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(54) **Title:** A CAPACITOR AND A VOLTAGE TRANSFORMER

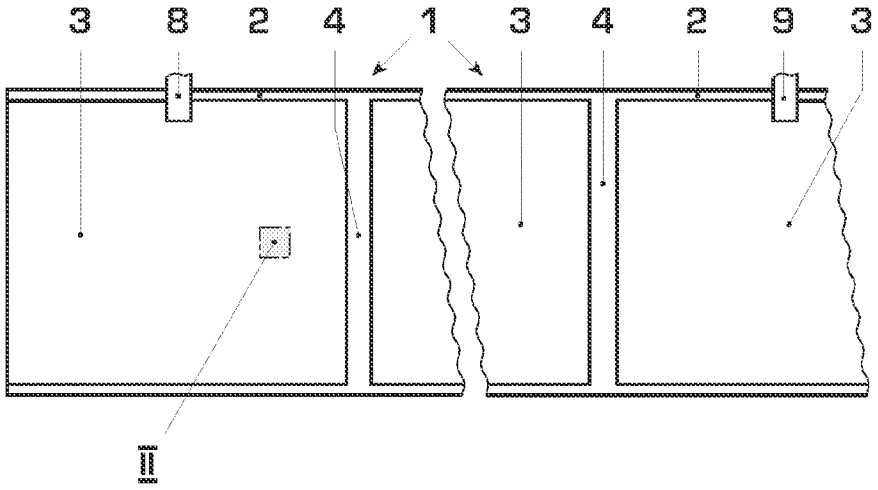

Fig. 1

(57) **Abstract:** A capacitor comprises a winding made from a film (1). The film (1) comprises a base (2) consisting of an electrically insulating polymer which carries on one of its surfaces a 5 sequence of conductive areas (3) where the base (2) carries an electrically conductive coating, separated by non-coated interstices (4). The conductive areas (3) are all of the same shape and size, preferably forming parallelograms aligned with a longitudinal direction of the film (1) and of 10 equal lateral positions on the base (2). The capacitor has a plurality of essentially concentric electrodes which are insulated from each other and consist each of one or more electrode layers formed by one of the conductive areas (3) and separated by dielectric layers formed by sections of the 15 base (2). The capacitor is easy to produce by the winding of the film (1) on a suitable support and has high voltage withstand capacity. It can be used as a high voltage capacitor in a capacitive voltage transformer in series with a conventional low voltage capacitor wound from two 20 superposed conductively coated films.

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D E S C R I P T I O N

A CAPACITOR AND A VOLTAGE TRANSFORMER

Field of the invention

The invention concerns a capacitor according to the generic part of claim 1 and a voltage transformer comprising a capacitor according to the invention as a high voltage capacitor. Capacitors and voltage transformers of this type are typically employed in MV and HV electrical installations.

Prior art

Capacitors of the generic type are known from EP 1 801 825 A1. According to this document, every conductive area of the film the capacitor is wound from covers a fixed constant angle, e.g., slightly more than two full turns.

It has been found that the production of such capacitors is quite difficult because the conductive areas vary in length, their longitudinal extensions being required to precisely follow a certain function of their distance from the front end of the film. In addition, the capacitor must be wound with great precision and in particular the tension of the film kept within a narrow range during the winding process.

Summary of the invention

It is an object of the invention to provide a capacitor of the generic type which is easy to produce.

It has been found that a capacitor wound from a single film where the conductive areas are all of the same shape and size has essentially the same electrical properties as a prior art capacitor. The only difference lies in the fact that there is a variable overlap between subsequent parts of the same conductive area depending on the radial position of the latter within the winding. If a minimum such overlap, e.g., of slightly more than one winding, is required this has the consequence that the overlap will generally, that is, apart from the outermost layers, be larger than required. This results in a somewhat larger winding for a given capacitance but it has been found that this is usually not a serious disadvantage. On the other hand, the advantages gained by the simple and straightforward production of the winding are very substantial.

It is a further object of the invention to provide a capacitive voltage transformer of high accuracy and reliability which is at the same time easy to produce. This object is achieved in that a capacitor according to the invention is employed as a high voltage capacitor where its capacity of withstanding high voltage differences is used to advantage while its relatively low capacitance does not constitute a drawback.

Brief description of the drawings

In the following, the invention will be explained in more detail with reference to the following figures which show only embodiments.

Fig. 1 schematically shows a partial top view of a polymer film used for the production of a capacitor according to the invention,

Fig. 2 shows enlarged a cutout from Fig. 1 as indicated by II,

Fig. 3 shows an axial section through a voltage transformer according to the invention,

Fig. 4 schematically shows a partial longitudinal section of a film according to Fig. 1, and

Fig. 5 schematically shows a cutout from a section of a capacitor wound from the film according to Fig. 1 and Fig. 4.

Description of the preferred embodiments

A film 1 which may be used for producing a capacitor, in particular for a voltage transformer as shown in Fig. 3 comprises (Fig. 1) a base 2 essentially consisting of electrically insulating polymer material, with one surface partially covered by a coating of electrically conductive material. The film 1 forms a long strip of constant width. Its thickness is preferably between 2µm and 20µm. The material of the base 2 is, e.g., polyethylene, polystyrole, polypropylene, polycarbonate, polyimide, PET, PEN, PPS (polyphenylene sulphide), polyester, epoxy resin, polysulfone or a mixture of such polymers possibly also containing additives and suitable for forming a thin film with high dielectric strength. The coating is in the form of a single sequence of at least four but usually a much greater number of parallelogram-shaped, as a rule at least nearly rectangular conductive areas 3 where the base 2 carries an electrically conductive coating and which follow one upon the other in a longitudinal direction. The lateral boundaries of the said conductive areas 3 are spaced from

the lateral edges of the film 1, i.e., the margins of the base 2, so the latter exhibits non-coated strips adjacent to its margins which extend over virtually the whole length of the film 1 without interruption. Subsequent conductive areas 3 are in each case separated by a transverse interstice 4 or gap in the coating. As a consequence, the conductive areas 3 are electrically insulated from each other.

The coating consists preferably of metal, and is in particular a metallization applied by vapour deposition, but use of other electrically conductive materials beside metals, e.g., carbon, is also possible. The electrically conductive coating is patterned as known per se (s. EP 0 225 822 A1), that is, it consists of, e.g., quadratic, patches 5, 5′ (s. Fig. 2 which shows an enlarged cutout II from Fig. 1) with adjacent patches 5, 5′ separated by uncoated strips 6 and only connected by thin bridges 7 of coating at the corners. If a partial breakdown occurs at one of the patches, e.g., patch 5′, the surrounding bridges 7 evaporate, thereby interrupting the electrically conductive connections of the patch 5′ in question with its neighbours. Alternatively, a graded or uniform conductive coating can be used. The electrical conductivity of the coating may be relatively low as larger currents will normally be perpendicular, that is, its surface resistivity will usually be at least $1\Omega_{\square}$.

The leftmost of the conductive areas 3 in Fig. 1 is electrically conductively connected to a lead 8. The conductive areas 3 are congruent, i.e., of the same shape and size, throughout the longitudinal extension of the film 1. They are aligned with the longitudinal direction, their lateral margins being substantially parallel to the lateral margins of the base 2. Their lateral positions on the base

2, i.e., their distances from the lateral margins of the latter, are equal. The interstices 4 are of equal lengths, too. The rightmost of the areas 3 is connected to another lead 9. Due to the geometrical regularity of the coating forming the conductive areas 3 films of any desired length are easy to produce.

The film 1 is suitable for forming a cylindrical winding which can be used as a capacitor. A capacitor of this type is particularly suitable as a high voltage capacitor in a capacitive voltage transformer as shown in Fig. 3. This capacitor 10 is carried by a tube-shaped support 11 of electrically insulating material, e.g., fiber-enforced plastic on which the film has been wound and which in turn surrounds a conductor rod 12. A contact ring 13 which also surrounds the conductor rod 12 and contacts the same with elastic contact fingers is electrically conductively connected to the innermost of the conductive areas 3 via lead 9. The capacitor 10 also comprises as a separate first terminal electrode a measuring electrode 14 surrounding the winding and consisting of metal, preferably aluminium foil. It is electrically conductively connected to the outermost of the conductive areas 3 by lead 8.

Alternatively, lead 8 is omitted and the measuring electrode merely capacitively coupled to the outermost conductive area of the capacitor winding. In principle it is possible to omit lead 9 as well but this may compromise measuring accuracy. A further possibility is to wind the capacitor directly onto the conductor rod 12 with lead 9 and contact ring 13 omitted.

The measuring electrode 14 is surrounded by a further tube-shaped support 15 carrying a further capacitor, a low

voltage capacitor 16. It may be of a conventional design, e.g., as described in EP 1 329 915 A1, consisting of two films wound on the support 15 together, each with a contiguous electrically conductive coating at an inner surface, the coating covering an area extending essentially over the whole length of the winding in each case, where with a first one of the said films the said area extends to a first lateral edge which forms a first face of the winding and at the second film to an opposite second lateral edge which forms the opposite second face of the winding.

The first face is covered by a contact ring 17 which contacts the conductive area of the first film and is electrically conductively connected to the measuring electrode 14 whereas the second face is covered in the same manner by a contact ring 18 which contacts the conductive area of the second film and is grounded. The capacitance of low voltage capacitor 16 is much larger than that of capacitor 10, preferably by a factor of between 100 and 10'000 which is at the same time the conversion factor of the voltage transformer. The measuring electrode 14 is electrically conductively connected via the contact ring 17 to an evaluation circuit 19 which may be of known design and delivers an output signal corresponding to the potential of the measuring electrode 14 which reflects the potential of conductor rod 12.

It is advantageous to use in both the high voltage capacitor 10 and the low voltage capacitor 16 the same material for the film or at least for its base as in this case the influence which variations of parameters like temperature or voltage may have on the electrical properties of the said capacitors will be substantially the same and the conversion factor will remain practically unaffected, in particular,

where they are arranged in close proximity of each other, e.g., immediately adjacent to each other. As a consequence, high measuring accuracies can be achieved which allows application of the transformer in fields with particularly stringent respective requirements like metering. The voltage transformer can be encapsulated in a casing of electrically insulating material for mechanical stabilization and protection.

The equal lengths of the areas 3 of the film 1 forming the capacitor 10 may be chosen in such a way that each of them has a certain minimum overlap with itself, e.g., extending over slightly more than two turns of the capacitor 10 in the outermost layers, thereby forming an electrode comprising two essentially parallel electrode layers. Subsequent interstices 4 can be slightly staggered there (see Figs. 4, 5). As a consequence, radial components of the electric field are small in the neighbourhood of the interstices 4. Also, throughout every second winding of the film 1 both surfaces of the base 2 are adjacent to electrode layers pertaining to the same electrode as formed by one of the conductive areas 3. Therefore the base 2 is not subjected to a strong and permanent electric field which is a further obstacle to an extension of any partial breakdown. As the length of a turn is inversely proportional to its radius the angular extension covered by one of the conductive areas 3 follows the same rule, i.e., the self-overlap of the conductive areas increases with decreasing radius (s. Fig. 5). The overall capacitance of the capacitor 10, that is, the capacitance pertaining to the series of capacitances formed by the pairs of subsequent conductive areas, is thereby somewhat increased. As a consequence, the dimensions of a winding having a certain capacitance will be slightly

larger, but this is usually acceptable, in particular in a high voltage capacitor of a capacitive voltage transformer.

The width of the interstices 4 will have to be chosen large enough to prevent surface flashovers at the expected voltages. The interstices may, however, be much wider than this requirement necessitates. The risk of flashovers at the margins is generally quite small, the conductive areas 3 being spaced from the lateral edges of the film 1. It is, however, possible to seal the winding there by welding or by covering it with resin or some other suitable material in order to protect the winding against humidity.

The capacitor 10 is produced by winding a predetermined length of film 1 from, e.g., a reel, on the support 11. The winding step can be carried out in a straightforward manner without extensive precautions and controls. The whole or part of the winding forming the capacitor 10 may, in addition to the film 1 as described above, comprise further layers which consist, e.g., of another film of the same type or a film having only an insulating base with no conductive coating. Such additional layers may be wound on the support together with the film 1.

Beside the measuring electrode 14, the capacitor 10 may comprise a second terminal electrode which may also consist of metal, in particular, aluminium foil and which surrounds the support 11 and is electrically conductively connected to contact ring 13. The coupling between a terminal electrode and an adjacent electrode of the winding can be via a lead or other electrically conductive connection or merely capacitive. On the other hand, a separate measuring electrode can be omitted and the outermost conductive area

of the winding directly connected to contact ring 17 and evaluation circuit 19.

As the electrodes in capacitor 10 are electrically insulated from each other they are on usually different floating potentials. It is advantageous if the distances between subsequent electrodes are such that, with the expected maximum overall potential difference between the conductor and ground, the potential difference between the said electrodes is always below the minimum of the Paschen curve as in this case partial breakdowns of an insulating layer between two subsequent electrodes cannot occur.

The capacitors are preferably dry, that is, they do not contain impregnation fluids applied to the film during the manufacturing of the capacitor and having penetrated its base. Of course, the dimensions, shapes and arrangement of the conductive areas and their electrical properties as well as the dimensions and properties of the base may vary widely depending on the specific purposes of the capacitor.

List of reference symbols

1	film
2	base
3	conductive area
4	interstice
5, 5’	patch
6	uncoated strip
7	bridge
8, 9	lead
10	(high voltage) capacitor
11	support
12	conductor rod

13	contact ring
14	measuring electrode
15	support
16	low voltage capacitor
17, 18	contact ring
19	evaluation circuit

P A T E N T C L A I M S

1. A capacitor (10) comprising a winding of at least a film (1) with an electrically insulating base (2) of constant width in a transverse direction comprising at least one polymer, the film (1) having a partially conductive surface where the base (2) carries a partial coating of electrically conductive material forming on the said surface a sequence of contiguous conductive areas (3), each of them spaced from lateral edges of the film (1), the conductive areas (3) following upon each other in a longitudinal direction perpendicular to the transverse direction separated by non-coated interstices (4), **characterized in that** the conductive areas (3) are of the same shape and size and the interstices (4) of equal lengths.

2. A capacitor (10) according to claim 1, **characterized in that** the base (2) comprises at least one of the following: polyethylene, polystyrole, polypropylene, polycarbonate, polyimide, PET, PEN, PPS, Polyester, epoxy resin, polysulfone.

3. A capacitor (10) according to claim 1 or 2, **characterized in that** the partial coating is a metallization.

4. A capacitor (10) according to one of claims 1 to 3, **characterized in that** the partial coating has non-uniform conductivity, in particular, is patterned or graded.

5. A capacitor (10) according to one of claims 1 to 4, **characterized in that** a thickness of the film is between 2µm and 20µm.

6. A capacitor (10) according to one of claims 1 to 5, **characterized in that** the extension of the conductive areas (3) perpendicular to the longitudinal direction is constant.

7. A capacitor (10) according to claim 6, **characterized in that** the conductive areas (3) are parallelogram-shaped.

8. A capacitor (10) according to claim 7, **characterized in that** the conductive areas (3) are aligned with the longitudinal direction.

9. A voltage transformer comprising, as a high voltage capacitor, a capacitor (10) according to one of claims 1 to 8 and a low voltage capacitor (16) series-connected to the high voltage capacitor (10).

10. A voltage transformer according to claim 9, **characterized in that** the low voltage capacitor (16) coaxially surrounds the high voltage capacitor (10).

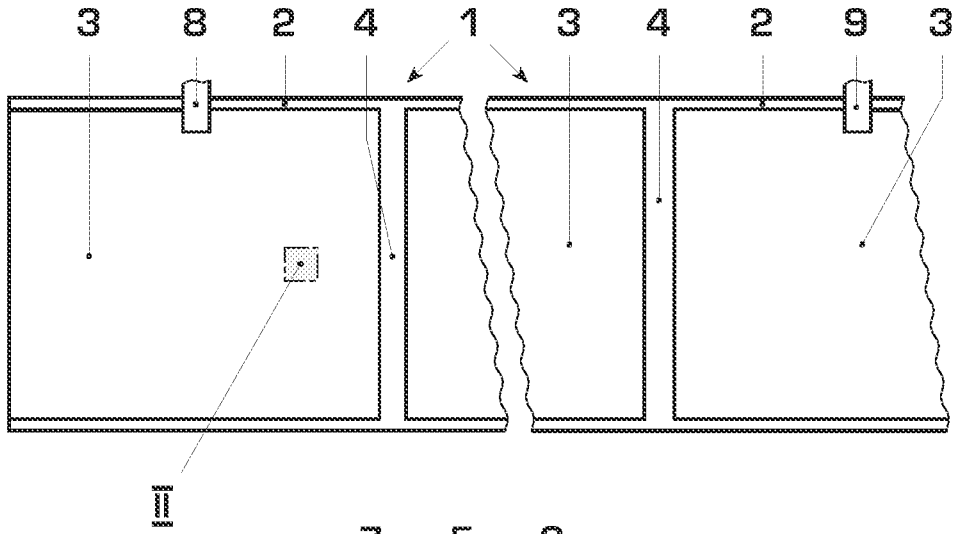

Fig. 1

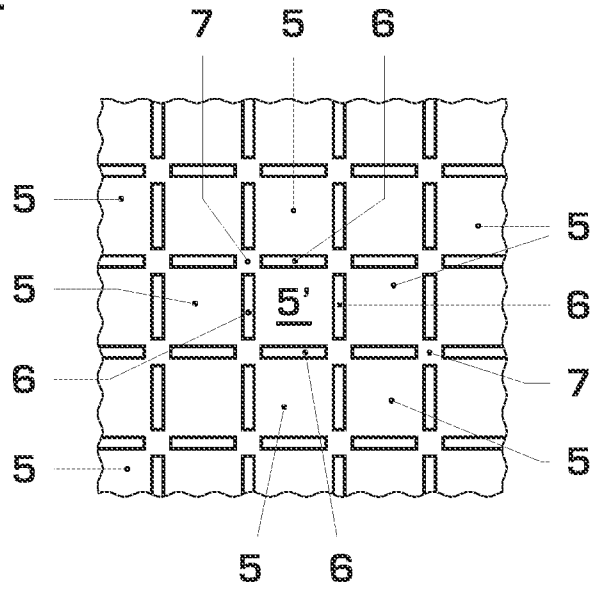

Fig. 2

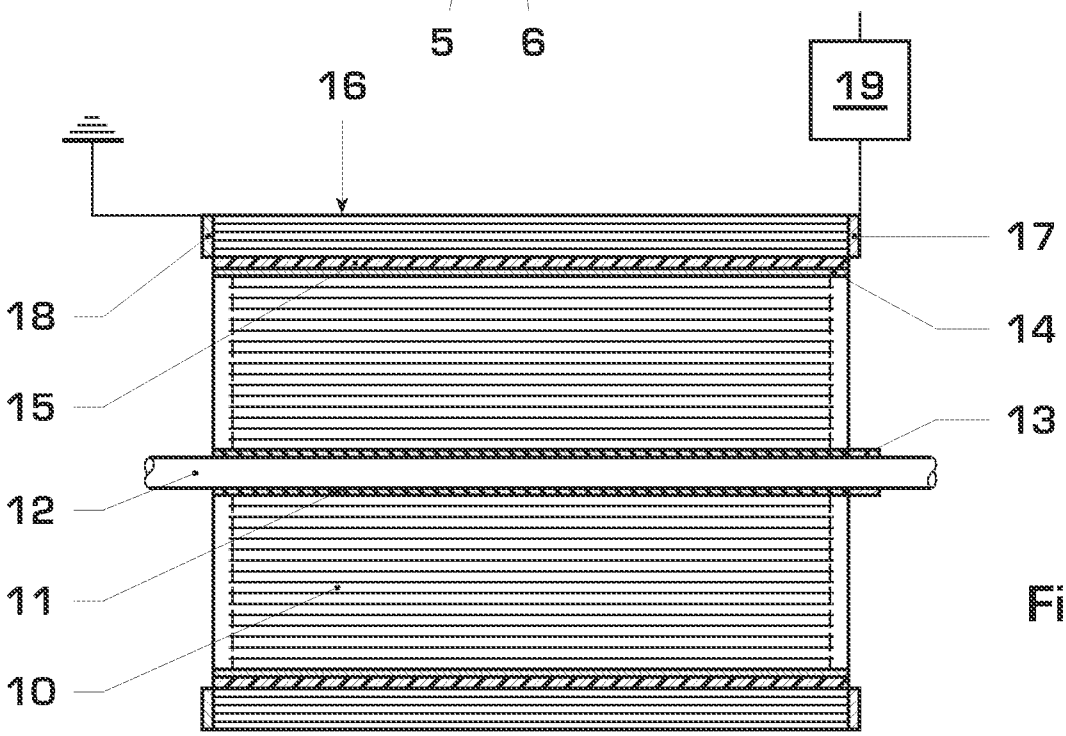

Fig. 3

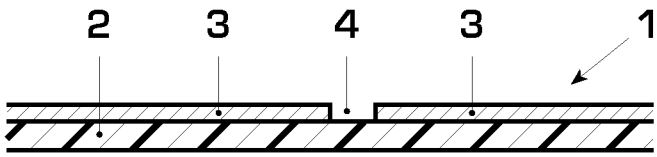

Fig. 4

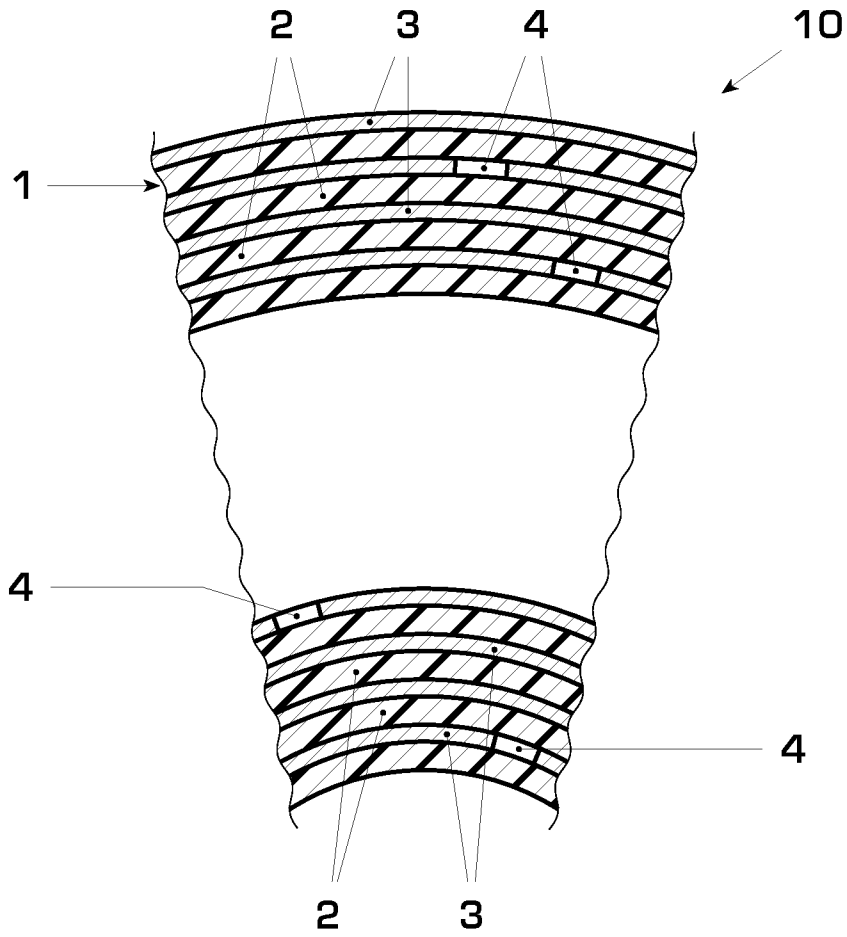

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2007/062874

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01G4/012 H01G4/32

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)
H01G

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	DE 24 57 438 A1 (PHILIPS PATENTVERWALTUNG) 10 June 1976 (1976-06-10) page 4, line 8 - page 5, line 4; figure 2 page 6, lines 10-26	1-3,5,6, 8
Y	EP 0 056 010 A (MATSUSHITA ELECTRIC IND CO LTD [JP]) 14 July 1982 (1982-07-14) page 2, line 22 - page 3, line 9 page 5, line 1 - page 6, line 19 page 10, lines 9-21; figures 1,8	1-10
Y	EP 1 801 825 A (ABB RESEARCH LTD [CH]) 27 June 2007 (2007-06-27) cited in the application abstract; figures 1,2	1-10

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

☒ See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2007/062874

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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