Identification Of Faulted Distributed Line In An Ungrounded System For Symmetrical Faults

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ABSTRACT: Occurrence of symmetrical fault causes very low fault current, which causes difficulty in identifying the faulted line in an ungrounded system. Due to the complexity of distribution network, there is every necessity to clear the fault in very short span of time otherwise complete system will be affected. In order to overcome this difficulty, an ungrounded system is temporarily converted as a grounded system using thyristor based grounding. Due to this the magnitude of fault current will be increased, which helps in identifying the faulted line in distribution system. In this paper the methodology of identification of faulted line is presented using thyristor grounding method. The effectiveness of this method is verified by theoretical analysis and simulation results. This method is also applicable for resonant grounded and high resistance grounded systems.

Keywords: Distribution system, Power system Faults, grounding methods.

I.INTRODUCTION

Ungrounded, high-resistance grounded, and resonant grounded neutrals are commonly practiced in power distribution systems of some European and Asian countries and in several types of industrial systems in North America. When a single-phase-to-ground fault occurs, such configurations allow the system to continue to operate without tripping immediately. After the fault is detected, it can be cleared at a convenient time, resulting in minimized losses. Typically, the faulted line must be identified and cleared within a required time frame of 30 min to 2 hr. identifying the faulted line among a number of distribution lines connected to the same distribution bus is a significant challenge due to the small ground fault currents produced in the systems.

The identification of faulted distribution line has motivated a great deal of research work since the 1980s. One series of the developed methods identifies the faulted distribution line according to the steady-state zero-sequence fault current on each distribution line. These methods have problems in accuracy since the steady-state fault currents in ungrounded systems are weak signals. Another series of methods uses the transient currents caused by single-phase-to-ground faults for identification. Although the transient fault currents are stronger than the steady-state fault currents, they are highly random and no repeatable, reducing the reliability of the identification of the faulted distribution line. In a present days new series of methods works by injecting special current signals between the neutral and the ground. Strong current signals flow through the faulted distribution line and are used for identification of fault. In some heavily polluted industrial systems, the faulted distribution lines are still identified by switching off the distribution lines one by one.

The proposed method utilizes a thyristor to temporarily ground the system and, therefore, creates a transient current pulse. This current pulse mainly flows through the faulted line and is used to identify the faulted distribution line. An important feature of the method is that the strength of the current signal is adjustable by changing the thyristor firing angle, so that strong enough signal can be generated for identifying the faulted line when the fault resistance is high. Moreover, the voltage transient caused by thyristor firing can be maintained in a small range so that it will not disturb the load operation.

II. Fault location studies

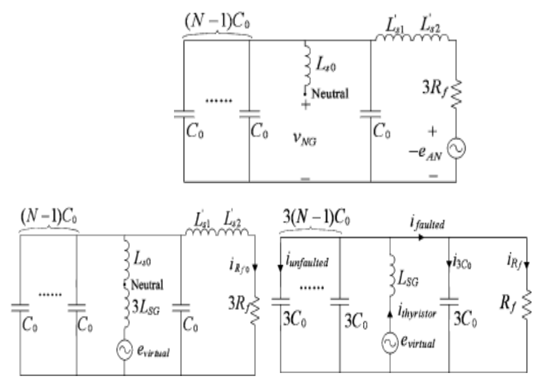
Considerable work has been done in identification of faults in transmission as well as distribution network. Various algorithms and techniques are proposed [6, 7] for identification of faults in different systems. Locating ground fault is a typical and challenging task for low voltage power systems that are ungrounded. Recent work in pilot signals has renewed efforts in developing fault location methodologies [1]. Method of fault location based on fundamental components of voltage and frequency is available [2]. Although the ground fault current is small and usually less than load currents, the fault has zero sequence component that distinguish it from the load. Signal processing techniques are used to identify and compare the fault signals to determine fault direction. Ground fault relay is also used in identifying fault direction in ungrounded system [8].the remote fault indicators are used to visually indicate where the fault is. A new approach called ground fault localization is used to identify the fault in low voltage power system network [3].

III. Fault location formulation

Identifying the distribution line experiencing a single-phase-to-ground fault is very difficult due to the small steady-state fault current available for identification. The cause of the small fault current, in turn, is that the system is not effectively grounded [4]. To solve this difficulty, we proposed to temporarily convert a noneffectively grounded system into an effectively grounded system using a controllable grounding device connected between the neutral and ground. A large fault current pulse will appear if a ground fault exists in the circuit [5]. This fault current mainly flows through a low-impedance path composed of the faulted line, the fault point, and the ground. Regular current transducers (CTs) installed at the sending end of each feeder can be used to acquire the line current waveforms and send them to a central transient current signal detector. This detector extracts the transient current signal flowing through each line and identifies the faulted one

Theoretical Analysis

For an ungrounded system, when a ground fault occurs to phase A of a distribution line and reaches its steady-state, a voltage $v_{NG}(t)$ is established between the neutral and ground, which can be analyzed using the sequence-circuit shown in Fig. 1(a). In this figure, $e_{AN}(t)$ represents the phase A to neutral voltage in normal system condition. $R_f$is the fault resistance; N is the number of distribution lines



(a) (b)

(c)

Fig 1: Analysis circuits for current signals

C_o is the single-phase zero-sequence shunt capacitance of each line; L'_{s1} and L'_{s2} are, respectively, the positive-sequence system inductance plus the faulted line inductance (for the segment from the sending end to the fault point) and the negative-sequence system inductance plus the faulted line inductance; L_{s0} is the zero-sequence supply system inductance. Therefore

$$V_{NG} = -E_{AN}\frac{-JX_{C\Sigma}}{R_f + J\left(-X_{C\Sigma}\right)} \quad (1)$$

Where V_{NG} and E_{AN} are the rms of$v_{NG(t)}$and $e_{AN(t)}$, respectively, $X_{C\Sigma}=1/(3NC_O\omega_1)$ Andω_1 is the fundamental angular speed. L's1 and L's2 are omitted in (1) due to their small values when a high $F_{ry}$is studied (say, above 100 Ω).

The transient current signals created by the controllable grounding device are analyzed as follows. A temporary short circuit created by thyristor firing is equivalent to the injection a virtual voltage source $e_{virtual} = -\upsilon_{NG}(t)$ between the neutral and the ground in Fig. 1(a). Therefore, the created transient signals can be calculated using the sequence circuit energized by $e_{virtual}$ as shown in Fig. 1(b), where L_{SG} is the signal-generator transformer leakage inductance. Fig. 1(c) is derived from Fig. 1(b) and shows the real instead of sequential transient current signals. In Fig. 1(c), L'_{s1} and L'_{s2} are ignored. i_{Rf} is the transient current flowing through the fault resistance; i_{3Co} is the current flowing through the three-phase shunt capacitances of each line. Based on the industry practice in China, zero-sequence CTs are available at the sending end of each line for identifying the faulted line. In this paper, the triples of these CT outputs are studied for the purpose of simplicity. Therefore, the transient current signal on the faulted line and that on an unfaulted line are, respectively, $i_{faulted}$ and $i_{unfaulted}$, and

$$\mathrm{i}_{\mathrm{Faulted}} = i_{R_f} + i_{3C_0} \quad (2)$$

$$\mathrm{i}_{\mathrm{Unfaulted}} = i_{3C_0} \quad (3)$$

Assuming the thyristor is fired ahead of υ_{NG}'s rising-edge zero-crossing-point by an angle of δ (denoted as the firing angle) at t = 0 , the virtual voltage source is

$$\mathrm{e}_{\mathrm{virtual}} = -v_{NG}(t) = -\sqrt{2}V_{NG}\sin(\omega_1 t - \delta) \quad (4)$$

The transient current i_{Rf}, i_{3co} and the thyristor current are

$$i_{R_f} = I_m \frac{R_f^{-1}}{Y_\Sigma}\{-\sin(w_1 t-\beta)+e^{-\tau t}\times[-\sin\beta\cos\sigma t+(\sigma C_\Sigma)^{-1}(X_{SG}^{-1}\cos\beta+(2R_f)^{-1}\sin\beta-Y\cos\delta)\sin\sigma t]\}$$

$$i_{3C_0} = \frac{i_m X_C^{-1}}{Y_\Sigma}\{-\cos(\omega_1 t-\beta)+e^{-\tau t}\times[\cos\beta\cos\sigma t+(\sigma C_\Sigma)^{-1}(X_{SG}^{-1}\sin\beta-(2R_f)^{-1}\cos\beta)\sin\sigma t]\}$$

$$i_{thyristor} = i_{R_f} + N i_{3C}$$

distribution network are typically ungrounded, they have little influence on the generated current signals. Therefore, the proposed method works independent of the load balance condition.

IV. Simulation Studies

This section presents the simulation results to evaluate the developed fault identification using thyristor. The developed fault identification is implemented in MATLAB®.The model has been created with a toolbox of MATLAB/SIMULINK® called SIMPOWERSYSTEMS®. It is a collection of blocks that allow the modeling of different elements that usually are present on power systems. It uses the SIMULINK as simulation engine.Computer simulations were performed to verify the aforementioned analysis using the MATLAB software for the following system

Supply: 25KVA, 50 Hz, three-phase-to-ground fault level of 100MVA, 100km distribution line system.
The simulation of the identification faulted distribution line on a single phase-to- ground fault.
Distribution line: a total of nine overhead lines, each 20km; R1 =0.01273 Ω/km, R0 = 0.3864Ω/km, L1 =0.9337*10^{-3}H/km, L0 = 4.1264*10^{-3}H/km, C1 = 12.74*10^{-9}, C0 = 7.751*10^{-9}.
Load : each line has a three-phase load of 10kw, PF =0.9, ungrounded-Y connected;
Single-phase-to-ground fault: occurs to phase A at the sending end of one line.

The results of the simulations are the voltage and current waveforms of the three phases at the header of the line, the same information that can be obtained from real faults. The voltage and current phasors are found taking the fundamental frequency by using the fast Fourier transform. With the phasors and the model of the network can be computed. The SIMULINK® model used to simulate the algorithm used is shown in the Figure.

According to Fig. 1(c), the transient current signals are mainly determined by the system zero-sequence circuit. Since the loads connected to the

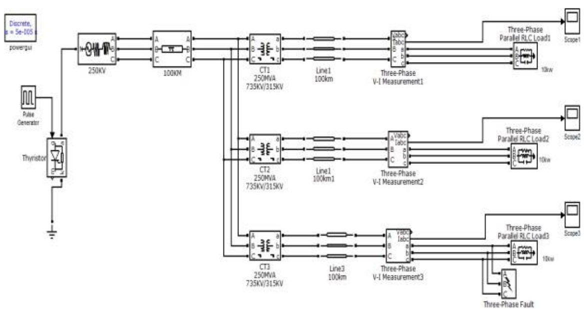


Fig: SIMULINK model of Test system

Three-phase π -section line is used to represent the transmission line. The model consists of one set of RL series elements connected between input and output terminals and two sets of shunt capacitances lumped at both ends of the line. A three-phase voltage source block is connected to supply power to the line. Three-phase transformer by using three single-phase transformers with three windings. Set the winding connection to 'Yn' when you want to access the neutral point of the Wye (for winding 1 and 3 only). Implements an N-phases distributed parameter line model. The R, L, and C line parameters are specified by [NxN] matrices.

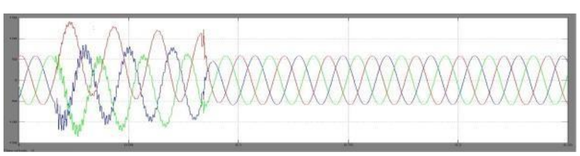


Fig: Current waveforms on distribution line, where the measuring equipment is installed, with an LLL fault occurring in the distribution line at 0.025s.

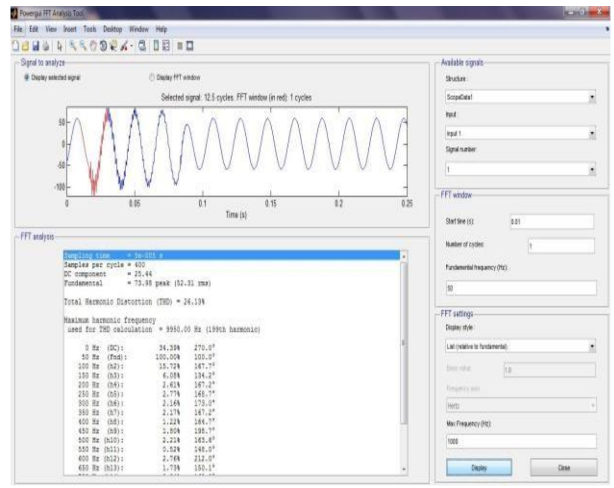


Fig:The FFT Analysis of phase-A, Dc component results with an LLL fault occurring in the starting time at 0.01s

RESULTS

We have applied the three phase and three phase to ground fault in 3-phase overhead distribution system. During the fault time ungrounded system is temporarily converted to grounded system using thyristor. We applied this technique in two conditions i.e. balanced and unbalanced conditions. The respective output waveforms are also shown. The FFT Analysis of dc component results under various phase-ground faults on distribution system table shown in this section.

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FAULT	PHASE	DC COMPONENT					
		BALANCED			UNBALANCED		
		LOAD 1	LOAD 2	LOAD 3	LOAD 1	LOAD 2	LOAD 3
LLL	A	25.44	25.44	25.44	25.44	25.44	25.44
	B	21.17	21.17	21.17	21.17	21.17	21.17
	C	46.61	46.61	46.61	46.61	46.61	46.61
LLL-G	A	25.44	25.44	25.44	25.44	25.44	25.44
	B	21.17	21.17	21.17	21.17	21.17	21.17
	C	46.61	46.61	46.61	46.61	46.61	46.61

Table: The FFT Analysis of dc component results under various symmetrical faults on distribution line

From the above table it is clear that the occurrence of LLL and LLLG faults causes for large value of DC component in all the phases, whereas under normal conditions the value of DC component lies between 2.073 to 6.683 for the same test circuit. This has been verified for balanced and unbalance loads and corresponding values are shown in table.

CONCLUSION

This paper proposed a novel concept and associated scheme for identifying the faulted line in ungroundeddistribution systems. A test system is created with thyristor grounding concept in MATLAB/SIMULINK. Transient currents are extracted for various faults occurred in systems, further fast Fourier transformer (FFT) is applied for the extracted currents for all the lines. Depending upon the magnitude of DC component of transient current faulted line is identified. This is implemented for both balanced and unbalanced loads and for the LLL and LLLG faults.

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