

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
25 January 2007 (25.01.2007)

PCT

(10) International Publication Number
WO 2007/010083 A1

(51) International Patent Classification:
H04B 3/56 (2006.01)

(21) International Application Number:
PCT/FI2006/000255

(22) International Filing Date: 14 July 2006 (14.07.2006)

(25) Filing Language: Finnish

(26) Publication Language: English

(30) Priority Data:
20050766 18 July 2005 (18.07.2005) FI

(71) Applicant (for all designated States except US): **ABB OY**
[FI/FI]; Strömberingtie 1, FI-00380 Helsinki (FI).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **KOSONEN, Antti**
[FI/FI]; Miilukatu 2 B 17, FI-53850 Lappeenranta (FI).
AHOLA, Jero [FI/FI]; Punkkerinkatu 9 B 17, FI-53850
Lappeenranta (FI).

(74) Agent: **KORPELAINEN, Seppo**; ABB Oy, Legal Af-
fairs/Patents, P.O. Box 210, FI-00381 Helsinki (FI).

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,

AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN,
CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI,
GB, GD, GE, GH, GM, HN, HR, HU, ID, IL, IN, IS, JP,
KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT,
LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA,
NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC,
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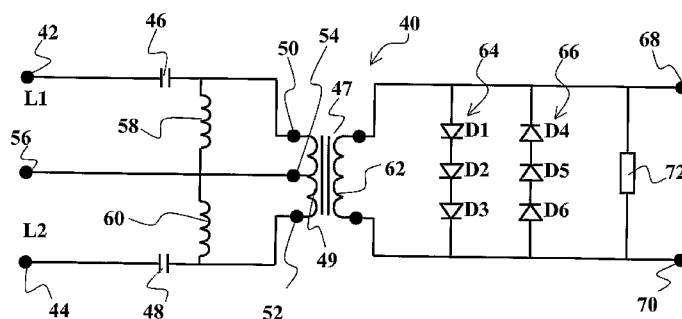
(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,
ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,
FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT,
RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA,
GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report
- before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments

For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.

(54) Title: APPARATUS FOR ARRANGING DATA TRANSFER



(57) Abstract: The object of the invention is apparatus to form a data transfer connection in order to transmit at least diagnostics information between an AC motor or a machine using an AC motor and a frequency converter controlling the AC motor. The motor is controlled using a frequency converter and the motor is connected to the frequency converter with a motor cable. According to the invention, a high-frequency data transfer transmitter/receiver is coupled to the motor cable at both ends of the motor cable with a data transfer coupling. The data transfer frequency is substantially higher than the frequency supplied to the motor cable by the frequency converter. The data transfer coupling interface includes the first filter devices (46,48) in order to filter the motor control voltage supplied by the frequency converter, the second filter devices (42,49,58,48,60) to isolate the data transfer signal, and the isolation transformer (47) to isolate the motor cable and data transfer equipment from each other. The data transfer coupling interface comprises the devices (64,66) to remove the over-voltage transients generated by the frequency converter to the motor cable. The primary winding (49) of the isolation transformers is connected to the motor cable through the filter elements and the secondary winding (62) is connected to the data transfer equipment.

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APPARATUS FOR ARRANGING DATA TRANSFER

The object of the invention is equipment according to the preamble part of Claim 1.

Controlled electric motor and generator drives are becoming more common in industrial and production plants. A substantial part of these electric drives are implemented with AC machines, which are controlled by frequency converters connected to the power supply system. In industrial drives the AC machines are controlled by inverters, which are connected to a DC bus line, which is fed from the power supply system with a rectifier or frequency converters, which are connected to the AC network and used to control the motor. A frequency converter may contain a rectifier block and an inverter block, or a block that converts the frequency and voltage. An electric power generator is often connected to the power supply system through a frequency converter in smaller electric power plants.

In controlled electric drives the voltage and frequency of an electric machine is adjusted according to its use. Part of the controlled variables is brought in from the outside and part is measured from the controlled process or the frequency converter and machine. A machine's measurement and diagnostics information is also gathered to diagnose its condition and define the service need. Data is transmitted with a data transfer network through a specifically built wired or wireless data transfer network. Wired data transfer networks can be divided in two parts: a conventional wired data transfer network and power line communication network. In some embodiments the frequency converter and the machine it controls are close to each other, in which case the data transfer bus can be arranged relatively easily. The situation becomes problematic when the distance between the controlling and the controlled devices is long. A distance of a few dozen meters, even two hundred meters, is quite possible. In addition to the process requirements, safety and reliability factors influence the placement of the machine and frequency converter.

It was suggested a long time ago that the power supply network be used for data transmission, and functional solutions have been presented for several applications. In the traditional embodiment the data transfer apparatus is connected to the power supply system with a coupling that is based on a filtering capacitor of a network-frequency component and a transformer making a galvanic isolation, as will later be presented in more detail in Figure 1.

In frequency converter use the problem is caused by the high frequencies contained in the voltage transients, which are caused by the output stage power transistor switchings of the frequency converter. Due to the resulting interference, data transfer in a motor cable is practically impossible, for instance, a GENELEC data transfer band of 3-148.5 kHz
5 standardized for power line communications in Europe.

An embodiment in which the motor cable transmitting electric power between the motor and frequency converter is utilized to transfer diagnostics information is already known. This type of solution, in which one-way data is transmitted to the frequency converter from sensors connected to the motor, is described in the publication IEEE Transactions on
10 Industry Applications, vol. 30, no. 4, July/August 1994, Shatotang Chen, Erkuan Zhong, Thomas Lipo, "A New Approach to Motor Condition Monitoring in Induction Motor Drives". Coupling interfaces are different for the transmitter and receiver. Voltage transients are entered in the secondary of the transformer of the receiver coupling interface due to the switching states of the frequency converter. In order to filter these out, a passive
15 tenfold Butterworth filter must be added in the secondary of the receiver transformer.

The objective of the presented invention is to develop a new coupling interface between data transfer network and power supply that will solve the problems in the known technology. It will achieve sufficient data transfer bandwidth in a motor cable, which contains high-frequency voltage transients. The motor cable is between the frequency
20 converter and electric machine. In order to achieve this, the invention is characterized by the features specified in the characteristics section of Claim 1. Some other embodiments of the invention are defined with the characteristics of the dependent claims.

With the presented coupling interface the motor cable between the frequency converter and electric motor/generator will be efficiently utilized as a data transfer channel. The
25 interface is particularly applicable to use with the power line communication technologies in accordance with the HomePlug® standards (HomePlug® is a trade mark owned by HomePlug Powerline Alliance, Inc) on frequency band of approx. 4-21 MHz. The invention also operates with other power line communication methods operating in the same frequency band. The structure of the coupling interface is simple and operates in the
30 transmitting and receiving ends.

A connection formed with a cable or, for instance, a wireless connection can be replaced with the embodiment according to the invention. There is no need to install separate data transfer cables, which is a substantial advantage in an industrial environment. The apparatus can be coupled to generator terminals or the output terminal of a frequency
5 converter for instance. The coupling to the motor cable transferring electric power is formed outside the connections of the motor/generator and frequency converter, in which case the internal interference of the motor or frequency converter do not have an influence on the reliability of the data transmission. A network-frequency voltage component is filtered with the coupling interface, as well as the interference caused by the output stage
10 power transistor switchings of the frequency converter in the case of a controlled electric drive, so that the data transfer apparatus will not be damaged and there will be no disturbance in its operation.

According to an embodiment of the invention, the data transfer interface is coupled to the motor cable between two phase conductors. As a consequence, the data transfer signal can
15 be injected in the motor cable differentially between two phases in the transmission.

The invention enables the data transfer signal to be fed to the motor cable, and received from the motor cable, through the coupling interface with little attenuation. One coupling interface operates at both ends of the motor cable in the transmitting and receiving ends of the data transfer signal.

20 In addition, the motor cable circuit is galvanically isolated from the circuit of the data transfer equipment with the coupling interface in accordance with the invention.

According to a characteristic of the invention, the coupling interface protects the data transfer apparatus from over-voltage transients the frequency converter generates in the motor cable.

25 In the following the invention will be described in detail with the help of certain embodiment examples by referring to the enclosed drawings, where

- Figure 1 illustrates the conventional coupling interface,
- Figure 2 illustrates a controlled motor drive, to which the invention is applied, and
- Figure 3 illustrates a coupling interface in accordance with the invention.

The coupling interface generally used in power line communications is illustrated in Figure 1. Especially in a coupling used in one-phase power supply, the coupling interface 2 is coupled to the power supply between the phase and the neutral conductor. The interface 4 is coupled to the power supply phase conductor and the interface 6 is coupled to the power supply neutral conductor, between which is the series connection formed by the capacitor 8 and the primary 12 of the isolation transformer 10. The secondary 14 of the isolation transformer 10 is connected to the data transfer equipment with interfaces 15 and 16. The resistor 18 is connected parallel to the secondary 14 of the isolation transformer. The impedance series connection of the capacitor 8 and isolation transformer 8 form an LC circuit, which filters the network frequency. On the network frequency, i.e. the frequency of 50/60 Hertz, the impedance of the capacitor dominates, whereas the impedance is small on the frequency used for the data transfer and the magnetization-inductance of the isolation transformer dominates. The isolation transformer 10 forms a galvanic isolation between the power supply system and the data transfer network.

15 The electric diagram concerning the application environment of the presented invention, i.e. the frequency converter use of an electric machine, is illustrated in Figure 2. The frequency converter 20 is connected to the three-phase power supply system 22 with feeder cables 24. The three-phase voltage of the frequency converter with adjusted frequency and voltage is supplied to the motor cable 28 through the du/dt filter 26, possibly contained by the system, and further to the input terminal of the induction motor 30. The data transfer equipment 35, containing a modem based on HomePlug® technology, is coupled to the frequency converter end 34 of the motor cable 28 through the combined coupling interface 33. The modem can be connected to a broadband data transfer connection with an Ethernet network cable. A second data transfer equipment 38, which is fundamentally similar to the equipment 35, is correspondingly fitted at the motor end 36 of the motor cable 28 with a coupling interface 37. The coupling interfaces 33 and 37 are also fundamentally similar. The frequency converter 20 is based on, for instance, PWM technology, but it may as well be a different frequency converter when applying the invention. In addition, the motor type is not tied to an induction motor. In order to transmit diagnostics information, the data transfer equipment 38 is connected with a known method to the sensors measuring the motor condition and operation, such as temperature and vibration sensors. The data transfer equipment 35 is correspondingly connected to, for instance, the screen, control or analysis equipment fitted in connection with the control unit of the frequency converter.

The data transfer coupling interface is formed according to a diagram illustrated in Figure 3. The coupling interface 40 connectors 42 and 44, which are connected to the ends 50 and 52 of the primary winding 49 of the isolation transformer 47 through the capacitors 46 and 48, are connected to the two phases L1 and L2 of the motor cable. The center point 54 of the primary winding 49 of the isolation transformer is connected to the protective earth 56 of the motor cable. The inductance 58 is connected parallel to the first half of the primary winding, i.e. between the center point 54 and the first end 50 of the winding, and inductance 60 is correspondingly connected parallel to the second half of the winding, i.e. parallel to the center point 54 and the other end 52 of the winding, in which case the other ends of the inductances 58 and 60 are tied to the same potential, i.e. the protective earth. As a consequence, the data transfer signal can be injected in the motor cable differentially between two phases in the transmission. As a result of the connection, common mode voltage components, which could be seen as current in the protective earth 56 and other ground loops, are not much generated in the transmission. The binding of the isolation transformer 54 to the protective earth also prevents the formation of substantial voltage difference between the primary winding 49 of the isolation transformer 47 and secondary winding 62, which could cause a disruptive discharge between the primary and secondary of the isolation transformer.

The secondary winding 60 of the isolation transformer is connected to the data transfer bus, such as a modem utilizing the HomePlug® technology, with interfaces 68 and 70. The resistor 72 is connected between the interfaces 68 and 70.

The capacitors 46 and 48 operate as the main voltage frequency filter for the motor cable, and the frequency of the main voltage typically changes between 0 and 100 Hz. The inductances 58 and 60 and the magnetization-inductance of the isolation transformer 46 operate as the LC low pass filter with the capacitors 46 and 48.

The capacitors 46 and 48 of the coupling interface must bear the voltage strains caused by the switchings of the output stage power transistors of the frequency converter. Due to cable vibration, the motor's maximum amplitude of the voltage between the phases may be double to that of the voltage of the DC link of the frequency converter. For instance, a motor controlled by a frequency converter and connected to a three-phase power supply system of 690 V may, because of cable vibration, have voltage amplitudes of 2 kV and the frequency content of which often goes up to many megahertz. The second task of the

coupling capacitors is to pass the data transfer signal with minor loss. Attention should therefore be paid to the loss factor of the capacitor and its frequency dependency, due to which ceramic or plastic capacitors are suitable. An example of a suitable capacitor is a ceramic capacitor designed for a DC voltage of 10,000 V.

- 5 The isolation transformer 47 should be suitable for high signal frequencies. The isolation transformer can well be implemented with a double-hole ferrite ring because the structure is suitable for the high signal frequencies. Double-hole ferrite core transformers are generally used in RF transformers. In addition, it is important to minimize stray variables, e.g. stray inductance and stray capacitance, in the implementation of the transformer.
- 10 Parallel stray capacitance in particular can easily become a problem because the capacitance of the connection capacitors is small. The ferrite material is another substantial factor in the selection of the inductive components. The ferrite material must operate on a frequency band of 30 MHz with minor loss, in which case the complex permeability of the material must be low in this frequency band. For instance, F10b manufactured by Neosid
- 15 Pemetzrieder GmbH & Co is suitable as the ferrite material.

The other half, i.e. the data transfer modem half, of the coupling interface is connected to the secondary winding 62 of the isolation transformer. Two back-to-back connected diode circuits 64 and 66, which handle the transient protection of the coupling interface, are connected parallel to the secondary winding. The purpose is to prevent over-voltage

20 transients entering the data transfer device. Voltage peaks are caused by, for instance, the switchings of the output stage power transistors of the frequency converter, which the coupling interface cannot sufficiently filter in all cases. The protection takes place by cutting the voltage over the coupling interface to a certain maximum level.

Transient diodes are generally used in transient protection. However, the transient diodes

25 are not suitable for use in the above-mentioned coupling interface because their capacitance is nanofarads and they work slowly considering the frequencies used in the embodiment. The series capacitance of the transient diodes would cause substantial attenuation even in an ideal situation concerning the presented coupling interface.

The transient protection is implemented with small signal diodes D1...D3 (diode circuit 64)

30 and D4...D6 (diode circuit 66), with which the possible over-voltage peaks, which can break through the interface, are cut. Several diodes must be connected in series because

their forward voltage is approximately 0.7 V. The diodes are divided into two parallel branches, one of which is always biased in a forward direction regarding the signal influencing over the secondary of the interface. The parallel capacitance formed by this type of protection concerning the secondary of the coupling interface is only picofarads, and the switching time of the diodes is very short, a maximum of 4 nanoseconds.

Data is simultaneously transferred with parallel carrier waves. This frequency division is implemented with the OFDM technology (Orthogonal Frequency Division Multiplexing). Different variations of the phase modulation (PSK) from the HomePlug standard are used as modulations with known methods.

10 In the above, the invention has been described with the implementation of certain embodiments. However, the implementation of the invention may vary within the limits defined by the attached claims.

CLAIMS

1. Apparatus for the formation of a data transfer connection, at least in order to transmit diagnostics information between an AC motor (30), or a machine using an AC motor and a frequency converter (20) controlling the AC motor, in which case the motor is controlled using the frequency converter (20) and the motor (30) is connected to the frequency converter (20) with a motor cable (28), in which apparatus the data transfer frequency is substantially higher than the frequency supplied by the frequency converter (20) to the motor cable (28), **characterized** in that:
- similar high-frequency data transfer transmitters/receivers (35,38) are coupled at both ends (34,36) of the motor cable (28) to the motor cable with the data transfer coupling interface,
 - the data transfer coupling interface includes the first filter devices (46,48) in order to filter the motor control voltage supplied by the frequency converter, the second filter devices (42,49,58,48,60) to isolate the data transfer signal, and the isolation transformer (47) to isolate the motor cable and data transfer equipment from each other,
 - the data transfer coupling interface comprises the devices (64,66) to remove the over-voltage transients generated by the frequency converter to the motor cable, and
 - the primary winding (49) of the isolation transformers is coupled to the motor cable through the filter elements and the secondary winding (62) is connected to the data transfer equipment.
2. Apparatus according to Claim 1, **characterized** in that the data transfer coupling interface is coupled to the motor cable between two phase conductors (L1,L2).
3. Apparatus according to Claim 1, **characterized** in that the data transfer coupling interface is coupled between two phase conductors (L1,L2) of the motor cable so that the primary couplings (50,52) of the isolation transformer are coupled to the phase conductors through the capacitors (46,48), in which case the capacitors operate as the first filter devices in order to filter the control voltage of the motor, and the LC filter formed by the inductance of the isolation transformer (47) and the capacitors (46,48) as the second filter device.

4. Apparatus according to Claim 1, **characterized** in that the center point (54) of the primary winding (49) of the isolation transformer is connected to the protective grounding (56) of the motor cable.
5. Apparatus according to Claim 4, **characterized** in that inductances (58,60) parallel to the first half of the primary winding of the isolation transformer and, correspondingly, to the second half are connected between the first phase and the protective earth, as well as the second phase and the protective earth, which inductances, together with the isolation transformer inductance and the capacitance of the capacitors, form the LC filter.
- 10 6. Apparatus according to Claim 1, **characterized** in that the devices to remove over-voltage transients comprise two back-to-back connected diode circuits (64,66) connected parallel to the secondary (62) of the isolation transformer.
7. Apparatus according to Claim 6, **characterized** in that the diode circuits (64,66) consist of the series connection of two or more diodes (D1,D2,D3;D4,D5,D6).
- 15 8. Apparatus according to Claim 7, **characterized** in that the diodes are small signal diodes.
9. Apparatus according to any of the preceding Claims, **characterized** in that the data transfer coupling interfaces coupled to both ends of the motor cable (28) are essentially similar.
- 20 10. Apparatus according to any of the preceding Claims, **characterized** in that the data transfer channel connected to the data transfer coupling interface is a broadband.

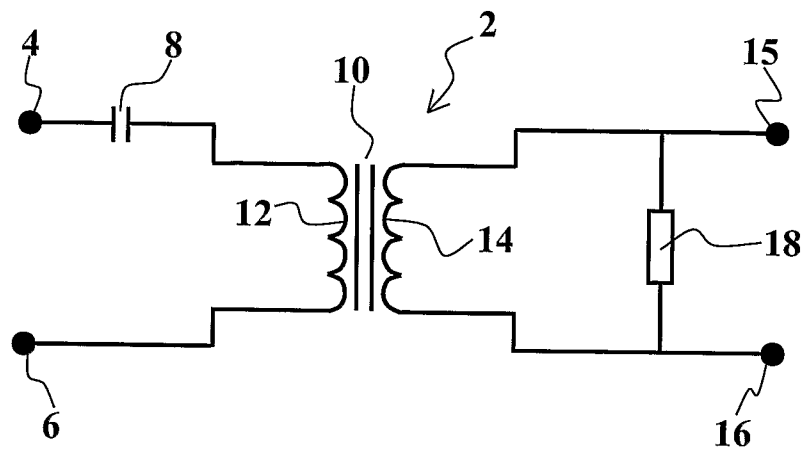


Fig. 1

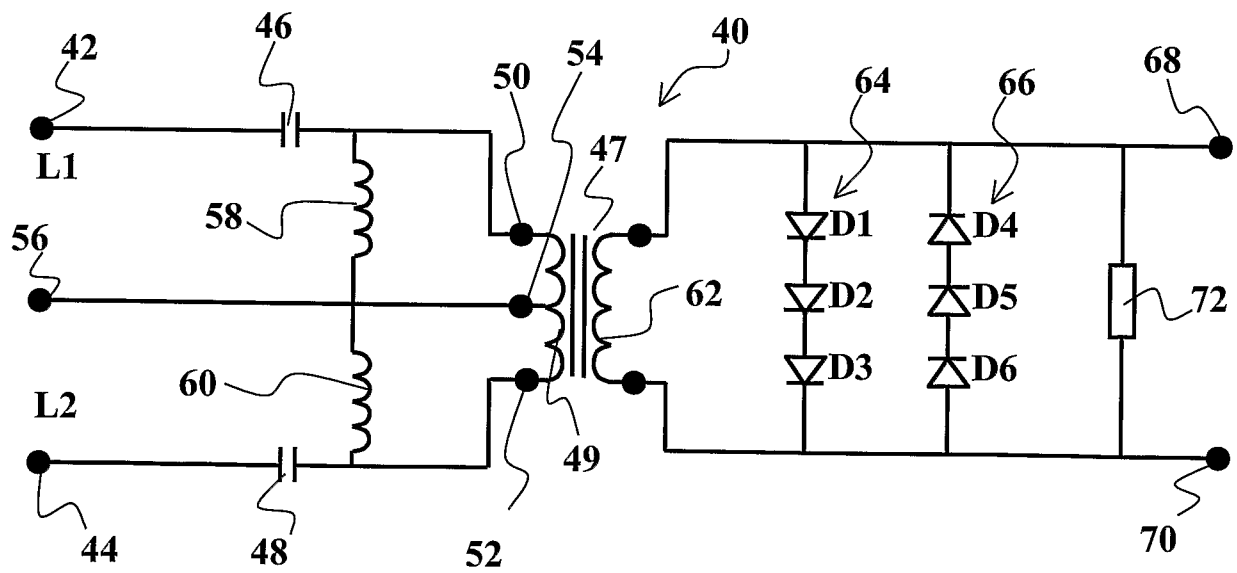


Fig. 3

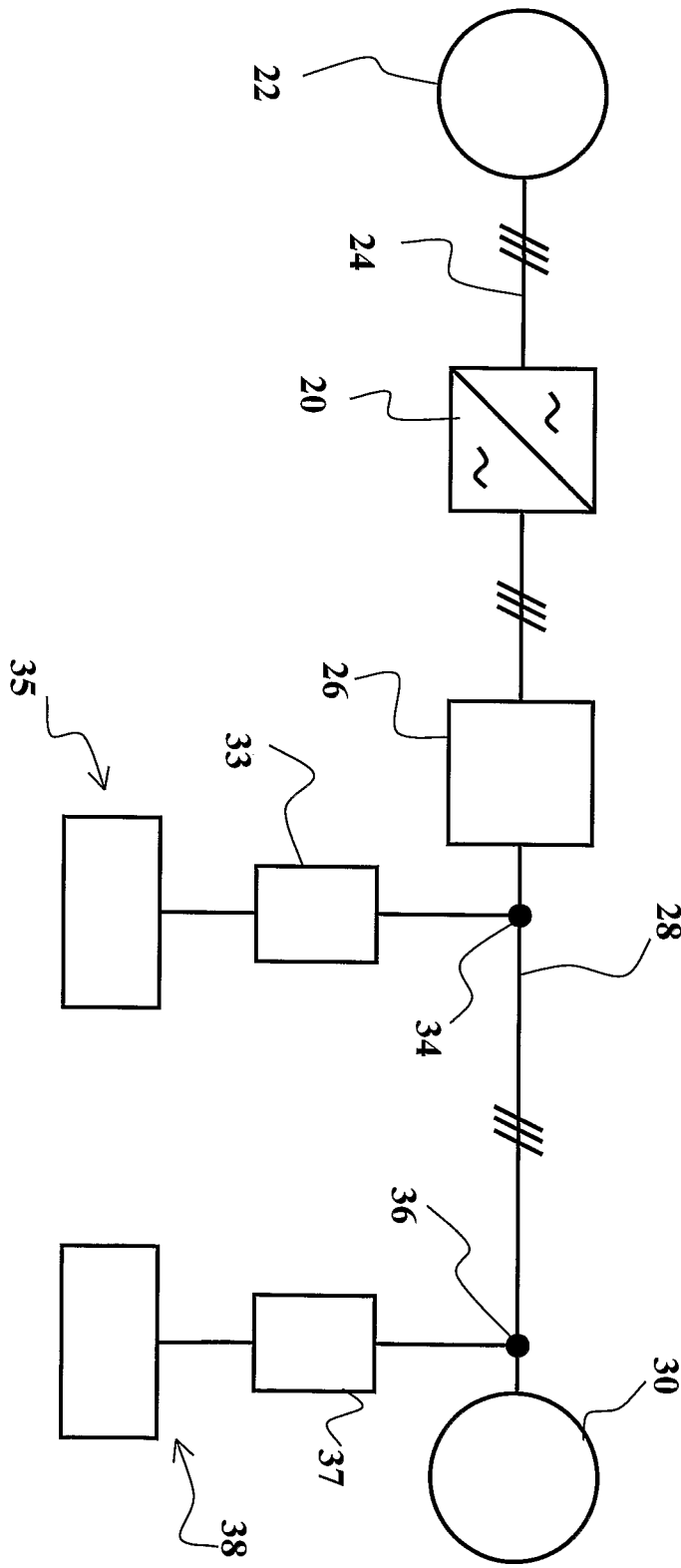


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2006/000255

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: H04B

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 20040142599 A1 (LEONARD D. COPE ET AL), 22 July 2004 (22.07.2004), figures 2,3	1-3,6-10
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A	US 20050046550 A1 (RALPH E. CRENSHAW ET AL), 3 March 2005 (03.03.2005), figures 3,3B	1-10
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Date of the actual completion of the international search

29 November 2006

Date of mailing of the international search report

29-11-2006

Name and mailing address of the ISA/

Swedish Patent Office

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Facsimile No. +46 8 666 02 86

Authorized officer

Tomas Erlandsson/MN

Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2006/000255

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 20040105539 A1 (JEAN-MARC AUZIZEAU), 3 June 2004 (03.06.2004), figure 2 -- -----	1-10

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Cited literature, if any, will be enclosed in paper form.

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