High-Voltage Vacuum Circuit Breaker "MULTI-VCB"

Yukio Osawa
Masamitsu Kitsunai
Takashi Hosono

1. Introduction

In high-level information based society, demands have increased for power supply equipment with improved reliability. Reliability requirements for high-voltage circuit breakers whose main purpose is the short-circuit current protection of an electrical circuit, are also increasing.

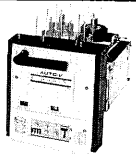
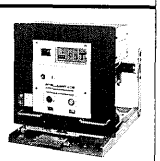
The vacuum circuit breaker (VCB) is the most widely used high voltage circuit breakers and meets market place demands of small size, light weight, longevity, fire resistance, and ease of maintenance.

At the same time, however, demand has increased for devices which are integrated with intelligent functions such as handling ease and preventive maintenance, in these response to these market trends and needs, Fuji Electric recently improved all VCB models of rated voltage 7.2 kV and rated breaking current 12.5 kA. This improved product line was introduced to the market as the "MULTI-VCB" series.

The MULTI-VCB series of products offer increased safety and reliability through the research and is also and development to meet various customer needs, and is also based on the VCB technologies which Fuji Electric has accumulated over the years.

In this paper, a summary of ratings, specifications, features, and test results of standardized vacuum circuit breakers (hereafter, referred as MULTI-VCB or standard VCB), automatic vacuum circuit breakers (AUTO-V), and intelligent VCBs in the MULTI-VCB series are introduced.

Table 1 Composition of MULTI-VCB series

Item \ Series	MULTI-VCB (Standard VCB)	AUTO-V	Intelligent VCB
Appearance			
Function	- Switching load current - Switching short-circuit current	- as MULTI-VCB - Overcurrent detection (Equipped OCR & CT)	- as AUTO-V - Preventive maintenance - Transmission

2. Ratings and Specifications

The MULTI-VCB series consists of three series: standard VCB, AUTO-VCB (standard VCB integrated with a current transformer and overcurrent relay), and INTELLIGENT-VCB (includes additional functions of preventive maintenance and transmission).

Table 1 shows the model configuration of the MULTI-VCB series. Ratings and specifications are shown in **Table 2.**

3. Development Concept of MULTI-VCB Series

3.1 Targets of development

Beside having excellent breaking performance, circuit breakers ought to have;

(1) High safety
(2) High reliability
(3) Easy maintenance, and
(4) Small size and light weight

Further, to supply stable, high-quality electric power

Table 2 Ratings and specifications

Item		HA08	HA12
Rated voltage (kV)		3.6/7.2	
Rated current (A)		400	600
Rated interrupting current (kA)		8	12.5
Rated short-circuit making current (kA)		20	31.5
Rated short-time current (kA)		8	12.5
Rated frequency (Hz)		50/60	
Rated interrupting time (cycle)		3	
Insulation level		Dielectric (1min): 22kV Impulse (1.2 x 50μs): 60kV	
Operating duty		O-1min-CO-3min-CO or CO-15s-CO	
Life expectancy	Mechanical (operations)	10,000	
	Electrical (operations)	10,000	
No. of operations (operations/hour)		60	
Applicable capacitor bank capacity (kVA)		3,000*	5,000*
Auxiliary switch		2a2b (max. 5a5b)	
Standard		JIS, IEC	

*Applicable for 6.6kV circuit with reactor (6%).

and decrease equipment maintenance engineers, the following is desired.

(5) Ease of use
(6) Easy system protective coordination between devices
(7) Intelligence

The MULTI-VCB series was developed with the basic concept: "to provide VCBs which give people a sense of security."

3.2 Features

The MULTI-VCB series is composed of three series: standard VCB, Auto-V, and intelligent VCB, as mentioned above. **Table 3** compares features of the MULTI-VCB series.

3.2.1 High safety

To improve safety further, the high voltage live part of the circuit breaker is not exposed, an operation mechanism is placed in front of the operator, and the high voltage live part is located in the interior of the basic structure.

3.2.2 High reliability

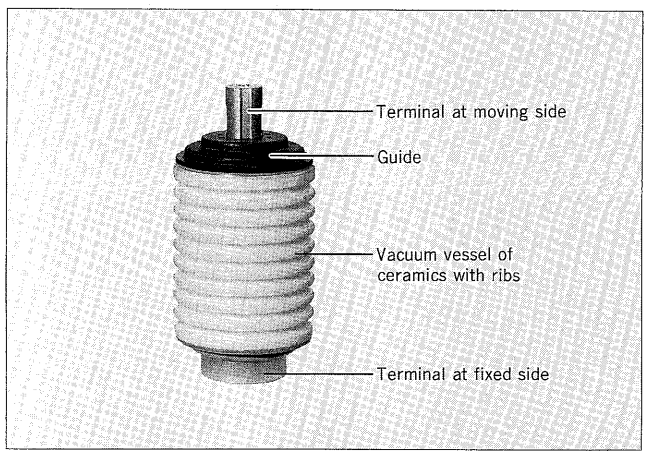
(1) Adoption of auxiliary switches with improved contact reliability.

High contact reliability is required for auxiliary switches which transfer various signals between the circuit breaker and the other devices.

Table 3 Features of MULTI-VCB series

Item		Standard VCB	Auto-VCB	Intelligent VCB
High safety and reliability	Non-exposure of live part	○	○	○
	Sliding contacts (Auxiliary S.W.)	○	○	○
	Vacuum interrupter with ribbed vessel	○	○	○
Easy operation	Plenty of variation	○	○	○
	Standardized front panel cut out holes	○	○	–
	Can be installed by one person	○	○	–
	Can be used for AC and DC	○	○	○
Designed with consideration for protection coordination	Electronic OCR is incorporated	–	○	○
	CT is incorporated	–	○	○
Preventive maintenance	Vacuum condition check function	–	–	○
	Abnormal temperature rise detector	–	–	○
	Trip healthy function of trip coil	–	–	○
	Signal transmitting function (option)	–	–	○

Fig. 1 Vacuum interrupter



The slide-action contact system was adopted as a standard auxiliary switch for the MULTI-VCB series, and contact reliability has been improved.

(2) Adoption of vacuum interrupter with high contamination resistance capability

To provide reliable breaking performance, a special Cr-Cu alloy with excellent breaking and anti-weld performance and small chopping current value was adopted as the contact material.

Moreover, a ribbed ceramic vessel was adopted as the vacuum vessel shown in **Fig. 1**. This greatly improved contamination resistance capability.

3.2.3 An easy to use VCB

(1) Great variety of types

(a) Drive system

The following two types of standard closing drive systems are available.

(i) Manual-spring drive system
(ii) Motor-spring drive system

These can be selected according to the intended use.

(b) Mounting system

If the circuit breaker is classified by mounting system, it can be divided roughly into either the fixed type or the draw-out type. There are four fixed type mounting systems (B, C, P and D types) available to select the optimum mounting system for an intended use and particular panel structure. Selection of a fixed mounting system is based on the difference between the output direction and layout of the main circuit connection terminals.

The draw-out type has three varieties (X, U and Y types). The X and U type have a structure which is adaptable to the CW class of JEM 1425 "Enclosed metal-clad switchgear and control gear". The Y type is adaptable to PW and MW class of the same standard. For motor-spring drive of the draw-out type, a cover over the manual closing button is installed as shown in **Fig. 2** to prevent faulty operation, and a caution plate is attached to the disconnect part of auxiliary circuit. This makes the breaker compatible with the JEM 1425.

Fig. 2 Draw-out type AUTO-V applicable to JEM 1425

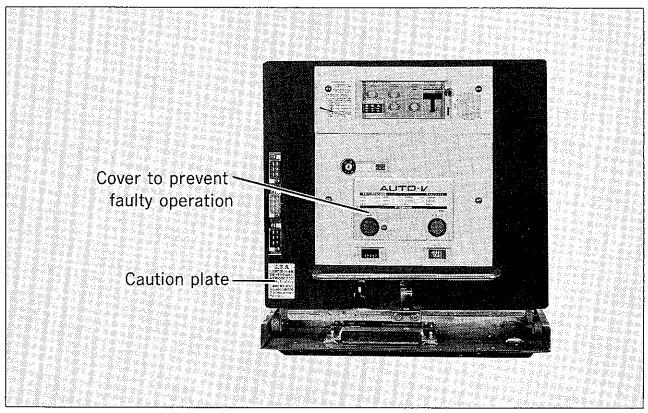
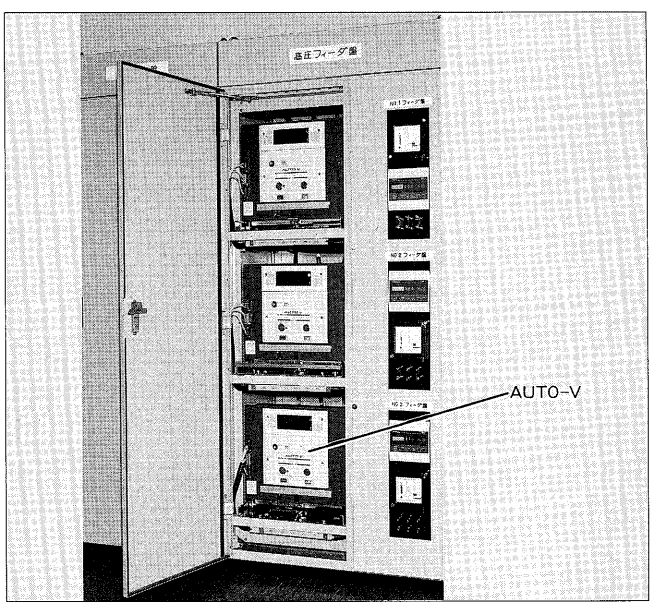


Fig. 3 Three tiers AUTO-V stacking within a thin cubicle of depth 700 mm



AF92-95

U-type MULTI-VCB and AUTO-V have a structure which can be three tiers within a thin cubicle of depth 700 mm. **Figure 3** shows an example application.

(2) Standardization of panel cutout size

When the fixed type VCB is to be installed directly on a panel, a cutout opening for mounting must be made in the panel. Previously, four different types of cutouts were necessary according to the output direction of the main circuit terminals of the circuit breaker.

With the MULTI-VCB, cutout sizes, were standardized to two types, the manual-spring drive type and the motor-spring drive type. As the result, processing of the panel was simplified and made more efficient.

(3) Simplification of mounting work

In general, mounting of the fixed type VCB is performed by two persons. However, so that the MULTI-VCB could be mounted by one person, mounting metal hooks were attached on the front face of the circuit breaker. The circuit breaker can be temporarily mounted by hanging its metal hooks on the holes in the panel plate.

Table 4 Comparison of functions of CB type interrupting device

Apparatus / Function	CB type interrupting device			AUTO-V
	CT	OCR	CB	
Detection of main circuit abnormality	○	–	–	○
Check for abnormality and issue command	–	○	–	○
Interrupt circuit with command (Short-circuit current, overload current)	–	–	○	○

(4) Common AC and DC use

The closing control circuit of the motor-spring drive was made common for AC and DC and unified to one standardized model to eliminate the problem of model selection.

(5) Reduction of operating force for closing

It is important that the operating force for the manual-spring drive type circuit breaker is sufficient to safely and securely switch the circuit breaker. On the other hand, the operator requires light and easy operation. In response to these conflicting requirements, a new drive mechanism was developed for the MULTI-VCB, reducing the closing operation force of the manual-spring drive to 1/2 or less of the conventional type, and improving operability.

3.2.4 Easy system protective coordination

In general, each circuit breaker, current transformer (CT) for current detection and overcurrent relay (OCR) is designed and manufactured based on individual specifications. Therefore, if these are combined without sufficient examination of the application, less than optimum performance may result.

The AUTO-V, equipped with a special current transformer and solidstate overcurrent relay in the MULTI-VCB, will solve these problems. **Table 4** compares the functions of CB type interrupting equipment and the AUTO-V.

The AUTO-V has the following features.

(1) Easy to use as a molded case circuit breaker

It is possible to use the AUTO-V only by connecting cables to the main circuit terminals and setting the integrated overcurrent relay dials.

(2) Easy protective coordination

There are three rated operating current regions available : 8 to 80 A as small rating region, 16 to 160 A as standard rating region, and 80 to 480 A as large rating region. The operating current can be set to load capacity with only one touch of the dial.

Further, operating time is adjustable over a wide range. Protective coordination of the operation with other apparatus can be easily set due to the wide range of adjustable operation time and super-inverse-time characteristic of the delay element.

(3) Use of a highly reliable current transformer

Fig. 4 AUTO-V

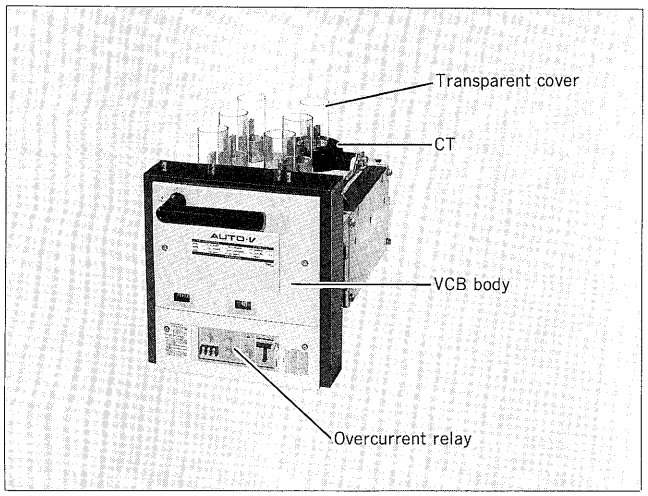


Fig. 5 AUTO-V overcurrent relay

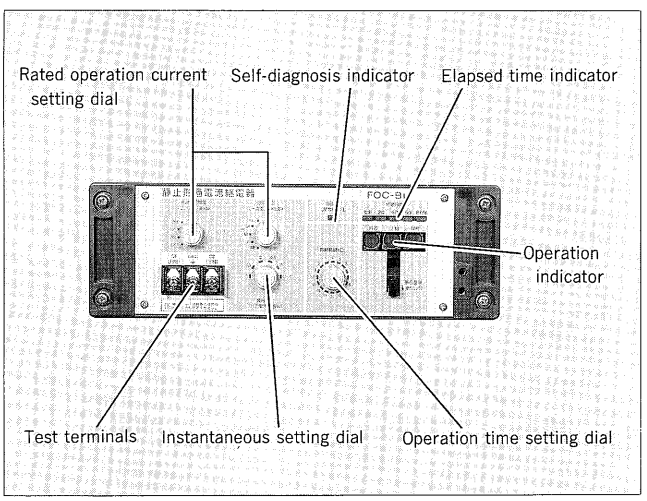
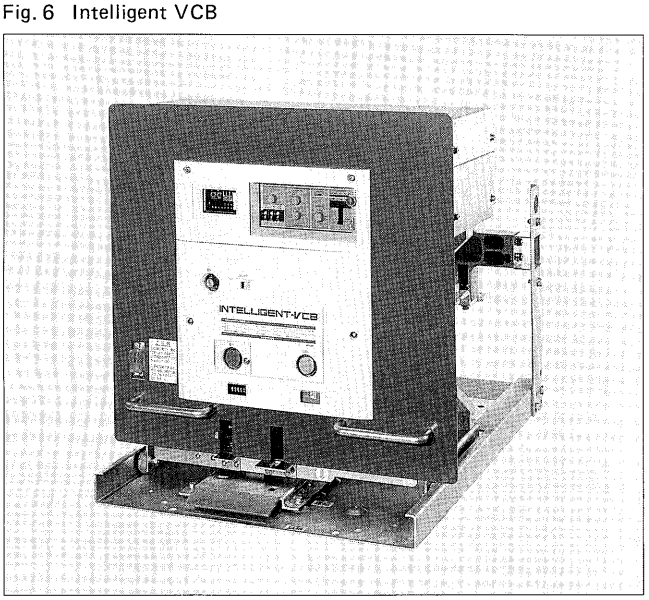


Fig. 6 Intelligent VCB



AF92-218

(a) Large overcurrent constant of current transformer (n>20)

If primary current exceeds a certain valve, magnetic saturation of the iron core will cause the secondary current to be unproportional. The overcurrent constant (n) is the valve of current at the point that error reaches 10% divided by the rated current. When this overcurrent constant is small, the operation value and operating time will vary. A current transformer with large overcurrent constant must be selected for this interrupting equipment so that protection may operate securely.

In the current transformer of AUTO-V, since n is 20 or greater, the overcurrent relay will operate correctly even in the short-circuit current region. The short-circuit current will be interrupted.

(b) Capability of current transformer to withstand large overcurrent (12.5 kA, 1 second)

The current transformer for the overcurrent relay should be durable enough to sustain no damage even if there is a short-circuit current. Since the current transformer used for the AUTO-V possesses the capability for an overcurrent of 12.5 kA and 1 second, it will not be damage by a short-circuit current.

(4) Mounting a solid state overcurrent relay

(a) Operating time is adjustable with 16 stages from 0.5 to 50 seconds.

(b) An internal microcomputer provides a built in self-diagnosis function.

(c) Elapsed operating time display is built in (four stages between 20 to 80%).

(d) Instant operation characteristics make it easy to avoid malfunction of the breaker due to the excitation inrush current of a transformer.

(e) Displays for instant and delay elements are separated. Further, when the delay element operates, operation at each phase is displayed.

An example of the AUTO-V is shown in **Fig. 4** and the overcurrent relay equipped with a microcomputer is shown in **Fig. 5**.

3.3 Intelligent VCB

Figure 6 shows the intelligent VCB which was developed recently. The intelligent VCB is a MULTI-VCB with many added on functions.

The additional functions available for intelligent VCB, are roughly classified into three groups: protection function, preventive maintenance function, and transmission function.

The AUTO-V is based on the MULTI-VCB with added protection function. The intelligent VCB contains this protection function and additional preventive maintenance and transmission functions.

The functions of the intelligent VCB and standard VCB are compared in **Table 5**.

3.3.1 Preventive maintenance function

(1) Vacuum-strength monitoring function

The following three basic technologies are important in manufacturing a vacuum interrupter for VCB.

Table 5 Comparison of functions

Function		Standard VCB	Intelligent VCB
Control	ON/OFF command	Switch	With transmission function (Outside→VCB)
Status monitoring	Status of ON/OFF	Auxiliary contacts	With transmission function (VCB→outside)
Preventive maintenance	Monitoring of vacuum condition	None	Alarm output for decrease in vacuum level
	Monitoring of abnormal temperature-rise	None	Alarm output for abnormal temperature-rise
	Monitoring of open circuit of trip coil	None	Trip healthy function Alarm output for open circuit of trip coil
Protection	Detection, condition checking and command of overcurrent and short-circuit	None	Automatic interruption

(a) Vacuum sealing technology which will maintain the vacuum strength for a long time.
(b) Ceramic technology including junctions between ceramics and metal
(c) Contact technology including alloy technology

The quality of vacuum interrupters has risen greatly owing to the research of these technologies for many years and the remarkable advance of basic technologies. Vacuum detects have been very few. To meet the requirements of users who want to monitor VCB operation over a long term, the intelligent VCB function was developed.

In general, when the strength of the vacuum in the vacuum interrupter decreases, electric discharge will occur in the interrupter. This discharge is detected by an electrode and is amplified. When the signal reaches a certain level, an alarm is output externally as an electric signal.

(2) Abnormal temperature-rise monitoring function

Temperature-sensitive optical switches are located in the main circuit terminal area of the VCB and the temperature of the terminal area is always monitored. For instance, if an abnormal temperature-rise is caused by the loosening of bolts at the main circuit disconnect contact, a temperature sensitive optical switch will operate to output an electrical signal.

Figure 7 shows mounted temperature-sensitive optical switches.

(3) Trip healthy function (check on trip coil)

A very small current always flows into the trip coil of the VCB and the state of the trip coil is monitored. When the coil becomes an open circuit, the condition is detected as abnormal and an electrical signal is output.

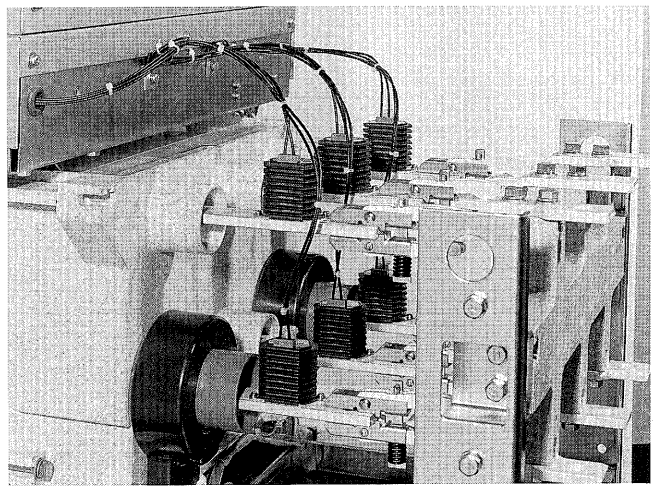
3.3.2 Transmission function

The intelligent VCB transmits information to the outside through a special signal multiplex transmission device attached to the body of the circuit breaker. Data from each function, status monitoring control, and protection, are collected and transmitted. An information network can be easily constructed from this configuration.

Opening and closing commands are transmitted from the outside to the circuit breaker through the transmission device. The circuit breaker switching status or an abnormal signal, detected by the preventive maintenance function described in paragraph 3.3.1, is transmitted from the circuit breaker to the outside. A display of the switching status of the circuit breaker, a count of the number of times switching occurred, and output of the abnormal alarm, etc. is possible with this information.

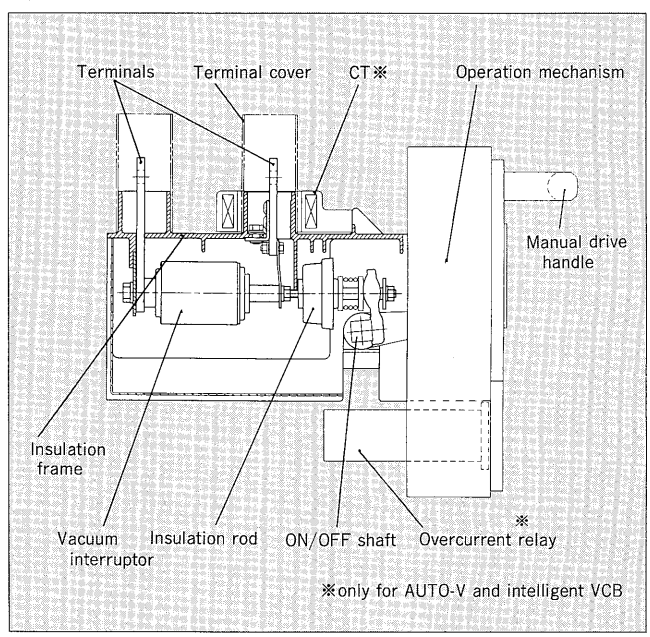
Moreover, since it is possible to transmit these various signals with two signal conductors, wiring is greatly simplified compared to conventional systems. This fact has increased the reliability of signal transmission and at the same time resulted in a system which is more economical.

Fig. 7 Mounting of temperature-sensitive optical switches



AF92-220

Fig. 8 Structure of MULTI-VCB (manual-spring drive)



4. Structure

Figure 8 shows the typical structure of the MULTI-VCB series.

The vacuum interrupters, which form the main interrupting part of the VCB, are put in a one-piece insulated frame which is molded with special polyester resin for three phases. A cover is placed over the aperture of the insulated frame. The main circuit terminal area also has a terminal cover to prevent high voltage live parts from being exposed.

The operating mechanism, attached to the insulated frame, operates the vacuum interrupters through a switching shaft and insulation rods. The standardization of panel mounting size was achieved by adopting a structure in which the operating mechanism is always on the front side of the circuit breaker even if the mount system is changed.

An operation status indicator, a switch operation counter and a closing-spring status indicator (only for motor-spring drive type) are equipped as standard features on the front side of the operating mechanism so that they may easily be read from the outside.

5. Test Results

Items were tested in accordance with JIS C4603 (1990), and the results confirmed that all test items passed. Furthers, reliability tests in various working environments were conducted in addition to the items which are specified in the standard. Excellent performance was confirmed. A summary of these tests is presented below.

5.1 Breaking test

Due to the excellent arc extinction performance of the vacuum interrupters and improved materials which have resulted in a much better anti-weld characteristic of the electrode, the breaking test results showed extremely stable performance in all regions to the rated interrupting current under small operation energy. After examining a series of breakings contact wear was minute, and it was verified that the increase of resistance between the contacts was small, **Figure 9** shows an oscillogram of the breaking test.

5.2 Switching characteristic test

It was verified that use of a new operating merchanism resulted in stable switching characteristics and high safety.

(1) Manual-spring drive type

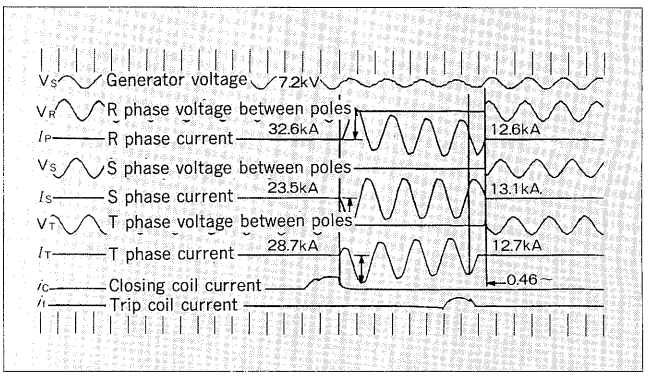
It was confirmed that the operating force for manual control closing is as small as 100N or less, and that appropriate closing and breaking speeds were obtained.

(2) Motor-spring drive type

Interlock operation and compound operation, such as simultaneous manual and electrical operation, of the control circuit as well as special operations which would not occur in conventional operation were systematically analyzed.

The results confirmed fail-safe operation in all states, and a high level of safety was verified.

Fig. 9 Oscillogram of breaking test



5.3 Insulation test

Sufficient insulation strength was verified through standard voltage tests such as lightning impulse voltage, and other tests including a tracking test, partial discharge test, etc.

5.4 Life span test

The results of a consecutive switching test for life span verification and the measurement of stress generated in each mechanical section confirmed that the mechanical strength was sufficient.

5.5 Noise resistance test of AUTO-V and intelligent VCB

In electronic circuits such as the overcurrent relay equipped with a microcomputer, it was confirmed that there was no abnormality such as a malfunction or circuit damage from electromagnetic induction caused by the switching of the short-circuit current, etc. Additional tests verified that there was no problem at all with simulator or radio wave noise, etc.

6. Conclusion

A summary of the newly developed MULTI-VCB series was presented above.

In the future, we think the importance of the role of the VCB will further increase as a circuit breaker for the protection of electrical equipment. Fuji Electric hopes the MULTI-VCB series will be useful for the design and protection of consumer electrical equipment.

We will make every effort to continue to develop and improve our VCB in response to consumer needs.