



# **Concept of Earthing in Power House & Switchyard with Operation Analysis of Earth Fault Controller using ATP Software**

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**ABSTRACT:** In this paper has described the process of Earthing sizing for Switch Yard & Power House with basic concept of ground grid design, comparison with switch yard & Power house sizing & selection of ground electrodes, soil resistivity measurement with improving methodology of soil resistive to achieve adequate minimum ground resistance. Earthing is to limit the effect of ground potential gradient to such as voltage & current levels that will not endanger the safety of people or equipment under normal and fault conditions. The system shall also ensure continuity of service. The main two following aspect behind earthing are,

- Provide a low-impedance ground to fault current return path in order to activate the protection and clear or alarm the ground fault as soon as possible. Low resistance path will also allow ground fault to flow through the earth conductor instead of person's.
- Limit the voltages on station structures and accessible equipment both during normal operation and during electrical transients to safe levels.

Another part of in this paper has described function of Earth Fault Controller (EFC) in a faulted phase earthing. Controller is used for reducing customer hours lost (CHL) and customer interruptions (CI) during earth fault in system to operate as an interchangeable high resistance earthed/isolated system in conjunction with FPE.

The proposed system used with Neutral Earth Resistor (NER), which is switched out during sustained faults. Basically natural earth resistor is required to restrict switching over-voltages. Transformer neutral will be isolated during a single line to ground fault in system & faulted phase will be earthed and as the phase to phase voltage is unchanged with the FPE applied, and load is connected via delta windings the supply voltage to customers is maintained. The concept for this controller was initially tested by Ireland Electricity Board. ATP Model is used for analysis of EFC controller operation & characteristic of faulty system.

**KEYWORDS:** Grounding Grid, Faulted Phase Earthing (FPE), Neutral Earth Resistor (NER) Continuity Supply, Line to Ground fault, ATP/ EMTP

## **I. INTRODUCTION**

In guide standard IEEE 80-2000 has defined the concept of grounding and there basic principal. The connection between a grounding system and metallic parts that are not usually energized but that may become live due to a fault or an accident; often referred to as equipment or frame ground. Concept of Grounding in Generating stations and substations also describe in IEEE 80-2000 & methods for achive low resistivity of ground with proper solution.

In the Second Part of this Paper has proposed system that will operate as an interchangeable high resistance earthed/isolated system in conjunction with FPE, by the use of a custom designed EFC. The proposed system uses a Neutral Earth Resistor (NER), which is switched out during sustained faults. This NER is required to restrict switching over-voltages. During a single line to ground fault, the faulted phase will be earthed and transformer neutral will be isolated. As the phase to phase voltage is unchanged with the FPE applied, and load is connected via delta windings the



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supply voltage to customers is maintained. The concept for this controller was initially developed in Ireland & performance analysis testing is also done.

## II. BASIC ASPECT OF GROUNDING

To establish the basic idea and concepts, the following points may serve as guidelines for starting a typical grounding grid design:

- a) A continuous conductor loop shall surround the perimeter to enclose as much area as practicable. This measure helps to avoid high current concentration and, hence, high gradients both in the grid area and near the projecting cable ends. Enclosing more area also reduces the resistance of the grounding grid.
- b) Within the loop, conductors are typically laid in parallel lines and, where practical, along the structure or rows of equipment to provide for short ground connections.
- c) Ground rods may be at the grid corners and at junction points along the perimeter. Ground rods may also be installed at major equipment, especially for surge arresters.
- d) This grid system would be extended over the entire substation switchyard and often beyond the fence line. Multiple ground leads or larger sized conductors would be used where high concentrations of current may occur, such as at a neutral-to-ground connection of generators, capacitor banks, or transformers.

## III. GROUND DESIGN IN DIFFICULT CONDITIONS

In areas where the soil resistivity is rather high or the substation space is at a premium, it may not be possible to obtain a low impedance grounding system by spreading the grid electrodes over a large area, as is done in more favorable conditions. Such a situation is typical of many GIS installations and industrial substations, occupying only a fraction of the land area normally used for conventional equipment. This often makes the control of surface gradients difficult. Some of the solutions include are,

- a) Connection(s) of remote ground grid(s) and adjacent grounding facilities, a combined system utilizing separate installations in buildings, underground vaults, etc. A predominant use of remote ground electrodes requires careful consideration of transferred potentials, surge arrester locations, and other critical points. A significant voltage drop may develop between the local and remote grounding facilities, especially for high-frequency surges (lightning).
- b) Use of deep-driven ground rods and drilled ground wells.
- c) Use of wire mats. It is feasible to combine both a surface material and fabricated mats made of wire mesh to equalize the gradient field near the surface. A typical wire mat might consist of copper-clad steel wires of No. 6 AWG, arranged in a 0.6m x 0.6m grid pattern, installed on the earth's surface and below the surface material, and bonded to the main grounding grid at multiple locations.
- d) Where feasible, controlled use of other available means to lower the overall resistance of a ground system, such as connecting static wires and neutrals to the ground. Typical is the use of metallic objects on the site that qualify for and can serve as auxiliary ground electrodes, or as ground ties to other systems. Consequences of such applications, of course, have to be carefully evaluated.

## IV. GROUNDING DIFFERENCES BETWEEN SUBSTATION & GENERATING STATION

- a) Two major differences between substations and generating stations are that generating stations usually occupy a much larger physical area and have numerous large buried structures and foundations. Although both of these characteristics have a significant impact in lowering the overall resistance of the station
- b) From the aspect of ground grid design, generating stations differ from substations in that the personnel to be protected are generally working indoors. Because they are not in direct contact (Not directly Contact with ground that's why chances of produce step & touch Voltage is reduced) with the earth or with a layer of crushed rock covering the earth, they are not exposed to many of the step and touch voltage conditions that personnel in substations are..



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- c) This clause, therefore, presents a procedure for evaluating the safety of those portions of the station grid outside of the main station building(s) where personnel are expected to be working, such as the step-up transformer area, the water intake pumping areas, and fuel and hydrogen handling areas.

## V. SALECTION OF CONDUCTOR & SIZING OF CALCULATION OF GRID

Conductors are used for creating underground grid for achieve low resistivity of ground with proper conductor size or what maximum allowable temperature limit needs to be applied in individual design situations.

Each element of the grounding system, including grid conductors, connections, connecting leads, and all primary electrodes, should be so designed that for the expected design life of the installation.

Basic requirements in conductors are,

1. Conductor has high conductivity, so that will not contribute substantially to local voltage differences.
2. Resist fusing and mechanical deterioration under the most adverse combination of a fault magnitude and duration.
3. High melting point & mechanically reliable and rugged to a high degree.

### Characteristic of following Conductor Material used for Ground Grid

Type of conductor	Melting Point	Conductivity	Corrosion effect	Cost
Copper	1208°C (approx.)	High	Low corrosion	High
Copper-clad steel	1082°C (approx.)	Low with respect to copper	Lower	Lower than copper
Aluminum	608°C (approx.)	Low	Lower	Low
Steel	1368°C (approx.)	Very low	Higher than Alum.	Very Low

Mostly steel Flat or Conductor is used for the ground grid due to good conductivity & more corrosion resist. For above ground & protective bus conductor has used galvanized steel flat or conductor & it's economically & cheap but for better conductivity used copper conductor or flat in transformer neutral, metallic gate, window & LA.

## VI. CONDUTOR SIZE FOR GROUND GRID

Conductor sizing is one of the most another aspect grounding sizing in IEEE 80 has defied proper conductor sizing method with respect to system fault current. Conductor size and material of conductor is used according to required value grid resistance. Formula is drive bellow for conductor size are,

$$A_{mm^2} = I \frac{1}{\sqrt{\left(\frac{TCAP \cdot 10^{-4}}{I_c \alpha_r \rho_r}\right) \ln\left(\frac{K_g + T_m}{K_g + T_a}\right)}}$$

## VII. METHODOLOGY FOR SOIL RESISTIVITY MEASUREMENT

A number of techniques for soil resistivity measurement described but most commonly used technique is Wenner Four Pin Method with four probes are driven in to earth at straight line at equal distance a apart, driven to a depth b. The voltage between the two inner (potential) electrodes is then measured and divided by the current between the two outer (current) electrodes to give a value of resistance R.

Estimates based on soil classification yield only a rough approximation of the resistivity. Actual resistivity tests

$$\rho_a = \frac{4\pi aR}{1 + \frac{2a}{\sqrt{a^2 + 4b^2}} - \frac{a}{\sqrt{a^2 + b^2}}}$$

therefore are imperative. These should be made at a number of places within the Substation sites where the soil may possess uniform resistivity throughout the entire area and to a considerable depth are seldom found.

Typically, there are several layers, each having a different resistivity

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Four Pin methodologies is better for uniform soil resistivity but some surface has multi-layer non-uniform soil resistivity than two-layer soil model can be represented by an upper layer soil of a finite depth above a lower layer of infinite depth. Soil resistivity is not only depending upon the soil characteristic it's depend on the weather, moisture, temperature also.

For improving soil resistivity various kind soil treatment is use as like sodium chloride, magnesium, and copper sulfates, or calcium chloride, to increase the conductivity of the soil immediately surrounding an electrode. State or federal authorities may not permit using this method because of possible leaching to surrounding areas. Further, the salt treatment must be renewed periodically.

Use of bentonite, a natural clay containing the mineral montmorillonite, which was formed by volcanic action years ago. It is noncorrosive, stable, and has a resistivity of 2.5 ohm/m at 300% moisture. In fig. has shown following no of grid lay in Thermal & Hydral Generation station.

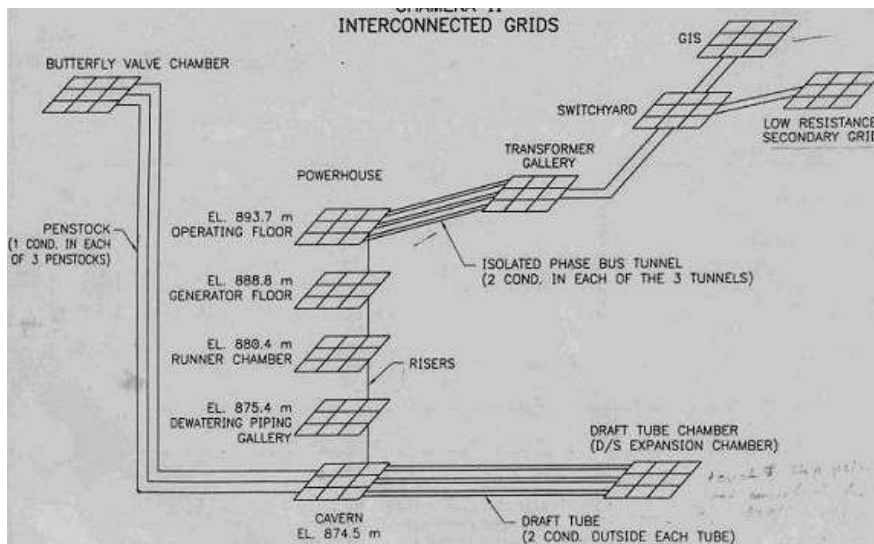


Figure1. Number of grid design in Generating Station

### III. SIZING CHECK & ADEQUATE CONDITION OF EARTHING

1. Soil resistivity shall be low as possible after treatment.
2. Ground grid resistance shall be less than 1 ohm.
3. Calculated touch voltage for 50 or 70 kg body is greater than calculated mesh voltage of Grounding (E<sub>TOUCH</sub> > E<sub>M</sub>).
4. Calculated Step voltage for 50 or 70 kg body is greater than calculated mesh voltage of Grounding (E<sub>STEP</sub> > E<sub>S</sub>).
5. Adequate Sizing of Earthing done if checked all condition is satisfied otherwise changed initial parameter grid resistance and resize according to provide process.

This is the following calculation process of earthing done with some initial calculation (System study fault current calculation) & Collective data like Soil Resistance, Ground Grid Area etc.

This process is applicable for all kind of generating plant like Hydral, Thermal, wind, solar, substation & also normal area for grounding calculation.

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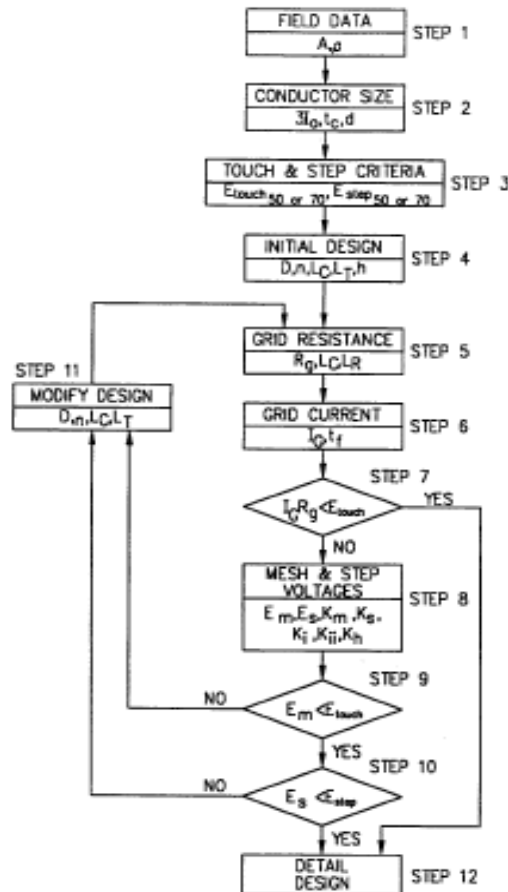


Figure2. Process for Earthing Calculation

## IV. CONCEPT OF EFC CONTROLLER & EXISTING METHOD OF OPERATION

In Generating station & transmission line has mostly occur single line to ground fault as comparison to line to line & 3 phase fault. Earth fault controller is used for resolving unbalance condition in other phase during single line to ground fault in system & also used for reducing mal operation of CB tripping condition during switching operation. In fig no.3 has shown the operation of EFC during normal condition and in fig no.4 has shown operation during single line to ground fault.

When SPF fault occur in system remaining two phase sections has result a high level of capacitive unbalance. Fault current make a loop circuit with transformer neutral & unbalance supply interrupted the whole system due to fault in single phase. Main function of this controller is reducing the customer hours lost (CHL) and Supply interruptions during single line to ground fault. Controller has used switches with high sensitive relays during SLG fault condition switch of faulted phase will be closed with earth & transformer neutral switch will be open at the time till fault will not isolate from the system after fault clearance neutral switch close again and controller switch will be open without interruption of other phase supply only disconnected faulty single phase supply from system.

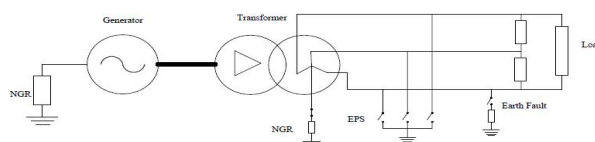


Figure3. System under Normal Condition when no fault

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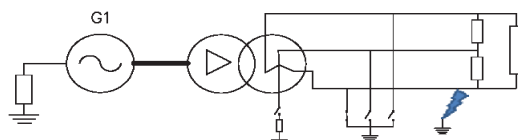


Figure4. System During fault Condition

## V. MODELING WITH ATP FOR ANALYSIS CONTROLLER OPERATION

ATP (Alternating Transient Programming) EMTPT is a valuable tool for Insulation Coordination study, Switching & Transient performance analysis of network. Model of Earth fault controller is drawn in ATP & analysis the performance of network during single line to ground fault with EFC & without controller.

Model has used Saturated Transformer with 3 phase & single phase load, Voltage & current probe for supply analysis with 3 Phase generator rating. EFC controller with switches is connected in the line side at normally open condition with closed transformer neutral switch. Model has connected Single phase load for phase supply analysis during fault condition and capacitive current effect & for single line to ground fault creation switch is connected in single phase at normally open condition.

This ATP model is only for analysis of controller performance but in actual controller has used high sensitive fast operated relay for switching operation performance. There are different switching operations involved in carrying out the live earth fault testing, steps include; fault application, FPE application, isolation of neutral, switching in neutral and isolation of faulted phase. ATP model is shown in the fig no. 5.

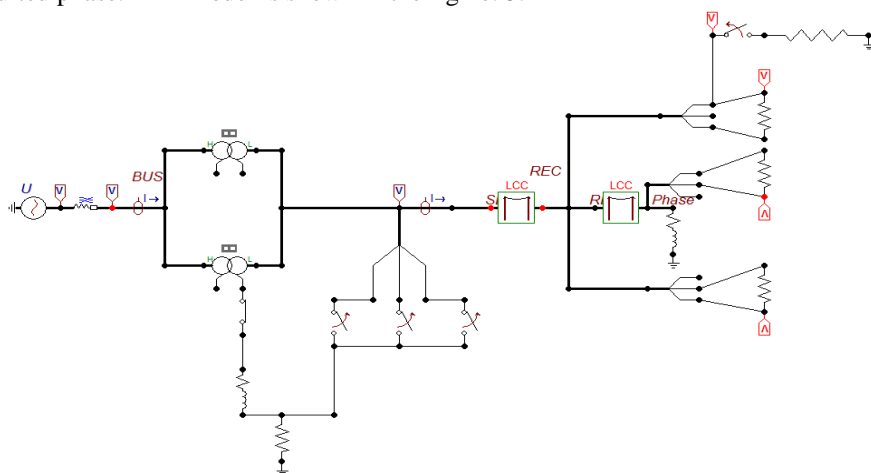


Figure5. ATP model for analysis of EFC

Figures 7 & 8 have display the voltage waveforms measured during line to ground fault & EFC operation condition. The waveforms correspond to the following actions of the FPE system

1. FPE open, NER closed, Closing fault
2. FPE closing, NER closed, Fault on
3. FPE Removal, NER closed, Fault on
4. Removal of FPE, NER closed, Fault off

## VI. RESULT AND DISCUSSION

In the analysis of these curve its clear phase voltage rise during the fault condition & cleared through EPF controller with switching operation. During the operation of this controller insulation of NGT & cable may be fail due to high voltage stress & voltage rise in phase.



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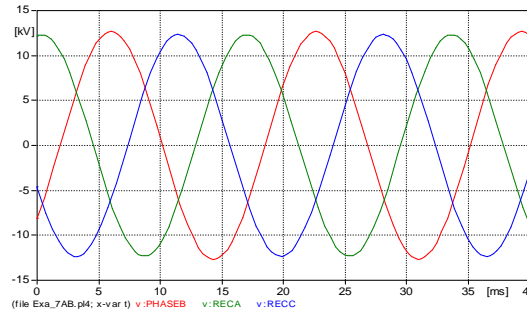


Fig No. 6 No fault in system & FPE is off

These voltage wave forms have no disturbance and no more earth fault is normally off in this condition. No voltage fluctuation & all the phase operated normally.

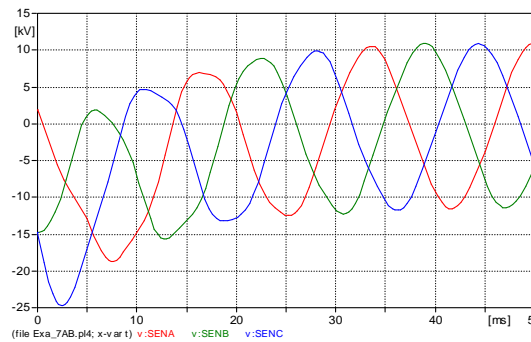


Fig No. 7 Fault is on & FPE off condition

Ground fault is happen the voltage is suddenly start rising due to ground fault and reactance value of system.

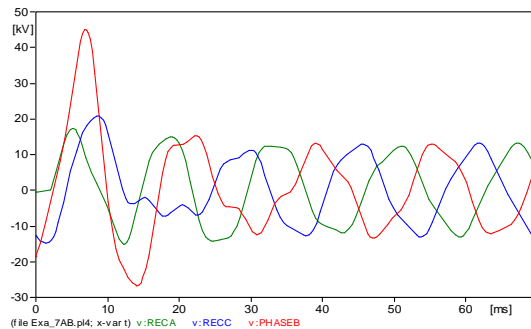


Fig No. 8 fault open & unbalanced voltage

the capacitive voltage and become system stable.



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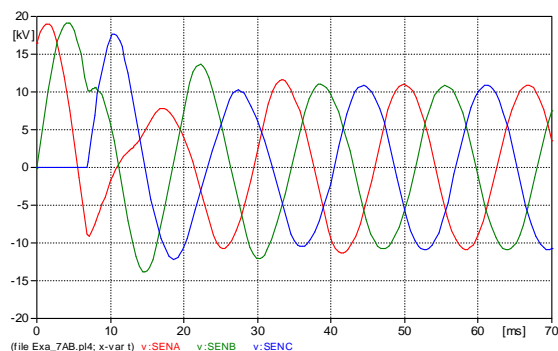


Fig No. 9 FPE closes & Fault condition clear

This is the final condition in which unbalanced system get balanced condition after removing fault & voltage supply only unbalanced during of Earth fault Controller operation.

## VII.CONCLUSION

As per shown result of ATP model FPE system concluded benefits are to reduced fault site voltages and, reduced over voltages & FPE switches has not exceeded the line to line voltages.

The new system has the capability to both detect high impedance faults and maintain supply during single line to ground faults. Numerous benefits of this system have been identified such as: improved sensitivity, selectivity, and fault location. There are also a number of benefits associated with the FPE method of operation but not specifically associated with this work, such as: supply continuity, fault site safety.

The result shown in the Fig 6 & 7 has fault clear through Earth fault controller without unbalanced of other phase supply. There are drawbacks associated with increasing the voltage stress at transformer neutral some time insulation of cable & NGT cubicle may be breakdown if neutral switch open during fault. For controlling arc & voltage stress at NGT switch fuse & arc controller shall be used with FPE controller.

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