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Fault phase selection and fault Identification in weak-infeed side

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Abstract*—*Traditional low voltage phase selector and sequence current based fault phase selector will not operate satisfactory under weak infeed condition. The study proposes a new method of fault phase selection for transmission lines under weak infeed conditions. The method uses the relative phase angle relationship between negative and zero sequence voltages and superimposed positive and negative voltages to identify the faulty phase under weak infeed condition. The location fault is also determined by using negative sequence components of voltage and current at both ends of the line. The simulation of the system is done with MATLAB and PSCAD.

I. INTRODUCTION

Transmission lines are a vital a part of the electrical power system, as they give the path to transfer power between generation and load. In protection for the transmission line, faults should be cleared as fast as possible in order to enhance the transient stability of the power system, minimizing voltage disturbances and damage to the equipment. As a primary procedure of the relay, fault phase selection is required to be fast and accurate in transmission-line protection. The measured impedance of the distance relay indicates the distance from the relay to fault point correctly only if the fault phase selector identifies the fault phase accurately.

The traditional sequence current-based fault phase selector and traditional low-voltage fault phase selector have difficulties in being applied to the weak-infeed side. It is well known that protection elements such as distance or phase-overcurrent may fail to provide accurate phase indication for particular line faults for the reasons outlined below: First, when a fault occurs those elements that respond most quickly may not correctly identify the fault type. This could be resolved by delaying a trip output, but this is undesirable. Second, protection elements can exhibit an inadvertent operation due to weaknesses in their specific design. For example, some phase distance elements may malfunction on close-in single-line-to-ground faults. Third, some protection elements such as the negative-sequence or zero-sequence directional overcurrent can be programmed to trip the line but they lack the ability of identifying the fault type.

In the case of a weak infeed, the fault currents can be very low. In fact, the currents may drop below the pre-fault load level for a fault on the line. In addition, wye-connected transformers installed in the adjacent substation or in near vicinity may generate significant zero-sequence infeed. If this happens, the asymmetry in the phase currents that is a signature of the fault type is buried beneath the dominating zero sequence current. The phase currents can be almost identical and reliable phase selection based exclusively on the current signals becomes extremely difficult.

This study proposes a new method of ground fault phase selection for high-voltage/extra-high-voltage transmission-line protection under weak-infeed conditions. The method utilizes the relative phase-angle relationship between negative- and zero-sequence voltages and a relative phase relationship between superimposed positive-sequence voltage and superimposed negative-sequence voltage to identify the fault phase under weak-infeed conditions and the location is determined using negative sequence components of both ends of the line.

II. PROPOSED METHODOLOGY

A method of fault phase selection that can be applied to the weak-infeed condition, regardless of whether it is conditional or unconditional, the relay only needs the local voltage information for the fault phase selection by using this method. The method provides a simple way for fault phase selection in the weak-infeed side and it has high immunity against fault resistance, impedance phase-angle inequality, and overload.

A. Algorithm for this method

Step 1: Measure the Local Voltages.
Step 2: Measure the phase displacement between negative and zero sequence voltage.
Step 3: Measure the phase displacement between positive and negative sequence voltages of superimposed components.
Step 4: Identifying the faulty phase by using the relative phase-angle relationship between negative- and zero-sequence

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voltages to define a distinctive phase region which indicates the probable fault phases shown in figure 1.

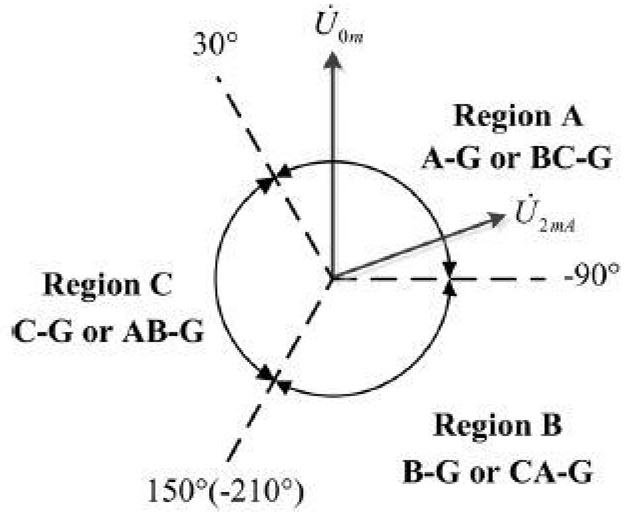

Figure 1 Distinctive Phase Region

Step 5: Fault type identification based on the relative phase-angle relationship between superimposed positive and negative-sequence voltages is used to differentiate between single-phase-to-ground faults and phase-to-phase-to-ground faults, as shown in figure 2

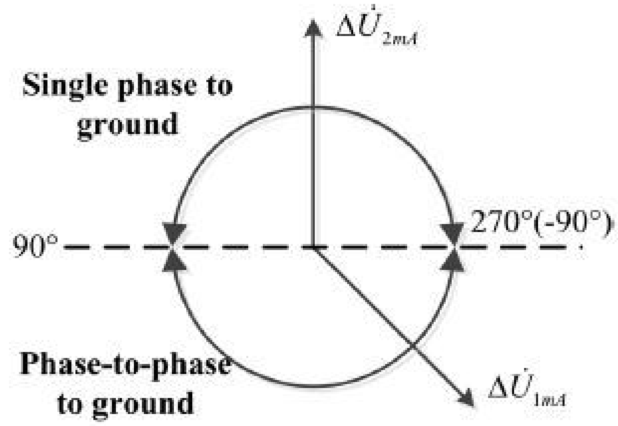

Figure 2 Fault Type Identification

Step 6: Estimation of fault location .location of fault is estimated using negative sequence components of voltage and current at both ends of transmission line.

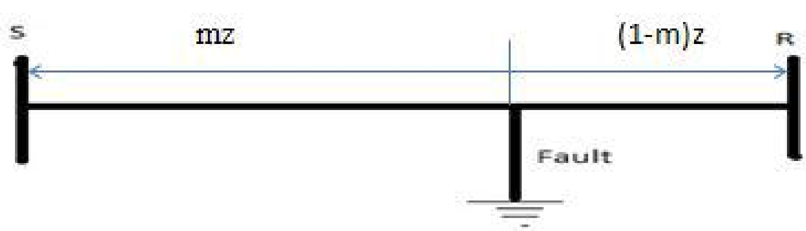

Figure 3 Fault Location Identification.

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Solving the voltage equation we get,

$$m = \frac{V_{2s} - V_{2r} + I_{2r} * Z_2}{(I_{2s} + I_{2r}) * Z_2} \tag{1}$$

Therefore location of fault =

$$Fault - location = m * Total - length - of - line \tag{2}$$

The flowchart of fault phase selection scheme is shown in figure 4

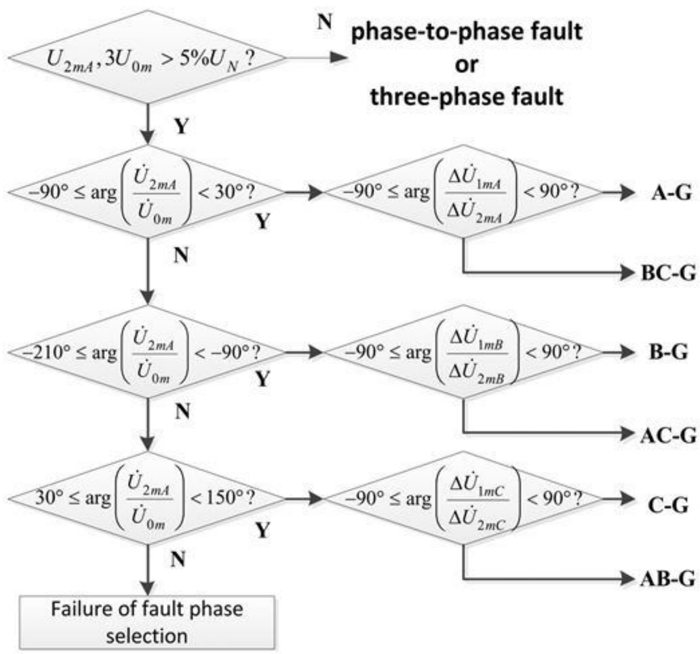

Figure 4 Flowchart

III.SIMULATION MODEL AND RESULT

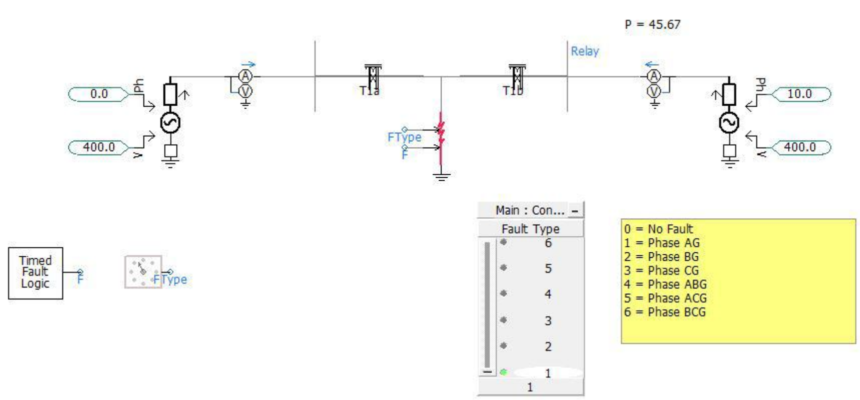

Figure 5 PSCAD model of test system

The PSCAD model of transmission lines under weak infeed condition is shown in figure 5. The various type of ground faults is simulated and various measurements such as positive, negative and zero sequence voltage magnitudes and their phase angles were measured. These measured quantities are then given as input to a MATLAB program based on algorithm mentioned in section II.

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For example when there is a A phase to ground fault, the various measurements obtained from the PSCAD model is shown in figure 6. These measurements are then given as input to MATLAB program based on algorithm in section II and the obtained relative phase angle between negative and zero sequence voltage 6.319 and it lies in region A in figure 1 so it is either A-G fault or BC-G fault. The relative phase angle difference between positive and negative superimposed voltages is 0 and it lies in upper region of figure 2 then the fault will be A-G fault.

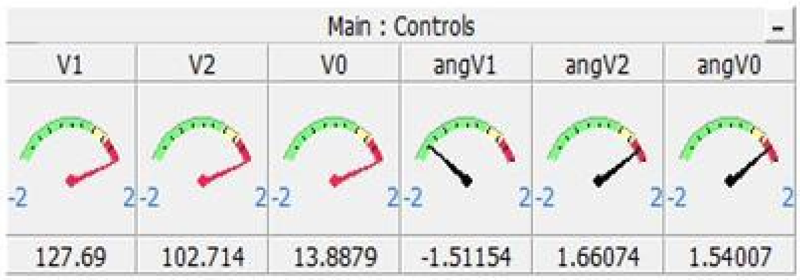

Figure 6 Measurements obtained for A-G fault

Similarly various other cases of fault is shown below. Table 1 shows various measurements obtained for various cases . v1,v2,v0 are the magnitudes of positive, negative and zero sequence voltages and Angv1, Angv2 and Angv0 are respective phase angles.

TABLE 1: Measurements obtained for various cases

cases	V1	V2	V0	Angv1	Angv2	Angv0
1	36.9866	32.1874	21.8843	-1.61188	-1.61409	-1.56945
2	127.69	102.714	13.8879	-1.51154	-2.52805	-0.554327
3	36.9866	32.1874	21.8843	-1.61188	0.480303	2.61934
4	127.69	102.714	13.8879	-1.51154	-0.433657	-2.64872
5	36.9866	32.1874	21.8843	-1.61188	-2.5747	0.524945

These measurement values are given as input to MATLAB program based on algorithm in section 2. The Table 2 shows the relative phase angle between negative and zero sequence voltages, SA and the relative phase angle between superimposed positive and negative sequence voltages SI and the predicted fault type for various cases.

TABLE 2: Output for Various cases

Cases	SA	SI	Fault Type
1	-2.5577	175.6455	BC-G
2	-113.0860	0	B-G
3	-122.5580	175.6555	AC-G
4	126.9136	0	C-G
5	117.4417	175.6455	AB-G

A. Estimation fault location

For estimation of location of fault the negative sequence components of voltage and current at both ends of the transmission line between two bus bars are measured. These measured values are given as input to the MATLAB program for estimating the fault location based algorithm in section II. For example a fault is occurred at 70Km of 170KM length line, the measured negative sequence components of voltage and current are shown in figure 7. These measurements are given as input to the MATLAB program and then solving the equation 1 we get m=0.4150 and then solving equation 2 we get fault location at 70.544Km

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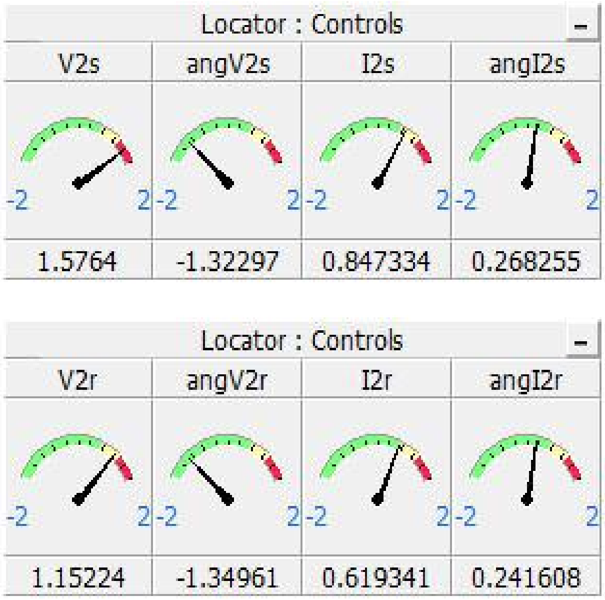

Figure 7 Measured negative sequence voltage and current at both ends of line

Measurements at the sending and receiving end for estimating fault location for various cases are shown in Table 3 and 4.the estimated fault location for various cases are shown in Table 5.

TABLE 3: Measurements at sending end

Total length (Km)	Fault location	V2s	ang V2s	I2s	ang I2s
110	10	2.78606	-0.600059	1.49754	0.991164
130	30	2.12973	-0.840209	1.14476	0.751014
150	50	1.80065	-1.07007	0.967548	0.52115
170	70	1.5764	-1.32297	0.847334	0.268255
190	90	1.36038	-1.60614	0.731218	-0.0149128
200	100	1.23917	-1.75503	0.666068	-0.163811
220	120	0.968129	-2.04682	0.52038	-0.455599

TABLE 4: Measurements at receiving end

Total length (Km)	Fault location	V2r	ang V2r	I2r	ang I2r
110	10	0.550224	-0.361375	0.295752	1.22985
130	30	0.803326	-0.791645	0.431797	0.799578
150	50	1.0004	-1.07996	0.537725	0.511264
170	70	1.15224	-1.34961	0.619341	0.241608
190	90	1.23432	-1.62185	0.663465	-0.306276
200	100	1.23917	-1.75503	0.666068	-0.163811
220	120	1.17379	-1.99378	0.630925	-0.402562

TABLE 5: Estimated fault location for various cases

Total length (Km)	Fault location	Estimated Location (Km)
110	10	11.021
130	30	30.91
150	50	51
170	70	70.5443
190	90	90.0124
200	100	100
220	120	121.014

IV.CONCLUSIONS

A new method of ground fault phase selection for weak-infeed conditions was tested. The proposed method reliably defines a distinctive phase region according to the phase-angle difference between negative- and zero-sequence voltages. The relative phase-angle relationship between superimposed positive- and negative-sequence voltages is used. The location of fault is also estimated using negative sequence voltages and currents at both ends of the transmission line. The simulation software used for the same PSCAD and MATLAB.

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