PATENT.

No. 274536.

Arthur John Stephens

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PATENT.

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GEORGE V, BY THE GRACE OF GOD,

Of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas King, Defender of the Faith, Emperor of India: To all to whom these presents shall come greeting:

WHEREAS Arthur John Stephens, Chartered Patent Agent a subject of the King of Great Britain and Ireland of the firm of Sefton Jones O'dell & Stephens of 285, High Holborn, London W.C.1.

hath declared that he is in possession of an invention for Improvements in electric controlling apparatus for supplying current to electric nets

that the said invention has been communicated to him by Jancu Solomon of 7 Strada Paleologu Bucarest, Roumania, a subject of the King of Roumania

that he claims to be the true and first inventor thereof, and that the same is not in use within the United Kingdom of Great Britain and Ireland and the Isle of Man by any other person to the best of his knowledge and belief:

AND WHEREAS the said declarant hath humbly prayed that a patent might be granted unto him for the sole use and advantage of his said invention:

AND WHEREAS the said declarant (hereinafter together with his executors, administrators, and assigns, or any of them, referred to as the said patentee) hath by and in his complete specification particularly described the nature of his invention:

AND WHEREAS We, being willing to encourage all inventions which may be for the public good, are graciously pleased to condescend to his request:

KNOW YE, THEREFORE, that We, of our especial grace, certain knowledge, and mere motion do by these presents, for us, our heirs and successors, give and grant unto the said patentee our especial license, full power, sole privilege, and authority, that the said patentee by himself, his agents, or licensees, and no others, may at all times hereafter during the term of years herein mentioned, make, use, exercise, and vend the said invention within our United Kingdom of Great Britain and Northern Ireland, and the Isle of Man, in such manner as to him or them may seem meet, and that the said patentee shall have and enjoy the whole profit and advantage from time to time accruing by reason of the said invention, during the term of sixteen years from the date hereunder written of these presents: AND to the end that the said patentee may have and enjoy the sole use and exercise and the full benefit of the said invention, We do by these presents for us, our heirs and successors, strictly command all our subjects whatsoever within our United Kingdom of Great Britain and Northern Ireland, and the Isle of Man, that they do not at any time during the continuance of the said term of sixteen years either directly or indirectly make use of or put in practice the said invention or any part of the same, nor in anywise imitate the same, nor make or cause to be made any addition thereto or subtraction therefrom, whereby to pretend themselves the inventors thereof, without the consent license or agreement of the said patentee in writing under his hand and seal, on pain of incurring such penalties as may be justly inflicted on such offenders for their contempt of this our Royal command, and of being answerable to the patentee according to law for his damages thereby occasioned:

PROVIDED ALWAYS that these letters patent shall be revocable on any of the grounds from time to time by law prescribed as grounds for revoking letters patent granted by Us, and the same may be revoked and made void accordingly: PROVIDED ALSO, that if the said patentee shall not pay all fees by law required to be paid in respect of the grant of these letters patent, or in respect of any matter relating thereto at the time or times, and in manner for the time being by law provided; and also if the said patentee shall not supply or cause to be supplied, for our service all such articles of the said invention as may be required by the officers or commissioners administering any department of our service in such manner, at such times, and at and upon such reasonable prices and terms as shall be settled in manner for the time being by law provided, then, and in any of the said cases, these our letters patent, and all privileges and advantages whatever hereby granted shall determine and become void notwithstanding anything hereinbefore contained: PROVIDED ALSO, that nothing herein contained shall prevent the granting of licenses in such manner and for such considerations as they may by law be granted: AND lastly, we do by these presents for us, our heirs and successors, grant unto the said patentee that these our letters patent shall be construed in the most beneficial sense for the advantage of the said patentee.

IN WITNESS whereof we have caused these our letters to be made patent and to be sealed as of the eighteenth day of March one thousand nine hundred and twenty-six

W. S. JARRATT,
Comptroller-General of Patents, Designs, and Trade Marks.

19

PATENT SPECIFICATION

Application Date: Dec. 14, 1927. No. 33,888/27.

309,615

Complete Left: Sept. 10, 1928.

Complete Accepted: April 15, 1929.

PROVISIONAL SPECIFICATION.

Improvements in or relating to Electrical Relays and Relay Systems.

I, JANCU SOLOMON, of 241, Strada Romano, Bucarest, Roumania, a subject of the King of Roumania, do hereby declare the nature of this invention to be as follows:—

It is well known that the voltages in the individual phases of a polyphase system, as far as their magnitude and phase position is concerned, remain in quite definite relation to one another, which when represented vectorially would appear as a closed or open polygon, which is characteristic for every polyphase system and may be called the voltage diagram of the type of current concerned. Every disturbance of the normal working conditions alters to a greater or less extent the magnitude and also the phase position of the individual voltages which make up the system, or vectorially expressed causes a distortion of the characteristic voltage diagram of the system in question.

The object of this invention is a relay in which the alteration in the phase position (or distortion of the voltage diagram) produced by a disturbance in the system, causes an action which serves to indicate the disturbance and to cut out the damaged part of the system.

According to the invention, when a distortion of the voltage diagram of the system, (that is, an alteration of the phase position of the voltages) occurs, an induction apparatus of electrodynamic or Ferraris type such as phase meters, watt meters or meters in which both operative fields are produced by two voltages is affected which device is connected between any desired points of the system: for, as is well known, all the above mentioned instruments are sensitive to displacements in phase of the fields or of the currents or voltages producing these fields. Thus such a phase position can be chosen for the operative fields or the voltages producing them, that with an undistorted voltage diagram the operative force remains nil or is a maximum.

As the three phase system is the most widely used of all polyphase systems, the arrangements suitable for three phase working will be described hereinafter for the sake of example. Similar arrangements can however be provided within the scope of the invention for all other polyphase systems.

Referring to the accompanying drawings,

Fig. 1 and Fig. 2 show the vectorial voltage diagram for delta connection. Fig. 3 shows the voltage diagram for star connection. Fig. 4 shows the connections for a relay. Fig. 5 shows a somewhat modified arrangement of the connections for a relay. Figure 6 shows the relay used in a selective protective system. Figs. 7 and 8 show two more complete examples of the selective protective system with the relay according to the invention.

The equilateral triangle RST in Fig. 1 shows the linked voltages of a three phase network in an undisturbed condition. If a disturbance occurs in the system, for example a short circuit between the phases S and T, this triangle abandons its normal shape and contracts itself into the triangle R S^1 T^1.

In accordance with the above described principle, an apparatus is provided which is operated when this distortion of the triangle occurs, that is, upon a disturbance occurring in the system, if the two circuits of an apparatus constructed on the principle of an electrodynamometer are connected to two voltages, one of which is taken for example to be between R and T, and the second between S and A, where A is the mid point of RT, so that the voltage SA in normal conditions is at 90° to the voltage RT.

If the fields in the apparatus have the same phase difference as the voltages producing them, which can always be provided by known means, then under normal working conditions there will be no effective action in the electrodynamometer connected as described, because the operative fields or the voltages producing them remain at right angles to each other.

At the instant when owing to a disturbance in the system the voltage diagram has been distorted to the triangle RS^1T^1, the voltage S^1A^1 and the voltage

RT^1 form an angle $S^1A^1T^1$ which is smaller than 90°, so that action can take place between the two fields which brings the relay into action.

In the case of an apparatus on the Ferraris principle, it must be remembered that the greatest turning moment occurs at the moment when the fields are at right angles. In this case therefore one of the two fields must have an artificial phase alteration of 90° or alternatively both fields must be given such a phase alteration that whether or not the voltages producing them are at right angles to each other, the fields themselves have a phase alteration of 0° or 180° so that no operative action occurs under undisturbed working conditions.

As can easily be seen, the relay acts in the same way also in the case of a short circuit between S and R and in the case of any distortion of the voltage diagram other than that shown in Figure 1, for only with an undistorted equilateral triangle is the median SA perpendicular to the line RT.

Where a short circuit occurs between R and T the triangle is distorted so that it becomes the isosceles triangle SR^1T^1 with the base R^1T^1. As in this case the median SA^1 remains perpendicular to R^1T^1, the relay would not be operated (Fig. 2). In order to make the relay operative in this as in all other cases of distortion, a second operating system must be provided, which is connected between S and T and also between R and B, B being the mid point of ST. The special case of a short circuit on all three phases will be gone into hereinafter.

A relay according to the invention could be considered as an asymmetric relay, and when it is provided with two operating means, as above set forth, it will hereinafter be called a bipolar relay.

The position of mid points A and B can be obtained in a known way by means of resistances or choking coils with a tapping in the middle connected between R and T and S and T. In high tension systems, where connections are made through voltage transformers, the above mentioned mid points A and B can be taken from a tapping in the middle of the secondary windings of the transformers.

If instead of a triangle the voltage diagram of the three phase system is a three branched star, as shown in Fig. 3, the two voltage connections of the relay at right angles to each other, can be positioned firstly between the phases R and T and secondly between the third phase S and the zero point O. In the case of a disturbance, the star is distorted into RS^1T^1, the zero point shifts to O^1, S^1O^1 is no longer perpendicular to RT^1 so that the relay is operated. In this arrangement also two operating means are provided to allow for all possible distortions of the star. With the above arrangement there is a further possibility for the connection of the relay by using of the artificial zero point shown in the arrangement or one provided in known manner.

The complete arrangement for a bipolar relay of the type shown in Fig. 2 is shown diagrammatically by way of example in Fig. 4. In this arrangement voltage transformers with tappings at the mid points are used. The transformers are connected to the three conductors RST. To the secondary winding of each transformer one of the windings 3 or 4 of the relays is connected, whilst the other windings 5 and 6 of the relays are connected to the mid points of the secondary windings.

It can be seen that the use of special resistances, choking coils, artificial zero points, or even transformers with tapped secondary windings, is troublesome. This disadvantage can be avoided by a special arrangement. For this it is sufficient to dispose the points of connection A and B of the windings 5 and 6 on the windings 3 and 4 of the relay itself, which are connected between the phases, for these windings divide up the voltages and any desired tapped voltage can be obtained from the same. The diagram of connections for a bipolar relay according to this arrangement connected to an ordinary voltage transformer is shown in Fig. 5. The two operative means of the relay in this case can be either independent or mechanically connected.

The subsequent operation of the switchgear of the system can be effected directly by the relay described, or in known manner by any suitable main current relay, voltage relay, directional relay, earthing relay or time relay connected with or if desired built together with the relay according to this invention.

The characteristic feature of the asymetric relay, as above described, is that under normal working conditions no operative force can be developed and the same is first developed in the case of disturbance. It can be arranged however that the operative force is at its greatest under normal working conditions and is counterbalanced by a suitable restraining force, as for example springs, counterweights etc. For this with relays built on the electrodynamic principle it is necessary to impart an artificial additional shifting of the phases of the operative fields about an angle of 90°. With Ferraris instruments according to this arrangement the operative fields, as also the voltages producing them, must be at right angles to each other.

The main uses of the relay according to the invention are as selective protective means for overloads and earths in feeder networks, as protective means for generator windings, as differential protective means for transformers, as protective means for motors against overloads and failing of a phase, as disturbance indicator for circuits connected to voltage transformers and as an indicator or measuring instrument for asymmetry in electrical apparatus.

In considering the use of this relay for selective protection for overloads and short circuits, it should be remembered that in a widely distributed system the disturbance is so much the greater the nearer the locality of the point of disturbance is approached. Therefore a relay provided for this disturbance will act the stronger or more violently according to how near it is to the disturbance. Therefore such a relay should definitely be selective.

To obtain a relay especially suitable for short circuits to earth, the field windings of the same are connected each with one end to earth and the other end to one of the phases. The operative fields are in this case given such a phase position that with the connected voltages having phases disposed at 120°, the operative effect remains nil (or is a maximum). To protect the system against a short circuit to earth in any of the three phases it is necessary to use three relays selectively connected each between one phase-pair and earth.

The action of the asymmetric relay in this construction and method of operation is as follows: If the system is well insulated from earth, the phase angle of the connected voltages is 120° (the angle at the star point) and, as mentioned above, the operative effect in the relay is nil. If a short circuit to earth occurs in one of the phases, the zero point of the system moves to the apex of the triangle corresponding to a short circuit to earth. In this case, the connection angle of the two relay current paths is smaller than 120°, the active voltages being at the same time greater, because the same approach the short circuited voltage, a dual cause which brings the relay into operation.

With a complete short circuit to earth, just next to the place where it has occurred, the connected voltages approximate to the short circuited voltage, the phase angle (the angle of the apex of the triangle) of the same being even 60°. The operating force in the relay then attains its highest value. The relay is thus adapted to indicate short circuits to earth, and that selectively, in that it works most violently with doubly effective operation next to the place where the earth has occurred.

The same principle of the distortion of the voltage diagram by the use of relays adapted for such distortions according to the invention, can also be applied for the protection of polyphase motors against the failing of a phase as follows: Under normal working conditions, for example in three phase working, the three voltages impressed on a motor form an equilateral triangle. If one phase is interrupted, a reverse voltage is produced in this phase by the continued running of the motor as a single phase generator, which is smaller than the voltage of the other phases remaining connected. This reverse voltage therefore forms with the other two voltages a non-equilateral triangle, in which the medians no longer remain perpendicular to the appropriate sides.

If the relay, for example with the arrangement and connection shown in Fig. 5, is connected to the terminals of the motor, under normal working conditions the relay remains at rest, being unaffected by the variations of voltage in the network and the load conditions; but it is immediately affected by the interruption of a phase owing to distortion of its triangle of connections and also in a known way by the cutting out of the motor. In order to make the relay react to interruption of any one of the motor phases with equal certainty, a bipolar relay connected as shown in Fig. 2 must be used.

This phase interruption relay can be developed further into an overload relay and thus form a complete protective relay for motors, or motor cut out. For this purpose, in three phase working, in two out of the three current supply lines one choking coil is inserted in each line before the point of connection to the asymmetric relay. These choking coils cause voltage drops in the two lines in which they are inserted, whereby the voltage triangle behind them is distorted.

The choking coils are of such a value and the operative means of the asymmetric relay are sufficiently insensible, that as long as the normal allowable voltage is not exceeded, the relay is not operated. In the case of an overload or a defect in the motor the current rises in the choking coils as well as the voltage drops caused by them until the asymmetric relay connected behind the choking coils is operated owing to distortion of the voltage connection triangle. So that the relay is not operated in any case by the high current required for starting, the operative means are provided with a delay mechanism.

If an asymmetric relay, as herein described, is connected to the secondary terminals of a group of voltage transformers, an interruption or similar disturbance in the group of transformers is at once indicated and the disturbances which would thereby be caused in the meters, wattmeters and voltage relays connected to these transformers are avoided.

A differential protection of transformers or other apparatus can be obtained with the said asymmetric relay in that the voltage diagrams on the in-put and output sides (or the primary and secondary sides) of the protected apparatus or transformers are superimposed.

The use of the said asymmetric relay for protecting generators against short circuits in the windings is obvious from the reflection that in such a case of disturbance the voltage triangle at the generator terminals would be distorted.

For many of the above described uses it would be desirable to provide a delay mechanism, a simple form of which would be an eddy current brake acting on the operating member itself.

For the selective protection of conductor networks the asymmetric relay built on the Ferraris principle would be suitable without any additional brake mechanism, so that only the braking torque of the alternating field is effective. Thus for a selective protective device a satisfactory and almost straight line time characteristic curve of the relay is obtained.

For many purposes an operating member which simply oscillates and does not rotate is suitable. For such a relay without bearings and rotary parts it is sufficient to mount the operating member on an oscillating arm. If the operating member is situated in the operative field of the relay operating core, because the operating member cannot turn, only a tangential force is developed at the outer edges of the same, which will cause a deflection of the member and its arm to the corresponding side. In this construction the operating member can be reduced to a sector element sufficiently large to allow the magnetic operating flux to flow through it. In this way a very simple and compact relay can be constructed.

As mentioned above, the said asymmetric relay can be used for the selective protection of conductor networks without it being necessary to choose and regulate each individual relay at installation according to the working conditions. On the contrary all the relays employed can always be made the same and the due sequence of the closing of the individual relays is automatically controlled according to the magnitude of the distortion of the voltage diagram at the connection points in question.

The main current of the system in the examples given above does not enter into the working of the relay and therefore the relay does not need a definite overload to operate it but only a sufficient distortion of the voltage diagram at its place of connection. This gives the asymmetric relay another valuable property and that is that it is still capable of acting when, as for instance often happens in large networks, late at night the reduced production of the power station is insufficient to send an overload through the network.

In any desired case, however, use can be made of the overload principle for the protection of the system; in which case the asymmetric relay according to the invention plays the part of a timer. The action of the relay is then in this case analogous to that of a voltage drop selective relay. Here the voltage drop is used to effect the suitable sequence of the cut out times of separate overload relays, the distortion of the voltage diagram being used there according to the invention for the same purpose.

Moreover the said asymmetric relay, like other known devices such as the usual voltage drop relays, can be combined with relays of other types. For example this relay can be connected to main current solenoids or with main current relays without time lagging or if desired can be built in the same unit therewith. For example Fig. 6 shows the complete connections of a selective protective system for three phase working made up of three main current solenoids 19, each in one phase, and a bipolar asymmetric relay according to the invention AR. In this Figure, 15 indicates the current transformers, 16 the voltage transformers, 17 oil switch, AR a bipolar asymmetric relay, 18 oil cut out, 19 three main current solenoids with their closing contacts and 20 the auxiliary circuit.

If the selection of the conductor to be cut out is also to be determined by the direction of the energy, the closing contact of a directional relay should be

inserted in the system in series with the closing contacts of the main current solenoids and the asymmetric relay. With these connections the main current solenoids act as overload contact maker without lagging, the directional relay serves for a further selection of the conductor, as it locks or frees the cut out switchgear according to the direction of the energy and the asymmetric relay according to the invention acts as timer. In a power station with a plurality of out going conductors a single asymmetric relay can act as a timer for any desired number of conductor ends, which only need in addition their own overload relays and possibly directional relays.

Although at the beginning of this specification it was stated that all cases of disturbance were provided for by a bipolar asymmetric relay, a special case was passed over and that was the case of a substantially simultaneous short circuit between all three phases of a three phase system. Here the three voltages fail but all in the same ratio, so that the diagram although on a smaller scale is not distorted. The said relay, which is only operated in the case of alteration of the angular relation of the voltages, would fail to act here.

In order to protect the system against the consequences of the possible failure of the relay under these rare circumstances of a three phase short circuit, a special precaution must be taken. According to the invention this consists in providing a time contact, which is shunted across the closing contact of the asymmetric relay. This time contact has a definite and lengthy lag, which should correspond to the greatest allowable period of the overload. All the closing times normally determined by the asymmetric relay must remain less than the closing time of this auxiliary time contact. In the case of an equalised short circuit of all three phases or any other case of failure of the asymmetric relay, after the expiration of the maximum time to which it is set, the auxiliary time relay comes into operation and cuts out the system through its auxiliary contacts shunted across the asymmetric relay.

For the above purpose an entirely separate time relay of known construction can be used, which in case of a short circuit can be set in operation by other auxiliary relays. Two examples of the connections for such arrangements are given in Figs. 7 and 8.

In the arrangement shown in Fig. 7, in contradistinction to the arrangement shown in Fig. 6, the closing contact of the asymmetric relay AR is connected directly in the operative circuit of the cut out coil 18 of the main switch 17. For the completion of this example the closing contact of a possibly necessary directional relay RR is shown in this circuit. ZR is the time relay, whose closing contact is according to the invention shunted across the closing contact of the asymmetric relay. To set this time relay in operation there are three main current relays 19 operated by the main current of the system, whose closing contacts are connected in series in the operative circuit 21 of the time relay.

The apparatus works as follows: In the case of any disturbance as soon as a sufficient voltage asymmetry is reached at the relay connection point, the asymmetric relay AR without respect to the absolute magnitude of the short circuit current operates the cut out switch. With an equalised three phase short circuit with symmetrical voltage drop the asymmetric relay cannot come into operation. In this case however the short circuit currents in all three phases operate the three main current relays 19 and thus set in operation the time relay ZR, which then, after the expiration of the period to which time lag is set, operates the cut out switch.

The above described arrangement has the disadvantage that the protection is only independent of the absolute magnitude of the short circuit current so long as the asymmetric relay is operative. As soon however as the short circuit is tripolar and thus symmetrical, the protection of the system depends on the time relay, and then the short circuit current must rise above the normal current of the system, because otherwise the main current relays which are necessarily set to this nominal current cannot respond.

The next arrangement shown in Fig. 8 is free from this disadvantage. Here three voltage drop relays 23 connected to to three phases of the system are provided for setting the time relay in operation in the case of a three phase short circuit, whose closing contacts as before are in series with the operative circuit 21 of the time relay.

In the case of a three phase short circuit all three voltages of the system drop, the armatures of the three voltage drop relays are consequently released and close the operative circuit of the time relay, and the latter after the expiration of the time lag to which it is set cuts out the system, unless in the meantime there has been a sufficient degree of asymmetry to operate the asymmetric relay AR.

As in this arrangement main current relays are neither inserted in the circuit of the asymmetric relay nor of the time relay, the protective action for all cases of short circuit, including equalised tripolar short circuit, is independent of a given overload, i.e. a load greater than the nominal current of the system.

Another very important advantage is obtained by using voltage drop relays for setting the time relay operation. These voltage drop relays are desirably operated at those places nearer to the locality of the disturbance, where the voltage drop is the greater, so that a certain selective protective action can be obtained even in the exceptional case of an equalised three phase short circuit, although the system is cut out only by the non-selective time relay.

Where a switch is manually or automatically opened at a station, the voltages to all the stations on that line are cut out. In the arrangement shown in Fig. 8 this causes all the voltage drop relays to be operated, so that in consequence the switches at all these stations could be dispensed with as superfluous. To avoid this the arrangement given is further provided with a zero current relay 24 connected with any one phase, which serves to open the contacts if necessary in the operative circuit 20 of the time relay.

If now a conductor in a station high up in the system is broken the voltage drop relays 23 close their contacts, but at the same time the zero current relay 24 opens its contacts, thus preventing the superfluous operation of the time relay.

For any conductor a single zero current relay will be sufficient, for this device is only necessary for protection in case of three phase short circuit, and in this case the short circuit current obviously flows through all conductors and therefore the zero current relay will hold its core attracted irrespective of which phase it is connected with.

Dated this 14th day of December, 1927.

SEFTON-JONES, O'DELL & STEPHENS,
Chartered Patent Agents,
285, High Holborn, London, W.C. 1,
Agents for the Applicant.

COMPLETE SPECIFICATION.

Improvements in or relating to Electrical Relays and Relay Systems.

I, Jancu Solomon, Engineer, of 241, Strada Romana, Bucarest, Roumania, of Roumanian nationality, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

As is well known, the phase voltages of a polyphase system may be represented vectorially in magnitude and phase relation as a closed or open voltage polygon characteristic of the system. Every disturbance of normal working conditions (save an earth arising on a normally unearthed system) alters more or less the magnitude and phase relation of the phase voltages, or, vectorially expressed, causes distortion of the voltage diagram characteristic of the system.

This invention relates to a relay, (applicable to systems with or without an earthed neutral,) actuated by the alteration in the phase relation (or distortion of the voltage diagram) produced by a disturbance in the system to indicate the disturbance and to cut out the damaged part of the system. According to the invention a relay of the dynamometer or induction meter type is employed, in which two interlinked fields are produced by voltages derived from the voltage diagram, so as to set up a torque dependent on their vectorial product, and approximately proportional to the change in phase angle resulting from the disturbance.

Preferably the voltages producing the fields should be of such phase relation that the torque is zero or a maximum when the voltage polygon is undistorted. In order that the derived voltages may freely follow the distortion of the voltage diagram the relay circuits must not be earthed if they are directly connected to the mains.

As the three phase system is the most widely used of all polyphase systems, arrangements suitable for three phase working will be described hereinafter for the sake of example. Similar arrangements can however be provided within the scope of the invention for all other polyphase systems.

The invention is illustrated in the accompanying drawings in which Figure 1 and Figure 2 show the vectorial voltage diagram for delta connection. Figure 3 shows the voltage diagram for star connection. Fig. 4 shows the connections of a relay. Figure 5 shows a somewhat

modified arrangement of the connections of a relay. Figure 6 shows the relay used in a selective protective system. Figures 7 and 8 show two more complete selective protective systems according to the invention.

The equilateral triangle RST in Figure 1 shows the linked voltages of an undisturbed three phase network. If a disturbance occurs in the system, for example a short-circuit between the phases S and T, this triangle departs from its normal shape and contracts into the triangle $R\ S^1\ T^1$.

If the two circuits of an instrument of the dynamometer type are connected to two voltages derived from this triangle, for example to R T, and S A, (where A is the mid point of RT, so that the voltage SA is normally at 90° to the voltage RT), the instrument will be actuated on the principle above described when such distortion of the triangle occurs.

If the fields in the apparatus have the same phase difference as the voltages producing them, as can always be arranged by known means, there will normally be no torque in an instrument so connected because the fields will be at right angles. Only when a disturbance distorts the voltage diagram, e.g. into the triangle $RS^1\ T^1$, will the voltages S^1A^1 and RT^1 form an angle $S^1A^1T^1$ less than 90°, so that the two fields can react on each other and bring the relay into action.

In an apparatus of the induction or Ferraris type, the greatest turning moment occurs when the fields are in quadrature. For this type of instrument therefore one of the two fields should be artificially shifted in phase through 90° or both fields should be so shifted in phase that although the voltages producing them are at right angles, the fields themselves have a phase difference of 0° or 180° so that normally no torque is produced.

If a short circuit occurs between R and T the triangle may be distorted into the isosceles triangle SR^1T^1 (Fig. 2). As in this case the median SA^1 remains perpendicular to R^1T^1, the relay would not be operated. In order to make the relay operative in these circumstances, a second operating system must be provided, which is connected between S and T and R and B, B being the mid point of ST. The relay will then act upon any distortion of the voltage diagram, for only in an undistorted equilateral triangle is each median perpendicular to the side it intersects. The special case of a short circuit on all three phases will be gone into hereinafter.

A relay constructed according to the invention may be termed an asymmetry relay, and when provided with two operating systems, as has just been shewn to be desirable, it will hereinafter be called a bipolar relay.

The mid points A and B can be got in known manner by means of resistances or choking coils with a tapping in the middle connected between R and T and S and T. In high tension systems where the connections are made through voltage transformers the mid points A and B can be tappings in the middle of the secondary windings of the transformers.

If the voltage diagram of the three phase system is a three branched star as shown in Figure 3 instead of a triangle, two voltages at right angles can be derived from the phases R and T and from the third phase S and the neutral point O. On a disturbance occurring, the star is distorted say into $RS^1\ T^1$ (Fig. 3), the neutral point shifts to O^1, S^1O^1 is no longer perpendicular to RT^1, and the relay is operated. In this scheme also two operating means are provided to deal with all possible distortions of the star.

As may be gathered from the above an alternative way of connecting the relay is to use the neutral point of the system if it has one or an artificial neutral point obtained in known manner.

Complete connections for a bipolar relay of the type shown in Fig. 2 are shown diagrammatically by way of example in Fig. 4. The scheme assumes the use of voltage transformers with tappings at the mid points of the secondaries. The primary windings of the transformers 1, 2 are connected to the three lines RST. One winding 3 or 4 of each pair of relay windings is joined to the secondary winding of each transformer, whilst the other winding 5 or 6 of the pair is connected between a terminal of one transformer secondary and the mid point A or B of the other.

The need for resistances, choking coils, artificial neutral points, or transformer secondary tappings can be avoided by making the points of connection A B points in the windings 3 and 4, for these windings being connected across the phases any desired voltage can be tapped from them. The diagram of connections for a bipolar relay supplied on this scheme by ordinary voltage transformers is shown in Figure 5. The two operating means of the relay in this case can be either independent or mechanically connected.

It is a characteristic of the asymmetry relay above described that there is no torque under normal working conditions. It can be arranged, however, that the torque is at its greatest under normal working conditions and is counterbalanced by a suitable restraining force, as for example springs, counter-weights etc. For this purpose with relays built on the dynamometer principle the phase of one of each pair of fields must be artificially shifted by 90°; with Ferraris instruments the fields, like the voltages producing them, must be at right angles to each other.

The main uses of the relay according to the invention are as selective protective means against overload in supply systems, as protective means for generator windings, as differential protective means for transformers, as protective means for motors against overload and failing of a phase, as disturbance indicators for circuits connected to voltage transformers and as an indicator or measuring instrument for asymmetry in electrical plants.

The use of the relay for selective protection against overloads and short circuits depends on the fact that in a system of considerable extent the distortion of the voltage diagram increases as the fault is approached. Hence a relay indicating such a distortion will act the more vigorously the nearer the fault. The relay is therefore intrinsically selective.

The same principle of using the distortion of the voltage diagram to actuate a relay according to the invention, can also be applied for the protection of polyphase motors against the failing of a phase as follows: Under normal working conditions, for example in three phase working, the three voltages impressed on a motor form an equilateral triangle. If one phase is interrupted, a back E.M.F. is generated, the corresponding motor phase acting as a single phase generator. This back E.M.F. is smaller than the voltage of the other phases and therefore forms with them a non-equilateral triangle, in which the medians are no longer perpendicular to the sides they intersect.

If for example a relay constructed and connected as shown in Fig. 5, is joined to the terminals of the motor, under normal working conditions the relay remains at rest, unaffected by variations of the supply voltage and of the load; but it immediately responds to the interruption of a phase owing to the distortion of the voltage triangle to which it is joined, and may then disconnect the motor in known manner. In order that the relay may respond to interruption of any one of the motor phases with equal certaininty, a bipolar relay connected as shown in Fig. 2 must be used.

This phase interruption relay can be developed further into an overload relay and thus form a complete protective relay for motors. For this purpose, in three phase working, a choking coil is inserted in each of two of the supply lines before the connection to the asymmetry relay. These choking coils cause voltage drops in the two lines and distort the voltage triangle beyond them. The choking coils are of such value and the operating means of the asymmetry relay are so far insensible, that as long as the normal allowable current is not exceeded the relay is not operated. In case of an overload or a defect in the motor the current rises in the choking coils, as do also the voltage drops caused by it, until the asymmetry relay beyond the choking coils is operated by the distortion of its voltage triangle. In order that the relay may not be operated by a starting current exceeding full load, delay action means are provided.

If an asymmetry relay, as herein described, is connected to the secondary terminals of a group of voltage transformers, an interruption or other disturbance in the group is at once indicated, and the disturbances which would therby be caused in meters, wattmeters, shunt relays or other apparatus dependent on voltage connected to these transformers are avoided.

Differential protection of transformers or other apparatus by the asymmetry relay is obtained by balancing the voltage diagrams on the input and output sides (or the primary and secondary sides) of the protected apparatus or transformers. For this purpose a relay is joined to the input side and another to the output side of the apparatus to be protected, in such fashion that similar distortions on the two sides of the connected system result in equal opposite torques in the two relays, which are coupled or otherwise mechanically connected.

Instead of this the one field coil of a relay may be connected to a voltage derived from the input side and the other to a voltage derived from the output side, these voltages being so chosen that the fields in the relays (due to their natural or a superposed artificial phase displacement from the voltages producing them,) differ in phase, in undisturbed conditions, by 90° in dynamometer type apparatus and by 0° or 180° in Ferraris type apparatus.

The applicability of the asymmetry relay to protection against short circuits in generator windings is obvious from the consideration that such disturbance distorts the voltage triangle at the generator terminals.

For many of the above described uses it would be desirable to add to the relay a delay action device, which may most simply be an eddy current brake acting on the disc of the relay.

For selective protection of supply networks an asymmetry relay built on the Ferraris principle without additional braking is suitable, only the braking torque of the alternating fields operating. This gives the relay an almost straight line time characteristic which is very appropriate for selective protection. For the general theory of the Ferraris disc applied to this relay and other considerations show that an induction type relay used for selective protection of a network needs no additional braking, but on the contrary such additional braking is best avoided.

In point of fact, as may easily be found from the known theory of the induction meter, the torque on the stationary disc of the asymmetry relay is:—

$$(1) \qquad D = k\phi_1.\phi_2.\ \text{Cos.}\ \psi$$

and the braking torque of the alternating fields is

$$(2) \qquad D_1 = k_1\phi_1.^2 + k_2\phi_2^2 + k_3\phi_1\phi_2\ \sin\ \psi.u$$

where ϕ_1 and ϕ_2 are the alternating fields, ψ is the phase angle between the connection voltages, u the speed of the disc and k, k_1, k_2, and k_3 are constants depending on the construction and dimensions of the relay.

It will be noted that in the above formula for D, as compared with the usual theory of induction meters, cos ψ takes the place of sin ψ, and in that for D^1, sin ψ takes the place of cos ψ. This difference arises from the fact above mentioned, that in asymmetry relays, in order that there may be no torque in normal conditions, the operative fields within the relay are given an additional relative phase displacement of 90°, so that the normal total phase difference between them is 0° or 180°.

Neglecting friction, balance is obtained when

$$(3) \qquad D - D^1 = 0$$

or the closing time T of the relay (apart from a constant proportion factor) is

$$(4) \quad T = \frac{1}{u} = \frac{k_1.\phi_1^2 + k_2\phi_2^2 + k_3\phi_1\phi_2\ \sin\ \psi}{k\phi_1\phi_2\ \cos\ \psi}$$

or

$$(5) \quad T = \frac{k_1\phi_1^2 + k_2\phi_2^2}{k\phi_1\phi_2}.\ \frac{1}{\cos\ \psi} + \frac{k_3}{k}\ \tan\ \psi$$

Since there is no distinction between the relay voltages ϕ_1 may be equal to ϕ_2, and there is no constructional difficulty in making it so.

Equation (5) then simplifies to

$$(6) \qquad T = \frac{k_1 + k_2}{k} \cdot \frac{1}{\text{Cos}\ \psi} + \frac{k_3}{k} \tan\psi$$

or combining the constants

$$(7) \quad T = C_1.\frac{1}{\text{Cos}\ \psi} + C_2\ \tan\ \psi$$

It will be seen therefore that the closing time T is a simple function of the angle ψ.

Under normal working conditions, $\psi = 90°$ and the closing time is infinitely great. With a two pole short circuit $\psi = 0°$, T is then $= C_1$, which is the basic time of the relay. Between these two extreme values both terms of equation (7) rise and fall with ψ, so that the time characteristic is approximately a straight line as is necessary for selective protection.

For many purposes the relay disc may simply oscillate and not rotate. To make such a relay without bearings and rotary parts the disc may be mounted on an oscillating arm. If the disc is in the field of the relay core, since it cannot turn it will be subject to a tangential force at its outer edge which will cause a corresponding deflection of the disc and arm. In this construction the disc may be reduced to a sector large enough for the magnetic flux to traverse it. This results in a very simple and compact relay.

The consequent operation of the switchgear of the protected system can be effected directly by the relay described, or in known manner by any suitable series or shunt relay, directional relay earthing relay or time relay connected with or if desired built together with the relay according to this invention.

As indicated above, when the asymmetry relay is used for the selective protection of supply networks it is not necessary to choose and adjust each individual relay according to the working conditions at the point where it is installed. On the contrary all the relays employed are of the same construction and the due sequence of closing of the individual relays results automatically from the magnitude of the distortion of the voltage diagram at the relay location.

So far the main current of the system has not entered into the working of the relay and therefore the relay does not need a substantial overload to operate it but only a sufficient distortion of the voltage diagram at its place of connection. This brings out another valuable property of the asymmetry relay, namely that it will still act even when, as for instance often happens in large systems late at night, the reduced output of the power station is insufficient to send an overload current into the system.

In certain cases, however, use can be made of the overload principle for the protection of the system; in which case the asymmetry relay according to the invention plays the part of a timer. The action of the relay is then analogous to that of a voltage drop selective relay. In such a relay the voltage drop is used to secure the proper sequence of operation of separate overload relays, while according to the invention the distortion of the voltage diagram is employed for the same purpose.

Accordingly the asymmetry relay may be combined with relays of other types in otherwise known arrangements such as the usual voltage drop relays. For example this relay can be connected with series solenoils or series relays without time lag or if desired may be structurally combined with them. for example Fig. 6 shows the complete connections of a selective protective system for three phase working made up of three series solenoids 19, one in each phase, and a bipolar asymmetry relay according to the invention. In this Figure 15 are current transformers, 16 voltage transformers, 17 is an oil switch, AR a bipolar asymmetry relay, 18 an oil circuit-breaker, 19 are three series solenoids with their contacts, and 20 is the auxiliary circuit.

If the selection of the conductor to be cut out is also to depend on the direction of the energy, the contact of a directional relay should be included in series with the contacts of the series solenoids and the asymmetry relay. With these connections the series solenoids act as an overload contact maker without lag, the directional relay serves to select the conductor, as it locks or frees the cut out switchgear according to the direction of the energy, and the asymmetry relay according to the invention acts as timer.

In a power station with a plurality of outgoing conductors a single asymmetry relay can act as a timer for any desired number of conductor ends, which only need in addition their own overload relays and possibly directional relays.

When at the beginning of this specification it was stated that all cases of distortion were provided for by a bipolar asymmetry relay, a special case was passed over and that was the case of a substantially simultaneous short circuit between all three phases of a three phase system. Here the three voltages fall but all in the same ratio, so that the diagram although on a smaller scale is not distorted; and the relay described, which is only operated by an alteration in the angular relation of the voltages, would fail to act.

To protect the system against the consequences of the possible failure of the relay in the rare circumstance of a balanced three phase short circuit, a special precaution must be taken. According to the invention this consists in providing a time contact in parallel with the contact of the asymmetry relay. This time contact has a definite and lengthy lag, which should correspond to the greatest allowable period of the overload. All the closing times determined in usual cases by the asymmetry relay must be less than the closing time of this auxiliary time contact. In case of failure of the asymmetry relay through a balanced short circuit of all three phases or any other cause the auxiliary time relay comes into operation after the expiration of the maximum time to which it is set, and cuts out the system by closing its contact.

For the above purpose an entirely separate time relay of known construction can be used, which in case of a short circuit can be set in operation by other auxiliarly relays. Two examples of the connections for such arrangements are given in Figs. 7 and 8.

In the arrangement shown in Fig. 7, in contradistinction to the arrangement shown in Fig. 6, the contact of the asymmetry relay AR is connected alone in the circuit of the release coil 18 of the main switch 17; or the circuit may include also the contact of a directional relay RR. ZR is the time relay, the contact of which is according to the invention in shunt with the contact of the asymmetry relay. This time relay is set in operation by the three series relays 19 one in each phase whose contacts closed by the excitation of the relays are connected in series in the circuit 21 of the time relay.

The apparatus works as follows: As soon as any disturbance causes a sufficient voltage asymmetry at the point where the relay AR is connected, the relay operates the cut out switch irrespective of the absolute magnitude of the short circuit current. Upon a balanced three phase short circuit with symmetrical voltage drop the asymmetry relay cannot come into operation. In this case however the short circuit currents in all three phases operate the three series relays 19 and thus set in operation the time relay ZR, which then, after the expiration of its time lag, operates the cut out switch.

The above described arrangement has the disadvantage that the protection is only independent of the absolute magnitude of the short circuit current so long as the asymmetry relay is operative. When the short circuit is tripolar and so nearly symmetrical that the protection of the system depends on the time relay, the short circuit current must rise above the normal current of the system, otherwise the series relays which are necessarily set according to this normal current cannot respond.

The next arrangement shown in Fig. 8 is free from this disadvantage. Here three voltage drop relays 23 connected to the three phases of the system are provided for setting the time relay in operation in the case of a three phase short circuit, their contacts as before being in series in the circuit 21 of the time relay.

Upon a three phase short circuit all three voltages of the system drop, the armatures of the three voltage drop relays are consequently released and close the circuit of the time relay, and the latter after the expiration of the time lag to which it is set cuts out the system, unless in the meantime there has been a sufficient degree of asymmetry to operate the asymmetry relay AR.

As in this arrangement there are no series relays either in the circuit of the asymmetry relay or in that of the time relay, the protective action is indepenent of substantial overload in all cases of short circuit, including balanced tripolar short circuit.

Another very important advantage is obtained by using voltage drop relays for setting the time relay in operation. For the voltage drop relays nearest the fault will operate first, the voltage drop being greatest there, so that a certain selective protective action will be obtained even in the exceptional case of a balanced three phase short circuit, although in this instance the defective plant is cut out only by the non-selective time relay.

When a switch is manually or automatically opened at a station all stations beyond it are cut out. In the arrangement so far described with reference to Fig. 8 this would cause all the voltage drop relays to operate, so that the switches at all these stations would be unnecessarily released. To avoid this the scheme is completed by a no-load relay 24 connected with any one phase, which on operating opens contacts in the circuit 21 of the time relay. If then a line is interrupted in a preceding station the voltage drop relays 23 close their contacts, but at the same time the no-load relay 24 opens its contacts, thus preventing the unnecessary operation of the time relay.

For one line a single no-load relay joined to any phase will be sufficient, for this whole relay system is only needed for protection in case of three phase short circuit, when the short circuit current obviously flows in all conductors, and therefore the no-load relay will hold its core attracted irrespective of which phase it is connected with.

Protective systems have been devised in which a rotating disc is acted upon by two or more independent magnetic fields produced by voltages derived from the protected polyphase system. In this case the torque on the disc is not due to the interaction of the magnetic fields but is the algebraic sum of their separate effects. Thus in the case of two voltages derived by a Scott transformation from a three phase system the couple acting on the disc is

$$C = k\ (X_1^2 + X_2^2)$$

k being a constant and X_1 and X_2 the ampere turns of the two electromagnets. In the relay of the present invention the two fields of each relay must interact and the couple produced (using the same terms) is

$$C = X_1 . X_2 . \cos\ (\widehat{X_1 X_2})$$

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. A relay operating on distortion of the voltage polygon for indicating disturbances in polyphase electric systems, in which two voltages derived from the voltage polygon are employed to produce in a dynamometer or induction type of instrument two interlinked fields which by their mutual action set up a torque dependent on their vectorial product and approximately proportional to the change in phase angle of the two voltages which results from any disturbance that distorts the voltage polygon.

2. A construction of relay according to claim 1 in which the torque set up by an undistorted voltage polygon is zero.

3. A construction of relay according to claim 1 in which the torque set up by an undisturbed voltage polygon is a maximum and is balanced by a spring or the like.

4. A relay as claimed in claim 1 and 2 or 3 for a three phase system having one field winding connected to any two phases and the second field winding connected to the third phase and the electric centre of the first two phases.

5. A relay as claimed in claim 4 having the second field winding connected to the centre of the first field winding.

6. A relay comprising two relay elements as claimed in any of claims 1

to 5 coupled mechanically or electrically and connected to different pairs of derived voltages.

7. A relay as claimed in any of claims 1 to 5, fitted with a retarding device such as an eddy current brake or the like.

8. A relay as claimed in any of claims 1 to 5 having no braking save that of the alternating fields of the relay cores.

9. A relay as claimed in any of claims 1 to 8 in which the moving element is a disc mounted non-revolubly on an oscillating arm or lever.

10. A selective protective system comprising a relay as claimed in any of claims 1 to 9 in combination with the usual series, directional or other relays, the contacts made by all of said relays being included in series in the operating circuit of the protective apparatus.

11. A selective protective system comprising an asymmetry relay as claimed in any of claims 1 to 9, arranged to make a contact in the operative circuit of a protective apparatus, in combination with a time relay set to act on expiry of the maximum permissible duration of the disturbance in the part of the system protected, and to make a contact in parallel with that of the asymmetry relay.

12. A selective protective system as claimed in claim 11 in which the circuit of the time relay is closed by series relays one in each phase operated by the short circuit current in the system.

13. A selective protective system as claimed in claim 11 in which the circuit of the auxiliary time relay is closed by voltage drop relays one in each phase, when the armatures of all of said relays are released.

14. A selective protective system as claimed in claims 11 and 13 in which the circuit of the time relay includes a contact broken by the response of a no-load relay actuated by the main current of the system.

15. A relay as claimed in claims 1 to 9 for protecting generators against short circuiting of coils, or motors and circuits connected to voltage transformers against failure of one phase, or for differential protection of transformers and other devices, having its windings connected to the terminals of the generator, or motor, or of the circuits connected to voltage transformers or to both sides of the transformer.

16. A relay as claimed in claims 1 to 9 for protecting motors against overload and failure of one phase having its windings connected to the motor supply lines on the motor side of choke coils inserted in two of said lines.

17. A relay or protective system as claimed in any of claims 1 to 16 wherein the asymmetry relay windings are connected to the circuit or apparatus to be protected through instrument transformers.

18. The improved protective systems embodying an asymmetry relay constructed and connected substantially as described with reference to the annexed drawings.

Dated this 10th day of September, 1928.

SEFTON-JONES, O'DELL & STEPHENS,
Chartered Patent Agents,
285, High Holborn, London, W.C. 1,
Agents for the Applicant.

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Fig.1

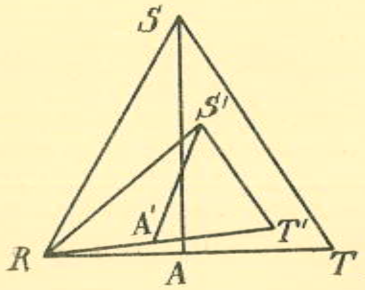


Fig.2

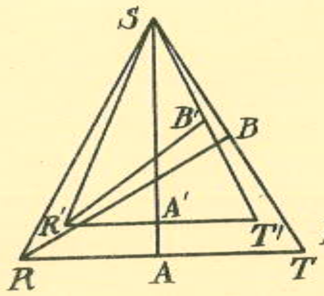


Fig.3

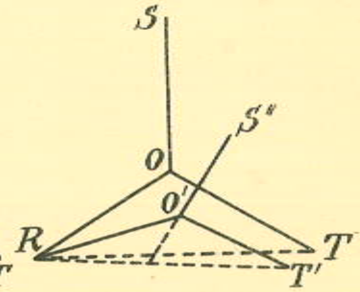


Fig.4

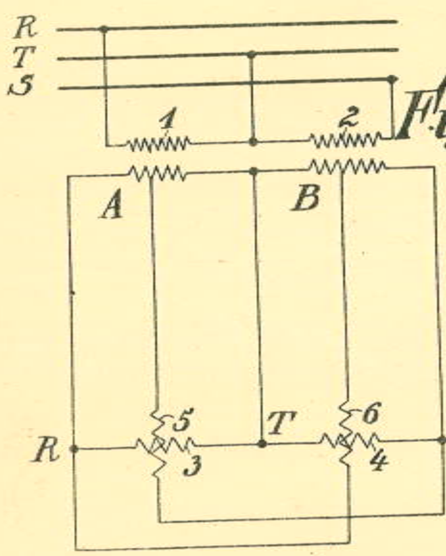


Fig.5

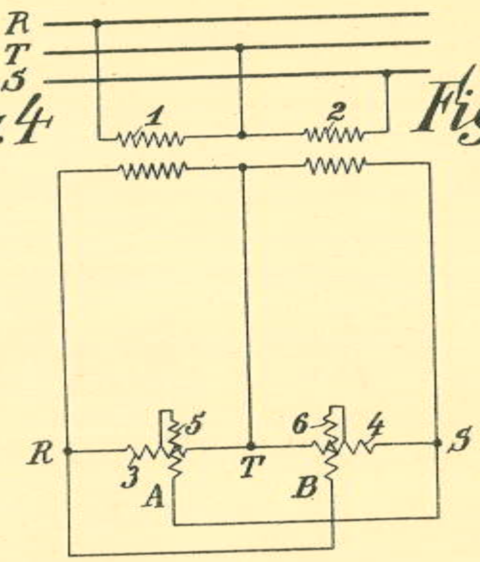


Fig.6

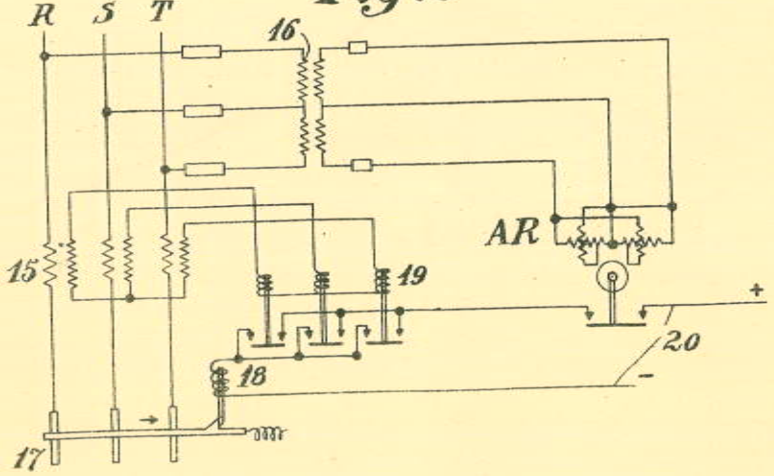


Fig.7

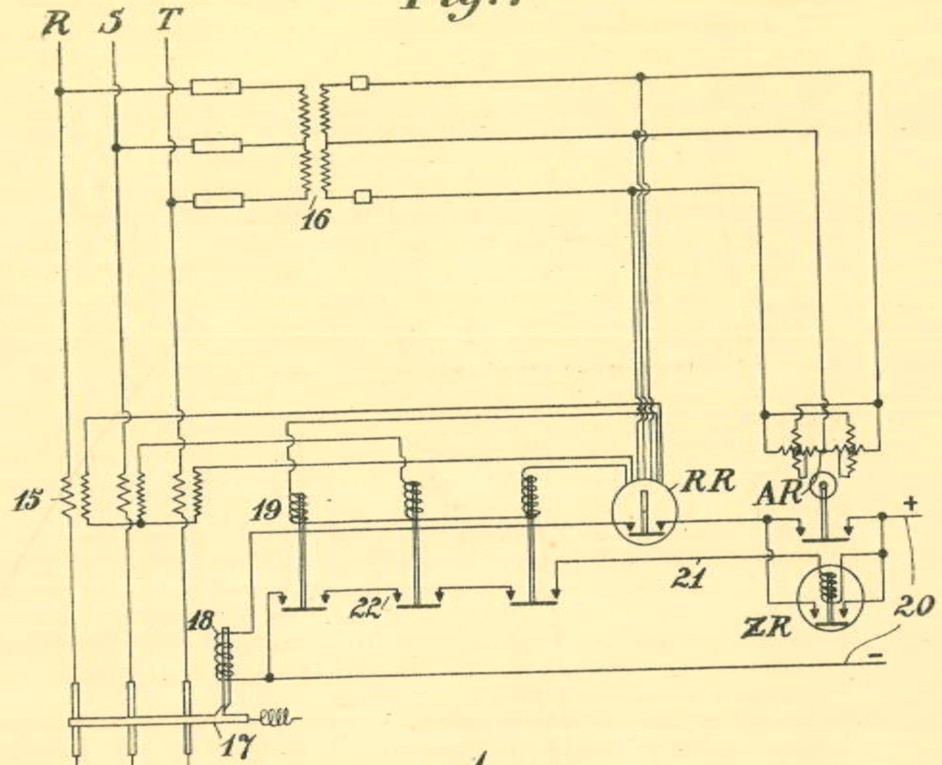


Fig.8

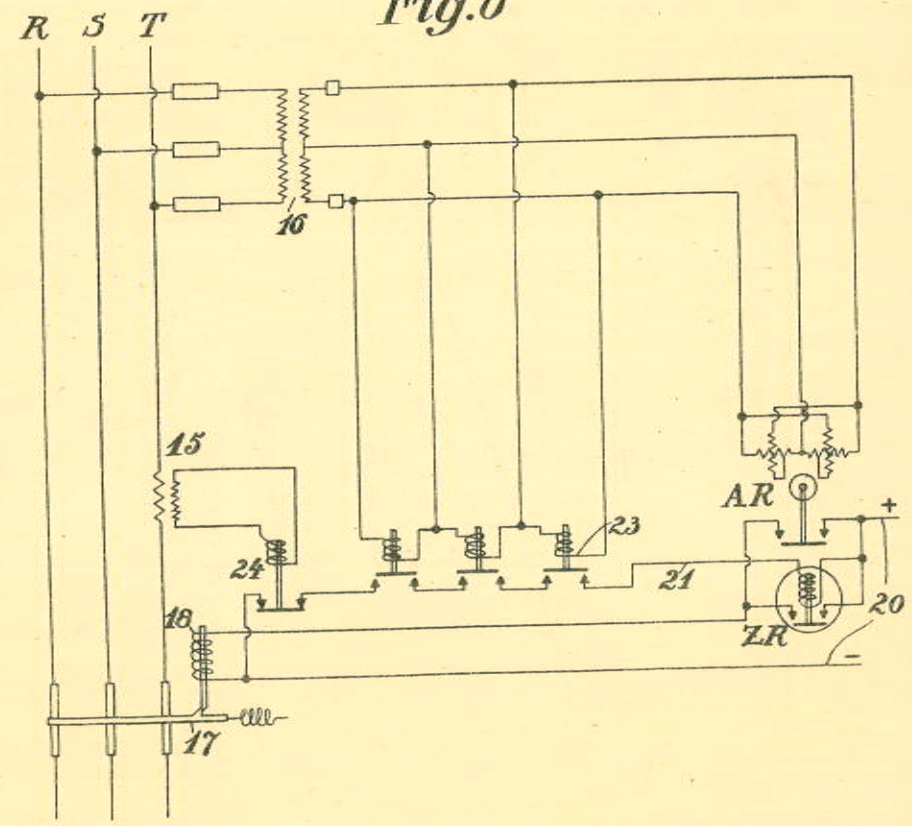


Fig. 1

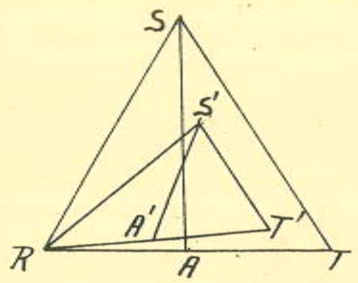


Fig. 2

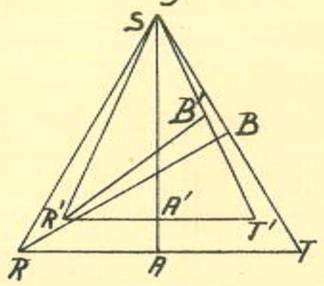


Fig. 3

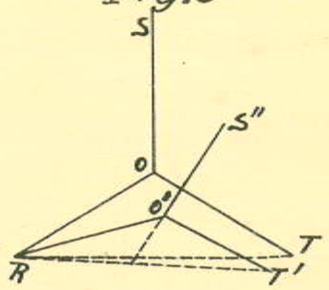


Fig. 4

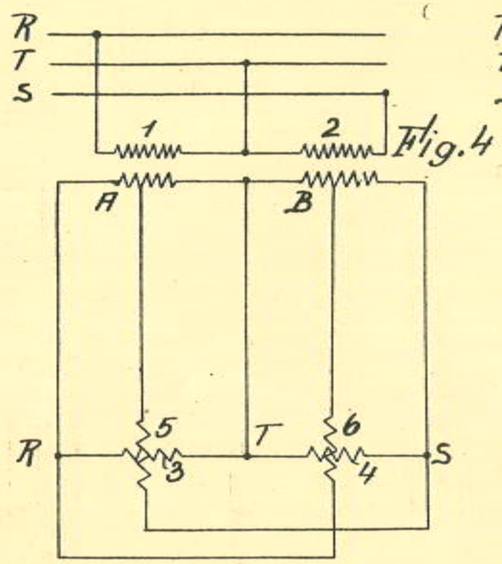


Fig. 5

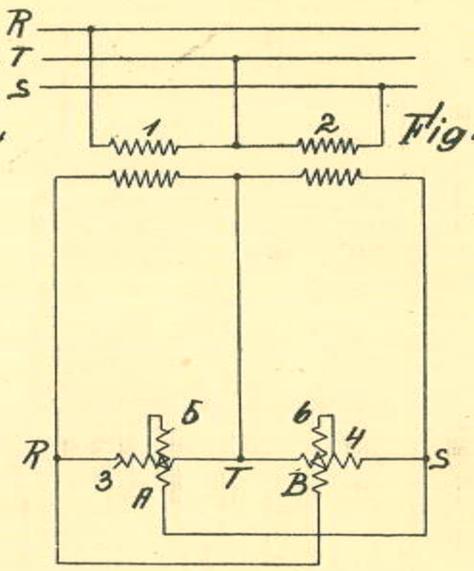


Fig. 6

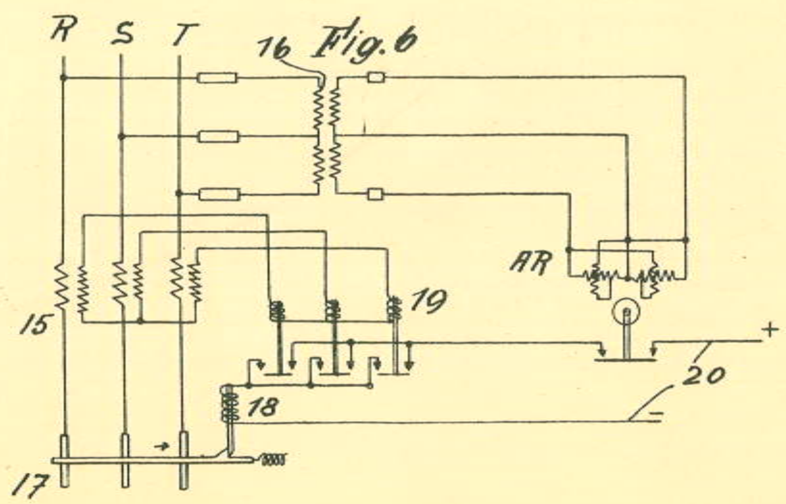


Fig. 7

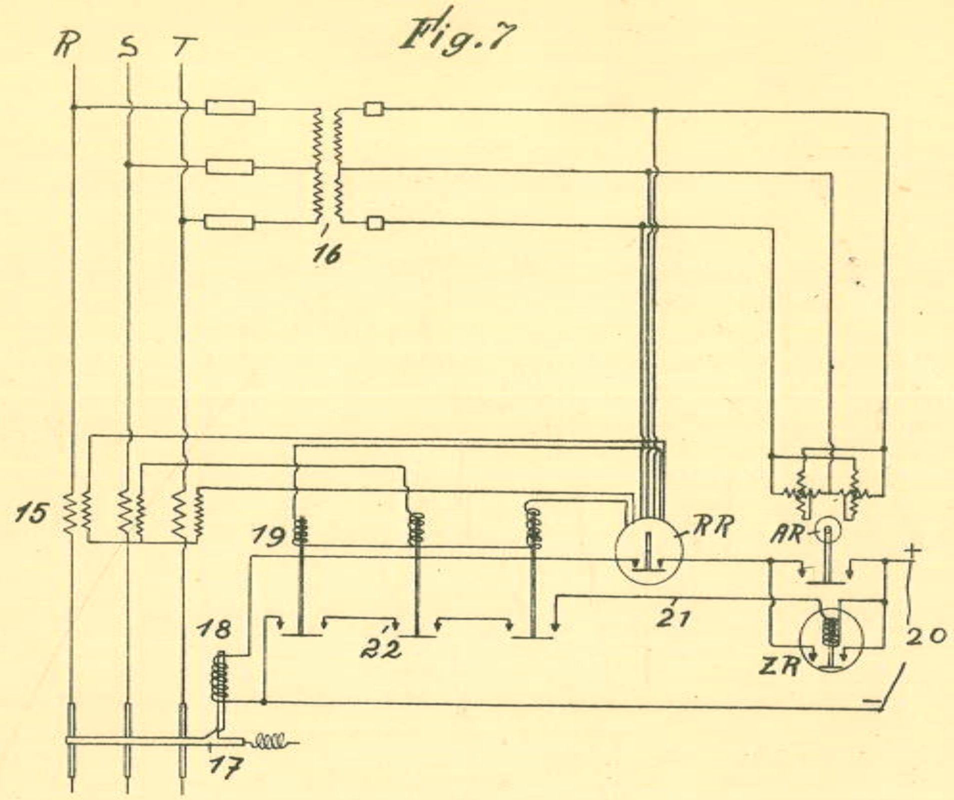
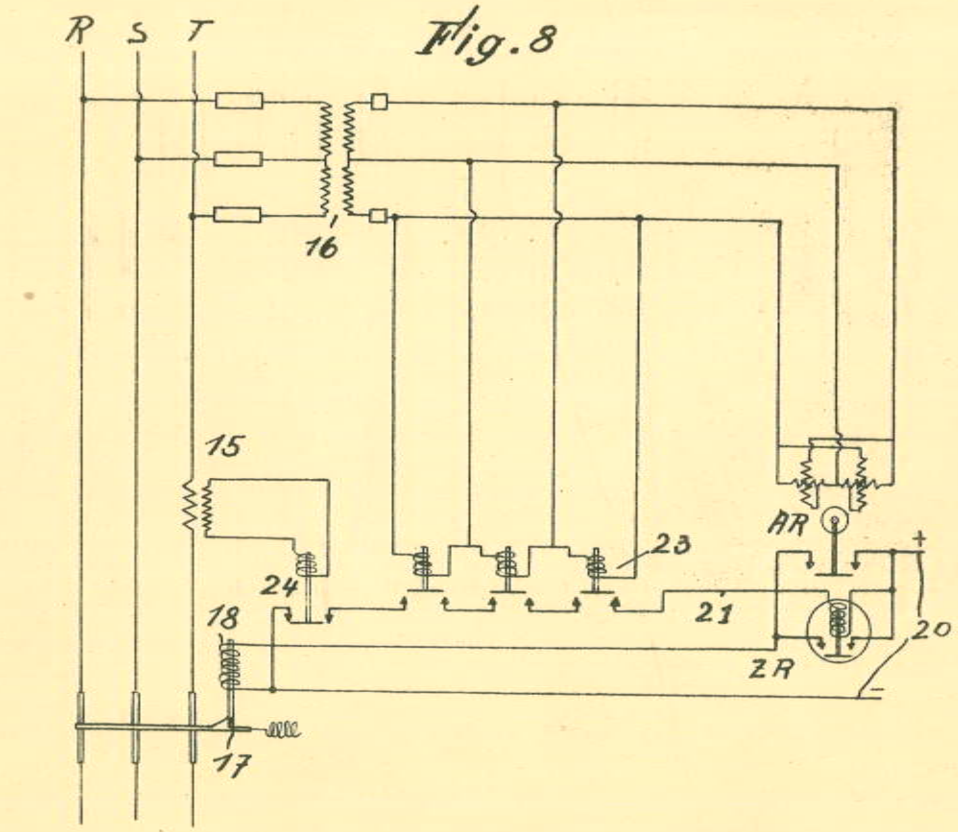


Fig. 8



[This Drawing is a reproduction of the Original on a reduced scale]