



BSI Standards Publication

Fuel cell technologies

Part 3-202: Stationary fuel cell power systems — Performance test methods for small fuel cell power systems for multiple units operation

National foreword

This British Standard is the UK implementation of EN IEC 62282-3-202:2025. It is identical to IEC 62282-3-202:2025.

The UK participation in its preparation was entrusted to Technical Committee GEL/105, Fuel cell technologies.

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

Contractual and legal considerations

This publication has been prepared in good faith, however no representation, warranty, assurance or undertaking (express or implied) is or will be made, and no responsibility or liability is or will be accepted by BSI in relation to the adequacy, accuracy, completeness or reasonableness of this publication. All and any such responsibility and liability is expressly disclaimed to the full extent permitted by the law.

This publication is provided as is, and is to be used at the recipient's own risk.

The recipient is advised to consider seeking professional guidance with respect to its use of this publication.

This publication is not intended to constitute a contract. Users are responsible for its correct application.

© The British Standards Institution 2025
Published by BSI Standards Limited 2025

ISBN 978 0 539 21153 5

ICS 27.070

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 May 2025.

Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

English Version

Fuel cell technologies - Part 3-202: Stationary fuel cell power systems - Performance test methods for small fuel cell power systems for multiple units operation
(IEC 62282-3-202:2025)

Technologies des piles à combustible - Partie 3-202:
Systèmes à piles à combustible stationnaires - Méthodes
d'essai des performances pour petits systèmes à piles à
combustible destinés à l'exploitation d'unités multiples
(IEC 62282-3-202:2025)

Brennstoffzellentechnologien - Teil 3-202: Stationäre
Brennstoffzellen-Energiesysteme -
Leistungskennwerteprüfverfahren für kleine
Brennstoffzellen-Energiesysteme hinsichtlich eines
Parallelbetriebs mehrerer Einheiten
(IEC 62282-3-202:2025)

This European Standard was approved by CENELEC on 2025-05-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.



European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of document 105/1094/FDIS, future edition 1 of IEC 62282-3-202, prepared by TC 105 "Fuel cell technologies" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 62282-3-202:2025.

The following dates are fixed:

- latest date by which the document has to be implemented at national (dop) 2026-05-31 level by publication of an identical national standard or by endorsement
- latest date by which the national standards conflicting with the (dow) 2028-05-31 document have to be withdrawn

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

Any feedback and questions on this document should be directed to the users' national committee. A complete listing of these bodies can be found on the CENELEC website.

Endorsement notice

The text of the International Standard IEC 62282-3-202:2025 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standard indicated:

IEC 61850-7-420	NOTE	Approved as EN IEC 61850-7-420
IEC 62282-3-200:2025	NOTE	Approved as EN 62282-3-200:2023 ¹
IEC 62282-3-201:2025	NOTE	Approved as EN 62282-3-201:2023 ²
ISO 6974 (series)	NOTE	Approved as EN ISO 6974 (series)
ISO 6975	NOTE	Approved as EN ISO 6975
ISO 6976:1995 ³	NOTE	Approved as EN ISO 6976
ISO 9000	NOTE	Approved as EN ISO 9000

¹ To be published. Stage at the time of publication: prEN 62882-3-200:2023.

² To be published. Stage at the time of publication: prEN 62882-3-201:2023.

³ Withdrawn.

CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope.....	7
2 Normative references	7
3 Terms and definitions	7
4 Symbols	12
5 Configuration of small stationary fuel cell power system	14
6 Reference conditions.....	15
7 Heating value base.....	15
8 Test preparation	15
8.1 General.....	15
8.2 Uncertainty analysis.....	16
8.3 Data acquisition plan	16
9 Test set-up	16
10 Instruments and measurement methods	18
10.1 General.....	18
10.2 Measurement instruments.....	18
10.3 Measurement points.....	19
10.4 Minimum required measurement systematic tolerance	20
11 Test conditions	21
11.1 Laboratory conditions.....	21
11.2 Installation and operating conditions of the system	21
11.3 Test fuel	21
12 Parameter list.....	21
12.1 Electrical characteristics for fuel cell power system.....	21
12.1.1 Power generation electrical efficiency (rated, partial load)	21
12.1.2 Start-up, shut-down energy.....	21
12.1.3 Ramp-up rate and ramp-down rate between rated and minimum load	21
12.1.4 Waiting time for restart (hot restart)	21
12.2 Thermal characteristics for fuel cell power system	21
12.2.1 Heat recovery efficiency	21
12.2.2 Full heat storage amount of hot water tank	21
12.2.3 Remaining hot storage amount of hot water tank	22
12.2.4 Heat insulating performance of hot water tank	22
12.2.5 Heat recovery temperature	22
12.2.6 Pressure drop characteristics from feed water inlet to hot water outlet.....	22
13 Test methods.....	22
13.1 Electrical characteristics for fuel cell power system.....	22
13.1.1 Power generation electrical efficiency (rated, partial load)	22
13.1.2 Start-up, shut-down energy.....	27
13.1.3 Ramp-up rate and ramp-down rate between rated and minimum load	30
13.1.4 Waiting time for restart (hot restart)	35
13.2 Thermal characteristics for fuel cell power system	35
13.2.1 Heat recovery test	35
13.2.2 Full heat storage amount of hot water tank	37

13.2.3	Remaining heat storage amount of hot water tank	38
13.2.4	Heat insulating performance of hot water tank	39
13.2.5	Heat recovery temperature	39
13.2.6	Pressure drop characteristics from feed water inlet to hot water outlet.....	40
14	Test reports	40
14.1	General.....	40
14.2	Title page.....	40
14.3	Table of contents	40
14.4	Summary report	41
Annex A (informative)	Heating values for components of natural gases	42
Annex B (informative)	Examples of nominal composition for natural gas and propane gas	44
Annex C (informative)	Guidelines for the contents of detailed and full reports	47
C.1	General.....	47
C.2	Detailed report.....	47
C.3	Full report	47
Annex D (informative)	Pressure drop characteristics from feed water inlet to hot water outlet	48
Bibliography		49
Figure 1	– Configuration of a fuel cell power system that can be complemented with a supplementary heat generator or thermal storage system covered by this document.....	14
Figure 2	– Test set-up for small stationary fuel cell power system fed with gaseous fuel which supplies electricity and useful heat.....	17
Figure 3	– Test set-up for small stationary fuel cell power system fed with gaseous fuel which supplies only electricity	18
Figure 4	– Example of electric power chart during start-up time	27
Figure 5	– Example of liquid fuel supply systems	28
Figure 6	– Electric power chart during shutdown time	29
Figure 7	– Electric power output change pattern for ramp-up and ramp-down rate test.....	32
Figure 8	– Example for electric power change stabilization criteria.....	33
Figure 9	– Explanation of temperature sensor locations and V_j	38
Figure D.1	– Example for the pressure drop characteristics from feed water inlet to hot water outlet.....	48
Table 1	– Symbols and their meanings for electric and thermal performance	12
Table A.1	– Heating values for components of natural gases at various combustion reference conditions for ideal gas	42
Table B.1	– Examples of composition of natural gas (%).....	45
Table B.2	– Examples of composition of propane gas (%).....	46

INTERNATIONAL ELECTROTECHNICAL COMMISSION

FUEL CELL TECHNOLOGIES –

Part 3-202: Stationary fuel cell power systems – Performance test methods for small fuel cell power systems for multiple units operation

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 62282-3-202 has been prepared by IEC technical committee 105: Fuel cell technologies. It is an International Standard.

The text of this International Standard is based on the following documents:

Draft	Report on voting
105/1094/FDIS	105/1101/RVD

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 International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62282 series, published under the general title *Fuel cell technologies*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

This part of IEC 62282 provides consistent and repeatable test methods for the electrical thermal and environmental performance of small stationary fuel cell power systems.

This document limits its scope to small stationary fuel cell power systems (electric power output below 10 kW) and provides test methods specifically designed for them in detail. It is based on IEC 62282-3-201.

For multiple units operation, each electric power output of the unit is limited to below 10 kW.

This document is intended for manufacturers of small stationary fuel cell power systems or those who evaluate the performance of their systems for certification purposes.

Users of this document can selectively execute test items that are suitable for their purposes from those described in this document. This document is not intended to exclude any other methods.

This document describes type tests and their test methods only. In this document, no routine tests are required or identified, and no performance targets are set.

FUEL CELL TECHNOLOGIES –

Part 3-202: Stationary fuel cell power systems – Performance test methods for small fuel cell power systems for multiple units operation

1 Scope

This part of IEC 62282 provides performance test methods specialized for the thermal and electrical characteristics of an energy management system to effectively share the heat and power of networked small stationary fuel cell power systems. These test methods are applied for each small stationary fuel cell power system. This document covers small stationary fuel cell power systems which can be complemented with a supplementary heat generator or a thermal storage system, or both, such as:

- output: rated electric power output of less than 10 kW for each system;
- output mode: grid-connected or independent operation or stand-alone operation with alternating current (AC) output not exceeding 240 V or direct current (DC) output;
- operating pressure: maximum allowable working pressure of less than 0,1 MPa (G) for the fuel and oxidant passages;
- fuel: gaseous fuel (natural gas, liquefied petroleum gas, propane, butane, hydrogen) or liquid fuel (kerosene, methanol);
- oxidant: air.

This document does not apply to small stationary fuel cell power systems with electricity storage other than (small scale) back-up power for safety, monitoring and control.

NOTE Regarding data linkage for conducting the performance tests specified in this document with operating management systems (energy management system) of multiple fuel cell power systems (mFCPS), an appropriate IEC standard can be selected and implemented. The related standards are IEC 61850-7-420, IEC TR 61850-90-27, IEC 62394, IEC 62746-10-1, IEC 62746-10-3, etc. The data linkage and implementation for realizing the functions of the system that monitors mFCPS and peripherals differ depending on the vendor of the mFCPS control system, so the methods for data linkage and implementation are not specified in this document.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

cold state

state of a fuel cell power system, which is entirely at ambient temperature with no power input or output, ready for start-up

[SOURCE: IEC 60050-485:2020, 485-21-01, modified – "ready for start-up" added.]

3.2

electrical efficiency

ratio of the average net electric power output produced by a fuel cell power system to the average fuel power input supplied to the fuel cell power system

Note 1 to entry: The lower heating value (LHV) is assumed unless otherwise stated

[SOURCE: IEC 60050-485:2020, 485-10-02, modified – "electrical" instead of "electric" in the term; "average net electric power output" instead of "net electric power"; "average fuel power input" instead of "total enthalpy flow".]

3.3

electric energy input

integrated value of electric power input at the electric input terminal

[SOURCE: IEC 62282-3-201:2025, 3.8]

3.4

electric energy output

integrated value of electric power output at the electric output terminal

[SOURCE: IEC 62282-3-201:2025, 3.9]

3.5

electric power input

electric power input at the electric input terminal of the fuel cell power system

[SOURCE: IEC 62282-3-201:2025, 3.10]

3.6

electric power output

electric power output at the electric output terminal of the fuel cell power system

[SOURCE: IEC 62282-3-201:2025, 3.11]

3.7

fuel cell power system

generator system that uses one or more fuel cell modules to generate electric power and heat

[SOURCE: IEC 60050-485:2020, 485-09-01]

3.8

fuel input

amount of natural gas, hydrogen, methanol, liquid petroleum gas, propane, butane, or other material containing chemical energy entering the fuel cell power system while it is working at the specified operating conditions

[SOURCE: IEC 62282-3-201:2025, 3.13]

3.9

fuel power input

fuel energy input per unit of time

[SOURCE: IEC 62282-3-201:2025, 3.14]

3.10**heat recovery efficiency**

ratio of the average recovered thermal power output of a fuel cell power system to the average total power input supplied to the fuel cell power system

[SOURCE: IEC 60050-485:2020, 485-10-04, modified – "the average recovered thermal power output" instead of "recovered heat flow"; "average total power input" instead of "total enthalpy flow"; Note 1 to entry deleted.]

3.11**heat recovery fluid**

fluid circulating between the fuel cell power system and a heat sink for recovering the thermal energy output

[SOURCE: IEC 62282-3-201:2025, 3.16]

3.12**hot restart**

start operation of the fuel cell power system before the power system temperature condition reaches the "cold state"

3.13**inert purge gas**

inert gas or dilution gas, not containing chemical energy, supplied to the fuel cell power system during specific conditions to make it ready for operation or shutdown

Note 1 to entry: Dilution gas containing chemical energy shall be considered as fuel.

[SOURCE: IEC 62282-3-201:2025, 3.17]

3.14**integrated fuel input**

volume or mass of fuel consumed by the fuel cell power system under specified operating conditions

[SOURCE: IEC 62282-3-201:2025, 3.18]

3.15**interface point**

measurement point at the boundary of a fuel cell power system at which material or energy, or both, either enters or leaves

Note 1 to entry: This boundary is intentionally selected to accurately measure the performance of the system, including all normal operation, both steady state and transient. If necessary, the boundary or the interface points of the fuel cell power system (Figure 1) to be assessed should be determined by agreement between the parties.

Note 2 to entry: Typical conditions to be standardized refer to fuel and oxidant parameters, like compositions, flow rates, temperature, pressure and humidity, as well as to the fuel cell parameters, like temperature.

[SOURCE: IEC 60050-485:2020, 485-09-12, modified – reference to Figure 1 added.]

3.16**minimum electric power output**

minimum net power output, at which a fuel cell power system is able to operate continuously at a steady state

[SOURCE: IEC 62282-3-201:2025, 3.21]

3.17

net electric power output

power generated by the fuel cell power system and available for external use

[SOURCE: IEC 60050-485:2020, 485-14-03, modified – "output" added to the term, Notes 1 and 2 to entry deleted.]

3.18

rated electric power output

maximum continuous electric power output that a fuel cell power system is designed to achieve under normal operating conditions specified by the manufacturer

[SOURCE: IEC 60050-485:2020, 485-14-04, modified – "electric" and "output" added to the term, Note 1 to entry deleted.]

3.19

ramp-up time

duration required for transitioning from zero or minimum net electric power output to rated net electric power output

[SOURCE: IEC 62282-3-201:2025, 3.29, modified – "zero or minimum" instead of "positive"; "after start-up" deleted.]

3.20

ramp-down time

duration required for transitioning from rated net electric power output to minimum or zero net electric power output

3.21

recovered heat

thermal energy that has been recovered for useful purpose

Note 1 to entry: The recovered heat is measured by determining the temperatures and flow rates of the heat recovery fluid (water, steam, air or oil, etc.) entering and leaving the thermal energy recovery subsystem at the interface point of the fuel cell power system.

[SOURCE: IEC 62282-3-201:2025, 3.30]

3.22

recovered thermal power

recovered heat per unit of time

[SOURCE: IEC 62282-3-201:2025, 3.31]

3.23

shutdown energy

sum of electric or chemical (fuel) energy, or both required during the shutdown time

[SOURCE: IEC 62282-3-201:2025, 3.32]

3.24**shutdown time**

duration between the instant when a shutdown action is initiated at rated electric power output and the instant when the cold state or storage state, as specified by the manufacturer, is attained

[SOURCE: IEC 60050-485:2020, 485-20-04, modified – "a shutdown action is initiated at rated electric power output" instead of "the load is removed"; "the cold state or storage state, as specified by the manufacturer, is attained" instead of "the shutdown is completed".]

3.25**start-up energy**

sum of the electric, thermal, mechanical and chemical (fuel) energy required by a fuel cell power system for transitioning from cold state or storage state to positive net electric power output

[SOURCE: IEC 60050-485:2020, 485-18-05, modified – "for transitioning from cold state or storage state to positive net electric power output" instead of "during the start-up time".]

3.26**start-up time**

<for fuel cell power systems that do not require external energy to maintain a storage state> duration required for transitioning from cold state to positive net electric power output

[SOURCE: IEC 60050-485:2020, 485-20-05, modified – "positive" added.]

3.27**start-up time**

<for fuel cell power systems that require external power to maintain a storage state> duration required for transitioning from storage state to positive net electric power output

[SOURCE: IEC 60050-485:2020, 485-20-06, modified – "positive" added.]

3.28**stationary fuel cell power system**

fuel cell power system that is connected and fixed in place

[SOURCE: IEC 60050-485:2020, 485-09-24, modified – the figure has been omitted.]

3.29**storage state**

state of a fuel cell power system being non-operational and possibly requiring, under conditions specified by the manufacturer, the input of thermal energy, electric energy or an inert atmosphere, or any combination thereof, in order to prevent deterioration of the components or energize the control systems and other components, or both and is ready for start-up

[SOURCE: IEC 60050-485:2020, 485-21-06, modified – "or energize the control systems and other components, or both and is ready for start-up" added.]

3.30**thermal storage unit**

unit that stores heat recovered from the fuel cell power system in the thermal storage medium and supplies the heat with heat carrier externally as needed

Note 1 to entry: It is composed of a thermal storage tank, a heat exchanger and a heat carrier supply system.

Note 2 to entry: A typical thermal storage medium is water.

[SOURCE: IEC 62282-3-201:2025, 3.39]

4 Symbols

The symbols and their meanings used in this document are given in Table 1 with the appropriate units.

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

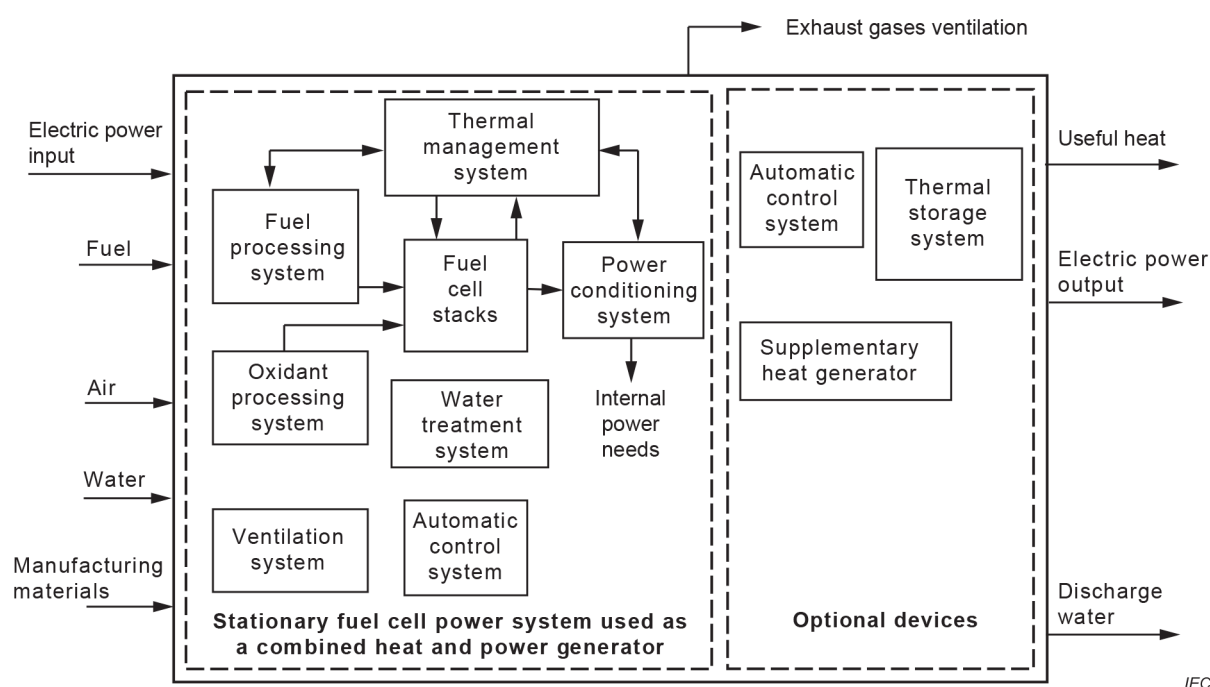
Symbol	Definition	Unit
c	Specific heat	
c_{HR}	Specific heat capacity of heat recovery fluid	kJ/(kg·K)
c_{pj}	Specific heat of water at the temperature T_{vj}	kJ/(kg·K)
E	Energy	
E_{mf}	Energy input of gaseous fuel per unit mass	kJ/kg
E_{vf}	Energy input of the fuel per unit volume	kJ/m ³
E_{fin}	Fuel energy input	kJ
H	Heating value	
H_{f0}	Heating value of fuel on a molar basis under reference conditions	kJ/mol
H_{f0j}	Heating value of component j at reference temperature T_0	kJ/mol
H_{fl}	Heating value of liquid fuel	kJ/kg
M	Molar mass	
M_f	Molar mass of fuel	kg/mol
m	Mass	
m_f	Fuel mass measured over the test duration	kg
m_{HR}	Heat recovery fluid mass	kg
P, dP	Power, power change rate	
P_n	Average net electric power output	kW
P_{rated}	Rated electric power output	kW
P_{min}	Minimum electric power output	kW
P_d	Electric power output change range between P_{rated} and P_{min}	kW
P_{HR}	Average recovered thermal power	kJ/s
P_{fin}	Average fuel power input	kJ/s
dP_{downi}	Decrease rate of electric power output	kW/s
dP_{upi}	Increase rate of electric power output	kW/s
p	Pressure	
p_0	Reference pressure (101,325 kPa (abs))	kPa (abs)
p_f	Average fuel pressure	kPa (abs)
Q	Amount of heat	
Q_{full}	Storage heat amount of the hot water tank	kJ
$Q_{remaining}$	Remaining heat storage amount of the hot water tank	kJ
ΔQ_{loss}	Heat loss of the hot water tank	kJ/h
Q_{init}	Initial heat storage amount of the hot water tank	kJ
Q_{10h}	Heat storage amount of the hot water tank after 10 h of heat loss	kJ

Symbol	Definition	Unit
q_m	Mass flow rate	
q_{mf}	Average mass flow rate of fuel	kg/s
q_{mHR}	Average mass flow rate of heat recovery fluid	kg/s
q_V	Volumetric flow rate	
q_{Vf}	Average volumetric flow rate of fuel under the test conditions	m ³ /s
q_{VT0}	Average volumetric flow rate of fuel under reference conditions	m ³ /s
q_{VHR}	Average volumetric flow rate of heat recovery fluid	m ³ /s
T	Temperature	
T_0	Reference temperature (288,15 K)	K
T_f	Average fuel temperature	K
T_{HR1}	Average temperature of heat recovery fluid output	K
T_{HR2}	Average temperature of heat recovery fluid input	K
T_{Vj}	Average temperature of the temperatures measured by sensor $j-1$ and sensor j	K
T_{feed}	Feed water temperature	K
t	Time	
Δt	Test duration	s
Δt_{st}	Start-up time	s
t_{st1}	Start-up initiation time	
t_{st2}	Start-up completion time	
Δt_{shut}	Shutdown time	s
t_{shut1}	Shutdown initiation time	
t_{shut2}	Shutdown completion time	
$\Delta t_{ramp-upi}$	Ramp-up time	s
$t_{ramp-upi-1}$	Ramp-up start time	
$t_{ramp-upi-2}$	Ramp-up completion time	
$\Delta t_{ramp-downi}$	Ramp-down time	s
$t_{ramp-downi-1}$	Ramp-down start time	
$t_{ramp-downi-2}$	Ramp-down completion time	
V	Volume	
V_f	Fuel volume measured over the test duration	m ³
V_{HR}	Heat recovery fluid volume	m ³
V_j	Water volume in the order of j divided part	L
V_m	Molar volume	
V_m	Reference molar volume of ideal gas ($2,364\ 5 \times 10^{-2}$ m ³ /mol at reference temperature $T_0 = 288,15$ K and reference pressure $p_0 = 101,325$ kPa)	m ³ /mol
W	Electric energy	
W_{out}	Electric energy output	kW·h
W_{in}	Electric energy input	kW·h
W_{inst}	Electric energy input during start-up time	kW·h

Symbol	Definition	Unit
W_{inshut}	Electric energy input during shutdown time	kW·h
$W_{\text{ramp-up}i}$	Electric energy output during ramp-up time	kW·h
$W_{\text{ramp-down}i}$	Electric energy output during ramp-down time	kW·h
x	Molar ratio	
x_j	Molar ratio of component j	
η	Efficiency	
η_{el}	Electrical efficiency	%
η_{th}	Heat recovery efficiency	%
ρ	Density	
ρ_{HR}	Density of heat recovery fluid at T_{HR1}	kg/m ³
ρ_j	Density of water at the temperature T_{Vj}	kg/L

5 Configuration of small stationary fuel cell power system

Figure 1 illustrates the general configuration of a small stationary fuel cell power system which is the subject of this document and shows the system boundary and physical quantities entering and leaving the fuel cell power system. The fuel cell power system can be complemented with a supplementary heat generator, a thermal storage system or electricity from the grid.



NOTE This Figure 1 displays only the major interconnections between the subsystems.

Figure 1 – Configuration of a fuel cell power system that can be complemented with a supplementary heat generator or thermal storage system covered by this document