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[54] HYBRID CIRCUIT BREAKER HAVING MEANS FOR DETECTING THE LEADING EDGE OF THE ARC VOLTAGE AT THE CONTACTS THEREOF

5 Claims, 1 Drawing Fig.

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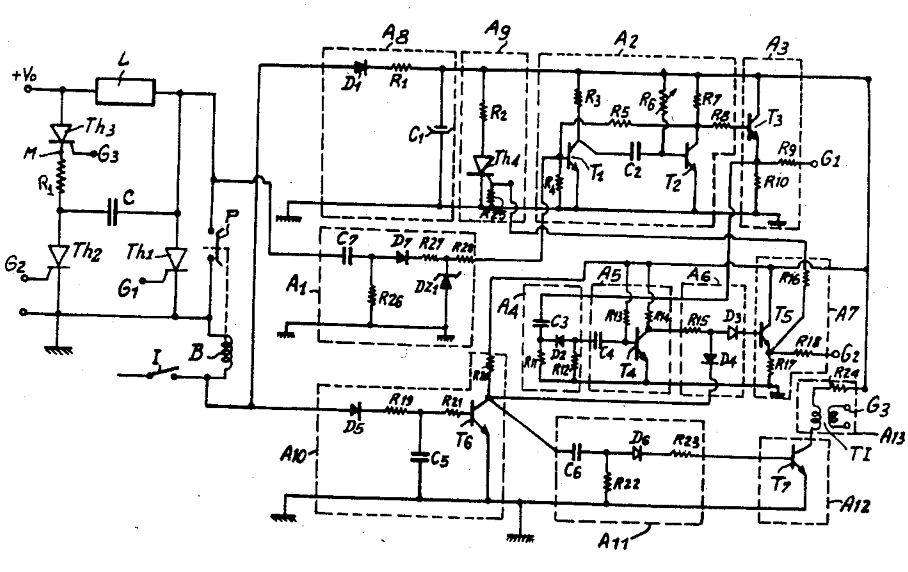
ABSTRACT: A hybrid circuit breaker comprising a pair of contacts actuated by an electromagnet, a thyristor for shunting the contacts, an extinction condenser for the shunt thyristor, an extinction thyristor adapted to control the discharge of the condenser, and a circuit for controlling the firing of the thyristors comprising a circuit for differentiating the leading edge of the arc voltage across the contacts and a monostable multivibrator responsive to the leading edge of said arc voltage for generating an impulse for firing the shunt thyristor.



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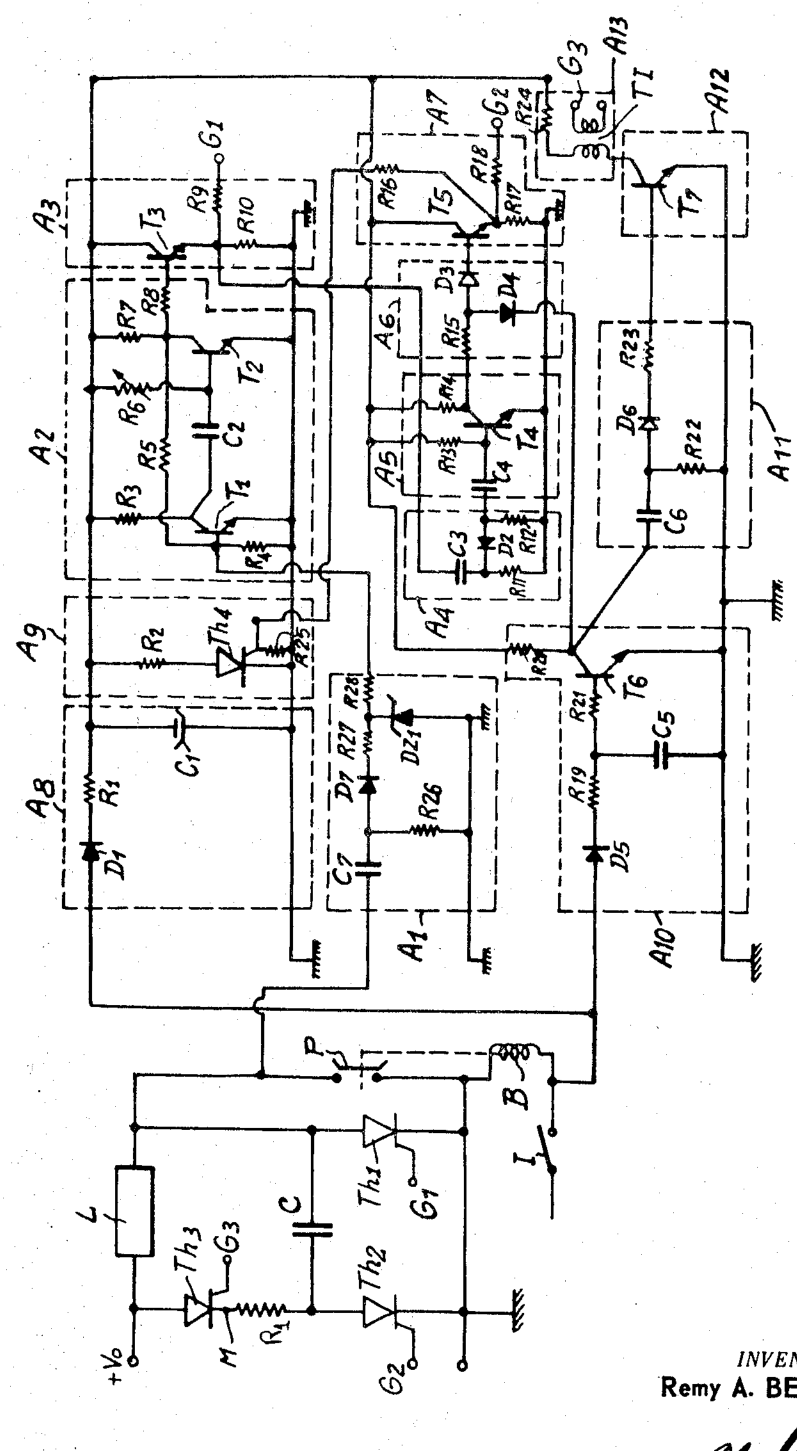

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HYBRID CIRCUIT BREAKER HAVING MEANS FOR DETECTING THE LEADING EDGE OF THE ARC VOLTAGE AT THE CONTACTS THEREOF

The present invention relates to circuit breakers called "-hybrid circuit breakers," in which a controlled rectifier, usually a thyristor, shunts the contacts of the circuit breaker when they are open usually by means of an electromagnet. This prevents the buildup of an arc across the contacts, but the latter, during the working cycle of the circuit breaker, generally carry alone the flow of current so that the thyristor is subjected to large thermal strains only for short intervals of time. For this purpose, it is known to provide means for ensuring the extinction of the shunt thyristor, these means comprising, in certain hybrid circuit breakers, a condenser and a thyristor which controls the sudden discharge of the condenser across the terminals of the shunt thyristor. A monitoring device responsive to the voltage, across the contacts ensures the ignition of the shunt thyristor and of the extinction thyristor.

In accordance with the invention, the monitoring device, whose supply is provided by the source of the excitation current of the electromagnet which operates the contacts, is an electronic circuit comprising a network for differentiating the leading edge of the arc voltage established at the contacts at the opening thereof, and means responsive to the pulse resulting from such differentiation for controlling the conduction of the shunt thyristor during a period of time which is short and well defines defined.

With the above arrangement, the shunt thyristor is subjected, at the opening of the contacts, only to an overload of very short duration and properly controlled, so that a thyristor having a relatively small power rating may be used and that consequently an important saving may be effected.

In accordance with a characteristic of the invention, the monitoring circuit is arranged so that the shunt thyristor is fired at each rebound of the contacts for a period of time corresponding to that of the rebound. This permits to completely eliminate the risk of damaging the contacts.

The various characteristics as well as the advantages of the invention will be clearly illustrated in the following description which relates to an embodiment which is particularly interesting.

The attached single figure of drawing represents the electrical diagram of a hybrid circuit breaker in accordance with the first embodiment.

The circuit comprises a thyristor TH_1 connected in parallel with contacts P operated by an electromagnet B. This combination controls the flow through a load L of a current fed by a source of DC voltage connected between terminals $+V_0$ and ground.

Electromagnet B is excited by a control current which may be fed or interrupted by known means illustrated in the drawing by means of an interrupter I. The circuit illustrated in the drawing is particularly adapted to the case where the control current is a fully rectified single phase current, but the invention is not limited to this case.

Likewise, the invention is not limited to the case where the source of voltage V_0 is a DC source. However, it is in such a case that the problem of extinguishing the arc which is initiated at the opening of the contacts is more difficult to solve and, that, consequently, the interest of the invention is the largest.

The circuit further comprises a thyristor TH_2, a resistor R_1, a thyristor Th_3 and a condenser C, connected as indicated in the drawing, and an electronic circuit comprising the blocks A_1 to A_{13}, which will now be disclosed. The invention is mainly concerned with the design of this electronic circuit. As a matter of fact, the use of a thyristor to shunt the contacts P (such as TH_1), of a thyristor (such as TH_2) to control the the extinction of the shunt thyristor, and of a condenser (such as C) whose discharge causes the above extinction is well known in the technique of hybrid circuit breakers. Moreover, thyristor Th_3 only performs, as it will be seen later, an auxiliary function.

It may be seen in the drawing that the output of block A_3 is connected to the control electrode G_1 of thyristor Th_1, while the output of block A_7 is connected to the control electrode G_2 of thyristor Th_2, and that the output of block A_{13} is connected to control electrode G_3 of thyristor Th_3.

Blocks A_1, A_2 and A_3 constitute a control chain for thyristor Th_1.

Block A_1 includes a differentiator circuit having a condenser C_7 and a resistor R_{26} and a circuit for selecting positive impulses comprising a diode D_7, resistors **27** and **28** and a Zener diode DZ_1.

Block A_2 is a monostable multivibrator comprising two transistors T_1 and T_2, resistors R_3 to R_8, and a condenser C_2.

Block A_3 is a current amplifier comprising a transistor T_3 connected as an emitter follower by means of resistors R_9 and R_{10}.

Blocks A_4 to A_7 comprise a control chain for thyristor Th_2 and for a thyristor Th_4. The latter, together with resistors R_2 and R_{25}, forms a block A_9 whose function will be explained later.

Block A_4 includes a differentiator circuit consisting of a condenser C_3, connected to a junction point between resistors R_9 and R_{10} of block A_3, of a resistor R_{11} and of a circuit for selecting negative impulses, comprising a diode D_2 and a resistor R_{12}.

Block A_5 is an inverter circuit comprising a transistor T_4, a condenser C_4 and resistor R_{13} and R_{14}.

Block A_6 is a gate comprising diodes D_3 and D_4 and a resistor R_{15}.

Block A_7 is a current amplifier consisting of a transistor T_5 and resistors R_{16} to R_{18}.

Block A_8 whose function will be explained later, comprises a diode D_1 and a resistor R_1 connected in series to the excitation terminal of electromagnet B, and a condenser C_1 in parallel.

Blocks A_{10} to A_{13} constitutes a control chain for thyristor Th_3.

Block A_{10} is an inverter circuit comprising a transistor T_6, diode D_5, and resistors R_{19} to R_{21}.

Block A_{11} includes a differentiator circuit consisting of a condenser C_6, of a resistor R_{22}, and of a circuit for selecting positive impulses, comprising a diode D_6 and a resistor R_3.

Block A_{12} is an amplifier comprising a transistor T_7, which block A_{13} comprises an impulse transformer T_1 and a resistor **24**. The secondary winding of transformer T_1 is connected, on the one hand to control electrode G_3, and on the other hand to point M which is common to resistor R_1 and thyristor Th_3.

The operation of the illustrated embodiment is as follows:

A few dozen milliseconds after electromagnet B has been energized, i.e. after, contacts P are closed. At the time of the energization of electromagnet B, thyristor Th_1 is not conducting so that, at the closure of the contacts, the current fed by voltage source V_o flows through load L and through the contacts P only. In the absence of any bouncing of the contacts, it will be seen later that the electronic circuit does not operate at the time of closure of the contacts. The device then works as a conventional circuit breaker, which is the result sought, because there is no formation of an arc and the operation of the shunt thyristor is not required.

At the time of closure of contacts P, the differentiator circuit including condenser C_7 and resistor R_{26} is subjected to a sudden variation of voltage, because the voltage across the contacts P drops from $+V_o$ to O volt. The negative impulse which is then created across resistor R_{26} is obviously blocked by diode D_7, so that the blocks A_2 and A_3 do not operate.

On the contrary, when the contacts P bounce the voltage across them varies suddenly from a null value to a value of the order to 12 volts, which corresponds to the beginning of the development of an arc.

The result of the above is a waveform which results in a positive impulse at the terminal of resistor R_{26}. This positive impulse flows through D_7 and is applied through resistor R_{27} and R_{28} to the base of transistor T_1. Zener diode D_{21} has an inverse voltage characteristic which is higher than the amplitude of the impulse, so that it does not break down. Transistor T_1 becomes conductive and a negative impulse appears between its collector and emitter electrodes. Before the formation of this negative impulse, transistor T_2, whose base is connected by means of resistor R_6 to the positive supply voltage of the electronic circuit (this supply voltage is provided by condenser C_1, charged through resistor R_1 by the excitation current of electromagnet B at the closure of interrupter I), was conductive and condenser C_2 was charged.

The negative impulse causes the discharge of C_2 through resistor R_6. During the discharge of condenser C_2, whose discharge time may be varied through adjustment of resistor R_6, transistor T_2 is blocked. The result is that during this well defined period of discharge, there appears on the collector of transistor T_2 a positive rectangular impulse. The impulse amplified by transistor T_3 provides, through resistor R_9, the current required for the firing of thyristor Th_1. The latter further has at its terminal the beginning of the development of the arc voltage and so becomes conductive during the whole period of the rebound.

At the end of the rebound, the contacts of the circuit breaker are closed, and the voltage across them and at the terminals of thyristor Th_1 becomes null so that thyristor Th_1 is extinguished.

In order words, during each of the consecutive rebounds which may happen, the contacts of the circuit breaker are shunted by thyristor Th_1 which replaces the contacts. This is a very important advantage of the invention, because this prevents the dissipation of energy in the form of heat during the rebound, and eventually, the premature destruction of the contacts.

When a signal for opening the contacts is provided, the electronic circuit continues to be fed by a positive voltage during a time sufficiently long to permit its operation, through condenser C_1 whose discharge time constant through the circuit is chosen at a value sufficiently long to this effect. The result is that thyristor Th_1 is fired under the control of the chain A_1, A_2, A_3. This chain works in the same way that when the contacts were open under the action of rebound, and so prevents the development of an arc at the terminals of the contacts. It will be seen later how thyristor Th_1 is extinguished at the end of a predetermined period.

The firing impulse of thyristor Th_1 is moreover applied to block A_4, and differentiated by circuit C_3 and R_{11}, which generates a positive impulse corresponding to the leading edge of the firing and a negative impulse corresponding to the trailing edge thereof. The negative only flows through diode D_2 and is applied, by means of condenser C_4, to the base of transistor T_4.

During the whole time a contact-closing signal is provided, that is, until the end of the rebounds, condenser C_1 has acquired and maintained a charge sufficient to feed the control electronic circuit. This renders transistor T_4 conductive, its base being connected to one terminal of condenser C_1 through resistor R_{13}, 13, and condenser C_4 is charged.

The negative impulse flowing through diode D_2 causes the discharge of condenser C_4 and so blocks transistor T_4 during a predetermined interval depending on the values of condenser C_4 and resistor R_{13}. The result is the appearance during such period, of a positive impulse, which is applied through resistor R_{15} to gate A_6.

As long as a contact-closing signal is provided, transistor T_6 is conductive and its collector electrode is subjected to a small voltage. Indeed, condenser C_5 is rapidly charged through resistor R_{11} as soon as interrupter I is closed. The base current of transistor T_6 is then established before the appearance of the voltage at the terminals of capacitor C_1, consequently before the collector voltage of transistor T_6 exceeds the saturation value, namely 0.5 volt for example. This voltage of 0.5 volt is maintained as long as capacitor C_5 stays charged, that is as long as the contacts of the circuit breaker are not opened. The positive impulse applied to resistor R_{15} in case of rebound is then grounded through diode D_4 and transistor T_6. **153** Blocks A_6 and A_7 do not operate, which is desirable because the extinction of Th_1 must be produced at the end of each rebound and not controlled by Th_2.

On the contrary, when a contact opening signal is provided transistor T_6 is blocked and gate A_6 is opened. Capacitor C_5 is then discharged through the control circuit in a few milliseconds, while capacitor C_1, which is discharged in a much longer time through resistor R_2, continues to feed the electronic circuit until the firing of thyristor Th_2. Consequently, as soon as C_5 is discharged, transistor T_6 is blocked and its collector voltage takes the value of the voltage at the terminals of C_1, that is for example 30 volts which is sufficient to block diode D_4.

The positive impulse applied to resistor R_{15} is then amplified by transistor T_5. The result is that the control electrode of thyristor Th_2 is excited through resistor R_{18} and that the control electrode of thyristor Th_4 is excited through resistor R_{16}.

The firing of thyristor Th_2 so initiated causes, in a known manner, the discharge of the extinction condenser C and the appearance of an inverse voltage at the terminals of thyristor Th_1 which causes its extinction. Thyristor Th_2 is extinguished as soon as the inverse discharge current of condenser C reaches the value of the sustaining current through thyristor Th_2, which is produced for example in less that 500 microseconds. It is important to note that when the contacts open, thyristor Th_1 remains conductive for a period of time which is rigorously determined by the duration of the impulses generated by monostable multivibrator A_2, for example for 1 to 3 milliseconds depending on what is required to prevent the arc, as a function of the speed of contact opening and of the value of the operating voltage. As a matter of fact, it is only at the end of these impulses that the firing impulse is initiated. The duration of the firing impulse which is determined by A_5, is established at a value such as to cause the firing of the thyristor.

The firing of thyristor Th_4 caused by the positive impulse applied through resistor R_{15} and resistor R_{16} has the effect of discharging condenser C_1 through resistor R_2. The electronic circuit ceases to be energized and the sequence of operation of the circuit breaker is terminated. Because of thyristor Th_4, the electronic circuit is no more energized after the extinction of thyristor Th_1 so that the overvoltage which occurs, across the contacts at the time of their effective opening, does not have any effect, which constitutes a useful safeguard.

If we consider now the control chain of thyristor Th_3, it is seen that, at the time of the closure of the contacts, block A_{12} does not operate, which is the result sought as mentioned previously. As a matter of fact, at the time of closing the interrupter I, it has been mentioned above that the voltage between the collector and emitter electrodes of transistor T_6 does not exceed the saturation value thereof, that is 0.5 volt for example. The variation of this voltage from 0 to 0.5 volt is insufficient to cause conduction of transistor T_7.

On the contrary, upon the contact-opening signal being transmitted, it has been seen that the collector voltage of transistor T_6 goes from 0.5 to 30 volts. The leading edge of the positive impulse corresponding to this variation is differentiated by circuit C_6 and resistor R_{22} thereby initiating a positive impulse at the terminals of resistor R_{22}. This impulse flows through resistor R_{23} to the base of transistor T_7 and has the effect of rendering transistor T_7 conductive, thereby causing the appearance of an impulse at the terminals of the secondary of transformer T_1 and, consequently, the firing of thyristor Th_3.

This thyristor, which only performs a secondary function, permits to obtain a more rapid charge on condenser C through resistor R (for example, a few milliseconds). The thyristor is extinguished as soon as the inverse charging current reaches the value of its sustaining current. The device has then come back to the initial rest position in which the thyristors are extinguished and condenser C charged.

If we now resume the operation which has been disclosed, we see that:

(1) When a contact-closing signal is applied, the electronic circuit is fed as soon as the circuit of the electromagnet B is energized, but only operates in case of rebound of the contacts, and only to render conductive the shunt thyristor exactly during the rebound period. The firing impulse of the shunt thyristor, generated at each rebound, has no action on the firing of the other thyristors because of the state of conduction of transistor T_6 which under these conditions blocks gate A_6 which is provided to supply an enabling pulse to the extinction thyristor Th_2.

(2) When a contact-opening signal is applied, the electronic circuit, operated by the leading edge of the voltage across the contacts (and not by the arc voltage) and by the breaking of the circuit of the electromagnet, causes successively the firing of the shunt thyristor and, at the end of a time interval determined by a monostable multivibrator, the extinction of the thyristor Th_1 by the firing of extinction thyristor Th_2 and, at the same time, the firing of thyristor Th_4 which cancels the supply of the electronic circuit (by discharging condenser C_1) and finally the firing of thyristor Th_3 which controls the charge of extinction condenser C.

(3) The capacitor C_1 charged at the time of energizing the electromagnet, feeds the electronic circuit at the opening of the contacts and so permits the electronic circuits to perform the operations mentioned under (2) above.

(4) Condenser C_1 being discharged at the time of the extinction of the shunt thyristor, the electronic circuit is then nonsensitive to the voltage impulse generated across the contacts at the time of the effective opening thereof.

(5) During the working cycle of the circuit breaker, the electronic circuit, being short-circuited by the closed contacts of the circuit breaker, is inoperative.

(6) A gate controlling the extinction being open only at the time of the opening of the contacts, the extinction condenser C cannot start to discharge too early.

It must be well understood that other modifications may be effected through the above-disclosed circuit, in particular, to adapt such circuit to other types of current, without departing from the scope of the invention.

I claim:

1. A hybrid circuit breaker comprising: one pair of contacts; an electromagnet having an excitation coil serially connected with said contacts and an armature adapted for actuating said contacts; a controlled rectifier connected to across said contacts and having a control electrode; differentiator circuit means connected across said contacts and responsive to the leading edge of the voltage appearing across said contacts upon opening of said contacts; a monostable multivibrator connecting the said differentiator circuit means to the said control electrode, whereby the said controlled rectifier is fired upon each opening of said contacts; and further circuit means, connected across the said controlled rectifier for extinguishing the said controlled rectifier.

2. A hybrid circuit breaker comprising: one pair of contacts; an electromagnet having an excitation coil serially connected with said contacts and an armature adapted for actuating said contacts; excitation means for applying contact-opening signals and contact-closing signals to said coil; a first thyristor connected across said contacts and having a control electrode; first differentiator circuit means connected across said contacts and responsive to the leading edge of the voltage appearing across said contacts upon opening of said contacts; a monostable multivibrator connecting the first differentiator circuit means to the control electrode of the first thyristor, said monostable multivibrator generating a pulse of predetermined amplitude and duration upon each opening of the said contacts whereby the said thyristor is fired upon each opening of said contacts; a first condenser and a second thyristor serially connected across the first thyristor, said second thyristor having a control electrode; supply means, connected to the first condenser for charging the said condenser; second differentiator circuit means; means connecting the second differentiator circuit means to the monostable multivibrator, the second differentiator circuit means being responsive to the trailing edge of the said pulse; gating means connecting the second differentiator circuit means to the control electrode of the second thyristor and means for opening said gating means when a contact-opening signal is applied to said coil, whereby the second thyristor is fired, the first condenser is discharged and the first thyristor is extinguished a predetermined delay after the said contact-opening signal is applied to the coil.

3. A hybrid circuit breaker as claimed in claim 2, further comprising a second condenser; means connecting the second condenser to the excitation means, for charging the said second condenser when a contact-closing signal is applied to the coil; means connecting the monostable multivibrator and the gating means to the second condenser; and a third thyristor having a control electrode connected to the said gating means, said third thyristor being connected across the second condenser and providing a discharge path for the second condenser, whereby the third thyristor is fired and the second condenser is discharged after the said predetermined delay.

4. A hybrid circuit breaker as claimed in claim 3, wherein the means for opening said gating means comprise a transistor having a base, an emitter and a collector, the second condenser being connected across the said emitter and collector; and resistance-capacitance circuit means connecting the said base to the excitation means, said resistance-capacitance circuit means having a time constant which is substantially lower than the time constant of the charge of the second condenser.

5. A hybrid circuit breaker as claimed in claim 4, further comprising third differentiator circuit means connected across the said emitter and collector; a fourth thyristor connecting the said supply means to the first condenser, said fourth thyristor having a control electrode; and further gating means connecting the last-mentioned control electrode to the third differentiator circuit.