IEC 62282-3-201

Edition 2.0 2022-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

AMENDMENT 1

AMENDEMENT 1

Fuel cell technologies –
Part 3-201: Stationary fuel cell power systems – Performance test methods for small fuel cell power systems

Technologies des piles à combustible –
Partie 3-201: Systèmes à piles à combustible stationnaires – Méthodes d'essai des performances pour petits systèmes à piles à combustible

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IEC 62282-3-201:2017-08/AMD1:2022-02(en-fr)

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IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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FUEL CELL TECHNOLOGIES –

Part 3-201: Stationary fuel cell power systems – Performance test methods for small fuel cell power systems

AMENDMENT 1

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Amendment 1 to IEC 62282-3-201:2017 has been prepared by IEC technical committee 105: Fuel cell technologies.

The text of this Amendment is based on the following documents:

Draft	Report on voting
105/839/CDV	105/866/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Amendment is English.

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INTRODUCTION to Amendment 1

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This amendment to IEC 62282-3-201:2017 provides a method of estimating the electric and heat recovery efficiency of small stationary fuel cell power systems for a duration of up to ten years of operation. Furthermore, this amendment to IEC 62282-3-201:2017 provides an evaluation method for electric demand-following small stationary fuel cell power systems, which are operating at changing levels of power output. It has been developed as a reference for the life cycle assessment calculations in IEC TS 62282-9-101.

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3 Terms and definitions

Add, at the end of Clause 3, the following new entries:

3.41
test duration
duration of the complete test for the estimation of the electric and heat recovery efficiency up to ten years of operation, comprising a specific number of test runs

3.42
degradation rate
reduction of the electric efficiency of a stationary fuel cell power system per time of operation

Note 1 to entry: The degradation rate is expressed in efficiency per cent points per time (%/h).

4 Symbols

Table 1 – Symbols and their meanings for electric/thermal performance

Replace the existing title of Table 1 with the following new title:

Symbols and their meanings for electric and thermal performance

Under the header relating to "Time", in the unit column for "Test duration", add the unit "h" after "s" and insert between the existing definitions of "Test duration" and "Start-up time" the following new symbol, definition and unit, as shown:

t	Time	
Δt	Test duration	s, h
Δt_a	Number of hours between point s and point a	h
Δt_{st}	Start-up time	s

Under the header relating to "Efficiency", add, after the last existing definition of "Operation cycle electrical efficiency", the following new symbols, definitions and units:

$\eta_{el,est,av}$	Estimated average electric efficiency during one year of operation	%
$\eta_{el,est}(k)$	Estimated electric efficiency at the end of year k	%
$\eta_{el,init}$	Calculated value of the linear regression of the electric efficiency at the time of point a	%
$\Delta\eta_{el}$	Approximated degradation rate of the electric efficiency	%/h
$\eta_{th,est}(k)$	Estimated heat recovery efficiency at the end of year k	%

9 Test set-up

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Add, after the first paragraph and before Figure 3, the following new paragraph:

For the electric demand-following test (14.14), the electric load shall be capable of applying or simulating an electric load profile to the system. It may be replaced or upgraded by a device, which is capable of doing this. Alternatively, the tested small stationary fuel cell power system may be equipped with means for setting and operating a load profile.

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14 Type tests on electric/thermal performance

Replace the existing title of Clause 14 with the following new title:

Type tests on electric and thermal performance

Add, at the end of 14.12.11, the following new subclauses:

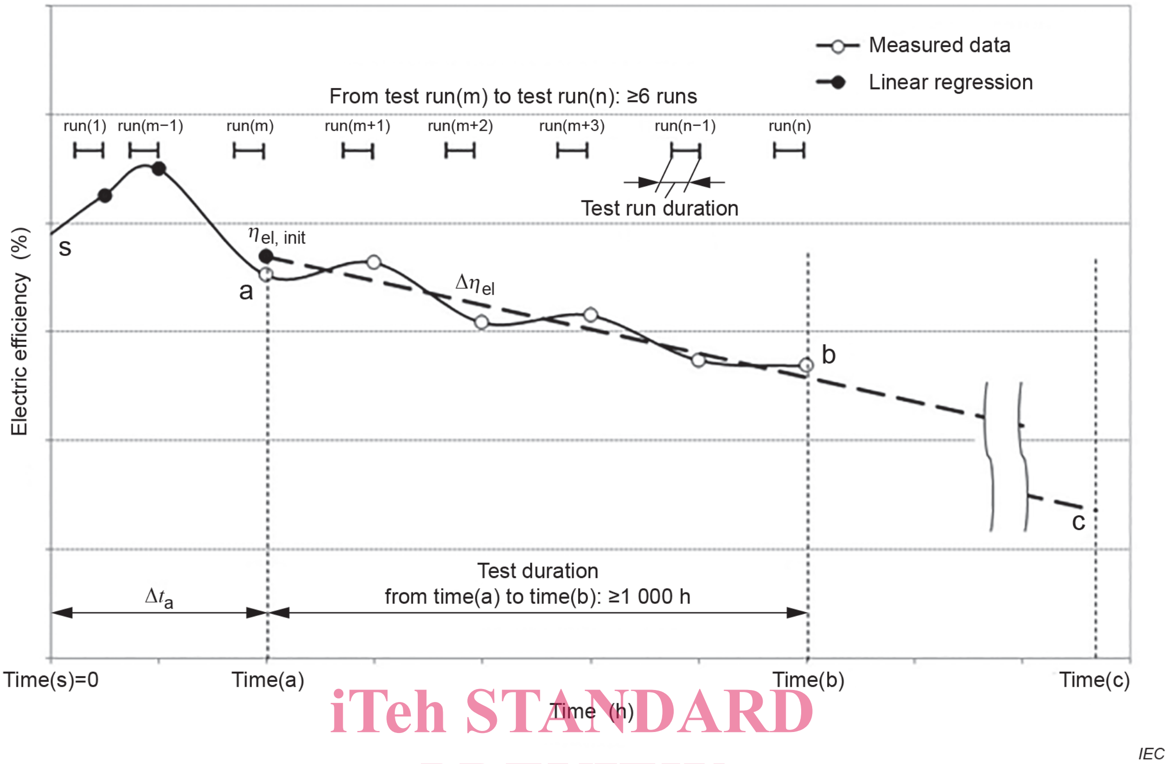
14.13 Estimation of electric and heat recovery efficiency up to ten years of operation

14.13.1 General

The main objective of this test is to identify and evaluate the environmental performance of a small stationary fuel cell power system based on life cycle approach. The test estimates the electric efficiency through lifetime due to long term effects on the small stationary fuel cell power system.

NOTE Approximating the degradation rate on small stationary fuel cell power systems is only useful if there is substantial daily operation, which is not the case for e.g. backup power systems.

Figure 16 shows an example of electric efficiency during ten years of operation.



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Key

s starting point of the operation

a point at which degradation rate starts to be almost constant

b point at which degradation rate is confirmed as almost constant

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c point when the operation duration is ten years, at which the electric efficiency is calculated by the linear extrapolation of the behaviour between a and b

Δt_a number of hours between point s and point a

$\eta_{el,init}$ calculated value of the linear regression of the electric efficiency at the time of point a

$\Delta\eta_{el}$ approximated degradation rate of the electric efficiency

Figure 16 – Example of electric efficiency during ten years of operation

In general, electric efficiency is gradually degraded with the passage of time. However, the degradation rate is not stable at the beginning of the lifetime of a small stationary fuel cell power system, such as the time between the points s and a.

The approximated degradation rate $\Delta\eta_{el}$ is obtained from the change rate of electric efficiency over the test duration from point a to point b. Electric efficiency at point b is expected to be lower than that at point a.

14.13.2 Test method

Start up the system and operate it at rated power output, either

- in continuous mode, if the purpose of the system is to deliver power output in a continuous way (e.g. combined heat and power systems) and if allowed by the system specification, or

- in cycling mode, if the purpose of the system is to deliver power output in a continuous way, but the system requires regular start-stop operation cycles (e.g. for recovery purposes). The system shall be operated at maximum allowed continuous operating hours at rated electric power output and at minimum required continuous operation at zero electric power output, as given by the system specifications, or

  NOTE 1 Typically this is a daily recovery cycle, such as 23 h of rated operation and 1 h of zero electric power output.

- in discontinuous mode, if the purpose of the system is to deliver power output in a non-continuous way (e.g. power generators in remote areas). A daily duty cycle, which is typical for such a system and its application, shall be specified and applied to the system during testing. The duty cycle shall include at least one phase of rated power output, which is longer than 3,5 h.

  NOTE 2 The minimum test duration for a rated power output test is 3,5 h (30 min of stabilization followed by 3 h of measurements, see test methods in 14.2, 14.3 and 14.4).

During the test several different test runs of equal duration are carried out. Define the duration of the test runs and carry out performance measurements according to 14.2, 14.3 and 14.4 for each test run, which is named as run(m−1), run(m), run(m+1), and so forth in Figure 16.

The duration of the test run shall be chosen between a minimum of three hours and a maximum of 24 h. The first test run shall be applied right after start-up in point s, when rated output is reached. Continuous processing of test runs is not required, there may be gaps between two test runs, but operation shall be continued during this gap.

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Small stationary fuel cell power systems may operate in a cycling or discontinuous mode. In this case, the test run shall be put in a period of rated operation and not in a period of the system being in start-up, ramp-up, shutdown, storage or pre-generation state.

The test shall be continued until at least 1 000 h after the degradation rate of the electric efficiency has become almost constant, which means that the coefficient of determination of the linear regression between point a and point b is higher than 0,95.

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The electric efficiency of each test run shall be calculated according to 14.10.

Point a and point b shall be found by tracing back the efficiency results of the single test runs and calculating the coefficient of determination after each test. The interval for the calculation of the coefficient of determination shall be evaluated on the following requirements:

- coefficient of determination of the electric efficiency > 0,95;
- duration of the interval ≥ 1 000 h;
- number of tests runs in the interval ≥ 6.

If an interval is found, which fulfils these requirements, the starting point of the interval is point a and the ending point is point b.

14.13.3 Calculation of estimated electric efficiency

The approximated degradation rate $\Delta\eta_{el}$ (%/h) shall be determined from the absolute value of the slope of the linear regression between the points a and b.

The estimated electric efficiency after each year of operation is obtained by linear extrapolation of the behaviour between point a and point b when the degradation rate of the electric efficiency is almost constant, which means that the coefficient of determination of the linear regression of the electric efficiency is higher than 0,95.

The estimated electric efficiency after ten years (maximum 87 600 h) of operation is obtained by using the same approach.

The estimated electric efficiency at the end of each year of operation shall be calculated by using Equation (59). The expected annual operating hours depend on the appliance purpose and shall be specified by the manufacturer. Operating hours are time intervals, where the stack is hot and in pre-generation state or operation state. Expected cold state intervals, for example due to seasonal shutdowns, may be subtracted from the maximum annual operating hours, which are 8 760 h.

$$\eta_{\text{el,est}}(k) = \eta_{\text{el,init}} - \Delta\eta_{\text{el}} \times \left(k \times t_{\text{op}} - \Delta t_{\text{a}}\right) \quad (59)$$

where

$\eta_{\text{el,est}}(k)$ is the estimated electric efficiency at the end of year k (%);

$\eta_{\text{el,init}}$ is the calculated value of the linear regression of the electric efficiency at the time of point a (%);

$\Delta\eta_{\text{el}}$ is the approximated degradation rate of the electric efficiency (%/h);

t_{op} is the number of expected annual operating hours (h);

Δt_{a} is the number of hours between point s and point a (h).

The estimated average electric efficiency during the first year of operation is calculated from the average of the measured electric efficiency at point s and the estimated electric efficiency at the end of the first year of operation using Equation (60).

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$$\eta_{\text{el,est,av}}(\text{year1}) = \frac{\eta_{\text{el}}(\text{s}) + \eta_{\text{el,est}}(1)}{2} \quad (60)$$

where

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$\eta_{\text{el,est,av}}(\text{year1})$ is the estimated average electric efficiency during the first year of operation (%);

$\eta_{\text{el}}(\text{s})$ is the measured electric efficiency after the start of the test (point s) (%);

$\eta_{\text{el,est}}(1)$ is the estimated electric efficiency at the end of the first year of operation (%).

The estimated average electric efficiency during the second year of operation is calculated from the average of the estimated electric efficiency after the first year and the second year of operation using Equation (61), calculated by linear extrapolation of the approximated degradation rate using Equation (59).

$$\eta_{\text{el,est,av}}(\text{year2}) = \frac{\eta_{\text{el,est}}(1) + \eta_{\text{el,est}}(2)}{2} \quad (61)$$

where

$\eta_{\text{el,est,av}}(\text{year2})$ is the estimated average electric efficiency during the second year of operation (%);

$\eta_{\text{el,est}}(1)$ is the estimated electric efficiency at the end of year 1 (%);

$\eta_{\text{el,est}}(2)$ is the estimated electric efficiency at the end of year 2 (%).

The estimated average electric efficiency during the third year and during each other year up to the tenth year shall be calculated, using the same approach as that used during the second year.

14.13.4 Calculation of estimated heat recovery efficiency

The calculation of the estimated heat recovery efficiency during ten years of operation is based on the assumption that the overall energy efficiency remains rather constant. This means that losses in electric efficiency are gained in heat recovery efficiency.

NOTE This assumption is proved by experience but is not valid for all cases.

Each estimated heat recovery efficiency at the end of each year of operation can be calculated by subtracting each estimated electric efficiency at the same year from the initial overall energy efficiency measured at point s, which is the sum of the electric efficiency and heat recovery efficiency at the first test run, using Equation (62).

$$\eta_{\text{th,est}}(k) = \eta_{\text{th}}(\text{s}) + \eta_{\text{el}}(\text{s}) - \eta_{\text{el,est}}(k) \tag{62}$$

where

$\eta_{\text{th,est}}(k)$ is the estimated heat recovery efficiency at the end of year k (%);

$\eta_{\text{th}}(\text{s})$ is the measured heat recovery efficiency at the initial test run (%);

$\eta_{\text{el}}(\text{s})$ is the measured electric efficiency at the initial test run (%);

$\eta_{\text{el,est}}(k)$ is the estimated electric efficiency at the end of year k (%).

The estimated average heat recovery efficiency during each year of operation shall be calculated by the average of the estimated heat recovery efficiency at the beginning and at the end of that year, using the approach of Equation (61).

14.14 Electric demand-following test

14.14.1 General

This test is for measuring the fuel consumption, the electric power output and the recovered thermal power of a stationary small fuel cell power system, operating in electric demand-following mode. Subsequently it provides a calculation method for electric, heat recovery and overall efficiencies, based on the measured values.

NOTE The test conditions are defined in Clause 11.

The test is carried out by applying in principle the test methods of 14.2, 14.3 and 14.4 to the system.

14.14.2 Electric demand profile

The test shall be carried out using a 24 h electric demand profile, which is applied to the system. The profile shall be chosen from available regional energy demand data. Depending on the objective of the test, it may be necessary to carry out tests with several different profiles.

The ratio of the maximum electric demand of the profile and the maximum electric power output of the small stationary fuel cell system shall be chosen in a way that represents a typical application. The maximum demand of the profile may exceed the maximum electric power output of the fuel cell system temporarily, but not permanently. The demand profile shall represent a full day (24 h), with a resolution of at least 15 min.

Figure 17 shows an example of an electric demand for a residential application.

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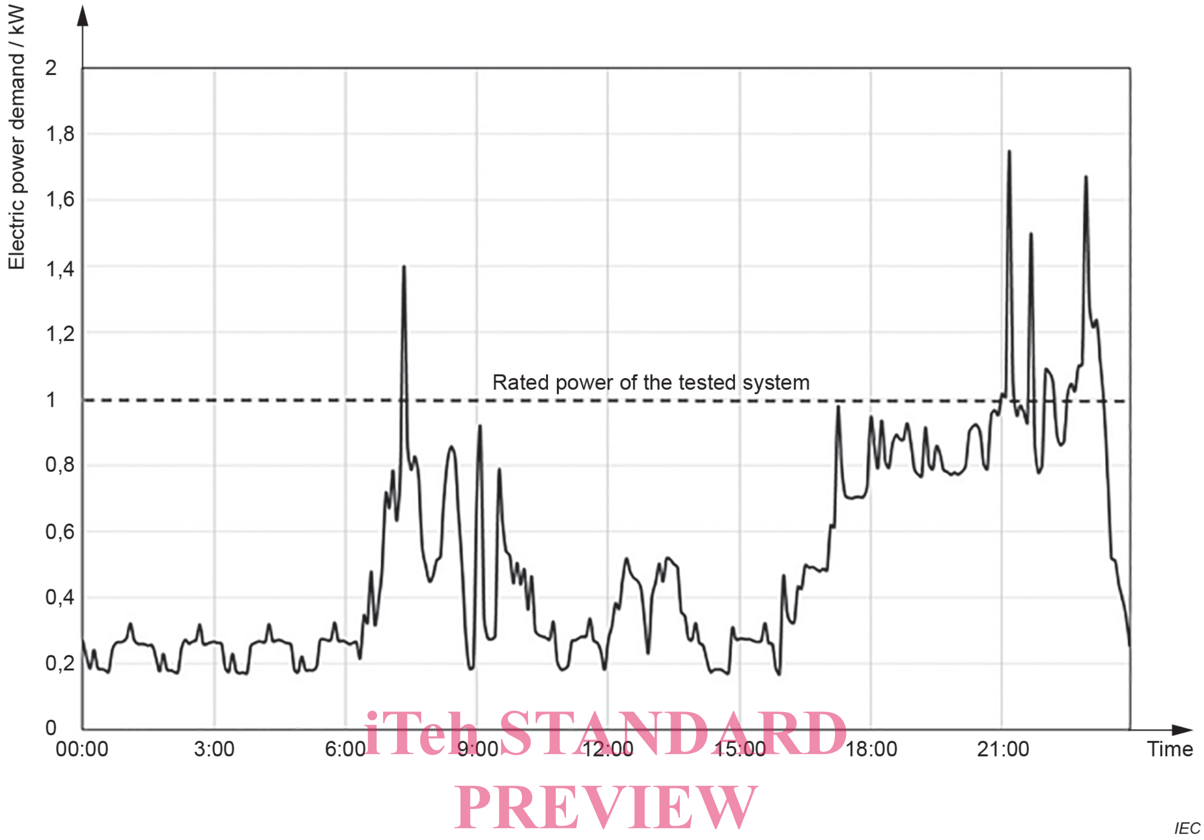

Figure 17 – Example of the electric demand of a residential application

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14.14.3 Test method

Carry out the test by concurrently applying the test methods for the fuel consumption test (14.2.1.2 or 14.2.2.2), for the electric power output test (14.3.2) and for the heat recovery test (14.4.2).

Apply the following instead of 14.2.1.2 c) and d):

c) Start the test by applying the values of electric demand profile to the system.

d) Measure the fuel temperature, fuel pressure, and integrated fuel input flow (in volume or in mass). Each measurement shall be taken at intervals of 15 s or less during the entire duration of the electric demand profile of 24 h.

Apply the following instead of 14.2.2.2 c) and e):

c) Start the test by applying the values of electric demand profile to the system.

e) Each measurement shall be taken at intervals of 15 s or less during the entire duration of the electric demand profile of 24 h. If fuel is to be supplied intermittently, the mass of the supplied fuel shall be measured and added to the value measured in d).

Apply the following instead of 14.3.2 c) and d):

c) Start the test by applying the values of electric demand profile to the system.

d) Measure the electric energy output and electric energy input over the test duration. Each measurement shall be taken at intervals of 15 s or less during the entire duration of the electric demand profile of 24 h.