IEC 62689-2

Edition 1.0 2016-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Current and voltage sensors or detectors, to be used for fault passage indication purposes – Part 2: System aspects

Capteurs ou détecteurs de courant et de tension, à utiliser pour indiquer le passage d'un courant de défaut – Partie 2: Aspects systèmes

IEC 62689-2:2016-05(en-fr)

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CONTENTS

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CURRENT AND VOLTAGE SENSORS OR DETECTORS, TO BE USED FOR FAULT PASSAGE INDICATION PURPOSES –

Part 2: System aspects

FOREWORD

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International Standard IEC 62689-2 has been prepared by IEC technical committee 38: Instrument transformers.

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

FDIS	Report on voting
38/504/FDIS	38/511/RVD

Full information on the voting for the approval of this standard 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 the parts in the IEC 62689 series, under the general title *Current and voltage sensors or detectors, to be used for fault passage indication purposes,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability 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

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- withdrawn,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

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INTRODUCTION

0.1 General

The IEC 62689 series is a product family standard for current and voltage sensors or detectors, to be used for fault passage indication purposes by proper devices or functions, indicated as fault passage indicator (FPI) or distribution substation unit (DSU), depending on their performances.

Different names are used to indicate FPIs depending on the region of the world and on their functionalities concerning capability to detect different kinds of faults, for instance:

- fault detector;
- smart sensor;
- faulted circuit indicator (FCI);
- short circuit indicator (SCI);
- earth fault indicator (EFI);
- test point mounted FCI.
- combination of the above.

Simpler versions, only using local information/signals and/or local communication, are called FPI, while very evolved versions are called DSU. The latter are explicitly designed for smart grids and based on IEC 60870-5 and IEC 61850 communication protocols.Compared to instrument transformers, digital communication technology is subject to on-going changes which are expected to continue in the future.

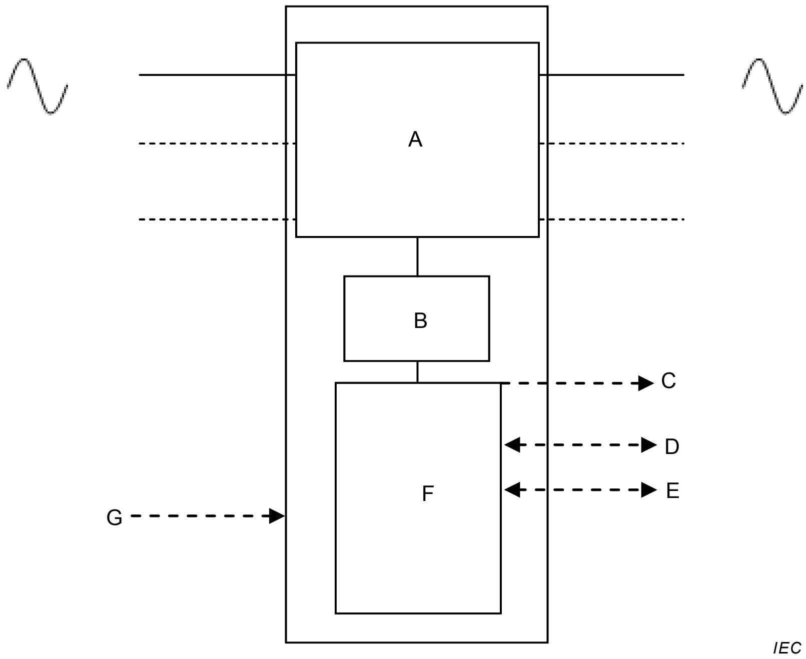
Profound experience with deep integration between electronics and instrument transformers has yet to be gathered on a broader basis, as this type of equipment is not yet widespread in the industry.

DSUs, besides FPI basic functions, may also optionally integrate additional auxiliary functions such as:

- voltage presence/absence detection for medium voltage (MV) network automation, with and without distributed energy resources presence (not for fault confirmation, which can be a basic FPI function depending on the adopted fault detection method, neither for safety-related aspects, which are covered by IEC 61243-5);
- measuring of voltage, current, and active and reactive power, etc., for various applications, such as MV network automation, monitoring of power flows, etc.;
- smart grid management (such as voltage control and unwanted island operation) by means of a proper interface with local distributed generators (DER);
- local output of collected information by means of suitable interfaces;
- remote transmission of collected information;
- others.

A general FPI scheme is outlined in Figure 1.

A DSU may have a much more complex scheme.



Key

A Current (and, if necessary, voltage) sensors. 1 or 3 phases may be monitored.

B Transmission of signals between sensors and electronics.

C: Local indications (lamps, LEDs, flags, etc.).

D Analogue, digital and/or communication inputs/outputs for remote communication/commands (hard wired and/or wireless).

E Connections to field apparatus.

F Signal conditioning, processing and indicating unit (CPIU).

G Power supply.

Current sensor(s) may detect fault current passages without any need of galvanic connection to the phase(s) (for instance in case of cable type current sensors or of magnetic field sensor).

Not all the above listed parts or functions are necessarily included in the FPI, depending on its complexity and on its technology. However, at least 1 one of C or D functions shall be present.

Figure 1 – General architecture of an FPI

0.2 Position of this standard in relation to the IEC 61850 series

The IEC 61850 series is intended to be used for communication and systems to support power utility automation.

The IEC 62689 series will also introduce a dedicated namespace to support integration of FPIs/DSUs into power utility automation.

In addition, it defines proper data models and different profiles of communication interfaces to support the different use cases of these FPIs/DSUs.

Some of these use cases rely on the concept of extended substation, which is intended as the communication among intelligent electronic devices (IED) through IEC 61850 located both along MV feeders and in the main substation, for the most sophisticated FPI versions (and therefore DSUs) (for smart grid applications, for instance). Such a profile may not be limited to FPI/DSU devices, but may embrace features needed to support extensions of these substations along the MV feeders connected to the main substation themselves.

CURRENT AND VOLTAGE SENSORS OR DETECTORS, TO BE USED FOR FAULT PASSAGE INDICATION PURPOSES –

Part 2: System aspects

1 Scope

This part of IEC 62689 describes electric phenomena and electric system behaviour during faults, according to the most widely diffused distribution system architecture and to fault typologies, to define the functional requirements for fault passage indicators (FPI) and distribution substation units (DSU) (including their current and/or voltage sensors), which are, respectively, a device or a device/combination of devices and/or of functions able to detect faults and provide indications about their localization.

By localization of the fault is meant the fault position with respect to the FPI/DSU installation point on the network (upstream or downstream from the FPI/DSU's location) or the direction of the fault current flowing through the FPI itself. The fault localization may be obtained

- directly from the FPI/DSU, or
- from a central system using information from more FPIs or DSUs,

considering the features and the operating conditions of the electric system where the FPIs/DSUs are installed.

This part of IEC 62689 is therefore aimed at helping users in the appropriate choice of FPIs/DSUs (or of a system based on FPI/DSU information) properly operating in their networks, considering adopted solutions and operation rules (defined by tradition and/or depending on possible constraints concerning continuity and quality of voltage supply defined by a national regulator), and also taking into account complexity of the apparatus and consequent cost.

This part of IEC 62689 is mainly focused on system behaviour during faults, which is the "core" of FPI/DSU fault detection capability classes described in IEC 62689-1, where all requirements are specified in detail.

2 Normative references

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

IEC 62689-1, *Current and voltage sensors or detectors, to be used for fault passage indication purposes – Part 1: General principles and requirements*

3 Terms, definitions, abbreviations and symbols

For the purposes of this document, the terms and definitions given in IEC 62689-1 and the following apply.

3.1 Terms and definitions related to neutral point treatment

3.1.1
arc-suppression coil
single-phase neutral earthing reactor intended for compensating the capacitive line-to-earth current due to a single-phase earth fault

Note 1 to entry: Instead of a pure reactor, with high quality factor Q, a resistive-reactive impedance may be used to render easier the earth fault detection and/or clearance.

Note 2 to entry: An arc-suppression coil is also known as a Petersen coil in certain areas.

[SOURCE: IEC 60050-421:1990, 421-01-04, modified – Note 1 and Note 2 to entry have been added.]

3.2 Abbreviations and symbols

For the purposes of this document, the abbreviations and symbols given in IEC 62689-1 apply.

4 Choice of FPI/DSU requirements related to fault detection according to network operation mode and fault type

4.1 General

Clause 4 is mainly focused on radially operated distribution networks, because this is, generally, the most widely adopted mode of operation.

Fault (or fault current passage) detection on such networks strongly relies on MV neutral point mode of operation.

In case of closed loop distribution networks, different considerations are necessary.

Directional fault detection, both concerning earth faults and overcurrents, based on vector relationships among voltages and currents, is influenced by the impedance of the feeder and have to be evaluated case by case. Communication among FPIs may be required.

A simpler solution may consist in opening the closed loop returning to radial operation and/or to adopt communication among FPIs.

An example of a possible solution is shown in Annex A.

4.2 FPIs/DSUs for isolated neutral system

4.2.1 Earth fault detection

The earth fault current is influenced both by the network configuration and typology and by the fault resistance.

The capacitive earth fault current contribution of medium voltage feeders' healthy sections is generally an appreciable percentage of total earth fault current.

NOTE The contribution to earth fault current of an underground medium voltage cable is about 50 times that of an overhead feeder of the same length.

Hence, in case of a fault upstream from the location of a FPI/DSU not equipped with directional detection of fault current passage, to avoid incorrect indications regarding the fault location, the current threshold set on FPI/DSU should be higher than the maximum earth fault current contribution from the healthy feeder section downstream from the FPI/DSU itself.

Low sensitivity with regards to fault resistance could, therefore, be obtained in case of non-directional FPIs/DSUs.

One method to discriminate the fault current with relatively high sensitivity with regards to fault resistance could be the adoption of FPIs/DSUs based on directional earth fault detection.

If the contribution to capacitive earth fault current from the network downstream from the FPI's/DSU's location is negligible, non-directional earth fault detection may be considered without any significant decrease of FPI/DSU performance.

Possible presence of DER has no effect on the direction of fault current.

4.2.2 Polyphase fault detection

For the purpose of this document, the term polyphase is used to include the following faults:

- three phase
- phase to phase
- cross country

as they all involve mainly overcurrent.

If no DER (or not appreciable amount of DER) is present, in case of polyphase faults, the fault current is coming from the HV/MV transformer. Directional FPIs/DSUs should, generally, be required if DER contribution to polyphase fault current is appreciably present or in case of closed-loop configuration.

4.3 FPIs/DSUs for resonant earthed (neutral) system – arc-suppression-coil-earth (neutral) system

4.3.1 Earth fault detection

4.3.1.1 General

The fault current is influenced by the network configuration, the coil design (pure inductive or inductive-resistance or inductive with short-term resistance, etc.), the connection to MV neutral point, the tuning of the resonant coil, the network losses at zero sequence and the fault resistance.

Two main solutions are possible: a "pure" arc-suppression coil, a fixed or tunable inductor with negligible resistive component due only to internal losses or an inductance with an intentional resistor to increase the amount of resistive current due to the coil.

4.3.1.2 "Pure" arc-suppression coil

In case of "pure" arc-suppression coil, tuned nearly to 100% of network capacitve current and standard losses value in the network components, the earth fault current is extremely low, mainly resistive, as the capacitive earth fault current contribution from the MV network is compensated by the inductive contribution from the arc suppression coil. The magnitude of the earth fault current would have near zero value when an earth fault occurs at any location on the same HV/MV substation busbar network.

Moreover, earth fault current through all FPIs/DSUs, whatever their location on the network (upstream or downstream from the fault position), is mainly reactive (vector relationship between residual current in any FPI/DSU and residual voltage is the same, corresponding to 90° degree leading angle of residual current with respect to residual voltage), with negligible active component (this component is the only one able to modify vector relationships between residual current and residual voltage on faulty feeders with respect to healthy ones).

FPIs/DSUs for pure resonant earthed (neutral) systems should, therefore, be directional for phase to earth fault detection.

NOTE Without the adoption of a resistive-inductive arc-suppression coil (4.3.1.3), it may be possible to detect an earth fault with non-directional FPI/DSU and with temporary modification of the network configuration, by, for instance, creating a mistuning of the arc-suppression coil using a capacitor in parallel to the coil itself and switching it on and off with different modalities.

4.3.1.3 Resistive-inductive arc-suppression coil

If a high-value resistor is installed in parallel to the arc suppression coil, temporarily or permanently connected to earth:

- earth fault current through FPI/DSU installed on healthy feeders or downstream from the fault is mainly reactive (the vector relationship between residual current and residual voltage nearly corresponds to 90° leading angle of residual current with respect to residual voltage), with negligible active component;
- earth fault current through FPI/DSU installed on faulty feeders upstream from the fault is resistive-reactive (the vector relationship between residual current and residual voltage is usually in the range from 90° to 180° leading angle of residual current with respect to residual voltage), with non-negligible active component.

The magnitude of the earth fault current would have a value nearly corresponding to the active current from the earthing resistor when an earth fault occurs at any location on the same substation busbar network.

FPIs/DSUs for resistive-inductive resonant earthed (neutral) systems should, therefore, have either directional or non-directional capability for phase to earth fault detection.

Possible presence of DER has no effect on the direction of fault current.

NOTE Detection of intermittent earth faults by FPI/DSU might be required.

4.3.2 Polyphase fault detection

See 4.2.2.

4.4 FPIs/DSUs for solidly earthed neutral systems (systems with low-impedance earthed neutrals)

Overcurrent detection can be used to detect both earth and polyphase faults.

If no DER (or no appreciable amount of DER) is present, the fault current comes from the HV/MV transformer. Phase directional FPIs/DSUs may be required only if DER is appreciably present.

Moreover, earth directional FPIs/DSUs may be required even if, according to the DER neutral point and the DER transformer group, a phase to earth current contribution may have come from the DER.

4.5 FPIs/DSUs for impedance earthed neutral system (resistive impedance earthed neutral system)

4.5.1 Earth fault detection

If the MV system neutral point is earthed by a resistor installed in the HV/MV substation, the fault current is assumed to come from the HV/MV transformer.

FPIs/DSUs could be directional and/or non-directional, depending on the values of the intentional earthing resistor (the lower it is, the higher is the neutral current, thus directional detection could be avoided in some circumstances), on the network configuration, on the network capacitive current and on the desired sensitivity concerning fault resistance value detection.

In the case of an earthing resistor injecting low or moderate neutral currents in the event of an earth fault, FPIs/DSUs should preferably be directional for earth fault detection. This is to obtain appropriate sensitivity with regards to faults with high resistance value. The resulting earth fault current obtained with this solution is not much higher than the pure capacitive earth fault current component.

In the case of an earthing resistor injecting moderate or high neutral current in the event of an earth fault, non-directional FPIs/DSUs may be used. With this solution, the earth fault current is higher than the network capacitive current.

4.5.2 Polyphase fault detection

See 4.2.2.

4.6 FPIs/DSUs for systems with high presence of DER

The presence of DER on a network is considered to be high when the current contribution from DER downstream from the FPI's/DSU's location for a fault located upstream from the FPI/DSU itself (even on another MV feeder connected to the same HV/MV or MV/MV transformer) is comparable to the FPI/DSU overcurrent thresholds.

In this case, FPIs/DSUs shall have directional detection of phase faults if the DER significantly contributes to short-circuit currents (see 5.2.4 and 5.2.5). Concerning phase to earth fault detection, see 4.2.1, 4.3.1, 4.4, 4.5.1. In any case, if directional detection is present for polyphase overcurrents, the same should be true for phase to earth currents.

NOTE This version of FPI/DSU can also be able to:

- manage many smart grid network configurations, assuming that smart grids are distribution networks with a high penetration of DERs;
- offer additional features (for instance, advanced network automation, including self healing and automatic supply restore) even in the presence of DER;
- support easy network reconfiguration, DER active power and reactive power control for voltage regulation, etc.

Even additional distribution network operation structures, different from the main diffused radial ones, may be successfully handled by these FPIs/DSUs (for instance closed loop operation of MV feeders).

4.7 Summary of FPI/DSU requirements with respect to fault detection according to network operation mode and fault type

Table 1 gives a summary of FPI/DSU requirements described in 4.1 to 4.6.

Table 1 refers only to whether it is possible or not to adopt the directional fault detection principle on FPIs, i.e. the detection of the fault current through the FPI itself.

The direction may be obtained with different solutions: by measuring the angle between residual/phase voltage and residual/phase current, by transient analysis of current (and/or voltage) of the first millisecond after fault occurrence, etc.

The complete FPI (and DSU) classification by classes is included in IEC 62689-1.

The content of Clause 4 is technically justified in Clause 5.