© 2018 IJSRSET | Volume 4 | Issue 6 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology

Protection of 220KV Transmission Line During LLLG Fault using PSB and OST Unit in MATLAB

Roshni Rahangdale[1], Archana Gupta[2]
[1]Department of Electrical Engg SSGI(SSTC) Bhilai, Durg, Chhattisgarh, India
[2] Department of Electrical Engg. BIT,Durg, Durg, Chhattisgarh, India

ABSTRACT

Contingency analysis of any Power system involves studying the behavior of the Power System when applying to disturbance or any abnormal condition. This project involves the study of methods to detect Power Swing on a transmission line and verification of methods to detect Power Swing based on rate of change in Impedance. Here, Software is required for such analysis because in practical cases networks are very complicated and for the same system, modeling the entire component according to real system facilitates easier approach to study the same network without imposing it to practical condition. So to maintain system stability such contingency analysis plays vital role. A three area Power System model is designed in SIMULINK software and simulated data is used for analysis in this paper. Impedance seen by Distance Relay enters zone which is set generally 90% of transmission line impedance within one-cycle and it will be almost stable at Impedance equal to fault Impedance seen by relay. Whereas in case of Power Swing Impedance changes slowly and takes longtime to enter zone settings. So, using this method, we can detect Fault within one -cycle. If Impedance is changing slowly, we can block relay from operation.

Keywords: Contingency, Relay, Power Swing, Faults, Distance Relay.

I. INTRODUCTION

Power systems under steady-state conditions operate typically close to their nominal frequency. A balance between generated and consumed active and reactive powers exists during steady-state operating conditions and the sending and receiving end voltage differences are typically within 5%. The system frequency on a large power system will typically vary +/- 0.02 Hz on a 50 Hz power system. 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 input to generators remains relatively constant. These system disturbances cause oscillations in machine rotor angles and can result in severe power flow swings. Depending on the severity of the disturbance and the actions of power system controls, the system may remain stable and return to a new equilibrium state experiencing what is referred to as a stable power swing. Severe system disturbances, on the other hand, could cause large separation of generator rotor angles, large swings of power flows, large fluctuations of voltages and currents, and eventual loss of synchronism between groups of generators or between neighboring utility systems. Large power swings, stable or unstable, can cause unwanted relay operations at different network locations, which can aggravate further the power-system disturbance and possibly lead to cascading outages and power blackouts [12]. Normally in Power system when resistance is neglected the amount of power (P) transmitted in the simple system shown in

Figure 1.1 can be represented by the following equation:

$$P = \frac{E_s . E_r}{X} Sin\delta \qquad [1]$$

Where:

E_s is sending end voltage

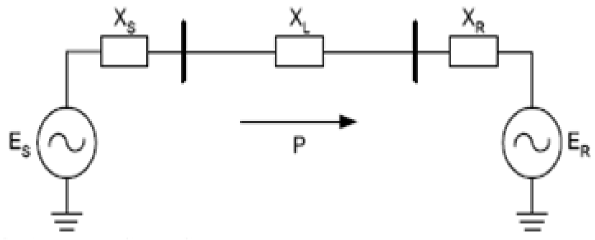

Figure 1. A Two- Source System

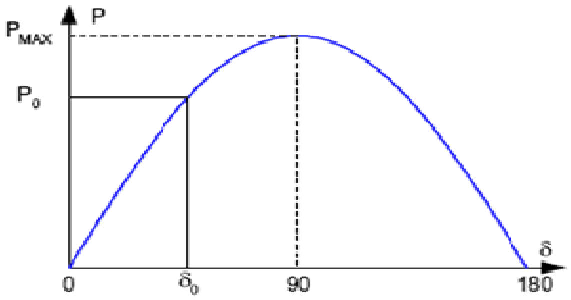

Figure 2. Power Angle Curve

Methods to Detect Power Swing:

Concentric Characteristic Schemes

R-dot Scheme

Continuous Impedance Calculation

The first two methods are based on change of Impedance while the last one is not exactly change of Impedance rather it's based on continuous Impedance calculation.

Power-Swing Phenomena And Their Effect On Transmission Line Relaying

- System Risks Due to Power Swings and Out of Step Conditions
- Transient Recovery Voltage (TRV) causing Breaker Failure
- Isolating Load and Generation
- Equipment Damage
- Cascading Tripping of Lines

Unwanted Cascading Tripping of Generating UnitsThe loss of synchronism between power systems or a generator and the power system affects transmission line relays and systems in various ways. The required settings for the PSB and OST elements could be difficult to calculate in many applications. For these applications, extensive stability studies with different operating conditions must be performed to determine the fastest rate of possible power swings.

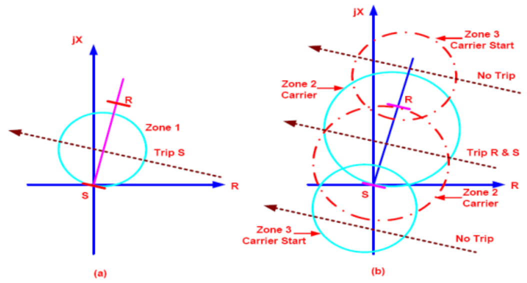

Figure 3. (a) & (b) Zone 1 and Directional Comparison Blocking Scheme Characteristics

Figure 3(a) shows the operation of a Zone 1 distance relay when the swing locus goes through its operating characteristic and figure 3(b) shows a directional comparison blocking scheme characteristic and how it may be impacted by the swing locus.

Impedance Measured by Distance Relays during Power Swings:

During a system Out-Of-Step event, a distance relay may detect the Out-Of-Step as a phase fault if the Out-Of-Step trajectory enters the operating characteristic of the relay. To demonstrate this, let us look at the impedance that a distance relay measures during an Out-Of-Step condition for the simple two-source system. Considering Fig: 3.2, the current I_L at bus A is computed as:

$I_L = (E_S - E_R) / (Z_S + Z_L + Z_R)$ [2]

The direction of current flow will remain the same during the power swing event. Only the voltages change with respect to one another. The impedance measured at a relay at bus A would then be:

$Z = V_A / I_L = (E_S - Z_S . I_L) / I_L = E_S / I_L - Z_S = [E_S (Z_S + Z_L + Z_R) / (E_S - E_R)] - Z_S$ [3]

Let us assume that E_S has a phase advance of δ over E_R and that the ratio of the two source voltage magnitudes $|E_R/E_S|$ is k. We would then have:

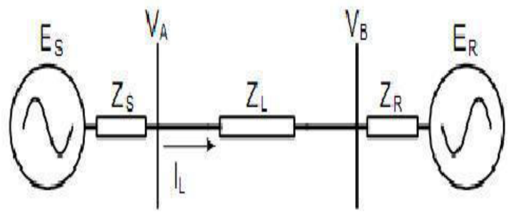

Figure 4. Two Machine System

$E_S/(E_S-E_R) = k(\cos\delta + j\sin\delta) / [k(\cos\delta+j\sin\delta)-1] = k[(k-\cos\delta)-j\sin\delta]/[(k-\cos\delta)2 + \sin2\delta]$ [4]

For the particular case where the two sources magnitudes are equal or k is one, equation 3 can be expressed as:

$E_S/(E_S-E_R) = ½(1-j\cot\delta)$ [5]

And finally the impedance measured at the relay will be:

$Z=V_A/I_L = [1/2\,(Z_S+Z_L+Z_R)\,(1-j\cot\delta)]-Z_S$ [6]

Remembering that δ is the phase angle between the sources, there is a geometrical interpretation to equation 5 that is represented in Fig 3.3(a). The trajectory of the measured impedance at the relay during a power swing when the angle between the two source voltages varies corresponds to the straight line that intersects the segment A to B at its middle point. This point is called the electrical center of the swing. The angle between the two segments that connect P to points A and B is equal to the angle δ. When the angle δ reaches the value of 180 degrees; the impedance is precisely at the location of the electrical center.

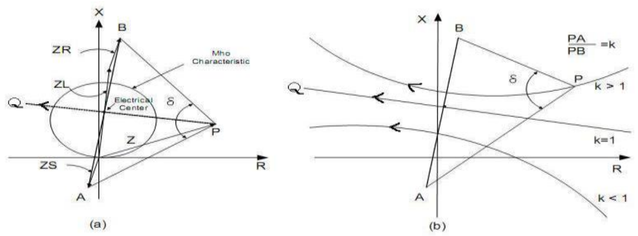

Figure 5. (a) & (b) Impedance trajectories at the Relay during a Power Swing for Different k Values

The performance of distance relays during swings is dependent to some extent on the relative magnitudes of system and line impedances. For instance, if the line impedance is small with respect to the system impedances, it is likely the various distance relay zones will trip only on swings from which the system will not recover.

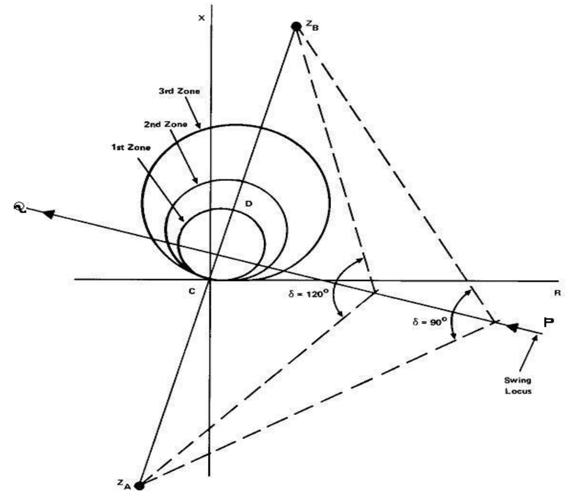

Figure 6. Impedance Locus when Line Impedance is small

This situation is illustrated for terminal C in Figure 2.3. As shown in this diagram, the swing locus will enter the distance relay characteristics only when the angular difference between systems is greater then 120 degrees. In this case, tripping may be provided by any of the three zones. If the slip between the systems is slow and if the time settings of the second and third zones are low, it is possible that either the second or the third zone relays or both may operate during the swing. If these two zones do not operate, the first zone will certainly operate when the locus enters its characteristic.

II. METHODS FOR DETECTION OF POWER SWING

Continuous Impedance Calculation:

This method determines a power swing condition based on a continuous impedance calculation as shown in fig 3.1. Continuous here means, for example, that for each 5 ms step an impedance calculation is performed and compared with the impedance calculation of the previous 5 ms. As soon as there is a deviation, an out-of-step situation is assumed but not proven yet. The next impedance that should be calculated 5 ms later is predicted based on the impedance difference of the previous measured impedances.

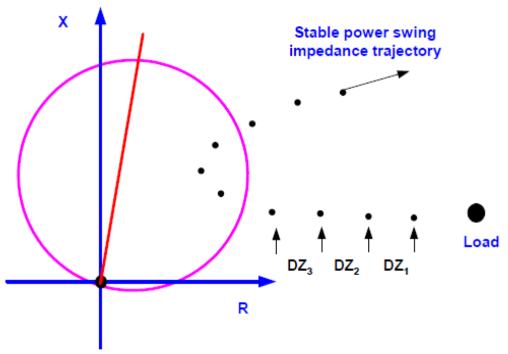

Figure 7. Power swing detection with continuous impedance calculation

If the prediction is correct, then it is proven that this is traveling impedance. In this situation a power swing condition is detected. For security reasons additional predictive calculations may be required.

Conventional Rate of Change of Impedance PSB and OST Methods:

Conventional Power Swing Blocking schemes are based mostly on measuring the positive-sequence impedance at a relay location. During normal system operating conditions, the measured impedance is the load impedance, and its locus is away from the distance relay protection characteristics. When a fault occurs, the measured impedance moves immediately from the load impedance location to the location that represents the fault on the impedance plane. During a system fault, the rate of impedance change seen by the relay is determined primarily by the amount of signal filtering in the Relay. During a system swing, the measured impedance moves slowly on the impedance plane, and the rate of impedance change is determined by the slip frequency of an equivalent two-source system. Conventional Power Swing Blocking schemes use the difference between impedance rate of change during a fault and during a power swing to differentiate between a fault and a swing. To accomplish this differentiation, one typically places two concentric impedance characteristics, separated by impedance ΔZ, on the impedance plane and uses a timer to time the duration of the impedance locus as it travels between them. If the measured impedance crosses the concentric characteristics before the timer expires, the relay declares the event a system fault. Otherwise, if the timer expires before the impedance crosses both impedance characteristics; the relay classifies the event as a power swing.

Quantities Used for Power-Swing Detection:

Assuming that the total system impedance is X_T and $E_S = E_R = E_1$, the following quantities used for power swing detection are shown below:

Power :

$$P = E1.I.\cos\phi = \frac{E1^2}{X_T} Sin\delta$$

Current:

$$I = 2.E1/X_T \; Sin(\delta/2)$$

Impedance:

$$Z = V/I = X_T/2.\cot(\delta/2)$$

Rate of change of impedance:

$$\frac{dZ}{dt} = -\frac{X_T}{2}.\left[\frac{1}{1-\cos\delta}\right].\frac{d\delta}{dt}$$

SVC:

$$V\cos\phi = P/I = E1.\cos(\delta/2)$$

We can observe that most of them are dependent on the total system impedance X_T, a changing and not well-defined quantity.

Psb and Ost Protection Philosophy

Protective relays that monitor voltages and currents may respond to variation in system voltage and currents and cause tripping of additional equipment, there by weakening the system and possibly leading to cascading outages and the shutdown of major portions of the power system. In addition to distance relays, other protective relays prone to respond to stable or unstable power swings and cause unwanted tripping of transmission lines or other power system elements include over current, directional over current and under voltage.

The philosophy of PSB and OST relaying is simple and straightforward: avoid tripping of any power system element during stable swings. Protect the power system during unstable or out-of-step conditions. When two areas of a power system, or two interconnected systems, lose synchronism, the areas must be separated from each other quickly and automatically in order to avoid equipment damage and shutdown of major portions of the power system. Uncontrolled tripping of circuit breakers should be avoided and a controlled well-designed system separation is necessary in order to prevent equipment damage, widespread power outages, and minimize the effects of the disturbance.

Method for Determining Need for Power Swing and OOS Protection:

In this section we present a simplified method to give an indication of where to apply power swing detection, PSB and OST protection in a particular transmission line in the power system.

Assuming a simplified two-source equivalent system with equal sending and receiving end voltages, the impedance trajectory will cross the total system impedance at right angles at half the sum of the protected line plus the sending and receiving end

Thevenin impedances. The method consists of determining the system electrical center and the electrical center lies on the line under investigation. The simplified system shown in fig 4.1 will be used to illustrate the method. In using this method it is important to note that the current does not change direction, but the voltages go 180 degrees out phase with each other.

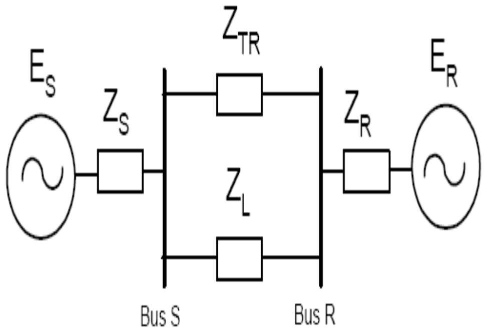

Figure 8. Two-Source System Equivalent

Where,

E_S = Equivalent sending end voltage

Z_S = Equivalent sending end source impedance

Z_L = Line impedance

E_R = Equivalent receiving end voltage

Z_R = Equivalent receiving end source impedance

Z_{TR} = Equivalent impedance of the system interconnecting sending and receiving buses

III. SIMULATION RESULT

During Normal Conditions:

During normal condition, the system is stable and the relay does not activate. The plot of Impedance, Relay operation, Current and Voltage waveforms are shown in fig 5.1, 5.2, 5.3, & 5.4, respectively.

Plot of impedance during normal condition:

In the normal condition, Impedance value Zp.u (line-line) = 1.58. The plot is shown for t= 2sec.

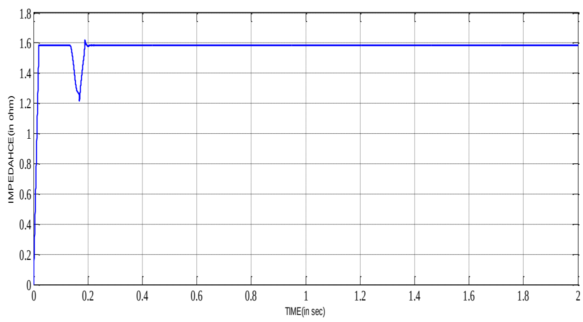

Figure 9. Plot of impedance during normal condition

Plot of Relay operation during normal condition:

In normal condition, the relay does not operate and its position is high (level 1) as shown in figure 10

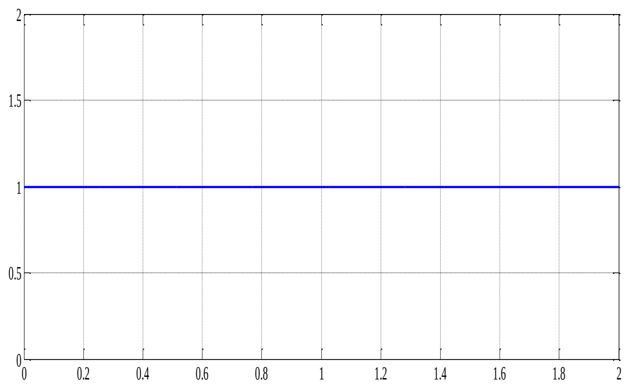

Figure 10. Plot of Relay operation during normal condition

Plot of Current during normal condition:

In normal condition, three phase Current values are as shown in the fig7.3:

I_a = 388.93∟-32.78˚ A

I_b = 388.93∟152.78˚ AI_c = 388.93∟87.22˚ A

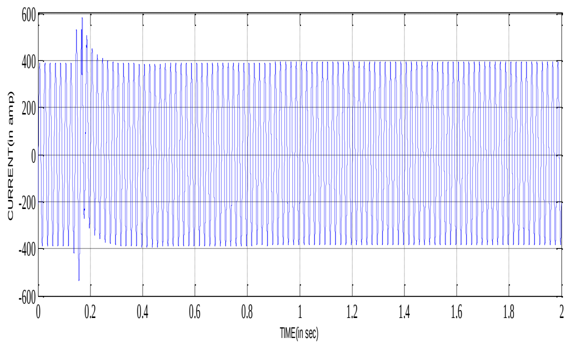

Figure 11. Plot of Current during normal condition

Plot of Voltage during normal condition:

In normal condition, three phase Voltage values are as shown in the fig7.4:

(1)V_{ab} = 284.450∟5.45˚ KV

(2)V_{bc} = 284.450∟-114.55˚KV

(3)V_{ca} = 284.450∟125.45˚KV

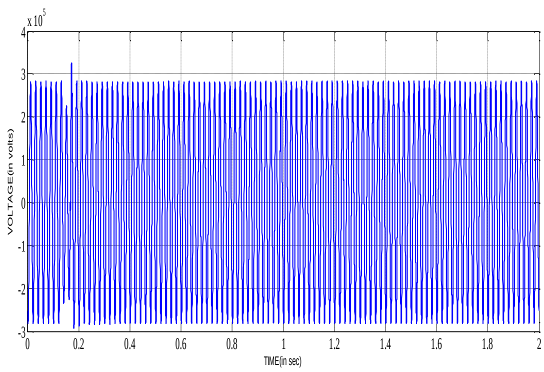

Figure 12. Plot of Voltage during normal condition

During Three phase to ground fault Conditions:

. The plot of Impedance, Relay operation, Current and Voltage waveforms are shown in fig 5.5, 5.6, 5.7, & 5.8 respectively.

Plot of impedance during three phase to ground fault condition:

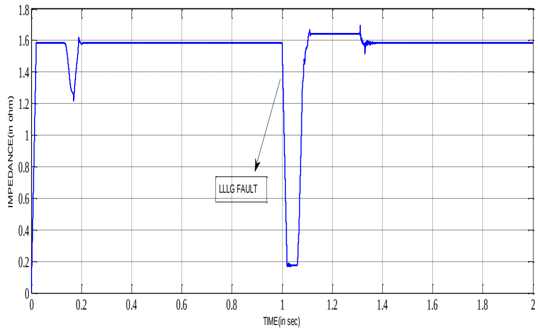

Figure 13. Plot of impedance during three phases to ground fault condition

Plot of Relay operation during three phases to ground fault condition:

In normal condition , the relay does not operate and its level is high [1].When three phase to ground fault is applied at t = 1.00sec and after sensing for 3 cycles at t = 1.06sec, relay operates and its level goes low [0] and gives signal to breaker-1 and 2 to trip the line – 1 up till the fault is cleared. Fault is cleared at t=1.31sec, after auto reclosing the breaker relay level goes high [1] as shown in the figure 14.

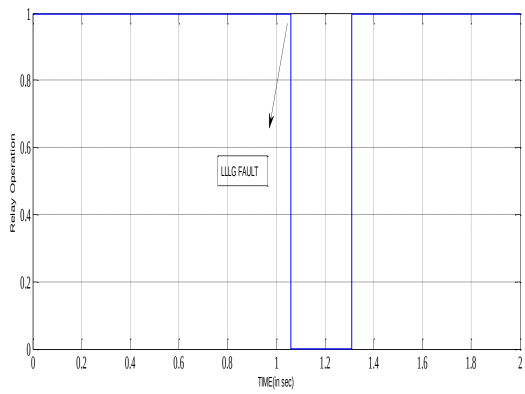

Figure 14. Plot of Relay operation during three phases to ground fault condition

Plot of Current during three phase to ground fault condition:

When three phase to ground fault is applied at t = 1.00sec and after sensing for 3 cycles at t = 1.06sec, relay operates and gives signal to breaker-1 and 2 to trip the line – 1 up till the fault is cleared. Fault is cleared at t=1.31sec ,after auto reclosing the breaker ,the power swing appears for 80ms which is less than 120ms as per OST setting as shown in the figure 15. Therefore, swing is stable and thus relay does not operate.

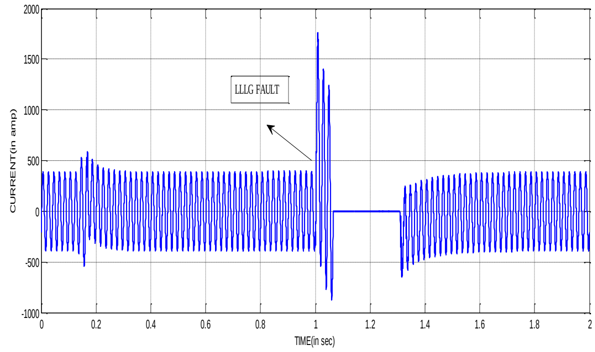

Figure 15. Plot of Current during three phases to ground fault condition

Plot of Voltage during three phase to ground fault condition:

When three phase to ground fault is applied at t = 1.00sec and after sensing for 3 cycles at t = 1.06sec, relay operates and gives signal to breaker-1 and 2 to trip the line – 1 up till the fault is cleared. Fault is cleared at t=1.31sec ,after auto reclosing the breaker ,the power swing appears for 10ms which is less than 120ms as per OST setting as shown in the figuew 16. Therefore, swing is stable and thus relay does not operate.

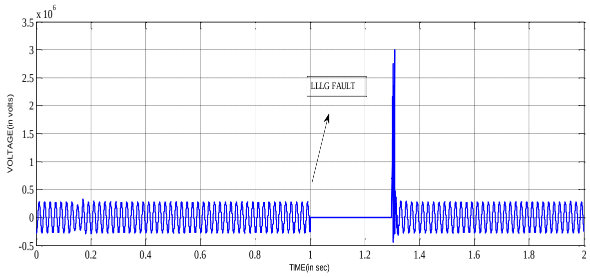

Figure 16. Plot of Voltage during three phases to ground fault condition

During Three phases to ground fault condition without OST unit:

A Three phase to ground fault (LLLG) is applied on line-1 at 60 Km away from the three phase source-1as shown in the fig 6.1 simulink model for t = 300ms. Fault has been occurred at t = 1.00sec and cleared at t = 1.3sec. The plot is shown for t = 2sec.

The plot of Impedance, Relay operation, Current and Voltage wave forms are shown in figure 17,18,19, & 20 respectively.

Plot of impedance during three phase to ground fault condition without OST:

As three phase to ground fault applied on line-1 at t = 1.00sec,on line-1 the value of positive sequence impedance (line-line) falls down from Zp.u = 1.58 to Zp.u = 1.1 as shown in the figure .The fall in the value of impedance enter the zone of a distance relay setting with only PSB unit. The PSB unit senses the sudden change in impedance as per setting for fault case and thus fault is detected and it gives signal to relay and circuit breaker to trip line – 1. The variation in the value of impedance continuous during fault period.

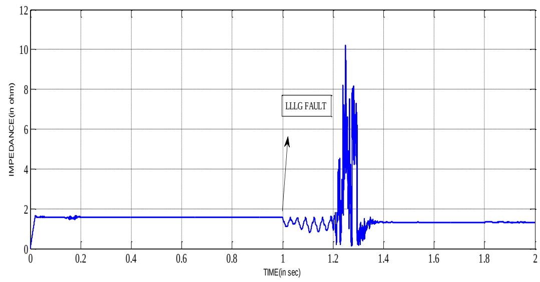

Figure 17. Plot of impedance during three phases to ground fault condition without OST

Plot of Relay operation during three phases to ground fault condition with out OST:

Even in normal condition, at the beginning when the system reaches toward steady state, the waveform of current and voltage distort due to inductance and capacitance presence in the system as shown in figure 19 and figure 20 respectively.

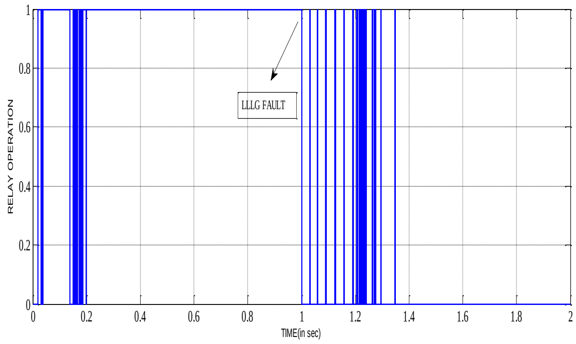

Figure 18. Plot of Relay operation during three phases to ground fault condition without OST

Plot of Current during three phase to ground fault condition without OST:

As three phase to ground fault applied on line-1 at t = 1.00sec,on line-1 the value of positive sequence impedance (line-line) falls down from Zp.u = 1.58 to Zp.u = 1.1 as shown in the fig 5.9. After opening of circuit breaker, the value of impedance reaches to its normal value and relay sense the system is normal, breaker again reclosed. Since the fault is continue, again the value of impedance falls down .Thus breaker reopen. This phenomena continues up to t = 1.3sec.After fault clearing, again the value of impedance becomes Zp.u = 1.32 which is less than the value of PSB setting (Zp.u = 1.56). Thus the relay operates again and trips the line - 1 and no current flows through it as shown in the figure 19.

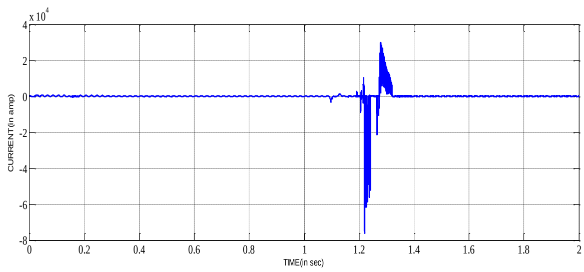

Figure 19. Plot of Current during three phases to ground fault condition without OST

Plot of Voltage during three phase to ground fault condition with out OST:

As three phase to ground fault applied on line-1 at t = 1.00sec,on line-1 the value of positive sequence impedance (line-line) falls down from Zp.u = 1.58 to Zp.u = 1.1 as shown in the fig5.9.

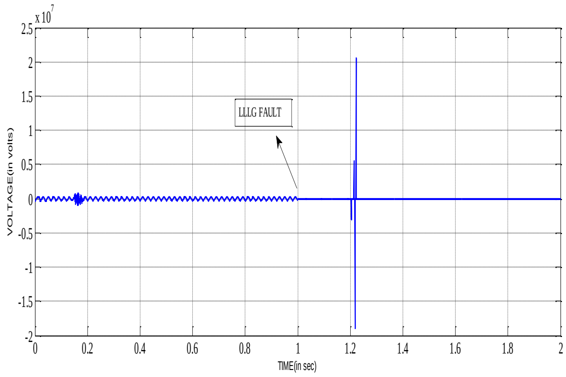

Figure 20. Plot of Voltage during three phases to ground fault condition with out OST

IV. CONCLUSIONS AND FUTURE SCOPE

Above simulation results validate that the methods i.e. Change of positive sequence impedance is useful for detection of power swing. But it has to have protective equipments which can response faster in order to response quickly to detect it. This analysis is useful to enable the power system blocking (PSB) setting of relays. Power swings both stable and unstable can precipitate wide spread outages to power systems with the result that cascade tripping of the power system elements occur. Protection of power systems against the effects of power swings both stable and unstable has been described in this thesis. The thesis has given an overview of power swings, their causes and detection. Methods of detecting and protecting the power system against power swings have been discussed and elaborated. Detailed system studies both steady state and transient are required to determine the application of power swing protection. Extensive stability studies under different operating conditions must be performed to determine the rate of change of power swings. Protective relays use a number of methods to detect the presence of a power swing, the most common being the change of the positive sequence impedance. Other power System quantities have also been used for power-swing detection such as power and its rate of change, the phase angle difference across a transmission line or path and its rate of change.

V. REFERENCES

[1]. Majid Sanaye-Pasand and Ali Naderian Jahromi ,"Study, Comparison and Simulation of Power System Swing Detection and Prediction Methods", 0-7803-7989-6/03/$17.00 02003 IEEE
[2]. Xiangning Lin, Yan Gao, and Pei Liu, "A Novel Scheme to Identify Symmetrical Faults Occurring During Power Swings". IEEE Trans. On Power Delivery, vol. 23, no. 1, January 2007.
[3]. Edith Clarke, "Impedance Seen by Relay during Power Swing With and Without Faults", AIEE Trans., pp.372-384.
[4]. A. R. Van C. Warrington, "Graphical Method for Estimating the Performance of Distance Relays during Faults and Power Swings," AIEE Trans.vol. 68 (1949), pp. 660-672.
[5]. Liancheng Wang and Adly A. Girgis, "A New Method for Power System Transient Instability Detection", IEEE Transactions on Power Delivery, Vol. 12, No. 3, pp.1082-1089 , July 1997.
[6]. J. Blumschein, Y. Yelgin, and M. Kereit, "Proper detection and treatment of power swing To reduce the risk of Blackouts", DRPT2008 6-9 April 2008 Nanjing Chin,pp.2440-2446.
[7]. Dali Wu, Xianggen Yin , Zhe Zhang, and Kanjun Zhang, "Research on Improved Fault Classification Scheme during Power Swing", UPEC 2007,pp. 296-299.
[8]. Hiroyuki Amano, Teruhisa Kumano, and Toshio Inoue, "Nonlinear Stability Indexes of Power Swing Oscillation Using Normal Form Analysis", IEEE Trans. On Power Systems, Vol. 21, No.2, pp. 825-833, May 2006 .
[9]. Rudra Pratap, "MATLAB -7",Oxford University,0195179374 RG