E01.07/A6-34

GENERAL CHARACTERISTICS OF CIRCUIT BREAKERS FOR THE ULTRA HIGH VOLTAGE POWER SYSTEMS

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ABSTRACT

Due to the increasing energy request the ultra high voltage power systems come more to the fore. In this paper the circuit breakers for the power systems of 1,000kV are especially taken into account. The present development state, important technical specifications, the temperature and interruption performance, and monitoring system of the high voltage circuit breakers of this type have been explained thanks to practical applications.

1. INTRODUCTION

1,000kV power transmission lines require overvoltage protection so that insulation requirements can be held to reasonable levels. The circuit breakers were developed to keep switching surge levels low enough so that ground fault surges do not rise above the maximum suppressible level of 1.6~1.7 per unit (pu). The new circuit breakers control closing surges using a resistance creation method similar to that developed for 550kV and prevent opening surges with a newly developed resistance interruption method. New technologies for the resistance interruption include resistance interrupters, a resistor array 15 times larger than that in 550kV , and a delayed operation function to open the resistance interrupters at a specified interval after the main interrupters open [1,2,3,4] .

2. THE PRESENT DEVELOPMENT STATE

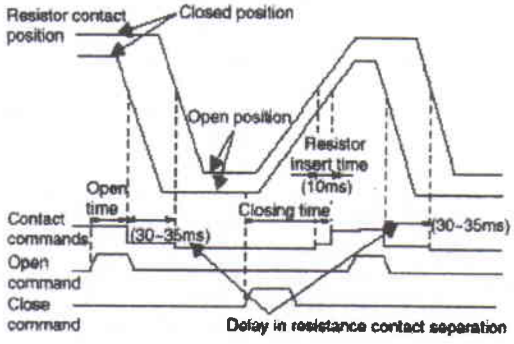
The first purpose of development of these circuit breakers was to maintain reliability in the largest and heaviest interruption equipment ever developed, including a breaker unit with very large capacity, and a hydraulic operating mechanism specially developed for operating the main interrupters.

The second was to develop new technologies for resistance creation and resistance interruption. Fig. 1 shows the operating sequence and Table. 1 lists the ratings for the 1,000kV.

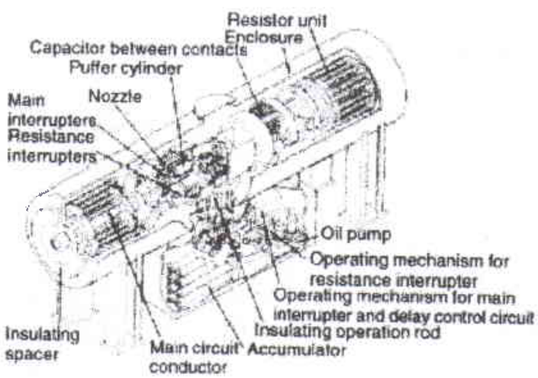
Table:1 Operation Ratings

Rated voltage	1,100kV
Rated current	8kA
Rated interrupt current	50kA
Rated interrupt time	2 cycles
Rated fluid operating pressure	31.5MPa (hydraulic)
Rated SF_6 gas pressure	0.6MPa
Resistance	700 ohms (operating and closing)
No. of breaks	2

Two operating mechanisms for the main and resistance interrupters are used, and a new delayed operation function was developed so that the resistance interrupters open after the main interrupters. Another development purpose was to design the breaker, resistor array and other elements as independent units that could be easily assembled, and to raise assembly reliability by eliminating the need for adjustments after the units are united inside the enclosure.



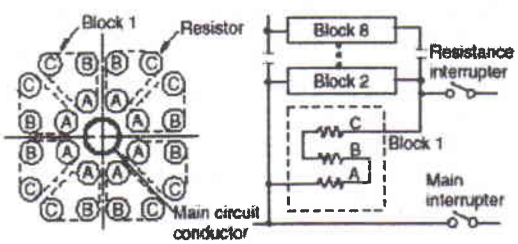
Figur:1 Operation Sequence



Figur:2 Internal Construction of Breaker

3. FEATURES

Fig.2 shows the internal construction. The enclosure diameter can have reduced by placing the main and resistance interrupters (two sets each) in parallel at the enclosure center with resistors at either end. The transfer of mechanical stress from the resistors to the interrupter was minimized by mounting the resistor units on specially developed large diameter insulators attached to the ends of the enclosure. The tulip contacts of the main and resistance interrupters are used to make adjustment-free connections between the resistor units and the interrupt unit, which eliminates all adjustments inside the enclosure. The main contacts open at a speed just 30% faster than the two sets of main contacts used in the 550kV. The speed was kept down by using a long Laval nozzle designed to maintain the hot gas flow in a cohesive stream at high flow rates, and by optimizing the puffer cylinder diameter for maximum flow rate [1,5]. The main interrupters had already been qualified in a 550kV, 63kA. The resistance interrupters require excellent dielectric recovery characteristics. With a maximum interrupting current of 2kA under out-of-phase breaking, the duty of the resistor contacts is considerably less than the main interrupters, however, the transient recovery voltage reaches a rate-of-rise of 3kV/μs during terminal fault breaking, and the peak voltage reaches 2,515kV during small capacitive current breaking demands similar to those on the main interrupters [6]. For these reasons, the same high breaking speed used for the main interrupters was selected , and developed and qualified a new interrupt technology employing the small diameter puffer of a 72kV with a rotary arc drive effect achieved by permanent magnets. The resistors typically dissipate 145MJ of energy from O to BO (i.e., terminal faulting to out-of-phase creation and breaking). This is 15 times the power dissipated during resistance creation of a 550kV, and the large size of these resistors is a major factor in the size increase required for the 1,000kV. Fig. 3 shows the resistor configuration.



a) Physical layout b) Circuit (for one break)

Figur:3 Resistor Configuration

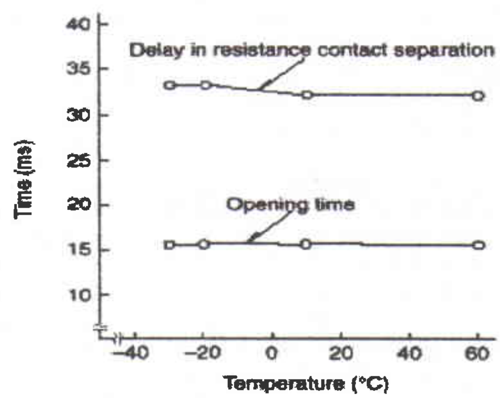
The resistors are placed around the conductor connected to the main interrupters; with three resistors connected in series to form one block, and eight blocks connected in parallel. This configuration ensures adequate insulation between the resistor elements and between the resistor blocks while occupying minimum space. The hydraulic operating mechanism for the main interrupters uses a new design to provide the necessary output, which is double the out – put required of the 550kV operating mechanism. The operating mechanism for the resistance interrupters is the same one proven for 300kV. A hydraulic pressure stabilization mechanism prevents variations except momentarily during contact closing and opening. The two operating mechanisms operate with a delay when the contacts open and simultaneously when the contacts close. This function is implemented using hydraulic circuits for reliability. When the piston of the operating mechanism for the main interrupters reaches a breaking point, the dashpot pressure is detected, activating a delay control valve that triggers the operating mechanism for the resistance interrupters.

4. VERIFICATION TEST

The basic performance parameters of the 1,000kV have been qualified and the equipment approved for practical application.

4.1 Performance At Extreme Temperatures

To confirm that proper opening and closing performance is maintained at extreme temperatures, the related circuit breakers are operated at temperatures from -30°C to +60°C. Fig. 4 shows that the change in opening times was negligible [7,8].

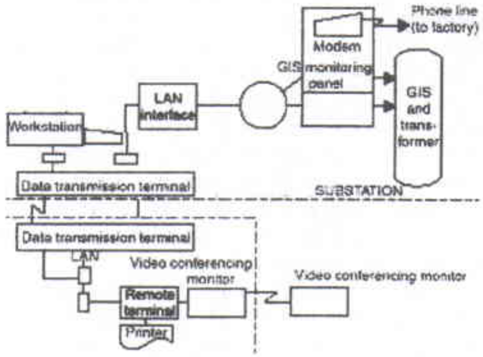


Figur: 4 Opening characteristics at Ambient temperatures.

The delay time of the contact separation in the opening operation of the resistance interrupter remained within the stable range of 32~33ms, confirming that the hydraulic delay circuitry is sufficiently immune to temperature-induced variations in the viscosity of the hydraulic fluid [9].

5. MONITORING SYSTEM FOR 1,000kV GAS-INSULATED SWITCHGEAR

Fig.5 shows the detailed monitoring system configuration. The monitoring panel receives data from sensors, which it processes and analyzes to determine the equipment status [1].



Figur:5 Monitoring system configuration.

This information is sent out over an optical LAN to an on-site control room, where it is logged and displayed. The system monitors the following items.

5.1 Partial Discharge

An internal antenna detects partial discharges. Factory testing demonstrated a maximum detection sensitivity of 0.5pc.

5.2 Internal Fault Locator

This function is realized using gas pressure sensors, and is capable of detecting pressure increases of 100 pascals.

5.3 Lightning Arrestor Leakage Current

A current transformer installed on the lighting arrestor ground circuit detects leakage current. The total value of the leak current components at the fundamental frequency and phase angle Δ are used to determine the resistive leakage current.

5.4 Travel Characteristics

A control current sensor, which monitors the control current run time of the control circuit, a travel sensor that directly measures movement of the operating mechanism and auxiliary contacts are used to monitor travel characteristics. Combined operation of the high-speed ground switch and gas circuit breaker can also be monitored locate internal faults.

5.5 Hydraulic Pump Operating Characteristics

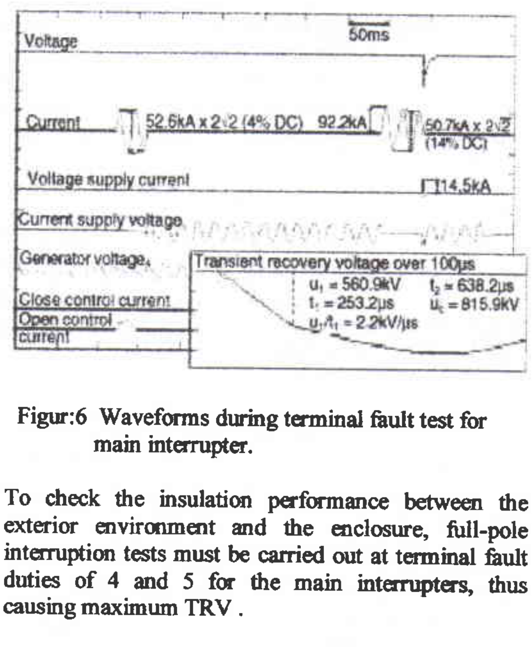
The operating times and operating duty of the electromagnetic relay that powers the hydraulic pumps are monitored. This does not include pump operation associated with manually initiated equipment operation.

5.6 SF6 Gas Pressure And Density

Sensors monitor gas pressure and density to identify leaks and to locate internal faults. The equipment also monitors contact wear and lightning arrestor discharge current. The single-panel monitoring unit is capable of monitoring a three-phase gas-insulated switchgear unit. The naturally-cooled cubicle has a protective sun shade and an internal dehumidifier. A monitor enables visual monitoring of the instrumentation data and sensor operation status, and screens can be printed on demand. Data can be uploaded to a remote location via an optical LAN or via modem over telephone lines. The data received from this equipment will be analyzed and used to design future gas-insulated switchgear and related monitoring equipment.

6. CONCLUSIONS

Limits of the test apparatus prohibited testing of the entire interruption process and the interrupt performance at once; however, selected intervals and parameters of the interruption process should be tested in a multipart testing regime that covers the entire process and gives a clear picture of structural and functional behaviors [10]. The main interrupters should be tested up to the peak transient recovery voltage (TRV) with the resistors mounted normally (terminal fault duties 4 and 5), then with the resistors disconnected to allow a higher recovery voltage to be applied to the main interrupter. Fig. 6 shows waveforms for a typical qualification test during the terminal fault duty 4 test series with the resistors connected at up to the peak TRV. The resistance interrupters were qualified for thermal and dielectric characteristics [11].



Figur:6 Waveforms during terminal fault test for main interrupter.

To check the insulation performance between the exterior environment and the enclosure, full-pole interruption tests must be carried out at terminal fault duties of 4 and 5 for the main interrupters, thus causing maximum TRV .

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