IEC 61757-4-3

Edition 1.0 2020-07

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Fibre optic sensors –
Part 4-3: Electric current measurement – Polarimetric method

Capteurs fibroniques –
Partie 4-3: Mesure du courant électrique – Méthode polarimétrique

IEC 61757-4-3:2020-07(en-fr)

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

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

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

A propos de l'IEC
La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC
Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC - webstore.iec.ch/advsearchform
La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,…). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished
Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc
Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

Electropedia - www.electropedia.org
Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 000 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary
67 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

IEC®

IEC 61757-4-3

Edition 1.0 2020-07

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Fibre optic sensors –
Part 4-3: Electric current measurement – Polarimetric method

Capteurs fibroniques –
Partie 4-3: Mesure du courant électrique – Méthode polarimétrique

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 33.180.99 ISBN 978-2-8322-8729-3

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

FIBRE OPTIC SENSORS –

Part 4-3: Electric current measurement – Polarimetric method

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

International Standard IEC 61757-4-3 has been prepared by subcommittee SC 86C: Fibre optic systems and active devices, of IEC technical committee TC 86: Fibre optics.

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

CDV	Report on voting
86C/1578/CDV	86C/1611/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61757 series, published under the general title *Fibre optic sensors*, 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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

Current measuring techniques are essential for controlling and diagnosing apparatus that support industry and society. As current measuring devices, optical current sensors based on magneto-optic effect have been developed. As these sensors enable advanced current measurement free from the issues related to conventional current sensors based on electromagnetic induction, they have been applied in various fields including power systems.

Given the expectations for the potential of this sensing technology, various kinds of optical current sensors for various applications have been proposed by manufacturers. With this background, there are many kinds (target current for measurement, configuration of sensor, signal processing method, installation method) of optical current sensors for various applications. When developing a new optical current sensor, the evaluation and design of performance and characteristics are carried out in each case.

For promoting the dissemination of optical current sensors, it is important to define the terms representing performance and functionality of the optical current sensor, which is manufactured on the basis of sensing technology. It is also important to make clear how to evaluate such terms. This makes it possible to design the sensor efficiently and properly and to transfer the sensor smoothly from a supplier to a user by settling these issues. Under these circumstances, a set of methods is summarized in this document for evaluating the performance and characteristics of optical current sensors. As the required performance for a sensor depends on its application, the performance is not defined quantitatively in this document. However, with the help of this document, the quantitative measures of sensor performance will be defined in designing the sensor itself in anticipation of its practical application.

This document is based on standard OITDA FS 01 published by the Optoelectronics Industry and Technology Development Association (OITDA).

FIBRE OPTIC SENSORS –

Part 4-3: Electric current measurement – Polarimetric method

1 Scope

This part of IEC 61757 defines terminology, structure, and a characteristic test method of an optical current sensor using the polarimetric method. It addresses the current sensing element only and not the additional devices that are unique to each application. Generic specifications for fibre optic sensors are defined in IEC 61757.

As the specifications of optical polarimetric fibre current sensors required by each user vary depending on the application, this document does not define the required performance values. The required performance values are defined when designing a sensor according to the specific application.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 61757, *Fibre optic sensors – Generic specification*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61757 and the following apply.

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

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

3.1
current conducting coil
air-core coil made of lead wires that applies electric current, which is used to apply the equal magnetic field generated by the current to be measured to an optical fibre or a bulk-form Faraday element when conducting a characteristic test of optical current sensor

3.2
external magnetic field
magnetic field generated from anywhere other than the conductor where the current to be measured is passing in an optical current sensor

3.3
Faraday effect
circular birefringence that is generated when an external magnetic field is imposed on a substance

Note 1 to entry: The Faraday effect is a kind of magneto-optical effect. "Magneto-optical effect" is a general term that means the effect of a magnetic field on the optical characteristics of particles or crystal. In addition to the Faraday effect, there are other magneto-optical effects such as the Zeeman effect, magnetic birefringence, magnetic circular dichroism, the magnetic Kerr effect, and magneto-oscillatory absorption.

3.4
Faraday element
optical element for detecting Faraday effect

3.5
Faraday mirror
reflecting mirror that rotates the polarization angle by the Faraday effect

3.6
intensity modulation method
method of converting the rotation of a polarization plane to light intensity and generating an optical signal that corresponds to the current to be measured by passing light, first through a sensing element and then through a polarization separation element, in an optical current sensor

3.7
interferometric method
method of generating an optical signal that corresponds to the current to be measured by an optical current sensor by converting the left-handed and right-handed circularly polarized light that passed through the Faraday element to the same polarization, then interfering with each other to convert the polarized light to the light intensity

3.8
maximum measurable current
maximum measurable value of the current to be measured by an optical current sensor

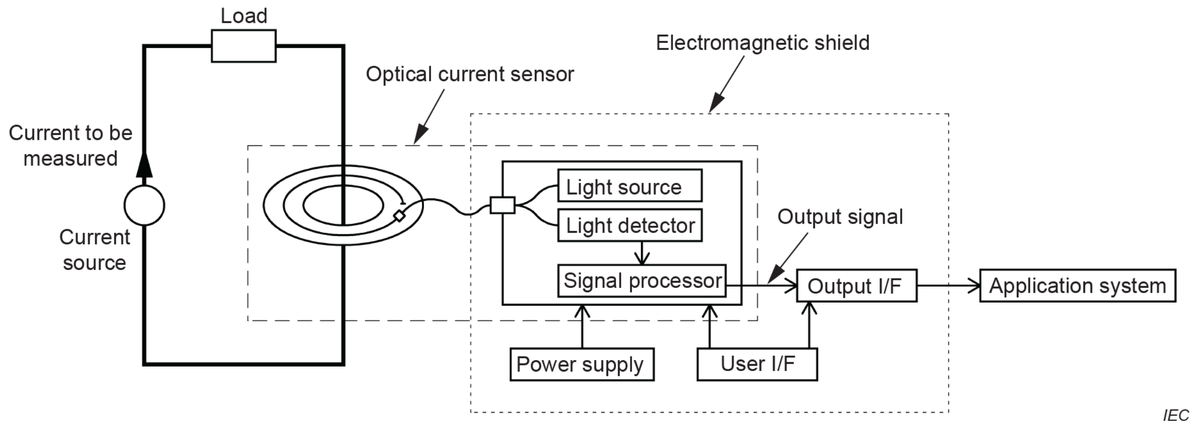
3.9
maximum measurable frequency
maximum measurable frequency of the current to be measured by an optical current sensor

3.10
minimum measurable frequency
minimum measurable frequency of the current to be measured by an optical current sensor

3.11
operating temperature range
range of temperatures within which an optical current sensor satisfies the defined performances

3.12
optical current sensor
part, module, sub-assembly, assembly, or equipment that measures the electric current using fibre optic technology

Note 1 to entry: Optical current sensors are commonly used with power supplies, user interface, and electromagnetic shields, as shown in Figure 1. The output signal is arranged in a signal form required by the output interface, and a signal is sent to an application system such as an oscilloscope or a control system. An optical current sensor using the polarimetric method consists of the sensor part, optical transmission part, and signal processing part (see Clause 4).



Key

I/F interface

Figure 1 – Measurement system using optical current sensor

3.13
optical part
part consisting of lens, prism, mirror, and optical element, such as a phase modulator, in an optical current sensor

Note 1 to entry: While the term "sensor part" focuses on the component position (see Clause 4), the term "optical part" focuses on the component materials.

3.14
outer conductor
conductor other than the conductor in which the current to be measured is passing in an optical current sensor

3.15
rated current
value of the current to be measured by an optical current sensor that is used as a basis for showing the performance in a given test under defined conditions

3.16
required specifications
list of specifications an optical current sensor satisfies

3.17
spun optical fibre
optical fibre that is manufactured by rotating a preform at high speed in the drawing process

3.18
transient characteristic
phenomenon of changing the current value that is output from an optical current sensor when the current to be measured fluctuates from the defined current value in a short period of time

4 Components of optical current sensor using polarimetric method

4.1 General descriptions

Figure 2 shows the construction of an optical current sensor. For exposing each part to a different environment, this document focuses on the position of each part and divides the sensor into three parts.

In the optical current sensor, a portion of a Faraday element that is adjacent to the conductor and is affected by the Faraday effect is connected with a portion that houses a processing circuit outputting a current calculation value via optical fibre, and each portion is exposed to a different environment in general. In this case, while a portion in which the Faraday element is arranged and exposed to the same environment is called a sensor part, a portion containing a processing circuit for outputting the current calculation value is called the signal processing part, and an optical fibre that connects the sensor part and the signal processing part is called the optical transmission part. For the specific functions of each part, see Annex A.

NOTE The sensor part can have elements of controlling polarization and phase at the same time in addition to Faraday elements. The signal processing part can have elements of controlling polarization and phase at the same time in addition to a light source, a power supply, and a light detector.

For the features expected of an optical current sensor, see Annex B. For design considerations of an optical current sensor, see Annex C.

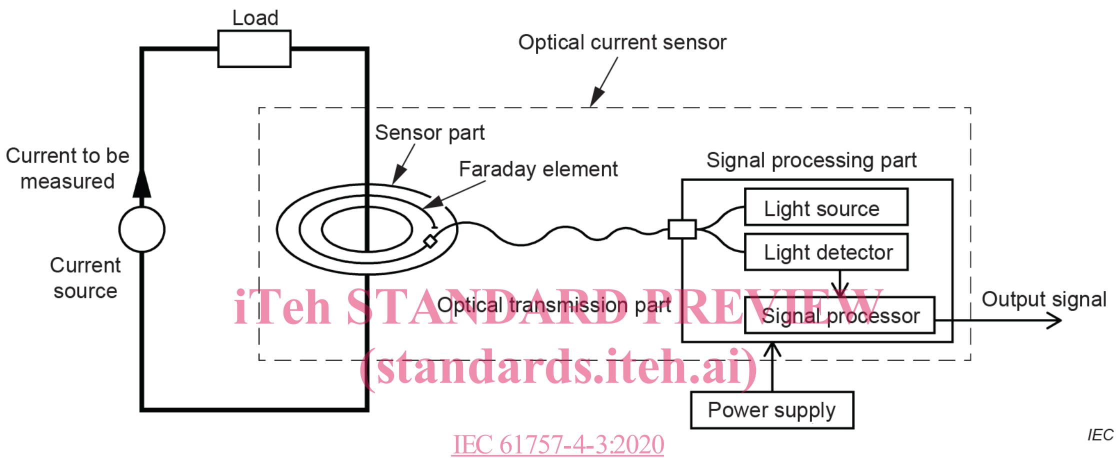


Figure 2 – Construction of optical current sensor

4.2 Classification of Faraday elements

The classification of Faraday elements is shown in Figure 3. As a method of propagating light in a Faraday element, a waveguide type element is used. This is an element having a waveguide structure for guiding light by providing difference in refractive index in a sensor. While candidates for the waveguide type element include optical fibres and planar waveguides, only the optical fibre type is currently put to practical use.

There is also a bulk type element that guides light into a sensor using a lens and mirror without utilizing a difference in refractive index. The element made of a nonmagnetic material and that made of a ferromagnetic material are distinguished from each other based on the element material used.

Bulk type sensors use optical fibres for signal transmission, and the optical fibres themselves are not Faraday elements.

This document is applicable to both waveguide element and bulk element sensors using optical fibre technology.

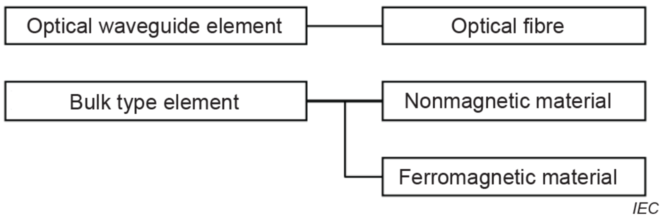


Figure 3 – Classification of Faraday elements

5 Characteristic test

5.1 General information

Clause 5 specifies a characteristic test method of the optical current sensor. Output power of light source, described in 5.2, and input power of light detector, described in 5.3, shall be measured at the beginning of a characteristics test to confirm normal operation of the light source and optical part. The input-output (I/O) characteristics described in 5.4 are the basis of the test. Subclause 5.5 describes the warm-up time, which often is not considered in conventional current sensors. In 5.6 through 5.8, definition of the dependency of parameters is made that is recommended for testing and the dependence on external environment in the test method for each factor. Subclause 5.6 describes the current condition for obtaining each parameter. The parameter list to be acquired is shown in Table 1. For each parameter, requirement (R) or option (O) is shown. Measurement results are summarized in the inspection report (see Annex E) and shown to the user.

Table 1 – List of parameters to be obtained

No.	Parameters			Requirement (R) or option (O)
1	Output power of light source			R
2	Input power of light detector			
3	I/O characteristics			
4	Warm-up time			
5	Parameter dependency	Input parameter dependency	Frequency characteristic	R for type test
			Transient characteristic	R for type test
		External environment dependency	Steady state temperature characteristic	R for type test O in routine test for outdoor use sensor
			Transient temperature characteristic	R for type test O for routine test for outdoor use sensor
			External magnetic field	O
			Conductor position	O
			Vibration	O

5.2 Output power of light source

Output power of the light source shall be measured in a routine test using one of the following methods:

a) measure the output power of the light source by optical power meter;

b) measure the output signal of the optical power monitor.

Figure 4 is an example of the optical power monitor. The light source is often provided with a photodiode for the power monitor, which can be used. By amplifying the signal of the photodiode, an output of optical power monitor is obtained.

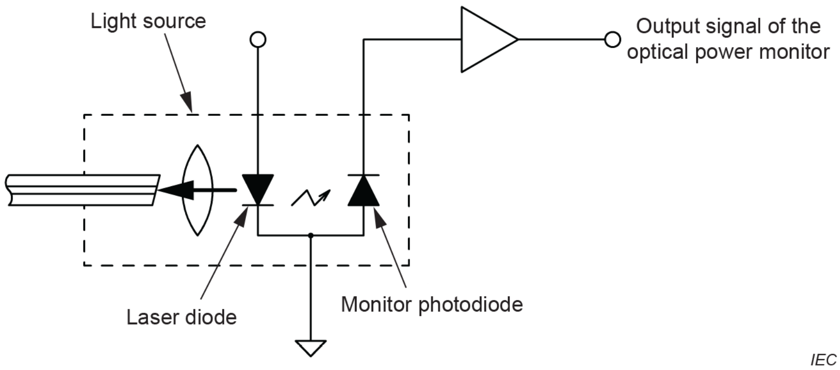


Figure 4 – Example of an optical power monitor

5.3 Input power of light detector

Input power of the light detector shall be measured in a routine test using one of the following methods:

a) measure the input power of the light detector by optical power meter;

b) measure the output signal of the light detector.

For example, as shown in Figure 5, the output of the light detector can be amplified.

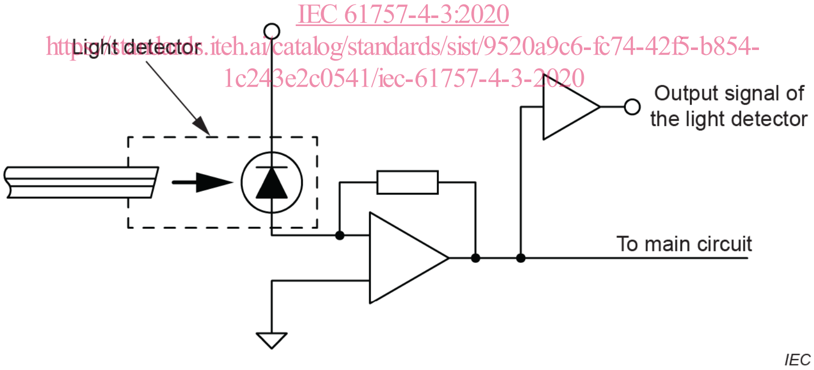


Figure 5 – Example of the amplifying circuit of a light detector

5.4 I/O characteristics

5.4.1 General

I/O characteristics are the most basic characteristics of optical current sensors. Figure 6 shows the I/O characteristics of the optical current sensor. Ideally, the current to be measured and the output instruction value are the same, but an error actually occurs. The error is classified into the following three factors.

a) Noise

Unnecessary output. Particularly, the DC components are called offsets and should be distinguished from noise. Some noises are correlated with the current to be measured, and some noises are not. Therefore, they shall be acquired separately.