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Problem in Distance Protection for Series-Compensated Transmission Line

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Abstract: *Insertion of series capacitor in transmission line reduces net transfer reactance of line and it gives greater power transfer capability of the lines. It also improves power flow control & voltage regulation of lines. But it also causes problem to the conventional distance protection scheme during fault condition. The major problem to the distance relay is to measure correct impedance from relaying point to fault point when series capacitor remains in fault path. This paper briefly discusses need of series compensation, problems due to series compensation and focus is made on the problem of over-reach.*

Keywords: *Distance protection, positive sequence impedance, power system simulation, series compensation, transmission line.*

I. Introduction

In this paper, a brief introduction to Series Compensation is given along with its operation, advantages and disadvantages. Series compensation is defined as insertion of reactive power elements into transmission lines. Use of series capacitors for compensation part of the inductive reactance of long transmission lines will increases the transmission line capacity. It also increases transient stability margins. Transmission line compensation implies a modification in the electric characteristic of the transmission line with the objective of increase power transfer capability. In the case of series compensation, the objective is to reduce the transfer reactance of the line at power frequency by means of series capacitors. This result is an enhanced system stability [1]. These relays measure the positive-sequence impedance to the fault and compare it with their predefined characteristic. The presence of series capacitor in the fault loop affects reach and directionality of distance relays [2]. The fixed series compensations of lines are normally used for better utilization on the existing power transmission systems. It is presented as the best choice, because not only does it increase the power transmission capacity but also it stabilizes the interconnected networks by reducing net transmission line impedance. Also significantly increases the distance over which AC power can be transmitted [3]. Insertion of capacitor bank in to the transmission line creates several problems to the protection scheme. Series compensation makes the protection scheme more complex. There are several problems that occur due to insertion of capacitor bank into the transmission line.

The problems are briefly discussed as [4], [5], [6].

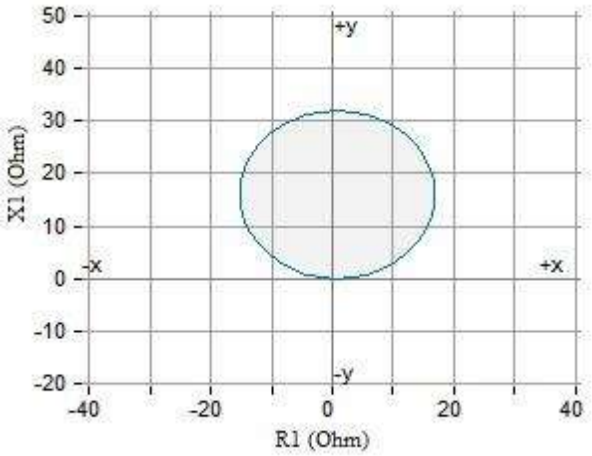


Fig. 1: Characteristic of mho relay

This paper observed a distance protection over-reach in series compensated transmission line, the positive sequence impedance is affected by series compensation. The rest of this paper is organized as follows:

In Section II, the characteristic of the mho relay is introduced. The conventional protection algorithm for non-compensated line is presented in Section III. Section IV analyses the effects of series compensation on the positive sequence impedance. Simulation results are presented in Sections V. Finally, Section VI contains the conclusions of this paper.

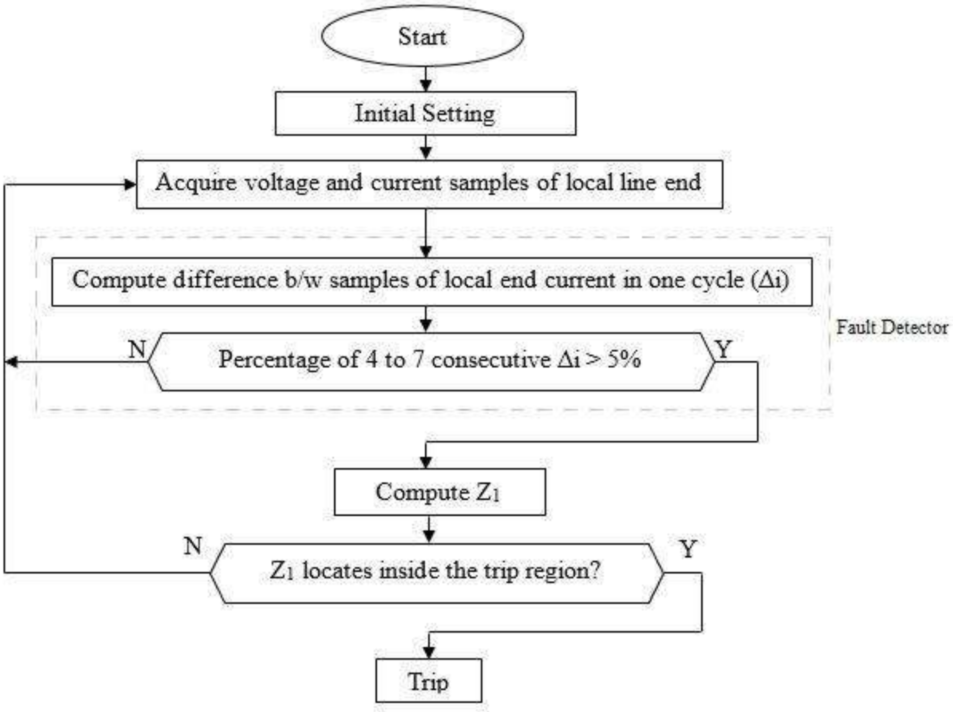


Fig. 2: Conventional protection algorithm

II. Characteristics Of The Mho Relay

The positive-sequence impedance is proportional to the distance between the relay and fault point. Therefore, the concept of the protective zone in conventional distance protection can be applied to the proposed protective scheme. This means that the first zone may cover 85% of the main line, the second zone can cover the main line plus 50% of the next shortest line, and the third zone may contain the main line plus the next longest line plus a 25% margin. Since the nature of positive sequence impedance are resistive and inductive, a characteristic similar to the mho relays can be used for the conventional protective relay. A typical characteristic is represented in Fig. 1. This characteristic is only for the first zone, where is equal to 85% of the positive sequence impedance of the main protected line. Characteristics of the second and third zone can be easily set according to their reaches. It should be noted that by restricting zone 1 to 85% of the line length, the conventional protective relay is unable to protect the entire line instantaneously, and 10 to 15% of the line end will be protected in zone 2 with a definite time delay.

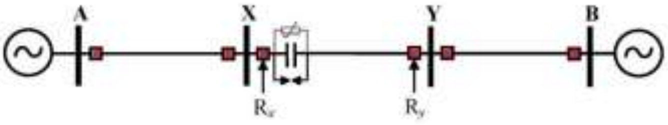


Fig. 3: Simulated system

III. Conventional Protection Algorithm

In normal conditions (when no fault occurs), the power system operates as a symmetrical three-phase system. It means that during normal conditions, the power system is only modeled by a positive-sequence network and its corresponding zero- and negative-sequence networks are open circuit. The flowchart of the conventional protection algorithm is depicted in Fig. 2. It should be noted that this algorithm describes the first zone of the relay, and it can be easily developed for zones 2 and 3.

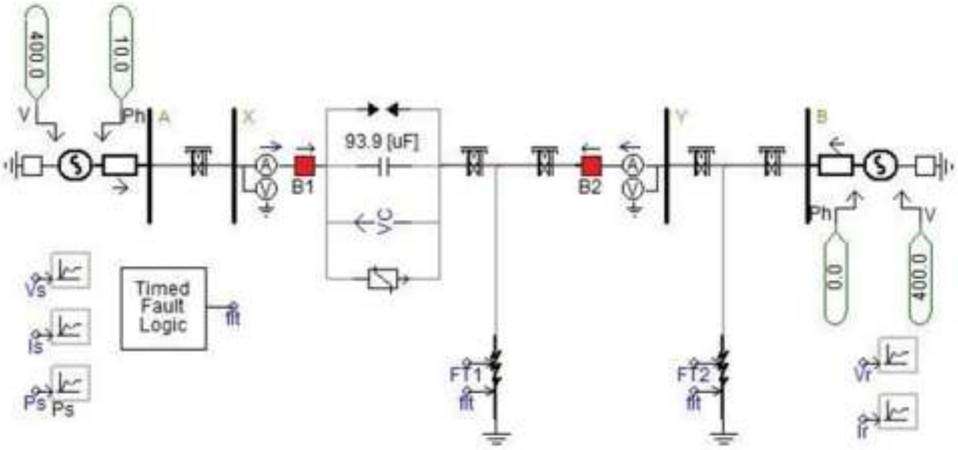


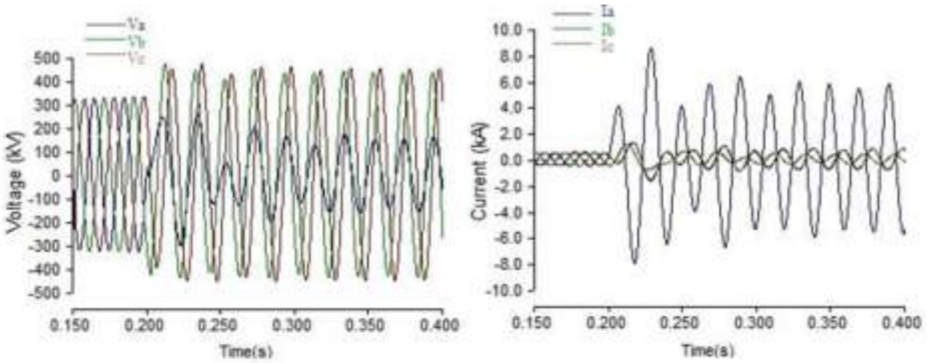
Fig. 4: Transmission line model in PSCAD/EMTDC Table I: Simulated System Data

Parameter	**Value**	**Unit**
System Voltage	400	kV
System Frequency	50	Hz
Line Length (AX, XY, YB)	100	km
Line Positive Seq. Series Impedance	0.0185 + *j*0.3766	Ω/km
Line Positive Seq. Cap. Reactance	0.22789	MΩ × km
Line Zero Seq. Series Impedance	0.3618 + *j*1.2277	Ω/km
Line Zero Seq. Cap. Reactance	0.34513	MΩ × km
Sources Positive Seq. Impedance	1.43 + *j*16.21	Ω
Sources Zero Seq. Impedance	3.068 + *j*28.746	Ω

IV. Simulation Results

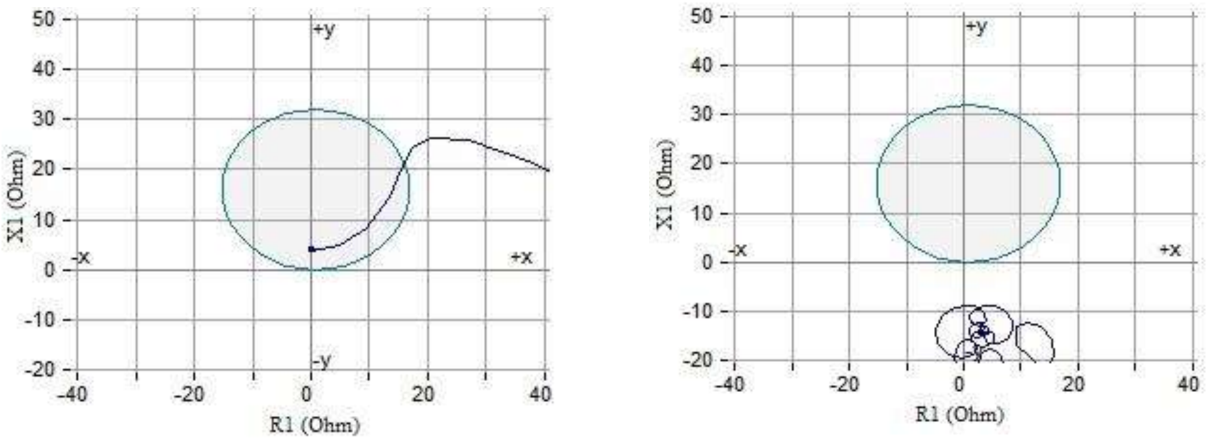
In this section, the conventional protection method is tested in different cases where the series capacitor is placed at the beginning of the transmission line.

Fig. 3 shows the simulated system and Fig. 4 is Transmission line model in PSCAD/EMTDC software. The system data are given in Table I [7]. The line XY is compensated by a series capacitor (SC). The degree of compensation is 30%. Moreover, the mho relay is denoted by Rx.



(a) (b)

Fig. 5: Internal LG fault. (a) Three-phase voltages. (b) Three-phase currents.



(a) (b)

Fig. 6: Simulation results for an internal fault. (a) Distance protection without SC. (b) Distance protection with SC.

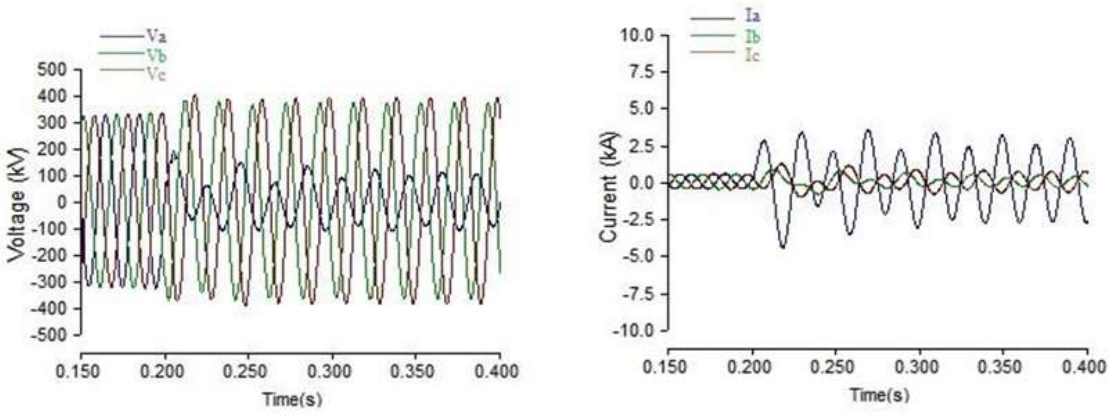
Internal faults are investigated by applying a single-line-to ground (LG) fault on phase at 10% of line. The fault inception instant is t = 0.2 s, and Rf is zero. Three-phase voltages and currents are shown in Fig. 5. Fig. 6 demonstrates performances of the conventional distance protection. As shown in Fig. 6(a), when the line is not compensated, methods operate correctly and detect the internal fault. However, Fig. 6(b) shows that in the series-compensated line, the conventional distance protection may fail to operate for close-in faults.

Study on external faults has been carried out by applying an LG fault, with Rf = 0 Ω, at 10% of line YB. (It should be noted that we do not worry about the external faults located on line AX, since they are directional (mho) relay.) Fig. 7 shows the measured voltages and currents. Similarly, Fig. 8(a) shows that protection methods provide reliable performances in non- compensated lines. However, as shown in Fig. 8(b), the conventional distance protection may experience an over-reach condition for external faults and lose its security.

The different percentage of over-reach with different percentage of compensation data and different fault location are given in Table II and Table III respectively.

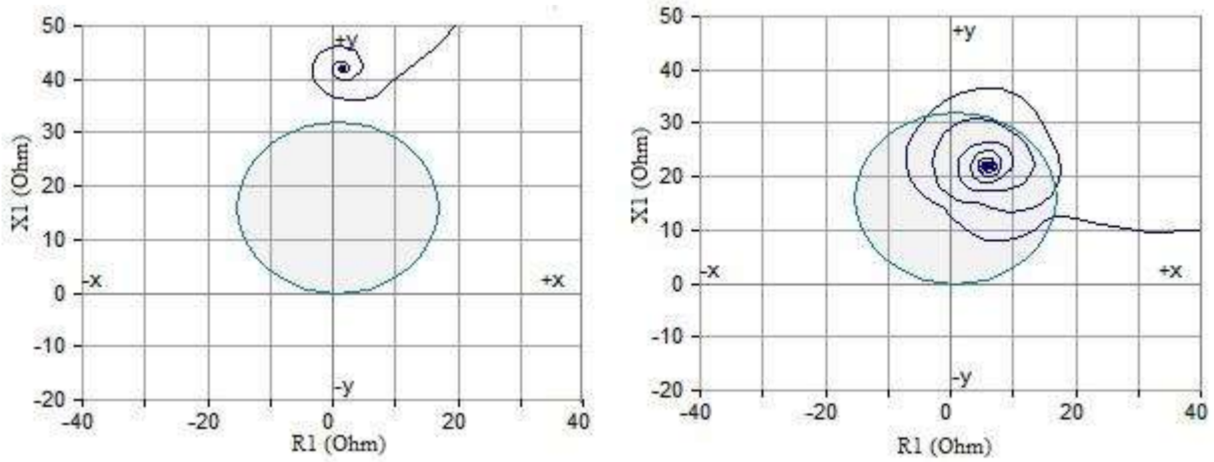
Table II: %Over-reach with %Compensation

%Xc(Compensation)	**%Over-reach**
10 %	40 %
20 %	70.58 %
30 %	114.11 %



(a) (b)

Fig. 7: External LG fault. (a) Three-phase voltages. (b) Three-phase currents.



(a) (b)

Fig. 8: Simulation results for an external fault. (a) Distance protection without SC. (b) Distance protection with SC.

Table III: Fault Location

Fault Location	Line Length (km, from X bus)	Type
FL1	10	Internal
FL2	110	External

V. Conclusion

This paper successfully demonstrates the problem of over-reach of distance relay with conventional distance relaying. The mho relay application to distance protection of series compensated line is successfully simulated using PSCAD/EMTDC. Authors are presently working on replication of a reported scheme to detect and prevent this over-reach using mutual impedance of the line.

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