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(54) **A device for detecting a difference between currents in an electric circuit**

(57) The present invention relates to a device used to detect a difference between currents in an electric circuit, designed as an electrical four-terminal network included in a DC or AC electric circuit, comprising a movable magnetic yoke (3) and a magnetic core (2). The magnetic core (2) consists of the first lateral leg (6) of the core and the second lateral leg (6') of the core and is equipped with a permanent magnet (9) situated symmetrically between the legs (6, 6') of the core. The first wind-

ing (4) and the second winding (4') are installed on the legs of the core respectively. The device is characterised in that the permanent magnet (9) is a component of the middle leg (7) of the core with its longitudinal axis (A) being the axis of symmetry of the core which is identical with the axis of the permanent magnet defined by its NS magnetic poles (9), where the magnetic yoke (3) is designed to rotate in a plane parallel to the longitudinal cross-section of both legs (6, 6').

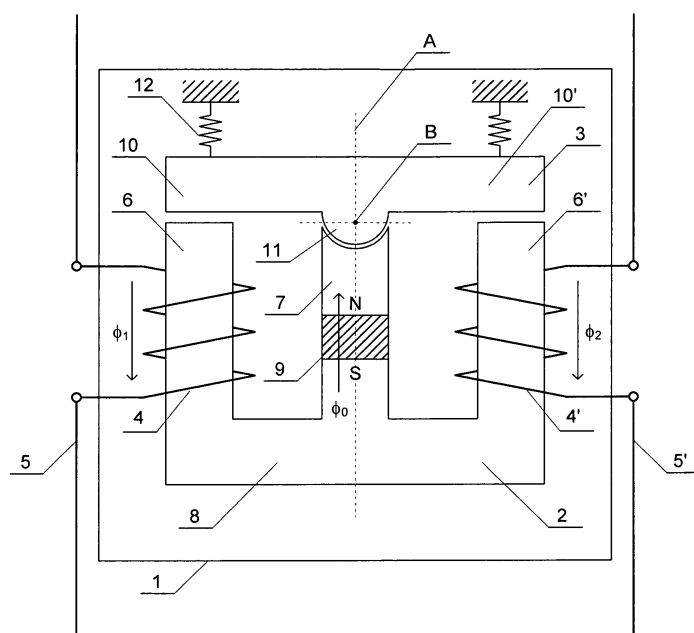


Fig. 1

## Description

**[0001]** The present invention relates to a device used to detect a difference between currents in an electric circuit. The device is designed both for direct current (DC) and alternate current (AC) circuits which include both electrical loads and power sources.

## BACKGROUND OF THE INVENTION

**[0002]** The patent application DE102010034001 describes a system designed to detect leakage currents in a DC circuit and a system designed to break a DC circuit if current leakage occurs in the circuit. The system comprises switches that are installed in the supply and return line respectively and connected with a magnetic releasing component. Shunt resistors are installed into the supply and return line. The magnetic releasing component comprises a double-leg core with a base and an yoke. A constant force is applied to the yoke, which is produced e.g. by a spring and pulls away the yoke from the core. Excitation windings are installed on the legs of the core and connected to the terminals of the supply and return wires respectively. The currents flowing in the excitation windings induce two magnetic fluxes in the core, the first and the second one, with opposite directions. The base of the core contains a permanent magnet whose axis defined by its NS poles is oriented parallel to the lines of the magnetic field generated in the core by the excitation windings. The permanent magnet generates in the core another magnetic flux with a direction coincident with that of the second flux and opposite to that of the first flux. When there is no leakage current in the electric circuit, the first flux and the second flux cancel each other and only the flux generated by the permanent magnet exists in the core. The value of the flux generated by the permanent magnet is sufficient to produce a force that keeps the yoke attracted to the core and to outbalance the force produced by the spring pulling the yoke away. If leakage current occurs in the electric circuit, the second flux is weaker than the first flux and their superposition has a direction opposite to the direction of the flux generated by the permanent magnet. Consequently, the total magnetic flux being a combination of all three fluxes is too weak to produce magnetic force that would keep the yoke attracted to the core. The movement of the yoke opens the switches and breaks the supply and return line

**[0003]** There is a disadvantage of the described solution. Namely if there is an additional current, instead of leakage current, generated by an additional source included in the electric DC circuit, the second magnetic flux will be stronger than the first magnetic flux. The superposition flux will have a direction consistent with that of the flux generated by the permanent magnet and this will produce even a higher force attracting the yoke to the core than in the circumstances where the first flux and the second flux have an equal value. None of the switches will be opened and the device will not break the electric

circuit despite a difference detected between the currents flowing in the excitation windings.

## SUMMARY OF THE INVENTION

**[0004]** A device used to detect a difference between currents in an electric circuit, designed as an electrical four-terminal network included in a DC or AC electric circuit, comprising a movable magnetic yoke and a magnetic core. The magnetic core is equipped with the first lateral leg of the core and the second lateral leg of the core and is equipped with a permanent magnet situated symmetrically between the legs of the core. The first winding and the second winding are installed on the legs of the core respectively. The device is characterized by the fact that the permanent magnet is designed as a component of the middle leg of the core with a longitudinal axis being the axis of symmetry of the core and identical with the axis of the permanent magnet defined by its NS magnetic poles while the magnetic yoke is designed to rotate in a plane parallel to the longitudinal cross-section of both legs.

**[0005]** Preferably, the movable magnetic yoke comprises two arms and a central supporting component designed as a part of the yoke, situated in the symmetry axis between the arms of the yoke and containing within its area the axis of rotation of the magnetic yoke.

**[0006]** Preferably, at least one of the arms of the magnetic yoke or the supporting component of the magnetic yoke is connected with at least one spring component keeping the magnetic yoke balanced in the symmetrical position.

**[0007]** Preferably, the magnetic yoke is connected with two identical spring components situated symmetrically to the axis of rotation of the magnetic yoke.

**[0008]** Preferably, the supporting component has a shape compatible with the end of the middle leg of the magnetic core.

**[0009]** Alternatively, the magnetic yoke is equipped with a central supporting component designed as a part of the yoke and characterized by a flat surface parallel to the axis of rotation of the magnetic yoke and perpendicular to the longitudinal axis of the core.

**[0010]** Preferably, the flat surface of the supporting component remaining in contact with the end of the middle leg of the core is designed to keep the magnetic yoke balanced in the symmetrical position.

**[0011]** A device based on the invention is suitable for detecting a difference between currents flowing in a direct current (DC) or alternate current (AC) electric circuit. The difference between currents may result both from leakage current in the electric circuit and from the appearance of an additional current in the electric circuit.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0012]** A system based on the invention is explained by example implementations shown on the drawing of

which Fig. 1 represents a schematic diagram of a device designed to detect a difference between currents in the first example of implementation, and Fig. 2 represents a schematic diagram of a device designed to detect a difference between currents in the second example of implementation.

#### DETAILED DESCRIPTION OF THE INVENTION

**[0013]** Device 1 used to detect a difference between currents flowing in an electric circuit is designed as an electrical four-terminal network connected in series in the electric circuit of a DC or AC network comprising two branches.

**[0014]** Device 1 is equipped with a magnetic core 2 with a magnetic yoke 3 making up together a magnetic circuit. There are the first electrical winding 4 and the second electrical winding 4' installed on the magnetic core 2, both generating magnetic fields in the magnetic circuit. The first electrical winding 4 is included in the first branch 5 of the electric circuit and the second winding 4' is included in the second branch 5' of the electric circuit. The magnetic core comprises at least two lateral legs, the first lateral leg 6 and the second lateral leg 6' and at least one middle leg 7 which are connected by the base 8 and arranged with a common axis of symmetry. The first winding 4 and the second winding 4' are installed on the first lateral leg 6 and the second lateral leg 6' respectively. The middle leg 7 contains a permanent magnet 9 designed as an insert installed inside the middle leg 7 or, which is not represented on the drawing, as an insert installed on the middle leg 7 or at the base of the leg, symmetrically to the longitudinal axis of the middle leg 7. Also the entire middle leg 7 may be designed as a permanent magnet 9. The permanent magnet 9 is situated so that the axis defined by its NS magnetic poles is identical with the longitudinal axis of the middle leg 7.

**[0015]** The magnetic yoke 3 has a symmetrical shape and is designed as a swinging beam which axis of rotation is perpendicular to the longitudinal axis of the middle leg 7. The magnetic yoke 3 has two symmetrical arms: the first arm 10 and the second arm 10' and a central supporting component 11 with the axis of rotation of the beam situated within the area of the component.

**[0016]** The operation of the invention is based on proper adjustment of the position of yoke 3 during the use of the invention. The yoke may take on one of three positions in the magnetic circuit: the symmetrical position, the first inclined position and the second inclined position. Each of these positions is stable which means that a force with a defined threshold value must be applied to change the position. If the value of force acting upon the magnetic yoke 3 is lower than the threshold value, the magnetic yoke 3 will not change its position.

**[0017]** In the symmetrical position, the distance between the first arm 10 of the magnetic yoke and the first lateral leg 6 of the magnetic core is equal to the distance between the second arm 10' of the magnetic yoke and

the second lateral leg 6' of the magnetic core. In the first inclined position, the distance between the first arm 10 of the magnetic yoke and the first lateral leg 6 of the magnetic core is shorter than the distance between the second arm 10' of the magnetic yoke and the second lateral leg 6', and in the second inclined position the former distance is longer than the latter.

**[0018]** The symmetrical position of the magnetic yoke 3 is the steady state position of the device 1. The symmetrical position is maintained when there is no emergency condition in the electric current, i.e. the current flowing in the first winding 4 is equal to the current flowing in the second winding 4'. In normal circumstances, the magnetic flux  $\Phi_1$  generated by the first winding 4 is equal to the magnetic flux  $\Phi_2$  generated by the second winding 4', and consequently the magnetic force attracting the first arm 10 to the first lateral leg 6 is equal to the magnetic force attracting the second arm 10' to the second lateral leg 6'. Both forces neutralize each other and have no effect on the position of the magnetic yoke 3. A magnetic flux  $\Phi_0$  is also generated in the core by the permanent magnet 9. When the magnetic yoke 3 is in the symmetrical position, the magnetic flux generated by the permanent magnet 9 in the first lateral leg 6 is equal to the magnetic flux generated by it in the second lateral leg 6'. The magnetic forces generated by the permanent magnet which attract the first arm 10 to the first lateral leg 6 and the second arm 10' to the second lateral leg 6' are equal in terms of value and opposite in terms of direction, cancel each other and do not affect the position change of the magnetic yoke 3.

**[0019]** The magnetic yoke 3 will move to take on the first or the second inclined position if the currents flowing in the first winding 4 and the second winding 4' differ at least by the threshold value required to activate the device.

**[0020]** When the magnetic yoke 3 moves to take on the first inclined position, the value of reluctance (magnetic resistance) in the first section of the magnetic circuit consisting of the central leg 7, the base of the core 8, the first lateral leg 6 and the first arm 10 of the yoke is lower than the value of reluctance in the second section of the magnetic circuit consisting of the central leg 7, the base of the core 8, the second lateral leg 6' and the second arm 10' of the magnetic yoke. The lower value of reluctance in the first section of the magnetic circuit results from the fact that the distance between the first arm 10 and the first lateral leg 6 is shorter than the distance between the second arm 10' and the second lateral leg 6', and consequently the magnetic flux generated by the permanent magnet 9 in the first section of the magnetic circuit is stronger than that in the second section of the magnetic circuit. As a result, the attracting magnetic forces generated by the permanent magnet 9 are stronger in the first section of the magnetic circuit and this keeps the magnetic yoke 3 stable in its first inclined position, regardless of the value of currents flowing in the first winding 4 and in the second winding 4'.

**[0021]** The first and the second inclined positions are durable, i.e. they do not change even if the currents flowing in the first winding 4 and the second winding 4' become balanced again. The stable nature of the positions results from the operation of the magnetic field generated by the permanent magnet 9. The symmetrical position of the magnetic yoke 3 may be restored e.g. with the use of a mechanical push component known from other solutions and not disclosed in the drawings.

**[0022]** Stability of the symmetrical position may be achieved with the use of various technical solutions. In the first example, movements of the magnetic yoke 3 are limited by spring components 12. The spring components 12 are arranged symmetrically to the axis of symmetry of the magnetic yoke 3. If the resultant force acting upon the first arm 10 or the second arm 10' is weaker than the defined threshold value, the yoke will return to the symmetrical position after slight inclination.

**[0023]** In the second example of implementation, the central supporting component 11' of the magnetic yoke 3 has a flat contact surface 13 which adheres to the flat surface of the middle leg 7 when the magnetic yoke 3 is in the symmetrical position. The threshold value of magnetic attracting force acting between the magnetic yoke 3 and the middle leg 7 must be overbalanced in order to tilt the magnetic yoke.

**[0024]** Both in the first and in the second examples of implementation, the magnetic yoke 3 may be equipped with a damper component not disclosed in the drawings, whose aim is to damp out oscillation of the magnetic yoke 3 while its symmetrical position is being restored.

## Claims

1. A device used to detect a difference between currents in an electric circuit, designed as an electrical four-terminal network included in a DC or AC electric circuit, comprising a movable magnetic yoke (3) and a magnetic core (2) equipped with the first lateral leg (6) of the core and the second lateral leg (6') of the core and equipped with a permanent magnet (9) situated symmetrically between the legs (6, 6') of the core with the first winding (4) and the second winding (4') installed on the legs respectively, **characterized in that** the permanent magnet (9) is designed as a component of the middle leg (7) of the core with its longitudinal axis (A) being the axis of symmetry of the core which is identical with the axis of the permanent magnet which is defined by its NS magnetic poles (9), where the magnetic yoke (3) is designed to rotate in a plane parallel to the longitudinal cross-section of both legs (6, 6').
2. A device according to claim 1 **characterized in that** the movable magnetic yoke (3) has two arms (10, 10') and a central supporting component (11) designed as a part of the yoke and located in the axis

of symmetry of the arms of the yoke (10, 10') and containing within its area the axis of rotation (B) of the magnetic yoke (3).

3. A device according to claim 2 **characterized in that** at least one of the arms (10, 10') of the magnetic yoke (3) or the central supporting component (11) of the magnetic yoke (3) is connected with at least one spring component (12) that keeps the magnetic yoke (3) balanced in the symmetrical position.
4. A device according to claim 3 **characterized in that** the magnetic yoke (3) is connected with two identical spring components (12) situated symmetrically to the axis of rotation (B) of the magnetic yoke (3).
5. A device according to claim 2 **characterized in that** the shape of the supporting component (11) is compatible with the shape of the end of the middle leg (7) of the magnetic core (2).
6. A device according to claim 1 **characterized in that** the magnetic yoke includes a central supporting component (11') designed as a part of the yoke and **characterized by** a flat surface (13) parallel to the axis of rotation of the magnetic yoke (3) and perpendicular to the longitudinal axis of the core (A).
7. A device according to claim 6 **characterized in that** the flat surface (13) of the supporting component (11') remaining in contact with the end of the middle leg (7) of the core is so designed that the magnetic yoke (3) is kept balanced in the symmetrical position.

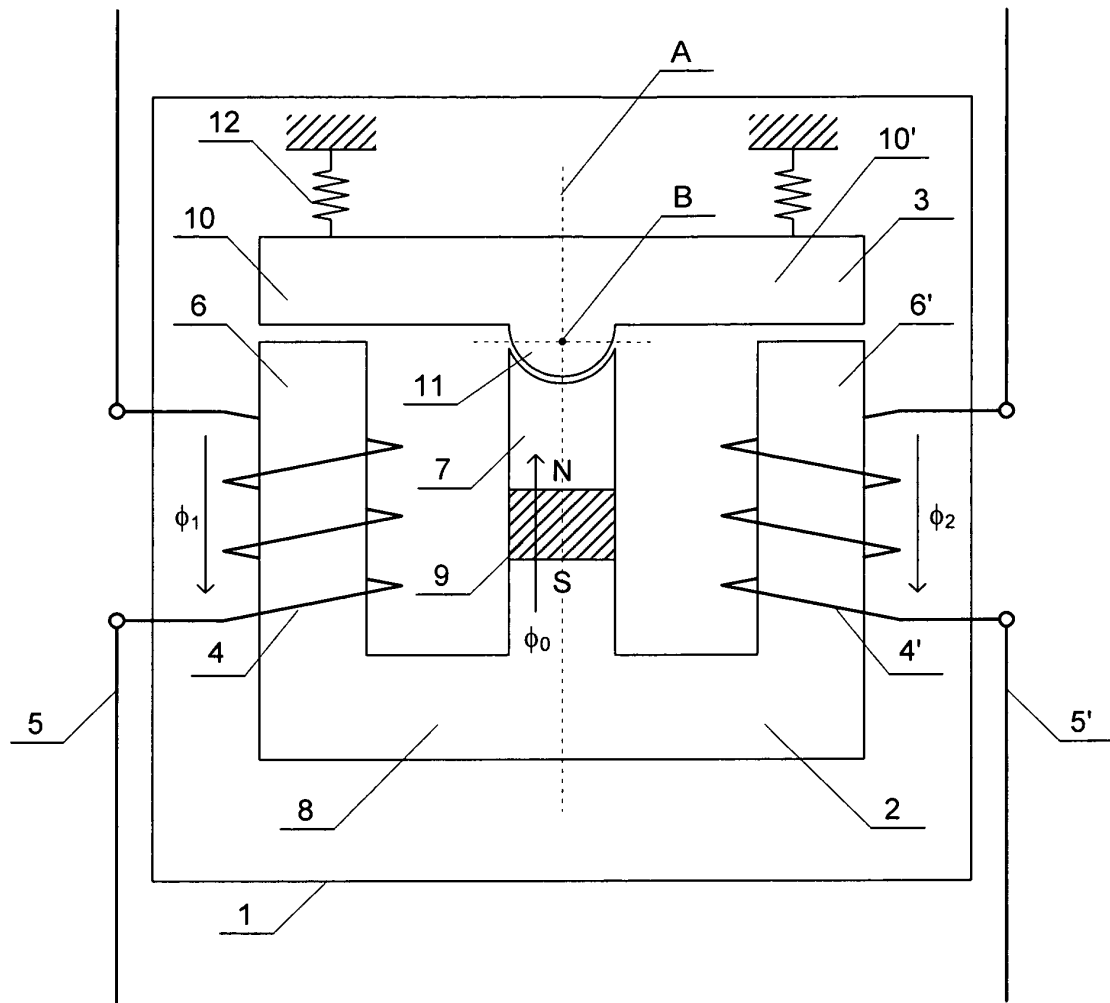


Fig. 1

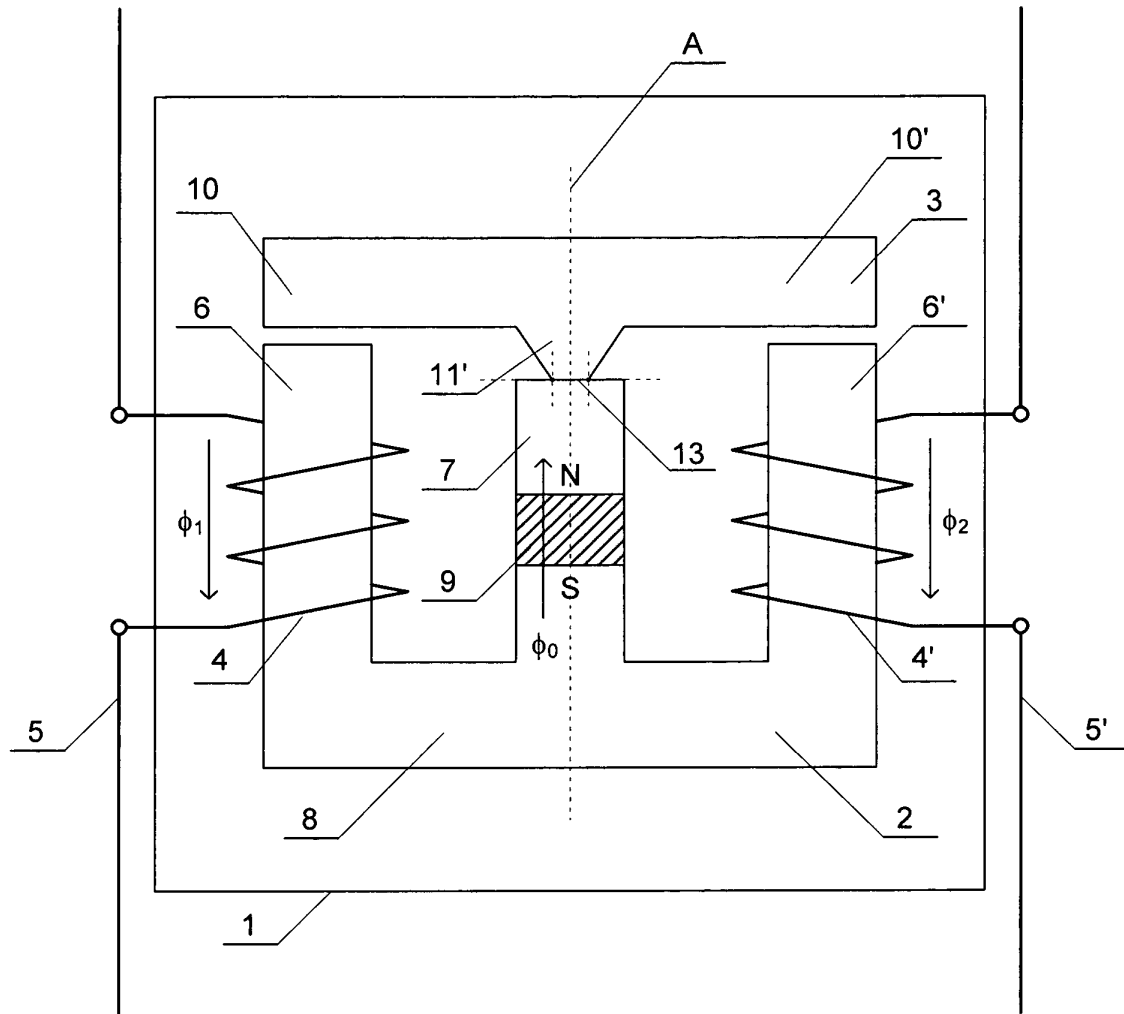


Fig. 2



## EUROPEAN SEARCH REPORT

Application Number  
EP 13 46 0022

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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                      |                                                       |                                            |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|--------------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Citation of document with indication, where appropriate, of relevant passages                                                                        | Relevant to claim                                     | CLASSIFICATION OF THE APPLICATION (IPC)    |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | WO 2006/099909 A1 (TRIPCO LTD [IE]; WARD PATRICK [IE])<br>28 September 2006 (2006-09-28)                                                             | 1-4,6                                                 | INV.<br>H01H83/14<br>H02H3/32<br>H01H71/32 |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | * paragraph [0006] *<br>* paragraph [0026] - paragraph [0029] *<br>* paragraph [0033] *<br>* figures 5,6,9 *                                         | 5,7                                                   |                                            |
| A,D                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | -----<br>DE 10 2010 034001 A1 (SIEMENS AG [DE])<br>16 February 2012 (2012-02-16)<br>* paragraph [0024] - paragraph [0027] *<br>* figure 2 *<br>----- | 1-7                                                   |                                            |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                      |                                                       | TECHNICAL FIELDS SEARCHED (IPC)            |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                      |                                                       | H01H<br>H02H                               |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                      |                                                       |                                            |
| Place of search<br>Munich                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                      | Date of completion of the search<br>16 September 2013 | Examiner<br>Fribert, Jan                   |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                                                      |                                                       |                                            |

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**ANNEX TO THE EUROPEAN SEARCH REPORT  
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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