(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 759 218 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
08.07.1998 Bulletin 1998/28

(21) Application number: **95918003.5**

(22) Date of filing: **11.05.1995**

(51) Int Cl.[6]: **H01T 4/08**, H02H 9/06

(86) International application number:
PCT/FI95/00250

(87) International publication number:
WO 95/31844 (23.11.1995 Gazette 1995/50)

(54) **OVERVOLTAGE PROTECTION OF A TRANSFORMER**

ÜBERSPANNUNGSSCHUTZ FÜR EINEN TRANSFORMATOR

PROTECTION D'UN TRANSFORMATEUR CONTRE LA SURTENSION

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IE IT LI NL PT SE

(30) Priority: **11.05.1994 FI 942176**

(43) Date of publication of application:
26.02.1997 Bulletin 1997/09

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EP 0 759 218 B1

Printed by Jouve, 75001 PARIS (FR)

Description

The present invention relates to an overvoltage protection system for a transformer, especially a supply transformer, as defined in the preamble of claim 1.

It is known that during a thunderstorm a large voltage difference exists between the earth and the cloud. In most cases the cloud has a more positive charge than the earth, so a discharge occurs from cloud to earth more often than the other way round. However, the overvoltage protectors used also function in the case of lightning strokes from earth to cloud.

As to the surge generated by a lightning and its behaviour, the following is known. The surge diverges into branches partly in accordance with Kirchhoff's and Ohm's laws, in other words it is discharged to earth along several paths and principally along paths that offer the least resistance, i.e. where the specific resistance of the medium is as low as possible. When a surge advancing at 1/3 of the velocity of light along a straight conductor encounters an abrupt bend in the conductor, it cannot proceed along the conductor but instead there occurs at the bend a phenomenon resembling an explosion (arc, corona), whereupon the discharge has to find a new path, being induced into nearby metallic structures on its way towards the earth. Moreover, the surge behaves in an unpredictable manner. For instance, having jumped over a distance of several kilometres from cloud to earth, a lightning may also leap on a transformer from one structure to the next across a few metres.

The best way to subdue the surge and protect the transformer is to offer the surge a path that is advantageous for the transformer and a spark gap that is mounted in the right place and has a lower electrode with a strong earth potential. When an overvoltage is discharged, an arc is set up and a ground contact occurs. To extinguish the arc, automatic relays switch off electricity from the network for about one second. This power break is termed quick reconnection.

In currently used known technology, the facts stated above have not been given close enough consideration. Mistakes are made in small details, thereby even inviting the lightning to damage the transformer. The commonest types of damage in known transformer constructions are as follows: the transformer windings are burnt out, a feedthrough insulator of a transformer full of oil is sooted and cracked, the outer shell of an oil-filled transformer is burst due to the melting action of an arc or the shell is cracked due to the pressure created by an internal explosion. In other words, the problem with known technology is that the surge cannot be safely and securely conducted past the transformer and its various parts, but instead the surge is often allowed to damage different parts of the transformer.

The object of the present invention is to eliminate the drawbacks mentioned above. A specific object of the invention is to present a new type of transformer overvoltage protection system that effectively protects the structures of the transformer against a surge and directs the surge past the transformer to the earth.

As to the features characterizing the invention, reference is made to the claims.

According to the invention, the overvoltage protection system for a supply transformer comprises a by-pass rail extending substantially horizontally from the top end of the feedthrough insulator of the transformer, one end of said rail being connected to a downlead leading down from the disconnector above the transformer. Also connected to this same end of the by-pass rail is a first protective horn pointing downwards and forming an essentially straight extension to the downlead. Mounted on the transformer frame is a second protective horn placed below the first protective horn and connected from the transformer frame to earth by means of a separate earth conductor. Like the first protective horn and the downlead, the second protective horn and the earth conductor connected to it also form an essentially straight downward conductor link having no significant bends or curvatures where the surge could not follow the conductor.

Thus, the essential point in the structure of the invention described above is that a surge advancing towards the transformer is directed past the whole transformer structure along a substantially straight path that may only have smooth or round bends so that the surge, regardless of its magnitude, is able to follow the conductor without significant arcs or corona discharges, naturally excluding the arc occurring across the spark gap.

The second protective horn is preferably attached to a supporting rail mounted on the transformer frame. In this case, the corresponding second protective horns of different phases can all be connected to one and the same supporting rail, allowing the earth conductors to be joined into one earth lead common to all phases with conductors running in a curvilinear fashion from the protective horns and supporting rail to a common earth juncture.

As compared with previously known technology, the overvoltage protection system of the invention provides the advantage that the surge can be safely directed past the whole transformer structure including the frame, thus ensuring that the transformer will suffer no damage whatsoever, but after quick reconnection the transformer is always in full working order.

In the following, the invention is described in detail by referring to the attached drawings, in which

Fig. 1 presents a previously known overvoltage protection system for a supply transformer,
Fig. 2 presents another previously known solution, and
Fig. 3 presents the overvoltage protetion system of the invention.

Fig. 1 shows a typical distribution substation of a type which was commonly used until the end of the

1970's, in which lightning protection is implemented using an air gap 7 formed by protective horns 5 and 6 mounted on the feedthrough insulator 2. The lower protective horn 6 has earth potential via the transformer frame 1, while the upper protective horn 5 is at the voltage potential (usually 20kV). The transformer is filled with oil, and the feedthrough insulator 2 also contains oil and a conductor passing the electricity to the windings inside the transformer. As for protection, the protective horns are in the right place but in the wrong position.

When a lightning strikes the electric line 3 and a travelling wave or a surge advances towards the transformer, a first explosion A takes place in the terminal holder 17 (termination of the straight eelctric line 3). From the terminal holder, the conductor generally continues upwards at an angle of 90°. For a lightning, this is the wrong direction, because a lightning always seeks the shortest path to earth. In explosion A, the surge branches upwards and downwards directly to the high-voltage connection lead or downlead. Traces found on such equipment indicate that a second explosion B occurs at the bend at the upper end of the distance rail. From here, part of the surge may proceed to the transformer windings, damaging these (explosion C). Another part of the surge jumps from explosion point B, as can often be stated on the basis of fusion traces, via the protective horns 5 and 6 to the transformer frame 1, which is connected 18 to earth. If protective horn 6 has not been properly fixed at the juncture (oxidated, paint between the parts), an explosion D takes place at the loose junction and the arc set up burns a hole in the transformer cover.

In such cases, the highly inflammable transformer oil leaks out, almost invariably causing a fire in the transformer and its environment. The outer shell or frame 1 of an oil-filled transformer should not be used as part of the earth lead. Another drawback with this manner of protection is that animals getting into the spark gap 7 can cause electric disturbances. For this reason, it has been necessary to use an excessively wide spark gap, although there would have been a need to reduce the spark gap width 7 to improve overvoltage protection.

A frequent mounting fault in the situation depicted by Fig. 1 is that the downlead 4 feeding the transformer is connected directly from the disconnector 9 to the connectors of the feedthrough insulator 2, without a lateral bend in the downlead. In this case, explosion B occurs right at the upper or lower end (explosion C) of the feedthrough insulator 2, with the result that the insulator is smashed to pieces. In addition to the situation in Fig. 1, the explosion B creates a third discharge path for the surge, and in this case the arc causes the outer surface of the feedthrough insulator 2 to be blackened with soot and burns a hole in the transformer cover at the foot of the feedthrough insulator 2.

Fig. 2 presents another known transformer station type, in which the protective horns 20 and 21 are placed high up above the rest of the equipment, even above the electric line 22. In this case, the air gap 23 (spark gap) is in a horizontal direction. Therefore, the fact that a lightning discharged from a cloud is always attracted towards the earth is ignored in this solution. Moreover, upon reaching the first explosion point A, the travelling wave generated by a lightning stroke may proceed almost linearly downwards via the downlead 24 to the transformer 25. The surge advancing along the electric line 22 has to make two 90° bends before encountering the earth-potential protective horn 21 after the arc. Before a disruptive discharge occurs in the spark gap 23, a parallel surge can travel a long way down along the downleads 24. This downward "suction" could be reduced by removing the earth connection 26 from between the transformer shell and the ground, but there are other more important reasons which forbid this disconnection. When the protective horns are mounted on the highest point on the transformer station, the earthing functions as an excellent lightning arrester in the case of direct lightning strokes, but the surge discharged through the earth conductor and the travelling wave induce in the parallel downleads 24 an overvoltage which is discharged unabated into the transformer windings. In this case, the protective horns are in the wrong place and in the wrong position with respect to the transformer.

Fig. 3 presents an overvoltage protection system for a transformer as provided by the invention, which eliminates the problems described above. For immediate protection of the transformer, it is important that the protective horns 5 and 6 be mounted in the vicinity of the feedthrough insulator 2. A new feature is that the downlead 4 from the overhead disconnector is passed in as straight a form as possible to the end of a by-pass rail 8 extending essentially horizontally from the top end of the feedthrough insulator 2, the rail 8 being additionally provided with a spark horn 5 forming an essentially straight downward extension. A protector 12 of insulating material around the by-pass rail 8 prevents animals from getting into contact with live metallic parts. Another new and inventive feature is that the earth conductor 10 starts directly from the supporting rail 11 below the spark horn 6, forming an essentially straight extension to the horn, so that no explosion points are created for the surge. Thus, the easily damaged transformer frame 1 is not used as a discharge path for the surge. By means of the by-pass rail 8 and the supporting rail 11, the spark gap 7 can be adjusted to a sufficient horizontal distance from the feedthrough insulator 2. In this arrangement, an arc struck in the spark gap 5-6 will not cause sooting of the feedthrough insulator 2.

The protective horns 5 and 6 may have a curved shape. In this case, as seen from one side, the upper horn 5 may form a triangle whose function is to throw e. g. twigs off the spark gap electrodes. The upper horn 5 consisting of the triangle may also act as an excellent connection loop for temporary earth clamps. As the tendency is nowadays to provide all live parts with a plastic

coating, this loop is about the only possible place for earth connection. The protective horns 5 and 6 may also be implemented in some other form, e.g. as pointed electrodes. It is likewise possible to connect to the by-pass rail 8 some other kind of temporary earth loop suitably shaped.

The by-pass rail 8 is mounted in a slightly slanting position with a downward and outward slope. This ensures that rainwater will flow outwards from the rail, thus making it more difficult for the surge to move towards the feedthrough insulator 2.

The embodiment in Fig. 3 also comprises a previously known protective bracket 13 placed in the air gap 7 to prevent animals (usually birds and squirrels) from perching between the protective horns 5 and 6, where they could cause a ground contact (quick reconnection). The bracket is of a platelike shape and has a slight downward slope in the outward direction. When an arc is initiated from protective horn 5 towards horn 6, it encounters the platelike obliquely downward sloping bracket 13. Upon this encounter the arc is broken up and, due to the position of the bracket, thrown aside in a direction away from the feedthrough insulator 2, so it will not cause the feedthrough insulator 2 to become sooty. Due to this break-up, the arc is also quickly extinguished, which means that no quick reconnection takes place. The platelike bracket also prevents animals from simultaneously approaching both arc electrodes 5 and 6 from a lateral direction, so no arcs caused by animals will occur. For this reason, the shape of the bracket permits a narrower spark gap 7 to be used, thus improving the overvoltage protection of the transformer.

The platelike bracket (bird prong) described can also be mounted in a place different from the feedthrough insulator as described above, e.g. on the disconnector of the transformer.

In addition, the overvoltage protection system in Fig. 3 comprises a protective element 16 which is connected to the earth conductor 15 linking the frame of the disconnector 9 to ground and which extends to a height above the electric line 3 and the disconnector 9. This by-pass arrangement guides direct lightning strokes from above past the transformer station structures directly to earth.

Thus, the overvoltage protection system described above effectively directs the surge generated by lightning which has strayed into electrical parts past the transformer without damaging it. At the same time, it also considerably reduces the number of short-time power failures.

The invention has been described above in detail by the aid of the attached drawings, but different embodiments of the invention are possible within the scope of the inventive idea defined by the claims.

Claims

1. Overvoltage protection system for a transformer, designed to conduct a surge which has strayed into an electric line to earth, said transformer comprising a frame (1) and, mounted on top of it, feedthrough insulators (2), to which the electricity from the line conductors (3) flows via a disconnector (9) and downleads (4), overvoltage protection being formed by a spark gap (7) provided between protective horns (5,6) mounted in connection with the feedthrough insulator (2), **characterized** in that the overvoltage protection system comprises

   - a by-pass rail (8) extending substantially horizontally from the top end of the feedthrough insulator (2), the downlead (4) from the disconnector (9) above being passed to one end of this rail,
   - a downward directed first protective horn (5) attached to the end of the by-pass rail (8) and forming an essentially straight extension to the downlead,
   - a second protective horn (6) mounted on the transformer frame (1) and placed below the first protective horn (5), said second protective horn (6) being connected from the transformer frame to earth by means of a separate earth conductor (10).

2. Overvoltage protection system for a transformer as defined in claim 1, **characterized** in that the second protective horn (6) is attached to a supporting rail (11) mounted on the frame (1) of the transformer.

3. Overvoltage protection system for a transformer as defined in claim 2, **characterized** in that the second protective horns (6) of different phases are mounted on a common supporting rail (11).

4. Overvoltage protection system for a transformer as defined in claim 3, **characterized** in that the earth conductors (10) run separately from the second protective horns (6) downwards in a curvilinear fashion, being joined further down into one earth lead common to all phases.

5. Overvoltage protection system for a transformer as defined in any one of claims 1 - 4, **characterized** in that the by-pass rail (8) verges gently downwards from the top end of the feedthrough insulator (2), preventing the flow of rainwater onto the feedthrough insulator.

6. Overvoltage protection system for a transformer as defined in any one of claims 1 - 5, **characterized** in that the by-pass rail (8) is provided with an insulation (12) to ensure that animals cannot touch the

live metallic parts.

7. Overvoltage protection system for a transformer as defined in any one of claims 1 - 6, **characterized** in that it comprises an essentially horizontal platelike protective bracket (13) placed in the spark gap (7) between the protective horns (5,6) and supported by the feedthrough insulator (2).

8. Overvoltage protection system for a transformer as defined in claim 7, **characterized** in that the platelike protective bracket (13) verges downwards from the feedthrough insulator (2), directing arc coming from above away from the feedthrough insulator.

9. Overvoltage protection system for a transformer as defined in any one of claims 1 - 8, **characterized** in that the frame (1) of the transformer is earthed by means of a separate earth conductor (14).

10. Overvoltage protection system for a transformer as defined in any one of claims 1 - 9, **characterized** in that it comprises a protective element (16) connected to the earth conductor (15) of the frame of the disconnector (9) and extending to a height above the electric line (3) and the disconnector, said element being designed to guide direct lightning strokes from above past the transformer station structures directly to earth.

11. Overvoltage protection system for a transformer as defined in any one of claims 1 - 10, **characterized** in that the first protective horn (5) is used as a connection loop for temporary earth.

12. Overvoltage protection system for a transformer as defined in any one of claims 1 - 10, **characterized** in that a connection point for temporary earth is provided in connection with the by-pass rail (8).

Patentansprüche

1. Überspannungsschutzsystem für einen Transformator, um einen in eine elektrische Leitung geratenen Spannungsstoß gegen Erde zu leiten, bei dem der Transformator einen Rahmen (1) enthält, auf dessen oberen Oberfläche Durchführungsisolatoren (2) angeordnet sind, an die über Unterbrecher (9) und Zuführungsleitungen (4) Elektrizität von elektrischen Leitungen (3) fließt, und bei dem der Überspannungsschutz durch eine Funkenentladungsstrecke (7) zwischen Schutzhörnern (5,6) gebildet ist, die mit den Durchführungsisolatoren (2) in Verbindung stehend montiert sind, **dadurch gekennzeichnet,** daß das Überspannungsschutzsystem folgendes enthält:

eine Umleitungsschiene (8), die sich im wesentlichen vom oberen Ende des Durchführungsisolators (2) aus horizontal erstreckt, wobei die vom Unterbrecher (9) kommende Zuführungsleitung (4) von oben an ein Ende dieser Schiene (8) herangeführt ist;
ein nach unten ausgerichtetes erstes Schutzhorn (5), das an dem Ende der Umleitungsschiene (8) befestigt ist und eine im wesentlichen geradlinige Verlängerung der Zuführungsleitung bildet; und
ein auf dem Rahmen (1) des Transformators und unterhalb des ersten Schutzhorns (5) angeordnetes zweites Schutzhorn (6), über das der Transformatorrahmen mittels eines separaten Erdverbindungsleiters (10) mit Erde verbunden ist.

2. Überspannungsschutzsystem für einen Transformator nach Anspruch 1, **dadurch gekennzeichnet,** daß das zweite Schutzhorn (6) mit einer auf dem Rahmen (1) des Transformators angeordneten Trägerschiene (11) befestigt ist.

3. Überspannungsschutzsystem für einen Transformator nach Anspruch 2, **dadurch gekennzeichnet**, daß die zweiten Schutzhörner (6) für unterschiedliche Phasen auf einer gemeinsamen Trägerschiene (11) montiert sind.

4. Überspannungsschutzsystem für einen Transformator nach Anspruch 3, **dadurch gekennzeichnet,** daß die Erdverbindungsleiter (10) separat von den zweiten Schutzhörnern (6) aus krummlinig nach unten verlaufen und weiter unten in einem allen Phasen gemeinsamen Erdungsleiter zusammenlaufen.

5. Überspannungsschutzsystem für einen Transformator nach irgendeinem der Ansprüche 1 bis 4, **dadurch gekennzeichnet,** daß die Umleitungsschiene (8) vom oberen Ende des Durchführungsisolators (2) ausgehend leicht nach unten geneigt ist, um zu verhindern, daß Regenwasser auf den Durchflührungsisolator fließt.

6. Überspannungsschutzsystem für einen Transformator nach irgendeinem der Ansprüche 1 bis 5, **dadurch gekennzeichnet,** daß die Umleitungsschiene (8) mit einer Isolation (12) versehen ist, um eine Berührung der stromführenden Teile durch Tiere auszuschließen.

7. Überspannungsschutzsystem für einen Transformator nach irgendeinem der Ansprüche 1 bis 6, **dadurch gekennzeichnet,** daß es einen im wesentlichen horizontal verlaufenden plattenähnlichen und in der Funkenentladungsstrecke (7) zwischen den

Schutzhörnern (5, 6) angeordneten Schutzarm (13) enthält, der von dem Durchführungsisolator (2) getragen wird.

8. Überspannungsschutzsystem für einen Transformator nach Anspruch 7, **dadurch gekennzeichnet,** daß der plattenähnliche Schutzarm (13) von dem Durchführungsisolator (2) ausgehend nach unten geneigt ist, um einen von oben kommenden Lichtbogen von dem Durchführungsisolator wegzuleiten.

9. Überspannungsschutzsystem für einen Transformator nach irgendeinem der Ansprüche 1 bis 8, **dadurch gekennzeichnet**, daß der Rahmen (1) des Transformators durch einen separaten Erdverbindungsleiter (14) mit Erde verbunden ist.

10. Überspannungsschutzsystem für einen Transformator nach irgendeinem der Ansprüche 1 bis 9, **dadurch gekennzeichnet,** daß es ein mit einem Erdverbindungsleiter (15) des Rahmens des Unterbrechers (9) verbundenes Schutzelement (16) enthält, das sich bis in eine Höhe über der elektrischen Leitung (3) und dem Unterbrecher erstreckt, und direkte Blitzeinschläge von oben an dem Transformatorstationsaufbau vorbei direkt gegen Erde leitet.

11. Überspannungsschutzsystem für einen Transformator nach irgendeinem der Ansprüche 1 bis 10, **dadurch gekennzeichnet,** daß das erste Schutzhorn (5) als Anschlußschleife zur temporären Erdung verwendet wird.

12. Überspannungsschutzsystem für einen Transformator nach irgendeinem der Ansprüche 1 bis 10, **dadurch gekennzeichnet,** daß ein mit der Umleitungsschiene (8) in Verbindung stehender Anschlußpunkt zur temporären Erdung gebildet ist.

Revendications

1. Système de protection contre les surtensions pour transformateur, conçu pour conduire à la masse une pointe d'énergie qui a été créée dans une ligne électrique, ledit transformateur comprenant une carcasse (1) et, montées sur la partie supérieure de celle-ci, des traversées isolantes (2), vers lesquelles l'électricité provenant des conducteurs (3) de la ligne circule via un déconnecteur (9) et des conducteurs descendants (4), la protection contre les surtensions étant formée par un éclateur (7) agencé entre des cornes de protection (5, 6) montées en connexion avec la traversée isolante (2), caractérisé en ce que le système de protection contre les surtensions comprend :

- un rail de dérivation (8) s'étendant pratiquement horizontalement à partir de l'extrémité supérieure de la traversée isolante (2), le conducteur descendant (4), provenant du déconnecteur (9) situé au-dessus, passant sur une première extrémité de ce rail,
- une première corne de protection (5) dirigée vers le bas, fixée à l'extrémité du rail de dérivation (8) et formant un prolongement pratiquement rectiligne du conducteur descendant,
- une seconde corne de protection (6) montée sur la carcasse de transformateur (1) et placée en dessous de la première corne de protection (5), ladite seconde corne de protection (6) étant connectée entre la caracasse de transformateur et la masse, par l'intermédiaire d'un conducteur de masse séparé (10).

2. Système de protection contre les surtensions pour transformateur selon la revendication 1, caractérisé en ce que la seconde corne de protection (6) est fixée sur un rail de support (11) monté sur la carcasse (1) du transformateur.

3. Système de protection contre les surtensions pour transformateur selon la revendication 2, caractérisé en ce que les secondes cornes de protection (6) de phases différentes sont montées sur un rail de support commun (11).

4. Système de protection contre les surtensions pour transformateur selon la revendication 3, caractérisé en ce que les conducteurs de masse (10) s'étendent séparément depuis les secondes cornes de protection (6) vers le bas d'une manière curviligne, en étant en outre reliés vers le bas en un conducteur de masse commun à toutes les phases.

5. Système de protection contre les surtensions pour transformateur selon l'une quelconque des revendications 1 à 4, caractérisé en ce que le rail de dérivation (8) descend légèrement à partir de l'extrémité supérieure de la traversée isolante (2), empêchant l'écoulement d'eau de pluie sur la traversée isolante.

6. Système de protection contre les surtensions pour transformateur selon l'une quelconque des revendications 1 à 5, caractérisé en ce que le rail de dérivation (8) est muni d'un isolant (12) pour assurer que les animaux ne peuvent pas toucher les parties métalliques sous tension.

7. Système de protection contre les surtensions pour transformateur selon l'une quelconque des revendications 1 à 6, caractérisé en ce qu'il comprend un étrier de protection (13) analogue à une plaque pratiquement horizontale, placée dans l'écarteur (7)

entre les cornes de protection (5, 6) et supportée par la traversée isolante (2).

8. Système de protection contre les surtensions pour transformateur selon la revendication 7, caractérisé en ce que l'étrier de protection (13) analogue à une plaque descend à partir de la traversée isolante (2), en dirigeant un arc provenant du dessus loin de la traversée isolante.

9. Système de protection contre les surtensions pour transformateur selon l'une quelconque des revendications 1 à 8, caractérisé en ce que la carcasse (1) du transformateur est reliée à la masse au moyen d'un conducteur de masse (14) séparé.

10. Système de protection contre les surtensions pour transformateur selon l'une quelconque des revendications 1 à 9, caractérisé en ce qu'il comprend un élément de protection (16) connecté au conducteur de masse (15) de la carcasse du déconnecteur (9) et s'étendant sur une hauteur au-dessus de la ligne électrique (3) et du déconnecteur, ledit élément étant conçu pour guider les coups de foudre, arrivant directement du dessus jusqu'au-delà des structures du poste de transformateurs, directement vers la masse.

11. Système de protection contre les surtensions pour transformateur selon l'une quelconque des revendications 1 à 10, caractérisé en ce que la première corne de protection (5) est utilisée en tant que boucle de connexion pour une masse temporaire.

12. Système de protection contre les surtensions pour transformateur selon l'une quelconque des revendications 1 à 10, caractérisé en ce qu'un point de connexion pour une masse temporaire est fourni en connexion avec le rail de dérivation (8).

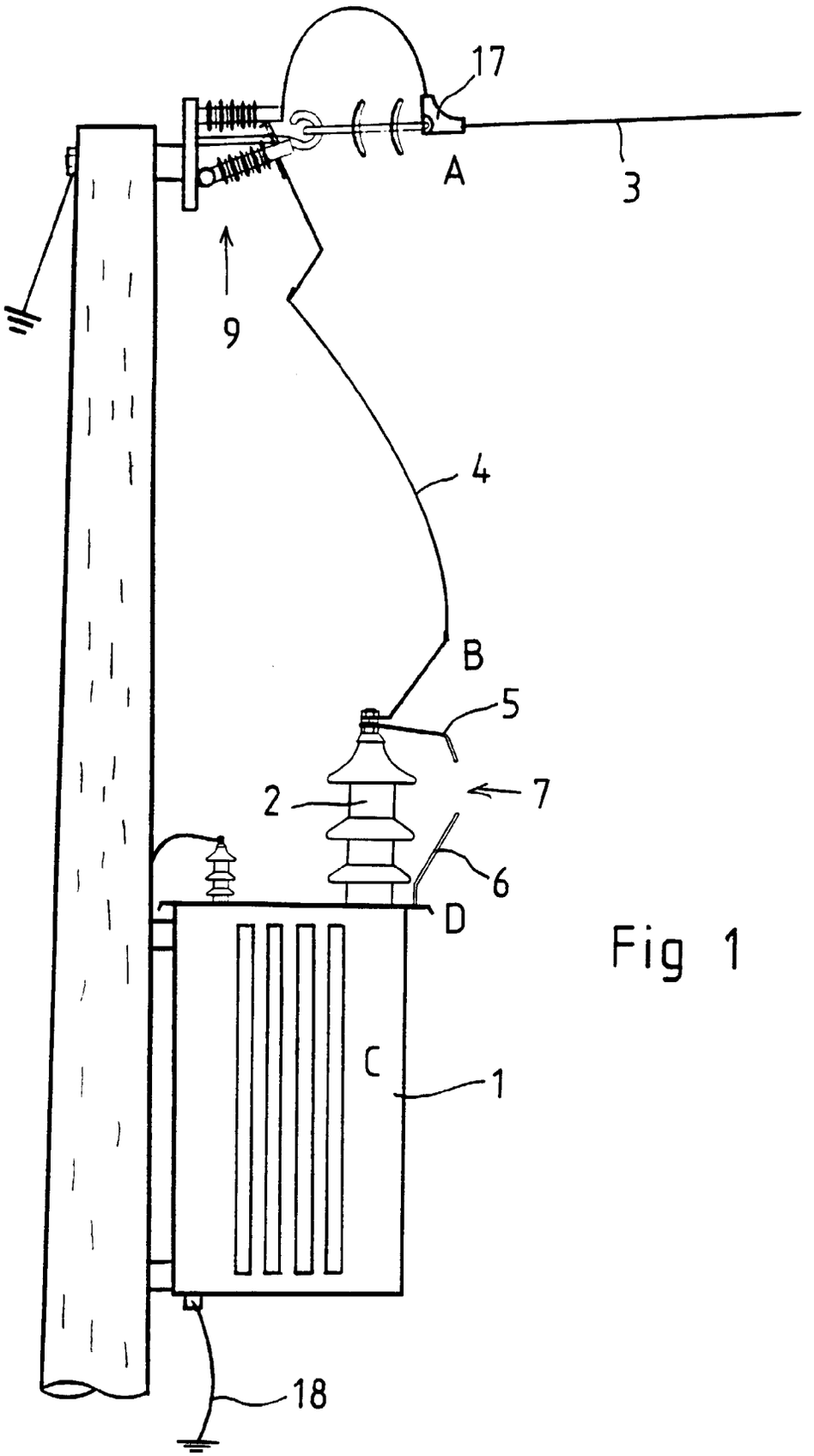


Fig 1

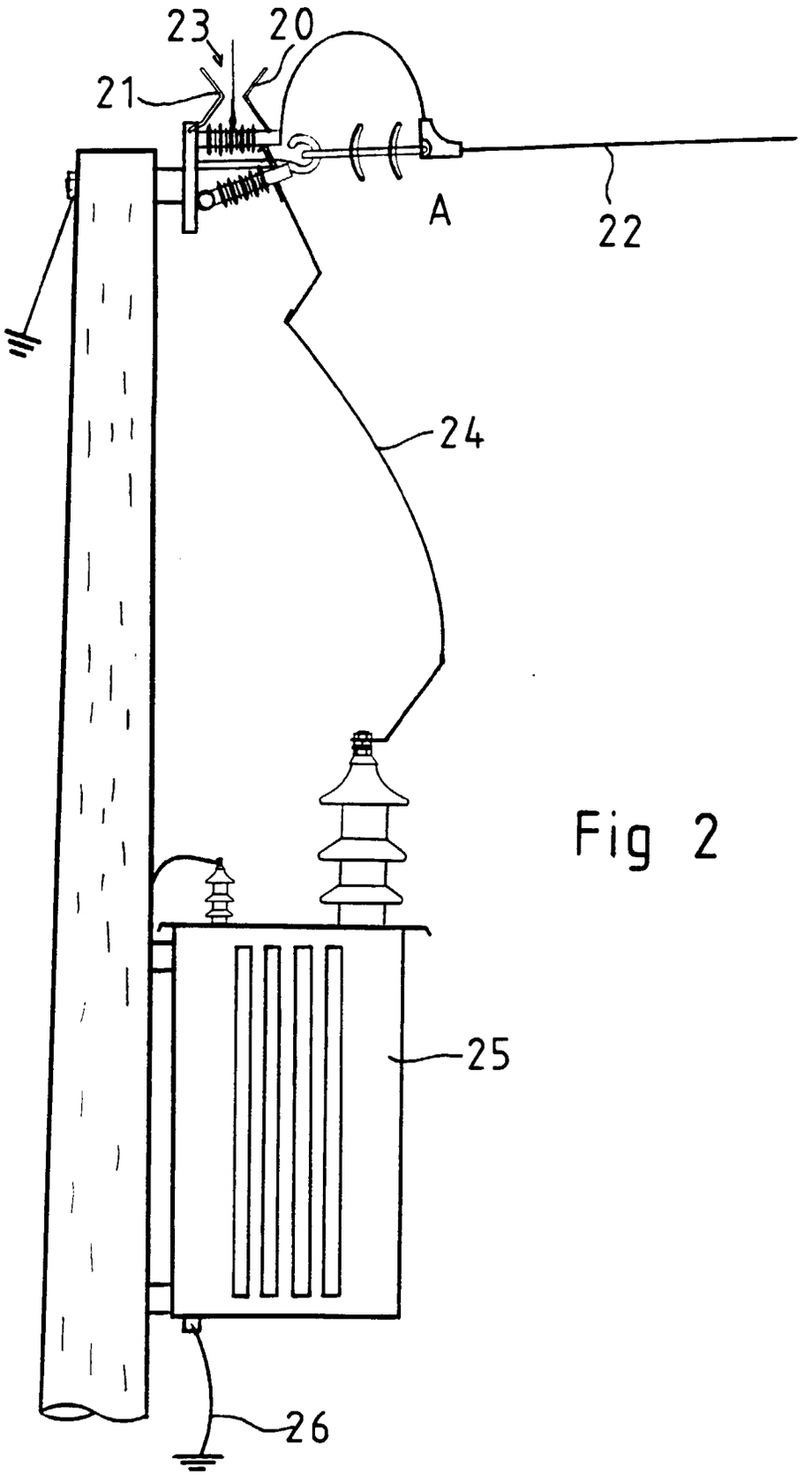


Fig 2

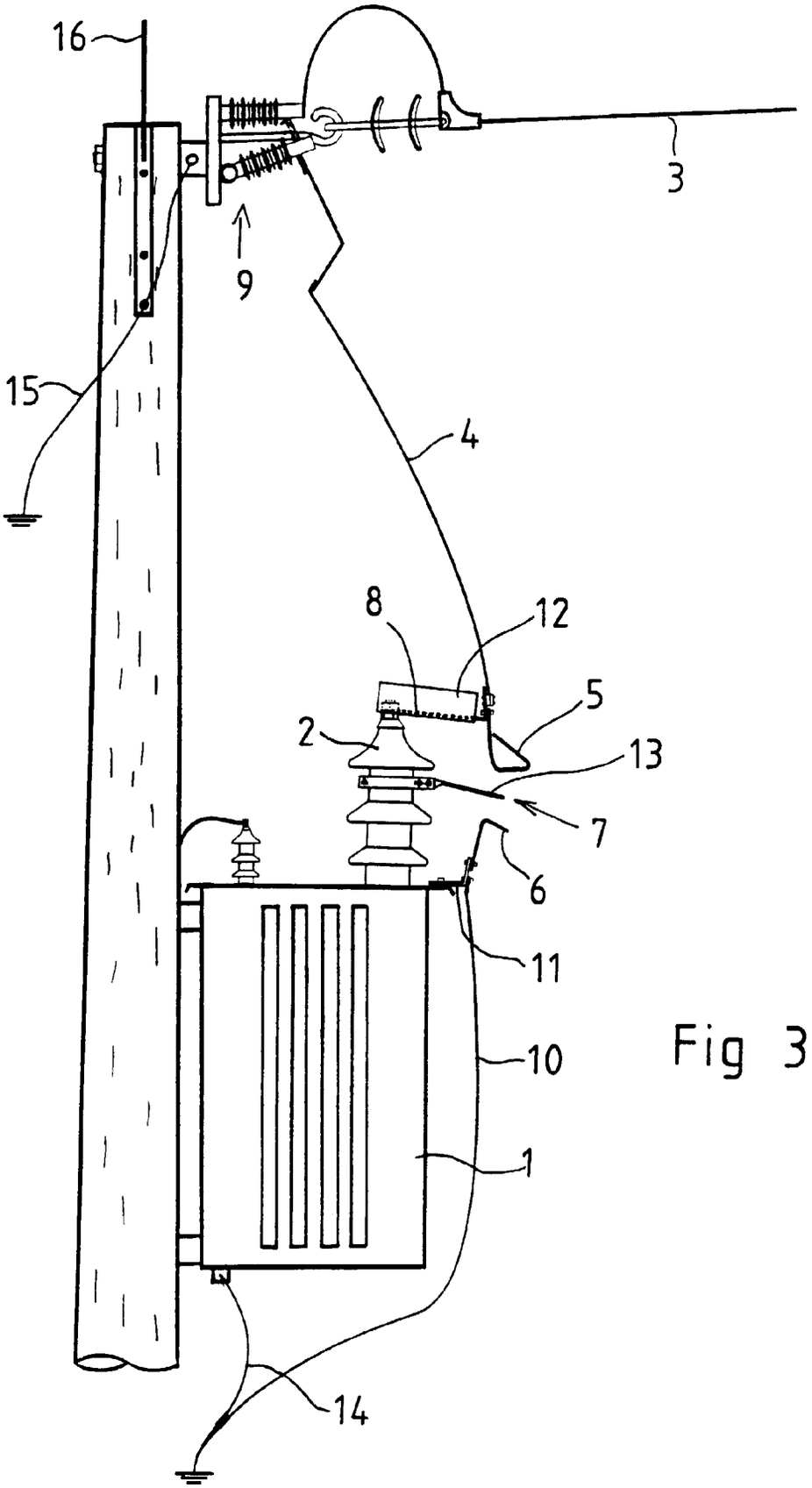


Fig 3