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DESIGN AND SIMULATION OF 2-PARAMETERS TRV SYNTHETIC TESTING CIRCUIT FOR MEDIUM VOLTAGE CIRCUIT BREAKERS

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ABSTRACT

Short circuit tests on circuit breakers are performed to prove the ratings of the circuit breakers.The drawbacks of direct testing using the power system or short circuit alternators: direct testing requires high power for testing CBs, high cost of installation, flexibility of the system available is limited and availability of limited power for testing of high voltage circuit breakers . Synthetic testing is an alternative equivalent method for testing of CBs.Parallel current injection synthetic testing method is widely used for testing CBs as it is capable of providing RRRV and recovery voltage as required by various standards.

This paper discusses the transient recovery voltage(TRV) rating concepts. Analysis and design of 2-parameters TRV synthetic testing circuit is done by using MATLAB. Computer simulation is performed to verify the validity and effectiveness of the circuit by means of PSIM simulator. Design examples and simulation results are shown for a medium voltage circuit breakers i.e for 12kV and 36 kV circuit breakers.

Index Terms-TRV rating concepts, TRV circuits, CBs, Synthetic tests.

1. Principle of Synthetic Testing

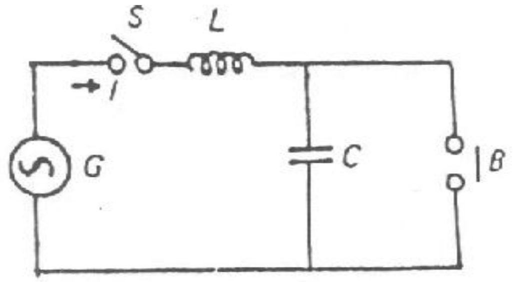


Fig.1. Basic circuit for testing C.B.

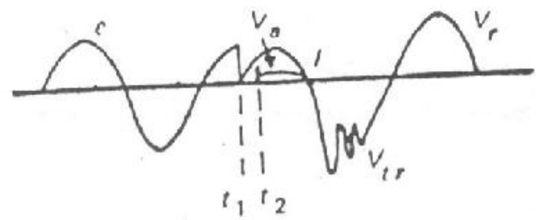


Fig. 2. Voltage waveforms across test C. B.

Fig.1 illustrates the principle of synthetic testing.When switch S is closed, short- circuit current I flows through the breaker B and when the test breaker B begins to open an arcing voltage V_a appears across the breaker terminal as shown in Fig.2. At current zero when the arc is extinguished a transient voltage V_{tr} appears across the breaker whose form is determined by the generator characteristics and the circuit constants L and C. The breaker has to withstand this transient recovery voltage if it is to clear the circuit.

During the period of main current flow there is comparatively small arcing voltage appears across the breaker and that during the period of transient recovery voltage little or no current flows through the breaker. Therefore there is no need to use a single high power source. Instead, the current can be supplied by a comparatively low voltage source, since the arc voltage is usually very small of the order of 1/20th of the rated voltage of the breaker, and the voltage can be applied from low energy HV source at the point of current zero to simulate recovery voltage.

2. SYNTHETIC TESTING OF CBS

In this method of testing, there are two sources of power supply for the testing.

(i) Current source (ii) Voltage source

The current source is a high current, low voltage source. It supplies short circuit current during the test.

The voltage source is a high voltage low current source. It provides restriking and recovery voltage.

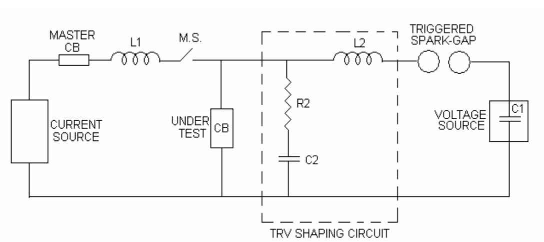


Fig.3. Synthetic testing circuit

The synthetic testing circuit is shown in Fig.3, where inductance L1 is to control the short circuit current. The master CB is used as backup circuit breaker. Make switch is used to apply short circuit current at the desired moment during the test.

The capacitor C1 is a high voltage source. L2, R2 and C2 are to control transient recovery voltage and RRRV. The triggered sparkgap is fired slightly before the short circuit current reaches its natural zero. There is a control circuit to fire the triggered spark gap at the desired moment.

Advantages

- The breaker can be tested for desired TRV and R.R.R.V.
- The short-circuit generator has to supply current at a relatively less voltage (as compared to direct testing).
- Both test current and test voltage can be independently varied. This gives flexibility to test.

3. IEC STANDARDS TRV ENVELOPES

Short circuit tests require circuit with response specified by IEC standards shown in Fig. 4 and Fig.5.

➢ IEC standards define two TRV envelopes.

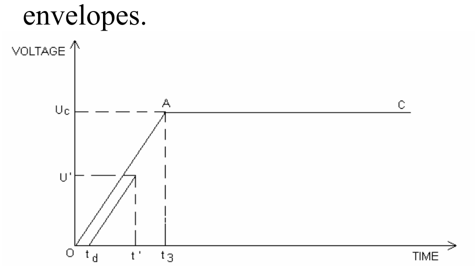


Fig. 4. 2 parameters TRV envelope

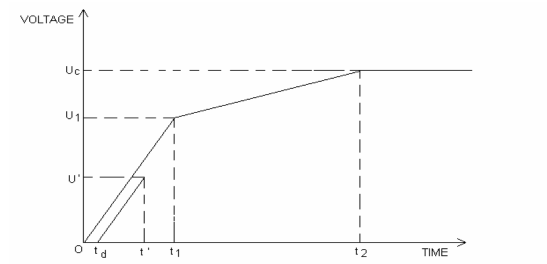


Fig. 5. 4 parameters TRV envelope

3.1 Case of Two Parameters

For circuit breakers rated 72.5 kV and below, the envelope is defined by the two parameter method shown in Fig. 4.

u_c = reference voltage (TRV peak value) in kV.

t_3 = time to reach u_c in microseconds.

$$u_c = 1.4 \times 1.5 \sqrt{\frac{2}{3}} = 1.715\ E_{rated}$$

$u' = 1/3\ u_c$

t_3 = variable

$t_d = 0.15\ t_3$ for $E_{rated} < 72.5$ kV

$= 0.05\ t_3$ for $E_{rated} = 72.5$ kV

$t' = t_d + ½\ t_3$

3.2 Case of Four Parameters

For circuit breakers rated above 72.5 kV, the TRV envelope is defined by the four-parameter method shown in Fig. 5.

u_1 = first reference voltage, in kilovolts,

t_1 = time to reach u_1, in microseconds

$u' = ½\ u_1$

u_c = second reference voltage (TRV peak value) in kilovolts

t_2 = time to reach u_c in microseconds.

$$u_1 = 1.3 \sqrt{\frac{2}{3}} \text{ times rated voltage}$$

$= 1.061\ E_{rated}$

or

$$u_1 = 1.5 \sqrt{\frac{2}{3}} \text{ times rated voltage}$$

$= 1.225\ E_{rated}$

$t_2 = 3t_1$

$td = 0.02\ t_1$

$u_c = 1.4\ u_1 = 1.485\ E_{rated}$ for grounded systems

$= 1.715\ E_{rated}$ for ungrounded system

Two ratings are available at voltage of 100 to 170 kV.The first, for grounded systems, uses a first pole to clear factor of 1.3.The second, for ungrounded systems, uses a first pole to clear factor of 1.5.For 245 kV and above only the 1.3 factor is used.

4. DESIGN OF 2–PARAMETERS TRV CIRCUIT

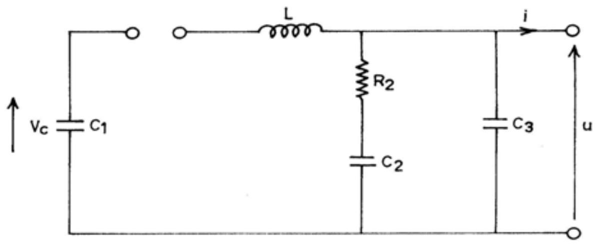


Fig. 6. 2 parameters TRV synthetic testing circuit

The circuit shown in Fig.6 permits to produce 2 – parameters transient recovery voltages (TRV) according to IEC standards. Vc is the charging voltage . C_1, C_2, C_3, L and R_2 are the circuit components. The magnitude and the frequency of the transient restriking voltage depend on the voltage to which the capacitor C1 is charged and the values of circuit components L and C_2. u is the transient restriking voltage. L,R_2,C_2 and C_3 are to control TRV and RRRV.

If we ignore the capacitor C_3, the expression for the transient restriking voltage is as follows :

$$u(t) = \frac{-C_1 v_C}{C_1 + C_2}\left[1 + \frac{e^{-\alpha t}}{\sin\phi}\sin(\beta t - \phi)\right]$$

Where $\alpha = \frac{R_2}{2L}$

$$\beta = \sqrt{\frac{C_1 + C_2}{LC_1C_2} - \frac{R_2^2}{4L^2}}$$

$$\tan\varphi = \frac{C_1}{C_1 + 2C_2} \times \frac{\beta}{\alpha}$$

The flowchart to design 2-Parameters TRV synthetic testing circuit is shown below.The program in MATLAB was developed for finding TRV parameters of single frequency(2- parameters) TRV synthetic circuit.Two design examples are solved for circuit breakers of rating 12kV and 36kV. The TRV envelops obtained for 12 kV and 36kV CBs are shown in Fig.7 and Fig.8 respectively.

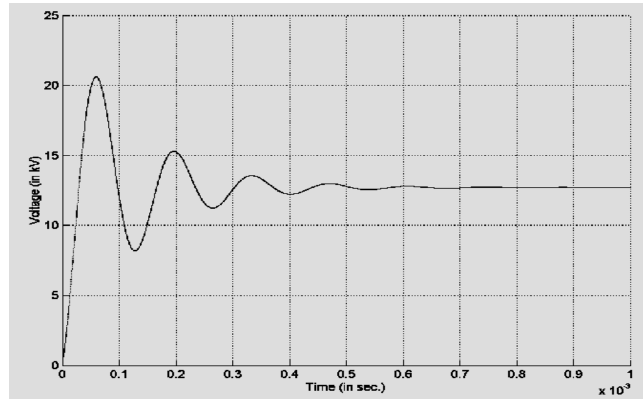
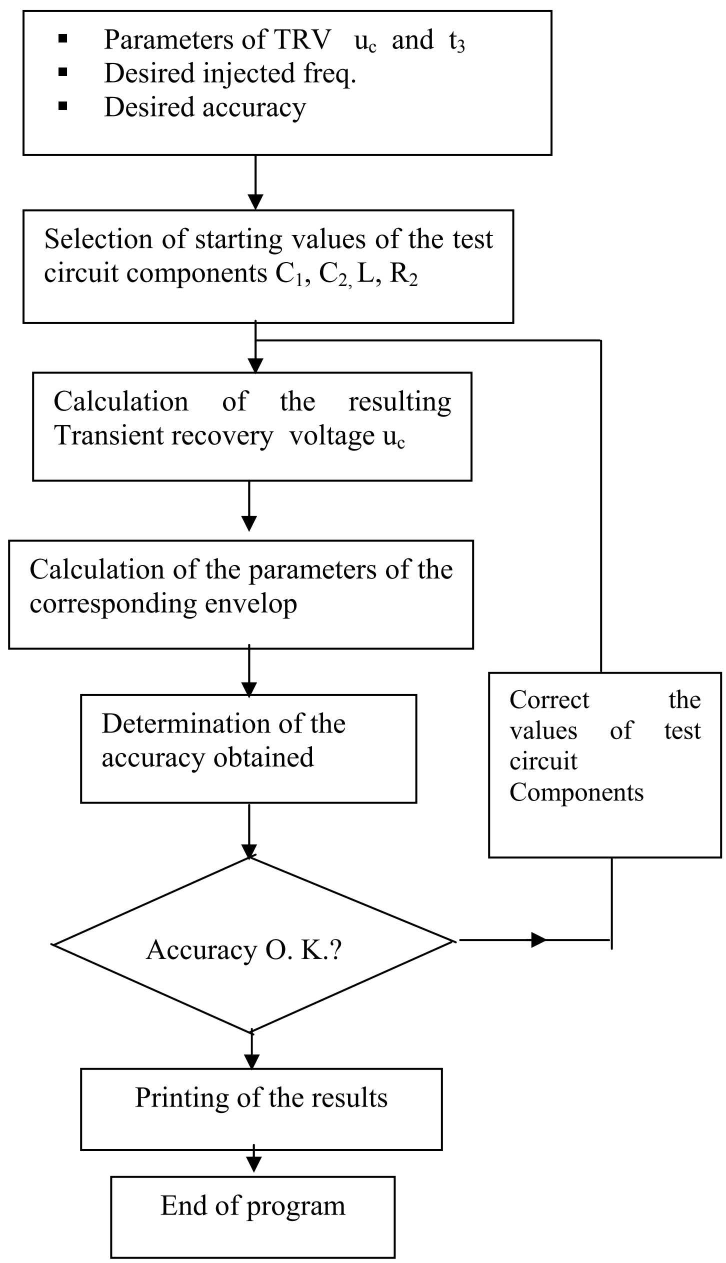


Fig.7. TRV curve for 12 kV CB. (by MATLAB)

Flow Chart for design of synthetic testing circuit:



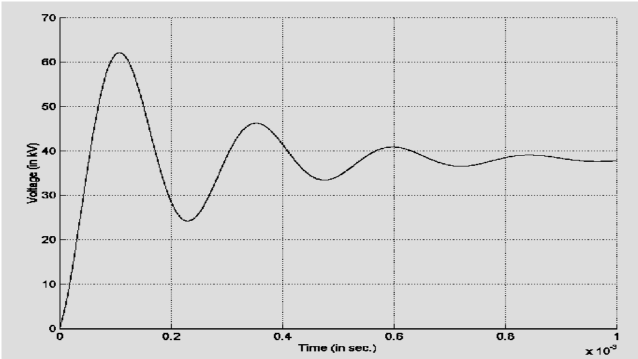


Fig.8. TRV curve for 36kV circuit breaker (by MATLAB)

TRV parameters from the TRV curve of Fig. 7 for 12kV circuit breaker :

Rated voltage, kV	12
TRV peak value u_c, kV	20.6
Time co-ordinate t_3 ,µs	60
RRRV, u_c/t_3, Kv/µs	0.345

TRV parameters from the TRV curve of Fig.8 for 36kV circuit breaker :

Rated voltage, kV	36
TRV peak value u_c, kV	62
Time co-ordinate t_3 ,µs	107.5
RRRV, u_c/t_3, kV/µs	0.576

5. SIMULATION OF 2-PARAMETERS TRV CIRCUIT

The simulations were also carried out with the PSIM software. The circuit shown in Fig. 6 were simulated for 12kVand 36 kV circuit breakers. The TRV curves obtained are shown in Fig. 9 and Fig.10.

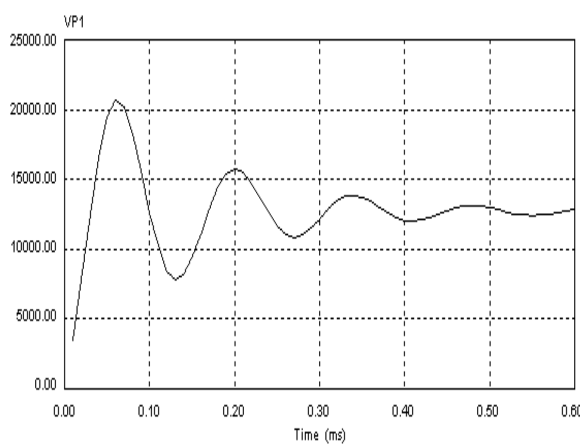


Fig. 9. TRV curve for 12kV circuit breaker by PSIM

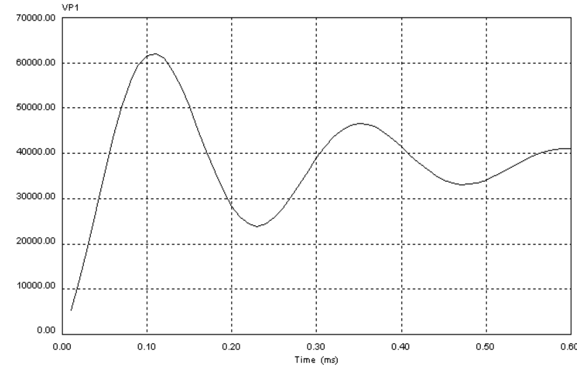


Fig. 10. TRV curve for 36kV CB by PSIM

TRV parameters from these waveforms are shown in table below:

Rated voltage, kV	12	36
TRV peak value u_c, kV	20.599	62
Time co-ordinate t_3 ,µs	60.7	108
RRRV, u_c/t_3, kV/µs	0.34	0.57

6. CONCLUSION

IEC standards define the parameters of TRV, it is quite impossible to analytically link these parameters with the values of the components of the test circuit. So a digital computation is first necessary in order to determine the parameters of the TRV corresponding to a given test circuit.

The objective was to design and simulate 2-Parameters TRV synthetic testing circuit for medium voltage circuit breakers. Design was done by using MATLAB and simulations were carried out by PSIM software. The results shown are the same according to IEC standards.

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