ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

Review: To Investigate Impacts of Various Factors on the Characteristics of Transient Recovery Voltage

Satyam S.Chandankar[1], Anita A.Bhole[2]

PG Student [EPS], Dept of EE, Government College of Engg, Aurangabad, Maharashtra, India

Associate Professor, Dept of EE, Government College of Engg, Aurangabad, Maharashtra, India

ABSTRACT: The Characteristic of Transient Recovery Voltage includes Peak amplitude & Rate of Rise of Recovery Voltage. Transient Recovery Voltage is an important Rating of Circuit breaker as it has to with stand it for successful interruption of fault current. Transient Recovery Voltage primarily depends upon Nature of circuit being interrupted. It will also depend upon the grounding system of the network. Another vital factor which affects Transient Recovery Voltage is Series Compensation. Other factors which affect TRV are Type of fault, Distance of fault location, Fault clearing Time. This paper presents a literature review on Impact of above factors on Transient Recovery Voltage. Thyristor Controlled Switched Capacitor (TCSC) is used for series compensation. Effects of Transient Recovery Voltage on Circuit Breaker are also reviewed.

KEYWORDS: Circuit Breaker (C.B), Thyristor Controlled Switched Capacitor (TCSC), Transmission Line, Transient Recovery Voltage (TRV), Rate of Rise of Restriking Voltage (RRRV).

I.INTRODUCTION

Overloading of line is a limiting factor to Transmit Power through a Transmission Line. It is caused due to change in Load & Faults taking place on line. As a result Voltage collapse take place & it is undesirable for Secure & Economic operation of line. Such problems can be mitigated by providing sufficient margin of power transfer but in practice is not possible due to Expansion of Transmission Network. Another technique is use of FACTS devices. TCSC is used for compensating part of Inductive Reactance of long transmission lines so voltage drop across line decreases and voltage profile improves. The current flowing through line increases and so active power transmitted over a transmission line also increases. Any Disturbance in the power system cause generator connected to the system to accelerate or De-accelerate which in turns lead to power swing. It results in shift of impedance to distance relay from normal load area and cause relay to trip. Thus it is necessary to compensate the power oscillation which can be achieved by using TCSC. TCSC is one of family member of Series compensation & is preferred over other types of series compensation because Reactance of Thyristor Controlled Switched Capacitor (TCSC) can be controlled continuously and instantaneously. Also by simply controlling firing angle of thyristors of TCSC degree of compensation can be controlled & the conventional thyristors are having more Current & Voltage blocking capability.

Transient Recovery Voltage severely affects duties of circuit breaker. It causes air around circuit breaker to be stressed & leads to insulation failure which further leads to failure of circuit breaker to operate. Also there is always a race between dielectric strength & restriking voltage. If the restriking voltage is more than dielectric strength of breaker then it cause reigniting of arc which again leads to failure of circuit breaker to operate. It is therefore necessary to investigate the Transient Recovery voltage.It can be minimized by using Resistance switching in which a resistance of large value is placed across the contacts of circuit breaker so the energy stored is dissipated to resistor.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

II.TCSC MODEL INCLUDING PROTECTIVE DEVICE

(i) Series Capacitor

(a) The size of series capacitor is decided on basis of the positive sequence impedance of Transmission line.

$$X_L = 2 * \pi * F * L_1 \qquad (1)$$

$$K = \frac{X_C}{X_L} \qquad (2)$$

$$X_C = \frac{1}{2*\pi*F*C_S} \qquad (3)$$

Where, X_L is reactance of transmission line; K is degree of compensation; X_C is capacitive reactance.

(b) The Best location for Series capacitor is at middle of Transmission line as voltage sag is Maximum at that point. But due to economical point of view the capacitor banks are located at receiving end sub stations.

(ii) By-Passed Mode

It is also called as the Thyristor Switched Reactor mode of operation. The firing angle of thyristors is varied from range of 90-130 degrees. Transmission Line operating at high voltage whereas capacitor is operating at low voltage. Hence this mode of operation is used to protect the capacitor against the over-voltage. Whenever fault takes place, large amount of current flow through the reactor and thyristor valves. Thus it helps to limit fault current as high impedance is provided to path of short circuit current.

(iii) Blocked-Mode

Gate pulse is blocked so no current flow through Thyristor valve. TCSC behave like a fixed capacitor. This mode of operation is done when line is heavily loaded & voltage profile has to be raised. Firing angle of thyristors of TCSC is kept in range of 140-180degrees.

$$I_S = I_C + I_{MOV} \qquad (5)$$

I_S is the instantaneous current of transmission line; I_{MOV} is the instantaneous current in the metal oxide varistor; I_C is current flowing through capacitor

(iv) Metal Oxide Varistor

They are used for Protection of series capacitor against over-voltage. Due to this reason they are connected in parallel with series capacitor. The Rating of Metal Oxide Varistor is decided on basis of the capacitor voltage & it is 2-2.5 times rated capacitor voltage. The other important rating of MOV is energy rating. An advantage of using MOV is that Re-Insertion time is instantaneous & it is having good non-linear characteristics.

(v) Spark Gap & By pass breaker

When the Metal Oxide Varistor exceeds its specified energy rating then spark gap conducts after a delay about of 1milli second & then it sends a tripping signal to By-pass breaker. The contacts of By-pass breaker is opened initially. It not only By-passes the series capacitor but also the Metal oxide varistor. It must be able to carry the rated MOV voltage as well as maximum capacitor discharge current. They are specially designed & rated to with stand higher transient frequency & interrupting current when by passing a series capacitor

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

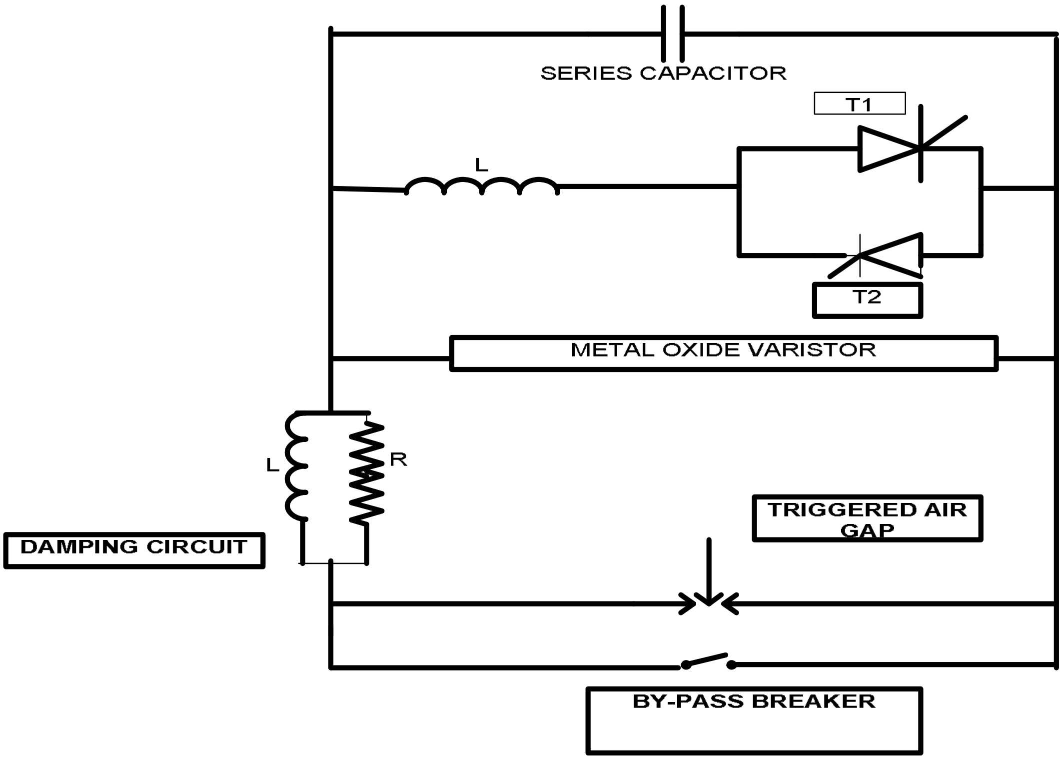

Fig. 1 TCSC model including protective device

(vi) Damping Circuit

It will consist a parallel combination of Resistor & Inductor. It is placed in series with the by-pass breaker & spark gap to limit & damp capacitor discharge current when spark gap triggers or by pass breaker is closed

III.TRANSIENT RECOVERY VOLTAGE

i. Basic concept

Circuit interrupting devices considered as a link that join two electrical networks. One side of electrical network delivers power which is source side & other side which consumes power is load side. When the interrupting device is opened, two electrical networks Re-distribute its trapped energy. As a result each network Re-distribute its trapped energy. Therefore each network develops a voltage that appears across simultaneously at respective terminal of interrupter. The algebraic sum of these two voltages represents the Transient Recovery Voltage. Nature of Recovery Voltage depends upon circuit being interrupted whether it is a Resistive, Inductive or Capacitive Circuit or combination of it..Additionally Distributed & Lumped circuit elements will produce different TRV wave shapes

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

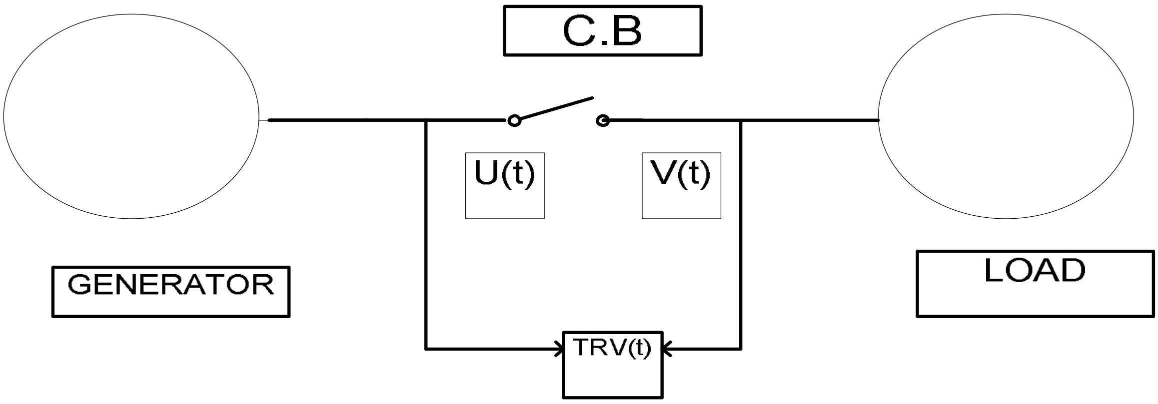

Fig. 2 TRV basic concept

ii. Definitions:

(a) **Transient Recovery Voltage (TRV):** It is the voltage that appear across the breaking contacts at the instant of Arc Extinction

(b) **Recovery Voltage:** It is voltage that appears across breaker contact after the complete removal of transient oscillations & final extinction of arc has resulted in all poles.

(c) **Rate of Rise of Restriking Voltage (RRRV):** It is ratio of peak value of the Restriking voltage to time taken to reach peak value

(i) Mathematical Expressions:

(a) **Amplitude of Transient Recovery Voltage (TRV)** = Transient Amplitude factor*First pole to clear factor*$\frac{\sqrt{2}}{\sqrt{3}}$* Rated maximum voltage

(b) **Transient Recovery Voltage** = Rated maximum voltage* (1-cos $W_0 t$)

Where $W_0 = \frac{1}{\sqrt{L*C}}$

(c) **Rate of Rise of Restriking Voltage (RRRV)** = $\frac{V_{MAX}}{\sqrt{L*C}} \text{Sin} \frac{t}{\sqrt{L*C}}$

iii. Factors affecting Transient Recovery Voltage:

(a) **Resistive Circuit:** Supply Voltage is Zero at time of interruption of current as the Voltage & current are in phase so Recovery Voltage has no transient component.

(b) **Inductive Circuit:** When interrupting a fault in inductive circuit, supply voltage at current zero is maximum. Input power is minimum & voltage on supply side terminal reaches supply voltage. Nature of Transient Recovery Voltage is step function & its amplitude is 1 per unit

(c) **Capacitive Circuit:** The Transient Recovery Voltage across capacitor will be of cosine signal of power frequency, Oscillation will be between 0 – 2 per unit..It will give a DC offset on TRV

(d) **Inductive- Capacitive Series Circuit :** High Frequency Transient Recovery Voltage but of small amplitude called voltage jump

(e) **Grounding** : Transient Recovery Voltage is low in effectively grounded system & more in un-grounded system

(f) **TCSC**: It consists of a series capacitor which decreases impedances of line. Also capacitor is an energy storage element which stores energy in form of Electro-static form of energy. The Electro-static form of energy is related to voltage. Thus when capacitor is discharged it will dissipated this voltage to transmission line which is simply a combination of Inductive & Capacitance elements

(g) **Fault Distance:** Resistance is directly proportional to length of transmission line. With an increase in distance of fault away from Circuit breaker or TCSC , then virtual length of line change & so is the Resistance

(h) **Fault Type:** The Amplitude of fault current depends upon type of fault. Fault current is highest for three phase faults while Lowest for single phase to ground faults. Depending upon amplitude of current to be interrupt accordingly Transient Recovery Voltage will appear across circuit breaker

IV.CONCLUSION

The Amplitude of the Transient Recovery Voltage is most when interrupting a fault current in the capacitive circuit & its peak value is about 2 per unit. The shape of TRV will be step function when interrupting a fault current in inductive circuit whereas it is ramp function in the capacitive circuit. Also TRV will be less when system is effectively grounded. Due to the Thyristor Controlled switched Capacitor (TCSC) it will cause to increase peak amplitude of TRV, whereas it will reduce Rate of Rise of Restriking Voltage (RRRV) .The peak amplitude of TRV & RRRV It is maximum for three phase symmetrical fault with ungrounded neutral & least for single phase to ground fault. If fault is taking place near circuit breaker then TRV will be less & if fault distance is large away from circuit breaker the TRV is reduced. The important effects of TRV on Circuit Breaker are insulation failure & Restriking of Arc.

REFERENCES

[1]M. K. Zadeh , A. S. Akmal, E. M. Siavashi and A. Parvizi, "Impacts of TCSC on switching Transients of HV Transmission Lines Due to Fault Clearing, " International Conference on Power Electronics & Intelligent Transportation System, no. 2, pp.231-237, 2009.

[2] A. Parvizi, M. Rostami, "Sensitivity Analysis of TRV in TCSC Compensated Lines during Fault clearing by Line CB, " IEEE International Conference on Power and Energy, no. 2, pp.1345-1349, Dec.2008.

[3] S. Omar, S. Aboreshaid, "Stochastic Evaluation of Transient Recovery Voltages Across Circuit power breakers of Series Compensated Transmission Lines", IEEE Transactions on Power Delivery, vol.16, no. 2, pp. 33-37, Jan.2001.

[4] S.Henschel, L. Kirschner, M.C. Lina, "Transient Recovery Voltage at Series Compensated Transmission lines", International Conference on Power Systems Transients, Montreal, Canada, June.2005

[5] M.Niasati, M.Pazoki, M.Gholamzadeh, "TRV Evaluation in Advanced Series Compensated System", International Journal of Computer Applications, Volume 34, no. 7, November 2011

[6] S. Warathe, R. N. Patel, "Power Oscillation Compensation by TCSC, " International Conference on Advanced Computing & Communication Systems, " Coimbatore, India, Jan. 2015

[7] IEEE Standard Rating Structure for AC High- Voltage Circuit Breakers ANSI C37.04-2006

[8] H. A. Halim, N. S. Noorpi, N.M. Mukhtar, M. Amirruddin, "Simulation Study of the Transient Recovery Voltage (TRV) on Circuit breaker, " International Conference on computational intelligence, Modeling & simulation, pp.300-305, Perlis, Malaysia, 2013

[9] H. C. Lee, J. H. Park, Y. G. Kim, " Study on transient recovery voltage for testing of high-voltage circuit breakers," International conference on Electric power equipment- Switching Technology, Busan, Korea, no.3, pp.459-461, October.2015

[10] G. V. Prudhviraj, S. Meikandasivam, D. Vijayakumar, " Implementing TCSC device in Kalpakam - Khammam line for power flow enhancement, " International conference on circuits, power & computing technologies, pp 138- 141, 2013

[11] P. A. Kulkarni, R.M. Holmukhe, K. D. Deshpande, P. S. Caudhari, " Impact of TCSC on protection of Transmission line, " International conference on Energy Optimization & control, pp. 117-124, Dec.2010

[12] A. Nekoubin , "Simulation of series compensated Transmission lines protected with MOV," International journal of Electrical, Computer, Energetic, & Communication Engineering, vol. 15, no. 10, pp. 1380-1384, October 2011

[13] P. M. Anderson, " Power System Protection, Wiley-Interscience, " a John Wiley & Sons, Inc., Publication, Chapter 15 Series-Compensated Line Protection, pp 575-642