Effect Of Earth Resistance on Performance of Protective Relay During Power Swing in IEEE 9 Bus System

Padmini Sharma¹, Dr. R.N. Patel²

¹Department of Electrical and Electronics CSIT, Durg, India
²Department of Electrical and Electronics SSCET, Bhilai, India

Abstract—A large disturbance in the power system is the cause of power swing and due to which mal-operation of distance relay occurs in power system network. This is highly undesirable and if it is not prevented, unnecessary tripping take place and finally blackouts may occur. This paper presents the effect of earth resistance in relay operation in case of power swing. Different cases presented here which show the effect of power swing on relay operation for different magnitude of power swing when different earth resistance is considered in each case. IEEE multi machine nine bus systems is chosen here for simulation purpose and it is done in PSCAD software.

Keywords—power swing, Distance relay, mal-operation, PSCAD.

I. INTRODUCTION

Transmission line are very important part of dynamic power grid used for connecting generator to load. Distance protection relay one of the most common or we can say most widely used relay for protection of transmission and distribution line. Stability is the very important parameter of a power system. Relay performance and power system stability both are related to each other. For maintaining system stability, protective scheme should operate as soon as possible. Power system stability of recent power grid is disturbed in case of power swing. Relay mal-operation due to power swing is the major cause of wide area cascading failure and finally blackout. Opening of healthy line due to power swing is highly undesirable. Whatever be the reason behind the blackout, if it occurs, take much time to again restart the system. Huge economical loss occur due to this, so it has to avoid form the system for maintain the continuity of supply and take desired action at the right time[1]. Hence it is desire for the new generation protection system; it must identify different condition before operation whether it is ideal condition, fault condition or high amplitude power swing condition.

Power swing basically defines as the “wide variation of power between two areas of power system”. It may occur in the power system due to unpredicted event or may be due to large disturbance. This disturbance present due to any of the following reason given below.

1) Sudden fault
2) Line switching
3) Generation disconnection
4) Addition of load
5) Loss of load
6) Paralleling other generator

All above mention situation create disturbance in the system equilibrium condition. It affects the constant power flow from generation end to load end and create wild fluctuation in electrical power, however the mechanical power relatively, and constant. Unbalance between electrical and mechanical power cause oscillation in load angle which create sudden variation in voltage, current, active power P and reactive power Q at relay location and produce power swing [2-3]. Depending upon the type and the disturbance occurrence time, power swing may be stable or may be unstable. It may be possible the power swing stable or unstable, but if its amplitude is high it affect the relay performance at different location and unwanted tripping disturb the continuity of supply which further convert into cascading outages and power blackout[4].

Generally the system blackout is the result of mal-operation of relay. With the help of present paper we can see the relay performance in different condition. Relay operation in fault condition at relay location as well as the relay performance when the disturbance occurs in any other part of power system network.

In this paper general feature of IEEE multi machine nine bus systems is discussed in section II. Then section III discussed the simulation model of IEEE nine bus systems in PSCAD. In section IV discuss the different cases and examine the relay response in various condition. Conclusion of presented paper is discussed in section V.

II. NINE BUS SYSTEM

An IEEE nine bus multi-machine system is referred from power system control and stability by Anderson and Found [5]. This test case consists of nine buses, three generator, three two winding power transformer, six transmission lines and three R-L-C static load.
Three generator units connected to bus number 1, 2 and 3 respectively through step-up transformer at 230KV in nine bus systems. Generating voltage of first generate is 16.5KV at 247.5 MW, generating voltage of second generate is 18 KV at 163.2MW and generating voltage of third generate is 13.8 KV at 108.8MW. Three large R-L-C loads load A, load B and load C connected to bus number 5, 6, and 8 respectively. Load connected from A is 134.629MVA; Rating of load B is 94.868 MVA and load C rating is 105.948 MVA. The three step-up star/delta connected transformer with proper data connected between buses 1-4, 2-7 and 3-9.

Simulation model is run for various conditions and examine the relay performance for various condition.

1) Normal and healthy
2) When single line to ground fault created in the transmission line near to bus number 4.
3) Three phase fault is created in bus number 5 and examine the performance of relay due to power swing.
4) Single phase line to ground fault created in bus number 5 and observed the relay response which is connected between buses 4-6.
5) Single phase line to ground fault again created in bus number 5, when increases the magnitude to ground resistance.

III. SIMULATION MODEL OF TEST SYSTEM

The IEEE 9 bus test system is simulated in PSCAD/EMTP with mostly data taken from power system control and stability by Anderson and Found and rest are assumed. For modeling the transmission line Bergeron model is used for entering the positive sequence line resistance and reactance. The one line diagram (OLD) of the simulated test system in PSCAD is shown in fig1 [6-7]. The data of generator and line parameter are given in appendix. Load A is connected to bus number 5, load B is connected to bus number 6 and load C is connected to bus number 8. The total generation of 9 bus system is ideally consider about 519.6 MW and the total connected load is 315 MW. G1 is connected to bus number 1, G2 is connected to bus number 2 and G3 is connected to bus number 3. Six transmission lines connecting the bus bars of test system and through step up transformer generator is connected to transmission line at 230 KV.

IV. SIMULATION RESULT FOR DIFFERENT CASES

CASE-1

Protective relay is connected between bus number 4 and 6. Relay performance is analysis under the normal running condition. Simulation model of IEEE 9 bus system is run under the healthy condition. Three phase balance sinusoidal voltage is seen in bus number 4. The magnitude of bus voltage is around 190KV is seen in fig (3). Active power generation from generator 1 is approximately 72MW is observed from fig (4) and reactive power observed around 21MVAR from fig (5). Constant amount of power flow is seen through transmission line approx 32 MW observed from (6). Trip signal response and mho relay characteristic is shown in fig (7).
Fig. (3) Voltage variation under normal condition in bus number 4

Fig. (4) Active power generation from generator 1

Fig. (5) Reactive power generation from generator 2

Fig. (6) Relay response during healthy condition

Fig. (7) Mho relay characteristic in X-Y plane

Fig. (8) Active power variation at G1 in fault condition

Fig. (3), (4) and (5) shows the voltage, active power and reactive power in bus number 4 in case of no fault between bus 4-6. Fig (6) show the trip signal response is zero in healthy condition and fig (7) gives the information about the transmission line impedance which is high during normal condition and not enters in the X-Y plane of mho relay characteristic.

CASE-II

When single phase to ground fault occurs in phase A of transmission line between bus 4-5. Fault occurs at 10.02 second for .05sec. Although the fault duration time is very less but it change the voltage, current, active and reactive. Since the magnitude of fault current increases suddenly that why impedance seen by the relay decreases and it come in the relay of mho relay characteristic. So trip signal is generated by relay at 10.02 sec and power flow is suddenly down zero through transmission line between bus4-5. Active power generation from G1 is varies from 72 MW to 100MW in first power swing observed from fig (8).
Fig. (9) Voltage variation in bus number 4 when single phase fault occurs.

Fig. (10) Power flow through transmission line in case of fault condition

Fig. (11) Reactive power flow through transmission line in faulty condition.

Fig. (12) Mho relay characteristic in fault condition.

Fig. (13) Unit step trip signal generation at 10.02 sec.

Fig. (8), (9) and Fig. (10) shows the active power, voltage at bus number 4 in fault condition. Fig (11) shows the active power transfer from bus 4 to 6, which is suddenly down to zero value at the time of fault. Transmission line impedance come in the region of mho relay characteristic and trip signal generate unit step response at 10.02 sec. After getting response from trip signal circuit breaker open and disconnect faulty part of the system from healthy part.

CASE-III

In this case we examine the effect of power swing in relay performance which connected between bus4-6 when three phase fault occurs in bus number 5 at 5 sec after starting for .08 sec time period.
Earth resistance considered here is zero that why although the fault takes place very away from relay location but it give response due to power swing.

Fig. (14) Voltage variation in bus number 4 when fault occurs in bus number 5.

Fig. (15) Power swing at G1 when fault occurs in bus number 5.

Fig. (16) Mho relay phase impedance characteristic in case of fault condition.

Fig. (17) Mho relay line impedance characteristic in case of fault condition.

Fig. (18) Unit step trip signal formation at 5 second

Fig. (19) Power flow through transmission line connect between 4-6.
From fig. (14) Shows the voltage variation in bus number 4, when 3 phase fault occur at bus number 5. Waveform shows that magnitude of voltage sudden down to zero value during fault duration. Fig (15) shows high magnitude power swing in bus number 4 due to fault in bus number 5. Fig (16) and (17) shows about the impedance of each phase in X-Y plane and from the waveform it is clear that each phase impedance enter into the region of mho relay characteristic that why unnecessary tripping take place and trip signal generate trip command at 5 sec.

**CASE-IV**

When single phase to ground fault occurs in bus number 5. In such situation although the magnitude of power swing in very less at generator one, when ear Resistance considered to 5 ohm but line impedance characteristic is just touch the mho relay characteristic that why trip signal generate unit step response at 5 second.

**CASE-V**

In these case again single phase line to ground fault is created in bus number 5 at 5 sec for .08 sec but here we control the fault current in bus number 5 by increases the ground resistance from 5 ohm to 10 ohm.
Fig. (25) Active power generation in G1 when single phase to ground fault.

Fig. (26) Mho relay line impedance characteristic for low power swing.

Fig. (27) Trip signal response for low power swing.

Fig. (28) Power flow through transmission line connect between 4-6.

Fig (24) (25) shows the voltage and power variation in generator 1. Since we control the magnitude of fault current so variation in power is very low and very soon it come to its normal value. From fig (26) it is very clear that impedance characteristic not touch the mho relay characteristic in X-Y plane that why trip signal response is zero in the fault duration time. Fig (28) shows the power transfer from bus number 4 to 6, which shows very low power variation.

V. CONCLUSION

This paper shows the relay performance in various conditions. Simulation results show that how the relay mal-operation takes place when different magnitude power swing occurs at different earth resistance value. Effect of high power swing in relay operation is seen when three phase fault take place in bus number 5 due to transmission line impedance where it enter the relay characteristic and for medium power swing when earth resistance considered 5 ohm again relay mal-operation take place because it just touches the characteristic. In case of low power swing relay performance is unaffected, where earth resistance considered 10 ohm.

REFERENCE