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Adaptive distance protection of transmission line in presence of SVC

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ABSTRACT

In this paper, the analytical and simulation results of the application of adaptive distance protection scheme for the transmission line incorporating Static Var Compensator (SVC) connected at the mid-point is presented. The mal-operation of the distance protection for the transmission line with SVC at various locations are studied. The simulation results show the under-reaching and over-reaching is more severe with SVC at mid-point of the transmission line. To mitigate the mal-operation of the distance protection, the adaptive scheme is presented based on recursive simulation study. The simulation result with adaptive scheme is outperformed as compared with the conventional scheme. Electro-magnetic Transient Program (EMTP) simulations on two machine system is used to substantiate the claim.

1. Introduction

The protection of the transmission line is an important aspect when we consider the stability of the power system as it is used to transfer bulk power from one area to other. The distance protection of the transmission line gives more reliable and the fast decision making capability to detect fault in the zone of protection and provides the information about trip or no trip [1]. The installation of the FACTS devices such as SVC in the transmission line enhances the power transfer capability of transmission line and provides optimum utilization of the system capability [2]. To utilize the maximum capacity of the transmission line the best suited point for the installation of the shunt connected FACTS device is mid-point of the transmission line [3]. It is well documented in the literature that the introduction of the FACTS devices has a great influence on the power system dynamics. As power system dynamics changes, many sub-systems are affected, including protection systems. Therefore it is important to study the effect of SVC on distance protection, which is the main protective element at Extra High Voltage (EHV) levels.

In the presence of SVC, the conventional distance relay characteristics are greatly subjected to mal-operation in the form of under-reaching and over-reaching the fault point [4]. Therefore the conventional characteristics cannot be utilized satisfactorily in the presence of SVC. The solutions presented in [5–8] are based on data exchange between the relays at the line ends in the presence of SVC. The other potential solution for the problem caused by the introduction of the SVC on the transmission line is adaptive distance protection.

In this paper the investigation of the characteristic impedance measured by the distance relay at the relaying point is presented in presence of SVC. The characteristic impedances measured are presented for the three installation point of the SVC on the transmission line. An adaptive distance protection is presented for the distance relay for the SVC present at mid-point on the transmission line. The Section 2 gives the simulation model of the two machine system using the system data of actual Iranian system. Section 3 presents the derivation of the various equations for the measured impedance for Single Line to Ground (SLG) fault for the system with and without SVC considering various installation point of the SVC. Section 4 shows the simulation results for the analysis of the distance relay characteristics with and without SVC utilizing the steady state characteristic of the SVC. Section 5 shows the comparative study of the conventional distance protection scheme with the distance relay characteristic impedance for SLG fault and proposes the adaptive distance protection scheme to mitigate the problem associated with the conventional distance relaying.

2. Simulation model of the system

Fig. 1. shows single diagram of study system without SVC on 400 kV, 300 km transmission line system. For modeling of long transmission line, distributed model of line is preferred so as to get the very accurate results. But when modeling in the software environment like EMTP [9], MATLAB, etc. we have to break the long line in sections to connect SVC at mid-point and to create various faults at different locations. Hence we have broken the long transmission line of 300 km in three sections as; from sending end to

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Nomenclature

Z_{1s}	positive sequence impedance of sending end source	E_s	sending end source voltage
Z_{0s}	zero sequence impedance of sending end source	E_r	receiving end source voltage
Z_{1r}	positive sequence impedance of receiving end source	δ	load angle
Z_{0r}	zero sequence impedance of receiving end source	Z_{Sa}	apparent impedance seen by distance relay for fault on phase-A
Z_{1line}	positive sequence impedance of transmission line	x	per unit distance
Z_{0line}	zero sequence impedance of transmission line		
R_f	fault resistance		
Z_{sh}	SVC Shunt impedance		

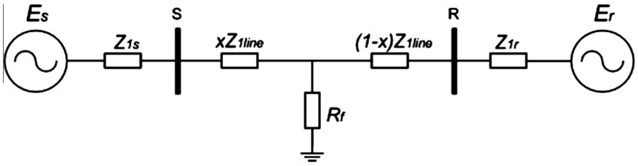

Fig. 1. Single line diagram for two machine system with line to ground fault.

mid-point, from mid-point to 75% of line length and 75% to receiving end. As the maximum length of line is 150 km in each section, line will be considered as medium line while modeling. Hence we used pi-section line model for modeling in EMTP. The load angle between the two generators is $\delta = 16°$, $h = 0.96$ and $E_s/E_r = he^{-j\delta}$. The detailed system data is given in Appendix A.

The ideal mho distance relay impedance characteristics are obtained in MATLAB from equations given in next section for two machine system with and without SVC. Different characteristics are obtained for SVC connected at near end, mid-point and far end with fault at different location on the transmission line. It is observed that when SVC is connected at mid-point, the ideal mho distance relay characteristics remains nearly same as ideal characteristics without SVC for the faults before SVC. It is because SVC does not come in the fault loop and it does not affect measured impedance [10–12]. But when fault occurs after the SVC, SVC is present in fault loop and measured impedance changes resulting in drastic change in ideal mho distance relay characteristics refer Fig. 6.

3. Measured impedances

From Fig. 1, for Single Line to Ground (SLG) fault at distance x, the equivalent circuit is shown in Fig. 2. By using the symmetrical fault analysis method, the following equations are obtained when SVC is not installed in the system as:

$$Z_{S1} = Z_{1s} + xZ_{1line} \tag{1}$$

$$Z_{R1} = Z_{1r} + (1-x)Z_{1line} \tag{2}$$

$$Z_{S0} = Z_{0s} + xZ_{0line} \tag{3}$$

$$Z_{R0} = Z_{0r} + (1-x)Z_{0line} \tag{4}$$

$$Z_{sum} = 2\frac{Z_{S1}Z_{R1}}{Z_{S1}+Z_{R1}} + \frac{Z_{S0}Z_{R0}}{Z_{S0}+Z_{R0}} \tag{5}$$

$$C_{S1} = \frac{Z_{R1}}{Z_{S1}+Z_{R1}} \tag{6}$$

$$C_{S0} = \frac{Z_{R0}}{Z_{S0}+Z_{R0}} \tag{7}$$

$$K_{m0} = \frac{Z_{0line} - Z_{1line}}{3Z_{1line}} \tag{8}$$

$$K_d = \frac{1 - he^{-j\delta}}{Z_{S1}he^{-j\delta} + Z_{R1}} \tag{9}$$

$$C_{load} = (Z_{sum} + 3R_f)K_d \tag{10}$$

$$Z_{Sa} = xZ_{line} + \frac{3R_f}{C_{load} + 2C_{S1} + C_{S0}(1+3K_{m0})} \tag{11}$$

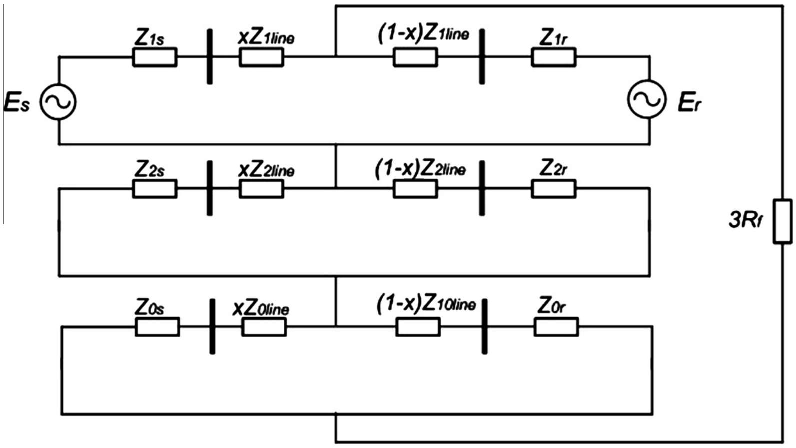

Fig. 2. Sequence network for phase-A to ground fault.