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Impact of MOV-Protected Thyristor Controlled Series Capacitor (TCSC) on Distance Relay Trip Boundaries in the Nigeria 330KV Power System

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Abstract— *Metal-oxide-varistor (MOV) devices, connected in parallel have been used to protect the series compensation against overvoltage during faults. The MOV-protected series compensation increases the complexity of fault analysis and device protection. Hence the performance evaluation of distance protection scheme in the presence of Flexible Alternating Current Transmission Devices (FACTS) controllers which affect the apparent calculations at relay is very essential so as to develop a new setting for zones for distance relay on a transmission line. This work explores the effects of the installation of MOV and Thyristor Controlled Series Capacitor in the Nigeria 330kv transmission line distance relays under various fault conditions.*

Keywords— *FACTS controller:TCSC: Metal oxide varistor: Distance relay: Transmission line*.

I. INTRODUCTION

The Metal Oxide Varistor scheme consists of a capacitor bank, metal-oxide-varistor bank, a triggered bypass air gap, a damping reactor, and a bypass switch as shown in Figure 1(a). The significant part of the protection system is the MOV device which has nonlinear voltage-current characteristics as shown in Figure 1(b). This figure shows that for the voltage across the MOV device below the overload voltage (threshold voltage, or protective voltage), the MOV acts as an open circuit. For voltages above the protection voltage, the MOV acts as a resistor. The higher the overload voltage, the lower is the MOV resistance [1]. MOV devices have nonlinear characteristic and are used for overvoltage surge protection. During high transient voltages, the MOV clamps the voltage to a safe level and dissipates the potentially destructive energy as heat, thus protecting the circuit element from overvoltage and preventing system from damage. The MOV consist of series and parallel arrangement of zinc-oxide disks to achieve the required protective voltage level and energy requirements. The series capacitor bank on each phase typically consists of a number of capacitor unit connected in a series –parallel arrangement to make up for the required voltage, current, and MVar rating [2].

The triggered air gap in the protection scheme is controlled to spark over in an event when the energy absorbed by MOV exceeds its nominal power rating. It is typically used as an intermediate bypass device since it is faster than the bypass circuit switch but not as instantaneous as the MOV. In the case of prolonged gap conduction (such as delayed fault clearing), the bypass switch automatically closes to limit the excess energy for both MOV and the triggered air gap [3]. The damping reactor limits the magnitude of the capacitor discharge current during the spark over of the triggered gap or the bypass breaker switch.

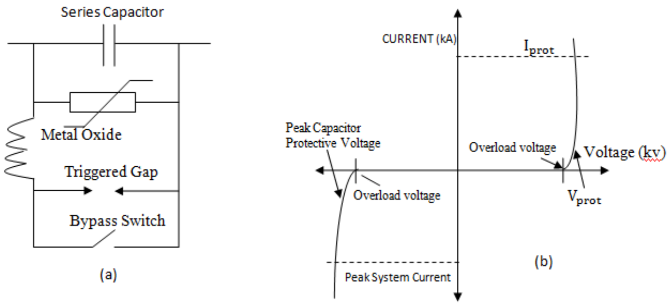

Figure 1 (a) MOV typical overvoltage protection scheme, and (b) V-I characteristics

During normal system operation, the equivalent impedance of the MOV connected in parallel with the capacitor is purely capacitive since the MOV does not conduct any current. During faults, the MOV action modifies the per phase line impedance.

II. MODELLING OF MOV/TCSC EQUIVALENT IMPEDANCE

During normal system operation, the equivalent impedance of the MOV connected in parallel with the TCSC is purely capacitive reactance since the MOV does not conduct any current. During fault, the MOV action modifies the per phase line impedance by partially bypassing the capacitor on the faulted phase [4]. The MOV/TCSC connection can be modelled as a series equivalent impedance during fault as shown in Figure 2.

The linearized model shows an important result that even though the TCSC is connected in parallel with a highly non-linear device, the resulting total current through the combination remains sinusoidal and the MOV/TCSC circuit under fault can be approximated by a reduced single phase circuit of Figure 2. This result is important for determining total line impedance and for distance protection.

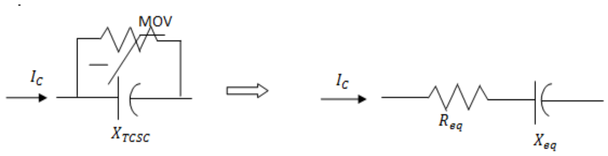

Figure 2: Modelling MOV/TCSC as equivalent impedance during

The linearized model was developed by varying the capacitance, capacitor protective voltage level, system voltage, system impedance, MOV voltage-current characteristics, and other system parameters.

$$Z_{eq} = R_{eq} + X_{eq} \qquad (1)$$

$$R_{eq} = {}^{R_{eq}}\!/_{X_{co}}, X_{eq} = {}^{X_{eq}}\!/_{X_{co}}\ , and\ I_{pu} = {}^{I_{cap}}\!/_{I_{prot}} \qquad (2)$$

III. MODELLING MOV/TCSC IN THE PRESENCE OF FAULT

For the system in Figure 3, consider a single line to ground fault on phase A at a distance, d, away from the TCSC device. Using the information on the system condition calculated by equations (3), (4), (5) and compensation level ($-jx_c$) by equation (6).

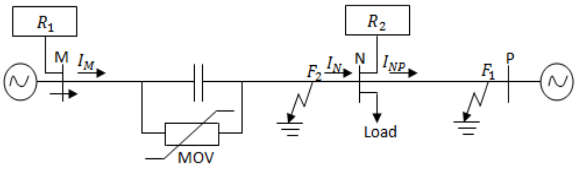

Figure 3: Two Buses with Series Compensation

$$\frac{\bar{E}_P}{\bar{E}_N} = he^{-j\delta} \qquad (3)$$

$$X_C = I_M(Z_{1L}) - I_M(Z_{1MN}) \qquad (4)$$

$$\bar{E}_P = A_P\bar{V}_N - B_P\bar{I}_{NP} \qquad (5)$$

$$\bar{E}_M = \bar{V}_M - Z_{SM1}\bar{I}_M \qquad (6)$$

Where A_p and B_p are the ABCD parameters for the section between bus N and P bus sources. Similarly, E_m is obtained from the measurement at bus M. The seen impedance for line-ground fault can be calculated from relation [5-7],

$$Z_{app} = \frac{\bar{V}_{aM}}{\bar{I}_{aM} + K_0\bar{I}_{M0}} \qquad (7)$$

Where K_o is the zero sequence compensating factor [8], $K_o=(Z_{0L}- Z_{1L})/ Z_{1L,}$ be the zero and positive sequence impedance of the line respectively. The K_0 value is different for the fault beyond the capacitor and depends on the MOV operation. However in this paper, we have fixed value of K_0, for both setting and decision processes which provides correct results and is addressed in [9-11].

The case power system data was taken from Transmission Company of Nigeria (TCN), 2015. One of the longest transmission lines with a length of 280km and 330kv from Ikeja West to Benin was modified to include a FACTS device Thyristor Controlled Series Capacitor which is protected by a Metal-Oxide-Varistor (MOV).

IV. CASE TRANSMISSION LINE IN THE NIGERIA 330KV NETWORK

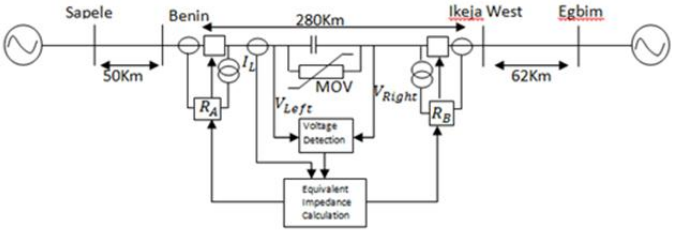

Figure 4: Schematic diagram of the MOV protected TCSC on the Benin to Ikeja west transmission line

A. System Simulations without TCSC

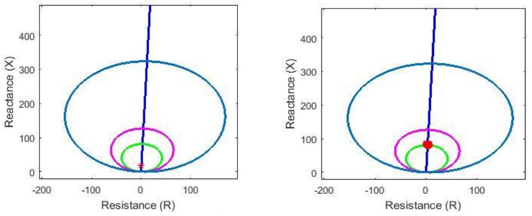

Figure 5: Mho characteristics of Relay A and Relay B for line to ground fault at 50Km without TCSC

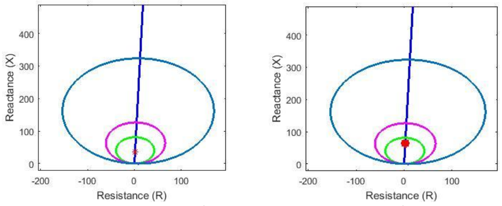

Figure 6: Mho characteristics of Relay A and Relay B for line to ground fault at 100Km without TCSC

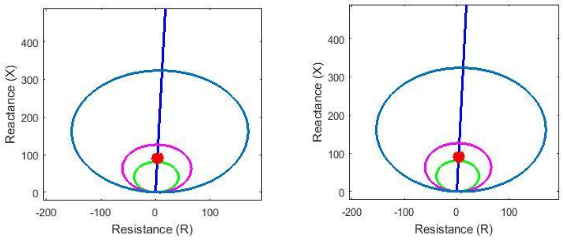

Figure 7: Mho characteristics of Relay A and Relay B for line to ground fault at 250Km without TCSC

Table 1: Relay A and Relay B location without TCSC

Length(km)	Fault Type	R_A	X_A	R_B	X_B	L_A	L_B
50km	LG	0.5387	14.96	0.6488	52.71	52.47	227.50
	L−L	0.641	17.62	6.613	61.14	50.03	229.47
	3Ph	0.642	17.64	3.182	84.18	50.13	228.89
100km	LG	1.201	29.65	1.478	37.85	83.97	106.9
	L−L	1.288	35.4	2.444	65.22	100.1	181.9
	3Ph	1.289	35.4	2.4442	65.23	100.1	181.9
250km	LG	0.2155	58.34	0.3063	9.014	259.05	30.11
	L−L	3.291	49.08	0.3839	10.57	250.17	29.15
	3Ph	3.363	49.08	0.3842	10.57	250.21	29.59

B. System Simulation in the Presence of Facts Devices Considering MOV Protection

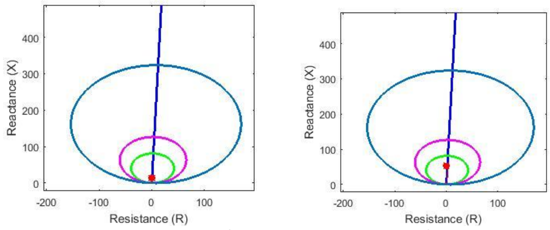

Figure 8: Mho characteristics of Relay A and Relay B for line to ground fault at 50Km in the presence TCSC considering MOV protection

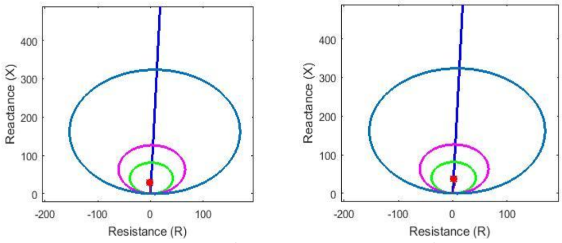

Figure 9: Mho characteristics of Relay A and Relay B for line to ground fault at 100Km in the presence TCSC considering MOV protection

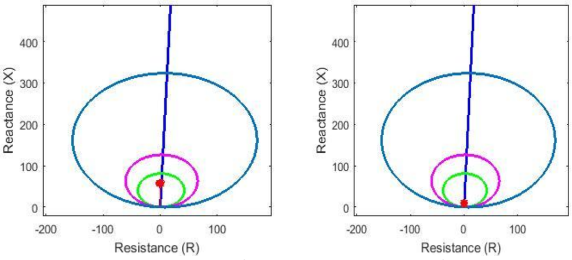

Figure 10: Mho characteristics of Relay A and Relay B for line to ground fault at 250Km in the presence TCSC considering MOV protection

Table 2: Relay A and Relay B location in the presence of TCSC considering MOV protection

Length(km)	Fault Type	R_A	X_A	R_B	X_B	L_A	L_B
50km	LG	1.287	22.49	105.3	57.13	57.13	271.6
	L – L	0.6401	3.225	41.6	50.03	51.15	117.6
	3Ph	0.6394	3.254	41.73	50.03	50.03	118.1
100km	LG	4.225	45.53	13.96	23.67	128.7	182.8
	L – L	1.289	35.4	2.531	23.81	100.1	67.46
	3Ph	1.289	35.4	2.56	23.81	100.1	67.84
250km	LG	26.46	123.9	0.5957	11.47	277.1	32.59
	L – L	3.35	49.06	0.3842	10.57	138.2	30.02
	3Ph	3.365	49.09	0.3841	10.57	138.3	30.02

V. DISCUSSIONS

The MOV is usually used to protect the FACTS device from very high fault current. Figure 8 – figure 10 show examples of the effect of MOV action for different fault locations on a TCSC compensated transmission line. Comparing the results in figure 5 – figure 7 with the result in figure 8 – figure 10 for 40% compensation on the Benin to Ikeja West transmission line, it is shown that for faults behind the MOV/TCSC, the equivalent MOV/TCSC impedance have small resistive components due to relatively small fault current passing through the TCSC from the source. For faults at 250km (after the MOV/TCSC), the fault current passing the MOV/TCSC becomes more significant. Inaccuracies will be more evident with increase in fault current. Larger fault current has a greater effect on the equivalent impedance as the compensation is reduced and the MOV partially bypasses the TCSC to protect it from the high fault current. The compensation level is reduced to nearly zero percent which would have similar effect on the apparent impedance thereby resulting to overreaching or underreaching of the relay. The effect of distributed parameters was also considered in the system simulations.

VI. CONCLUSION

The effects of MOV protection to the distance relay protection scheme in the presence of TCSC on the transmission line between Benin and Ikeja West in the Nigeria electric power system are shown in figure 8 – figure 10. The MOV partially bypasses the capacitor and modifies the equivalent MOV/TCSC impedance. Larger fault current has a greater effect on equivalent impedance. For very higher fault current, the compensation is reduced further to nearly zero percent this is due to the MOV action of protecting the TCSC during this condition and this would have a similar effect on the apparent impedance as shown in the Mho characteristics trajectories. Without adjusting the distance relay settings, overreaching or under-reaching may occur and will cause the relay to mal-operate.

REFERENCES

[1] Sivov, O. V., Abdelsalam, H. A., & Makram, E. B, "Operation of MOV-protected series compensator with wind power during faults*", 47th North American Power Symposium(NAPS)*, Charlotte, NC, USA, 2015.

[2] Mrehel, O. G., Elfetori, H. B., & Hawal, A. O, "Implementation and evaluation of a SIMULINK model of a distance relay in MATLAB/ SIMULINK", *Procurement of Electrical and Electronics Engineering, Clean Energy and Green Computing International Conference,* Tehran, Iran, 2013.

[3] Nayak, P. K., Pradhan, A. K., & Bajpai, P. Secured zone 3 protection during stressed condition. *IEEE Transaction on Power Delivery.* vol. 30, issue 1, pp. 89-96, 2015.

[4] Eissa, M. M, A new digital relaying scheme for EHV three terminal transmission lines. *Electrical Power System Research*, vol. 73, issue 2, pp. 107–112, 2005.

[5] Fortescue, C. L, "Method of Symmetrical Coordinates Applied to the Solution of Polyphase Networks", *Transactions of AIEE*, pp. 1027-1140, 1918.

[6] Gajbhiye, R. K., Gopi, B., & Soman, S. A. Computationally efficient methodology for analysis of faulted power systems with series-compensated transmission line: a phase coordinate approach. *IEEE Trans. Power Delivery*, vol. 23, issue 2, pp.1394-1400, 2008.

[7] Jagdale R., & Validya, G. A., Apparent impedance of ground distance relay using variable zero sequence current compensation factor. *International Journal of Emerging Technology and Advanced Engineering.* vol. 3, issue 8, pp. 12- 17, 2013.

[8] Kundu P., & Pradhan, A. K, Synchrophasor assisted zone-3 operation. *IEEE Transaction on Power Delivery*. vol. 29, issue 2, pp. 660-667, 2014.

[9] Khederzadeh, M., & Sidhu T.S, Impact of TCSC on the Protection of Transmission Lines. *IEEE Transactions on Power Delivery*, vol.21, issue 1, pp. 80-87, 2006.

[10] Mathur, R. M., & Varma R. K, *Thyristor-Based FACTS Controllers for Electrical Transmision Systems.* New York, USA: John Wiley & Sons, 2002.

[11] Phadke A. G., & Thorp, J. S, *Synchronized Phasor Measurements and Their Applications*. New York, USA: Springer, 2008.