November 1, 2020

Communication Signal for Rapid Shutdown Intellectual Property Prior Art Study

Abstract

This document is a reference to the sources of the prior art that are incorporated in the SunSpec *Communication Signal for Rapid Shutdown* specification.

Non-Disclosure Restriction

About The SunSpec Alliance

The SunSpec Alliance is a trade alliance of developers, manufacturers, and service providers, together pursuing information standards for the distributed energy industry. SunSpec standards address most operational aspects of PV and other distributed energy power plants on the smart grid—including residential, commercial, and utility-scale systems—thus reducing cost, promoting innovation, and accelerating industry growth. More than 120 organizations are members of the SunSpec Alliance, including global leaders from Asia, Europe, and North America. Membership is open to corporations, non-profits, and individuals. For more information about the SunSpec Alliance, or to download SunSpec specifications free of charge, please visit www.sunspec.org.

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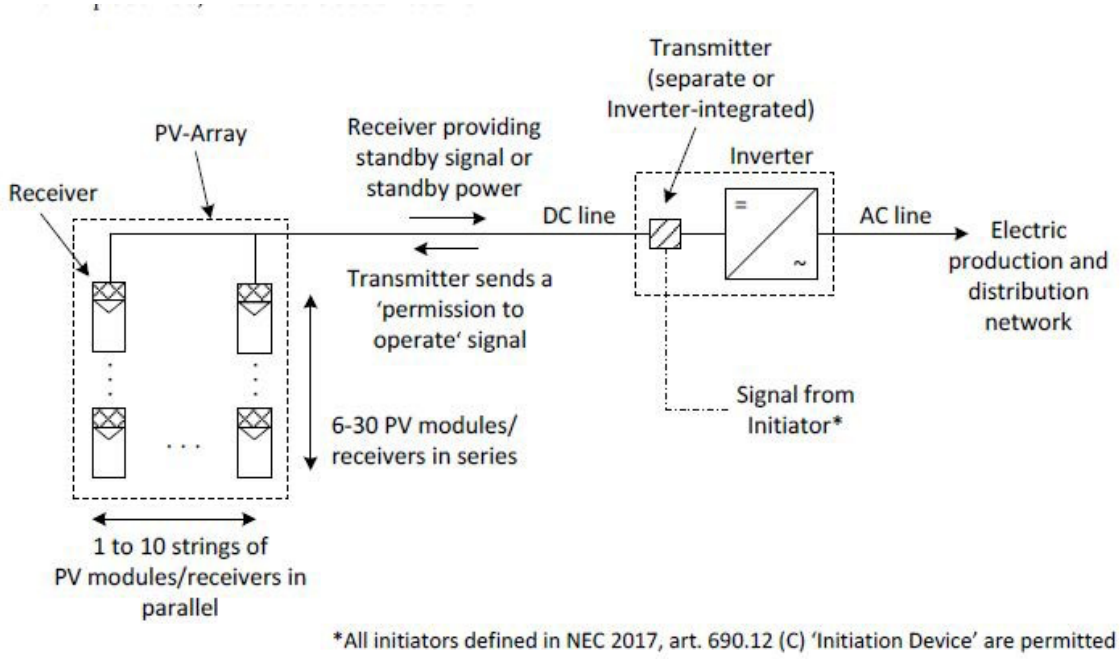
Executive Summary

This document is a collection of prior art, assembled by members of the SunSpec Alliance, compiled for the purpose of establishing that the technology comprising the SunSpec Communication Signal for Rapid Shutdown (SunSpec RSD) standard was invented or discovered years or even decades ago and are in the public domain.

The document is divided into twelve chapters: one for each of the primary technologies incorporated into the SunSpec RSD standard. Each chapter provides references to prior art. Presenting the information in this way was done to help the reader pinpoint the references without needing to read the entire source document.

The diagram below was excerpted from the SunSpec RSD specification:



For each reference, the name of the document (patent, textbook, international standard, or vendor-supplied documents) is given.

Chapter 1: Permission to Operate Signal

A “Permission to Operate” signal is generated and transmitted by a transmitter which is typically integrated in an inverter that is connected to a PV array built up of a plurality of PV modules.

When a receiver located at each of the PV modules continues to detect the "Permission to Operate" signal, it issues an "on" signal for the PV module to remain in active state. The “on” signal generated by the receiver is used to control a switch, which connects the PV module to a string. When the receiver located at each of the PV modules fails to detect the "Permission to Operate" signal, the “on” signal ceases and the PV module is disconnected from the string.

The "Permission to Operate" signal is the fundamental feature of a SunSpec rapid shutdown system.

The following pages gives examples of how this technology has been used in solar power generation systems.

The following patents (US6650031B1, DE102005018173A1, JP2001189476A, FR2894401A1) are examples of the use of a **Permission to Operate Signal** in a solar technology application.

US6650031B1

Earliest publication date: 2000-04-06 (WO)

Note: although US6650031B1 is related to a use of the disclosed system and method for anti-theft protection, the features of the disclosed system and method quite as well read exactly on the features of the SunSpec rapid-shutdown system and method

Relevant sections in US6650031B1 concerning Permission to Operate Signal

(All relevant sections are also highlighted in the supplied source materials)

Abstract

"interrupts the transfer, via a power line, of energy generated by the solar module to the consumer if the interruption device does not receive, … a second signal from the release device"

Column 2, lines 6 – 9

"The security system in accordance with the invention stops by advantageous ways and means the power output when the solar module-sited disabling device fails to receive a second signal…"

Column 4, lines 23 – 30

"The solar module-sited disabling device 3 is configured such that when it fails to receive a response to a first signal it has sent … from the consumer-sited enabling device 11, i.e. when not receiving a second signal from the consumer-sited enabling device 11 then the power generated by the solar cell array 2 transmitted to the consumer 8, 9 and 10 via the power transfer lines 6 and 7 is disabled."

Column 5, lines 36 – 47

"If the detector 23 for receiving the second signal receives a second signal … then a user authorization code, i.e. a consumer having consumer-sited enabling device 11 is connected to the solar module 1 and thus the power transfer is not disabled. When the detector 23 for receiving the second signal fails to receive a second signal … then the detector 23 outputs a corresponding signal to the activator means 21 so that the activator means 21 activates the switching device 22 such that the power transfer is disabled."

Claim 1

“a solar module-sited disabling device, adapted to be coupled to the power output terminal of the solar module, … a consumer-sited enabling device adapted to be coupled to the power input terminal of the consumer, and adapted … to transmit a second signal to the solar module-sited disabling device … and wherein the solar module-sited disabling device is configured to disable transfer of the power generated by the solar module to a consumer when the solar module-sited disabling device fails to receive the second signal ...”

Claim 6

“transmitting a second signal to the solar module … the second signal comprising a user authorization code; … verifying that the consumer is authorized to obtain power from the solar module, based on the second signal; and enabling power transfer from the solar module to the consumer; and disabling the power transfer when any one of the second signal is not received within a predetermined time period and the consumer is not authorized to obtain power.”

Claim 9

“A disabling device, disposed at a power output terminal of a solar module, the power output terminal being coupled to a power input terminal of a consumer via a power transfer line which enables power transfer from the solar module to the consumer, comprising: … a detector that receives a second signal … a switching device that disables the power output of the solar module when activated; and an activator device that activates the switching device when the detector fails to receive the second signal ....”

Claim 15

“An enabling device, disposed at a power input terminal of a consumer, the power input terminal being coupled to a power output terminal of a solar module via a power transfer line that enables power transfer from the solar module to the consumer, comprising: … an emitter adapted to transmit a second signal to the solar module …”

DE102005018173A1

Earliest publication date: 2006-10-26 (DE)

Relevant section in DE102005018173A1 concerning Permission to Operate Signal

(All relevant sections are also highlighted in the supplied source materials)

Claim 3

“The reactivation of the generator field (13) takes place via the control signal (18) or an additional control line without intervention in the protective device (17).”

JP2001189476A

Earliest publication date: 2001-07-10 (JP)

Relevant sections in JP2001189476A concerning Permission to Operate Signal

(All relevant sections are also highlighted in the supplied source materials)

Paragraph [0011]

“The solar cell device starts output of the converter by receiving a start signal from an external device connected to the converter.”

Paragraph [0018] - [0019]

“As shown in FIG. 3, the output of the arrow B from the converter 5 is started by receiving the start signal of the arrow A from the start signal transmitter 8 of the external device such as the inverter 3 connected to the converter 5.

Although the solar cell module receives light such as sunlight and generates power, in the solar cell device of the present invention, the operation of the converter is performed until a start signal transmitted from an inverter or the like connected to the output side of the converter is received. It is controlled so that it stops and keeps no output.”

Paragraph [0023]

“Also, since the output of the converter is started by receiving a signal from an external device connected to the converter, there is no output from the solar cell device during connection work, etc.”

Claim 2

“The output from the converter is started by receiving a start signal from an external device.”

FR2894401A1

Earliest publication date: 2007-06-08 (FR)

Relevant sections in FR2894401A1 concerning Permission to Operate Signal

(All relevant sections are also highlighted in the supplied source materials)

Page 3, lines 18 - 26

“According to the invention, to the electrical circuit in question is also coupled a transmitter, intended to periodically send an alternating signal intended to be picked up by a receiver controlling the circuit switch, to induce the opening or closing of the latter.

In other words, the invention consists in sending by any means an alternating signal of specific characteristics (for example frequency and / or determined amplitudes), suitable for being picked up by the receiver present at the level of the circuit, to control the opening or closing the circuit.”

Page 5, lines 9 – 10 and lines 20 - 22

“each of the modules includes an electronic switch (4), 10 and in the present case a field effect transistor,…”

“According to the invention, the operation of this transistor is controlled by a receiver (5) capable of inducing the opening or closing of said switch (4) as a function of a coded signal transmitted in the form of an alternating signal on the power circuit (1).”

Page 6, lines 1 – 6

“the transmitter (7) … stops the periodic emission of the alternating coded signal on the circuit (1), whose l absence identified by the receivers (5) induces the opening by the latter of the corresponding switches (4), so that the circuit (1) becomes de-energized,”

Claim 1

“Device for controlling an installation for producing electrical energy comprising a plurality of photovoltaic modules (3) mounted in series and / or in parallel and coupled to an electrical circuit (1) supplying a storage battery electricity (13) or power supply for one or more electric receivers, or even capable of being connected to the power supply network (9), said circuit integrating an electric switch (4) capable of neutralizing the electric power available in output of the power terminals of said modules (3), characterized in that the device comprises a transmitter (7), electrically supplied from the circuit, and intended to periodically send an alternating signal (8), intended to be picked up by a receiver (5) controlling the circuit switch (4), to induce the opening or closing of the latter.”

Chapter 2: Shutdown Signal

The "Shutdown" signal is considered as an alternative or additional measure to the "Permission to Operate" signal. This signal is likewise typically generated and transmitted by an inverter that is connected to a PV array built up of a plurality of PV modules.

When a receiver located at each of the PV modules detects the "Shutdown" signal, it issues an "off" signal for the PV module to change to shutdown mode. The “off” signal generated by the receiver is used to control a switch, which connects the PV module to a string. In response to an "off" signal, the PV module is disconnected from the string.

In the SunSpec Rapid Shutdown Communication Signal standard the “Shutdown” signal is used as an optional additional measure.

The following pages gives examples of how this technology has been used in solar power generation systems.

The following patents (DE102005018173A1, DE10136147A1) are examples of the use of a **Shutdown Signal** in a solar technology application

DE102005018173A1

Earliest publication date: 2006-10-26 (DE)

Relevant sections in DE102005018173A1 concerning Shutdown Signal

(All relevant sections are also highlighted in the supplied source materials)

Paragraph [0005]

“After triggering the protective device according to the patent, the generator field is switched to short circuit or idle and the energy transfer to the building is interrupted”

Paragraph [0008]

“The invention relates to a switching device (FIG. 1) (17) which switches the generator field into a low-energy operating point on request via a control line (FIG. 1) (18)”

Claim 1

“A protective device (17), which is expediently installed in the immediate vicinity of the generator field (13) inside or outside the building and short-circuits the generator field (13) via a control signal (18), which can be triggered manually or automatically.”

Claim 2

“switches the generator field (13) to the idle operating point.”

DE10136147A1

Earliest publication date: 2003-02-20 (DE)

Relevant section in DE10136147A1 concerning Shutdown Signal

(All relevant sections are also highlighted in the supplied source materials)

Paragraph [0025], lines 45 – 77

“Switching off the power controller 1 as a function of switching commands that are received by the central inverter 40 via the busbar 30.”

Chapter 3: Standby Signal / Standby Power

Standby power is electrical power used by appliances and equipment while switched off or not performing their primary function, often waiting to be activated by a triggering device, like a remote controller. The term is often used for any device that continuously must use a small amount of power even when not active.

In a SunSpec Rapid Shutdown System, when in shutdown mode, the Receiver will provide a Standby Signal to indicate the presence of irradiance. Furthermore, it is possible for Receiver(s) to provide enough Standby Power to supply both the Standby Signal and the “permission to operate” circuitry (e.g. the Transmitter or signal generator and a circuit which measures and signals the Shutdown operation) from the illuminated PV generator. This prevents a deadlock with purely PV powered systems. With this feature no AC supply is needed to power up the system.

According to the SunSpec RSD specification, the standby signal shall be a non-zero output voltage and current within the range allowed by NEC Article 690.12 (B)(2). This provides for the following benefits:

Reduced power consumption during the night: The presence of the standby signal of the Receivers indicates the presence of daylight. It allows to turn-off the permission to operate signal of the Transmitter overnight and reduces thereby the power consumption of the system.

Ease of installation: The installer can verify the correct polarity, the count of modules per string, the string associated wires etc. without a special tool to inject the permission to operate signal. He has the additional benefit of working on safe voltage levels and limited power.

The following pages explain how this technology has been used in solar communication technology.

The following patents (US6650031B1, JP2000174307A, FR2894401A1) are examples of the use of **Standby Signal / Standby Power** in a solar technology application

US6650031B1

Earliest publication date: 2000-04-06 (WO)

Note: although US6650031B1 is related to a use of the disclosed system and method for anti-theft protection, the features of the disclosed system and method quite as well read exactly on the features of the SunSpec Rapid Shutdown system and method.

Relevant sections in US6650031B1 concerning Standby Signal / Standby Power

(All relevant sections are also highlighted in the supplied source materials)

Abstract

"The interruption device transmits a first signal to the release device …"

Column 2, lines 10 – 11

"… after having sent a first signal to the consumer-sited enabling device ..."

Column 3, lines 57 – 66

"When the solar cell array 2 generates no power, e.g. at night, no voltage is available at the inputs of the solar module-sited disabling device 3. In this case the solar module-sited disabling device 3 has no 60 power supply and is OFF.

when the solar cell array 2 generates power, then the solar module-sited disabling device 3 receives a voltage supply via the output leads 4 and 5 of the solar cell array 2 and sends a first signal or first code to the consumer-sited enabling device."

Column 5, lines 33 – 36

"Once the first signal has been sent by these ways and means the solar module-sited disabling device assumes a standby condition for a first predefined period of time."

Claim 1

"a solar module-sited disabling device … that transmits a first signal; a consumer-sited enabling device adapted … to receive the first signal and to transmit a second signal to the solar module-sited disabling device when the receipt of the first signal is detected …"

Claim 6

"… transmitting a first signal to the consumer; transmitting a second signal to the solar module when the receipt of the first signal is detected, …"

Claim 9

"… an emitter that transmits a first signal … "

Claim 15

"… a detector adapted to detect receipt of a first signal from the solar module … and an emitter adapted to transmit a second signal to the solar module … when the detector detects receipt of the first signal."

JP2000174307A

Earliest publication date: 2000-06-23 (JP)

Relevant sections in JP2000174307A concerning Standby Signal / Standby Power

(All relevant sections are also highlighted in the supplied source materials)

Abstract

“When the output is not connected to the inverter (8), suppresses the output voltage of the circuit 50 to a level for safety operator or lower.”

Paragraph [0009]

“Diagnoses the connection of its own output to the grid-connected inverter, and when not connected, the output voltage of the power conversion circuit in the module is suppressed to a value that is safe for operation.”

Paragraph [0010]

“Suppress the voltage below a value that is safe for work, and set the output voltage to the normal operating voltage when connected.”

Paragraph [0011]

“The high voltage is not applied to the output terminal until the solar power generation module is actually fixed to the roof or other predetermined position and connected to the gridconnected inverter via the current collecting bus line.”

Paragraph [0014]

“The high voltage is not applied to the output terminal until the solar power generation module is actually fixed to the roof or other predetermined position and connected to the gridconnected inverter via the current collecting bus line.”

Paragraph [0032]

“Suppress the voltage to within 30 V in an unusual state such as installation work, and to output a high voltage of 30 V or more when it is confirmed that the power supply is correctly installed.”

Paragraph [0041]

“(here, set to 5V)”

Paragraph [0047]

“High voltage is not applied to the output terminal until it is connected to the inverter”

Claim 1

“Suppressing the output voltage of the power conversion circuit in the module to a safe value or less when not connected,”

FR2894401A1

Earliest publication date: 2007-06-08 (FR)

Relevant sections in FR2894401A1 concerning Standby Signal / Standby Power

(All relevant sections are also highlighted in the supplied source materials)

Page 5, lines 27 - 28

“a transmitter (7) supplied with electricity upstream … of the inverter (6).”

Chapter 4: Powerline Communications

Power Line Communication (PLC) enables data communication over electrical power lines. PLC operates by modulating a carrier signal into power cables. PLC applications vary in size or application.

For the purpose of understanding, PLC can be broadly viewed as:

- Narrowband PLC
- Broadband PLC

Narrowband PLC works at lower frequencies (3-500 kHz) and lower data rates (up to hundreds of kbps). Broadband PLC works at higher frequencies (1.8-250 MHz) and higher data rates (up to hundreds of Mbps).

Power Line Communication is used in a range of applications including smart grid, Home Area Networking, multimedia distribution, last-mile Internet access, transportation, and solar PV systems.

According to the SunSpec RSD specification, the Transmitter, typically integrated in the inverter, communicates with all Receivers, typically attached to the PV modules, over Power Line Communications.

This article from EE Times in 2011 provides a concise summary of the technology and market https://www.eetimes.com/what-is-power-line-communication/#.

The following pages explain how this technology has been used in solar communication technology.

The following patents (US6650031B1, JP2001189476A, DE10136147A1, FR2894401A1, US8264195B2) are examples of the use of **power line communication** in a solar technology application

US6650031B1

Earliest publication date: 2000-04-06 (WO)

Note: although US6650031B1 is related to a use of the disclosed system and method for anti-theft protection, the features of the disclosed system and method quite as well read exactly on the features of the SunSpec Rapid Shutdown system and method

Relevant sections in US6650031B1 concerning power line communication

(All relevant sections are also highlighted in the supplied source materials)

Abstract

“transmits a first signal to the release device via a power line and ... if the interruption device does not receive, via said power line, a second signal ...”

Column 2, lines 8 - 11

“... receive a second signal via the power line ... having sent a first signal ... via the power line.”

Column 3, line 67; Column 4, lines 7 - 8

“this may be done via the power transfer lines”

Column 7, lines 43 - 45

“a second signal is transmitted ... via the power transfer lines 6 and 7 to the solar module.”

Column 8, lines 64 - 67

“so that it generates a train of short-circuit marks and spaces corresponding to the second signal ... on the power transfer lines 6 and 7.”

Claim 1

“a power transfer line that extends between a power output terminal of the solar module and a power input terminal of the consumer, ... a solar module-sited disabling device, ... that transmits a first signal; a consumer-sited enabling device ... adapted to receive the first signal and to transmit a second signal to the solar module-sited disabling device when the receipt of the first signal is detected; wherein the power transfer line carries the first and second signals, ...”

Claim 9

... the power output terminal being coupled to a power input terminal of a consumer via a power transfer line which enables power transfer from the solar module to the consumer, comprising: an emitter that transmits a first signal via the power transfer line; a detector that receives a second signal via the power transfer line; ...

Claim 15

... the power input terminal being coupled to a power output terminal of a solar module via a power transfer line that enables power transfer from the solar module to the consumer, comprising: a detector adapted to detect receipt of a first signal from the solar module via the power transfer line; and an emitter adapted to transmit a second signal to the solar module via the power transfer line ...

JP2001189476A

Earliest publication date: 2001-07-10 (JP)

Relevant sections in JP2001189476A concerning power line communication

(All relevant sections are also highlighted in the supplied source materials)

Paragraph [0012]

“The communication of the start signal is performed by the output line of the converter.”

Paragraph [0020]

“As shown in FIG. 4, the start signal can be received by using the output line of the converter 5, that is, the output line may be used as a signal line.”

Paragraph [0024]

“Since the communication of the start signal is performed through the output line of the converter, a dedicated line for communication is not required, and the wiring work can be simplified.”

Claim 3

“An output line from the converter is also used as a signal line for receiving a start signal from the external device.”

DE10136147A1

Earliest publication date: 2003-02-20 (DE)

Relevant sections in DE10136147A1 concerning power line communication

(All relevant sections are also highlighted in the supplied source materials)

Paragraph [0015], lines 53 - 57

“The converted direct voltage (intermediate circuit voltage) on the busbar 30 serves as a carrier for the transmission of measurement and control signals from and to the solar modules 10a to 10n or their DC-DC converters 20a to 20n.”

Paragraph [0021], lines 43 - 47

“The busbar 30 or the intermediate circuit voltage applied to it represents a communication network between the solar modules 10a to 10n and their DC-DC converters 20a to 20n, on the one hand, and the central inverter 30, on the other hand, which is completely decoupled from the AC network.”

Paragraph [0024], lines 9 - 10

“Data communication via a modem”

Claim 6

“that the increased intermediate circuit DC voltage as a carrier signal for the transmission of control commands to the DC voltage converters (20a to 20n) and of measurement data on operating parameters of the solar modules (10a to 10n) from the DC voltage converters (20a to 20n) is provided.”

Claim 13

“a modem (8) for decoupling control commands from the intermediate circuit DC voltage and for coupling measurement data to the DC link DC voltage.”

FR2894401A1

Earliest publication date: 2007-06-08 (FR)

Relevant sections in FR2894401A1 concerning power line communication

(All relevant sections are also highlighted in the supplied source materials)

Page 4, lines 1 - 2

“said periodic signal can also be superimposed on the direct current carrier flowing in the power or use circuit.”

Claim 2

“the periodic signal (8) is transmitted ... by superposition on direct current. traversing the circuit (1).”

US8264195B2

Earliest publication date: 2010-04-01 (US)

This patent application filed on Oct. 1, 2008 clearly stated that PLC was already a well-known communication technology to monitor and control solar panel array

Relevant sections in US8264195B2 concerning power line communication

(All relevant sections are also highlighted in the supplied source materials)

Column 2, lines 24 – 29

“Another method known in the art for establishing communications between nodes in a control and monitoring network is referred to as power line communications (PLC). PLC technology includes interface circuits for coupling data to be transmitted from a data source onto an electrical power transmission line. “

Power Line Communication Products

There are many products with Power Line Communication available in the market, as shown in the following table of collateral found on the Texas Instruments website:

Part Name	Release Date	Description	Link
Applications Report	2013	Implementation of FSK Modulation and Demodulation using CD74HC4046a	http://www.ti.com/lit/an/slaa618/slaa618.pdf
Applications Report	1996	Teaching DSP through the Practical Case Study of an FSK Modem	http://www.ti.com/lit/an/spra347/spra347.pdf
Applications Report	2011	Analog Front-End Design for a Narrowband Power-Line Communications Modem Using the AFE031	http://www.ti.com/lit/an/sboa130a/sboa130a.pdf
Literature	2012	Efficiency from Metering and Service Solutions (* Covers both PLC and FSK)	http://www.ti.com/lit/ml/slyt495/slyt495.pdf
TI Designs	2014	TI G3 Power Line Communication Developer's Kit Design Guide	http://www.ti.com/lit/ug/tidu237/tidu237.pdf
TI Designs	2018	Power Line Communication Using RS-485 Simulation Reference Design	http://www.ti.com/lit/ug/tiduei9/tiduei9.pdf
User's Guide	2005	TMS320C2000™ Digital Signal Controller Power Line Communication	http://www.ti.com/lit/ug/spru714/spru714.pdf
Technical Article	2014	Configurable AFEs change the future of power line communications	https://e2e.ti.com/blogs_/b/analogwire/archive/2014/06/05/configurable-afes-change-the-future-of-power-line-communications?keyMatch=POWER%20LINE%20COMMUNICATION&tisearch=Search-EN-everything
Technical Article	2010	Power Line Communications (PLC) on a Worldwide Tour	https://e2e.ti.com/blogs_/archives/b/smartgrid/archive/2010/08/12/power-line-communications-plc-on-a-worldwide-tour?keyMatch=POWER%20LINE%20COMMUNICATION&tisearch=Search-EN-everything
Datasheet	2010	TMS320F2806x Microcontrollers	http://www.ti.com/lit/ds/symlink/tms320f28069.pdf
Datasheet	2010	AFE031 Powerline Communications Analog Front-End	http://www.ti.com/lit/ds/symlink/afe031.pdf

Table 2: FSK and PLC Communication Collateral at TI Website April 8, 2020

Chapter 5: Watchdog Timer

According to Wikipedia, “A watchdog timer is an electronic timer that is used to detect and recover from computer malfunctions.” In computing, the terms “watchdog” and heartbeat are often used interchangeably. According to PC Magazine, “heartbeat” is defined as: “A periodic signal generated by hardware or software to indicate that it is still running.” The watchdog timer was patented in 1995 (US5513319A) by engineers from Dell computer. This patent has since expired.

The SunSpec standard meets perfectly the “heartbeat” definition described above wherein a microprocessor (embedded in a solar inverter) communicates with another microprocessor (embedded in a PV module) to indicate that it is still running.

The following pages explain how this technology has been used in solar communication technology.

The following patent (US6650031B1) is an outstanding example of the use of the **watchdog function** in a solar technology application

US6650031B1

Earliest publication date: 2000-04-06 (WO)

Note: although US6650031B1 is related to a use of the disclosed system and method for anti-theft protection, the features of the disclosed system and method quite as well read exactly on the features of the SunSpec Rapid Shutdown system and method

Relevant sections in US6650031B1 concerning watchdog function

(All relevant sections are also highlighted in the supplied source materials)

Abstract

“if the interruption device does not receive, ... a second signal from the release device within a specified first period.”

Column 2, lines 6 – 11

“... when the solar module-sited disabling device fails to receive a second signal ... within a first predefined time ...”

Column 5, lines 36 – 38, lines 42 - 44

“If the detector 23 for receiving the second signal receives a second signal within the first predefined period of time ... When the detector 23 for receiving the second signal fails to receive a second signal within the first predefined time duration ...”

Claim 1

“... when the solar module-sited disabling device fails to receive the second signal within a predetermined time period.”

Claim 6

“... when any one of the second signal is not received within a predetermined time period ...”

Claim 9

“... when the detector fails to receive the second signal within a predetermined time period.”

Watchdog Products

There are many products with watchdog functionality available in the market, as shown in the following two tables of datasheets and application notes by Texas Instruments:

Part Name	Releas Date	Description	Link
TPS3813XXX	2000	Voltage supervisor (reset IC) with programmable window watchdog	http://www.ti.com/lit/ds/symlink/tps3813.pdf
TPS3123	2011	Supply Voltage Supervisor with Watchdog Timer and Manual Rese	http://www.ti.com/lit/gpn/tps3123
TPS3851	2016	High-Accuracy Voltage Supervisor With Integrated Watchdog Timer	http://www.ti.com/lit/ds/symlink/tps3851.pdf
TPS3852	2016	High-Accuracy Voltage Supervisor with Programmable Window Watchdog Timer	http://www.ti.com/lit/ds/symlink/tps3813.pdf
TPS3431	2018	Standard Programmable Watchdog Timer with Enable	http://www.ti.com/lit/ds/symlink/tps3431.pdf
TPS3124	1999	Supply Voltage Supervisor with Watchdog Timer	http://www.ti.com/lit/ds/symlink/tps3124.pdf
TPS382XFamily	1998	Voltage supervisor (reset IC) with watchdog and manual reset	http://www.ti.com/lit/ds/symlink/tps3824.pdf
UCC3946	1997/ 2007	Microprocessor Supervisor with Watchdog Timer	http://www.ti.com/lit/ds/symlink/ucc3946.pdf
TPS3850	2016	Precision window supervisor for OV & UV monitoring with window watchdog timer & programmable delay	http://www.ti.com/lit/ds/symlink/tps3850.pdf
TPS3430	2018	Window Watchdog Timer with Programmable Reset Delay	http://www.ti.com/lit/ds/symlink/tps3430.pdf
TPS7B63-Q1	2017	Automotive 300mA 40V High-Voltage Ultra-Low-Quiescent-Current Watchdog LDO	http://www.ti.com/lit/ds/symlink/tps7b63-q1.pdf
TPL5000	2013	Nano Power Programmable Timer with Watchdog Functionality	http://www.ti.com/lit/ds/symlink/tpl5000.pdf
TPL5010	2015	Ultra-low power timer with watchdog functionality & manual reset	http://www.ti.com/lit/ds/symlink/tpl5010.pdf
UCC2946-Q1	2004/ 2009	Automotive 2.1V to 5.5V Microprocessor Supervisor with Watchdog Timer	http://www.ti.com/lit/ds/symlink/ucc2946-q1.pdf
TPS3305	1998/ 2008	Dual Processor Supervisory Circuit with Watchdog Timer	http://www.ti.com/lit/ds/symlink/tps3305.pdf
TPS3306	2000/ 2006	Dual-Processor Supervisory Circuit with Power-Fail and Watchdog Timer	http://www.ti.com/lit/ds/symlink/tps3306.pdf
TPS3813K33-EP	2006	Enhanced Product Processor Supervisory Circuits with Window-Watchdog	http://www.ti.com/lit/ds/symlink/tps3813k33-ep.pdf
TCAN1146-Q1	2019	Automotive enhanced CAN FD and high-speed CAN transceiver with selective wake, Watchdog, and LIMP	http://www.ti.com/lit/ds/symlink/tcan1146-q1.pdf
TPS386000	2009/ 2018	Quad Supply Voltage Supervisors with Programmable Delay and Watchdog Timer	http://www.ti.com/lit/ds/symlink/tps386000.pdf
TPS3128	1999/ 2011	Supply Voltage Supervisor with Watchdog Timer and Manual Reset	http://www.ti.com/lit/ds/symlink/tps3128.pdf
UCC3946	1997	Microprocessor Supervisor with Watchdog Timer	http://www.ti.com/lit/ds/symlink/ucc3946.pdf
MSP430FR68X	2014	MSP430 Mixed-Signal Microcontroller	https://www.ti.com/lit/ds/symlink/msp430fr6989.pdf
MSP430FR58X	2014	MSP430 Mixed-Signal Microcontroller	https://www.ti.com/lit/ds/symlink/msp430fr6989.pdf

Table 3: TI watchdog products

Part Name	Release Date	Description	Link
User's Guide	2016	Evaluation module for the TPS3813-Q1 processor supervisory circuit with window watchdog	http://www.ti.com/lit/ug/sprui96/sprui96.pdf
User's Guide	2018	TPS3431EVM Standard Programmable Watchdog Timer with Enable	http://www.ti.com/lit/ug/snvu614/snvu614.pdf
User's Guide	2012	The watchdog timer is a 32-bit timer that can be used as a watchdog or as an interval timer	http://www.ti.com/lit/ug/slau399f/slau399f.pdf
Application Report	2003	Disabling the watchdog timer for TI's family of Supervisors	http://www.ti.com/lit/an/slva145/slva145.pdf
Application Report	2018	Voltage Supervisors (Reset ICs): FAQ	http://www.ti.com/lit/an/slvae47/slvae47.pdf
Application Report	1998	TPS382X Microprocessor Supervisory Circuits with Watchdog Function	http://www.ti.com/lit/an/slva039/slva039.pdf
User's Guide	2011	TIDM-Energy-Watchdog Single-Phase Electricity Sub-meter for Smart Buildings	http://www.ti.com/lit/ug/slau362a/slau362a.pdf
Evaluation Module	2018	TPS3431EVM Standard Programmable Watchdog Timer with Enable	http://www.ti.com/lit/ug/snvu614/snvu614.pdf
Evaluation Module	2017	TPS7B63xx-Q1 Watchdog LDO EVM	http://www.ti.com/lit/ug/slvuaz6/slvuaz6.pdf
Application Report	2009	All Window-Watchdog Supervisors	http://www.ti.com/lit/an/slva365/slva365.pdf
User's Guide	2012/2017	MSP430FR68X User's Guide	https://www.ti.com/lit/ug/slau367o/slau367o.pdf
Training Material	2006	MSP430 Timers In Depth	Not at TI Website
Technical Notes	2017	External Programmable Watchdog Timer Using MSP430 MCUs	http://www.ti.com/lit/an/slaa789/slaa789.pdf
Application Report	2007	Catalog TMS470 Watchdogs	http://www.ti.com/lit/an/spna108/spna108.pdf
Technical Notes	2019	Voltage Supervisors and Reset ICs: Tips, Tricks and Basics	http://www.ti.com.cn/cn/lit/ml/slyy167/slyy167.pdf
User's Guide	2009	TMS320C5515/14/05/04/VC05/VC04 DSP Timer/Watchdog Timer	Not at TI Website

Table 4: TI watchdog application notes

Chapter 6: Initiator

An Initiator is the equipment that is responsible for initiating the rapid shutdown mechanism in the System.

According to the SunSpec RSD specification, the term Initiator, in this context, is defined in the 2017 National Electrical Code (NEC), article 690.12 (C).

The following pages show examples on how an initiator has been used for rapid shutdown in solar technology applications.

The following patents (FR2894401A1, DE102005018173A1) are examples of the use of **an initiator for rapid shutdown** in a solar technology application

FR2894401A1

Earliest publication date: 2007-06-08 (FR)

Relevant sections in FR2894401A1 concerning power line communication

(All relevant sections are also highlighted in the supplied source materials)

Page 4, lines 13 - 17

“Advantageously, the transmitter is provided with means suitable for receiving remote control signals, such as for example a radio wave receiver, or a telephone network switch, in order to allow remote control of the installation, and in particular its inhibition, for example in the event of non-payment of maintenance invoices.”

Page 7, lines 15 – 22

“According to an advantageous version of the invention, still within the framework of the installation implemented in an isolated site, the transmitter (7) is provided with receiving or communication means, capable of allowing remote reception of instructions. These instructions can thus be sent over the air or by the telephone network. These instructions can order the transmitter to induce the opening of switches, for example due to the failure to pay maintenance invoices.”

Claim 8

“the transmitter (7) is provided with means suitable for receiving remote control signals intended to control the emission alternating periodic signals, these means being able to be constituted by a hertzian wave sensor, or a switch to the telephone network, and in general, any means of sending signals remotely.”

DE102005018173A1

Earliest publication date: 2006-10-26 (DE)

Relevant sections in DE102005018173A1 concerning power line communication

(All relevant sections are also highlighted in the supplied source materials)

Paragraph [0006]

“Rescue workers can activate the protective device remotely using key switches or other devices; people in the building can do this using emergency switches. Activation can also take place via existing warning systems such as fire, water or gas alarm systems.”

Claim 1

“Manual triggering can take place via emergency switches or key switches in or outside the building, automatic triggering via smoke, water, gas sensors or other switching devices located in or outside the building.”

Chapter 7: Optional Data

According to the SunSpec RSD specification, apart from the “Permission to Operate” signal and the “Shutdown” signal, further optional data can be transmitted via the PLC link between the transmitter and the receiver in a PV system.

The following page explains how this technology has been previously used in solar communication technology.

The following patent (US6650031B1) is an example of the use of **optional data in PLC** in a solar technology application

US6650031B1

Earliest publication date: 2000-04-06 (WO)

Note: although US6650031B1 is related to a use of the disclosed system and method for anti-theft protection, the features of the disclosed system and method quite as well read exactly on the features of the SunSpec rapid-shutdown system and method

Relevant sections in US6650031B1 concerning optional data in PLC

(All relevant sections are also highlighted in the supplied source materials)

Column 5, lines 24 - 33

"This train of pulses comprises at lease one, but preferably a plurality of short-circuit pulses in sequence on the power line. … It is by these ways and means that information of many different kinds can be transferred with the first signal by the information being communicated for example, by means of trains of short-circuit marks and spaces (PPM modulation)."

Column 9, lines 7 - 10

"by means of the first and second signals a plurality of information signals can be exchanged between the solar module-sited portion and the consumer-sited portion"

Chapter 8: Transmitter Placement

The electrical and electronic components comprising a solar inverter are contained in sheet metal, die cast, or other type of enclosures of varying sizes and dimensions. As functions and components are added to the bill of materials, the enclosure is sized appropriately to contain all of the components then in use.

The SunSpec RSD specification contains no normative requirements pertaining to the size, shape or placement of the Transmitter, and therefore the placement of the transmitter is irrelevant to system design. The SunSpec RSD specification does contain informative text in an illustration that references Transmitter placement.

The following prior art is an example of the use of the transmitter in a solar technology application. The term “integrated microprocessor” in the passage below is functionally equivalent to the term “transmitter” used in the SunSpec specification:

DE10136147A1

Paragraph [0014]

... The integrated microprocessor in the inverter 40 also acts as the "master" for communication with the DC-DC converters 20a to 20n and forms the interface to optionally provided devices, namely a personal computer 50, a modem 60 and / or a large-screen display 70.

Chapter 9: Spectrum Choice / Collisions

The SunSpec RSD specification utilizes a frequency range for power line communication in the range of radio frequencies as its fundamental communication medium.

The use of frequencies in the range of radio communication is governed by regulatory agencies in the U.S., Europe, China, and Japan. Some frequencies are “licensed.” This means that a governmental agency grants the rights to use a particular frequency range to specific parties in specific geographic regions. Other frequencies are “unlicensed.” This means that any party may use the specified frequency range without need for payment or license and without guarantee that others may also be using the same frequency at the same time.

The table below shows the regions of the world, the regulatory agency for that region, and the power line communications (PLC) frequency ranges that are regulated (and unregulated).

Narrowband PLC frequency ranges for various regions

Region	Regulatory Body	Frequency Band	Note
Europe	CENELEC	3-95kHz	A – Energy providers
		95-125kHz	B –Reserved for users
		125-140kHz	C – Reserved for users, regulated CSMA access
		140-148.5kHz	D –Reserved for users
Japan	ARIB	10-450kHz	
China	EPRI	3-90kHz	Not Regulated
		3-500kHz	
USA	FCC	10-490kHz	

When more than one frequency is in use, the spectra of the signals may overlap. Spectrum choice allows one to choose the nominal frequency, to avoid overlapping.

Frequency conflicts, where spectra overlap, are also knowns as “spectrum collisions.” Collisions can cause phase cancelations. If the nominal frequency is moved, so that collisions do not occur, the communication improves between the devices.

Because of the fundamental requirement to manage spectrum collisions, standards were formed covering various geographic regions and frequency ranges. The table below provides a summary of spectrum-related standards that are relevant to PLC.

PLC technology classification on the basis of data rate

	Low Data Rate	Medium Data Rate	High Data Rate
Data Rate	0-10kbps	10kbps-1Mbps	>1Mbps
Modulation	BPSK, FSK, SFSK, QAM	PSK+OFDM	PSK+OFDM
Standards	IEC 61334, ANSI/EIA 709.1, .2, UPB	PRIME, G3, P1901.2	G.hn, IEEE 1901
Frequency range	Upto 500kHz frequency	Upto 500kHz	In MHz
Applications	Contol and Command	Control and command, Voice	Broadband over powerline, home networking

SunSpec Communication Signal for Rapid Shutdown fits into the “low data rate” category shown in this table.

The following pages give the background information on which the operating frequency (and spectra) for the SunSpec Rapid Shutdown Standard have been chosen.

EN50065-1

Signaling on low voltage electrical installations in the frequency range 3 kHz to 148,5 kHz – Part 1: General requirements, frequency bands and electromagnetic disturbances

CISPR 11 Ed.6

The limits at the DC-Ports for Class B Devices is given in Table 5:

Frequency	Quasi-Peak Limit
150kHz – 500kHz	84-74 dBµV (decreasing linearly with the log. of frequency)
500kHz – 30MHz	74 dBµV

Table 5

This gives a limit of 5mV on the DC lines of a PV installation.

Below 150kHz: no Regulation

FCC: Rationale from 47 CFR 15

§15.107 Conducted limits.

(c) The limits shown in paragraphs (a) and (b) of this section shall not apply to carrier current systems operating as unintentional radiators on frequencies below 30 MHz. In lieu thereof, these carrier current systems shall be subject to the following standards: (3) Carrier current systems operating below 30 MHz are also subject to the radiated emission limits in §15.109(e).

§15.109 Radiated emission limits.

(e) Carrier current systems used as unintentional radiators or other unintentional radiators that are designed to conduct their radio frequency emissions via connecting wires or cables and that operate in the frequency range of 9 kHz to 30 MHz, including devices that deliver the radio frequency energy to transducers, such as ultrasonic devices not covered under part 18 of this chapter, shall comply with the radiated emission limits for intentional radiators provided in §15.209 for the frequency range of 9 kHz to 30 MHz. As an alternative, carrier current systems used as unintentional radiators and operating in the frequency range of 525 kHz to 1705 kHz may comply with the radiated emission limits provided in

§15.221(a). At frequencies above 30 MHz, the limits in paragraph (a), (b), or (g) of this section, as appropriate, apply.

§15.113 Power line carrier systems.

Power line carrier systems, as defined in §15.3(t), are subject only to the following requirements:

(a) A power utility operating a power line carrier system shall submit the details of all existing systems plus any proposed new systems or changes to existing systems to an industry-operated entity as set forth in §90.35(g) of this chapter. No notification to the FCC is required.

(b) The operating parameters of a power line carrier system (particularly the frequency) shall be selected to achieve the highest practical degree of compatibility with authorized or licensed users of the radio spectrum. The signals from this operation shall be contained within the frequency band 9 kHz to 490 kHz. A power line carrier system shall operate on an unprotected, non-interference basis in accordance with

§15.5 of this part. If harmful interference occurs, the electric power utility shall discontinue use or adjust its power line carrier operation, as required, to remedy the interference. Particular attention should be paid to the possibility of interference to Loran C operations at 100 kHz.

§15.205 Restricted bands of operation.

(a) Except as shown in paragraph (d) of this section, only spurious emissions are permitted in any of the frequency bands listed below:

MHz	MHz	MHz	GHz
0.090-0.110	16.42-16.423	399.9-410	4.5-5.15
0.495-0.505	16.69475-16.69525	608-614	5.35-5.46
2.1735-2.1905	16.80425-16.80475	960-1240	7.25-7.75
4.125-4.128	25.5-25.67	1300-1427	8.025-8.5
4.17725-4.17775	37.5-38.25	1435-1626.5	9.0-9.2
4.20725-4.20775	73-74.6	1645.5-1646.5	9.3-9.5
6.215-6.218	74.8-75.2	1660-1710	10.6-12.7
6.26775-6.26825	108-121.94	1718.8-1722.2	13.25-13.4
6.31175-6.31225	123-138	2200-2300	14.47-14.5
8.291-8.294	149.9-150.05	2310-2390	15.35-16.2
8.362-8.366	156.52475-156.52525	2483.5-2500	17.7-21.4
8.37625-8.38675	156.7-156.9	2690-2900	22.01-23.12
8.41425-8.41475	162.0125-167.17	3260-3267	23.6-24.0
12.29-12.293	167.72-173.2	3332-3339	31.2-31.8
12.51975-12.52025	240-285	3345.8-3358	36.43-36.5
12.57675-12.57725	322-335.4	3600-4400	(2)
13.36-13.41			

§15.209 Radiated emission limits; general requirements.

(a) Except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

Frequency (MHz)	Field strength (microvolts/meter)	Measurement distance (meters)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30.0	30	30
30-88	100**	3
88-216	150**	3
216-960	200**	3
Above 960	500	3

Chapter 10: Frequency Shift Keying (FSK)

Frequency shift keying (FSK) is used to transmit digital information by switching a carrier between two or more discrete frequencies. Binary FSK has two frequencies. M-ary FSK has more than two frequencies.

Binary FSK consists of two frequencies; the *mark* which is noted as (1) and the *space*, which is noted as (0). The center between these two frequencies is called the center deviation. This is also called shift, and where we get the name frequency shift keying. Pagers are the most common application, but FSK is also used in Bluetooth and DECT.

M-ary FSK has been used since the 1960's, especially in 2-way radios.

The SunSpec RSD specification uses the Spread Frequency Shift Keying (S-FSK) principle, which is a modulation and demodulation technique combining some of the advantages of a classical spread spectrum system, i. e., immunity against narrowband interferences with the advantages of a classical FSK system, low-complexity, and well-investigated implementations. The Transmitter must provide the Receiver(s) with signals at satisfactory level for demodulation. It must develop sufficient power on a given load impedance and must have a well-defined output impedance.

Frequency Shift Keying was described in detail by:

1. J.G. Proakis, *Digital Communications*, New York: McGraw-Hill, 1989.

2. Hendrik C. Ferreira, Lutz Lampe, John Newburry, Theo G. Swart, *Power Line Communications Theory and Applications for Narrowband and Broadband Communications over Power Lines*, John Wiley & Sons First Edition 2010, ISBN 978-0-470-74030-9, Chapter 5.2.4 *Frequency Shift Keying*.

The following pages will document how this technology has been commonly used in communication technology for decades.

ELSEVIR Science Direct

According to an article on **Frequency Shift Keying (FSK)** in ELSEVIR Science Direct, FSK was Introduced by Fessenden in the "*early 20th century*"

Relevant sections in ELSEVIR Science Direct concerning Frequency Shift Keying

(All relevant sections are also highlighted in the supplied source materials)

Source: ELSEVIR Science Direct
https://www.sciencedirect.com/topics/engineering/frequency-shift-keying
Downloaded / accessed on Apr. 02, 2020

Page 1 in PDF: FSK_Science-direct_.pdf

"9.2.1 Frequency Shift Keying

Frequency shift keying (FSK) was proposed in the early twentieth century by Fessenden [10], among others. In FSK, different frequencies are used to signal different messages."

Encyclopedia Britannica online

According to an article on **Frequency Shift Keying (FSK)** in Encyclopedia Britannica, FSK was Used by Bell in a Voiceband modem in 1962

Relevant sections in Encyclopedia Britannica online concerning Frequency Shift Keying

(All relevant sections are also highlighted in the supplied source materials)

Source: Encyclopedia Britannica online
https://www.britannica.com/print/article/585799
Downloaded / accessed on Apr. 02, 2020

Page 2 in PDF: Telecommunication -- Britannica Online Encyclopedia.pdf

“Frequency-shift keying

If frequency is the parameter chosen to be a function of the information signal, the modulation method is called frequency-shift keying (FSK). In the simplest form of FSK signaling, digital data is transmitted using one of two frequencies, whereby one frequency is used to transmit a 1 and the other frequency to transmit a 0. Such a scheme was used in the Bell 103 voiceband modem, introduced in 1962, to transmit information at rates up to 300 bits per second over the public switched telephone network. In the Bell 103 modem, frequencies of 1,080 +/- 100 hertz and 1,750 +/- 100 hertz were used to send binary data in both directions.”

The following IEC61334-5-1 standard gives the background information on the modulation scheme **Spread Frequency Shift Keying** (**S-FSK)** which was chosen for the SunSpec RSD specification.

IEC61334-5-1

Distribution automation using distribution line carrier systems

Second Edition 2001-05, Part 5-1:

"*Lower layer profiles – The Spread frequency shift keying (S-FSK) profile"*

Especially:

"Section 2 – Modulation: 2.1 Purpose

2.2 Spread Frequency Shift Keying (S-FSK) principle

2.3 Spreading"

Products using FSK

There are many products which use FSK available in the market, as shown in the following table of collateral found on the Texas Instruments website:

Part Name	Release Date	Description	Link
Applications Report	2013	Implementation of FSK Modulation and Demodulation using CD74HC4046a	http://www.ti.com/lit/an/slaa618/slaa618.pdf
Applications Report	1996	Teaching DSP through the Practical Case Study of an FSK Modem	http://www.ti.com/lit/an/spra347/spra347.pdf
Applications Report	2011	Analog Front-End Design for a Narrowband Power-Line Communications Modem Using the AFE031	http://www.ti.com/lit/an/sboa130a/sboa130a.pdf
Literature	2012	Efficiency from Metering and Service Solutions (* Covers both PLC and FSK)	http://www.ti.com/lit/ml/slyt495/slyt495.pdf
TI Designs	2014	TI G3 Power Line Communication Developer's Kit Design Guide	http://www.ti.com/lit/ug/tidu237/tidu237.pdf
TI Designs	2018	Power Line Communication Using RS-485 Simulation Reference Design	http://www.ti.com/lit/ug/tiduei9/tiduei9.pdf
User's Guide	2005	TMS320C2000™ Digital Signal Controller Power Line Communication	http://www.ti.com/lit/ug/spru714/spru714.pdf
Technical Article	2014	Configurable AFEs change the future of power line communications	https://e2e.ti.com/blogs_/b/analogwire/archive/2014/06/05/configurable-afes-change-the-future-of-power-line-communications?keyMatch=POWER%20LINE%20COMMUNICATION&tisearch=Search-EN-everything
Technical Article	2010	Power Line Communications (PLC) on a Worldwide Tour	https://e2e.ti.com/blogs_/archives/b/smartgrid/archive/2010/08/12/power-line-communications-plc-on-a-worldwide-tour?keyMatch=POWER%20LINE%20COMMUNICATION&tisearch=Search-EN-everything
Datasheet	2010	TMS320F2806x Microcontrollers	http://www.ti.com/lit/ds/symlink/tms320f28069.pdf
Datasheet	2010	AFE031 Powerline Communications Analog Front-End	http://www.ti.com/lit/ds/symlink/afe031.pdf

Table 6 (equals Table 2): FSK and PLC Communication Collateral at TI Website April 8, 2020

Chapter 11: Spread Spectrum

According to Wikipedia, Spread Spectrum techniques are defined as follows:

> *“In telecommunication and radio communication, spread-spectrum techniques are methods by which a signal (e.g., an electrical, electromagnetic, or acoustic signal) generated with a particular bandwidth is deliberately spread in the frequency domain, resulting in a signal with a wider bandwidth. These techniques are used for a variety of reasons, including the establishment of secure communications, increasing resistance to natural interference, noise, and jamming, to prevent detection, to limit power flux density (e.g., in satellite down links), and to enable multiple-access communications.*

Source: https://en.wikipedia.org/wiki/Spread_spectrum

In the SunSpec RSD Specification spread spectrum techniques are applied by encoding the binary information using Barker codes.

Spread Spectrum Systems were described in detail by Robert C Dixon in “*Spread Spectrum Systems*”, originally published in 1976.

The following pages explains how this technology has been used in solar communication technology.

The following publication (M. Nakagawa, 1994) is an example of the use of **Spread Spectrum** technology in power line communications

M. Nakagawa, 1994

"*Consumer communications based on spread spectrum techniques*"

Proceedings of IEEE 3rd International Symposium on Spread Spectrum Techniques and Applications (ISSSTA '94), Oulu, Finland, 1994, pp. 138-145 vol.1.

Relevant sections in (M. Nakagawa, 1994) concerning Spread Spectrum

(All relevant sections are also highlighted in the supplied source materials)

Page 138, Abstract

“Spread Spectrum Techniques; Power Line Communication”

Page 138, col. 2, par. 1

“The key technology for overcoming the poor transmission lines is Spread Spectrum”

Page 139, col. 2, par. 3

“The spread spectrum technique has been adopted to solve the above problems in power line communication. The first proposal using SS method was put forward by NEC in 1983[1]. A power line is utilized as a home bus connected with communication terminals, as shown in Fig.4. NEC Home Electronics Co., Ltd. has developed the spread spectrum power line home communication system whose specifications are shown in Table 1.”

Chapter 12: Barker Codes

According to Springer Computer Science and Communications Dictionary, 2001 Edition:

> *“Barker code:*
>
> *A binary code that (a) is suitable for pulse-code modulation (PCM) and synchronization, has optimal correlation properties, (c) is relatively immune to phase displacement, i.e., phase shifting, caused by random pulses immediately adjacent to the code patterns when compared to other codes, such as a code in which the pure binary numeration system is used, and (d) is relatively immune to phase displacement errors caused by the transmitter.”*

Source: Weik M.H. (2000) *Barker code*. In: *Computer Science and Communications Dictionary*. Springer, Boston, MA

In the SunSpec RSD Specification spread spectrum techniques are applied by encoding the binary information using Barker codes.

Barker codes were first described by H.R. Barker in 1953.

Source: R.H. Barker, “*Group Synchronizing of Binary Digital Sequences*”, In *Communication Theory*, London: Butterworth, 1953, pp.273-287