC 61730-2;
- conformity of the batteries, lamps, etc. with the relevant IEC standards and pre-selection process of potential products as recommended in the IEC/TS 62257 series;
- battery casing characteristics.

A short list of products potentially able to match the requirements of the GS shall be set up by the project implementer.

6 Comparative tests

6.1 General

After the pre-selection process, samples of products of the short list shall be processed through comparative technical tests.

IMPORTANT: All the pre-selected systems shall be tested simultaneously in the same local conditions in order to ensure that they are tested under the same environmental parameters (irradiation, humidity, temperature, etc.).

Tests could be performed either in outdoor conditions, in local laboratories or in site conditions (on future customer homes for instance). The systems installation rules provided in the GS are also applicable to test installations.

6.2 Service requirements

Pre-selected models shall be examined to ensure that they will provide the required services mentioned in the GS according to the load profile used for the design of the system.

A service is defined by:

- The types of appliances/loads powered by the system (such as lamps, TV set, etc.);
- For each type of appliance:
  - the number of appliances that can be simultaneously powered;
  - the daily duration of the power supply;
  - the fulfilment of the provided service.

6.3 Service quality index

A Quality of service Index (QI) of a system is based on one of these two terms:

- *d* = duration index, *d*, is the ratio of the measured daily duration of service compared to the required daily duration of service;
- *f* = fulfilment index, *f*, is the ratio of the measured performance (illuminance for lamps, temperature for refrigerator, etc.) compared to a reference level required by the GS.

For the different considered services the QI takes into account either, *d*, or, *f*:

- for lighting: *f*;
- for radio: *d*;
- for TV: *d*;
- for refrigeration: *f*.

The systems shall be compared through a Total Weighted Quality of service Index ($TWQI_T$) calculated on the basis of observations and measurements performed during, *T*, days of comparative tests.

The $TWQI_T$ and service ratio (S) are calculated as follows:

Step 1: for each service, calculation every day of either “duration” or “fulfilment” indexes

The following tables illustrate the necessary index evaluation data and calculation rules.

Table 3 – Lighting service indexes

Service	**Lighting**			
Requirements	Number of lamps	N_L		
	Daily duration of service per lamp (h)	D_L		
	Illuminance (lux)	Q		
Duration index		**Fulfilment index**		
Not relevant		Measured illuminance lux	Total measured illuminance for every hour of service lux see Note 1	Fulfilment index see Note 2
		For lamp 1: q_{L1} For lamp 2: q_{L2} … For lamp i: q_{Li}	$\sum_{i=1}^{i=n} q_{Li}$	$f_{Lighting} = \frac{\sum_{j=1}^{j=D_L} \sum_{i=1}^{i=n} q_{Li}}{n \times Q}$

NOTE 1 n = number of illuminance measurements at each hour of service; $n \leq N_L$;

NOTE 2 In order to limit the number of measurements, if $N_L > 3$, n could be limited to $n = 3$

In this case the formula becomes: $f_{Lighting} = \frac{\sum_{j=1}^{j=D_L} \sum_{i=1}^{i=3} q_{Li}}{3 \times Q}$

In this example only 3 lamps out of N_L are measured every hour. Generally it is preferable to ensure that all the lamps have been equally monitored at the end of the test.

A complete example for the lighting service is given in Table D.2.

Table 4 – Radio / TV service indexes

Service	**Radio (or TV)** (see Note)			
Requirements	Number of radio sets			N_R
	Daily duration of service per set (h)			D_R
Duration index				**Fulfilment index**
Total required daily duration of service	Measured daily duration of service h	Total measured daily duration of service h	Duration index	Not relevant
$N_R \times D_R$	For set 1: d_{R1}	$\sum_{i=1}^{i=N_R} d_{R_i}$	$d_{Radio} = \frac{\sum_{i=1}^{i=N_R} d_{R_i}}{N_R \times D_R}$	
NOTE In the TV set case, subscript R should be changed to T.				

Table 5 – Refrigeration service indexes

Service	**Refrigeration**			
Requirements	Number of refrigerators	N_F (N_F=1 in most cases)		
	Daily duration of service (h)	Not relevant		
	Temperature (°C)	Temperature reference: T°		
Duration index		**Fulfilment index**		
Not relevant		Measured temperature: Θ °C	Average measured temperature deviation °C	Fulfilment index
		measure 1 $\Delta\theta_1 = \Theta_1 - T$ measure 2 $\Delta\theta_2$ … measure n $\Delta\theta_n$	$\frac{\sum_{i=1}^{i=n} \Delta\theta_i}{n}$	$f = 1 - \left(\frac{\sum_{i=1}^{i=n} \Delta\theta_i}{n \times T} \right)$
n = number of temperature measurements				

Step 2: for each tested system, calculation of a $DWQI_T$:

For a given service X, the Quality of service Index (QI) is:

$QI_X = d_X$

or

$QI_X = f_X$.

If the project implementer does not give the same priority to the services, he could determine some "weighting coefficients", k, reflecting the relative importance assigned to the different services provided.

The relative priority of the different services shall be determined by a socio-economic study (see 5.1).

Using these weighting coefficients, a Daily Weighted Quality Index (DWQI) shall be calculated for a system, as given in the following formula (1). For a given day, t, and for X types of services:

$$\mathrm{DWQI_t} = \sum_{i=1}^{i=\mathrm{X}} k_i \times \mathrm{QI}_i \qquad (1)$$

– For lamps: $k_{\mathrm{Lighting}} = k_{\mathrm{L}}$
– For radios: $k_{\mathrm{Radio}} = k_{\mathrm{R}}$
– For TVs: $k_{\mathrm{TV}} = k_{\mathrm{T}}$
– For refrigerators: $k_{\mathrm{Fridge}} = k_{\mathrm{F}}$

Using this hypothesis, for a system providing all the mentioned services the DWQI for a day, t, is:

$$\mathrm{DWQI_t} = (k_{\mathrm{L}} \times \mathrm{QI_{Lighting}}) + (k_{\mathrm{R}} \times \mathrm{QI_{Radio}}) + (k_{\mathrm{T}} \times \mathrm{QI_{TV}}) + (k_{\mathrm{F}} \times \mathrm{QI_{Fridge}})$$

It is the project developer's responsibility to determine the k coefficients according to the importance he gives to each service.

NOTE As an example, a convenient rule to determine values for the weighting coefficient, k, may be based on the daily required duration of service (see Table D.6).

Step 3: for each tested system, calculation of a $\mathrm{TWQI_T}$:

On the complete duration of the test, a $\mathrm{TWQI_T}$ shall be determined according to the following formula (2). For a test performed on, T, days:

$$\mathrm{TWQI_T} = \sum_{t=0}^{t=T} \mathrm{DWQI_t} \qquad (2)$$

with $\mathrm{TWQI_{T,max}} = T \times \sum_{i=1}^{i=X} k_i$ (case where all service quality indexes are equal to 1)

Step 4: for each tested system, calculation of a service ratio, S

The laboratory operator shall calculate the maximum value of the $TWQI_T$ in the conditions of the test.

Then he shall calculate for each system the service ratio by the following formula (3):

$$S = \frac{TWQI_{T,act}}{TWQI_{T,max}} \tag{3}$$

where

$TWQI_{T,act}$: results of $TWQI_{T;}$

and $TWQI_{T,max}$: maximum value of $TWQI_T$

This ratio expresses to what extent the system is able to provide the service required by the GS.

6.4 Testing programme

6.4.1 General

The comparative tests include a set of 4 tests as indicated in Table 6.

The complete set of tests is intended to be performed within a period of 90 days during the appropriate season as identified during the project preliminary studies and according to the quality of service specified by the project developer (see IEC/TS 62257-2, Annex C).

The system shall be tested under two daylight conditions:

– Daylight favourable conditions: in this configuration local irradiation is at least 90 % of the reference value given in the GS.

– Daylight unfavourable conditions: in this configuration, the irradiation taken in account shall be determined by the project implementer as a percentage of the reference value given in the GS (such as for example the irradiation during the rainy season).

Table 6 – Testing programme

Test 1: Initial inspection and commissioning	**Test 2:** Ability to provide the required service under daylight *Favourable conditions*	**Test 3:** Ability to recover the required service under daylight *Unfavourable conditions*	**Test 4:** Final inspection
See 6.4.2	See 6.4.3	See 6.4.4	See 6.4.5

6.4.2 Test 1: initial inspection and commissioning

6.4.2.1 General

The purpose of the different inspection tests (Test 1 and Test 4) is to assess the evolution / degradation of the conditions of the different parts of the product during the test period, especially casings, lamps, cables and PV modules.

The initial inspection is intended to record all necessary details of each sample of each pre-selected model and identify the sample for the duration of all tests. It will also verify that the sample has been supplied with all necessary items and components required by the GS.

In Test 1, after the initial inspection, the system shall be commissioned.

As much information as possible concerning each sample to be tested should be recorded.

6.4.2.2 Sampling

Three samples of each model are required. For small projects, if the cost of the testing is too high, the sampling could be limited to two samples of each model.

A test item number shall be assigned to each sample and used in all data sheets and records to avoid confusing sample results. It is recommended that the unit should be photographed in such a way that all major accessible components are recorded.

6.4.2.3 Operation

The initial inspection shall be performed in two steps:

- unpacking step; and
- installation step.

A list (non comprehensive) of items to be checked and recorded during these two periods is provided as an example in Annex A.

After the initial inspection and installation of the system, commissioning shall be performed (an example of a commissioning sheet is given in Annex B).

6.4.2.4 Results

The *pass criteria* is based on the following**:**

For each sample:

- there shall be no visual evidence of a major defect on any component; and
- the sample is complete; and
- the installed system has been commissioned satisfactorily.

The *fail criteria* is based on the following**:**

For each sample:

- there is evidence of a major defect; or
- some components are missing or incorrect; or
- the system cannot be installed properly according to the GS requirements.

It is up to the project implementer to determine whether he will accept a certain model if one or more samples have failed this initial visual inspection.

6.4.3 Test 2: ability to provide the required service under daylight favourable conditions

6.4.3.1 General

The purpose of this test is to check the ability of a PV-IES product to perform the required service under daylight sunny conditions considered as favorable.

A reference load profile shall be established for the tests according to the service required in the GS. Some examples of such load profiles are given in Annex C.

6.4.3.2 Sampling

Each model for which the three samples passed Test 1 shall go through to Test 2.

6.4.3.3 Equipment

To perform Test 2 the following equipment shall be necessary:

- A power system to supply energy to all test instruments.

NOTE 1 If the testing is performed in a laboratory connected to a grid, no additional power system is necessary. If the testing is performed on site, a dedicated power system is necessary to supply energy to testing devices.

- A reference device (such as a reference PV module, pyrheliometer, and so on) to assess and record the daily irradiation.

NOTE 2 This device may also be initially used to assess the value of the irradiation to be taken in account for the design of the systems.

- Test instruments:
  - Programmable controllers to monitor the load profiles. If not, the loads may be switched on/off manually.
  - One (or several) illuminance measurement box(es) (see IEC/TS 62257-12-1).
  - A thermometer, preferably electronic.

6.4.3.4 Operation

Test 2 shall be performed according to the following phases:

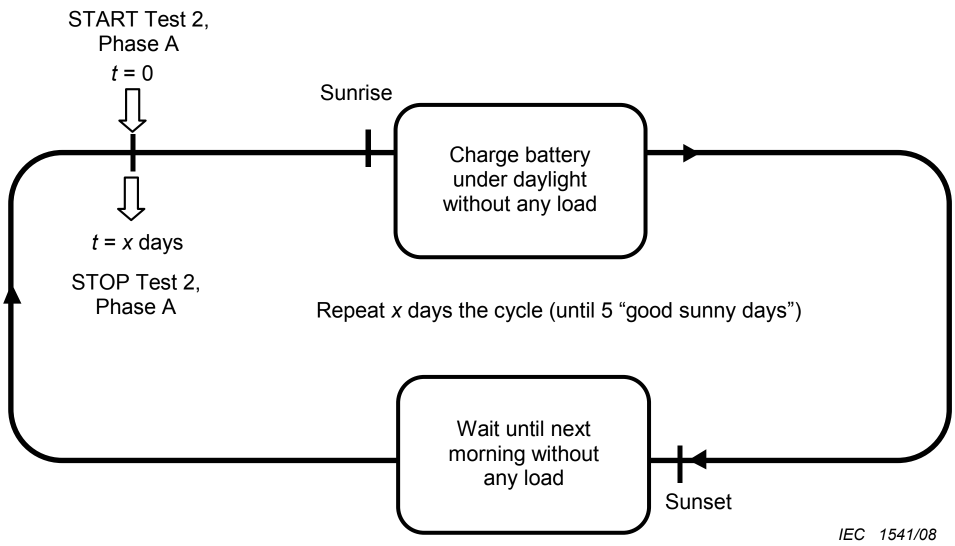
6.4.3.4.1 Phase A: initial preparation

This phase is dedicated to charge the battery before testing the ability of the system to perform the required service.

The initial charge is controlled by the charge controller of the PV-IES without any manual intervention. During the initial charge, all the loads shall be switched off.

The initial charge shall be performed for, x days ($x \geq 5$) until 5 “good sunny days” have been recorded. A “good sunny day” is defined as a day when irradiation is equal to or greater than 90 % of the reference irradiation defined in the GS (considered as favourable conditions).

The following Figure 1 illustrates the Phase A cycles:



NOTE It would be preferable to perform the initial charge in the season when the probability of having five “good sunny days” consecutively is the highest.

Figure 1 – Test 2, Phase A: initial charge cycles

6.4.3.4.2 Phase B: operating conditions

This phase is dedicated to run the system over a long period in order to check its ability to provide the required services under local operating conditions.

Phase B shall be performed immediately after Phase A.

Figure 2 illustrates the cycles to be performed.

The time for start is chosen a short while before sunrise.

The charging of the battery is controlled by the charge controller provided within the system.

The loads are switched on and off according to the load profile, either manually by the laboratory operator or automatically by a programmable controller.

Between sunrise and sunset, the system is intended to be both able to charge the battery and to supply energy to loads (according to the load profile).

After sunset, the system is intended to be able to supply the loads according to the load profile which reflects as close as possible the way of life of the future customers.

The sunrise-sunset cycle shall be repeated, *y,* days ($y \geq 30$) until 30 “good sunny days” have been recorded.

NOTE It is better to perform the test during the sunny season and to ensure that, *y*, is less than or equal to 40 days. This is intended to shorten the duration of the test and thus reduce its cost and ensure good quality records.

The laboratory operator shall observe and record the start and the end of the service according to each step of the load profile.

An example of an instruction sheet for the operator is given in Annex D. For the duration of the test, the laboratory operator will live at the same rhythm as the future customers.

As a debugging period, a preliminary cycle will be performed in order to verify that the programmable controller (if any) and all the test facilities are functional.

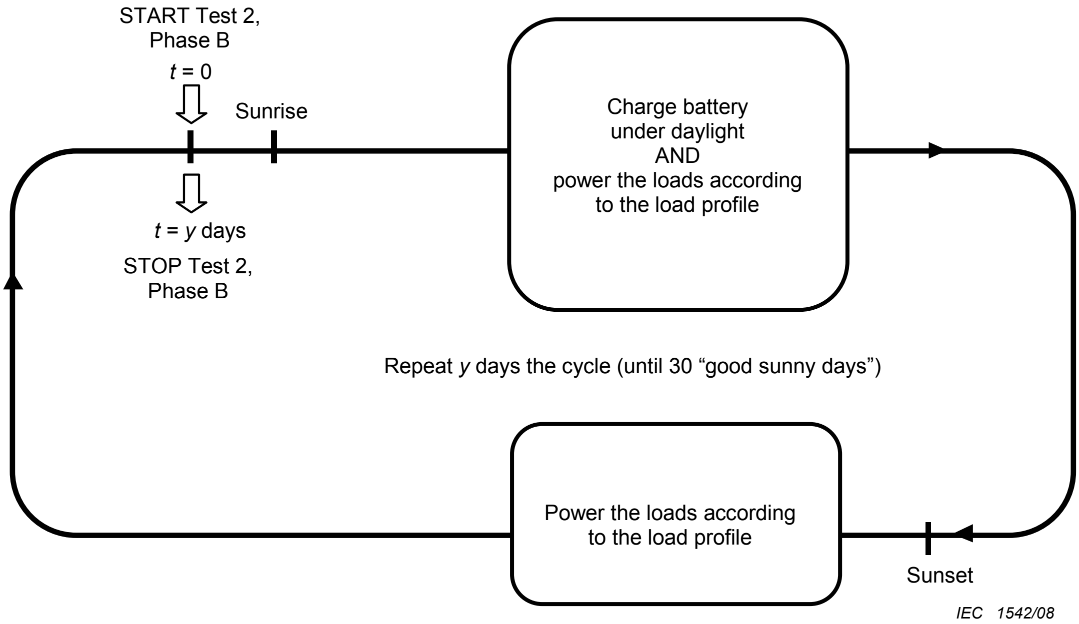


Figure 2 – Test 2, Phase B: operating cycles

All along the test, the characteristics of the service provided shall be recorded. Examples of record sheets are given in Annex D.

6.4.3.5 Results

The different tested systems shall be compared through the different quotations based on the total weighted quality of service index (see 6.3) and also on economic considerations (see IEC/TS 62257-4).

Pass criteria

For each tested systems, the service ratio $S_{good} = \frac{\text{actual TWQI}_T}{\text{maximum TWQI}_T}$ shall be ≥ 0,70.

Fail criteria

If the service ratio S < 0,70 the concerned system models shall be rejected.

If none of the tested products match the pass criteria the project implementer has two options:

- Change the GS requirements (if acceptable) and select the tested products which are able to match the new requirements; or
- Go back to the manufacturers for the selection of a new range of products to be tested.

6.4.4 Test 3: ability to provide the required service under daylight unfavourable conditions

6.4.4.1 General

The purpose of this test is to check the ability of a PV-IES product to perform the required service under daylight sunny conditions considered as unfavourable (as it could be for example during rainy seasons).

The systems shall be tested under the same reference load profile as used in Test 2.

6.4.4.2 Sampling

All the samples of each model which passed Test 2 shall go through to Test 3.

6.4.4.3 Equipment

The same as used for Test 2.

6.4.4.4 Operating conditions

Test 3 shall be performed immediately after Phase B of Test 2.

Figure 3 illustrates the cycles to be performed.

The time for start and stop is chosen a short while before sunrise.

It is the responsibility of the project developer to specify the procedure to simulate a daylight unfavourable condition as close as possible to the unfavourable conditions of the project.

It is suggested that a method of achieving reduced irradiation close to the unfavourable conditions described in the GS is to cover the PV modules for a part of the day. The laboratory operator may insure the same irradiation conditions for the tests systems.

The charging of the battery is controlled by the charge controller provided within the system.

The loads are switched on and off according to the load profile, either manually by the laboratory operator or automatically by a programmable controller.

Between sunrise and sunset, the system is intended to be both able to charge the battery and to supply energy to loads (according to the load profile).

After sunset, the system is intended to be able to supply the loads according to the load profile which reflects as close as possible the way of life of the future customers.

The sunrise-sunset cycle shall be repeated z days ($z \geq 30$) until 30 “bad sunny days” have been recorded.

For the duration of the test, the laboratory operator will live at the same rhythm as the future customers.

The laboratory operator shall observe and record the start and the end of the service according to each step of the load profile.

Instruction sheets and record sheets for the operator are the same as those used in Test 2 (Annex D).

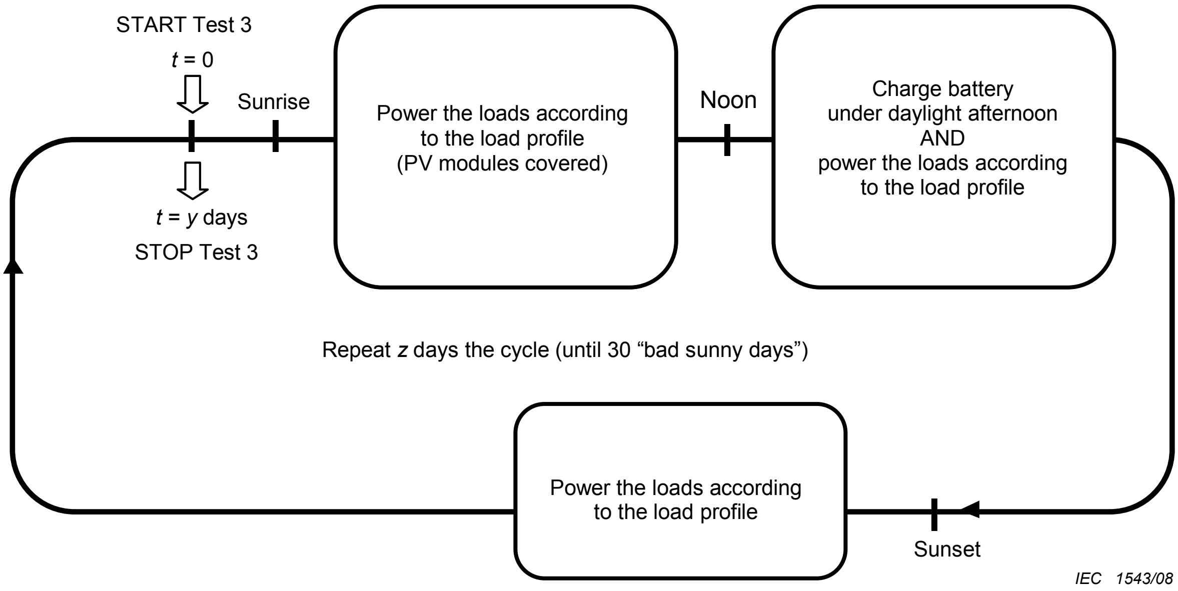


Figure 3 – Test 3, operating cycles

6.4.4.5 Results

The different tested systems shall be compared through the different quotations based on the total weighted quality of service index (see 6.3) and also on economic considerations (see IEC/TS 62257-4).

The laboratory operator shall calculate the maximum value of the $TWQI_T$ in the conditions of the test.

Pass criteria

For each tested systems, the service ratio, S; under unfavourable conditions S_{bad} shall be ≥ 0,35.

Fail criteria

If the service ratio S < 0,35 the concerned system models shall be rejected.

If none of the tested products match the pass criteria the project implementer has two options:

- Change the GS requirements (if acceptable) and select the tested products which are able to match the new requirements; or
- Go back to the manufacturers for the selection of a new range of products to be tested.

6.4.5 Test 4: final inspection

6.4.5.1 General

The final inspection will be used to determine any physical degradation and the durability of the product over the period of testing.

6.4.5.2 Products submitted to the final inspection

All the models which passed successfully Test 3 shall be inspected.

6.4.5.3 Operation

The final inspection will refer to the records of the initial inspection (Test 1) to determine any evidence of degradation of the accessible components.

The initial data sheet shall be completed.

Annex A contains examples of defects that may occur. This is not a complete list and the project implementer may discover other possible defects due to the individual model design.

6.4.5.4 Results

Pass criteria

For all samples:

- there shall be no deterioration of samples which impairs their functionality.

Fail criteria

For all samples:

- there is evidence of a major defect; or
- any deterioration which impairs the functionality of the sample.

6.4.6 General conclusion

6.4.6.1 Pass / fail criteria

The models of which the 3 samples have passed the 4 tests are accepted.

6.4.6.2 Classification of the accepted models

To choose among the accepted models, the project implementer should weight the results of Test 2 and Test 3 according to an annual simplified irradiation profile.

It is the responsibility of the project developer to establish this annual simplified irradiation profile.

EXAMPLE

k_1 could be the number of expected annual "good sunny days" (irradiation equal to or greater than 90 % of the irradiation specified in the GS).

k_2 could be the number of other days, with (k_2 = 365 – k_1).

With this hypothesis, a global service ratio evaluation is given by the following formula (4):

$$S_{global} = \frac{(k_1 \times S_{good} + k_2 \times S_{bad})}{365} \quad (4)$$

The project implementer shall choose among the accepted models, those which propose the best compromise between economic considerations and acceptable service ratio S_{global}.

NOTE To discriminate between two systems with similar global service ratio a comparison of the remaining capacity of the batteries at the end of the test period may be performed. Two methodologies may be used:

- to measure the battery voltage (simple but not accurate);
- to use the procedure described in IEC/TS 62257-8-1, 4.2.2.2.2.4.

Annex A
(informative)

Data record sheet for visual inspection

An example of a data record sheet for visual inspection is given in Table A.1.

Table A.1 – Data record sheet for visual inspection (example)

PV-IES comparative tests			
Tests 1 and 4: visual inspection			
Model tested: *expected brand name, manufacturer's name*	**Sample tested:** *Code used for identification of each sample*		
TEST 1 **Initial inspection**		**TEST 4** **Final inspection**	
Date: **Inspector:**		**Date:** **Inspector:**	
Item to be checked	**Record**	**Item to be checked**	**Record**
UNPACKING • name of the manufacturer/supplier • type or model number (for the whole system or for all the components) • date of manufacture of unit / or manufacture date of battery • serial or batch number • user documentation detailing usage and maintenance requirements • all the necessary components (as defined in Clause 4) and associate hardware (including spare parts if relevant) • physical condition (e.g. presence of damage or other marks etc. before installation) INSTALLATION • connecting points for the incoming conductors • physical condition during installation (e.g. all relevant screws are provided, there is enough electrolyte to fill the batteries, etc.) • commissioning (see commissioning sheet)	*OK, not OK*	*Evolution, degradation, major defects, such as:* • corrosion of any part of the component, inside or outside • dust, water or fungus intrusion into the electrically active interior of the component • loss of mechanical integrity, to the extent that the operation of the sample is impaired • failure of any system component, including lamp • broken, cracked, bent, misaligned or torn external surface of any component • deterioration of wiring insulation • electrolyte leakage from the batteries • signs of overheating	*YES, NO, Where*

Annex B
(informative)

Commissioning records sheet

An example of a commissioning records sheet is given in Table B.1.

Table B.1 – Commissioning records sheet (example)

Conformity to the GS design requirements				
	Characteristic	**Reference value**	**Conform Yes/No**	**Remarks and/or corrective actions**
UNPACKING				
Conformity of the PV-IES to the identification file				
	All components	See clause of the GS (GS)	Everything expected is supplied or not ?	
Conformity of the PV-IES with marking requirements				
PV generator	PV modules	See clauses of the GS		
	support structure			
Storage system	charge controller			
	battery			
	battery casing			
Adequate circuitry	cables			
	switches			
	protective devices			
Adequate loads/appliances	lamps			
	TV			
	radio set			
	refrigerators			
Conformity of the PV-IES to documentation requirements				
	installation manual	See clauses of the GS		
	operation manual			
	maintenance manual			

Table B.1 (*continued*)

INSTALLATION				
Commissioning inspection of the PV-IES / visual inspection				
	Items to be checked	See Annex B of IEC/TS 62257-9-6		
Commissioning inspection of the PV-IES / controls				
Electrical part	IP levels	Installation according to the GS		
	connections tightness			
	appliances			
	surge arrester			
Mechanical part				
Commissioning inspection of the PV-IES / measurements				
Electrical part	equipotential bonding	Measure / value of the GS		
	earth resistance	Measure / value of the GS		
Mechanical part	tilt angle of the PV modules	Measure / value of the GS		

Annex C
(informative)

Examples of load profiles for comparative tests

C.1 Examples of loads

Examples of loads are given in Table C.1.

Table C.1 – Example of loads

Loads	Unit power W
Lamps	10
Dim light	5
Radio set	20
TV set	70
Refrigerator	80

C.2 Examples of systems

Examples of systems are given in Tables C.2, C.3 and C.4.

Table C.2 – Example of small PV-IES loads (~50 Wp)

Loads	Unit Power W	Quantity	Operating duration per day h/d	Daily energy Wh/d
Lamps	10	3	3	90
			Total	90

Table C.3 – Example of medium PV-IES loads (~200 Wp)

Loads	Unit Power W	Quantity	Operating duration per day h/d	Daily energy Wh/d
Lamps	10	3	6	180
Radio set	20	1	5	100
TV set	70	1	3	210
			Total	490

Table C.4 – Example of large PV-IES loads (~500 Wp)

Loads	Unit Power W	Quantity	Operating duration per day h/d	Daily energy Wh/d
Lamps	10	3	6	180
Dim light	5	1	6	30
Radio set	20	1	5	100
TV set	70	1	4	280
Refrigerator	80	1	6	480
			Total	1 070

C.3 Examples of load profiles

Table C.5 gives examples of system load profiles.

Coloured cells in this table indicate the hours when the service is required.

Table C.5 – Example of system load profile to perform test on PV-IES

Hours		Small PV-IES (~50 Wp)	Medium PV-IES (~200 Wp)			Large PV-IES (~500 Wp)				
Start	End	Lamps	Lamps	TV	Radio	Lamps	TV	Radio	Refrig.	Dim light
0	1									
1	2									
2	3									
3	4									
4	5									
5	6									
6	7									
7	8									
8	9									
9	10								X	
10	11									
11	12								X	
12	13									
13	14									
14	15									
15	16									
16	17									
17	18								X	
18	19									
19	20								X	
20	21									
21	22									
22	23									
23	24									

NOTE 1 Coloured cells represent periods when lamps, TV and radio are operating and consuming energy; for the fridge, the cells are differently coloured to highlight that the refrigerator is operating all the time but we don't know when it is consuming electricity.

NOTE 2 X represents a sequence of opening/closing the door of the refrigerator.

Annex D
(informative)

Instruction and data record sheet models (according to a load profile as proposed in Annex A)

Examples of instruction and data record sheet models are given in Tables D.1 to D.6.

Table D.1 – Overview instruction sheet for daily records (example)

PV-IES comparative tests

Tests 2 and 3: ability to provide the required service

Date: | **Inspector:**

Model tested: *brand name, manufacturer's name* | **Sample tested:** *Code used for identification of each sample*

Configuration of the system

Appliances		Lamp		TV set		Radio set		Refrigerator		Dim light	
Quantity		N_L		N_T		N_R		N_F		N_{DL}	
Hours		Actions to perform during active periods of the load profile									
start	end	start	end	start	end	start	end	start	end	start	end
0	1										
1	2										
2	3										
3	4										
4	5		Check “lamps on”				Check “radio set on”				Check “dim light still on”
5	6		Measure Illuminance on *n* lamps				Check “radio set still on”			Check “dim light off”	
6	7	Check “lamps off”					Check “radio set still on”				
7	8					Check “radio set off”					
8	9										
9	10							Open [a] /close the door			
10	11						Check “radio set on”				
11	12						Check “radio set still on”	Open /close the door			
12	13					Check “radio set off”					
13	14							Measure T°			
14	15										
15	16										
16	17						Check “radio set on”				
17	18		Check “lamps on”				Check “radio set still on”	Open /close the door			
18	19		Measure Illuminance on *n* lamps		Check “TV set on”		Check “radio set still on”				
19	20		Measure Illuminance on *n* lamps		Check “TV set still on”	Check “radio set off”		Open /close the door			
20	21		Measure Illuminance on *n* lamps		Check “TV set still on”						
21	22		Measure Illuminance on *n* lamps		Check “TV set still on”						
22	23		Measure Illuminance on *n* lamps		Check “TV set still on”			Measure T°			Check “dim light on”
23	24	Check “lamps off”		Check “TV set off”							Check “dim light still on”

[a] Opening / closing of the door is intended to simulate picking up or storage operation; it shall be short (~10 s).

Table D.2 – Record sheet for lighting service (example)

PV-IES comparative tests		
Tests 2 and 3: ability to provide the required service		
Date:	**Inspector:**	
PV-IES Model tested: *brand name, manufacturer's name*	**Sample tested:** *Code used for identification of each sample*	
Lighting service (According to a load profile as proposed as example in Annex A)		
Number of lamps	**Lighting service daily duration reference value** (hours of daily lighting per lamp required in the GS)	**Illuminance reference value** (illuminance of the lamps required in the GS)
N_L **= 4**	D_L **= 6 h per lamp**	Q **= 110 lux**

Hours		**Actions**		**Fulfilment of service**					
				Records (q lux)				**Calculation** (see Note)	
start	end	start	end	**Lamp 1** q_1	**Lamp 2** q_2	**Lamp 3** q_3	**Lamp 4** q_4	**Formula**	**Result**
0	**1**								
1	**2**								
2	**3**								
3	**4**								
4	**5**		Check "lamps on"						
5	**6**		Measure Illuminance	70	70	75		$\sum_{i=1}^{i=n} q_{L_i}$	215
6	**7**	Check "lamps off"							
7	**8**								
8	**9**								
9	**10**								
10	**11**								
11	**12**								
12	**13**								
13	**14**								
14	**15**								
15	**16**								
16	**17**								
17	**18**		Check "lamps on"						
18	**19**		Measure Illuminance		90	90	90	$\sum_{i=1}^{i=n} q_{L_i}$	270
19	**20**		Measure Illuminance	85		90	85	$\sum_{i=1}^{i=n} q_{L_i}$	260
20	**21**		Measure Illuminance	83	88		85	$\sum_{i=1}^{i=n} q_{L_i}$	256
21	**22**		Measure Illuminance	81	80	78		$\sum_{i=1}^{i=n} q_{L_i}$	239
22	**23**		Measure Illuminance		78	70	80	$\sum_{i=1}^{i=n} q_{L_i}$	228
23	**24**	Check "lamps off"							
Number of measurements								n	18
Average measured fulfilment lighting service per lamp (lux)								$\frac{\sum_{i=1}^{i=n} q_{L_i}}{n}$	81
Required fulfilment lighting service per lamp (lux)								Q	110
Daily quality index of lighting service = fulfilment index $f = f_{\text{lighting}}$								$\frac{\sum_{j=1}^{j=D_L} \sum_{i=1}^{i=n} q_{L_i}}{n \times Q}$	**0,74**
NOTE n = number of illuminance measurements.									

Table D.3 – Record sheet for radio service (example)

PV-IES comparative tests	
Tests 2 and 3: ability to provide the required service	
Date:	**Inspector:**
PV-IES Model tested: *expected brand name, manufacturer's name*	**Sample tested:** *Code used for identification of each sample*
Radio service (According to a load profile as proposed as example in Annex A)	
Number of radio set	**Radio set service daily duration reference value** (hours of daily radio operation required in the GS)
$N_R = 1$	$D_R = 5$ h

Periods for radio		**Actions**		**Duration of radio service**			
				Records		**Calculation**	
start	end	start	end	Radio1	…	Formula	Result
0	**1**						
1	**2**						
2	**3**						
3	**4**						
4	**5**		Check "radio set on"				
5	**6**		Check "radio still on"	Yes = 1		$\sum_{i=1}^{i=N_R} Yes$	1
6	**7**		Check "radio still on"	No = 0		$\sum_{i=1}^{i=N_R} Yes$	0
7	**8**	Check "radio set off"					
8	**9**						
9	**10**						
10	**11**		Check "radio set on"				
11	**12**		Check "radio still on"	Yes = 1		$\sum_{i=1}^{i=N_R} Yes$	1
12	**13**	Check "radio set off"					
13	**14**						
14	**15**						
15	**16**						
16	**17**						
17	**18**	Check "radio set on"	Optional: check "Radio still on"	Yes = 1		$\sum_{i=1}^{i=N_R} Yes$	1
18	**19**		Check "radio still on"	Yes = 1		$\sum_{i=1}^{i=N_R} Yes$	1
19	**20**	Check "radio set off"					
20	**21**						
21	**22**						
22	**23**						
23	**24**						
Measured radio duration service (h)						$\sum_{j=1}^{j=D_R} \sum_{i=1}^{i=N_R} Yes$	4
Required radio duration service (h)						D_R	5
Daily quality index of radio service = duration index $d = d_{radio}$						$\frac{\sum_{j=1}^{j=D_R} \sum_{i=1}^{i=N_R} Yes}{D_R}$	**0,80**

Table D.4 – Record sheet for TV service (example)

PV-IES comparative tests	
Tests 2 and 3: ability to provide the required service	
Date:	**Inspector:**
PV IES Model tested: *expected brand name, manufacturer's name*	**Sample tested:** *Code used for identification of each sample*
TV service (According to a load profile as proposed as example in Annex A)	
Number of TV set	**TV service daily duration reference value** (hours of daily TV operation required in the GS)
$N_T = 1$	$D_T = 4$ h

Periods for TV		**Actions**		**Duration of TV service**			
				Records		**Calculation**	
start	end	start	end	TV 1	…	Formula	Result
0	**1**						
1	**2**						
2	**3**						
3	**4**						
4	**5**						
5	**6**						
6	**7**						
7	**8**						
8	**9**						
9	**10**						
10	**11**						
11	**12**						
12	**13**						
13	**14**						
14	**15**						
15	**16**						
16	**17**						
17	**18**						
18	**19**		Check "TV set on"				
19	**20**			Yes = 1		$\sum_{i=1}^{i=N_T} \text{Yes}$	1
20	**21**			Yes = 1		$\sum_{i=1}^{i=N_T} \text{Yes}$	1
21	**22**			Yes = 1		$\sum_{i=1}^{i=N_T} \text{Yes}$	1
22	**23**			No= 0		$\sum_{i=1}^{i=N_T} \text{Yes}$	0
23	**24**	Check "TV set off"					
Measured TV duration service (h)						$\sum_{j=1}^{j=D_T} \sum_{i=1}^{i=N_T} \text{Yes}$	3
Required TV duration service (h)						D_T	4
Daily quality index of TV service = duration index $d = d_{TV}$						$\frac{\sum_{j=1}^{j=D_T} \sum_{i=1}^{i=N_T} \text{Yes}}{D_T}$	**0,75**

Table D.5 – Record sheet for refrigeration service (example)

PV-IES comparative tests	
Tests 2 and 3: ability to provide the required service	
Date:	**Inspector:**
PV-IES Model tested: *brand name, manufacturer's name*	**Sample tested:** *Code used for identification of each sample*
Refrigeration service (According to a load profile as proposed as example in Annex A)	
Number of refrigerators	**Temperature reference value** **(required in the GS)**
$N_F = 1$	$T = 5$ °C

Hours		**Actions**		**Fulfilment of service**				
				Records (Temperature, Θ°C)			**Calculation**	
start	end	start	end	**Fridge 1** Θ_1	...	...	**Formula**	**Result**
0	**1**							
1	**2**							
2	**3**							
3	**4**							
4	**5**							
5	**6**							
6	**7**							
7	**8**							
8	**9**							
9	**10**	Measure temperature		7			$\Delta\theta_i = \Theta_i - T$	2
10	**11**							
11	**12**	Open/close the door						
12	**13**							
13	**14**	Measure temperature		5			$\Delta\theta_i = \Theta_i - T$	0
14	**15**							
15	**16**							
16	**17**							
17	**18**	Open/close the door						
18	**19**							
19	**20**	Open/close the door						
20	**21**							
21	**22**							
22	**23**	Measure temperature		9			$\Delta\theta_i = \Theta_i - T$	4
23	**24**							
Number of measurements							n	3
Average measured temperature deviation							$\frac{\sum_{i=1}^{i=n} \Delta\theta_i}{n}$	2
Daily quality index of refrigeration service = fulfilment index $f = f_{fridge}$								**0,60**

Table D.6 – System daily quality index of service evaluation (example)

PV-IES comparative tests								
Tests 2 and 3: ability to provide the required service								
Date: ***t***					**Inspector:** ***X***			
PV-IES Model tested: *brand name, manufacturer's name*					**Sample tested:** *Code used for identification of each sample*			
Configuration of the system								
Appliances	**Lamp**		**Radio set**		**TV set**		**Refrigerator**	
Quantity	$N_L = 4$		$N_R = 1$		$N_T = 1$		$N_F = 1$	
Daily quality index of services	$QI_{Lighting} =$	**0,74**	$QI_{Radio} =$	**0,80**	$QI_{TV} =$	**0,75**	$QI_{Fridge} =$	**0,60**
Weighting coefficient (see Note)	$k_{Lighting} = 6$		$k_{Radio} = 5$		$k_{TV} = 4$		$k_{Fridge} = 6$	
NOTE In this example the weighting coefficients, *k*, are based on the daily duration of each service for lighting, radio and TV. $k_{Fridge} = k_{Lighting}$ means that the importance given to the refrigeration service is the same as the lighting service.								

Quality index of service		
Weighted daily quality index of service of the system	$DWQI_t = \sum k_i \times QI_i$	**15,04**
Max. weighted daily quality index of service of the system	$DWQI_{t,max} = \sum k_i \times 1$	**21**
Daily service ratio: S_d	$S_d = \frac{DWQI_t}{DWQI_{t,max}}$	**0,72**

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