



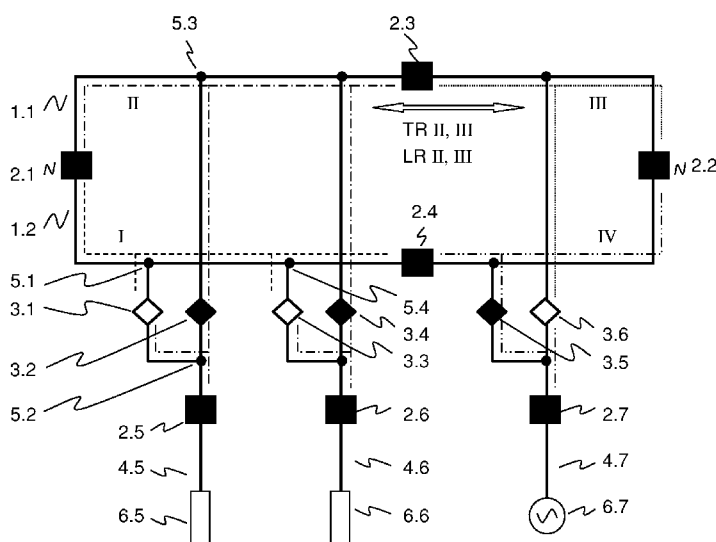
- (51) **International Patent Classification:**
H02H 7/26 (2006.01) *H02H 1/00* (2006.01)
- (21) **International Application Number:**
PCT/EP2010/057152
- (22) **International Filing Date:**
25 May 2010 (25.05.2010)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
09162631.7 12 June 2009 (12.06.2009) EP
- (71) **Applicant** (for all designated States except US): **ABB Technology AG** [CH/CH]; Affolternstrasse 44, CH-8050 Zürich (CH).
- (72) **Inventor; and**
- (75) **Inventor/Applicant** (for US only): **Wimmer, Wolfgang** [DE/CH]; Hinterdorf 220, CH-5323 Rietheim (CH).
- (74) **Agent:** **MEIER OBERTÜFER, Jürg**; ABB Patent Attorneys, c/o ABB Schweiz AG, Intellectual Property CH-LC/IP, Brown-Boveri-Strasse 6, CH-5400 Baden (CH).
- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) **Title:** PROTECTION LOCKOUT IN SUBSTATION AUTOMATION**Fig. 2**

(57) **Abstract:** The present invention is concerned with simplified engineering of protection lockout functionality in a Substation Automation (SA) system. Wiring complexity as well as supervision related engineering is replaced by including some protection-zone related intelligence into a lockout function block at a breaker IED. The main configuration effort then consists in assigning lockout function instances to respective protection zones, and in specifying for each protection function which protection-zone(s) it shall trip and reset after lockout. Hence for switch yard configurations and power networks where a protection function trips multiple breakers by using several bay control or protection devices a more efficient implementation of lockout functionality is possible.

DESCRIPTION

PROTECTION LOCKOUT IN SUBSTATION AUTOMATION

5

FIELD OF THE INVENTION

The invention relates to the field of Process Control systems, and in particular to Substation Automation SA systems, with a standardized configuration representation. More particularly, it relates to a method of implementing protection lockout functionality
10 within a distributed SA system.

BACKGROUND OF THE INVENTION

Substations in high and medium-voltage power networks include primary devices such as electrical cables, lines, bus bars, disconnectors, circuit breakers, power transformers and
15 instrument transformers, which are generally arranged in switch yards and/or bays. These primary devices are operated in an automated way via a Substation Automation (SA) system. The SA system comprises secondary devices, among which Intelligent Electronic Devices (IED) responsible for protection, control and monitoring of the primary devices. The secondary devices may be hierarchically assigned to a station level or a bay level of
20 the SA system. The station level often includes a supervisory computer comprising an Operator Work Station (OWS) with a Human-Machine Interface (HMI) and running a station-level Supervisory Control And Data Acquisition (SCADA) software, as well as a gateway that communicates the state of the substation to a Network Control Centre (NCC) and receives commands from it. IEDs on the bay level, also termed bay units, in turn are
25 connected to each other as well as to the IEDs on the station level via an inter-bay or station bus primarily serving the purpose of exchanging commands and status information.

A communication standard for communication between the secondary devices of a substation has been introduced by the International Electrotechnical Committee (IEC) as part of the standard IEC 61850 entitled "communication networks and systems in
30 substations". For non-time critical report messages, section IEC 61850-8-1 specifies the Manufacturing Message Specification (MMS, ISO/IEC 9506) protocol based on a reduced

Open Systems Interconnection (OSI) protocol stack with the Transmission Control Protocol (TCP) and Internet Protocol (IP) in the transport and network layer, respectively, and Ethernet and/or RS-232C as physical media. For time-critical event-based messages, such as trip commands, IEC 61850-8-1 specifies the Generic Object Oriented Substation Events (GOOSE) directly on the Ethernet link layer of the communication stack. SA systems based on IEC61850 are configured by means of a standardized configuration representation or formal system description called Substation Configuration Description (SCD).

The protection lockout function is a classical protection related function which prohibits a re-close of tripped circuit breakers until an authorized person has explicitly removed the lockout, e.g. after having inspected the switch yard and the secondary equipment to ensure that the cause of the preceding protection trip has been removed. Classically the lockout function is used for transformer protection trips, bus bar trips and breaker failure trips. The following functional requirements have to be fulfilled:

- Distribution to multiple relays that control affected breakers
- Presentation of state to local and remote operators
- Standard operating procedure to clear the lockout
- Non volatile state – the lockout state has to be stored in a way independent of power availability
- Independent handling of multiple lockouts of different protection functions on one and the same breaker

Conventionally, this function is solved by bi-stable relays in the closing circuit of the circuit breakers, which are set by the protection trip and generally reset manually. For each protection function respective protection zone which may trip the circuit breaker a separate bi-stable relay is provided at the breaker. However, for process bus based solutions, where the circuit breaker is controlled by some electronics integrated into it, an electronic reset of the lockout function would be preferred over a bi-stable relay.

The introduction of IEC 61850 with the GOOSE real time services offers the opportunity to replace the wiring to the circuit breakers by Ethernet based serial communication. The article (presented at Distributech 2009-02-03) entitled "The Application of IEC61850 to Replace Auxiliary Devices Including Lockout relays" by R.

Brantley, K. Donahoe, J. Theron and E. Udren, and available at the time of filing from www.ge-energy.com/prod_serv/plants_td/en/downloads/gtr_aiecradlrp.pdf, proposes a communication bus based solution as illustrated in Fig.1. The lockout function is implemented in the breaker IEDs 13 for each breaker, and blocks the Circuit Breaker Close (CC) path. It is triggered by the transformer (differential) protection function implemented in a transformer protection IED 11, and can be manually reset e.g. from a button or menu in the transformer protection IED 11. The trip command is transferred via a serial bus 12. In addition to the lockout of the transformer protection function, the breaker controlled by IED 13 can also be tripped with lockout from a breaker failure function or a bus bar protection function, needing additional lockout relays (RS-Flipflops) and making the logic at the close circuit more complex. This kind of configuration implemented via a bus, e.g. based on IEC 61850 communication protocols, therefore needs complex engineering to “logically wire” the trip signals across the bus, couple the lockout relays to the breakers close circuit, and also to show the lockout state of the system to the operator.

A protection function protects some primary object, may be a line, a transformer, or a busbar. A fault on the object is cleared by opening all circuit breakers surrounding this object and defining a so-called protection zone. Zones are electrically connected parts of the switchyard, which in general are limited by open disconnectors and open or closed circuit breakers. In case of a breaker failure protection being triggered by a failure of a particular circuit breaker, the trip is delegated to the circuit breakers of the protection zones connected to the left and right of the failed circuit breaker. Any closed circuit breaker is within two protection zones, one at its left side and one at its right side. The relation between circuit breakers and protection zones can be static as in ring configurations and 1 ½ breaker configurations, or is dynamically determined from the switchyard topology at single line level and by the current state of all disconnectors e.g. in case of double bus bar configurations.

Hence a circuit breaker needs at least two lockout relays, as long as redundant protection is not considered. As the breaker failure function will normally trip both zones right and left of a circuit breaker, a distinction between breaker failure protection and object related protection on behalf of an adjacent piece of primary equipment (transformer, line, bus bar) might require another lockout relay instance. Lockout reset will have to be arranged for on each relay instance separately. In the state of the art approach the trips

from each zone have to be physically or, with process bus, logically wired to all concerned breakers in a zone. For static configurations this might get complex if more than two breakers belong to a zone boundary. For dynamic zones this gets even more complex or nearly impossible.

5 EP 1819022 A1 aims at minimizing the potential damage caused by the failure of a single central Intelligent Electronic Device (IED) responsible for calculating, assigning and storing information about switchyard zones of a high or medium voltage switchyard comprising switchyard elements such as switches and connectivity nodes interconnected by lines. To this end, a distributed switchyard zone management is introduced, comprising
10 a distributed storage of the knowledge about the switchyard zones with assignments of individual switchyard elements or components to the various switchyard zones being stored on several IEDs. The switchyard zones considered primarily are either protection zones or equipotential zones, wherein the first comprise a number of switchyard elements that are to be isolated simultaneously in case of a failure of a primary device. The
15 boundary or circumference of a protection zone is defined by circuit breakers and open disconnectors. Specific ways of distributed zone calculation and reset message passing are likewise disclosed.

DESCRIPTION OF THE INVENTION

20 It is an objective of the invention to simplify the engineering as well as supervision and testing of a lockout functionality. This objective is achieved by a method of implementing protection lockout functionality in a Substation Automation (SA) system, as well as by an Intelligent Electronic Device (IED) according to the claims 1 and 6, respectively. Further preferred embodiments are evident from the dependent patent claims.

25 According to the invention, the above objective is achieved by removing wiring complexity as well as supervision related engineering, and by including some protection zone related intelligence into a lockout function block at the breaker IEDs instead. Hence, for switch yard configurations and power networks where a protection function trips multiple breakers by using several bay control or protection devices a more efficient
30 implementation of lockout functionality is possible.

The remaining main configuration effort consists in assigning lockout function instances to respective protection zones, and in specifying for each protection function which protection-zone(s) it shall trip and reset after lockout. Based thereupon, the lockout

function can evaluate all trip messages with their zone identification to determine if the breaker shall be tripped and the lockout set, or if the lockout function of the breaker is to be reset. The engineering effort is again reduced in case of system modifications such as connecting additional bays to the bus bars, where the zone related identifications of the old
5 respective unchanged parts may be retained.

A virtual lockout relay is represented by a lockout function block, instance, or module, shortly called lockout function. Each circuit breaker then is allocated two lockout functions for breaker failure protection, one to its right side and one to its left side, and optionally a further lockout function for object related protection on behalf of an adjacent piece of
10 primary equipment (transformer, line, bus bar). Each zone is uniquely identified by a zone ID or number, with each lockout function being aware of the zone to which it belongs. If an IED issues a protection trip to the communication system, it is accompanied by the zone ID of the protection zone to be tripped. If a breaker failure trip is issued, it is addressed to both zones to which the affected breaker is connected. This zone ID is then read and
15 recognized by the breaker control function allocated to the circuit breaker delimiting the respective protection zone. In addition, the lockout functions of the tripped circuit breakers are set, i.e. they block a re-close. The lockout state together with the zone ID can be communicated to a central place for an operator to get an overview about blocked zones as well as an easy means to remove the blockings. After clearance of the fault, with one single
20 command comprising the zone ID (in case of breaker failure both concerned zone IDs) an appropriate zone lockout reset message can be broadcast. The latter causes all lockout functions in the zone to reset, and may be generated locally at the breaker IED, at the protection IEDs, or even from a station level HMI.

The static zone identification respective the base identifications for a dynamic zone
25 calculation can be automatically determined from a formal description of the single line diagram e.g. as contained in an IEC 61850 SCD file. Each lockout function can be considered to be implemented as an IEC 61850 logical node instance, to be configured automatically by means of the appropriate zone identifier as well as the corresponding protection trip function, provided that these functions are allocated to the correct single line
30 elements in the SCD file as defined in IEC 61850-6. Furthermore, and based on SCL compliant information describing the SA system, the data flow of GOOSE type trip and lockout reset messages can be automatically configured.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter of the invention will be explained in more detail in the following text with reference to preferred exemplary embodiments which are illustrated in the attached drawings, in which:

- 5 Fig.1 schematically shows an electronic lockout relays according to the prior art; and Fig.2 shows a single line diagram of a switchyard with four protection zones.

The reference symbols used in the drawings, and their meanings, are listed in summary form in the list of reference symbols. In principle, identical parts are provided with the same reference symbols in the figures.

10

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig.2 depicts an electrical single-line diagram of a switchyard with an exemplary double busbar topology. The diagram comprises items or icons representative of various primary devices, such as bus bars 1, circuit breakers 2, disconnectors 3, line infeed or outgoing
15 conductors 4, nodes 5, and loads or generators 6. Devices of the same kind are distinguished via a continued decimal digit, i.e. 5.1 and 5.2 denote two distinct nodes. Generally, icons representative of open switches (disconnectors and breakers), are shown outlined, whereas switches that are in a closed state are represented as filled icons, for instance, a closed/open disconnector is depicted by a black/white rhomb. Obviously, other
20 topologies are conceivable, with or without bypass busses, and the topologies may comprise other primary devices such as power transformers, generators, earthing isolators and instrument transformers without limiting the applicability of the present invention. In the following, the distinction between the primary devices and their representation by icons or elements in the electrical line diagram on a drawing board, computer screen or other
25 display is neglected. Likewise, message or telegram exchange between elements or primary devices is to be understood as a communication between the respective IEDs of the SA system to which the elements are allocated and by which representations or instances of the primary device-objects are handled.

In detail, the topology depicted comprises two coupling circuit breakers 2.1, 2.2
30 separating two bus bars 1.1, 1.2, which in turn are divided in two sections by section circuit breakers 2.3, 2.4. Three bays are depicted, each comprising a bay circuit breaker 2.5, 2.6, 2.7 connected via conductors 4.5, 4.6, 4.7 to distant loads 6.5, 6.6 or a generator 6.7. The bay circuit breakers are each connectable to the two bus bars via two disconnectors 3.1,

3.2; 3.3, 3.4 and 3.5, 3.6. As mentioned above, protection zones are electrically connected parts of the switchyard which are delimited by open disconnectors and open or closed circuit breakers. The states of the disconnectors as depicted in Fig.2 give rise to four protection zones I, II, III, IV in the sense of the present invention, which are indicated by
5 broken lines of different patterns next to the sections of the bold-type single line diagram.

In the exemplary event of a breaker failure of circuit breaker 2.3, the circuit breakers 2.1, 2.5, 2.6 as well as 2.2, belonging to the two protection zones II and III adjacent to the failed circuit breaker, have to trip or open. Corresponding trip messages are propagated over the substation communication network to the IEDs controlling the respective circuit
10 breakers. As depicted by the block arrow in Fig.2, the failed circuit breaker sends a telegram TR II III with the breaker failure trigger and the IDs of the concerned zones to all circuit breakers. The above enumerated circuit breakers that are on the border of the concerned zones (left or right of the circuit breaker) will then trip without any further centralized input or action due to the fact that they know by themselves to which protection
15 zones they belong. When tripping, a breaker lockout function is set until, following clearance of the fault on circuit breaker 2.3, a lockout reset message LR II III with the previous zone IDs is received.

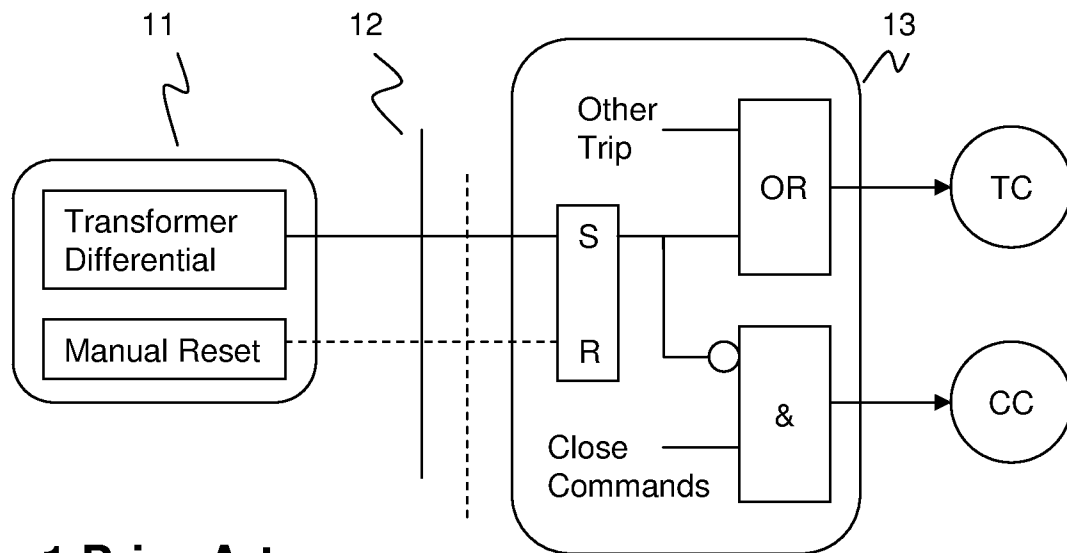
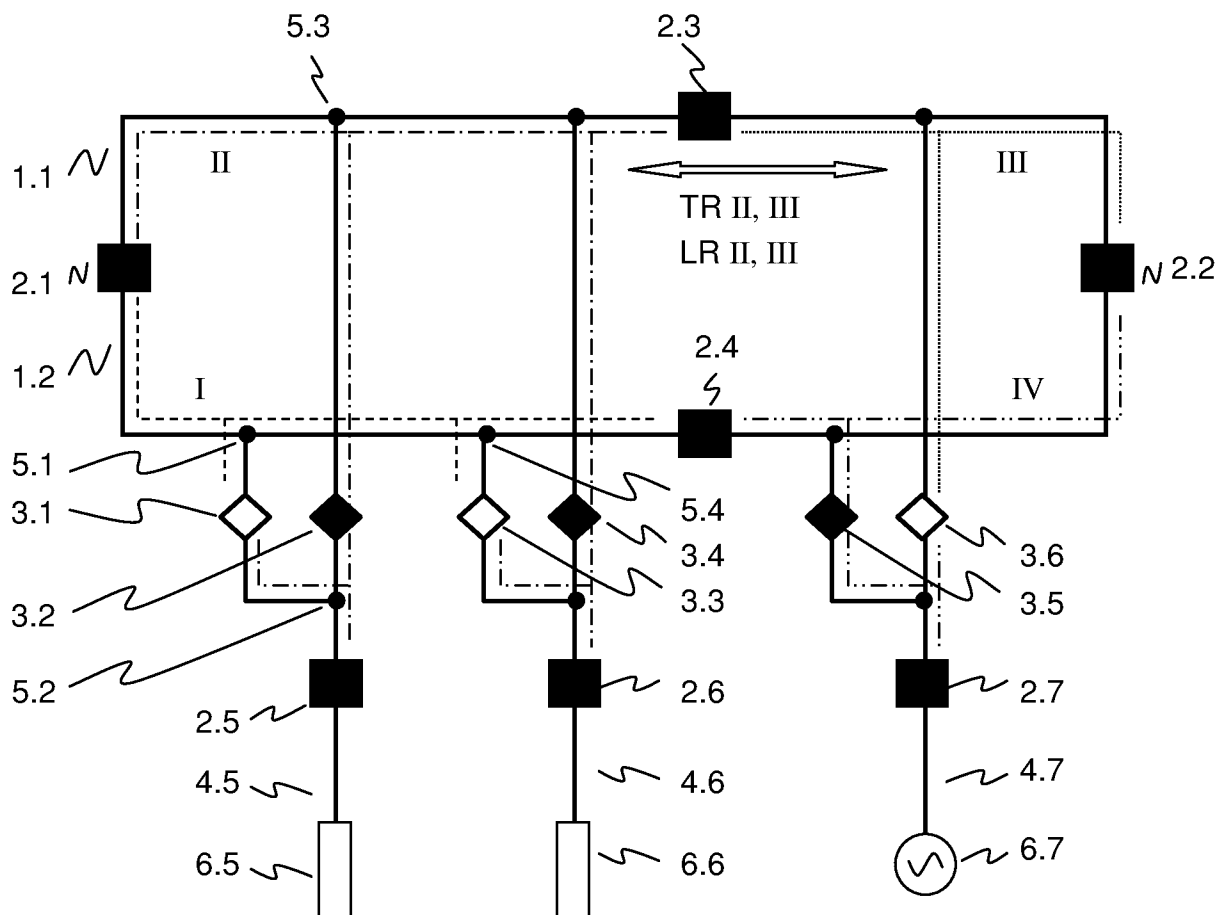
LIST OF DESIGNATIONS

20	1	bus bar
	2	circuit breaker
	3	disconnector
	4	feeder or outgoing conductor
	5	node
25	6	load
	11	protection IED
	12	SA communication network
	13	breaker IED

PATENT CLAIMS

1. A method of implementing protection lockout functionality in a Substation Automation
5 SA system for a substation of a power system with a first protection zone delimited by
first circuit breakers (2.1, 2.3, 2.5, 2.6), comprising
 - generating, for each of the first circuit breakers, a lockout function block configured
by a zone ID (II) indicative of the first protection zone,
 - broadcasting, by a SA protection function, a trip message (TR II) including the zone
10 ID, and
 - opening, upon reception of the trip message, the first circuit breakers and locking the
first circuit breakers for re-close.
2. The method according to claim 1, wherein the SA protection function is a Breaker
Failure BF protection of a second circuit breaker (2.3) of the substation, comprising
15 - broadcasting, by the BF protection function, a trip message (TR) including zone IDs
(II, III) of a first and second protection zone delimited by the second circuit breaker.
3. The method according to claim 2, comprising
 - broadcasting, following a breaker failure clearance, a lockout reset message (LR)
including the two zone IDs (II, III).
- 20 4. The method according to claim 1, comprising
 - updating, following a change in a dynamic topology of the substation, a protection-
zone identification.
5. The method according to claim 1, comprising
 - communicating a lockout state of all circuit breakers of the substation, together with
25 protection-zone identification, to an operator for display.
6. An Intelligent Electronic Device IED (13) for controlling a circuit breaker (2.1) in a
substation of a power system, adapted to receive and execute trip messages (TR) as
well as lockout reset messages (LR) including a zone ID (I, II) indicative of a
protection-zone of the substation delimited by the circuit breaker.
- 30 7. The IED according to claim 6, adapted to receive and execute trip as well as lockout
reset messages from different SA protection functions and including the same zone ID.

1/1

**Fig. 1 Prior Art****Fig. 2**

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/057152

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02H7/26 H02H11/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02H H02J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KASZTENNY B ET AL: "JEC 61850 - A Practical Application Primer for Protection Engineers" POWER SYSTEMS CONFERENCE: ADVANCED METERING, PROTECTION, CONTROL, COMMUNICATION, AND DISTRIBUTED RESOURCES, 2006. PS '06, IEEE, PI, 1 March 2006 (2006-03-01), pages 18-50, XP031102589	1-3,5-7
Y	ISBN: 978-0-615-13280-8 page 26, column II; figure 4 page 34, paragraph J; figures 9,10,A1 page 45, column II, paragraph 7 ----- -/--	4

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

27 September 2010

Date of mailing of the international search report

04/10/2010

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Colombo, Alessandro

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2010/057152

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	RECKERD D ET AL: "Application of Peer-to-Peer Communication, for Protection and Control, at Seward Distribution Substation" PROTECTIVE RELAY ENGINEERS, 2005 58TH ANNUAL CONFERENCE FOR TEXAS A&M UNIVERSITY, TEXAS, USA APRIL 5-7, 2005, PISCATAWAY, NJ, USA, IEEE, 5 April 2005 (2005-04-05), pages 40-45, XP010794859 ISBN: 978-0-7803-8896-3 paragraph [0III] -----	1
Y	EP 1 819 022 A (ABB TECHNOLOGY AG [CH]) 15 August 2007 (2007-08-15) cited in the application paragraphs [0012], [0018] - [0023]; figure 1 -----	4

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2010/057152

Patent document cited in search report		Publication date		Patent family member(s)		Publication date
EP 1819022	A	15-08-2007	WO	2007090302 A2		16-08-2007
			CN	101385213 A		11-03-2009
			US	2009005915 A1		01-01-2009
