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Earth Fault Protection for Network with Compensated Neutral

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Abstract: This paper introduces an earth fault protection for network with compensated neutral based on using an operative current with frequency of 25 Hz. This method has many advantages concerning the high selectivity and sensitivity of such system clearly appears by using an operative current with 25 Hz frequency, which eliminate the harmonic effects on the system function. The operating principles and the functional block diagram of the developed protection system is shown, analysis of the amplitude-frequency characteristics is provided to give a clear evaluation.

Key words: Protection systems, compensated neutral, 25 Hz frequency, single phase short circuit

Introduction

Faults on distribution networks are predominantly to earth. Under fault conditions the selection of the method of earthing is very important in order to enable the protection system to detect and isolate the fault (Jeff Roberts, 2001). To minimize the interruption due to earth faults, some systems are designed to operate with isolated neutral. In this case under fault condition, the phenomenon of arcing ground is commonly experienced. The arc extinguishes and reftrilces in a repeated regular manner and dangerous over voltages might accrue (Badri Ram, 1998 and Hanninen, 1999) to overcome this an arc suppression coil is introduced. This takes the form of a compensating earthing device. The inductive current of the coil neutralizes the oil impedance being such that under earth fault conditions the capacitive current to earth of sound phases. In this work we introduce an earth fault protection system based on using a source of 25 Hz frequency to detect the earth fault current in distribution networks with compensated neutral.

Networks with compensated neutral

In compensated distribution networks the system is earthed through a variable impedance reactor, which compensates the system phase to earth capacitance (Fig. 1). The reactor, known as Petrsoen coil, permits adjustment of the inductance value to preserve the tuning condition of the system for different network topologies. Because earth faults in compensated systems do not affect the phase-to-phase voltage triangle, it is then possible to continue operating even the system in the faulted condition. The system must have a phase-to-phase insulation level and loads must be connected phase-to-phase.

The majority of faults are single phase to earth faults. So, earth fault protection requires high sensitivity, because the fault current is very low compared with solidly earthed system (Mark 1998).

It is important to note that resonant adjustment of the inductance of the compensating device with the capacitance of a network concerning earth, which is:

$$X_L = X_C \quad \text{or} \qquad \omega L_{comp} = \frac{1}{3\omega C} \tag{1}$$

where X_L and X_C- are accordingly inductive reactance of the compensating device and capacitive reactance of all electrical connected network concerning ground; L_{comp}- inductance of the compensating device; C- phase^{-1} capacitance of all electrical connected network concerning ground.

The equation (1) is the condition in the steady state mode of single -phase to earth fault provides equality on magnitude capacitive I_C and inductive I_L current components of earth fault and, taking into account their direction, the residual current of earth fault becomes equal active components of a short circuit current I_a. In case of non-observance of a condition (1) residual currents are defined as the geometrical sum active and inductive components. Reactive component depends on a mistuning degree or what can be called disorder degree (the deviation from resonance adjustment):

$$v = \frac{I_L - I_C}{I_L} = 1 - 3\omega^2 CL = 1 - K \tag{2}$$

where $K = \frac{I_C}{I_L} = 3\omega^2 CL$ - is a factor of adjustment degree of the compensating device.

The compensating devices are working in three modes: The resonance mode, the under compensating mode in which the residual current of a single phase to earth carries capacitive character and the overcompensating mode where the residual current of short circuit to ground carries inductive character.

To estimate the reliability and damages of elements of a network and quality operation of protection, it is necessary to note the direct relation between this parameter with adjustment mode of the compensating device, as the adjustment mode of the compensating device determined the level of over voltages in a network at single phase to earth fault.

In Fig. 2 dependency of maximal level of over voltage from a disorder degree of compensating device are shown (Balasmeh, 1998). The value of factor (γ), taking into account the decreasing over voltages factors, generally depends on lengths of distribution networks lines, location of a fault concerning a source, resistance in the point of short circuit, and for practical application can be determined by expression:

$$\gamma = \frac{U_{over} - U_{st}}{U_{in}} \tag{3}$$

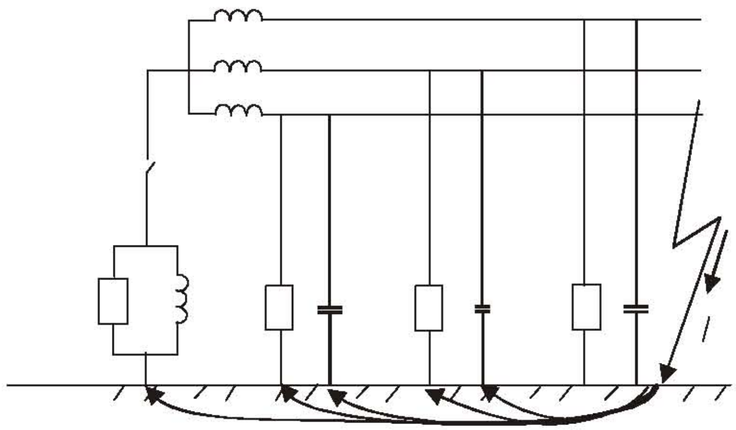

Fig. 1: Network with compensated neutral

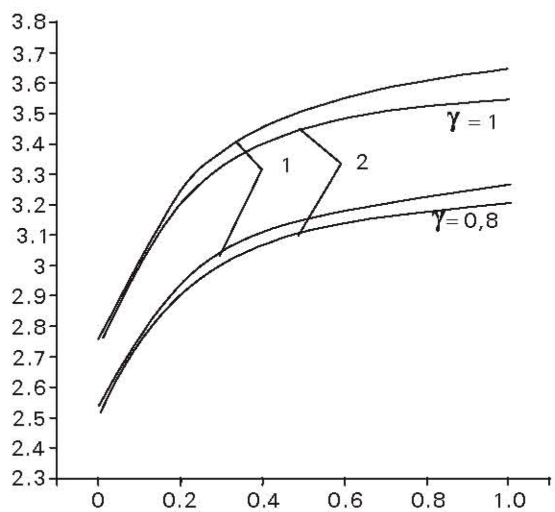

Fig. 2: Dependence maximal level of over voltage from degree of compensating device in: 1- over compensating 2-under compensating

where U_{st}- instant value of the voltage on the faulted phase has established directly after single phase to earth fault; U_{in}-value of the voltage on the healthy phase at moment of a short circuit. The real factor is at a level 0,8...0,9. From Fig. 2 it is visible, that at resonance adjustment of the compensating device and also at its disorder within the limit of 5%, even theoretical over voltage on the healthy phase cannot exceed 2,75 U_{ph} (Helmut Ungard, 1995).

Protection system based on using an operative current with 25 Hz frequency

As the executed researches have shown, the amplitude and phase characteristics of the fault at signal-phase to earth in electrical networks with compensated neutral, depend on the value of disorder degree of the compensating device with respect to the total capacitance of network and resistance in the point of earth fault and duration of the faults (Jalal, 2001 and GEC Guide, 1987).

For improving the performance of protection systems (signal systems) against earth faults in networks with compensated neutral a number of researchers offer to impose on an electrical network an operative current of non-industrial frequency, usually frequency of 100 to 300 Hz. For this purpose it is recommended to use an operative current with frequency 25 Hz, proceeding from the following reasons:

(1) Simply to realize a source of such frequency by use of electromagnetic element frequency dividers.
(2) Increasing the sensitivity is achieved by the smaller values of capacitive current (frequency 25Hz), from which by conditions of selectivity should build up current protection device.
(3) The Harmonic components of 25 Hz frequency in distribution network (6-35 kV) practically is absent.
(4) Low consumption of energy.

The operating principle of protection system and current flow can be explained with help of Fig. 3.

Where cmp- the compensating device; TV- the power transformer; C1, C2, C3 - the per phase capacitances to earth; SOC- the source of an operative current with frequency 25 Hz; TZS- transformers of a zero sequence current.

In the normal operation mode on each of the connections, the operative current is proportional to the capacitance of the appropriate connection and from which the conditions of selectivity which required to build up protection system:

$$\hat{I}_{\varphi.c_i} = 3\hat{U}_{op}\,\omega_{op}\,C_{c_i} \tag{4}$$

where: $\hat{U}_{op}$-the voltage of an operative current source with frequency 25 Hz.

At a fault, the operative current in the faulted connection is increased and causes actuation of protection. On the intact connections, fault to earth, their total capacitive current including the component of industrial frequency and harmonic components.

The functional diagram of the developed protection device against earth faults in the compensated network is illustrated in Fig. 4.

The circuit contains the following functional blocks:

(1) The input block.
(2) The frequency filter.
(3) The logic block adjusted on operative frequency of 25 Hz.
(4) The shaper of output signal.
(5) The supply unit.

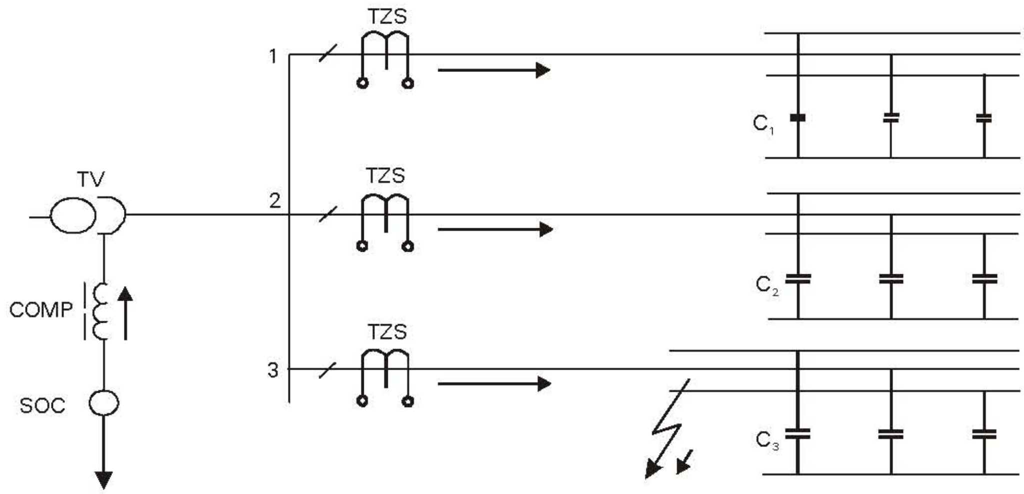

Fig. 3: The operative current flow in distribution network

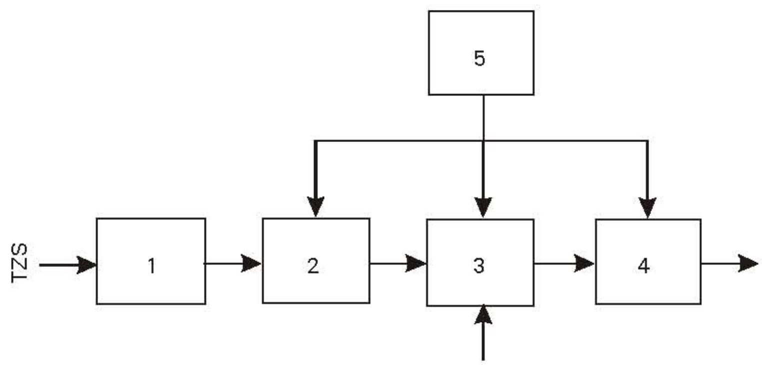

Fig. 4: The functional diagram of the developed protection device against earth faults in the compensated network

The input block 1 consists of the interposing transformer. The basic requirement, to which should satisfy the interposing transformer is, that in all possible range of change of a residual current of earth fault it should not be saturated. A saturating of the interposing transformer can result in a deviation in operating current and even to failure of protection. The frequency filter 2 is intended for permitting an input signal of 25 Hz frequency and is designed, as a frequency-selective amplifier. It should not respond to a capacitive current of 50 Hz frequency. Other requirement to the amplifier is that its amplitude-frequency characteristic should promote correct operation of protection under arcing earth fault conditions.

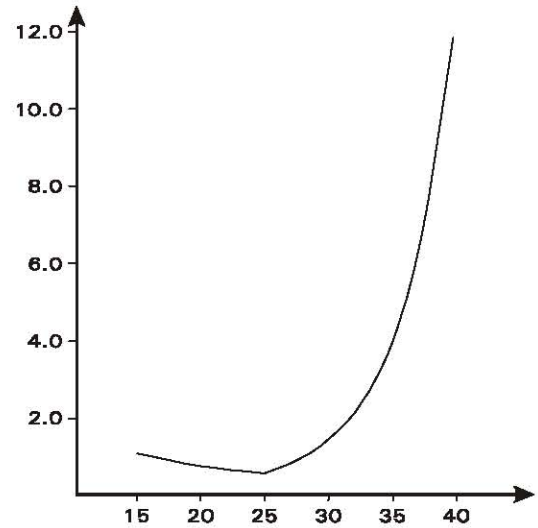

Fig. 5: The amplitude-frequency characteristic

Table 1: Dependence of the operating current of protection on frequency

F (Hz)	15	20	25	30	40	50	100	150
I (A)	0.67	0.42	0.25	0.97	12.6	52	270	320

The logic block 3 is represent in this circuit of protection a thershold element executed as a comparator on an integrated microcircuit. When the voltage of an input signal becomes more than the reference value, the voltage on the output of the comparator changes the polarity.

The shaper of an output signal 4 consists of a time relay, to prevent the operation of the protection under transient conditions and a static relay forming a control signal.

The main important characteristic of protection based on a frequency-selective principle, is the dependence of the operating current of protection on frequency of this current (amplitude-frequency characteristic of protection). The specified characteristic of the developed protection is given in Table 1 and its graphic representation is shown in Fig. 5.

From the Table 1 follows, that the protection has a maximum sensitivity under a current of 25 Hz frequency.

Compensated systems are earthed through a variable impedance reactor, which components are the system phase to earth capacitance. The proposed earth fault protection system can detect earth faults in networks with compensated neutral. Analysis of the results and the amplitude-frequency characteristic of the proposed system insures that is sufficiently selective and less affected by the higher harmonic components and able to detect the earth faults.

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