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Series Compensated Transmission Lines Defects Observation & Classification Based on Wavelet Transform

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Abstract- Distance protection of transmission lines including advanced Flexible AC Transmission System (FACTS) devices has been a very challenging task. FACTS device of interest in this paper is Fixed Capacitor (FC) connected in series with transmission system. The series devices are compensating reactive power. With their influence on the effective impedance on the line, they have an influence on stability and power flow. These devices are installed on platforms in series to the line. This paper presents application of wavelet transform in fault detection and classification of series compensated transmission line. The proposed scheme uses Discrete Wavelet Transform (DWT), which is widely used in recent for power system protection. DWT is used here to extract the hidden factors from the fault signal. The method used in this paper is based on the three-phase current waveform measured during the occurrence of fault in the power transmission line. The proposed algorithm is validated through MATLAB/Simulink software and the obtained results bring out the application of in fault detection and classification of series compensated transmission line.
Keywords-Flexible AC Transmission System (FACTS), Fixed Capacitor (FC), Discrete Wavelet Transform (DWT), multi resolution analysis (MRA), MATLAB/Simulink software.

1. INTRODUCTION

In Increased transmittable power, improved power system stability, reduced transmission losses; enhanced voltage control and flexible power flow control are the reasons behind installing Series Capacitors (SCs) on long transmission lines [1]. The environmental concerns stand for that too. Both, capacitors of fixed value (FSC – Fixed Series Capacitors) and of controlled value (TCSC – Thyristor Controlled Series Capacitors) are installed in transmission lines. This paper deals with application of MRA for a line compensated with a three-phase bank of fixed series capacitors (SCs) installed at sending end side (Fig. 1). SCs are equipped with their overvoltage protection devices: typically Metal Oxide Varistors (MOVs). Each MOV is in turn protected from overheating with the aid of the thermal protection (TP), which eventually sparks the respective Air-Gap, in order to by-pass its MOV. The compensating bank when installed in a line creates, however, certain problems for its protective relays and fault locators. If a series compensated line suffers a fault behind the SCs & MOVs, The problems mentioned in earlier article with protective relaying for series compensated lines are being extensively explored as a series of studies performed in [1], [2], [3]–[5], [6], [7], [8], [9].

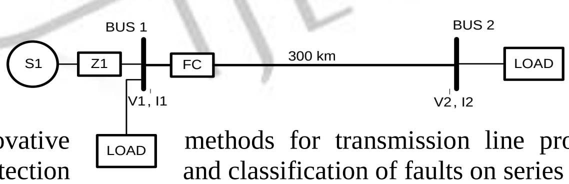

Fig.1 Long transmission line compensated with FC

There is always a need to develop innovative methods for transmission line protection. In this paper, Wavelet Multi Resolution Analysis is used for detection and classification of faults on series compensated transmission lines.

2. WAVELET TRANSFORM AND WAVELET

Wavelet transform (WT) is one of the most efficient methods to analyzed voltage and current of transient behaviour. The powerful feature is non-uniform division of frequency domain. Wavelet can be extracted data from a shot window at a high frequency range. In contract, during a long period of window the low frequency components can be addressed. According to this powerful feature wavelet transform is suitable to analyzed both time and frequency domain. The fundamental functions called decomposition which form as a high and low pass filter. The signal can be decomposed into various frequency bands, which are extracting by the mother wavelet. Mother wavelet selection also shows a different output. WT may consist of 2 main functions namely , scaling function $\varphi(t)$ and wavelet function $\psi(t)$ are defined by the following equations

$$\varphi(t) = \sqrt{2}\sum h(n)\varphi(2t-n) \qquad -(1)$$

$$\psi(t) = \sqrt{2}\sum g(n)\varphi(2t-n) \qquad -(2)$$

Where $g(n) = (-1)^n h(1-n)$

A sequence of $h(n)$ defines a mother wavelet. In this study, preferred mother wavelet is Daubechies (Db) to analyze the sample signal. Many researchers [19, 20] have discussed the properties and application of this mother wavelet. Mathematical expression for wavelet coefficients can be determined by the following expression. $CA1[k] = \sum_{n=-\infty}^{\infty} x(n) \times l[2k-n]$ -(3)

$$CD1[k] = \sum_{n=-\infty}^{\infty} x(n) \times h[2k-n] \quad -(4)$$

$CA1[k]$ and $CD1[k]$ are the coefficients of wavelet decomposition which essentially quantity the contribution strength of analyses signal at level 1. The coefficients also yield with the initialize of Mother Wavelet. To obtain another level of decomposition cascading of procedure are applied. The output signal of low frequency band will be the initial input of the next layer as shows in Fig. 2.

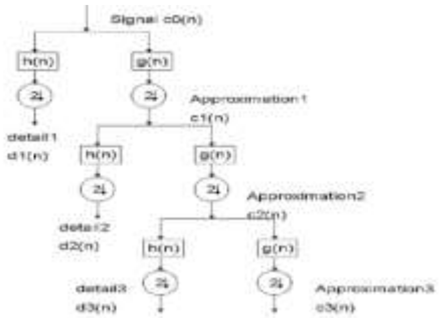

Fig. 2.Wavelet transform Multi- Resolution decomposition

The g(n) and h(n) present the low and high pass filter, respectively which this 2 parameter significant associate with the desire mother wavelet. The transmission line faults in power system are usually classified as Symmetrical faults and Unsymmetrical fault whereas the three-phase fault is termed as a symmetrical type of fault.

3. SIMULATION STUDY AND RESULTS:

A three-phase compensated transmission line with SCs of rating 400 kv and line length of 300 km has been considered for the study. Fig. 3 represents schematic diagram of simulated system.

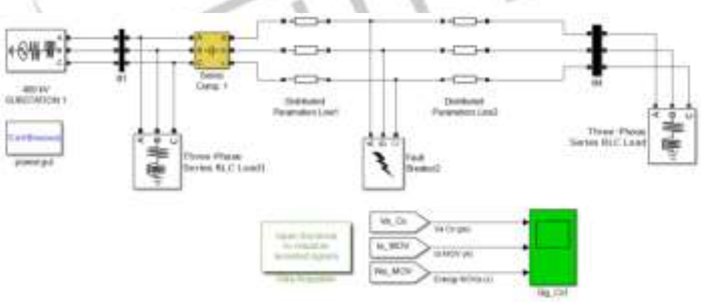

Figure 3 Final Simulation model developed for Long transmission line compensated with FC in MATLAB

System parameters are given in appendix A. for a line compensated with a three-phase bank of fixed series capacitors (SCs) installed at sending end side. SCs are equipped with their overvoltage protection devices: typically Metal Oxide Varistors (MOVs).Each MOV is in turn protected from overheating with the aid of the thermal protection (TP), which eventually sparks the respective Air-Gap, in order to by-pass its MOV. Three phase fault current obtained at source end for different abnormal conditions are utilise for fault identification in simulated transmission line. Sampling time taken for the analysis is 1ms which relates to sampling frequency of 1 KHz, and the total no of wavelet level consider is three, third level output corresponds to frequency band of 125 – 250 Hz, i.e. it consist of 2^{nd} and 3^{rd} harmonic component and are predominant in the situation of transmission line faults. The wavelet toolbox in MATLAB has used for DWT operation. Different decomposition levels such as a3 (Approximation at level three); detail levels one, two, three, represented as d1, d2, d3, respectively can be extracted using wavelet toolbox. The tables give summations of wavelet coefficients of 3 rd values for current in phases A, B and C respectively for different fault inception angle and locations. Different types of fault has been created using simulation model such as single line to ground (L-G), double line to ground (L-L-G), double line (L-L), and triple line (L-L-L).Different types of power system faults are created using simulation model at different fault location (D) having different fault having different fault inception angles (FIA) with different fault resistance (Rf). The waveforms are shown below,

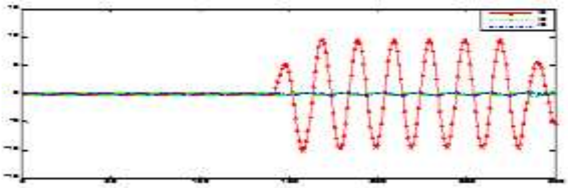

Figure4 Ia, Ib, and Ic for LG fault at D== 100 km, FIA = 0°, Rf= 0.001Ω

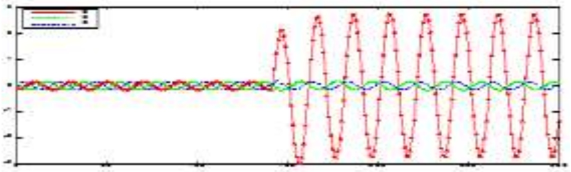

Figure 5 Ia, Ib, and Ic for LG fault at D== 100 km, FIA = 0°, Rf= 100Ω

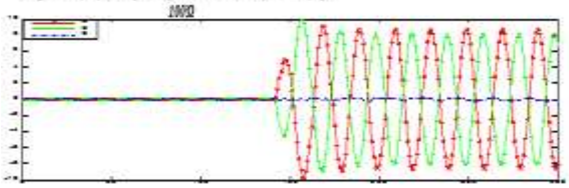

Figure 6 Ia, Ib, and Ic for LLG fault at D= 200 km, FIA = 0°, Rf= 0.01Ω

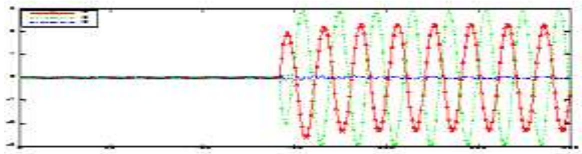

Figure 7 Ia, Ib, and Ic for LLG fault at D= 200 km, FIA = 0°, Rf= 100Ω

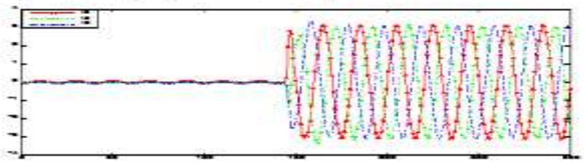

Figure 8 Ia, Ib, and Ic for LLLG fault at D= 50 km, FIA=6 0°, Rf= 0.01Ω

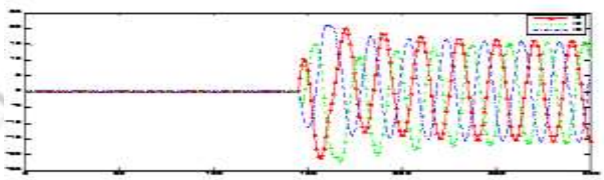

Figure 9 Ia, Ib, and Ic for LLLG fault at D= 50 km, FIA=6 0°, Rf= 100Ω

In order to reduce the computational burden the sampling frequency should not be too high but it should be high enough to capture the information of fault. By randomly shifting the point of fault on transmission line, more number of simulations has being carried out. The generated current signal for each case is analyzed using wavelet transform. A sampling frequency of 1 kHz is selected. In numerical analysis and functional analysis, a discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled. As with other wavelet transforms, a key advantage it has over Fourier transforms is temporal resolution: it captures both frequency *and* location information (location in time). Daubechies wavelet Db4 is used as mother wavelet since it has good performance results for power system fault analysis. Detail coefficients of fault current signal in 3rd level (d3), gives the frequency components corresponding to second and third harmonics. On this basis, summation of 3rd level detail coefficients of the three phase currents Ia ,Ib and Ic are being used for the purpose of detection and classification of faults in the transmission line.

Let Sa, Sb, Sc be the summation of 3^{rd} level detail coefficients for current signals for a, b, c phases respectively. Tables below shows the values of Sa, Sb, Sc for different types of faults. From these tables it is observed that the magnitudes of Sa, Sb, Sc increases whenever any fault occurs in a transmission line. Based on the sampling rate the signal is divided into four decomposition levels.

Table 1 L-G fault with different fault distances the values of Sa, Sb, Sc with FIA = 0°

Fault Location	10 km	50 km	100 km	150 km	200 km	250 km
Sa	-21.7338	-6.7328	-1.0731	-2.9490	-2.2135	-1.7735
Sb	-0.0036	-0.0133	-0.0460	-0.0083	0.0061	0.0185
Sc	0.0376	0.0279	-0.0048	0.0328	0.0473	0.0597

Table 2 L-L fault with different fault distances the values of Sa, Sb, Sc with FIA = 0°

Fault Location	10 km	50 km	100 km	150 km	200 km	250 km
Sa	-9.0003	-3.8612	-2.2661	-1.6008	-1.5370	-1.4120
Sb	8.9706	3.8330	2.2387	1.5886	1.5066	1.3807
Sc	0.0309	0.0294	0.0290	0.0171	0.0313	0.0312

Table 3 L-L-G fault with different fault distances the values of Sa, Sb, Sc with FIA = 0°

Fault Location	10 km	50 km	100 km	150 km	200 km	250 km
Sa	-23.2978	-8.1018	-4.5391	-3.1644	-2.8006	-2.5082
Sb	-5.3347	-0.4120	-0.0323	0.0201	0.0321	0.2817
Sc	0.0456	0.0372	0.0419	0.0448	0.0431	0.0550

Table 4 L-L-L fault with different fault distances the values of Sa, Sb, Sc with FIA = 0°

Fault Location	10 km	50 km	100 km	150 km	200 km	250 km
Sa	-31.4134	-13.2320	-7.7219	-5.4556	-5.0371	-5.3154
Sb	-13.4375	-5.5473	-3.2085	-2.2847	-5.2951	-2.5943
Sc	44.8508	18.7797	10.9294	7.7385	10.6124	7.9097

Among different levels only 3rd level is consider for analysis because the frequency corresponding to this level is covering 2nd and 3rd harmonics which are dominant in the fault conditions.

From Table 1 ,The summation of detail coefficients of all three phases sum is not equal to zero for L-G and L-L-G, which is used to discriminate L-G, L-L-G from L-L and L-L-L, Faulty phase summation value is very high compared to healthy phases. Healthy phase summation values are almost equal.

From Table 2, the summation coefficients in any two phases are equal and the third phase value is very less compared to two faulty phases.

From Table 3, the summation of detail coefficients sum is not equal to zero and all three phases have different summation values (summation coefficients of any two phases is not equal), which is used to discriminate L-G from L-L-G.

From Table 4, the summation of detail coefficients of three phases sum is zero but all three-phase summation values are different, in L-L fault two phases have a same value, which is used to discriminate L-L from L-L-L.

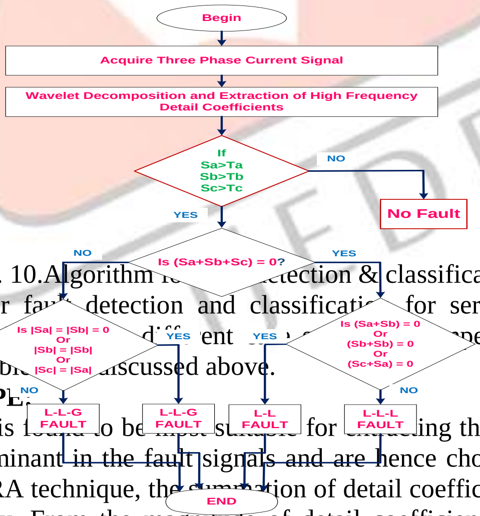

Fig. 10.Algorithm for fault detection & classification

Fig. 10 shows the detailed algorithm for fault detection and classification for series compensated transmission line, with application of wavelet MRA. Result obtained for different faults in series compensated transmission line is the basis for classification logic as shown in table1 to table 4 discussed above.

5. CONCLUSION AND FUTURE SCOPE:

Wavelet multi resolution (MRA) analysis is found to be most suitable for extracting the information from transient fault signals. Second and third order harmonics are dominant in the fault signals and are hence chosen for the analysis (d3 coefficients) and Db4 as mother wavelet. Using wavelet MRA technique, the summation of detail coefficients for third level are extracted from the current signal from sending end side only. From the magnitude of detail coefficient summations, the presence of fault in a particular phase is detected in series compensated transmission line. A generalized algorithm based on wavelets has been verified for the fault detection and classification of compensated transmission line faults. The most important of this algorithm is independent of fault location, impedance and inception angle.

6. REFERENCES:

[1] N. G. Hingorani and L. Gyugyi, “Understanding FACTS Concept and Technology of Flexible AC Transmission System”, IEEE Press, 2000.

[2] P. K. Dash, S. R. Samantaray and G. Panda, “Fault classification and section identification of an advanced series-compensated transmission line using support vector machine,” IEEE Trans. on Power Del., vol. 22, no. 1, pp. 67–73, Jan. 2007.

[3] A. A. Girigis, A. A. Sallam and A. K. El-Din, “An adaptive protection scheme for advanced series compensated (ASC) transmission lines,” IEEE Trans. on Power Del., vol. 13, no. 2, pp. 414–420, Apr. 1998.

[4] F. Ghassemi, J. Goodarzi and A. T. Johns, “Method for eliminating the effect of MOV operation on digital distance relays when used in series compensated lines,” Universities Power Engineering Conference, Manchester, UK, Sept. 10–12, 1997 pp. 113–116.
[5] J. Izykowski, Impedance-based fault location algorithms”, Publisher of Wroclaw University of Technology, 2001 –book in polish.
[6] J. A. S. B. Jayasinghe, R. K. Aggarwal, A. T. Johns and Z. Q. Bo, “A novel non-unit protection for series compensated EHV transmission lines based on fault generated high frequency voltage signals,” IEEE Trans. on Power Del., vol. 13, no. 2, pp. 405–413, Apr. 1998.
[7] D. Novosel, A. Phadke, M. M. Saha and S. Lindahl, “Problems and solutions for microprocessor protection of series compensated lines,” 6th International Conference on Developments in Power System Protection, Nottingham, UK, Conference Publication No. 434, IEE 1997, pp. 18–23, 25–27 March 1997.
[8] E. Rosolowski, J. Izykowski, B. Kasztenny and M. M. Saha, “A new accurate fault algorithm for series compensated lines,” IEEE Trans. on Power Del., vol. 14, no. 3, Jan. 1999, pp. 789–795.
[9] Q. Y. Xuan, Y. H. Song, A. T. Johns, R. Morgan and D. Williams, “Performance of an adaptive protection scheme for series compensated EHV transmission systems using neural networks,” Electric Power System Research, vol. 36, no. 1, Jan. 1996, pp. 57–66.
[10] T. B. Littler and D. J. Morrow, “Wavelets for the analysis and compression of power system disturbances,” IEEE Trans. Power Del., vol. 14, no. 2, pp. 358–364, Apr. 1999.
[11] A. M. Gaouda, M. M. A. Salama, M. R. Sultan, and A. Y. Chikhani, “Power quality detection and classification using wavelet-multiresolution signal decomposition,” IEEE Trans. Power Del., vol. 14, no. 4, pp. 1469–1476, Oct. 1999.
[12] X. Xu and M. Kezunovic, “Automated feature extraction from power system transients using wavelet transform,” in Proc. Int. Conf. Power System Technology, 2002, vol. 4, pp. 1994–1998.
[13] Allipilli, Y.; Rao, G.N., "Detection and classification of faults in transmission lines based on wavelets," in Electrical, Electronics, Signals, Communication and Optimization (EESCO), 2015 International Conference on , vol., no., pp.1-6, 24-25 Jan. 2015
[14] A. I. Megahed, A. M. Moussa, and A. E. Bayoumy, “Usage of wavelet transform in the protection of series-compensated transmission lines,” IEEE Trans. Power Del., vol. 21, no. 3, pp. 1213–1221, Jul. 2006.
[15] O. A. S. Youssef, “Online applications of wavelet transforms to power system relaying,” IEEE Trans. Power Del., vol. 18, no. 4, pp. 1158–1165, Oct. 2003.
[16] D. Chanda, N. K. Kishore, and A. K. Sinha, “Application of wavelet multi resolution analysis for classification of faults on transmission lines,” in Proc. IEEE Conf. Convergent Technologies for Asia-Pacific Region, vol. 4, pp. 1464–1469.
[17] J. D. Duan, B. H. Zhang, and H. X. Ha, “A novel approach to faulted phase selection using current traveling waves and wavelet analysis,” in Proc. Int. Conf. Power System Technology, 2002, vol. 2, pp. 1146–1150.
[18] Q. L. Su, X. Z. Dong, Z. Q. Bo, and F. Jiang, “New approach of fault detection and fault phase selection based on initial current traveling waves,” in Proc. IEEE Power Eng. Soc. Summer Meeting, 2002, vol. 1, pp. 393–397.
[19] Chul Hwan Kim and Raj Agganrval, "Wavelet transforms in power systems Part I General introduction to the wavelet transforms," Power Engineering Journal, April 2000.
[20] Chul Hwan Kim and Raj Agganrval, "Wavelet transforms in power systems Part 2 Examples of application to actual power system transients," Power Engineering Journal, April 2000.