International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Comparison of Ferroresonance Mitigation Techniques: RLC Circuit and Sparkgap

Vineet S. Ghare MCOER

Nashik, Maharashtra, India

Abstract : ***Ferroresonance incidences in Capacitive Voltage Transformers have been commonly regarded as an unexplained phenomenon due to its complexity. As a result, research conducted in this area is limited and the awareness on ferroresonance is relatively low amongst the utilities. However, as the electrical system evolves, its complexity increases in line with the increasing risk of ferroresonance. Ferroresonance is reportedly causing damaging consequences to power equipment. The application of ferroreso- nant circuits to the engineering problems has become increasingly important from both theoretical and practical considerations. This paper throws a light on methods of ferroresonance supression in Capacitive Voltage Transformers with their comparison. Two methods RLC circuit and spark gap were simulated in PSCAD and results are represented.***

Keywords: Ferroresonance, Capacitive Voltage Transformers, Over Voltages, Damping circuit, RLC Circuit, Spark Gap

1. Introduction

Ferroresonance is a widely studied phenomenon in power systems involving capacitors, saturable inductors and low losses.In linear circuits, resonance occurs when the capacitive reactance equals the inductive reactance at the circuit source frequency, resulting in large currents and voltages. Unlike linear resonance, ferroresonance is not so easy to predict. Due to the non-linearity, several steady state solutions may exist for a particular excitation and range of circuit parameters. The oc- currence of ferroresonant oscillations leads to overvoltage that can be temporary or sustained. The voltages at the terminals of network elements can dangerously exceed nominal values. It results in a degradation of insulating materials, overheating, damage to a device or even a complete destruction. Thus, when ferroresonance appears in electrical power system, it is neces- sary to mitigate it and bring the electrical system to normal state.Nevertheless, the ferroresonance phenomenon depends on many other factors and conditions such as initial conditions of the system, transformer iron core saturation characteristic, residual fluxes in the transformer core, type of transformer winding connection, capacitance of the circuit, point-of-wave switching operation or total losses. So its predictability may be considered as quite complex and difficult.

A low resistance system increase risk of ferroresonant condition. In some cases, a series path is constituted in the system including a saturable inductance and a capacitance. For these conditions, the capacitance is energized through the magnetizing inductance of the transformer. Since in this case the inductance and capacitance are in series, this type of ferroresonance is sometimes referred to as series ferrores- onance. A good example of this would be Capacitive Voltage transformers, which are very lightly loaded, as it feeds voltage measuring devices, becoming prone to ferroresonance condi- tion. Its effects are characterized by high sustained overvolt- ages and overcurrents with maintained levels of current and voltage waveform distortion, producing extremely dangerous consequences. The first step against ferroresonance is always to prevent it from appearing, either by modifying the initial design of the installation or by deciding about the appropriate actions to take. If the establishment of the ferroresonant circuit cannot be avoided, it is necessary to take some preventive measures that make it possible for this phenomenon to be damped. These measures basically consist of introducing some losses in the system, in order to make the energy supplied by the power source insufficient to maintain this phenomenon. These losses can either be temporary or permanent. On the one hand, the latter may affect the efficiency of the installation in a considerable way, even provoking thermal failures under unbalanced situations. On the other hand, if the introduction of these losses were temporary, some sort of ferroresonance detection device would be necessary. Ferroresonance Suppres- sion circuits (FSC) are used to dissipate energies and control Overvoltage. Different kinds of FSC are used now-a-days. Still there remains a scope to develop compact and cost effective circuits for ferroresonance damping. Ferroresonance systems are considered as a nonlinear dy- namic system because of the nonlinear nature of this phe- nomenon, so linear methods cannot be used to analyze fer- roresonance systems. The ferroresonance phenomenon appears after transient disturbances (transient overvoltage, lightning overvoltage or temporary fault) or switching operations (trans- former energizing or fault clearing). Its effects are character- ized by high sustained over voltages and over currents with maintained levels of current and voltage waveform distortion, producing extremely dangerous consequences [1]-[4].

Capacitive voltage transformer (CVT) is greatly used to transform the transmission and sub-transmission voltage levels to voltages that are suitable for monitoring, protection and control applications. Proper design and tuning of CVT com- ponents assure that its output is accurate under steady state conditions. However, during transients in power system such as fault, lightning, capacitive switching, and energizing the system, the CVT output waveform is not an exact replica of the input waveform. It may result in ferroresonance conditions as all the parameters are fulfilled which are necessary for the condition which may result in over voltages and over currents. Ferroresonance may occur in various modes like Chaotic, Sub harmonic, etc. Now-a-days transformers are made of low-loss with high magnetic flux density materials and so frequency of ferroresonance occurrence in CVTs will be increased in future. It has been proved that during ferroresonance in CVTs there are predominant 1/3rd Sub harmonic frequencies [5]- [6]. Suppressing ferroresonance is necessary as it may damage the insulation or core and results in breakdown of CVT. Maintaining the working flux density of the electromagnetic units at much lower levels as compared with the conventional voltage transformers. Greater utilization of the linear position of the magnetization curve by using strip wound cores, thus avoiding local saturation effects. Providing an air gap in the magnetic circuit to maintain the linearity of magnetizing induc- tance over a wide range of operating conditions. Connecting a suitable damping resistance permanently across the secondary. Deploying auxiliary tuning and damping networks in the electromagnetic unit. In this case, it is necessary that addi- tional precautions, are-taken to avoid introduction of additional transients in the process of damping ferroresonance effects. Various Suppressing circuits have been designed to suppress these oscillations. They are mainly classified as Active, Passive and Electronic type FSC. [7]-[11] The literature survey gives a scope to develop and analyze various circuits which may be compact and economical to damp these oscillations. From the literature survey it is observed that ferroresonance occurs in capacitive voltage transformer. Various ferroreso- nance suppression techniques have been proposed as mitigation solutions for ferroresonance in CVT in the literatures. The most common ferroresonance suppression techniques are the active FSC and passive FSC. Ferroresonance in CVTs may be further analyzed for its behavior and there may be a scope to develop FSC which is simple, compact & cost effective in practical conditions.

2. Capacitive Voltage Transformer

A generic CVT consists of a capacitive voltage divider (CVD), compensating reactor, a step down transformer (SDT) and ferroresonance suppression circuit (FSC). The function of capacitor voltage divider is to step down the line voltage to designated voltage level and it is typically 5kV to 15kV. This voltage level is further reduced to relaying voltage level through a step down transformer. The function of the compen- sating reactor is to prevent any phase shift between primary and secondary voltages due to capacitive divider network. Compen- sating reactor cancels the capacitive reactance contributed by capacitive divider network at the system frequency. It can be seen that there is a tapped primary in CVT. Taping is used to set the accuracy of CVT in its specified class.

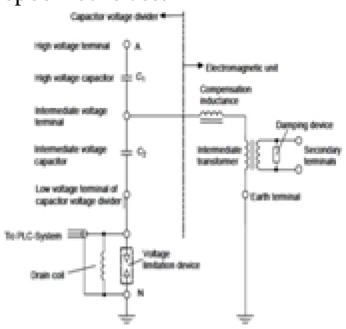

Figure 1: Capacitive Voltage Transformer Basic Construction.

3. Ferroresonance Suppression Circuits in Capacitive Voltage Transformer

Active FSCs
In these FSCs there is permanent load on Auxiliary winding

Passive FSCs
In these FSCs circuit is tuned at particular frequency so in normal condition it acts as open circuit but in case of overvoltage it loads the auxiliary winding

Electronic FSCs
They use thyristorized control to bring external resistor as a burden on winding as and when required. They do not have any energy storing elements. Hence response time is better.

4. Simulation and Results

During ferroresonance, if CVT circuit is undamped, it may result in unpredictable voltages which may damage the insulation of SDT. As defined in IEC 61869-5, ferroresonance oscillations should be damped within 0.5 sec i.e.25 cycles. The conventional damping circuit used is passive one which consists of RLC components. Though it is established tech- nique, it has some drawbacks like bulky circuit, permanent heavy burden and higher cost. This paper compares two ferroresonance damping circuits-one with RLC and another with sparkgap. These results may be useful to make tradeoff between them. Sparkgap circuit is cheap, not so bulky and burden for it comes in picture only after sparkgap fires in case of ferroresonance. Simulation results are also useful for academicians to give indepth understanding of ferroresonance phenomena and its suppression techniques through software.

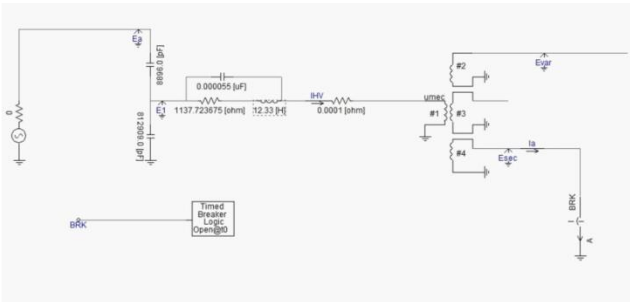

Figure 2: CVT Modelling without Ferroresonance Damping Circuit

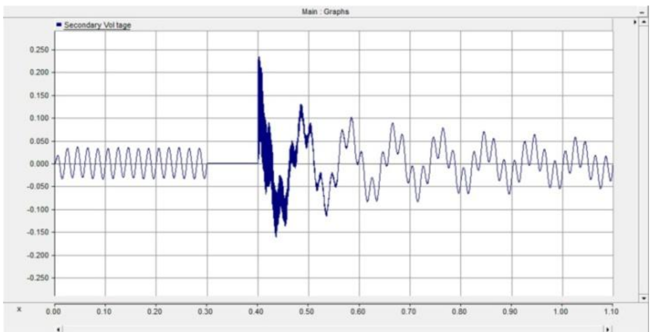

Figure 3: Results of secondary Voltage and Current 80 % of the rated Voltage

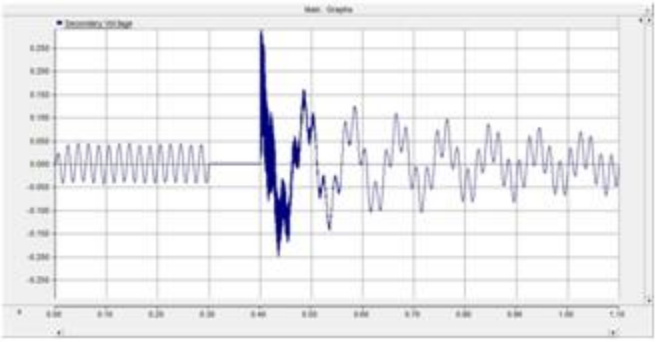

Figure 4: Results of secondary Voltage and Current 150 % of the rated Voltage

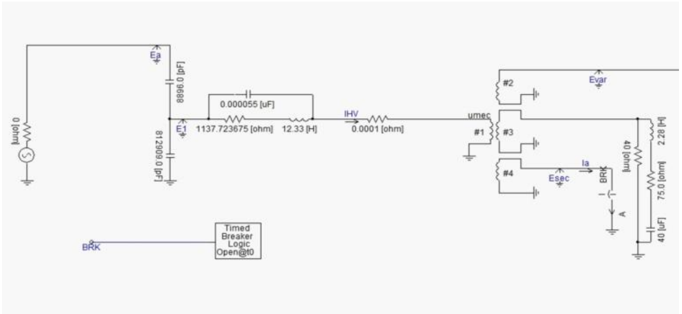

Figure 5: CVT Modelling with RLC Ferroresonance Damping Circuit

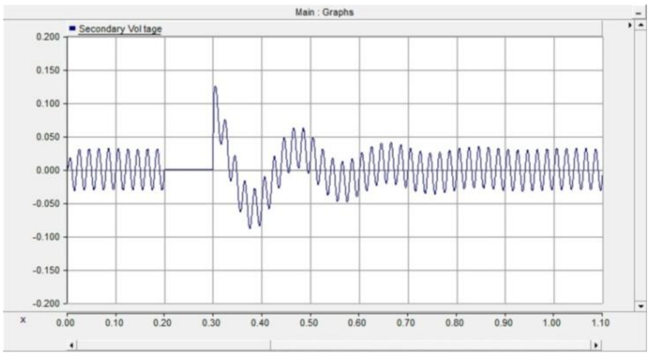

Figure 6: Results of secondary Voltage and Current 80 % of the rated Voltage: Damping in 20 cycles

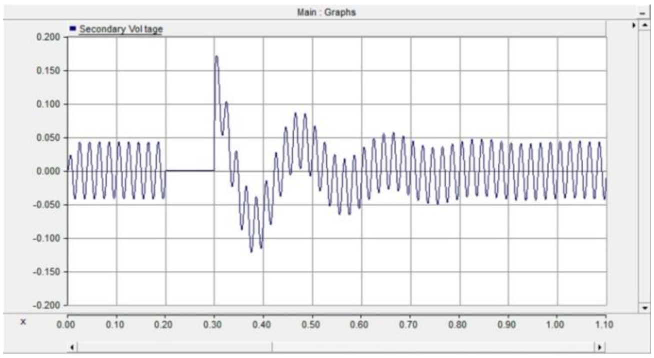

Figure 7: Results of secondary Voltage and Current 150 % of the rated Voltage: Damping in 23 cycle

5. Conclusion

Simulation results in PSCAD show that sparkgap when used in series with resistance as FSC in CVT satisfies the

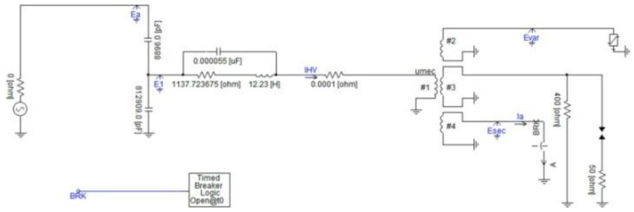

Figure 8: CVT Modelling with Sparkgap Ferroresonance Damping Circuit

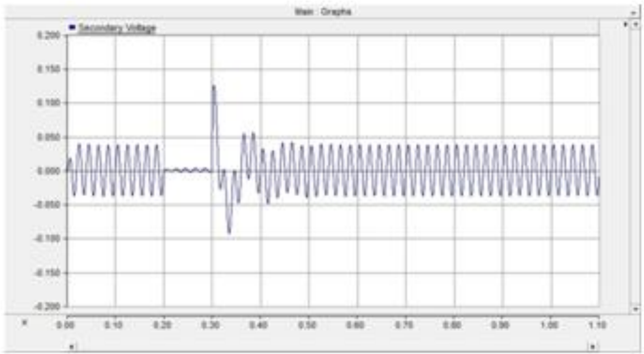

Figure 9: Results of secondary Voltage and Current 80 % of the rated Voltage: Damping in 7 cycle

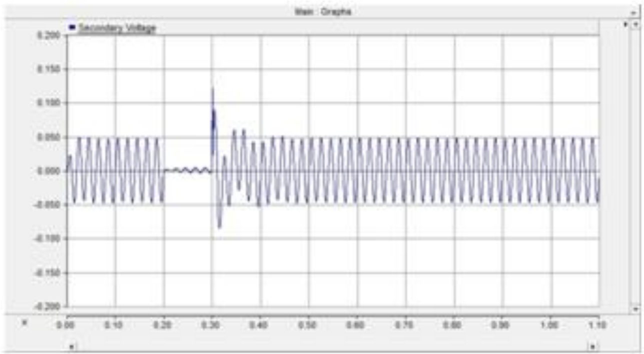

Figure 10: Results of secondary Voltage and Current 150 % of the rated Voltage: Damping in 6 cycle

condition of ferroresonance damping as per IEC61869-5. Thus it is having potential application in ferroresonant damping circuits. It is also having faster response time for damping comparing conventional technique with RLC. It is economical and non bulky solution as compared to conventional RLC damping circuit.

References

[1] V. Valverde, A. Mazon, I. Zamora, and G. Buigues, Ferroresonance in voltage transformers: Analysis and simulations.

[2] E. Price, A tutorial on ferroresonance, *i*n 2014 67th Annual Conference for Protective Relay Engineers, March 2014, pp. 676704.

[3] M. V. Escudero, I. Dudurych, and M. Redfem, Understanding ferroreso- nance, *i*n 39th International Universities Power Engineering Conference, IEEE 2004. UPEC 2004., vol. 3, Sept 2004, pp. 12621266 vol. 2.

[4] Experimental investigation of impact of remnant flux on the ferrores- onance initiation, International Journal of Electrical Power & Energy Systems, vol. 61, pp. 346 354, 2014.

[5] J. Izykowski, E. Rosolowski, P. Pierz, and M. M. Saha, Design of ferroresonance suppression circuit for

capacitive voltage transformer - analytical approach supported by simulation, in 2016 Power Systems Computation Conference (PSCC), June 2016, pp. 17.

[6] Analysis of subharmonic oscillations in a ferroresonant circuit, Interna- tional Journal of Electrical Power & Energy Systems, vol. 28, no. 3, pp. 207 214, 2006.

[7] M. Sanaye-Pasand, A. Rezaei-Zare, H. Mohseni, S. Farhangi, and R. Ira- vani, Comparison of performance of various ferroresonance suppressing methods in inductive and capacitive voltage transformers, in 2006 IEEE Power India Conference, Jan 2006, pp. 8 pp..

[8] J. N. Sakamuri, D. J. Yesuraj, and S. R. Joshi, Simulation and testing of novel ferro-transient suppression circuit for cvt, in 2015 IEEE Power Energy Society General Meeting, July 2015, pp. 15.

[9] J. Sakamuri and D. J. Yesuraj, Modeling and simulation of capacitor voltage transformer transients using PSCAD/EMTDC, in 2011 IEEE Trondheim PowerTech, June 2011, pp. 18.

[10] 5547-1983, Indian standard application guide for capacitor voltage transformers (first revision).

[11] H. Abu Bakar, S. A. Khan, T. C. Kwang, and N. A. Rahim, A review of ferroresonance in capacitive voltage transformer, in IEEJ Transactions on Electrical and Electronic Engineering, vol. 10, no. 1, 2015.