ISSN 2250-3153

Detection of Fault in Fixed Series Compensated Transmission Line during Power Swing Using Wavelet Transform

Rohan Kumar Gupta

M.Tech (Power System Engineering), Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, India

Abstract- At the time of power swing the measured impedance lies inside the relay operating region. There is undesired tripping of Distance relay during power swing without having any fault. So relay must be blocked & must trip after a fault occur during power swing. This paper presents new technique to detect fault during power swing. In the proposed technique process starts by simulating the double transmission line with one line series compensated. When we connect a fixed capacitor in one transmission line, fault detection become more difficult. The detection of symmetrical fault during swing is more difficult. So the proposed technique can easily detect any fault during swing with series compensated line. Sampled data of current and voltage passes through wavelet transform. It decomposes it into different levels. Then we calculate total energy of some selective levels of current and voltage. A double circuit line model is simulated in **EMTDC/PSCAD**.

Index Terms- Power Swing, Wavelet Transform, Fixed Capacitor, Total Energy, Multiresolution Signal Decomposition

I. Introduction

Power system faults, line switching, generator disconnection, and the loss or application of large blocks of load result in sudden changes to electrical power, whereas the mechanical power i.e. input to generators remains relatively constant. These system disturbances cause oscillations in machine rotor angles and can result in severe power flow swings. Power swings are simply oscillations in power flow. In normal fault condition measured impedance value lie within set impedance value of relay but during swing measured impedance value lie within set impedance value without having any fault [1].So to solve this problem there is an element that can distinguish between swing & fault which is called Power swing blocking element (PSB element) .Swing can be stable or unstable. Stable swing dies down in a short time but unstable swing remains for long time & a cause for loss of synchronism in the group of generators. The function which distinguishes between stable and unstable swing and separate the area during loss of synchronism is called out of step function (OST). In this paper we are only detecting fault during swing.

There are many techniques that used till now. One of the conventional techniques is rate of change of impedance. When the measured impedance value moves instantaneously on impedance plane, it is fault & when moves slowly, it is swing [2]. But in case of symmetrical fault during power swing this method unable to detect fault. As in case of unsymmetrical fault there is zero and negative sequence components and during stable swing both components do not present. So symmetrical fault is difficult to detect during power swing. When the double transmission line contain a series capacitor in one line then it is more difficult to detect fault in line during swing. Another method is based on the abrupt decrement of absolute value of the change rate of power swing centre voltage (PSCV) [3]. This takes two cycles for identification of fault**,** which is not acceptable in case of extremely high voltage (EHV) lines. Auto regression technique also used in symmetrical fault detection [4]. Rate of change of power [5] and [6] also used but the accuracy is less and take one and a half power frequency cycle. Approximate entropy of signal [7] also used for fault detection for the duration of swing.

The proposed method wavelet transform detect the fault during swing. First the given samples process through wavelet transform. It decomposes the voltage and current signals into different dyadic levels. Here we are using Db4 mother wavelet. We calculate total energy of some selective levels of current and voltage. The simulation is done using EMTDC/PSCAD of double circuit line with series compensation in one line.

II. EFFECT OF SERIES COMPENSATION ON LINE

Series compensation is used to enhance the power transfer capability of line by reducing the value of line reactance. As power transfer in transmission line for two source system is,

$$P = \frac{V1\ V2}{X} \mathrm{Sin}\delta \tag{1}$$

When a series capacitor is connected in line then power,

$$Pnew = \frac{V1V2}{(X-XC)} \mathrm{Sin}\delta \tag{2}$$

III. EFFECT ON DISTANCE RELAY

Due to the series compensation distance protection is influenced in following ways,

A. Voltage Inversion

There is voltage inversion when the impedance between relay and fault location is capacitive.

i.e. $X=X_s+X_c+X_L$

$X_c>X_L$, $X>0$, $X_c<X_s+X_L$

So due to this voltage seen by protection will be reversed in phase and this will affect relay.

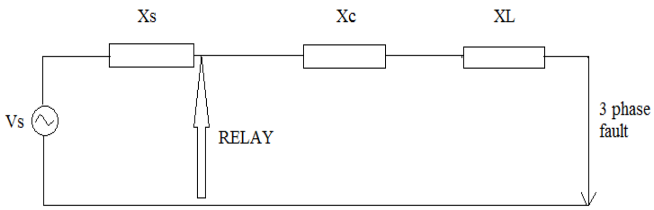

Figure 1: line with Series Capacitor with Fault

B. Current Inversion

There is current inversion when the total impedance between fault and source is capacitive.

$$X<0,$$
$$\text{i.e. } X_c>X_s+X_L$$

C. Subharmonics

When the capacitor and the inductance are connected in series, the combination set up a resonant circuit [], the natural frequency can be calculated,

$$fe=\frac{1}{2\pi\sqrt{LC}}=f\sqrt{\frac{XC}{XL}} \quad (3)$$

f is the power system frequency and X_L is system reactance. Since X_C/X_L is typically in the range of 0.25 to 0.75, f_e will be a sub harmonic of the power frequency.

Due to placing of the capacitor will result in the excitation of system at the sub harmonic frequency which can give rise to transient currents. These transients may last significantly longer.

D. Sub Synchronous Resonance

The occurrence of the transients may also excite one or more of the natural torsional frequencies of the mechanical shaft system of the generator(s). The interaction between capacitor and turbine generator is known as sub synchronous resonance (SSR). The SSR problem is mainly due to the high value of series capacitor. Interaction can damage the shaft torque

IV. SYSTEM STUDIED

The studied double circuit system is design using PSCAD/EMTDC. The complete power system includes parallel transmission lines (distributed model) of 280 km each and connected to the source (600 MVA) at one end and infinite bus at other end. The operating voltage of the transmission line system is 400 kV and the sampling rate is 20 kHz on 50 Hz base frequency (400 samples per cycle). During power swing a fault is applied at 1.81s for 0.01s. The system is given as below,

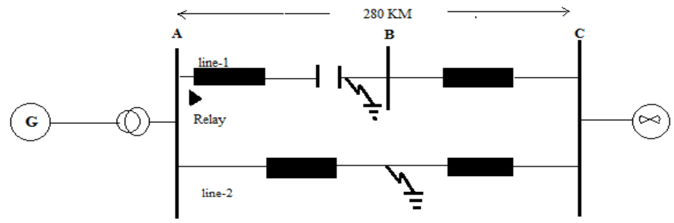

Figure 2: Simulated System

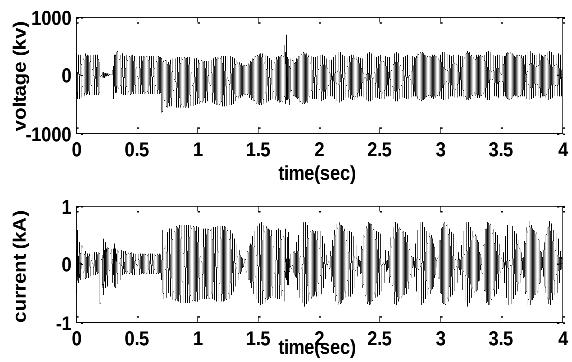

Figure 3: Power Swing in Voltage & Current (δ=45°)

V. PROPOSED TECHNIQUE

There are two types of signal stationary and non – stationary. The signal whose frequency does not change with time are called stationary signal & signal whose frequency change with time are called non-stationary signal.

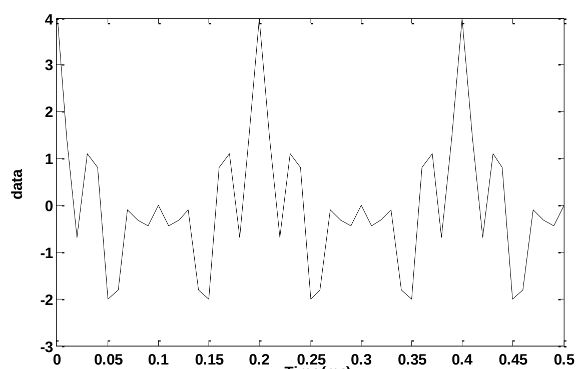

Figure 4: Stationary Signal

The given stationary signal contain different frequency component at any time.

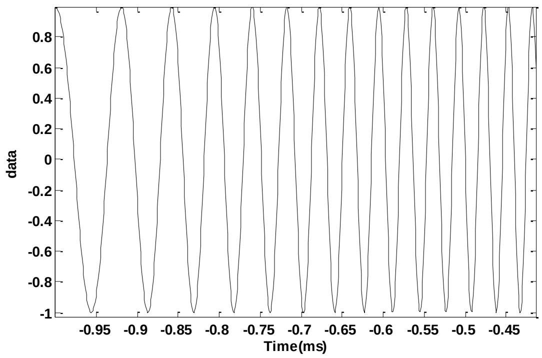

Figure 5: Non-Stationary Signal

Non-stationary signal have two frequency components at different time. So faulty signal is a non-stationary signal.

For signal analysis Fourier transform and wavelet transform are used. But Fourier transform gives only information of frequency of the signal while WT gives information about frequency as well as time of the signal. So this quality of WT can be used in fault analysis because to detect a fault information of signal frequency and time (at what time fault occurred) are required.

FT decomposes the given signal into functions of different frequency,

$$x(f) = \int_{-\infty}^{\infty} f(x) * e^{-2\pi ixf}\, dx \qquad (3)$$

DFT mother wavelet function is given by,

$$\varphi_{m,n}(t) = a_0^{-\frac{m}{2}} \varphi\left(\frac{t - nb_0 a_0^m}{a_0^m}\right) \qquad (4)$$

$$DWT_{\varphi} x(m,n) = \int_{-\infty}^{\infty} x(t)\, \varphi^*{}_{m,n}(t) dt \qquad (5)$$

DWT with multiresolution signal decomposition (MSD) decomposes the signal into different levels. Signal passes through high & low-pass filter. The output of the high-pass filter gives the detail coefficients and the low-pass filter gives approximation coefficients [13],[14].

$$\text{yhigh}[n] = \sum_{k=-\infty}^{\infty} x[k] h\,[2n-k] \qquad (6)$$

$$\text{ylow}[n] = \sum_{k=-\infty}^{\infty} x[k] g\,[2n-k] \qquad (7)$$

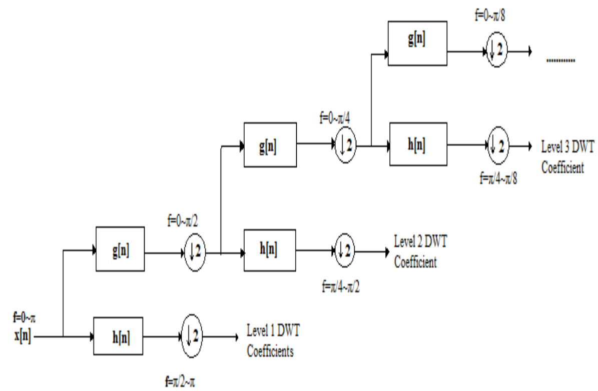

Figure 6: Different Level Decomposition

Since half of the frequency of the signal goes to HPF & half to LPF. The filter outputs are then sub sampled by 2. The process of decomposition will repeat till we get as much levels as we want.

Here we use mother wavelet Db4 (Daubechies wavelet) since it has given good performance for power system transient analysis.

The total energy "D" in each level "d",

$$D = \sqrt{\sum_{i=1}^{N} d(i)^2} \qquad (8)$$

Energy of each selective level i.e. D1 and D2 for voltage & D9 for current is calculated by above formula. D1 and D2 will be used to detect fault during swing & D9 will be used for detection of power swing [10].

VI. SIMULATION RESULTS

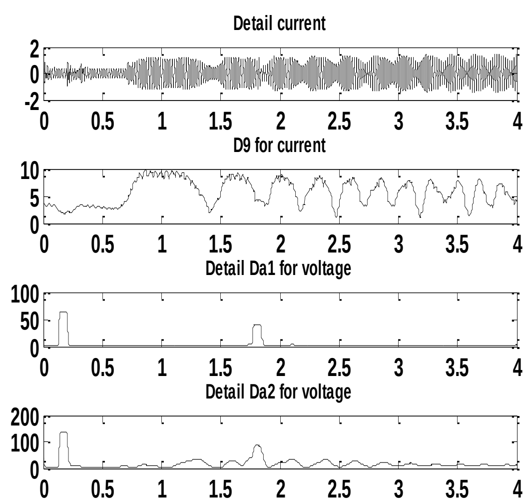

Figure 7: Result For δ=45° Fault At 279km

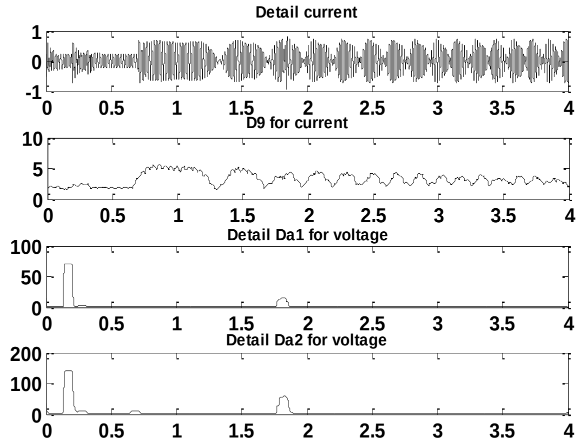

Figure 8: Result for δ=60° fault at 5km

As shown above the simulation results after applying wavelet transform and calculating total energy of different levels. Here we have selected D1 & D2 levels of all 3 phases of voltage and D9 level of any one phase of current. The summation of D1 & D2 is taken for more accurate result. So after summation voltage levels are D_{VA}, D_{VB}, D_{VC}. Now we will check for percentage rise in current level if rise increase continuously for two cycle while voltage levels is zero then it is power swing. For percentage rise in voltage levels D_{VA}, D_{VB}, D_{VC} rise is sudden then it is a fault. In order to accuracy WT is performed at every half cycle.

For relay as there is only swing it should not trip and if there is fault then it should be trip. So when current level increases continuously for 2 cycles, relay should not trip. When voltage level increases suddenly, relay should trip. In case of both condition occurs simultaneously then relay should trip.

VII. CONCLUSION

The proposed method quickly and reliably detects the swing and fault. The main advantage of this method it detect fault in less than half cycle. Table –I and table –II shows different cases for all types of fault for which this method works.

Table-I: Different cases for all type of fault for δ=60°

For δ=60°		
S.No.	**Fault Distance(km)**	**Fault Resistance(Ω)**
1.	5	1 50
2.	40	10 90
3.	80	5 100
4.	105	5 20
5.	240	10 50

Table –II: Different cases for all type of fault for δ=45°

for δ=45°		
S.No.	**Fault Distance(Km)**	**Fault Resistance(Ω)**
1.	5	1 50
2.	40	10 90
3.	80	5 100
4.	105	5 20
5.	240	10 50

Here our main purpose is to detect fault only so to block relay during swing without fault we can also use this technique also.

APPENDIX

Transmission Lines:

Parameter: Zero sequence impedance: Z_{L0}= 0.309+j1.297 Ω/km

Positive sequence impedance: Z_{L1}= 0.12+j0.88Ω/km

Zero sequence capacitance=0.00789 uF/km

Source Parameters:

Source impedance: Z_S=6+j 28.5 Ω

Source voltages: E_S= 22∠ δ kV

Where δ = load angle in degrees

X_d=1.81p.u,X_d'=0.3p.u,X_d"=0.23p.u,inertia,constant=4.4MW/MVA,50Hz

T_{do}'=8s, T_{do}"=0.03s, X_q=1.76p.u, X_q"=0.25p.u, T_{qo}"=0.03s, R_a=0.003p.u

Transformer Parameter:

600MVA, 22/400 kV, 50Hz Δ/Y,X=0.163p.u, X_{core}=0.33p.u, R_{core}=0,

REFERENCES

[1]. IEEE Power System Relaying Committee of the IEEE Power Eng. Soc. Power swing and out-of-step considerations on transmission line. Rep. PSRC WG D6, Jul. 2005. [Online]. Available: http://www.pes-psrc.org.
[2]. P. J. Moore and A. T. Johns, "New method of power swing blocking for digital distance protection," Proc. Inst. Elect. Eng., Gen. Transm. Distrib., vol. 143, no. I, pp. 19–26, Jan. 1996.
[3]. B. Su, X. Z. Dong, Z. Q. Bo, Y. Z. Sun, B. R. J. Caunce, D. Tholomier, and A. Apostolov, "Fast detector of symmetrical fault during power swing for

distance relay," in Proc. IEEE Power Eng. Soc. Gen. Meeting , 2005, vol. 2, pp. 1836–1841.

[4]. J. Ganeswara Rao and A.K. Pradhan "Differential Power-Based Symmetrical Fault Detection During Power Swing" IEEE Trans. Power Del. , vol.27, no. 3,pp.1557-1564,july 2012.

[5]. X. Lin, Y. Gao, and P. Liu, "A novel scheme to identify symmetrical faults occurring during power swings," IEEE Trans. Power Del. , vol.23, no. 1, pp. 73–78, Jan. 2008.

[6]. L. Xiangning, Z. Qing, L. Wenjun, W. Kecheng, and W. Hanli, "A fast unblocking scheme for distance protection to identify symmetrical fault occurring during power swings," inProc. IEEE Power Eng. Soc. Gen.Meeting, 2006, pp. 1–8.

[7]. L. Fu, Z. Y. He, R. K. Mai, and Z. Q. Bo, "Approximate entropy and its application to fault detection and identification in power swing," in Proc. IEEE Power Energy Soc. Gen. Meeting, 2009, pp. 1–8.

[8]. H. Kazemi Karegar and B. Mohamedi, "A new method for fault detection during power swing in distance protection," in Proc. IEEE ECTI-CON, 2009, vol. 01, pp. 230–233.

[9]. H. Khoradshadi Zadeh, "Evaluation and performance comparison of power swing detection algorithms," in Proc. IEEE Power Eng. Soc. Gen. Meeting, Jun. 2005, vol. 2, pp. 1842–1848.

[10]. S. M. Brahma, "Distance relay with out-of-step blocking function using wavelet transform," IEEE Trans. Power Del. , vol. 22, no. 3, pp.1360–1366, Jul. 2007.

[11]. M. J. Reddy and D. K. Mohanta, "Adaptive-neuro-fuzzy inference system approach for transmission line fault classification and location incorporating effects of power swings," Inst. Eng. Technol. Gen.Transm. Distrib. , vol. 2, no. 2, Mar. 2008.

[12]. W. Li, T. Bi, and Q. Yang, "Study on sequence component based fault phase selector during power swings," in Proc. CRIS 5th Int. Conf. , Beijing, China, Sep. 2010, pp. 1–5.

[13]. S. Santoso, E. J. Powers, W. M. Grady, and P. Hofmann, "Power quality assessment via wavelet transform analysis, " IEEE Trans.Power Del., vol. 11, no. 2, pp. 924 –930, Apr. 1996.

[14]. A. Osman and O. P. Malik, "Transmission line distance protection based on wavelet transform," IEEE Trans. Power Del. , vol. 19, no. 2, pp. 515–523, Apr. 2004.

AUTHOR

Rohan Kumar Gupta , M.Tech (Power System Engineering), Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, India, rohangpt36@gmail.com