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(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): **GAJIC, Zoran** [SE/SE]; Regementsgatan 59, S-723 45 Västerås (SE).(74) Agent: **AHRENGART, Kenneth**; ABB AB, Intellectual Property, Ingenjör Bååths Gata 11, S-721 83 Västerås (SE).

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(54) Title: A METHOD FOR OBTAINING AN INSTANTANEOUS DIRECT CURRENT VALUE, AND CONTROL DEVICE

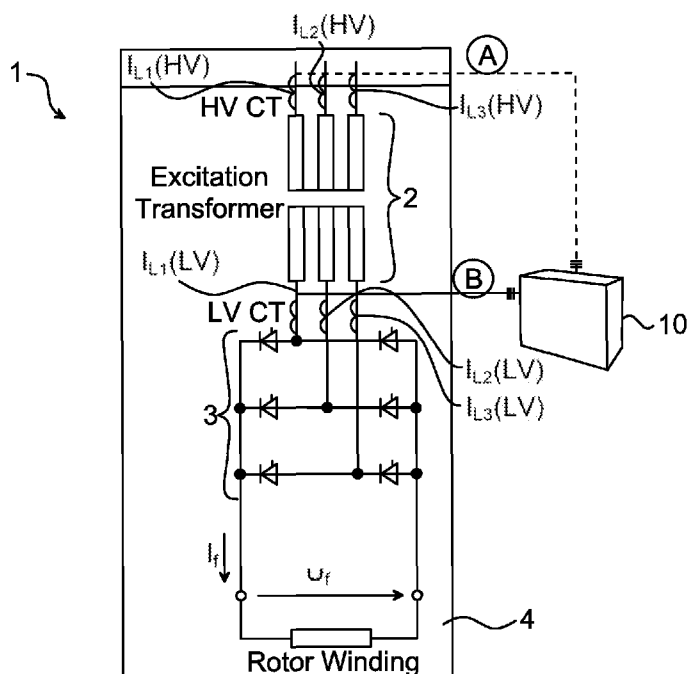


Fig. 1

(57) Abstract: The invention relates to a method (70) in a control device (10, 30, 40, 50, 60) for obtaining an instantaneous direct current (DC) current value, the control device (10, 30, 40, 50, 60) arranged to control, monitor and protect equipment (1, 31, 41, 61) within an electrical power system. The equipment (1, 31, 41, 61) comprises a DC side and comprises or is connected to an alternating current (AC) side, the AC side comprising one or more phases L1, L2, L3. The method comprises: measuring (71) the AC currents I_{L1} , I_{L2} , I_{L3} of the one or more phases L1, L2, L3; and calculating (72), based on the one or more AC currents I_{L1} , I_{L2} , I_{L3} the instantaneous DC current I_f , I_{DC1} , I_{DC2} value on the DC side. The invention also relates to a control device.

A method for obtaining an instantaneous direct current value, and control device

Field of the invention

The invention relates generally to the field of electrical power systems, and in particular to methods for enabling protection and control of the electrical power system and equipment therein.

Background of the invention

Within electrical power systems, protective equipment are essential for protecting the electrical power system and equipment within it.

In order to e.g. detect faults within the electrical power system voltages, currents, and frequencies are measured to detect anomalies. An AC current can be measured by means of current transformers (CTs), which produce a reduced current accurately proportional to the current in the equipment that is being measured. This reduced current can be conveniently connected to a measuring and recording instrument, such as an Intelligent Electronic Device (IED) that is used for protecting, controlling and monitoring the equipment.

An increasing number of direct current (DC) applications are introduced within the field of electrical power systems. Many parts of today's electrical power system comprise power electronic equipment containing large DC rectifiers or DC links. As a few examples the following can be mentioned: generator static excitation equipment, static frequency converters, Medium Voltage drives, and High Voltage Direct Current (HVDC) equipment.

As these and other DC applications are introduced, a need for measuring DC currents arises. There are a number of difficulties related to such DC current measurements. The IEDs protecting, controlling and monitoring the equipment within the electrical power system are adapted for measuring AC currents. This means that the IED would have to be redesigned in order to be suitable for measuring DC currents, including for example exchange of hardware. This would obviously be a costly solution. An alternative would be to use special measurement sensors and adapt the input devices of the IED. Again, this would be an expensive solution.

There are still further difficulties when measuring DC currents at the high voltages, which are used within the typical electric power system, for example voltage up to 300 kV. The security aspect is one such additional difficulty. In conventional AC current measurements, the current transformer isolates the measuring instruments from what may be a very high voltage in the monitored equipment. In a DC current measurement case, it would be difficult to get such galvanic separation from the primary circuit. High voltage shields could possibly be used, connected in series with the equipment being measured, but it would yet again be a costly and also a space-requiring solution.

From the above, it is clear that there is a need for an improvement on this situation in this field of technology.

Summary of the invention

It is an object of the invention to provide means and methods for enabling measuring of DC currents in electrical power systems.

In a first aspect of the invention, the object is achieved
5 by a method in a control device for obtaining an instantaneous direct current (DC) value. The control device is arranged to control, monitor and protect equipment within an electrical power system, wherein the equipment comprises a DC side and comprises or is connected to an alternating
10 current (AC) side, and the AC side comprises one or more phases. The method comprises: measuring the AC currents of the one or more phases; and calculating, based on the one or more AC currents the instantaneous DC current value on the DC side. By means of the invention, a cost-efficient way of
15 measuring DC currents is provided, as traditional AC measurements are used as a basis. In particular, special measurement sensor or special inputs into the control device are not needed when implementing the present invention. There is no need to make large and costly adaptations to the
20 existing IEDs, only the provision of e.g. updated software enabling the DC current calculation based on AC current measurements.

In an embodiment, the step of measuring comprises measuring the one or more AC currents at a low voltage AC side. When
25 measuring the AC currents at the low voltage AC side it is possible to directly proceed to the step of calculating the DC current.

In the above embodiment, the low voltage AC side may comprise a low voltage side of a power transformer feeding a
30 DC rectifier.

In another embodiment, the step of measuring comprises measuring the one or more AC currents at a high voltage AC side of the power transformer. The method then comprises the further step of recalculating the measured AC currents into
 5 corresponding AC currents on a low voltage side.

In the above embodiment, and wherein the equipment comprises a power transformer feeding a DC rectifier, the step of recalculating may be done utilizing the following equations:

$$\begin{bmatrix} I_{L1}(LV) \\ I_{L2}(LV) \\ I_{L3}(LV) \end{bmatrix} = k \cdot \begin{bmatrix} x & y & z \\ z & x & y \\ y & z & x \end{bmatrix} \cdot \begin{bmatrix} I_{L1}(HV) \\ I_{L2}(HV) \\ I_{L3}(HV) \end{bmatrix}$$

10 , where factors k, x, y and z depend on the ratio and vector group of the power transformer feeding the rectifier.

In an embodiment, the step of calculating, based on the one or more AC currents the instantaneous DC current value comprises using the following equation:

$$15 \quad I_f = \frac{|I_{L1}(LV)| + |I_{L2}(LV)| + |I_{L3}(LV)|}{2}$$

An easily implemented way of calculating the desired DC current is thus obtained.

In an embodiment, the step of measuring the one or more AC currents is repeatedly performed thus obtaining a number of
 20 samples, and the step of calculating an instantaneous DC current value is performed for each sample, thus obtaining a DC current waveform.

In an embodiment, the equipment comprises a DC link, a DC rectifier, a static frequency converter, a high voltage

direct current back-to-back station or a DC transmission line. Various equipment within the electric power network can be protected.

In a second aspect of the invention, the object is achieved
5 by a control device arranged to control, monitor and protect equipment within an electrical power system, wherein the equipment comprises a direct current side and comprises or is connected to an alternating current (AC) side, the AC side comprising one or more phases. The control device
10 comprises an input module arranged to measure AC currents and means for calculating a DC current based on the measured AC currents for use by the central processing unit.

In an embodiment, the means for calculating a DC current based on the measured AC currents comprises integrated
15 circuitry. A hardware solution is thus possible.

In an embodiment, the means for calculating a DC current based on the measured AC currents comprises a computer program comprising computer program code which when run on the central processing unit provides the DC current. A
20 software solution is thus possible.

In an embodiment, the control device is arranged to detect fault conditions in the equipment by using the DC current.

Further features and advantages thereof will become clear upon reading the following detailed description and the
25 accompanying drawings.

Brief description of the drawings

Figure 1 illustrates schematically a first environment in which embodiments of the invention may be implemented.

Figure 2 illustrates schematically a second environment in which embodiments of the invention may be implemented.

5 Figure 3 illustrates schematically a third environment in which embodiments of the invention may be implemented.

Figure 4 illustrates schematically a fourth environment in which embodiments of the invention may be implemented.

10 Figure 5 illustrates a flow chart over steps of a method in accordance with the invention.

Figure 6 illustrates a flow chart over steps of another embodiment of the method of figure 5.

Figure 7 illustrates a control device in accordance with the invention.

15 **Detailed description of embodiments**

In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular architectures, interfaces, techniques, etc. in order to provide a thorough understanding of the invention.

20 However, it will be apparent to those skilled in the art that the invention may be practiced in other embodiments that depart from these specific details. In other instances, detailed descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of
25 the invention with unnecessary detail.

Figure 1 illustrates schematically a first environment in which embodiments of the invention may be implemented. In particular, a typical structure of a static excitation system for a synchronous machine, such as a generator or motor, is schematically illustrated. The static excitation system 1 comprises an excitation transformer 2 connected to rectifier circuitry 3, which in turn are connected to the generator comprising inter alia a rotor 4. The three phase currents on the high voltage side are denoted $I_{L1}(HV)$, $I_{L2}(HV)$, $I_{L3}(HV)$ and the three phase currents on the low voltage side are denoted $I_{L1}(LV)$, $I_{L2}(LV)$, $I_{L3}(LV)$.

In order to calculate rectifier DC current I_f one of two ways to measure current is used. A first way, indicated in the figure at a dashed line A, is to measure the three phase currents $I_{L1}(HV)$, $I_{L2}(HV)$, $I_{L3}(HV)$ on the high voltage (HV) side of the excitation transformer 2. Such measurements can be performed by a control device 10, e.g. an Intelligent Electronic Device (IED), using conventional current transformers (CTs). The measurement values are thus input to the control device 10.

A second way, indicated in the figure at a continuous line B, is to measure the three phase currents $I_{L1}(LV)$, $I_{L2}(LV)$, $I_{L3}(LV)$ on the low voltage (LV) side of the excitation transformer 2. LV current transformers can be used. However, in electrical power systems, such LV current transformers are not often used.

If the first way A of measuring is used, measurements of the three phase currents $I_{L1}(HV)$, $I_{L2}(HV)$, $I_{L3}(HV)$ on the HV side are now available. These measurements have to be recalculated into phase currents on the LV side. In the

International publication WO 2007/057240, a method to perform such recalculations are presented. In essence, it can be shown that by using the following equations, the three phase currents $I_{L1}(HV)$, $I_{L2}(HV)$, $I_{L3}(HV)$ on the HV side can be recalculated into the corresponding three phase currents $I_{L1}(LV)$, $I_{L2}(LV)$, $I_{L3}(LV)$ on the LV side.

$$\begin{bmatrix} I_{L1}(LV) \\ I_{L2}(LV) \\ I_{L3}(LV) \end{bmatrix} = k \cdot \begin{bmatrix} x & y & z \\ z & x & y \\ y & z & x \end{bmatrix} \cdot \begin{bmatrix} I_{L1}(HV) \\ I_{L2}(HV) \\ I_{L3}(HV) \end{bmatrix} \quad (\text{eq 1})$$

, where factors k , x , y and z depend on the ratio and vector group of the power transformer feeding the rectifier.

It is noted that rating data for the excitation transformer must be known.

If the second way B of measuring is used, the phase currents $I_{L1}(LV)$, $I_{L2}(LV)$, $I_{L3}(LV)$ on the LV side are already available.

Next, now that the phase currents $I_{L1}(LV)$, $I_{L2}(LV)$, $I_{L3}(LV)$ on the LV side are available, they are used for calculating the DC current I_f in accordance with the following:

$$I_f = \frac{|I_{L1}(LV)| + |I_{L2}(LV)| + |I_{L3}(LV)|}{2} \quad (\text{eq 2})$$

That is, the instantaneous DC current I_f value is obtained as the sum of the absolute values of the AC phase currents divided by 2. It is noted that the above equation (eq 2) is an example on how to calculate the DC current based on AC measurements, and that more complex equations could alternatively be used.

Equation 1 (eq 1) is performed on a sample level, for example 20 times per fundamental power system cycle. A DC current waveform is thereby obtained.

It is possible to calculate average DC current I_{DC} over one
5 or more power system cycle(s), for example by using the following equation:

$$I_{DC} = \frac{1}{T} \int_0^T I_f \partial t \quad (\text{eq 3})$$

That is, by integrating the instantaneous DC current I_f over
e.g. one cycle T , multiplied with the inverse of the cycle
10 $1/T$, the average DC current I_{DC} is obtained.

This average DC current I_{DC} can be used to perform a number
of protection functions. For example, rotor winding
overcurrent protection, rotor winding undercurrent
protection (e.g. loss of field condition), rotor winding
15 thermal overload protection in accordance with ASA-C50.13
(American Standard Requirements for Cylindrical-Rotor
Synchronous Generators).

Additionally, spectral analysis of the DC current waveform
(i.e. I_f) can be performed. This spectral analysis can then
20 be used for detecting abnormal operating conditions of the
synchronous machine. Examples of such abnormal operating
conditions comprise stator winding turn-to-turn faults,
machine out of step condition and machine loss of excitation
condition.

25 For certain electronic devices, such as static frequency
converters, Medium Voltage drives, and High Voltage Direct
Current (HVDC) equipment a dc-link is used, e.g. for a back-

to-back connection of rectifier and inverter bridge. In such application the described way of obtaining DC current can be performed on both sides. In accordance with the law of energy conversion, the resultant DC current shall be the same on both sides regardless of the AC frequencies used on the two sides. The invention brings about a possibility to also apply differential protection for the DC link and associated power equipment connected in series as will be described next with reference to figures 2 and 3.

Figure 2 illustrates schematically a second environment in which embodiments of the invention may be implemented. In particular, figure 2 illustrates a static frequency converter 31 controlled by a control device 30. The static frequency converter 31 may for example be used for providing a source of variable voltage-variable frequency that supplies a synchronous machine during the starting process thereof. A generator/motor 32 is connected to the static frequency converter 31. Normally, it may be difficult to obtain differential protection for such static frequency converter and associated generator/motor 32 during start up and braking of the static frequency converter 31, i.e. when the generator/motor 32 runs at a frequency other than the frequency of an AC network to which it is connected. In particular, the measurements made on both sides for accomplishing differential protection is rendered difficult due to the different frequencies, as it is more difficult to make accurate comparisons. In contrast, the present invention enables differential protection of such static frequency converter 31 irrespective of frequency of the generator/motor 32.

The frequency converter 31 comprises in conventional manner a rectifier stage 34 converting the input from AC to DC and an inverter stage 33 that generates the variable frequency voltage from the DC stage, i.e. inverting the direct current to produce AC of the desired frequency. As mentioned earlier, the DC current shall be the same on both sides regardless of the AC frequencies on the two sides. In particular, the AC currents at a first measuring point MP1 (AC current at the rectifier input) and AC currents at a second measuring point MP2 (AC current at the motor/generator 32) are measured, e.g. by using conventional current transformers. The AC currents of the first measuring point MP1 are used for calculating the rectifier current I_{DC1} . The AC currents of the second measuring point MP2 are used for calculating the inverter current I_{DC2} . These DC currents I_{DC1} , I_{DC2} , which thus should be equal, can then be used in differential protection algorithms.

The control device 30 comprises means for measuring the needed AC currents, to convert these AC currents to corresponding DC currents and to thereby detect fault conditions, and e.g. trip one or more circuit breaker(s) CB1, CB2, CB3 if needed.

The earlier mentioned fault states, e.g. rotor winding overcurrent, rotor winding undercurrent such as loss of field condition, rotor winding thermal overload, can thus easily be detected by means of aspects of the invention.

Figure 3 illustrates schematically a third environment in which embodiments of the invention may be implemented. In particular, figure 3 illustrates a differential protection for a HVDC back-to-back station 41. The HVDC back-to-back

station 41 may for example be used to create an asynchronous interconnection between two AC networks 42, 43. In analogy with the case of the static frequency converter of figure 2, it may normally be difficult to obtain differential

5 protection for such HVDC back-to-back station when the AC networks are operating at different frequencies. In contrast, the present invention works equally well irrespective of whether the two AC networks 42, 43 operate on different or same frequencies.

10 AC currents, e.g. for three phases, at measuring point MP10 are measured and corresponding DC current at schematically illustrated measuring point 11 is calculated. AC currents at schematically illustrated measuring point MP20 are measured and corresponding DC current at measuring point 21 is
15 calculated. Differential protection for the HVDC back-to-back station 41 is thus provided.

Again, the control device 40 comprises means for measuring the needed AC currents, to convert these AC currents to corresponding DC currents and to thereby detect fault
20 conditions, and e.g. trip one or more circuit breaker(s) on the two sides of the DC-link if needed.

Figure 4 illustrates schematically a fourth environment in which embodiments of the invention may be implemented. In particular, by means of the invention, distributed
25 measurements similar to existing line differential protection control devices can also be used for HVDC transmission lines 61. Like numerals in figures 3 and 4 are used for denoting corresponding parts.

A communication link 51 is established between a control device 50 arranged at one side of the transmission line 61 and a control device 60 arranged at the other side of the transmission line 61. DC currents (measured at MP11, MP21) at both sides of the transmission line 61 are communicated and differential protections is enabled. The communication link 51 may be any suitable communication means, e.g. a fiber optic cable. The measurements can be synchronized for example by GPS time synchronization or echo principle.

Figure 5 illustrates a flow chart over steps of a method in accordance with the invention. The method 70 is performed in the control device 1, 10, 30, 40, 50, 60 for obtaining an instantaneous DC current value. The control device 1, 10, 30, 40, 50, 60 is, as described earlier, arranged to control, monitor and protect equipment 1, 31, 41, 61 within the electrical power system. The equipment 1, 31, 41, 61 comprises a direct current side and comprises or is connected to an alternating current side. The AC side comprises one or more phases L1, L2, L3. The method 70 comprises the first step of measuring 71 the AC currents I_{L1} , I_{L2} , I_{L3} of the one or more phases L1, L2, L3 on the AC side. This can be done by using conventional current transformers, as explained earlier.

The method comprises the second step of calculating 72, based on the one or more AC currents I_{L1} , I_{L2} , I_{L3} the corresponding instantaneous DC current I_f , I_{DC1} , I_{DC2} value on the DC side.

In an embodiment, the step of measuring 71 comprises measuring the one or more AC currents at a low voltage AC side. The measurements can then be used directly in order to

obtain corresponding instantaneous DC current I_f , I_{DC1} , I_{DC2} value on the DC side.

In another embodiment, illustrated in figure 6, the step of measuring 71 comprises measuring the one or more AC currents at a high voltage AC side. The method 70 then comprises the further step of recalculating 73 the measured AC currents into corresponding AC currents on a low voltage side.

The step of recalculating 73 is in an embodiment, wherein the equipment to be protected comprises a power transformer 2 feeding a DC rectifier 3 (figure 1), performed by utilizing the following matrix equations:

$$\begin{bmatrix} I_{L1}(LV) \\ I_{L2}(LV) \\ I_{L3}(LV) \end{bmatrix} = k \cdot \begin{bmatrix} x & y & z \\ z & x & y \\ y & z & x \end{bmatrix} \cdot \begin{bmatrix} I_{L1}(HV) \\ I_{L2}(HV) \\ I_{L3}(HV) \end{bmatrix} \quad (\text{eq 1})$$

, where factors k , x , y and z depend on the ratio and vector group of the power transformer feeding the DC rectifier.

Thereafter, the obtained low voltage side currents are used for calculating the desired DC current, step 72.

The step of calculating 72 based on the one or more AC currents I_{L1} , I_{L2} , I_{L3} the instantaneous DC current I_f , I_{DC1} , I_{DC2} value comprises, in an embodiment, using the following equation:

$$I_f = \frac{|I_{L1}(LV)| + |I_{L2}(LV)| + |I_{L3}(LV)|}{2} \quad (\text{eq 2})$$

The step of measuring 71 the one or more AC currents I_{L1} , I_{L2} , I_{L3} can be done repeatedly thus obtaining a number of samples. The step of calculating 72 an instantaneous DC

current value is then performed for each sample, thus obtaining a DC current waveform.

As described earlier, the equipment 1, 31, 41, 61 may for example comprise a DC link, a DC rectifier, a static
5 frequency converter, a high voltage direct current back-to-back station or a DC transmission line.

The method 70 can be implemented for protecting a DC device, and practically all equipment located in-between physical locations of the two sets of measuring devices (e.g. current
10 transformers). The method can be used for protecting for example the machines and devices as illustrated in the figures. The instantaneous DC currents are measured for two sides of a DC device, whereby a differential protection is enabled for the DC device and all equipment between the
15 measuring points.

The invention also encompasses the control device 1, 30, 40, 50, 60 arranged to control, monitor and protect the equipment 1, 31, 41, 61 within the electrical power system. As above, the equipment 1, 31, 41, 61 comprises a direct
20 current side and comprises or is connected to an alternating current (AC) side, the AC side comprising one or more phases L1, L2, L3.

In figure 7 such a control device is indicated at reference numeral 10. The control devices illustrated in different
25 application throughout the figures are such control devices, to be described next. The control device 10 comprises an input module 11 arranged to measure AC currents. This input module 11 may for example comprise a transformer module arranged to receive analog values (AC measurements) and

output them to an analog to digital converter (not illustrated).

The control device 10 further comprises means 13, 14, 15 for calculating a DC current based on the measured AC currents for use by the central processing unit 12. The means for calculating the DC current may be software or hardware. For example, the input module 11 may output the AC current measurements, e.g. via an analog to digital converter, to an integrated circuit 13 arranged to provide a DC current based on the input AC currents.

The means may alternatively comprise a computer program 15 comprising computer program code which when run on the central processing unit 12 provides the DC current.

The control device 10, and in particular the central processing unit 12 thereof may then be arranged to detect fault conditions in the equipment 1, 31, 41, 61 by using the DC current.

Claims

1. A method (70) in a control device (10, 30, 40, 50, 60) for obtaining an instantaneous direct current (DC) value, the control device (10, 30, 40, 50, 60) arranged to control,
5 monitor and protect equipment (1, 31, 41, 61) within an electrical power system, wherein the equipment (1, 31, 41, 61) comprises a DC side and comprises or is connected to an alternating current (AC) side, the AC side comprising one or more phases (L1, L2, L3), the method comprising:
- 10 - measuring (71) the AC currents (I_{L1} , I_{L2} , I_{L3}) of the one or more phases (L1, L2, L3),
- calculating (72), based on the one or more AC currents (I_{L1} , I_{L2} , I_{L3}) the instantaneous DC current (I_f , I_{DC1} , I_{DC2}) value on the DC side.
- 15 2. The method (70) as claimed in claim 1, wherein the step of measuring (71) comprises measuring the one or more AC currents at a low voltage AC side.
3. The method (70) as claimed in claim 2, wherein the low voltage AC side comprises a low voltage side of a power
20 transformer feeding a DC rectifier.
4. The method (70) as claimed in claim 1, wherein the step of measuring (71) comprises measuring the one or more AC currents at a high voltage AC side, the method comprising the further step of recalculating (73) the measured AC
25 currents into corresponding AC currents on a low voltage side.

5. The method (70) as claimed in claim 4, equipment (1, 31, 41, 61) comprises a power transformer (2) feeding a DC rectifier (3) wherein the step of recalculating comprises utilizing the following matrix equations:

$$5 \quad \begin{bmatrix} I_{L1}(LV) \\ I_{L2}(LV) \\ I_{L3}(LV) \end{bmatrix} = k \cdot \begin{bmatrix} x & y & z \\ z & x & y \\ y & z & x \end{bmatrix} \cdot \begin{bmatrix} I_{L1}(HV) \\ I_{L2}(HV) \\ I_{L3}(HV) \end{bmatrix} \quad (\text{eq 1})$$

, where factors k , x , y and z depend on the ratio and vector group of a power transformer feeding a DC rectifier.

6. The method as claimed in any of the preceding claims, wherein the AC side comprises three phases ($L1$, $L2$, $L3$), and
 10 wherein the step of calculating (72), based on the three AC currents (I_{L1} , I_{L2} , I_{L3}) the instantaneous DC current (I_f , I_{DC1} , I_{DC2}) value comprises using the following equation:

$$I_f = \frac{|I_{L1}(LV)| + |I_{L2}(LV)| + |I_{L3}(LV)|}{2} \quad (\text{eq 2})$$

7. The method (70) as claimed in any of the preceding
 15 claims, comprising repeatedly measuring (71) the one or more AC currents (I_{L1} , I_{L2} , I_{L3}) thus obtaining a number of samples, and calculating (72) an instantaneous DC current value for each sample, thus obtaining a DC current waveform.

8. The method as claimed in any of the preceding claims,
 20 wherein the equipment (1, 31, 41, 61) comprises a DC link, a DC rectifier, a static frequency converter, a high voltage direct current back-to-back station or a DC transmission line.

9. The method as claimed in claim 1, wherein the instantaneous DC currents are measured for two sides of a DC device (31, 41, 61), whereby a differential protection is enabled for the DC device (31, 41, 61).

5 10. A control device (10) arranged to control, monitor and protect equipment (1, 31, 41, 61) within an electrical power system, wherein the equipment (1, 31, 41, 61) comprises a direct current side and comprises or is connected to an alternating current (AC) side, the AC side comprising one or
10 more phases (L1, L2, L3), the control device (10) comprising an input module (11) arranged to measure AC currents and means (13, 14, 15) for calculating a DC current based on the measured AC currents for use by the central processing unit (12).

15 11. The control device (10) as claimed in claim 10, wherein the means (13) for calculating a DC current based on the measured AC currents comprises integrated circuitry (13).

12. The control device (10) as claimed in claim 10, wherein the means (13) for calculating a DC current based on the
20 measured AC currents comprises a computer program (15) comprising computer program code which when run on the central processing unit (12) provides the DC current.

13. The control device (10) as claimed in any of claims 10-12, wherein the central processing unit (12) is arranged to
25 detect fault conditions in the equipment (1, 31, 41, 61) by using the DC current.

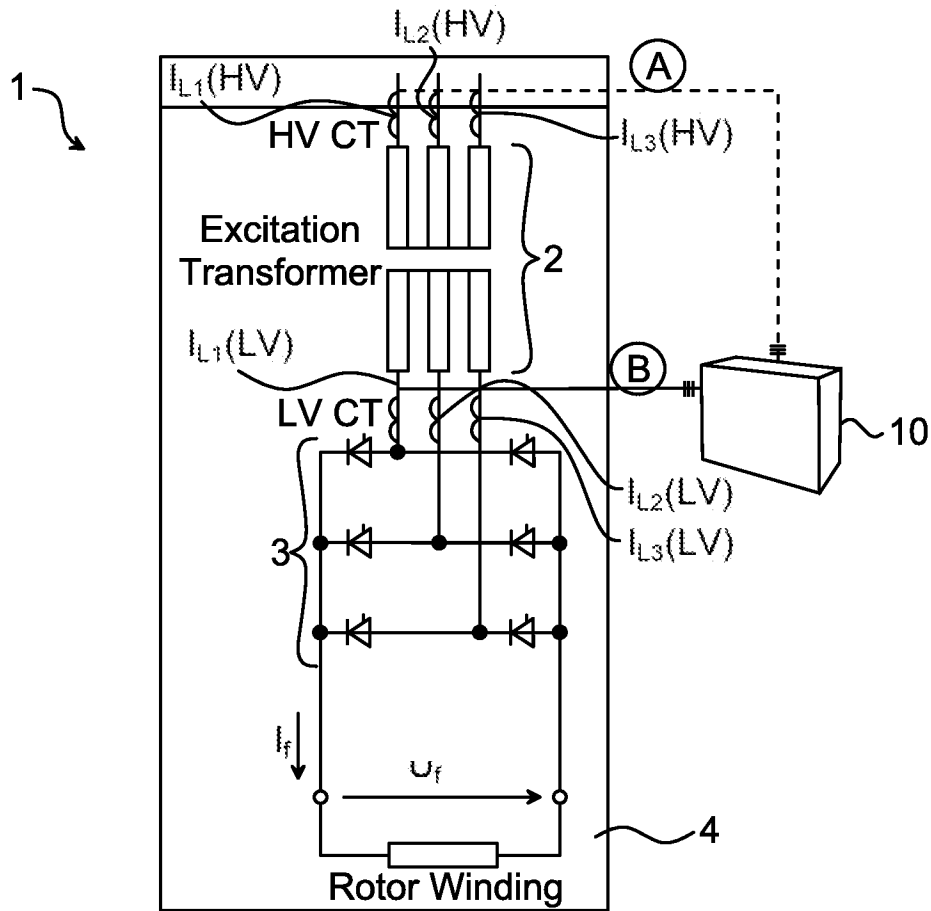


Fig. 1

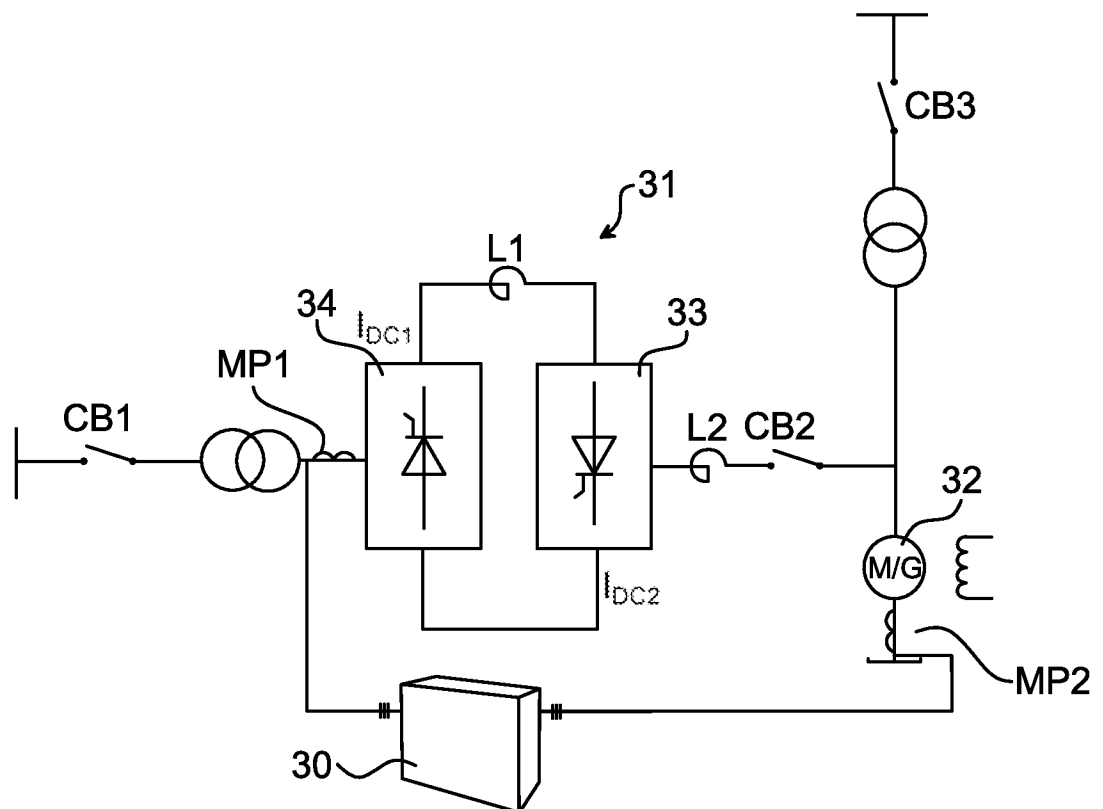


Fig. 2

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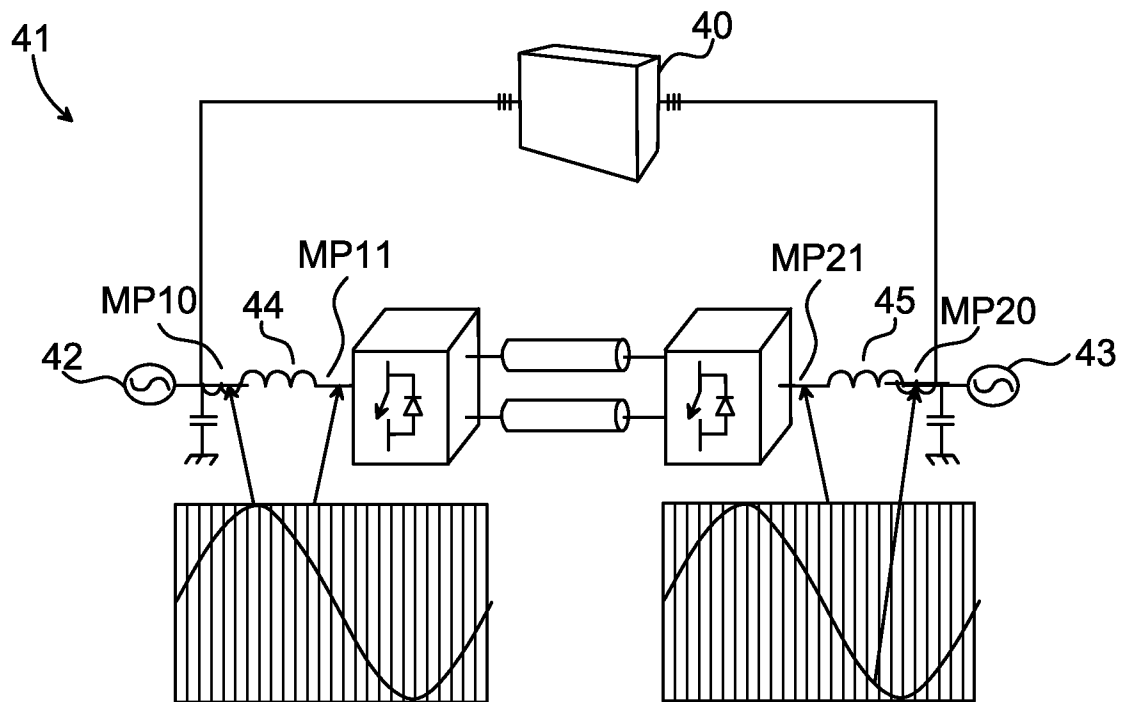


Fig 3

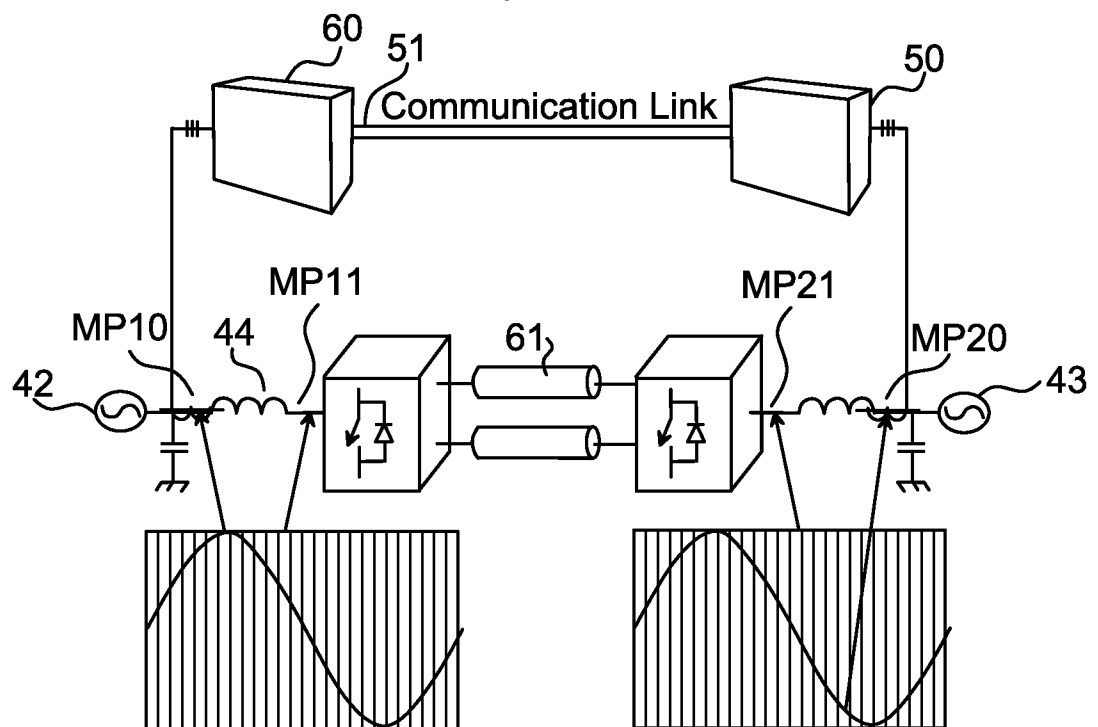


Fig 4

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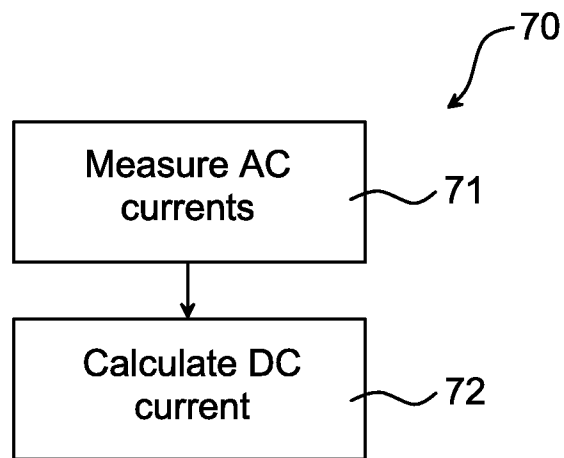


Fig. 5

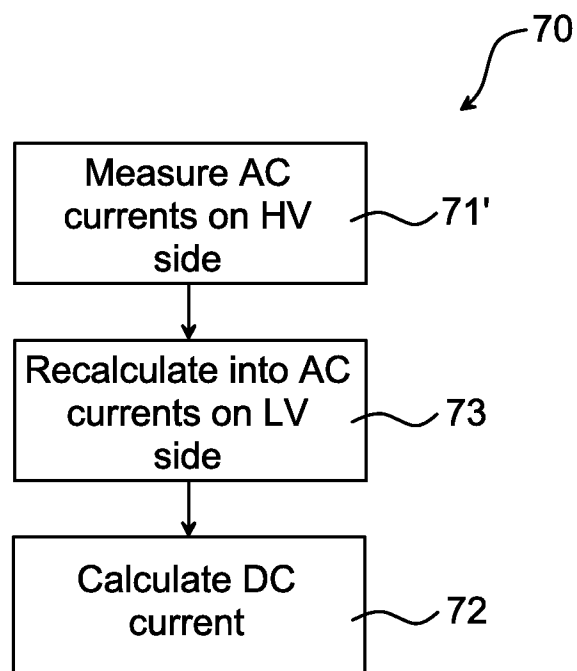


Fig. 6

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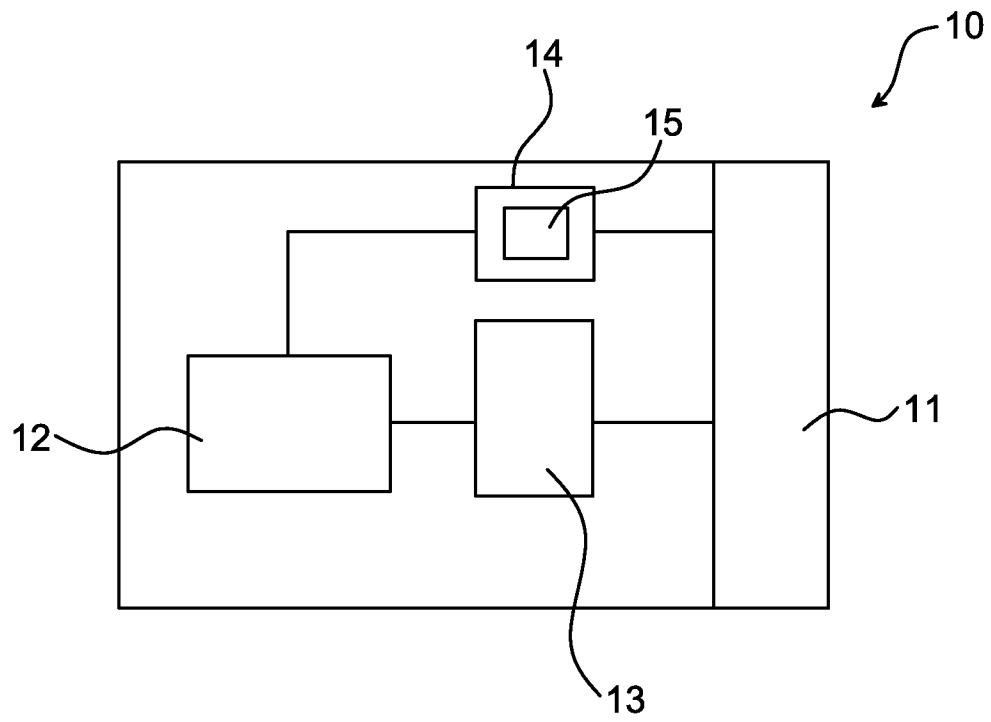


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/052799

A. CLASSIFICATION OF SUBJECT MATTER

INV. H02H7/125 G01R19/22
ADD. H02H3/087 H02H3/28 H02H7/12

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 G01R H02M H02J H01H

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 23 46 957 A1 (SIEMENS AG) 17 April 1975 (1975-04-17) the whole document	1-13
X	FR 2 106 732 A5 (ALSTHOM) 5 May 1972 (1972-05-05) the whole document	1-13
X	DE 28 41 856 A1 (SIEMENS AG) 27 March 1980 (1980-03-27) the whole document	1-13
X	EP 0 159 201 A1 (TELEMECANIQUE ELECTRIQUE [FR]) 23 October 1985 (1985-10-23) abstract page 1, line 12 - page 6, line 7; claim 1; figures 1,2	1-13



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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.

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Date of the actual completion of the international search

17 January 2012

Date of mailing of the international search report

25/01/2012

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

Palukova, Mila

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2011/052799

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