# Development of the Controlled Switching Device for a Cirrcuit Breaker

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**Abstract**: Studies on the controlled switching method have been done to prevent the power system surges which cause the insulation deterioration and electro magnetic compatibility (EMC) problems during closing and opening of a circuit breaker. The controlled switching method controls the closing and tripping time in coincidence with the voltage or current to suppress switching surge. It is used to switch condenser bank, no load transformer, and shunt reactor. In this study, basic concept of the controlled switching is introduced, and also the test is performed to find parameters of the controlled switching in a 24kV vacuum circuit. And then, the control device hardware using TMS320C31 DSP has been designed and manufactured. It has been found that the application of IT technology to a circuit breaker is very effective to depress the switching surge.

**Keywords:** the controlled switching principal, switching surges, vacuum circuit breaker, the switching algorithm

## 1. INTRODUCTION

The efforts to reduce switching surge during switching device operation has been made in technically advanced companies. Application of IT technology to a circuit breaker is very effective to depress the surge, in comparison with those using resistor, series reactor, and arrester. Especially, it is very useful to deduce the surge at switching of the condenser bank, no-load transformer, and reactor. The practical testing results are presented on this paper.

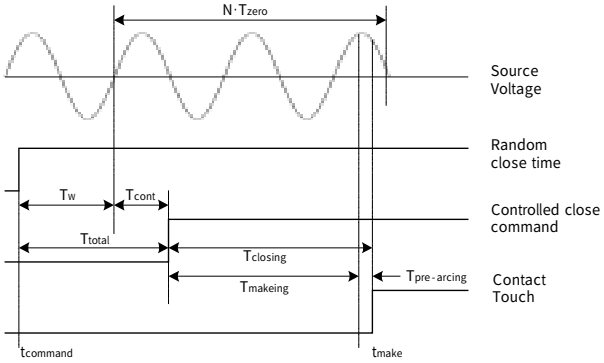


Fig. 1 Graph of closing sequence

This controlled switching circuit breaker can be used at the place where electric quality is very important. It makes the maintenance expenses down during its life of operation. The life cycle of the circuit breaker can be improved, and structure of the circuit breaker becomes simple. And also the driving force of the circuit can be reduced.

The most important thing is the distribution of the errors which have to be little in useful application of the controlled switching. By evaluating performance of the circuit breaker with the controlled switching device, the advantages to apply the controlled switching theory have been proved. The hardware design based on 32 bits DSP as well as manufacture of the control board has been made. That device is used to test a 24kV vacuum circuit breaker.

In this study, the usability of controlled switching theory has been proved, and the controller has been designed and manufactured. Controlled switching methods are under investigation to reduce the power system faults which are caused by the surge induced by a circuit breaker operation. The controlled switching method is applied to control the closing and tripping time coincidently with the voltage and current to suppress switching surge. It is used to switch condenser bank, no-load transformer, and reactor

## 2. PRINCIPLES AND CHARACTERISTICS OF CONTROLLED SWITCHING

Controlled Switching uses an electronic control device to close the switch at the set point for reducing switching surges, and to open contacts at the set separation point.

### 2.1 Principles

To implement the controlled switching, the information of current and voltage at the contact of a circuit breaker as well as ambient temperature is needed. This information comes from the sensor to the controller. Fig. 1 represents the sequence of closing time. The closing command comes form the arbitrary time independent upon phase of the current and the voltage waveforms. This command is delayed by the controller. The delay time is determined by the mechanical operation time like the pre-strike time and the setting time to close. In reactor switching, the optimal closing time is the peak point of the voltage wave while the pre-strike time is a quarter of one frequency.

In case of opening of controlled switching, the arbitrary opening command is delayed depending on the sum of delayed time and synchronous time. The delayed time can adjust the set point of contacts. The graph of the opening sequence is represented in Fig. 2.

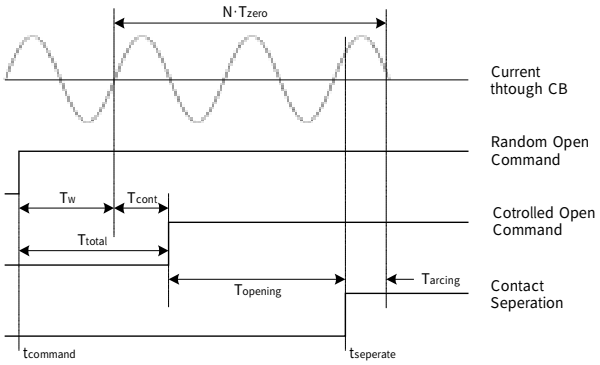


Fig. 2 Graphs of opening sequence

## 2.2 CHARACTERISTICS OF CONTROLLED SWITCHING

The application possibility of controlled switching to any circuit breaker depends on the insulation characteristics of the circuit breaker and uniformity of the standard deviation of mechanical operating time. For example, if the closing object point is the voltage zero point, there are problems caused by uniformity of the standard deviation of mechanical operating time and pre-striking time of contact. Namely, if the closing point is set to the zero voltage point, the instantaneous voltage of contactors comes out to be maximum voltage depending on the mechanism of driving part and pre-strike. Actually, there is some standard deviation of mechanical operating time, but in order to prevent re-ignition of shunt reactor switching, to remove the re-ignition of capacitor switching, and to minimize contacts consuming rate at fault current interruption, the standard deviation for the typical control is limited to below some degrees.

To apply the controlled switching theory to a circuit breaker, its reliable switching characteristics, the insulation recovery characteristics, and constancy of mechanical operation time should be guaranteed.

Recently the circuit breaker becomes reliable through the design improvement. The main developing points are to reduce part numbers, weighting, and mechanical driving force. Also the affecting factors of mechanical operating time are surrounding temperature, spring saving energy, and driving solenoid coil control voltage. Generally these factors influence more on closing operation whose operation time is longer than that of the opening operation.

## 3. TESTING OF A VACUUM CIRCUIT BREAKER

For the test of mechanical operation performance, a HAF type vacuum circuit breaker was used.
That circuit breaker is driven by motor and spring, and the rated current and short circuit interrupting current are 24kV, 25kA, respectively. The opening and closing tests are performed.

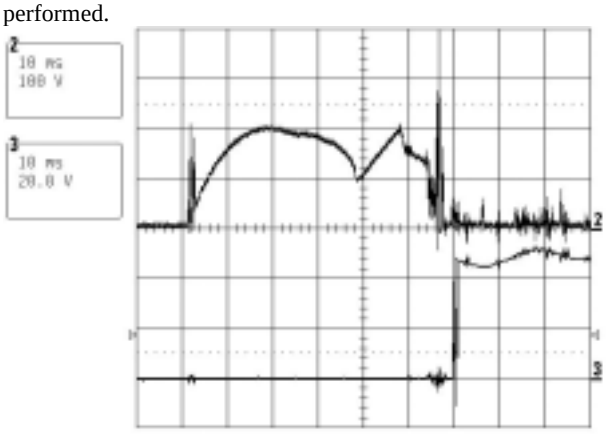


Fig. 3 Result of closing test

The representative case of closing test is shown in Fig. 3. Upper line of graphs represents control solenoid coil voltages. The operating time starts at the instants of control voltage applied to solenoid coil, and ends at the each contact touches. And then, the operating time of vacuum circuit breaker is 53.6msec. This kind of testing was performed many times, and the average operating time is 59.7msec. In this case, the difference between two cases is 6.1msec. The cycle time is 16.7mec. The percentage rate of difference is 36.2%.

The representative case of opening test is shown in Fig. 4. Upper line represents control solenoid coil voltage. The operating time of opening the contact was 42.1msec, and the average operating time of opening was 49.5msec. In this case, the difference between two cases is 7.4msec. The percentage rate of difference is 44.3%.

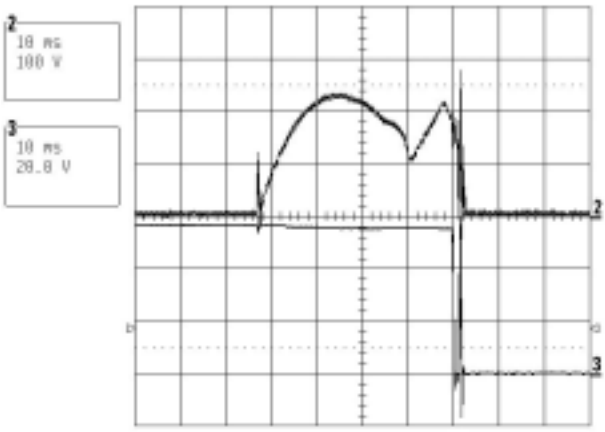


Fig. 4 Result of opening test

According to above test results, the standard deviation of operating time is 36.2% and 44.3%. In these cases, the controlled switching technique can not be applied. Therefore, to apply the controlled switching technique to a vacuum circuit, the new driving mechanism which has about 10% of deviation standard, would be needed.

## 4. Performance test of controlled switching to vacuum circuit breaker.

### 4.1 Constitution of controlled switching device

The developed control device to perform the controlled switching to a vacuum circuit breaker is represented in Fig. 5. The main processor is TI company 32bit DSP Tms320C31. The analog and digital I/O port and communication interface are used. In addition to these, driving units using IGBT of the excitation coil of the circuit breaker are included.

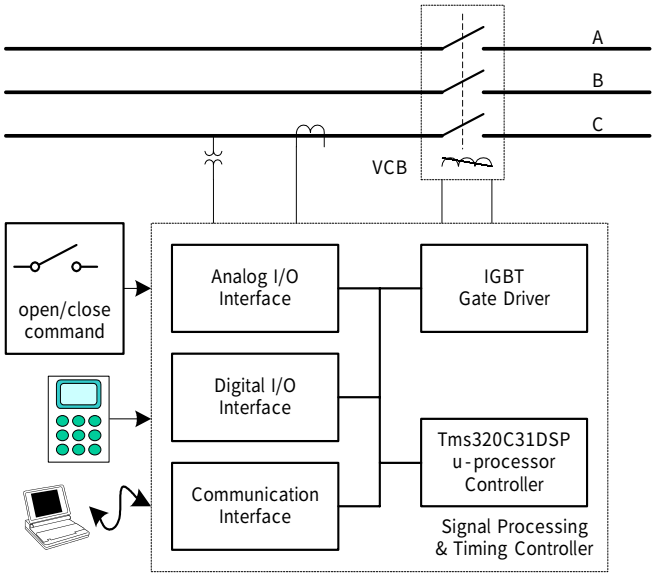


Fig. 5 Constitution of controlled switching device

The functions of this device are represented in Table 1. Main program is initializing internal resistor, controlling variables of DSP, checking the error of data, recognizing the initial phase angle of sources, monitoring and processing in an infinite loop.

Table 1 Function of control program

| | | Main Function |
|---|---|---|
| Main Program | | Check System error, abnormal state |
| Timer Interrupt Program | 0 | Voltage and Current PLL |
| | 1 | I/O Processing, MMI processing |
| External Interrupt Program | 0 | Serial Communication |
| | 1 | Controlled opening service |
| | 2 | Controlled closing service |

To get fast response to input signal of open and close of controlled switching circuit breaker without time delay, performance characteristics of controller used external interrupt service routine. The internal timer interrupt is set to 100μsec, 1msec cycle times, and phase angle checking circuit performs PLL operation, and also treats the various analog and digital and communication input signal and MMI process using time sharing method.

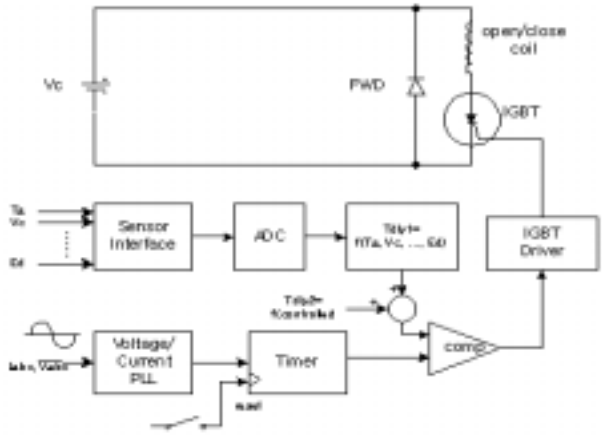


Fig. 6 Control Block of Controlled Switching Device

The control block diagram of controlled switching is represented in Fig. 6. Fundamentally each phase of current and voltage is monitored by a controller. The command of closing and opening comes out arbitrarily, and the controller can predict optimal closing and opening time.

But the arcing time and making time are different depending on the vacuum circuit breaker, the operating time is also different depending on driving mechanisms such as air pressure driving, motor spring driving, and oil pressure driving mechanism. And then the operation time of the circuit breaker is inputted by the MMI program. The operating time also depends on surrounding temperature of circuit breaker and control circuit voltage. In this study, those two parameters are adopted. These compensation methods are not sufficient to predict the operation time of a circuit breaker. Fundamentally, deviation of the driving mechanism has to be smaller to the one $10^{th}$ of cycle time.

At arbitrary time, on inputted signal for opening and closing, the controller monitors the phase angle of input current and voltage wave using synchronizing timer counter. It also checks the affecting factor of arcing and making time, and calculates the mechanical operation time and output deviation to zero point.

The comparators check the deviation of phase angle(zero point or peak point) and give an output of the constant bandwidth IGBT driving signal.

### 4.2 The results of ac interrupting test

The developed controlled switching device is used for the AC current interrupting test. Among ten tests, five of them are successful. Therefore, this controlled switching device can not apply to the present vacuum circuit breaker. This is because driving device operation time is not constants, and namely the deviation of the operation time is large. The driving method of motor spring mechanism has large deviation of operating time. As a conclusion, the deviation of drive operation time has to be much less to apply the controlled switching technique to a vacuum circuit breaker, and therefore the new driving method has to be developed.

## 5. Conclusions

In order to reduce switching surges at switching operations, and to prove usefulness of controlled switching, the manufacturing and testing of the controlled switching device as well as the design are performed.

The usefulness of the controlled switching are reported in various investigations. It can be used as instead of resistor switching, and also be applied in the shunt reactor switching, and the inrush current depression.

In the near future, a lot of researches about the controlled switching will be performed. For example, if the magnet driving mechanism or motor driving mechanism will be applied to a vacuum circuit breaker in the future and the high reliability of the controlled switching will be implemented.

In addition to the controlled switching function, preventive diagnosis technology implementation and communication function will be integrated on one controller. The new vacuum circuit breaker with these functions will be come out in the near future, and the surge of the switching will be depressed by employing the information technology.

Nowadays, electric machinery makers are trying to apply the information technology to a conventional machine like a vacuum circuit breaker. In order to successfully apply the technology, the driving method should be improved in the near future.

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