# NEW GENERATION OF MEDIUM VOLTAGE CIRCUIT BREAKERS

**A. Chaly, A. Gusev**

Tavrida Electric Ltd. 22 Vakulenchuck st, 335053 Sevastopol, Ukraine.

## ABSTRACT

Today vacuum circuit breakers (VCB) have become dominant apparatuses for a wide range of electrical networks with rated voltages of 6-36 kV. It is a matter of fact, that a portion of this kind of switching devices for these voltage classes within total amount of produced circuit breakers in Europe and USA is about 70%, in Japan is 100% and in 1997 in Russia this fraction outreached 50%.

## INTRODUCTION

The main advantages (in comparison with oil and gas circuit breakers) that caused quite a fast progress in development of vacuum switching devices are:

- Higher reliability;
- Less maintenance costs;
- Explosion- and flame- safety;
- Ecological purity.

It should be noted, that VCB in Russia are still more expensive than oil ones yet, but this difference is coming less from year to year.

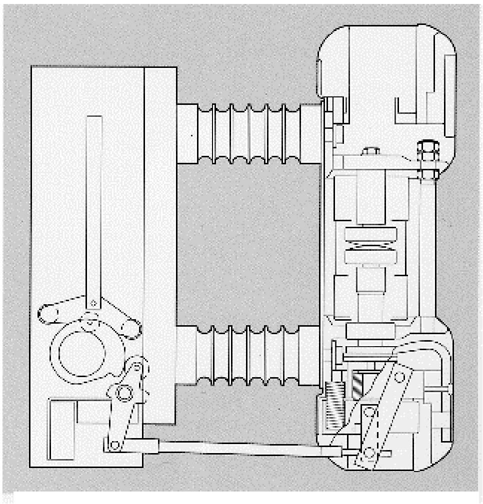
Today vacuum technology should be considered as “grown up” enough, there are commercially produced switching devices which are able to interrupt short-circuit current up to 100 kA, so there is no reason to improve VCB interrupting capacity any more. The requirement of the day now is not the improvement of top parameters but the development of less expensive, extremely reliable and maintenance-free designs.

The reduction of VCB cost mainly depends on the development of design and production technology of vacuum interrupters (VI), the heart of circuit breaker and the most expensive (30-40% of total cost) part of it. As for the circuit breaker drives of traditional types (motor-spring type chiefly), the opportunity of improvement of this part to reduce production costs is practically exhausted. The bright example of this is the 3AH series VCB made by Siemens, the mechanical life was decreased in order to simplify the design of breaker to decrease its first cost.

The analysis of experience in use of VCB shows us that modern vacuum bottles are extremely reliable, the declared mean time between failures of VI manufactured by best producers is now 2000 years. So, the only way to improve circuit breaker reliability is the development of circuit breaker drive.

In mid 1990’s the range of producers offered new concepts of maintenance—free circuit breaker drives. But it is obvious, that keeping to the traditional approach to VCB design development aimed breaker cost reduction will surely lead to the reliability problems.

No doubt that the progress in the field of circuit breaker designing is impossible without new technological and structural solutions. One of these solutions is a vacuum circuit breaker equipped with “magnetic latch”- type solenoid drive that was developed and patented by Tavrida Electric Ltd. in 1994.



Traditional design of vacuum circuit breaker

**Figure 1**

## VCB DEVELOPED BY TAVRIDA ELECTRIC LTD.

Design of VCB developed and produced by Tavrida Electric Ltd essentially differs from other designs that are being produced presently. The basic principle difference of this VCB structure is complete alignment of solenoid armature and vacuum interrupter. This configuration allowed designers to simplify mechanical structure of circuit breaker, do not use hinged joins or any sort of loaded shafts carried by bearings that, in its turn, made possible to create maintenance-free for 25 years circuit breaker with the mechanical life of at least 50 000 close-open operations.

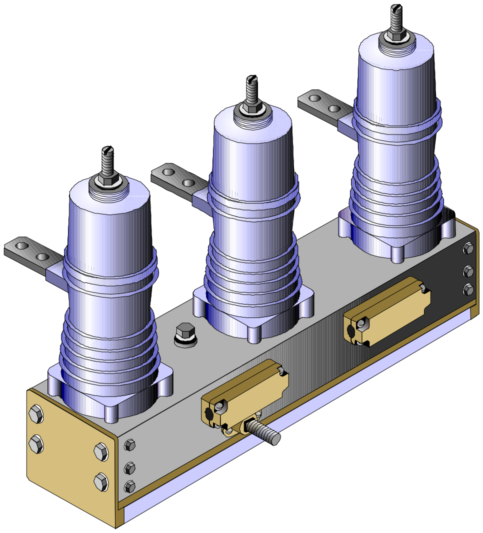
The appearance of this VCB is shown at Fig.2, its arrangement and operating principle are shown at Fig.3. Each phase (pole) of circuit breaker consists of:

- supporting insulator made of modern polycarbonate plastic material;
- parts of main circuit (VI and VCB terminals) that are mounted inside of supporting insulator;
- solenoid drive with magnetic latch which is situated inside the VCB base frame and connected to VI movable contact by means of plastic pulling insulator.

This picture (Fig.3) shows only one of three VCB poles. All three poles are connected together by synchronizing shaft to avoid non-synchronous operation of vacuum interrupters. This shaft is also used to operate VCB auxiliary contacts. The reed switches controlled by and attached to shaft permanent magnet are used as an auxiliary contacts.

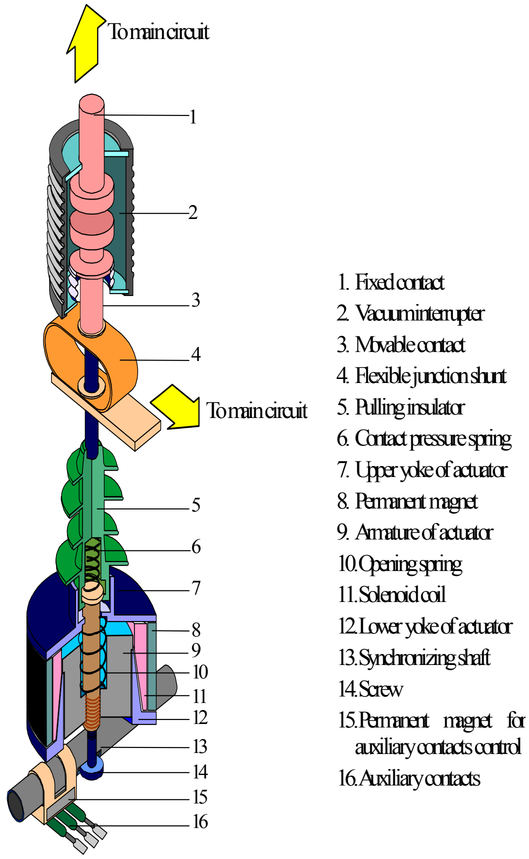
The shaft is intended to drive all required mechanical interlocks of switchgear where VCB is to be installed as well.

The typical synchronized oscillograms of main parameters of circuit breaker operation during the close-open cycle are presented at Fig.4.



The appearance of TEL-type VCB.

**Figure 2**



Arrangement and operating principle of TEL-type VCB

Figure 3

**Drive operation.**

**Process of circuit breaker closing.**

Before the start of the close process the vacuum interrupter contacts (1.3) are open due to action of the opening spring (10) transferred to movable contact through the pulling insulator (5). To close the contacts of the vacuum interrupter the control voltage shall be applied across the solenoid coil (11) terminals. The magnetic flux produced by solenoid coil current appears in the gap between upper yoke (7) and armature of actuator (9). When the coil current is rising the magnetic flux is being increased as well, so the electromagnetic force, attracting armature of the actuator (9) to upper yoke (7), is coming stronger. At the moment (line 1 Fig.4) when the electromagnetic force overcomes the resistance of opening spring (10) armature (9) starts to move and goes up together with pulling insulator (5) and VI movable contact. Armature (9) is squeezing opening spring (10) during this movement thus spring resistance is increasing, but so far as air gap within the actuator is coming less and less, magnetic flux is rising quickly, that causes the pulling force to increase rapidly also. The growing difference between pulling force and spring resistance enforces the armature to move with the intense acceleration. Such a quick change of magnetic flux induces electromotive force (emf) of self-induction, which impedes current to rise and even forces it to come lower. In the process of movement (the period between line 1 and line 2) the armature gains speed of approximately 1 meter per second, that allows to avoid contacts chatter and prevents pre-strikes of vacuum gap before contacts closing.

At the moment of contacts closing (line 2) the movable contact (3) stops immediately, but the armature (9) proceeds to move ahead for 2 millimeters more. The speed of the armature drops quickly within this phase due to the additional resistance of contact pressure spring (6). At the moment of magnetic latch closing (line 2a) the armature reaches the upper joke of actuator (7) and stops. The anti-emf disappears and current of solenoid coil (11) starts to rise again. During the period between lines 2a and 3 mechanical transient process is running, but the main purpose of this phase is to form necessary magnetic properties of permanent magnet (8) due to existing magnetizing current in the solenoid coil (11). The closing process is completed by interruption of closing current (line 3) by specific circuit breaker control device.

The peak current consumption of the actuator does not exceed 10 amperes.

The circuit breaker remains closed due to residual magnetic induction of permanent magnet, which holds the armature (9) in attracted to upper yoke (7) position without any additional magnetizing current. The circuit breaker is able to stay in the closed position as long as necessary until the action of current of the opposite direction will demagnetize the magnet or magnetic latch will be released mechanically (manual trip). This principle is widely used in low current applications in polarized relays. Modern technological achievements in magnetic hard alloys made possible to create the medium voltage class circuit breaker equipped with drive based on the same principle. The permanent magnet produces magnetic field sufficient to hold the circuit breaker in the closed position even under vibration and impacts influences.

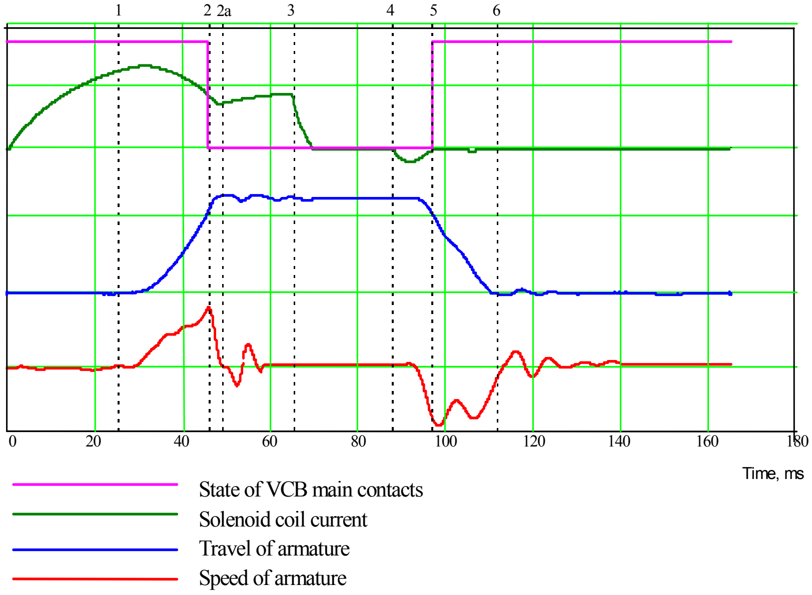


Figure 4- Typical oscillograms of VCB Operation

**Process of circuit breaker opening.**

To trip the circuit breaker the voltage of opposite polarity shall by applied to solenoid coil terminals for 15-20 milliseconds (line 4 Fig.4). In this case the solenoid coil current demagnetizes the permanent magnet (8). Mechanical energy stored in the opening spring (10) and contact pressure spring (6) extremely quickly accelerates the armature, after 2 millimeters way of acceleration it twitches (line 5 Fig.4) the pulling insulator (5) and movable contact (3). The peak pulling force produced by armature at this moment is at least 2000H, which helps to break points of welding at contacts surface that can appear due to short-circuit current action. The movable contact starts to run very rapidly, which increases the interrupting capacity of circuit breaker.

After contacts separation the armature (9) keeps going down entraining movable contact (3) by means of pulling insulator (5) until they take the state as shown at Fig.3 (line 6 Fig.4).

There is extremely low energy required to release the magnetic latch. The demagnetizing current consumption hardly exceeds 1.5 amperes for only 15-20 milliseconds.

Besides, there is the way to trip circuit breaker manually (for example in case of emergency when the auxiliary power supply fails). It is just necessary to pull down the armature with the force exceeding the force of magnetic attraction. The appeared air gap decreases the magnetic flux sufficiently and springs to (6.10) force the armature (9) to run away from upper yoke (7).

The armatures of all three circuit breaker poles are connected together with the common shaft (13). In the process of movement of armatures the screws (14) engaged into mash with the shaft turn this shaft and drive attached permanent magnet (15) which controls the VCB auxiliary switches.

The previously charged capacitor can also be used to close and trip the circuit breaker. In this case it is just required to discharge the capacitor to the solenoid coil. The value of capacitance and charging voltage can be chosen in the best way to provide the optimal combination of making and interrupting capacities and mechanical life of circuit breaker. The use of these capacitors is to reduce the current consumption from the auxiliary power supply and to get circuit breaker close time and open time independent from auxiliary voltage variations as well. All these functions are provided by the specific control device, which is included with the VCB installation kit and is supplied by the manufacturer together with the circuit breaker.

**Basic parameters of TEL-type serial circuit breakers.**

All serial circuit breakers are supplied with vacuum interrupters designed and produced by Tavrida Electric itself. The TEL-type vacuum interrupters are of very compact design and have quite a high (50 000 operations) mechanical life. The basic parameters of TEL-type circuit breakers are presented in the table below.

All circuit breakers of the TEL family are tested and certified in compliance with IEC and GOST standards by KEMA (Arnhem, Netherlands) and Russian National Test Center (Moscow, Russia).

Extremely small weight and dimensions, high reliability and reasonably low price make this circuit breaker rather attractive for different customers and applications. Started as a serial product in Russia and Ukraine in 1994, now there are more than 9000 circuit breakers of this type in use all over the world.

| Name of parameter | Value of parameter |
|---|---|
| Nominal system voltage, kV | 12, 24 |
| Interrupting capacity, kA | 12.5, 16, 20 |
| Rated normal current, A | 630, 1000 |
| Closing time, ms | 70 |
| Opening time, ms | 50 |
| Rated operating sequence | O-0.3s-CO-15s-CO |
| Interrupting life: | |
| • at rated breaking current, operations | 100 |
| • at rated normal current, operations | 50000 |
| Mechanical life, C-O operations | 50000 |
| Rated auxiliary voltage (AC&DC), V | 80-250 |
| Ambient temperature range | -40°C - +55°C |
| Maximum auxiliary current consumption (with the control device), A | 2 |
| Maximum dimensions, H×W×D, mm | 480×540×265 |
| Weight, kg | 32 |