Chapter 1
INTRODUCTION

1.1 Terms and definitions

Direct Test

Test in which the applied voltage, the current and the transient and power-frequency recovery voltages are all obtained from a circuit having a single-power source, which may be a power system or special alternators as used in short-circuit testing stations or a combination of both.

Synthetic Test

Test in which all the current, or a major portion of it, is obtained from one source (current circuit) and in which the applied voltage and/or the recovery voltages (transient and power frequency) are obtained wholly or in part from one or more separate sources (voltage circuits).

Test circuit – breaker

Circuit- breaker under test.

Auxiliary circuit-breaker(s)

Circuit-breaker(s) forming part of a synthetic test circuit used to put the test circuit-breaker into the required relation with various circuits.

Current circuit

That part of the synthetic test circuit from which all or the major part of power-frequency current is obtained.

Voltage circuit

That part of the synthetic test circuit from which all or the major part of the applied voltage and/or recovery voltage is obtained.

Current - injection method

Synthetic test method in which the voltage circuit is applied to the test circuit-breaker before power-frequency current zero.

Voltage-injection method

Synthetic test method in which the voltage circuit is applied to the test circuit-breaker after power-frequency current zero.

Injected current

Current supplied by the voltage circuit of a current injection circuit when it is connected to the circuit-breaker under test.

Post-arc current

Current which flows through the arc gap of a circuit breaker when the current and arc voltage fallen to zero and transient recovery voltage has begun to rise.

Amplitude factor

The ratio between the maximum of transient recovery voltage to the crest value of the power frequency recovery voltage.

Short-line fault (SLF)

Short circuit on an overhead line at a short, but significant, distance from the terminals of the circuit-breaker.

As a rule this distance is not more than a few kilometers.

First-pole-to-clear factor (in a three phase system)

When interrupting any symmetrical three-phase current the first-pole-to-clear factor is the ratio of the power frequency voltage across the first interrupting pole before current interruption in the other poles, to the power frequency voltage occurring across the pole or the poles after interruption in all three poles.

Restriking Voltage

The transient voltage which appears across the breaker contacts at the instant of arc being extinguished is known as restriking voltage.

Recovery Voltage

The power frequency rms voltage, which appears across the breaker contacts after the arc is finally extinguished and transient oscillations die out, is called recovery voltage.

Various Intervals during interrupting process of circuit-breaker

A circuit-breaker has two basic positions: closed and open.

In the closed position a circuit-breaker conducts full current with negligible voltage drop across its contacts.

In the open position it conducts negligible current but with full voltage across the contacts. This defines the two main stresses, the current stress and the voltage stress, which are separated in time.

If a closer attention is paid to the voltage and current stresses during the interrupting process, three main intervals can be recognized shown in Fig.1.1.

(a) High current interval

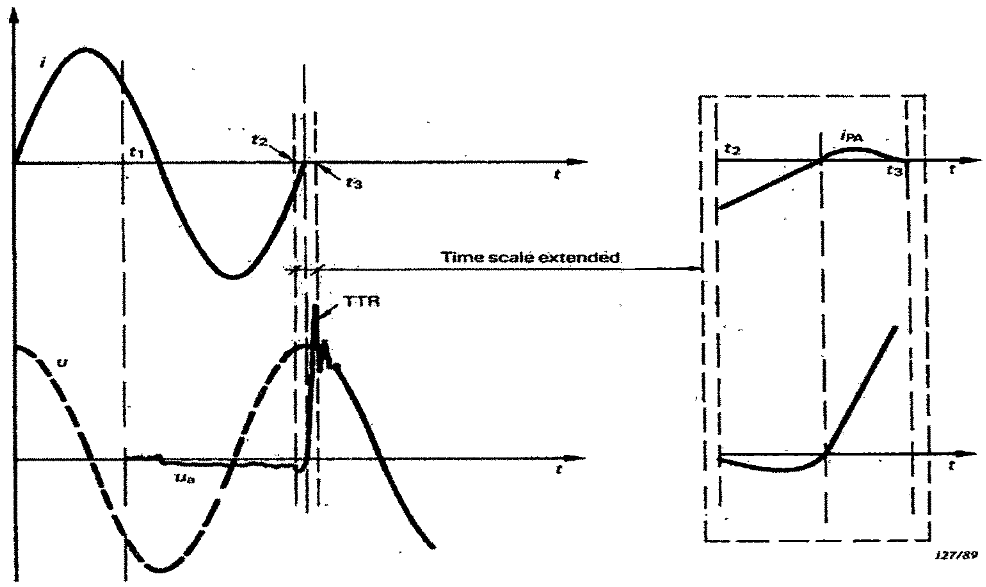
The high current interval is the time from contact separation to the start of the significant change in arc voltage. The high current interval precedes the interaction and high voltage intervals.

(b) Interaction interval

The interaction interval is the time from the start of the significant change in arc voltage prior to current zero to the time when the current including the post-arc current, if any, ceases to flow through the test circuit-breaker.

(c) High voltage interval

The high voltage interval is the time from the moment when the current including the post-arc current, if any, ceases to flow through the test circuit-breaker to the end of the test.



t_2 = start of significant change in arc voltage

t_3 = instant of cessation of post-arc current

$t_2 - t_1$ = high-current interval

$t_3 - t_2$ = interaction interval

After t_3 = high-voltage interval

Fig.1.1 Interrupting process of circuit-breaker: basic time intervals

1.2 MOTIVATIONS TO THE RESEARCH WORK

Short-circuit tests are conducted to prove the ratings of the circuit-breakers. Short-circuit tests can be performed either by direct testing or indirect testing methods.

Development in Electrical power transmission system requires the use of circuit-breakers with increasing breaking capacity. At present circuit-breakers are to be installed on 245kV to 1100kV power system with short-circuit ratings up to 120kA.

To test high voltage circuit-breakers, direct testing using the power system or short-circuit alternators are not feasible. The testing of high voltage circuit-breakers of larger capacity requires very large capacity of testing station. To increase testing plant power is neither an economical nor a very practical solution. Even a single pole of EHV circuit-breaker can not be tested by direct means.

The largest test facility in the world, KEMA high power laboratory, with a maximum short-circuit power of 8400MVA and a 145kV, 31.5kA, 3-phase direct test capability, is limited in its power to perform the direct tests. At the present time a complete pole of SF_6 circuit-breaker can consist of a single interrupting chamber with an interrupting power above the 10GVA level. Even KEMA'S high power laboratory can not verify the short-circuit interrupting capability by direct test methods.

The limitations of direct testing using the power system or short-circuit alternators are as follows :

- High cost of installation of testing stations
- Availability of limited power for testing of high voltage and Extra high voltage circuit-breakers
- Requires high power for testing circuit-breakers
- Flexibility of the system available is limited.

Therefore Indirect methods of testing are used for testing of large circuit-breakers.

Direct testing facility available at CPRI high power laboratory in India is of 2500MVA capacity at 36/72.5kV in three phase and 1400MVA capacity, up to 245kV in single phase for testing of circuit-breakers.

The Indirect testing methods can be classified as Unit testing and synthetic testing

Unit testing means testing one or more units separately. Generally, high voltage circuit-breakers are designed with several arc interrupter units in series. Each unit can be tested separately. From the test results of one unit, the capacity of the complete breaker can be determined.

The unit testing method is used in laboratory to test Extra and ultra high voltage circuit-breakers at present. With this method, interrupting units are tested at a part of rated voltage of the complete breaker. This method is recognized by the IEC standard, but one major problem remains, namely the influence of the post-arc conductivity on the voltage distribution across the units. The trend of increasing the interrupting capability of a single interrupting unit will result in it being impossible to test a single unit in the high power laboratory.

Synthetic testing is an alternative equivalent method for testing of high voltage circuit-breakers and is accepted by the various standards.

At present, synthetic testing facility for testing high voltage circuit breakers at CPRI high power laboratory, Bangalore is only up to 245kV, 63kA rating circuit breakers.

In this research work, 4-parameters TRV synthetic testing circuit has been proposed for testing circuit breakers of ratings up to 800kV for both terminal fault and short-line fault test conditions with optimized circuit components according to new TRV descriptions or parameters given in IEC 62271-100 (2008).

1.3 OBJECTIVES OF THE RESEARCH WORK

The following objectives have been laid down for this research work:

- To carry out investigations and research on the existing methods of testing circuit-breakers and their comparison.

- Detailed study about TRV rating concepts, TRV circuits, IEC standards TRV envelopes and standard values of TRV parameters for a particular ratings of circuit-breakers.

- Short circuit tests require circuit with response specified by IEC standards for 2 - Parameters and 4 -Parameters TRV envelopes.

  To develop program or software for finding circuit components and to optimize the values of capacitance banks for the desired TRV parameters according to IEC standards for a particular rating of circuit-breaker.

- To design and simulate 4-parameters TRV synthetic testing circuit for testing circuit-breakers of rating up to 800kV for both Terminal and short-line fault test duty conditions with optimized circuit components according to new TRV descriptions or parameters given in IEC 62271-100.

- To Analyze, design and simulate 2-parameters TRV synthetic testing circuit for testing medium voltage circuit for both Terminal and short-line fault test duty according to new TRV descriptions or parameters given in IEC 62271-100.

- To design and simulate various 4-parameters TRV control circuits based on parallel current injection method for a 245kV and 420kV rating circuit-breakers as per new TRV descriptions or parameters given in IEC 62271-100 for comparison purpose.

- To develop and fabricate laboratory model for 4-parameters TRV control circuits in order to verify the designed and simulated results.

  Also in order to test circuit-breakers by synthetic testing, it is needed to accurately control the synthetic test circuit so as to satisfy the test criterion. So to develop and fabricate automatic controller with triggering circuit for interrupting short circuit current and to fire the triggered spark gap at the desired moment.

1.4 PREVIEW OF THESIS

The research work reported in this thesis has been focused on the analysis, design, simulation and development of synthetic test circuits (TRV shaping circuits) with automatic controller and triggering circuit for testing high and extra high voltage circuit-breakers of ratings up to 800kV according to IEC standards.

The work reported in this thesis has been organized into 8 chapters. The contents of each chapter are presented in brief in the following paragraphs.

Chapter 2 reviews and reports various methods of testing circuit-breakers and their comparison, necessity of synthetic testing for circuit-breakers, comparison of various synthetic test circuits. It also covers the literature surveyed during the work carried out.