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Understanding the Concept of Earthing In Electric Power System Engineering

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Abstract: *Earthing is the concept of connecting a thing to the earth (or ground). In Power systems, engineering, ear thing is the one concept that cannot be dispensed with. Generators, reactors and transformers have to be earthed at their star or neutral point for proper operation and application of earth-fault relays; for the realization of single phase voltage supply (in the case of transformers); and for the drainage (as much as possible) of the harmonic voltages that cause distortions in system voltages. Furthermore, the metallic enclosure and non-conduction parts of every apparatus requires earthing for the protection of personnel and users from electrical hazards. It is inestimable the quantity and value of lives and properly that would have been lost to electrical faults but for the application of this concept. Thus, in this paper a detailed discussion of system and equipment ear thing is presented. The writer recommend the use of chem.-rods for better ear thing, as well as an appropriate routine earth-point maintenances schedule*
Keywords: *earth-fault relay, neutral point, harmonic voltage*

I. Introduction

Power system engineering is that field of conscious human endeavour in which energy is generated, converted and transmitted (over a long or short distances) for the purpose of distribution and eventual utilization for the benefit of man and beast. In this connection however, it is mechanical energy that is generated in the most cases and converted into electrical energy.

The concept of earthing in power system engineering is as old as this field of endeavour itself. It came into play from the age-long fact that the earth is a universal sink. Thus, this concept has to do with a connection to the general mass of earth in such a manner as to ensure immediate drainage of energy into the same without danger and for the avoidance of danger.

Therefore, earthing (or grounding as also referred to) features prominently in power system protection schemes. Indeed, the application of earthing is so widespread in electric power systems that at practically every point therefore, from the generating stations through the transmission lines and substation, to the very points of utilization, earth connections are made, unfailingly.

Two major categories of earthing are employed in practice, namely, neutral or mains earthing, and equipment or general earthing as discussed below:

II. Isolated Neutral System

The isolated neutral system is as shown in fig 1 below. With balanced voltages applied to such a line, the capacitive current will be equal in magnitude. Suppose an earth-fault occurs on one of the conductors, say line B. there will be capacitance current flow between the line B and earth. And, the voltage across the other two phases will rise to line voltage values (e.g V_{RN} -√3 V_{RN}.
As shown

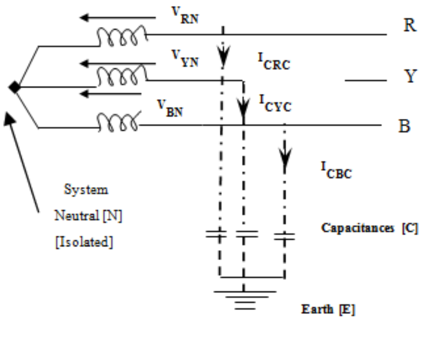

Fig 1: Isolated Neutral system and line-to-earth capacitances.

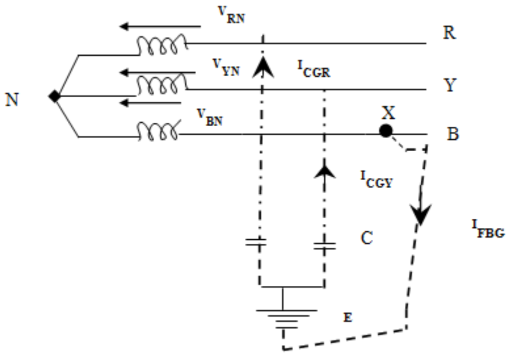

fig. 2. Capacitive currents due to line-to-earth fault at 'X' on line B

As shown in figure 2; the fault on line B feeds the currents I_{CGR} and I_{CGY}. These being capacitive currents, no current flows when the line-to-earth capacitance is fully charged. Therefore, arcing occurs at the faulted point "X" during which period the line capacitance is discharged and capacitive current flow resumes. The cycle of charging and discharging is repeated as long as the fault remains causing intermittent arcing at the point of fault and giving rise to abnormally high voltages across the health phases. Ultimately, the aftermath of this capacitive effect is the damage done to system insulation and consumer's appliances especially where proper over-voltage protection is not provided. Hence, isolated neutral system is not being adopted in practice.

III. Neutral Earthling

Neutral or mains ear thing is the category of ear thing that involves the connection of the star neutral point of power system lines and apparatus to the general mass of the earth. The two main method of neutral ear thing are shown below:

IV. Solid Or Effectively- Grounded Earthling

In this method a direct metallic connection is made between the system neutral and the ground (see fig. 3). The ground electrode resistance will have to be very small (usually less than 1 ohm)

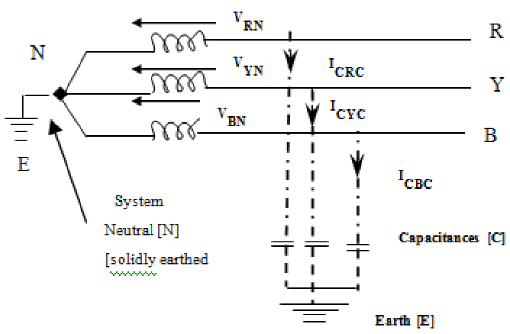

Fig 3 Solidly earth star point
And the line-to-earth capacitances

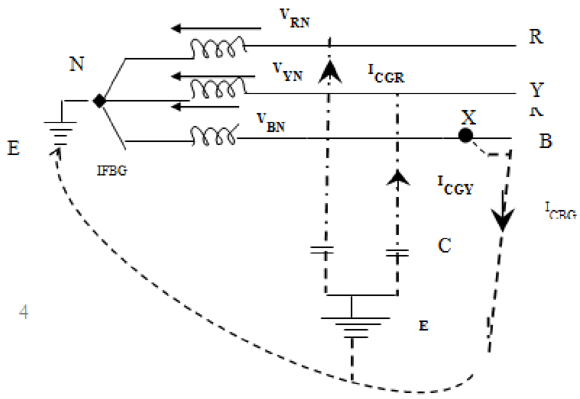

Fig. 4 Capacitive currents due
to line-to-earth fault on line

Under balanced voltage conditions and perfectly transposed line conductors, the phase-to-ground capacitive currents will, all the same, be equal and 120° apart. The star point of the capacitances will be at ground potential, hence no current flows between the capacitances and the neutral or star point.

Suppose now that a ground point 'X' (ie. $V_{BN} = 0$). The ground fault current will consist of two components, namely; I_{FBG} which flows into the system star point and I_{CBG} which flows into the capacitance star point. Comparatively, I_{FBC} is a much larger current than I_{CBG}.

The potentials V_{RN} and V_{YN} during the fault and before fault remain the same because the star point or neutral is not displaced from the ground potential.

Advantages of solid earthing

(i) There is no abnormal voltage rise on the other healthy phases, hence no voltage stress on the system insulation

(ii) The use of graded insulation is permitted meaning additional savings is power transformers of 132KV and above.

Disadvantage of solid earthing

(i) On overhead transmission lines, a majority of the faults are to be ground. Thus the number of severe shocks to the system is relatively much greater than with resistance or reactance grounding.

(ii) The increased ground fault currents affect neighboring telecommunication circuit.

Appraisal

Most of the adverse effects are overcome by the use of high rupturing capacity, high speed circuit breakers and fast acting protective relays. Therefore, solid earthy for the neutral of power system is being adopted in practice.

Resistance Ear thing

This is one form of impedance ear thing and introduced when it becomes necessary to limit the earth fault current. The resistance employed may be a solid metallic resistor or a liquid resistor. (Eg. Caustic soda electrolyte) or (a metallic resistor in transformer oil). The ear thing resistance is connected between the neutral or star point (N) and the ground (see fig 5)

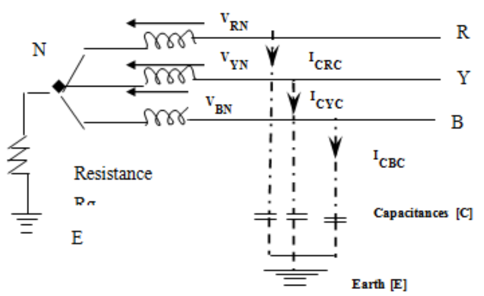

Fig 5: Resistance Earthing and line –to-earth capacitances

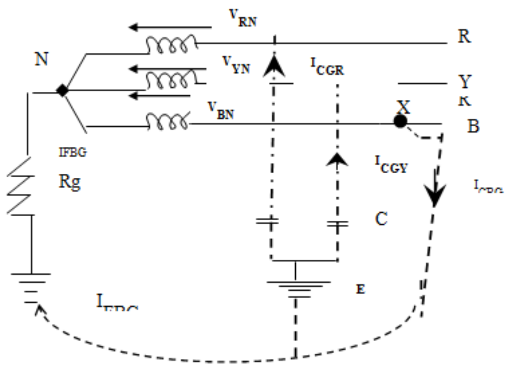

Fig 6: Capacitance current due to line-to-earth faults.

Assume an earth-fault, as usual, at point ‘X’ on line B. The magnitude and phase relationship of the fault current I_{FBG} depends on the relative values of the zero sequence reactance of the power source and the ohmic value of the earthing resistance. I_{FBG} can be resolved into the components, namely I_{FBG} (0) (not shown) in phase with V_{BN} and I_{FBG} (90^o) (not shown) lagging V_{BN} by 90^o . Furthermore, the choice of the ohmic value of Rg affects the power dissipation in Rg itself. The common practice is to choose a value of Rg that will limit the fault current I_{FBG} to the full rating of the full load of the largest generator or transformer in the system. Therefore, the value of Rg is given by, Rg = V_{PH} / I where: Rg → resistance in ohms: V_{PH} → line-to-neutral voltage in volts; I → full load current in amperes of largest generator or transformer.

Major Advantages of Resistance Earthing

(i) It permits the use of discriminative protection and control gear.
(ii) Interference with adjoining communication circuits is avoided.

Major Disadvantages of Resistance Earthing

(i) The system neutral will almost invariably be fully displaced in the cases of ground faults, thus necessitating the use of 100% lightning arresters at an increased cost.
(ii) Graded insulation cannot be used, hence, cost of transformers increases.

Appraisal

(i) Resistance earthing, where it is used, is limited to system voltages of 33KV and below and when the total system capacity does not exceed 5000 K VA(NORONHA, 1988).
(ii)

V. Reactance Earthling

This is another form of impedance earthing and is also referred to as “Peterson Coil earthing”. The practice here is the inclusion of a coil in the system neutral such that the reactance current (I_{FBG}) due to the coil exactly neutralize the network capacitance current (I_{CBG}) at the faulted point ‘X’

In actual practice, however, there will always be a small residual current present in the faulted phase due to the effect of resistance in the arc suppression coil, though too small to maintain an arc.

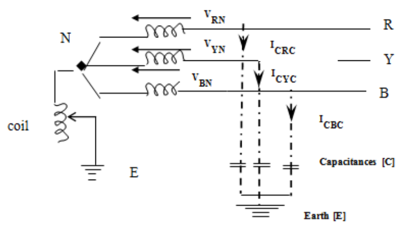

Fig. 7 Reactance Earthing And line-to-earth capacitance

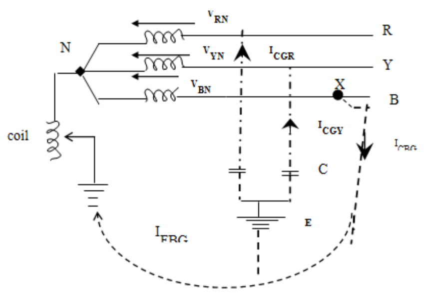

Fig 8 Capacitance currents due to to line-to earth fault

Equipment Earthing

Equipment (or general) earthing has to with the earthing or grounding of all the non-current-carrying metal parts of lines and apparatus used in supply systems and equipment employed in the utilization of electrical energy as completely different from neutral earthing.

Objects Of Equipment Earthing

The objects of equipment earthing include the following:

(i) To provide protection to plant and personnel from danger due to accidental grounding of live parts of equipment.

(ii) To cordon off the zone of dead line working to make it safe during working to prevent electrostatic and electromagnetic induction and also accidental contact from other energized lines and apparatus.

Methods Of Equipment Earthing

This is always done by the method of effective or solid earthing of parts concerned, including: the frames of generators, reactors, motors; tanks of transformer, circuit breakers, ring main units, enclosures of magnetic starters, distribution boards, switch-fuses; bodies of domestic appliances like electric cookers, pressing irons, electric heaters, etc.

General Code Of Practice

It is worthy to give a space, no matter how small, for a discussion of the general code of practice as affecting earthing in this paper. The subheadings that follow cover those necessary specifications that constitute the practical approach to earthing generally.

Selection Of Earthing Materials

Materials for the earthing conductor should have (a) high conductivity (b) low rate of corrosion by soil, and (c) low rate of corrosion due to galvanic action. Hence, copper finds application here since it fulfils all these requirements. The second best material, at any rate, is galvanized steel.

Size Of The Earthing Conductor

The size of conductor chosen for earthing should be such as would ascertain (i) the thermal stability of the conductor to earth-fault current, (ii) its mechanical strength, (iii) its durability (for several years) without causing a break in the grounding circuit due to corrosion (iv) sufficient conductivity so that it does not contribute substantially to local potential gradient.

The IEE Regulations stipulate that the cross-sectional area of the earthing lead (ie the final conductor by which the connection to the earth electrode, or other means of erathing is made), if copper, shall not be less than: 6mm^2 for the largest associated copper circuit conductors of 10 to 16mm^2 for the largest associated copper circuit conductors of 25 to 50mm^2; 50mm^2 for those of 70 to 150mm^2; and 70mm^2 for those of 185 to 630mm^2. They must be stranded.

Values Of Earth Electrode Resistance

The earth (electrode) resistance should not be more than 5 ohms generally. However, for better performance at power houses and at substations, its value should be 0.5 ohm and 1.00 ohm, receptively (UPPAL & LAROIA, 1981). Carbon dust, common salt and water are often used to improve earth resistance.

Burying The Earth Electrode

The earth electrode, if the rod type, is driven vertically into the ground at about 1.5m from the wall of the building or equipment to be earthed and to a minimum depth of 0.5m and as damp an area or position as possible. Extension lengths preferably with 70mm^2 bare copper may be provided for further depth penetration.

Basic Earth-Test Requirement

The basic earth test is to ascertain that the main protective devices will operate if the value of the earth-fault current exceeds: (i) 3 x the current of semi-enclosed fuse or any cartridge fuse having a fusing factor of more than 1:5; or (ii) 2.4 x the rating of the cartridge fusing factor of 1.5 or less; or (iii) 1.5 x tripping current of the overload circuit breaker.

VI. Conclusion and Recommendation

In power systems engineering, solid or effective earthing is the most commonly adopted method of earthing, working best with very low earth electrode resistance. The difficulty and cost of realizing acceptably low earth electrode resistance cannot be over-emphasized, especially in arid areas. But the advent of chem.-rode in recent times has made the practice a let easier and interesting.

Chem.-rod it an ultra-efficient low surge-impedance chemically-activated grounding electrode. It continually conditions the surrounding soil, making the soil more conductive than otherwise. With a diameter of 64.3mm, meaning greater surface area and greater contact with earth, one chem.-rod ahs the equivalent performance of 15 to 20 conventional earthing rods (LEC, 1995). Therefore, its immense usefulness cannot but be taken due advantages of.

It is rather appalling to observe in most residential and commercial premises that the earthing lead is never checked for continuity to the rod and nothing is ever done to improve the earth resistance after several years since installations. Hence, the reason for the several cases of electric shock from refrigerator, deep freezer/ electric pressing irons, electric cookers, kettles, grinders, etc in these premises is not far-fetched. We also see why noise signal which are supposed to be drained off public address amplifiers through proper earthing remain to introduce noise into system thus vitiating the system performance at many programmes held in such areas.
The author is particularly concerned about the electric shock hazard. Wherefore it is recommended here that:

1 BEDC(Benin electricity distribution company) meter reader should be made to also inspect the earthing lead to ascertain its continuity to the rod. Where it is found discontinued, the affected premises should be disconnected from power supply immediately until the customer makes good the same. This presupposes that the current practice of bill estimation by BEDC should be discontinued. BEDC meter readers must visit the premises of customers physically to performs this and other duties
2 Periodic measurement of the earth resistance, say, every 6 month-January (dry season) and July (wet season) – to ascertain the value of the electrode resistance to earth should also be carried out by the BEDC meter reader or other official with portable earthing resistance tester. It therefore means that a test point or head with earth-rod extension lead (of 70mm2 stranded copper, as earlier mentioned) must be made available and accessible at the customer's premises close to the meter area. Where the measured values are poor, the customer should be advised to improve the same, failing which the affected premised should be cut off from the general power supply. Apart from common salt, other chemical like magnesium sulfate, copper sulfate and calcium chloride can be used for each resistance improvement (IEEE std., 1976)
3 Every 3 years of 5 (at most) the main conventional earth electrode should be brought out and maintained (or changed with the clamps as the case may be) reburied properly
4 The use of Che-Rods should be greatly encouraged every where.

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