An explosive circuit-breaker comprising an insulation housing with a hollow conductor passing inside and insulated from said housing, an explosive charge disposed inside said conductor and a detonator, said circuit-breaker differing from the existing ones in that the destructible section of the conductor is made in the form of a corrugated tube and the housing is made essentially hermetic with an evacuated inner space.
EXPLOSIVE CIRCUIT-BREAKER

The present invention relates to circuit-opening and circuit-closing devices and more particularly to electric circuit-breakers which are actuated by the energy released by the detonation of an explosive.

The usual type of electric circuit-breakers is actuated by a force applied by mechanical, electromechanical, etc., means which reliably change the status of the electric circuit containing the circuit-breaker.

However, on some applications where a high reliability of circuit operation is required or accidental actuation of the circuit-breaker by vibration, short-circuit, etc. is undesirable the usual circuit-breakers do not provide the required degree of reliability. This is especially important on such applications as inductive or capacitive storage devices, circuits for emergency short-circuit protection of electric installations.

There exists an explosive circuit-breaker (U.S.A. Pat. No. 3,277,255, class 200–82) which comprises a tubular housing with two terminal contacts bridged by a frangible conductor and connected to a control circuit, a pyrotechnical charge and an actuating member held by a frangible disc. The force generated by the explosion causes the actuating member to move and break the frangible conductor thus opening the electric circuit. The operating speed of this circuit-breaker is rather low as the speed of the actuating member is equal to several tens of meters per second. There exists a circuit-breaker (U.S. Pat. No. 3,118,986, class 200–82) comprising a cylindrical housing made from a dielectric, and conductive terminals at its ends which form a chamber with a cylindrical contact disposed therein. The pressure produced by the explosion displaces the moving contacts which open the circuit.

The circuit-breaker disclosed in the Federal Republic of Germany Pat. No. 1,097,016, class 21C-69, comprises a hollow tubular conductor housing an explosive charge. The conductor may be provided with slits, notches or solder joints to make it more easily breakable by the explosion.

However, in this type of circuit-breaker the velocities initially imparted to the ends of the conductor when the latter breaks are parallel, i.e. their relative velocity is zero.

Besides, an intensive shock wave is formed in the surrounding air. This wave has a high temperature, is ionised and conductive and causes the gap formed by the explosion to be short-circuited.

The operating speed of this circuit-breaker is limited to tens of microseconds.

In explosive circuit-breakers described above the explosive charge is disposed within the closed space of the circuit-breaker. Owing to the fact that the explosives possess a limited chemical and physical stability and when disposed inside the circuit-breaker are subject to heating due to the Joule effect, the characteristics of the explosive change and they are liable to ignite spontaneously due to heating. This affects the reliability of the circuit-breaker in heavy-current and high-voltage circuits.

An object of the invention is to obviate the above disadvantages.

Another object of the invention is to provide a circuit-breaker suitable for use in high-voltage power circuits and capable of interrupting currents exceeding 1000 A at voltages above 5 kV.

Still another object of the invention is to increase the operating speed of the circuit-breaker to 10 microseconds.

A further object of the invention is to improve the reliability of explosive circuit-breakers.

With this object in view, in an explosive circuit-breaker comprising a strong housing, a hollow conductor which passes inside a strong housing, a hollow conductor which passes inside and is insulated from said housing, an explosive charge disposed inside the hollow conductor for breaking the conductor and a detonator, according to the invention, the destructible section of the conductor is made in the form of a corrugated tube and the insulating housing is essentially hermetic with an evacuated inner space, the residual pressure P (mm Hg) and the dimensions of the housing and of the conductor complying with the following relationships:

\[ P \leq 0.05/(R_i - R_o) \] and \[ R_i \geq 3R_o \],

where:

- \( R_i \) — inner radius of the insulation housing, centimeters;
- \( R_o \) — outer radius of the destructible section of the conductor, centimeters.

Other objects and purpose of our invention will be better understood from the following detailed description of one embodiment of an explosive circuit-breaker, according to the invention, when read in connection with the accompanying drawings, in which:

FIG. 1 is a general view of an explosive circuit-breaker, according to the invention;

FIG. 2 is a longitudinal sectional view of the explosive circuit-breaker (taken on line II—II of FIG. 1) prior to explosion;

FIG. 3 is a sectional view taken on line III—III of FIG. 2;

FIG. 4 is an enlarged view of assembly A, according to FIG. 2, showing the velocity directions of conductor sections when the conductor breaks;

FIG. 5 is a longitudinal sectional view of the circuit-breaker after explosion.

Referring to FIG. 1 an explosive circuit-breaker includes a conductor 1 connected to an electric circuit designated by lines 2 and 3.

The conductor 1 passes through a housing 4 of the circuit-breaker which is made essentially hermetic.

Cocks 5 and 6 are used to evacuate the housing 4 and discharge the explosion products after actuation of the circuit-breaker.

The circuit-breaker is actuated by means of a detonating signal source 7.

The construction of the circuit-breaker is shown in detail in FIGS. 2, 3.

The circuit-breaker housing 4 has a cylindrical shape and is made of a strong material, such as steel. On the inside of the housing is lined with a layer 8 of a viscous material, such as rubber, polyethylene, etc. This layer is used to absorb the fragments of a broken conductor.

The end faces of the housing 4 are closed by covers 9 made of a strong insulation material, such as organic glass or fluoroplastic, and secured by bolts 10. The joint between the covers and the housing is hermetically sealed by rubber seals 11.

The covers have central holes through which the conductor 1 passes. The conductor is hermetically sealed by clamp nuts 12 and rubber seals 13.
The conductor 1 may be made of magnesium, magnesium alloys or aluminium and has a tubular shape with a corrugated destructible section 14 housing an explosive charge 15. The circular corrugations of the destructible section 14 preferably have a triangular section which increases the operating speed of the circuit-breaker.

On the sides the explosive charge is held by heavy plugs 16 made of a thermally conductive material, such as copper. The plugs 16 serve to divert the Joule heat generated in the corrugated section of the conductor and to ensure radial scattering of the explosion products and more effective arc extinction.

The explosive is activated by an electric detonator 17 and a detonating cord 18.

The circuit-breaker operates as follows. When a circuitopening signal is applied, the detonator 17 detonates the explosive 15. Under the action of the explosion the elements of the corrugated section 14 of the conductor 1 are accelerated in a direction practically normal to their surface.

FIG. 4 shows the direction of the velocity vectors V of the elements of the corrugated section 14 and a relative velocity V of the destructible section 14.

Therefore the corrugated section of the conductor begins to break as soon as the detonation wave comes out to the surface of the explosive charge.

Thus the circuit is opened.

FIG. 5 shows the explosive circuit-breaker after actuation.

The advantages of the circuit-breaker described herein as compared to the existing circuit-breakers stem from the following.

The velocity vector V of the elements of a shell of any shape housing an explosive is practically directed along a line normal to the charge surface. Thus, for example, even when the detonation front is normal to the shell the velocity vector V forms an angle δ with the normal to the charge surface, which is equal to

\[ \delta = \arcsin \left( \frac{V}{V2D} \right) \]

where

- D is detonation rate.
- V = 2000 m/sec. and D = 8000 m/cm, \( \beta = 7^\circ \).

Therefore in the existing circuit-breakers wherein the destructible section of the conductor is made in the form of a cylinder the velocity vectors of two ends of the gap are initially parallel and their relative velocity is zero.

In the circuit breaker described herein the apex angle of the corrugation is equal to \( \beta \) and from the very moment the detonation comes out to the shell the rate \( \Delta V \) at which the gap expands is equal to

\[ \Delta V = 2V \sin \left( \beta/2 \right) \]

If the circuit-breaker has \( n \) corrugation, the rate at which the gap expands correspondingly increases \( n \) times:

\[ \Delta V = 2n \sin \left( \beta/2 \right) \]

Thus, in the circuit-breaker described herein the gap widens at a much greater rate than in the existing devices, thereby increasing the operating speed of the circuit-breaker.

When explosive charges housed in a shell arc detonated, an intensive shock wave is formed in the surrounding air. However, this shock wave appears not directly at the charge surface but at some distance equal to 10–40 mean free paths of air molecules.

In the existing devices actuation of the circuit-breaker results in intense heating of the air by the shock wave, causing dissociation and ionization of the air. As a result, though the metal conductor has been broken, it is still surrounded by a conductive air layer.

The housing of the circuit-breaker described herein is evacuated so as to avoid the formation of shock waves. Besides, in vacuum the explosion products expand much faster and more effectively extinguish the arc produced by break-induced currents. This increases the operating speed of the circuit-breaker still more.

In view of the fact that the mean three paths of air molecules depend on pressure, shock waves will fail to be formed in the circuit-breaker housing when the residual pressure \( P \) (mm Hg) complies with the following relationship:

\[ P \leq 0.05/(R_1 - R_2) \]

where \( R_1 \) and \( R_2 \)—dimensions of the housing and of the conductor, respectively, in centimeters.

Lastly, since the pressure of the expanding explosion products decreases in proportion to the sixth degree of the radius of the area occupied by them the dimensions of the housing to be used for localizing the explosion must only comply with the following relationship:

\[ R_1 \geq 3R_2 \]

What is claimed is:

1. An explosive circuit-breaker comprising, in combination: a housing made from a strong material, a hollow conductor passing inside and insulated from said housing, an explosive charge disposed inside said conductor within its section located inside said housing to break said conductor and a detonator to activate the explosive charge, wherein the destructible section of the conductor is made in the form of a corrugated tube and the insulation housing is essentially hermetic with an evacuated inner space, the residual pressure \( P \) (mm Hg) and the dimensions of the housing and of the conductor complying with the following relationships:

\[ P \leq 0.05/(R_1 - R_2) \] and \( R_1 \geq 3R_2 \]

where

- \( R_1 \) — inner radius of the insulation housing, centimeters;
- \( R_2 \) — outer radius of the destructible section of the conductor, centimeters.

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