보상제어 설비의 운용에 따른 보호설비 특성분석

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Protection System Characteristics Analysis by Compensation Equipment in Power Systems

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[Abstract]

This paper describes the possible undesier-able side effects that thyristor controlled compensation may have upon in several relays. This process co-nsisted of calculating line conditions for each of th-e fault, compensation and loading levels. In some cases their effectiveness at coordinating compensat-ed lines is lost, as they no longer can always acc-urately determine"distances" to faults.

1. Introduction

Since it is the primary responsibility of a power utility to ensure high reliability and safety to their customers, it is very important that the interaction between any new power-electronic applications and the system operation be explored. One of the vital components in any power network is the devices pr-otecting this system-the relays. And so it becomes imperative that this paper describes the possible u-ndesirable side effects that thyristor controlled co-mpensation may have upon these relays.

The traditional methods of relaying and an appr-opriate example of a protection scheme were cover-ed. After this a simplified model of a piece of a transmission network is quilted, and then calculate single phase to ground, double phase to ground, and three phase faults conditions at several differe-nt locations on it. For each of these individual faul-t conditions, the effects of varying levels of capacit-ive compensation and varying levels of power flow are examined. By changing both loading and comp-ensation levels it could be able to explore not only how capacitive compensation can affect these tradi-tional relays' effectiveness, but also show how mu-ch changes in compensation really mean anything in comparison to the everyday fluctuations of power flow in a transmission system. Also, since phase a-ngle controllers change transmission line power flo-w, this analysis makes for an easy interpretation of what effects these devices have on several traditio-nal relaying techniques.

2. Model System

A simplified transmission line model which series compensation is shown below.

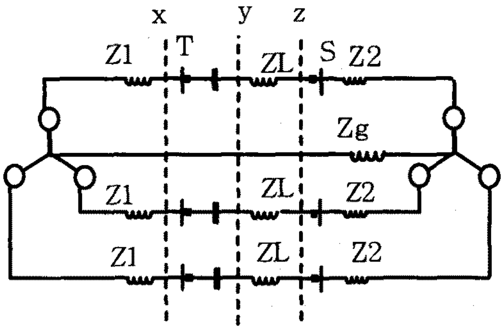


Fig. 1 Transmission Line model

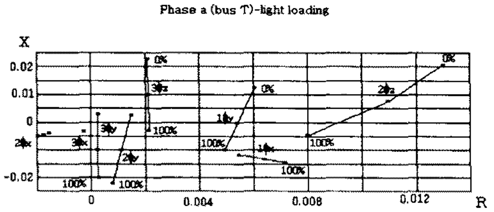
In the model above, the points x, y, and z are t-he fault points; one phase to ground, two phase to ground, and three phase faults. The two phase to ground vs. the two phase were selected because it would show two modes of operation the relays should operate on vs. just one. The single phase to ground on the phase A conductor and the two phase to ground between conductors A and B are calculated. Point x is 90% of the "effective" dista-nce from E1 to bus T, y is 10% of the distance fr-om T to S, and point z is 90% of the distance fr-om T to S. In this particular model, some case s-tudies are attempted to find how the variable co-mpensation at bus T affects the relays attempting to protect the line between buses S and T.

To do this, the capacitive compensation varies from 0 to 100% and the angle δ_2 varies from 11 to 45^0 This effectively varies the pre-fault loading the line is experiencing from light to heavy loading condition and probably a stability limit. This loadi-ng does cause the line to carry over-rated power at full compensation and full angle, but it's kept this way for the consistency of the analysis.

This process consisted of calculating line conditi-ons for each of the fault, compensation and loading levels. In the following analysis of this data, it is an attempt to make observations about possible failure modes in several types of relays.

3. Distance Relaying

Fig. 2 shows each of the types of faults at x, y, and z as a distance relay at bus T (phase A). This case only considers light loading conditions $-\delta_2=11^0$. The single phase fault at z is omitted because it's relative impedance is on the order of 5 times that of the other conditions. This is on the order of the impedance seen during steady state conditions; this shows in general how distance relays don't do a good at detecting single phase to ground faults.



PLOT 3

Fig. 2 Phase A (bus T)- light loading

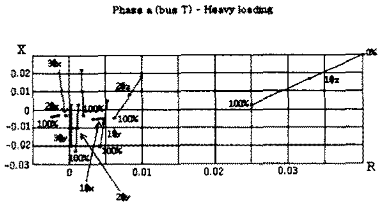
Notice the faults at x in this Fig. the faults the relay looking into the line don't want to operate on. Distance relays aren't good at detecting single phase faults in the line except at close distances such as at y, and they can incorrectly detect and relay on single phase faults in the wrong direction. This is shown by the single phase faults at x being indistinguishable from the many phase faults that are it's primary concern.

For the two and three phase faults, notice increasing compensation could easily bring the impedance out of the operate zone. It is apparent that this is the biggest effect that varying compensation levels would have on distance relay performance. In fact from this it becomes apparent that the initial -observations made about three phase faults in the -introduction hold true for the two phase fault case -as well. From these observations and system for three phase and single phase faults to be able to properly set relays in most conditions - even with capacitive compensation.

To effectively relay on these two and three phase fault with large compensation levels, impedance circle would have to be shifted down, possibly bring -ing phase faults in the wrong direction into the operate zone.

Fig. 3 shows each of the types of faults at x, y, and z as a distance relay at bus T(phase A). This case only considers heavy loading conditions - $\delta_2=45^0$. In general the same characteristic problems exist at these heavy loading conditions as exist at light loading conditions in Fig. 2

The increased loading has caused many of the faults to appear as much lower impedances. In fact notice how now it's included the single phase faults at z-it has changed an order of magnitude. this "tighter" pattern has caused it to be generally more difficult to differential a proper from an improper fault condition, expecially as compensation moves the fault points around so much.



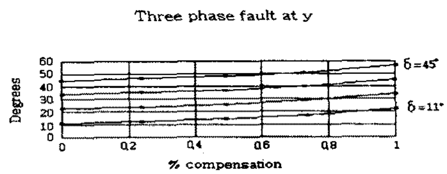
PLOT 4

Fig. 3 Phase A(bus T) heavy loading

4.Phase Comparison Relaying

This type of relaying technique involves communication on a pilot system where by the phase of the current in one line is compared with it's phase at the other end of the conductor. The current is defined as into the line at each bus, so during normal operation, the phase difference between the two relays is conditions, 180^0. Ideally, for fau-lt the phase difference would then be zero. But as it show in the following, this doesn't necessarily occur for high loading conditions or for high compensation levels. Phase comparison relays and /or Directional relays are used in most (if not all) pilot relaying schemes. Faults at x always had phase difference of 180^0, so it is only a ques-tion as to whether varying compensation adversely affects phase differences for faults internal to a line.

Fig.4 represents a three phase fault at point y. Both the three phase fault at y and z had similar characteristics. This figure specifically shows the phase difference between the currents on phase A at bus T and S for this fault. Notice loading has a lot more to do with how sens-itively we set these relays than does compensation.



PLOT 9

Fig. 4 Three phase fault at y

Fig. 5 represents a single phase to ground fault at point y and these are similar characteristics the single phase fault at z. This figure specifically shows the phase difference between the currents at bus T and S for a fault on phase A.

Fig. 4 varying loading represents more of a difficulty to setting relays than does varying compensation. Changing compensation does affect the phase difference quite a bit. Notice that for single phase fault direction sensing, this appears to have some serious downfalls. Ideally, the angle should be near zero for ideal detection. But now, more so than in the three phase fault case, increased loading and compensation levels brings the difference very near 180^0. In this case, the phase difference goes up to 150^0. For proper detection, setting these relays requires that the phase relay trip for angles less than or equal to 150^0. Only concern is that when activating a line, especially a long line, these phase relays would probably have to be deactivated or ignored as the phase difference between the two ends of such a line could be even more out of phase. For example in a reclosure procedure, it's doubt whether these phase relays are a reliable source for determining fault direction

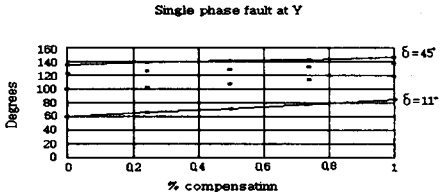


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Fig. 5 Single phase fault at y

Fig. 6 represents a two phase to ground fault at point y. The two phase fault at z had similar characteristics. This figure specifically shows the phase difference between the currents at bus T and S (phase A) for a fault on phase A and B. Phase B was identical. Notice that this characteristic is very similar to the three phase characteristic.

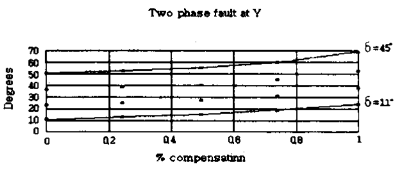

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Fig. 6 Two phase fault at y

5. Conclusion

Most traditional relaying techniques are rendered less sensitive by increased capacitive compensation, but not nearly so much as they would be by phase angle control. These relays operate on the order of 3 to 10 cycles for primary protection, as opposed to the less than one cycle relaying capability of newer relaying techniques may increase system stability. This will change in the future as transmission systems are pushed more dangerously close to their operating limits, as energy resources are increasingly shared, and as utility inter-dependence increases. It appears that right along with the increased use of thyristor controlled series capacitors and phase angle devices, newer and more reliable relaying techniques must come.

6. References

1. H. Faukhauser and S. Torseng, "Advanced simulation techniques for the analysis of power system dynamics", IEEE CAP, Vol. 3, No. 4, pp. 31-36, Oct. 1990.
2. E. Lerch and D. Povh, "Performance of AC System Using FACTS Equipment", FACTS EPRI Conference, Boston, May 18-20, 1992.
3. L. Angquist, B. Lundin and J. Samuelsson, "Power oscillation damping using controlled reactive power compensation", IEEE Trans. PS, Vol. 8, No. 2, pp. 687-700, May 1993.
4. FACTS technology, EPRI, 1994.
5. Kunder, Power system control & stability, EPRI, 1994.
6. X.R.Chen, N.C. Pahalawatha, "Controlled series compensation for improving the stability of multi-machinepower systems", IEE proc. GTD, Vol.. 142, No. 4,pp.361-366, July 1995
7. Arun G. Phadke, Power system Relaying, 1996