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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

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SECRETARIAT: United States of America	SECRETARY: Mr George Kelly
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.
FUNCTIONS CONCERNED: ☒ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☒ SAFETY	

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TITLE:

Power line communication for DC shutdown equipment

NOTE FROM TC/SC OFFICERS:

This project was discussed and supported by WG6 during their remote meeting in 2021-05.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

POWER LINE COMMUNICATION FOR DC SHUTDOWN EQUIPMENT –**Part 1: Communication signal, physical layer**

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International Standard IEC 63257 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

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

FDIS	Report on voting
XX/XX/FDIS	XX/XX/RVD

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.

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.

The National Committees are requested to note that for this document the stability date is 20XX..

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INTRODUCTION

As PV-systems are becoming a widespread technology it is important to think about the risks they pose for firefighters and installers due to their high DC-voltage and how to omit or lower those risks. A solution for this is to switch off the PV-modules at the DC-line as near to the PV-modules as possible when an emergency situation happens. In order to do this a communication is necessary from the inverter / initiator to the PV-modules. Today there are many ways to accomplish this communication task and it is possible to use either wired or wireless solutions. With wireless solutions issues with range and/or communication robustness may occur. Although Robustness can be tackled with some protocols and modulation schemes it is sometimes hard to get the necessary range due to physical limitations and normative regulations. With wired communication we normally have the problem of installing an additional wire which has to be installed with the DC power-cabling. A solution for this is to use Powerline communication so that the DC power and the information signal are on the same cable and therefore installation requirements and costs are low because the necessity of laying an extra communication cable is eliminated.

POWER LINE COMMUNICATION FOR DC SHUTDOWN EQUIPMENT –

Part 1: Communication signal, physical layer

1 Scope

This international draft-standard applies to Photovoltaic (PV) system components and communication networks supporting the communication of the DC shutdown equipment using powerline communication.

This standard defines how to propagate the operational state of the entire PV system to the individual power production components comprising the PV system. The standard also describes requirements and constraints associated with power line communication networks that are used to support this application.

This standard describes the supplementary use of this communication for monitoring purposes as an option.

This standard includes conformance test procedures including criteria, which have to be fulfilled to state conformity to this standard.

Note 1: It is possible to have systems communicating in different ways to this standard, for those systems this standard does not apply. E.g. in systems where all components of the PLC communication are from the same manufacturer.

Note 2: Not included in the scope of this standard are: DC shutdown initiator mechanism; disconnection and de-energization.

Note 3: It is not defined in this standard whether DC shutdown is a requirement at all.

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.

- SunSpec Communication Signal for Rapid Shutdown, Version 40
- SunSpec Communication Signal for Rapid Shutdown Test specification, Version 19
- IEC63027: DC arc detection and interruption in photovoltaic power systems (in progress)
- IEC62548: Photovoltaic (PV) arrays - Design requirements

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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>

Table 1 – List of abbreviations

AFD	Arc Fault Detector
AFPE	Arc Fault Protection Equipment
AGC	Automatic Gain Control
CDMA	Code Division Multiple Access
CSMA	Carrier Sense Multiple Access
MLE	Module Level Electronics
MLPE	Module Level Power Electronics
MLSD	Module Level Shutdown Device
PLC	Powerline Communication
PS	Power Supply
PV	Photovoltaic
RCMU	Residual Current Monitoring Unit
RSD	Rapid Shutdown Device
RSS	Rapid Shutdown System
S-FSK	Spread Frequency Shift Keying
SNR	Signal to Noise Ratio

3.1 Components

Equipment intended to be used in a PV Rapid Shutdown System to initiate, disconnect or isolate the controlled conductors of a PV system.

3.2**Communication Protocol**

Formal descriptions of digital message formats and rules.

3.3**Initiation Device / Initiator**

A manual or automatic switching device, input port or signal that will result in the activation of the Rapid Shutdown System function(s).

3.4**PV Power Source**

A dc array or aggregate of arrays that generates dc power.

3.5**Receiver**

The equipment that is responsible for accepting the communication signal sent by a Transmitter and is capable of initiating a state change of PV power source components based on the signal received (see Section 5.1 of this document).

3.6**System**

System made up of components intended to disconnect, isolate or attenuate the controlled conductors of a PV system.

3.7**Rapid Shutdown System**

Collection of Components and Communication Protocols that are used to fulfil rapid shutdown requirements. Components of a rapid shutdown communication system are Initiator(s), Transmitter(s), and Receiver(s).

3.8**Transmitter**

The equipment that is responsible for sending a communication signal that reflects the current state of the Initiation Device (see Section 5.1 of this document).

4 Power Line Communication Systems**4.1 Introduction to PLC**

Since the beginning of the electrification of households and the industry there has also been the need for Data communication so Power Line communication has an over hundred year history. It started with ripple control with very low frequencies (<2kHz) back in the early 1900s to switch street lights on and off and is nowadays capable of GBit/s transmissions with cheap plug in adapters that use frequencies from 2 MHz up to 300MHz for in home use.

As the calculation power of Microprocessors or Microcontrollers now reaches levels which were unimaginable at the beginning of the computer era (thanks to Moore's law) we can now have a myriad of carriers each with different complex modulation schemes and error correcting codes so we can reach the goal of a transmission system that operates nearly at the Shannon limit with very high data rates or very robust data transmission.

4.2 PLC Operational considerations

The main goal of this standard is to keep the complexity of the specification low so the implementation can be done in a cost effective way. Unnecessary human interaction or complexity is to be avoided if possible.

113 For this reason a very common, robust and easy modulation technique, Spread Frequency Shift
114 Keying (S-FSK) is used. Additionally Barker codes ensure robustness against noise and false
115 signal detection.

5 DC-Shutdown System Configuration

A DC-Shutdown system comprises components and communication protocols to fulfil system safety requirements.

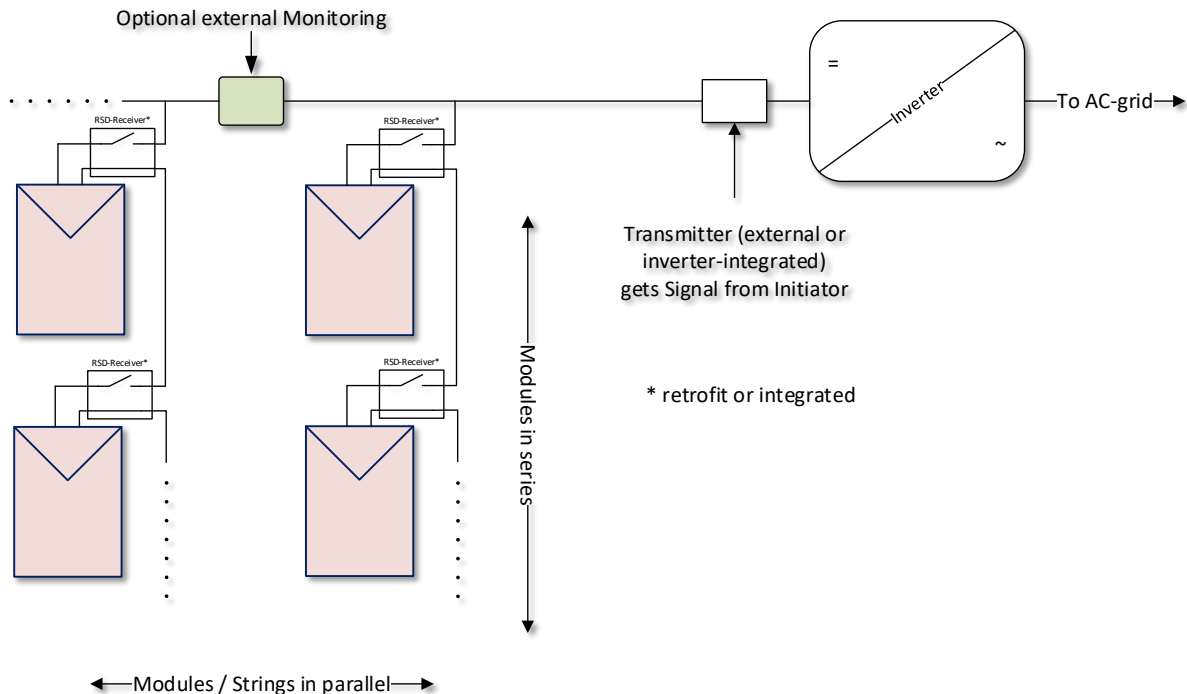


Figure 1 – DC-Shutdown System

5.1 System Setup

A system shall have at least one initiator and one transmitter and several receivers for the Shutdown signal. The receivers can also incorporate a Transmitter for sending status information back to the Inverter / Shutdown-Transmitter.

5.2 Operational Considerations

Shutdown Systems shall provide a mechanism to bring the PV system(s) back online after a shutdown event.

6 Operating modes

Two modes of operation are defined for a Shutdown system, Active-mode and Shutdown-mode.

In Active-mode the system generates power and operates unimpeded from the Shutdown system. This mode is active as long as the initiator is set to “on”. As the initiator is set to “off” the system shall change into the Shutdown-mode in a certain amount of time as specified in 6.4 –Table 2. The change from Shutdown-mode to Active-mode shall be done in a certain amount of time specified as TS in Table 2 .

6.1 Active Mode

No restrictions are placed on PV-generators. The system shall monitor the Initiator for a change in operating state.

6.2 Shutdown mode

In Shutdown-Mode the system needs to limit the power and voltage of the DC-system.

6.3 Standby Signal

When in Shutdown-mode each PV-module receiver can output a standby-signal. If a standby-signal is used it shall be a low voltage, low current signal as defined in Annex A.

6.4 Mode Transitions

As the PV-system has to be de-energized in a certain period of time, e.g. 30s, each Subsystem has to get a share of the total time to facilitate the process steps needed to do this.

A typical process can be considered as the following sequence of events:

- T1: Initiator signals shutdown mode to Shutdown-Transmitter
- T2: Shutdown-Transmitter stops sending the periodical permission to operate signal.
- T3: Receiver / MLE disconnects / de-energizes all PV Power Sources
- T4: Inverter stored charge is eliminated

The timing requirements can be found in table 2.

Table 2 – Timing requirements for Mode Transitions

Symbol	Mode Specification	Min.	Max.	Unit	Remark
T1	Time for Initiator to relay to Transmitter	NA	2	s	
T2	Time for Transmitter to stop sending permission to operate signal	NA	2	s	
T3	Time for receiver to switch off / de-energize PV-power sources	NA	13	s	
T4	Time for Inverter stored charge to be eliminated	NA	13	s	
TT	Total time T1+T2+T3+T4	NA	30	s	
TS	Time for the MLE to switch on PV-Power sources	NA	20	s	

7 Power Line Communication Requirements

7.1 Crosstalk

A big challenge in many communication systems, especially with PLC is Crosstalk. Crosstalk means that a (PLC-)signal on one line/wire is influencing a signal/channel on another line/wire that is not galvanically connected. Crosstalk is usually caused by unwanted capacitive and/or inductive coupling and can either lead to deteriorated signal reception or to unwanted behaviour due to misinterpreted signals. In a PV-system it is very common that the DC-wires of the modules are put together in conduits. If there are DC-wires from different inverters put together in one conduit the wires will run in parallel so Crosstalk is inevitable. If a communication system uses broadcast messages (unaddressed messages) than even receivers that are not directly connected with the Transmitter can receive the broadcasted message.

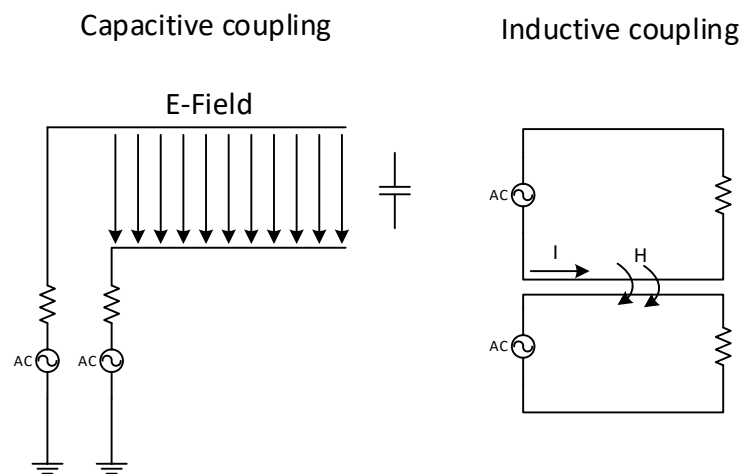


Figure 2 – Capacitive and inductive coupling

7.2 Crosstalk mitigation

There are two ways of coping with Crosstalk. Physically, by preventing signal coupling through shielding and/or better wiring practices or by implementing suitable protocols. A combination of both can be useful.

7.2.1 Physical Crosstalk mitigation

It is important that the wiring in the system is done according to applicable safety standards. By obeying to those rules (in e.g. IEC62548) and the points listed below, the system will be more robust against overvoltage from indirect lightning, will have lower EMI radiation and also have less crosstalk.

- The DC+ and DC- cables from one string shall be put as close together as possible. This reduces the loop area and therefore minimize the unwanted radiation of signals. See Figure 3 below.
- Cables going from the inverter to the PV-modules shall be placed in a metal-conduit that is connected to earth.
- Cables from different inverters shall be bundled in different conduits.
- Do not make loops with excessive wire.

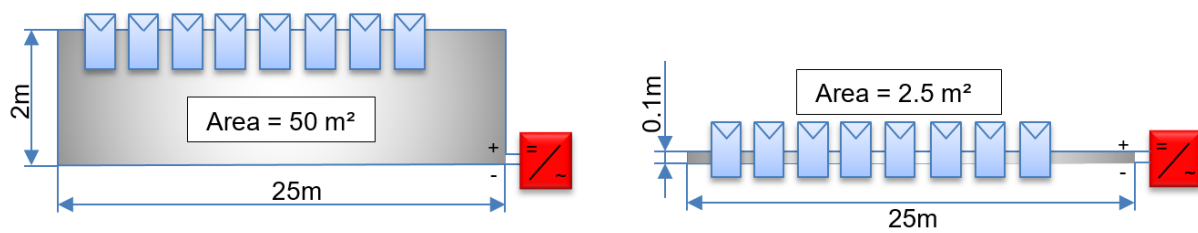


Figure 3 – Example of String cabling

See Annex E for more examples.

7.3 Physical layer aspects

The Transmitter uses the DC-Power Lines to transmit a signal to the receivers of the (Sub-)system. The Transmitters continuously send a “permission to operate” signal if the initiator is set to “permission to operate”. As long as the receivers get this signal they are allowed to put power on the DC-Lines. When the transmitter ceases to send this “permission to operate” signal, the receivers shall enter shutdown mode.

7.4 Transmitter

The Transmitter broadcasts a permission to operate signal using S-FSK modulation. The Transmitter shall have a well-defined output impedance and shall be capable of driving low impedance loads.

7.4.1 Requirements for the Transmitter:

- 7.4.1.1** Transmitter(s) shall continuously send a cyclical code sequence, which includes 'permission to operate' when an Initiator indicates rapid shutdown is not active, corresponding to the code sequences defined in Table 7.
- 7.4.1.2** Transmitter(s) shall have an output impedance in the range specified for Z_{OUT} in the transmission frequency band F_M to F_S .
- 7.4.1.3** Transmitter(s) shall provide an open circuit output voltage in the range specified for V_{TX} .
- 7.4.1.4** Transmitter(s) shall transmit permission to operate signal using a mark and space tone frequency of F_M and F_S respectively.
- 7.4.1.5** Transmitter(s) shall maintain the transmission of a mark or a space tone for TS duration.
- 7.4.1.6** Transmitter(s) shall transmit 'permission to operate' signals according to a fixed duty cycle defined by an integer number of consecutive transmitted code words followed by an integer number of zero-energy code words.
- 7.4.1.7** Transmitter(s) shall maintain phase coherency when transitioning between mark and space tones.
- 7.4.1.8** Transmitter(s) shall maintain S-FSK tone frequencies (F_M and F_S) and effective bit rate (RS) to within a ± 100 ppm tolerance when in operation inclusive of allowances for temperature and aging.
- 7.4.1.9** Transmitter(s) shall ensure that the S-FSK tone frequencies and the effective bit rate remain proportional to each other for variations within their permitted tolerances.

Transmitter Out-of-Band Emission Requirements

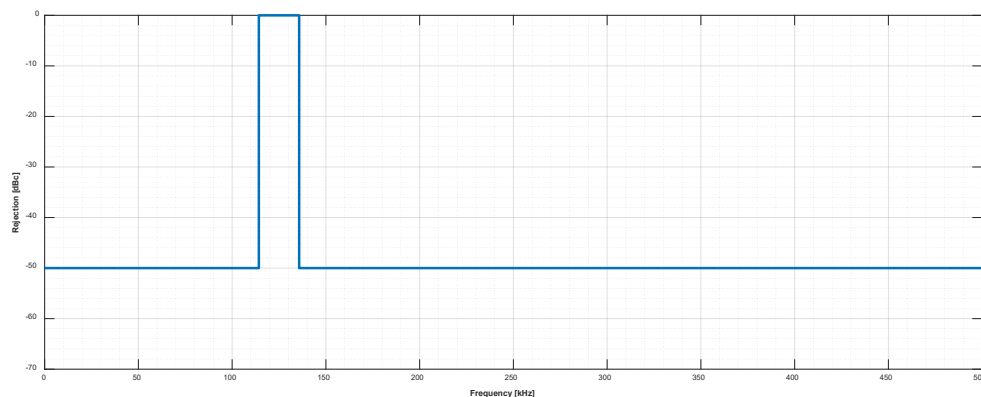
The Transmitter(s) shall not generate spurious out-of-band signals that could interfere with other communication systems or with PV system components like MPP tracker or AFPE.

- 7.4.1.10** The Out-of-Band spurious frequency components shall not exceed the levels defined in Table 3 and depicted in Figure 3.

Table 3 – Out-of-Band Spectral Mask Parameters

Out-of-Band Spectral Mask						
		$F_S-4,5$	$F_S-4,5$	$F_m+4,5$	$F_M+4,5$	
F (kHz)	0	114,25	114,25	135,75	135,75	500
P (dBc)	-50	-50	0	0	-50	-50

Figure 4 – Out-of-Band Spectrum Mask



7.4.1.11 Transmitter In-Band Emission Requirements

To ensure easy separation of the carriers in the demodulator, the In-band spectrum of the two FSK carriers shall be limited.

- In-Band frequency components shall not exceed the levels defined in Table 4 and depicted in Figure 3.

Table 4 – In-Band Spectral Mask Parameters

In-Band Spectral Mask					
F-Fc (kHz)	$-50 < F \leq -4,75$	$-4,75 < F \leq -0,75$	$-0,75 < F \leq 0,75$	$0,75 < F \leq 4,75$	$4,75 < F \leq 50$
P (dBc)	-50	Linearly rising to 0	0	Linearly falling to -50	-50

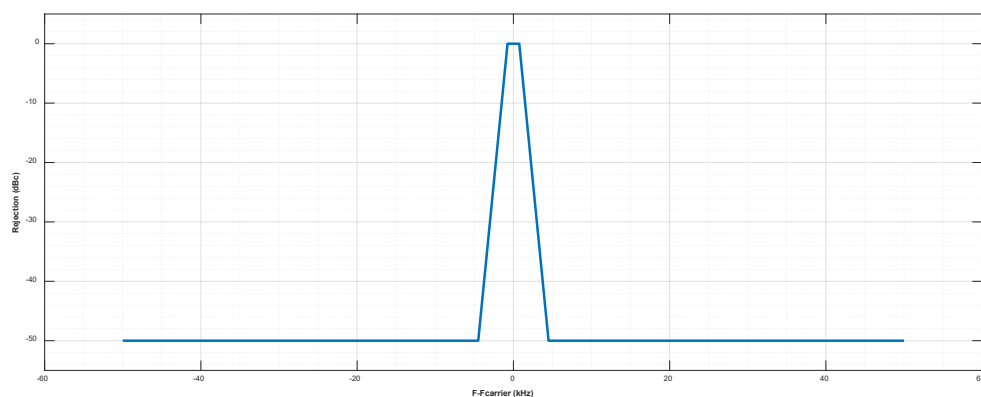


Figure 5 – In-Band Spectral Mask

If the Transmitter is integrated into an inverter than the measurement of the Transmitter Emission shall be done when the inverter is in Standby. The emission of the inverter during Standby or feed in operation shall not interfere with the Power Line communication therefore it is mandatory that the Switching Frequency of the inverter (also of the integrated DC/DC converters) and the resulting spurious emissions don't fall into the communication band of the PLC.