April 6, 1965 C. I. CLAUSING 3,177,401

CURRENT MULTIPLIER

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FIG. 1

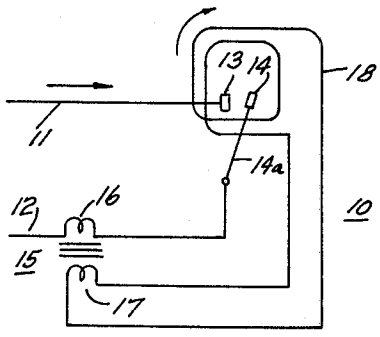


FIG. 3

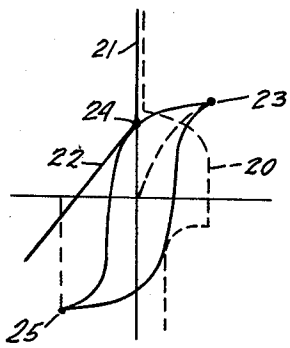


FIG. 2

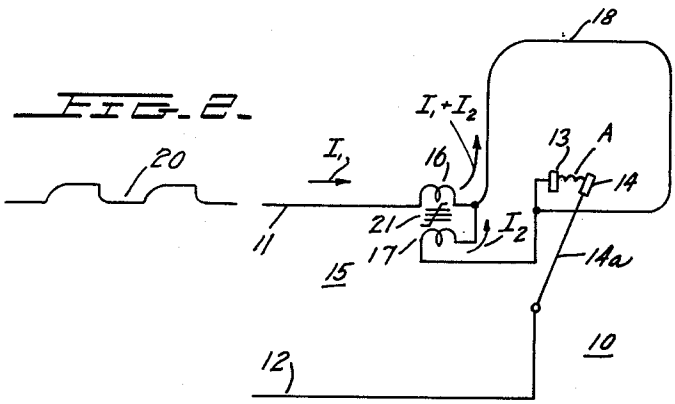


FIG. 4

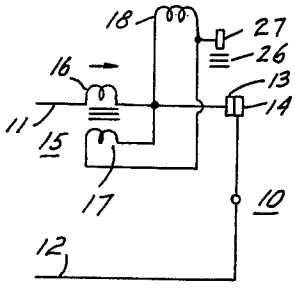
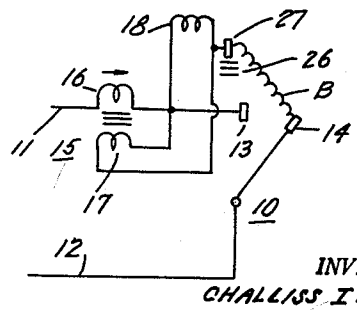


FIG. 4a



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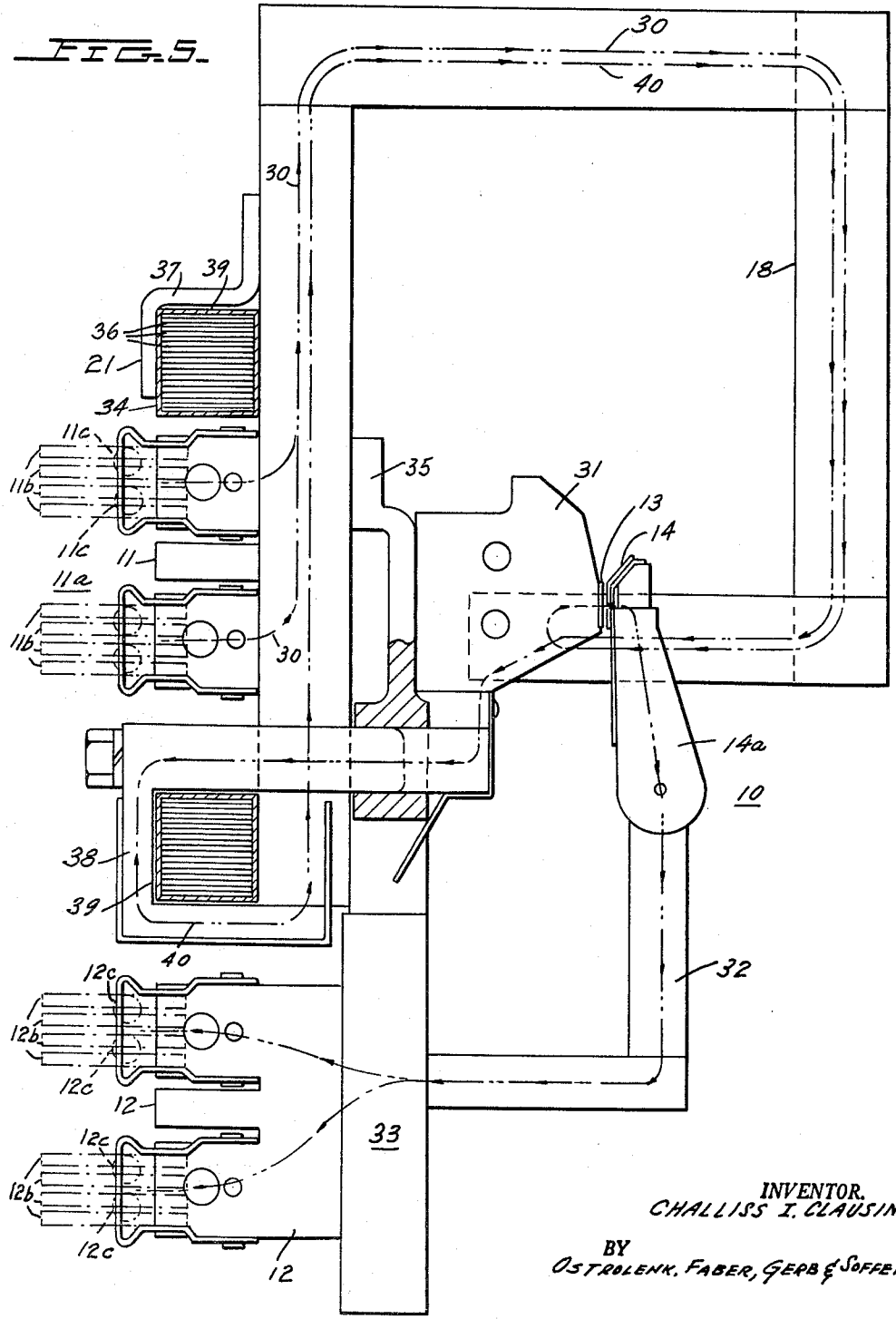
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CURRENT MULTIPLIER

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FIG. 5



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United States Patent Office 3,177,401 Patented Apr. 6, 1965

3,177,401

CURRENT MULTIPLIER

Challiss I. Clausing, Collingswood, N.J., assignor to I-T-E Circuit Breaker Company, Philadelphia, Pa., a corporation of Pennsylvania

Filed Feb. 15, 1961, Ser. No. 89,416
10 Claims. (Cl. 317—11)

My invention relates to blowout means for circuit interrupters and more particularly to blowout means having a novel current multiplier for increasing the current flow flow through the circuit interrupter blowout means during the tripping operation.

Prior art blowout means for circuit interrupters are designed to urge an arc formed between the interrupter cooperating contacts upward into the arc chute of the circuit interrupter in order that the arc may be rapidly extinguished. Blowout coils of the face-wound type have been widely used due to the advantageous flux pattern of the magnetic field which the face-wound blowout coil generates. Face-wound blowout coils have been designed to have usually one or two turns which turns encompass both the arc chute and the region of the separating contacts to generate a magnetic flux pattern which is concentrated in the region in which the arc exists.

The field strength of the magnetic field generated by the blowout coil is directly proportional to the number of turns of the blowout coil and to the current flowing through the coil. The flux density B, therefore, is equal to kNI where: B equals the flux density in gauss at the center of the coil, N is the number of turns of the coil, I is the current flowing through the coil and k is a constant of proportionality. It can be seen from this expression that if the number of amperes flowing through the coil is a fixed quantity, the coil may be designed to have a sufficient number of turns in order to generate a magnetic field of sufficient flux density to act on the arc formed during the interrupting operation.

Increasing the number of turns of the blowout coil becomes necessary for the interruption of a low magnitude current arc. However, the space needed for a large number of turns may be far greater than the space which is actually available thereby creating a limit on the number of turns which the blowout coil can have in an actual installation. In addition, the increased number of turns increases the impedance of the blowout coil which has an adverse effect upon the transfer of the current flowing in the circuit being protected from the circuit to the blowout coil.

The circuit interrupter of my invention comprises a pair of cooperating contacts which are electrically connected in series relationship with the blowout coil. This series combination is electrically connected between the upper and lower terminals of the circuit interrupter. A primary winding of a current transformer is then placed in series with the blowout coil and the cooperating contact combination. The secondary or output winding of the current transformer is connected in parallel with the blowout coil. The primary winding of the current transformer, being in series with the cooperating contacts, carries the same current which passes through the cooperating contacts. The current flow through the primary winding generates a current in the secondary or output winding. This current in the output winding flows through the blowout coil simultaneously with the flow of the primary current from the circuit being protected. The current transformer is electrically designed so that the current generated in the output winding and flowing in the loop comprises of the output winding of the current transformer and the blowout coil is flowing in the same direction as the primary current of the circuit being protected thereby increasing the amount of current passing through the blowout coil. This arrangement (using a one-to-one current transformer) provides a current in the blowout coil which is approximately double the amount of current which would flow through the blowout coil in the absence of the current transformer. This arrangement is extremely advantageous for the interruption of arcs of low current magnitude since it affords the same number of ampere turns (NI) as a blowout coil configuration having twice the number of turns as the blowout coil of my invention. The current transformer need not be positioned immediately adjacent the blowout coil but may be positioned in a less critical region of the circuit interrupter so that its inclusion within the circuit interrupter does not create additional design problems.

The current transformer of my device may also be designed to have a transformer core formed of a ferromagnetic material which exhibits a substantially square hysteresis loop. This is extremely advantageous when used in a circuit interrupter for the protection of a D.-C. current circuit, the transformer core being designed to present a high impedance to the primary current during normal current flow so that no current will be generated in the output winding of the current transformer during the period of normal current flow. When a D.-C. current is impressed upon the input windings of a transformer no transformed current appears at the output winding since a transformer requires an input current which is changing in magnitude and/or direction for transformer action to take place.

When an A.-C. current is rectified the wave form consists of a D.-C. voltage plus a number of A.-C. harmonics. The A.-C. harmonics are commonly known as the ripple voltage. The percentage of ripple voltage which is present at the D.-C. side of an A.-C. to D.-C. conversion system having a plurality of phases, such as the system described in U. S, Patent No. 2,905,865, is extremely low, resulting in a transformed current at the output winding of the transformer which is likewise very small. Therefore, during normal current flow the transformed current appearing at the transformer output windings is negligible.

During a reverse current condition, however, the current magnitude and direction changes very rapidly causing the transformer core to reverse its saturation pattern. As soon as the transformer core reverses to the opposing saturable state, the transformer core presents a very low reluctance permitting the current transformer to generate a current in the ouput winding which contributes to the current already flowing in the blowout coil. This results in a current flow through the blowout coil which is greater than the current capacity of the circuit only upon the occurrence of a fault current condition so that the blowout coil is not subjected to any heating during periods of normal operation.

The current transformer of my invention may also be used in combination with overload coils employed in circuit interrupters of the type described in U.S. Patent No. 2,891,123, issued June 16, 1959, to C. I. Clausing, entitled "High Speed Circuit Breaker," and assigned to the same assignee as the instant invention. Breakers of the type described in the above mentioned patent employ overload coils which generate a magnetic field used to trip the circuit breaker during the occurrence of a fault current condition. This overload coil (commonly known as a bucking bar) is usually limited to a single turn. In order that the bucking bar carry a greater magnitude current the current transformer of my invention is connected to the bucking bar in the same manner as the connections made to the blowout means resulting in an increased

current flow through the bucking bar during fault conditions to separate the cooperating contacts more rapidly than in circuit breakers of the prior art.

It is, therefore, one object of my invention to provide a circuit interrupter having a novel blowout means.

Another object of my invention is to provide a blowout means for a circuit interrupter having novel means to aid the blowout coil in the interruption of arcs of low magnitude current.

Another object of my invention is to provide novel blowout means for a circuit interrupter which is so arranged as to increase the magnetic field generated by the blowout coil without increasing the number of turns of the blowout coil.

Still another object of my invention is to provide a novel means for a circuit interrupter having a current transformer.

Another object of my invention is to provide a novel blowout means for a circuit interrupter having means to amplify the current supplied to the blowout means.

These and other objects will become apparent from the following description when taken in connection with the drawings, in which:

FIGURE 1 is a schematic diagram of a circuit interrupter utilizing my novel device.

FIGURE 2 is a schematic diagram which shows another embodiment of my novel device.

FIGURE 3 shows a typical hysteresis loop.

FIGURE 4 is a schematic diagram showing my novel device utilized in an A.-C. circuit breaker.

FIGURE 4*a* shows the circuit breaker of FIGURE 4 in the tripped position.

FIGURE 5 is a side plan view of a circuit breaker in which the blowout means is connected in the manner shown in FIGURE 2.

Referring now to the drawings, FIGURE 1 shows a circuit breaker 10 having upper 11 and lower 12 terminals. Upper 11 and lower 12 terminals are designed to be connected to the stationary disconnects (not shown) of the circuit being protected. Stationary contact 13 is electrically connected to upper terminal 11 and is positioned to cooperate with movable contact 14 which is affixed to movable bridge 14*a*. Bridge 14*a* is electrically connected to one terminal of primary winding 16 of current transformer 15, the other terminal of which is connected to lower terminal 12. The secondary or output winding 17 of current transformer 15 is connected in series relationship with blowout coil 18.

It can be seen that with cooperating contacts 13 and 14 in the engaged position, the current flowing through the primary winding 16 of current transformer 15 generates a current in the secondary or output winding 17 of transformer 15 which current also passes through blowout coil 18. The primary winding 16 is designed to have a greater number of turns than the secondary winding 17 resulting in the generation of a current in secondary winding 17 which is greater in magnitude than the current flowing through primary winding 16.

This arrangement produces a current in blowout coil 18 which is greater than the current flow which would be present in blowout coil 18 in the absence of current transformer 15; that is, with blowout coil 18 connected in series relationship with the cooperating contacts 13 and 14, a lower magnitude of current passes through 18 than would be available with the inclusion of current transformer 15. It can therefore be seen that the use of current transformer 15 avoids the necessity of increasing the number of turns of blowout coil 18 in order to obtain a larger magnitude current for the interrupting operation. Also, the positioning of current transformer 15 in the circuit interrupting housing is a less critical design consideration than that of increasing the number of turns of blowout coil 18 thereby simplifying the fabrication of circuit interrupter 10. It should be noted that blowout coil 18 is continuously energized to provide more rapid extinguishment of an arc during fault current conditions.

FIGURE 2 shows an embodiment of my invention for use in the interruption of current in a D.-C. system and is particularly adapted for the protection of mercury arc rectifiers in A.-C. to D.-C. conversion systems. Circuit interrupters employed in A.-C to D-C conversion systems having mercury arc rectifiers are commonly known as anode breakers. One type of anode breaker presently in use is set forth in U.S. Patent Number 2,905,865, entitled "Flux Shifting Trip Magnet for Circuit Breaker," issued September 22, 1959, to Clausing et al., and assigned to the same assignee as the instant invention. Anode breakers of the type described in the aforementioned U.S. patent are employed to rapidly interrupt reverse D.-C. current flow caused by an arc back in the mercury arc rectifier associated with the interrupting breaker causing the affected mercury tank to behave like a short-circuit. The current flowing through the anode breaker has a waveform 20 as shown in FIGURE 2.

The circuit breaker 10 of FIGURE 2 has its upper 11 and lower 12 terminals connected to the primary disconnects (not shown) of the D.-C. circuit being protected. Movable bridge 14*a* is pivotally connected to lower terminal 12. Contact 14 is secured to bridge 14*a* and is positioned to cooperate with stationary contact 13 which is electrically connected to upper terminal 11. Blowout coil 18 is also connected in series with upper terminal 11 such that blowout coil 13 is continually energized even with cooperating contacts 13 and 14 in the engaged position. The provision of continuously energized magnetic blowout coils aids the circuit breaker in performing a rapid extinguishment of the arc.

Current transformer 15 has its primary winding 16 connected between blowout coil 18 and upper terminal 11. Output winding 17 of current transformer 15 is connected in parallel with blowout coil 18. Blowout coil 18 thereby serves as the load means for the transformed current developed in output winding 17.

The operation of circuit breaker 10 shown in FIGURE 2 is as follows: In response to a fault current condition movable arm 14*a* is rotated (by means not shown) to cause cooperating contacts 13 and 14 to disengage as shown in FIGURE 2. Ignoring for a moment the current flow due to the presence of current transformer 15, the current I_1 in the circuit flows from upper terminal 11 through blowout coil 18, contact 13, arc A, contact 14, movable arm 14*a* and lower terminal 12. The current I_1 is equal in magnitude to the current flow through the blowout coil of prior art anode breakers such as those described in U.S. Patent 2,891,123, enttiled "High Speed Circuit Breaker," issued June 16, 1959, to C. I. Clausing, and assigned to the same assignee as the instant invention.

The main current, I_1, flowing through the D.-C. circuit, passes through the primary winding 16 of current transformer 15 causing a current I_2 to be generated in the output winding 17. The polarity of the output winding 17 is such that the induced current I_2 flowing through winding 17 flows in the same direction as the main current I_1 so that the current flowing through blowout coil 18 is the sum of I_1 and I_2. If current transformer 15 is wound so that there is a 1 to 1 ratio between the input 16 and the output 17 windings, the current flow in the output winding is equal to the current flow in the input winding, or expressing this mathematically, $I_1=I_2$. The current flow through blowout coil 18 is therefore equal to $2I_1$. This results in an ampere turns quantity (NI) which is twice as large as the ampere turns quantity which would flow through blowout coil 18 without the use of a current transformer.

In order to reduce the current flow through blowout coil 18 during normal operation of circuit breaker 10 the transformer core 21 of current transformer 15 is formed of a ferro-magnetic material having a hysteresis loop such as that shown in FIGURE 3.

During normal current flow, the rectified current wave form 20 is shown in FIGURE 2. This wave form is also shown by dotted line 20 of FIGURE 3. During normal current flow, the magnitude of flux in transformer core 21 varies between points 23 and 24 as shown in FIGURE 3. Transformer core 21 therefore presents a very high reluctance to the current I_1 causing a negligible transformed current to appear in output winding 17. In addition the ripple voltage is very small causing the transformed current at the output winding to be negligible as described above. Upon the occurrence of a very large reverse current flow such as shown by solid line 22 in FIGURE 3, the direction of flux in transformer core 21 is reversed. This occurs because of the rapid changes in magnitude and direction of the fault current. At the instant the reverse current 22 achieves a magnitude sufficient to drive the saturable state of transformer core 21 to point 25 on the hysteresis loop, transformer core 21 presents a very low reluctance to the circuit I_1 flowing through the primary winding 16. This arrangement provides increased current flow through blowout coil 18 only upon the occurrence of a fault current condition thereby cutting down on the heating losses of coil 18 during routine operation.

FIGURE 4 shows my novel current multiplier utilized in an A.-C. circuit breaker 10. In this embodiment, blowout coil 18 is continuously energized by current transformer 15. Upon the occurrence of an arcing condition due to the separation of cooperating contacts 13 and 14 the arc B formed between the cooperating contacts is transferred from cooperating contact 13 across jump gap 26 to arc runner 27 as shown in FIGURE 4*a*. At this instant, the current through circuit breaker 10 flows from lower terminal 12, contact 14, arc B, arc runner 27, blowout coil 18, primary winding 16 of current transformer 15 and upper terminal 11. The fault current flowing at this instant passes through primary winding 16 generating a current in output winding 17. The polarity of output winding 17 is so arranged that the current generated by current transformer 15 adds to the current flowing through blowout coil 18 due to the tansfer of arc B resulting in an increase of current through blowout coil 18 which is double the current that is available in blowout coils of the prior art. Since the blowout coil 18 of FIGURE 4 would be continuously energized by current transformer 15 even during periods of normal operation, the turns ratio of current transformer 15 is selected to keep blowout structure losses low while still contributing to the current flow through blowout coil 18 during a tripping operation in response to a fault current condition.

FIGURE 5 shows an actual physical embodiment of a circuit breaker 10 which is electrically connected in the manner shown by the schematic diagram of FIGURE 2. Circuit breaker 10 is comprised of upper 11 and lower 12 terminals. Disconnect means 11*a* which consists of a plurality of contact fingers 11*b* and springs 11*c* are mounted to the protruding portions of upper terminal 11. Contact fingers 11*b* are mounted on opposite sides of each protruding portion of upper terminal 11 and are drawn towards one another by springs 11*c* to provide rigid contact engagement with the primary disconnect (not shown) of the circuit being protected. The design and operation of lower terminal 12 is the same as that of upper terminal 11.

The current flow through circuit breaker 10 during normal operation, shown by phantom line 30, follows the path from disconnects 11*b*, upper terminal 11, blowout coil 18, conductive head 31, stationary contact 13, arcing contact 14, movable bridge 14*a*, L-shaped arm 32, conductive member 33, lower terminal 12 and disconnects 12*b*.

Transformer core 21 consisting of a plurality of laminations 36 is supported at its upper end by a clamp 37 and at its lower end by O-shaped conductor member 38. Insulating means 39 surrounding laminations 36 serves

to electrically insulate transformer core 21 from the surrounding conductive members. The primary winding for the transformer core consists of the upper terminal 11 which is threaded through transformer core 21 thereby forming an input winding of one turn. The output winding consists of O-shaped member 38 which surrounds the lower portion of transformer core 21 thereby forming an output winding having one turn. Blowout coil 18 is connected in series relationship with the output winding formed by O-shaped member 38. The current path between the output winding and blowout coil 18 is shown by phantom line 40. The polarity of the output winding is arranged so that the current supplied to blowout coil 18 by the output winding adds to the current supplied to blowout coil 18 from the D.-C. circuit being protected such that the primary current shown by phantom line 30 and the induced current shown by phantom line 40 add together to create a current in blowout coil 18 which is approximately twice the magnitude of the primary current supplied by the D.-C. current source alone, thereby resulting in a magnetic force generated by blowout coil 18 which is twice as great as blowoff forces generated by prior art circuit interrupters.

Although I have here described preferred embodiments of my novel invention, many variations and modifications will now be obvious to those skilled in the art and I prefer therefore to be limited not by the specific disclosures herein but only by the appended claims.

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows:

1. In combination, a pair of cooperating contacts operable between an engaged and a disengaged position, blowout coil means for said cooperating contacts extinguishing an electric arc formed between said cooperating contacts upon separation thereof, current multiplying means connected between one of said cooperating contacts and said blowout coil means for increasing the current flow through said blowout means to aid said blowout coil means in the extinguishment of an arc formed during the separation of said contacts, said blowout coil means being electrically isolated from said cooperating contacts.

2. A circuit interrupter for protecting a power transmission system comprising a pair of cooperating contacts operable between an engaged and a disengaged position, blowout means for extinguishing an arc formed between said cooperating contacts upon separation thereof, current amplifying means having an input means connected in series with said cooperating contacts for receiving the current flowing through said cooperating contacts and an output means connected in series with said blowout means, said current amplifying means being adapted to generate an amplified current at said output means to aid said blowout means in the extinguishment of an arc formed during the separation of said contacts, said blowout means comprising a blowout coil having at least one turn.

3. A circuit interrupter for protecting a power transmission system comprising a pair of cooperating contacts operable between an engaged and a disengaged position, blowout means for extinguishing an arc formed between said cooperating contacts upon separation thereof, current amplifying means having an input means connected in series with said cooperating contacts for receiving the current flowing through said cooperating contacts and an output means connected in series with said blowout means, said current amplifying means being adapted to generate an amplified current at said output means to aid said blowout means in the extinguishment of an arc formed during the separation of said contacts, said blowout means comprising a blowout coil having at least one turn, and said current amplifying means comprising a current transformer.

4. A circuit interrupter for protecting an A.C. power system comprising a pair of cooperating contacts operable

between an engaged and a disengaged position, blowout coil means for extinguishing an arc formed between said cooperating contacts upon separation thereof, current multiplying means for aiding said blowout coil means in the extinguishment of said arc, said current amplifying means comprising a current transformer having an input winding connected in series with said cooperating contacts and an output winding connected in series with said blowout coil means.

5. A circuit interrupter for protecting an A.C. power system comprising a pair of cooperating contacts operable between an engaged and a disengaged position, blowout means for extinguishing an arc formed between said cooperating contacts upon separation thereof, current multiplying means for aiding said blowout means in the extinguishment of said arc, said current amplifying means comprising a current transformer having an input winding connected in series with said cooperating contacts and an output winding connected in series with said blowout means, said output winding having fewer turns than said input winding, said blowout means comprising a blowout coil having at least one turn.

6. A circuit interrupter for protecting an A.C. power system comprising a pair of cooperating contacts operable between an engaged and a disengaged position, blowout means for extinguishing an arc formed between said cooperating contacts upon separation thereof, current multiplying means for aiding said blowout means in the extinguishment of said arc, said current amplifying means comprising a current transformer having an input winding connected in series with said cooperating contacts and an output winding connected in series with said blowout means, said output winding having fewer turns than said input winding, said blowout means comprising a blowout coil having at least one turn, said blowout coil being adapted to be continuously energized.

7. A circuit interrupter for protecting an A.C. power system comprising a pair of cooperating contacts operable between an engaged and a disengaged position, a pair of arc runners operatively positioned to extinguish an arc formed between said cooperating contacts upon separation thereof, blowout means for urging said arc upward along said arc runners, current amplifying means for receiving the current flowing through said contacts, said amplifying means comprising transformer means having an input winding connected in series with said cooperating contacts and an output winding connected in series with said blowout means, conductive means connected between one terminal of said output winding and one of said arc runners to place said blowout means in series with said cooperating contacts when said arc transfers to said one arc runner, said current amplifying means causing a first current component to flow through said blowout means and said conductive means causing a second current component to flow through said blowout means, said current amplifying means being connected to cause said first current component to flow in the direction as said second current component.

8. A circuit interrupter for protecting an A.C. power system comprising a pair of cooperating contacts operable between an engaged and a disengaged position, a pair of arc runners operatively positioned to extinguish an arc formed between said cooperating contacts upon separation thereof, blowout means for urging said arc upward along said arc runners, current amplifying means for receiving the current flowing through said contacts, said amplifying means comprising transformer means having an input winding connected in series with said cooperating contacts and an output winding connected in series with said blowout means, conductive means connected between one terminal of said output winding and one of said arc runners to place said blowout means in series with said cooperating contacts when said arc transfers to said one arc runner, said current amplifying means causing a first current component to flow through said blowout means and said conductive means causing a second current component to flow through said blowout means, said current amplifying means being connected to cause said first current component to flow in the direction as said second current component, said blowout means comprising a coil having at least one turn.

9. A circuit interrupter for protecting an A.C. power system comprising a pair of cooperating contacts operable between an engaged and a disengaged position, a pair of arc runners operatively positioned to extinguish an arc formed between said cooperating contacts upon separation thereof, blowout means for urging said arc upward along said arc runners, current amplifying means for receiving the current flowing through said contacts, said amplifying means comprising transformer means having an input winding connected in series with said cooperating contacts and an output winding connected in series with said blowout means, conductive means connected between one terminal of said output winding and one of said arc runners to place said blowout means in series with said cooperating contacts when said arc transfers to said one arc runner, said current amplifying means causing a first current component to flow through said blowout means and said conductive means causing a second current component to flow through said blowout means, said current amplifying means being connected to cause said first current component to flow in the direction as said second current component, said blowout means comprising a coil having at least one turn, said output winding having fewer turns than said input winding.

10. A circuit interrupter for protecting a D.-C. power system having a pair of cooperating contacts operable between an engaged and a disengaged position, blowout means for extinguishing an arc formed between said contacts upon separation thereof, current amplifying means for receiving the current flowing through said cooperating contacts, said amplifying means comprising a current transformer having an input winding connected in series with said cooperating contacts and an output winding connected in series with said blowout means, said blowout means comprising a blowout coil having at least one turn, conductive means for connecting one terminal of said blowout coil to one terminal of said input winding and the other terminal of said blowout coil to one of said cooperating contacts, said conductive means generating a second current component through said blowout coil, said current amplifying means being connected to generate said second current component having a current direction which is the same direction as said second current component.

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SAMUEL BERNSTEIN, *Primary Examiner.*