

EARTH FAULT PROTECTION VIS-À-VIS GENERATOR GROUNDING SYSTEM

H. C. Mehta

Power Linker Group Cos, Mumbai

ABSTRACT

Operation of all zero sequence current protection is dependent upon the type of system neutral grounding. Running electrical system supplied from Electricity Board are usually solidly grounded (fault current kA) or low resistance grounded fault current 1000A to 2000A. The difficulty is experienced, when captive power generators are introduced with high resistance grounding system (fault current <100A). Then it is necessary that,

- a) Sensitivity of existing earth fault protection system is to be reviewed
- b) Existing and new grounding systems are to be rationalized. Wherever required
 - i. Neutral Grounding system is modified OR
 - ii. Existing relays are replaced by sensitive earth fault protection relay

A case study of a cement plant is considered, where existing system of 132/6.6 kV, 15 MVA transformer is low resistance grounded with earth fault current magnitude limited to 1313 Amps. Later on a captive power generators with high resistance grounding (Current limited to 100 A) was introduced. This resulted into

- a) Non-operation of some of the feeders' earth fault protection relays against earth fault and
- b) Mix-up of grounding system, where higher magnitude of Earth Fault current can damage the Generators.

The solutions discussed are :

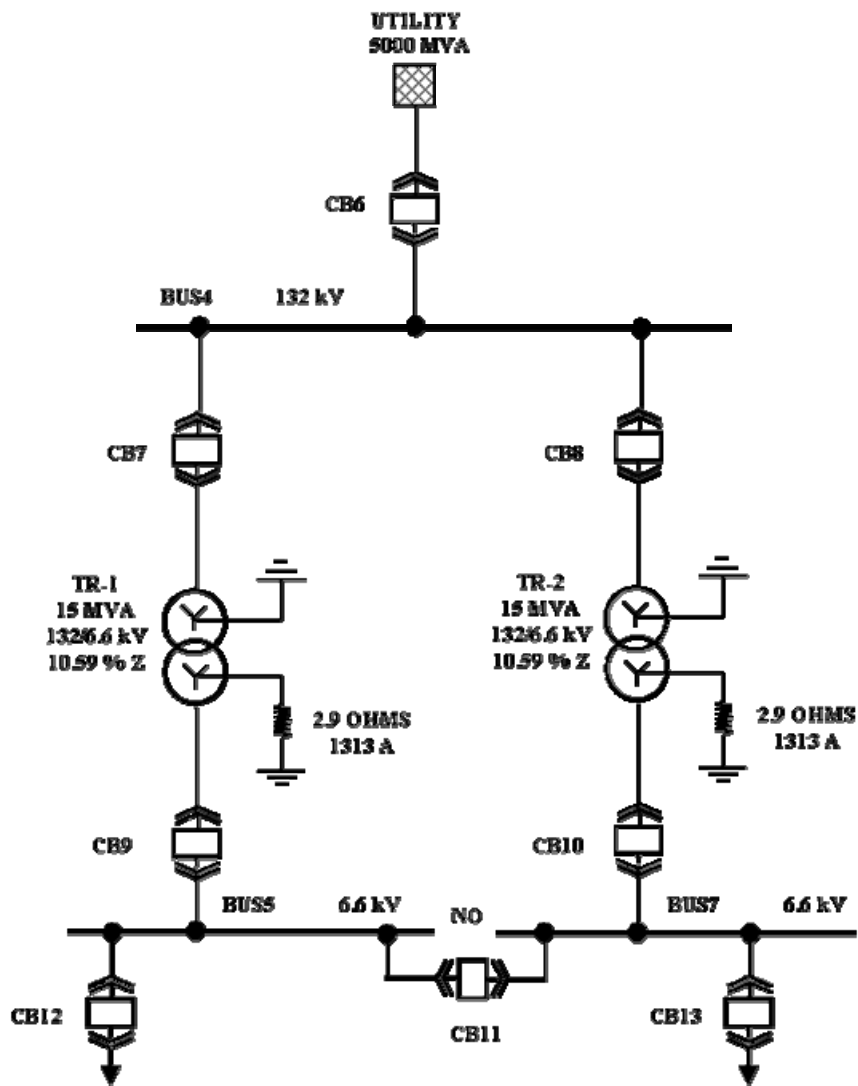
Rationalize grounding system by introducing Generator Transformer with load side winding grounding system equivalent to existing grid transformer grounding system, thus retaining the earth fault current magnitude as existing and retaining the sensitivity of existing earth fault protection system.

Alternate solution: Rationalize grounding system by changing the Neutral Grounding Resistor (NGR) of existing grid transformer to protect the generator core from getting damaged. However, this will require replacement of the existing earth fault relays by sensitive earth fault relays, which can detect the reduced earth fault current magnitude.

INTRODUCTION :

For existing plant operation, power is received from Electricity Board with 5000 MVA short circuit level at 132 KV voltage. This power is distributed to integrated cement plant loads at 6.6 KV voltage level through 2 x 15 MVA, 132/6.6 kV, star/star, (YNyn0) transformers. 132KV star winding is grounded solidly, whereas the 6.6 kV star winding is grounded through a low resistance neutral grounding resistor of 2.9 ohms, thus, limiting the earth fault current magnitude to 1313 Amps.

FIG. 1 EXISTING SYSTEM SINGLE LINE DIAGRAM



The outgoing feeders at 6.6 kV voltage level has current transformer ratio of 2000/1. In case of earth fault, the current transformer secondary current was 65% of relay nominal current ($1313A/2000 = 0.65A$). The minimum setting on the relay was 10%. Hence, in case of earth fault, relay operating sensitivity was high (650%). Thus, the existing protection system was considered to be selective, sensitive and operating with high speed.

ADDITION OF CAPTIVE POWER GENERATORS :

Due to inconsistency in availability of Electricity Board power and the higher cost of per unit of power, the management of the plant decided to add 2 X 15 MW coal based thermal power plant. The proposed power evacuation system after the addition of this 2 X 15 MW CPP is given below:

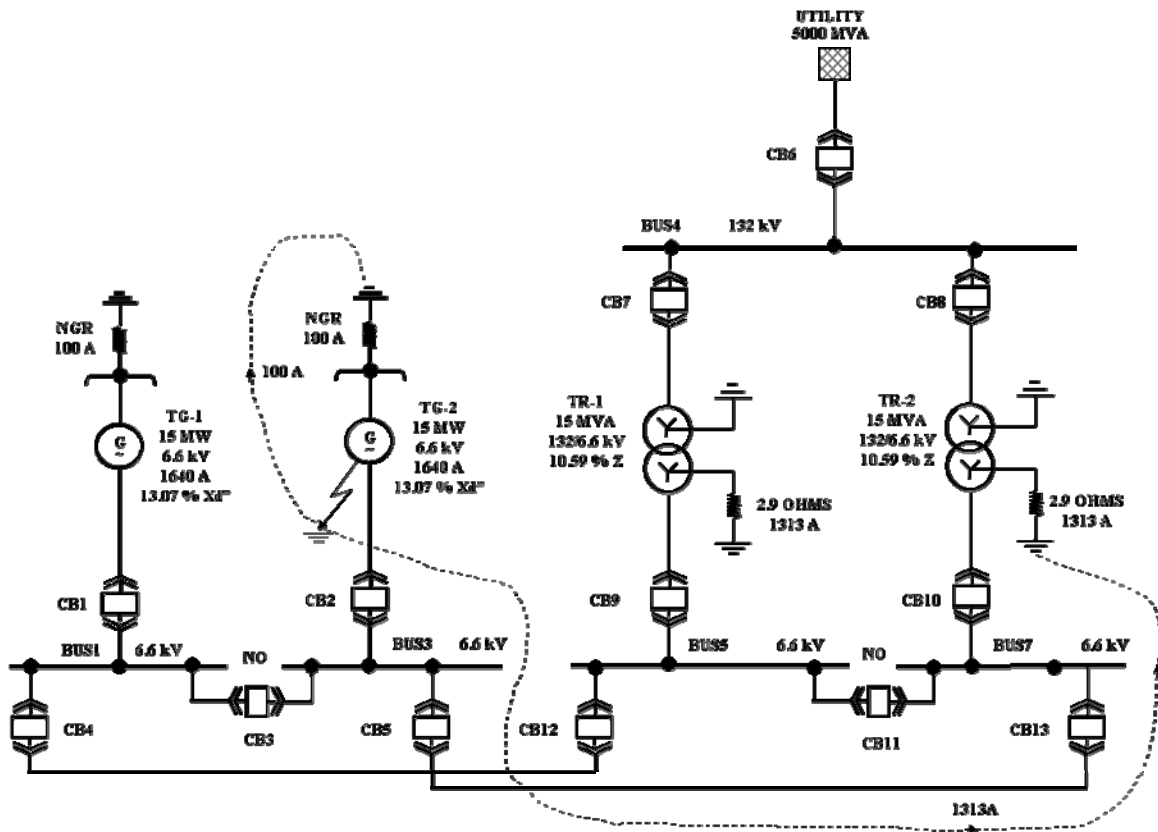


FIG. 2 SLD AFTER ADDITION OF 2 x 15 MW CAPTIVE POWER PLANT

Disadvantages of Proposed System

The review of the above system exposes the following disadvantages of electrical power system on addition of CPP.

- In case of fault in a Generator circuit, the earth fault current discharged through generator winding will be 100 amps + 1313 amps. This is very high and not acceptable as the generator core cannot withstand the current more than 100 amps for app = 0.7 seconds as per the typical core damage curves indicated below,

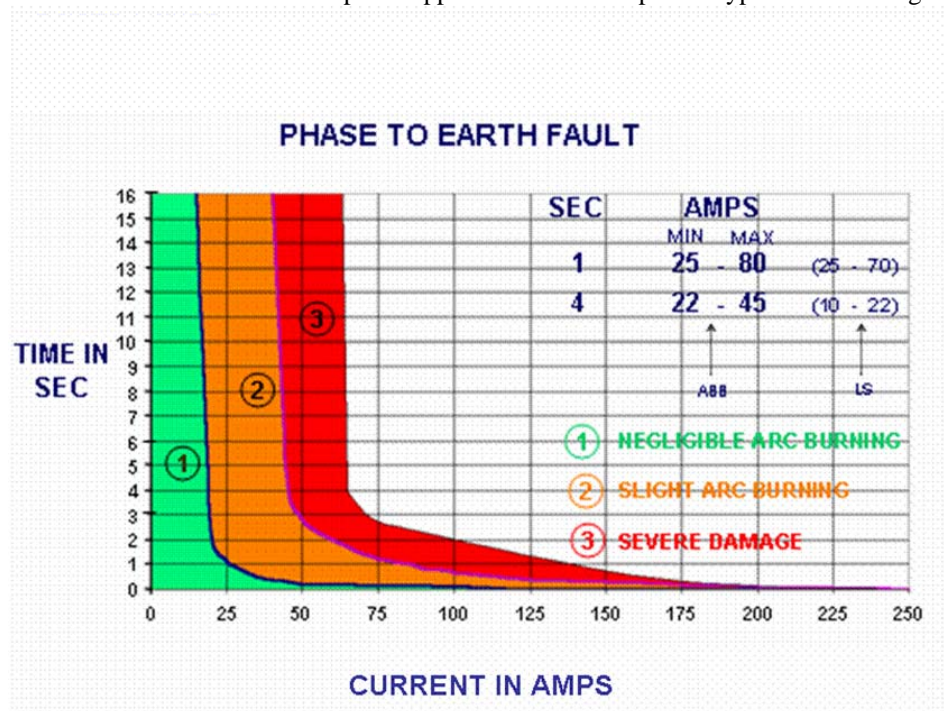


FIG. 3 TYPICAL GENERATOR – CORE DAMAGE CURVE

- Variation in Earth Fault Current

The out going feeders will experience a variation in earth fault current magnitude under different operating conditions, with and without grid supply. With grid supply, earth fault current will be 100 amps + 1313 amps = 1413 amps, whereas without grid supply earth fault current will be only 100 amps. For outgoing feeders, earth fault current isolation sensitivity reduces drastically with only one generator operation. For few outgoing feeders with higher C.T. ratio, the existing relays do not pick up for this low earth fault current magnitude.

SOLUTIONS :

To overcome the difficulties experienced above, various solutions were considered as follows;

Rationalizing Grounding System by introducing Generator Transformer:

It was proposed to introduce Generator Transformer (URT: Unit Ratio Transformer). This transformer shall have a vector group of delta/star. The delta winding will be connected to the Generator and the star winding shall be connected to the load side.

The proposed single line diagram with rationalization of grounding system by addition of Generator Transformer (URT) is as follows:

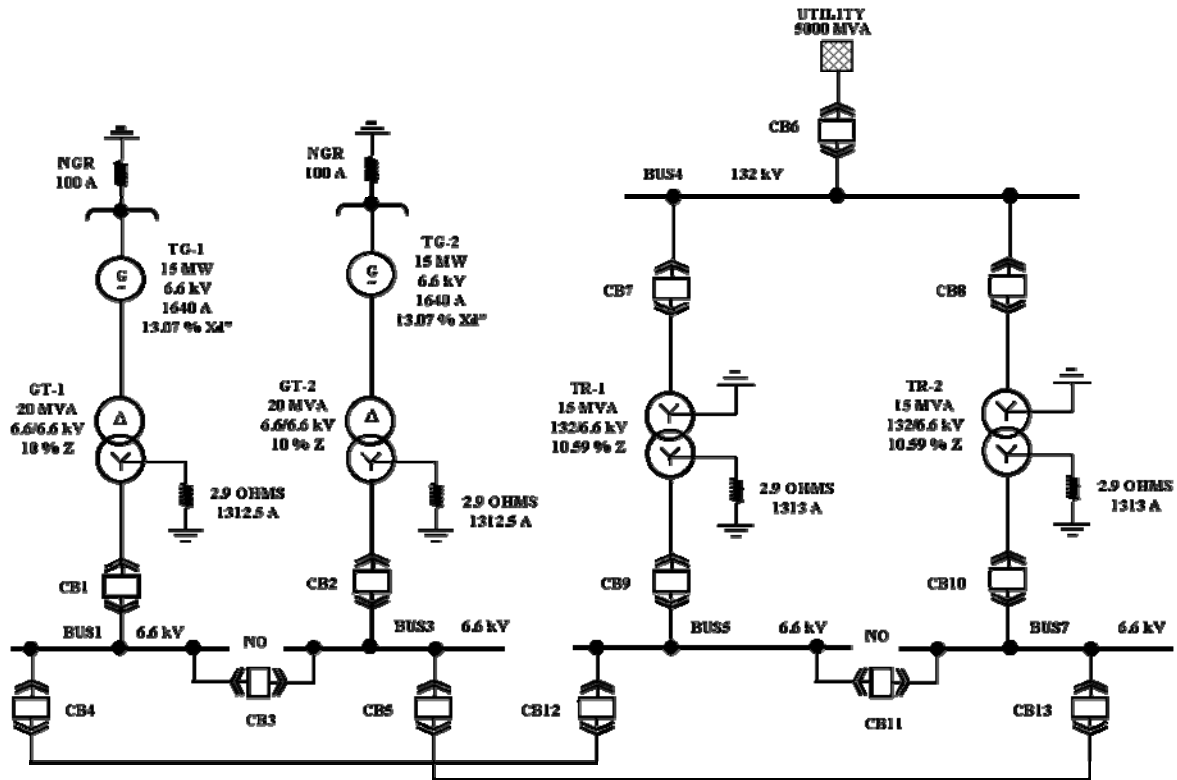


FIG. 4 RATIONALIZATION OF GROUNDING SYSTEM BY ADDITION UNIT RATIO GENERATOR TRANSFORMER

The star winding of this generator transformer (URT) shall be grounded through low resistance neutral grounding resistance of the same rating as that of existing grid transformer NGR i.e., 2.9 ohms with current limited to 1313 amps.

Advantages with addition of Unit Ratio Transformer as Generator Transformer are,

- The earth fault current magnitude for 6.6KV power distribution system is sufficient to maintain higher sensitivity for earth fault current.
- Generator cores are protected against high earth fault current while operating in parallel with grid power supply.
- Generators are isolated from 6.6 kV distribution system, phase as well as earth fault current, thus stability of generator (increase in critical clearance time) increases substantially while operating in parallel with the grid.

Disadvantages:

No disadvantage as far as the electrical system is concerned, except that this solution requires additional capital investment in terms of addition of Generator transformer.

Rationalization of grounding system by replacement of NGR:

This solution envisages rationalization of grounding system of captive power plant and grid power supply by changing the neutral grounding resistor value of Grid Transformer to match with Generator Neutral Grounding Resistor.

The modified single line diagram is as follows:

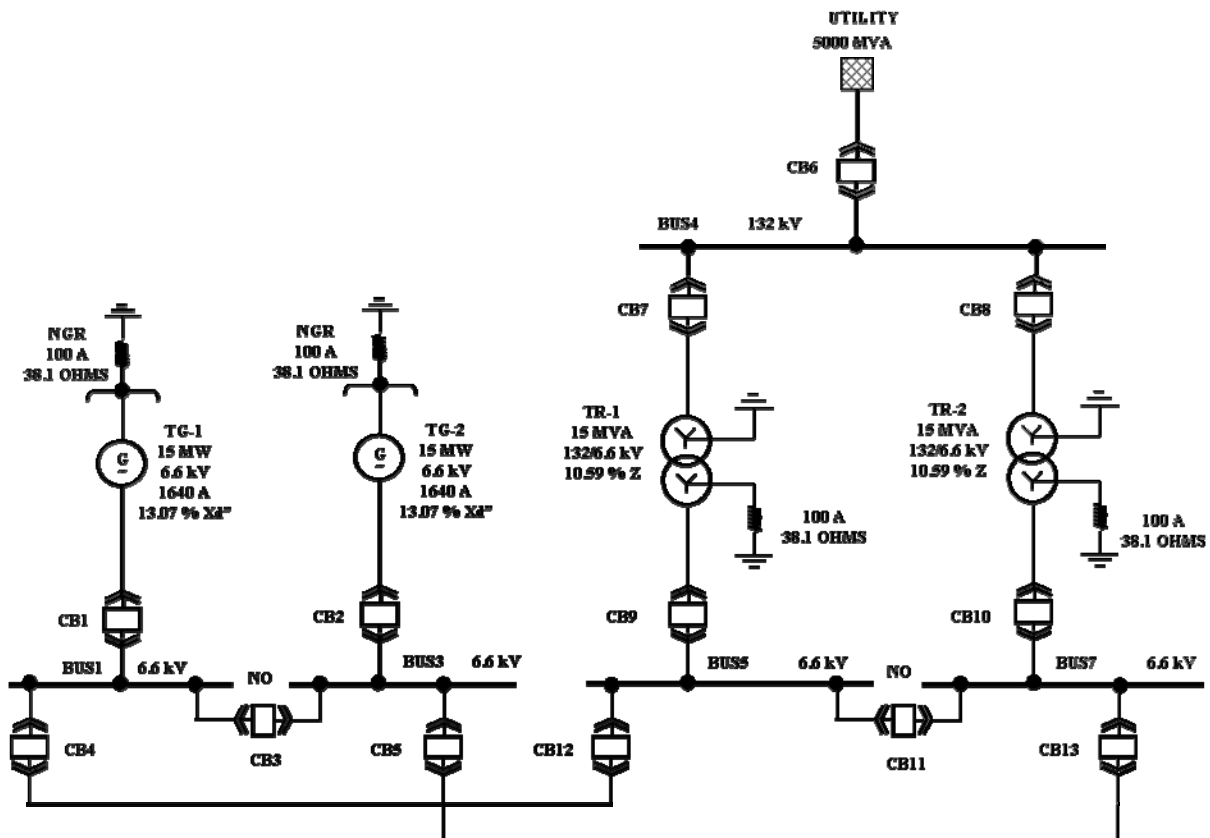


FIG. 5 RATIONALIZATION OF GROUNDING SYSTEM BY REPLACEMENT OF NGR

The precautions to be taken while increasing the value of neutral grounding resistance (limiting earth fault current to lower value) was that transformer manufacturer needs to be consulted to check whether the 6.6 kV neutral insulation is uniform or graded. If the insulation is graded then proposal for increasing the value of NGR is not recommended.

The difficulty was experienced in obtaining this confirmation as transformer was more than 15 years old and manufacturer was unable to locate the design data, however, finally the confirmation was available that insulation of 6.6 kV neutral of this transformer was uniform and it is feasible to ground the transformer secondary neutral through high resistance grounding.

Advantages:

- Earth fault current magnitude is limited to 100 amps, thus limiting the quantum of damage at the point of fault anywhere in system.
- The generator core is protected against earth fault by limiting the earth fault current magnitude from grid transformer to 100 amps.

Disadvantages:

The sensitivity of clearing earth fault current reduced drastically with the limitation of earth fault magnitude only to 100 Amps with one generator or 200 A with Generator and Grid parallel operation. This condition was more severe when only one generator is operating in isolation from the grid on its own bus.

SENSITIVE EARTH FAULT PROTECTION :

Solution for detecting low magnitude earth fault current for high rating incoming and outgoing feeders was considered as follows,

The highest rating feeder was having a CT ratio of 2000/1. The earth fault current magnitude as seen on this current transformer secondary was $100/2000 = 0.05$ Amps. This necessitated the requirement of sensitive earth fault current relay with

- Pick up less than 5%,
- Characteristics to reject 3rd Harmonic current and
- High relay reset current (greater than 95% of operating current).

The relay with,

- The setting range of 0.5 % to 15.2 % of rated current,
- Feature to filter 3rd Harmonic current
- A time delay range of 0.1 to 9.9 seconds,
- Relay reset current of greater than 95% of operating current was recommended.

This resolved, the difficulty of detecting a low magnitude earth fault current of 100 amps in feeder with higher CT ratio.

Neutral Displacement Relay :

Due to very low setting recommended for the earth fault relay (<5%) the mal-operation of this relay was suspected during transient conditions. To avoid this maloperation neutral displacement relay was connected on open delta PT secondary winding. This neutral displacement relay contact was connected in series with the tripping contact of sensitive earth fault relay, thus preventing mal-operation of Earth Fault relay.

The scheme as indicated below was implemented, commissioned and is operational.

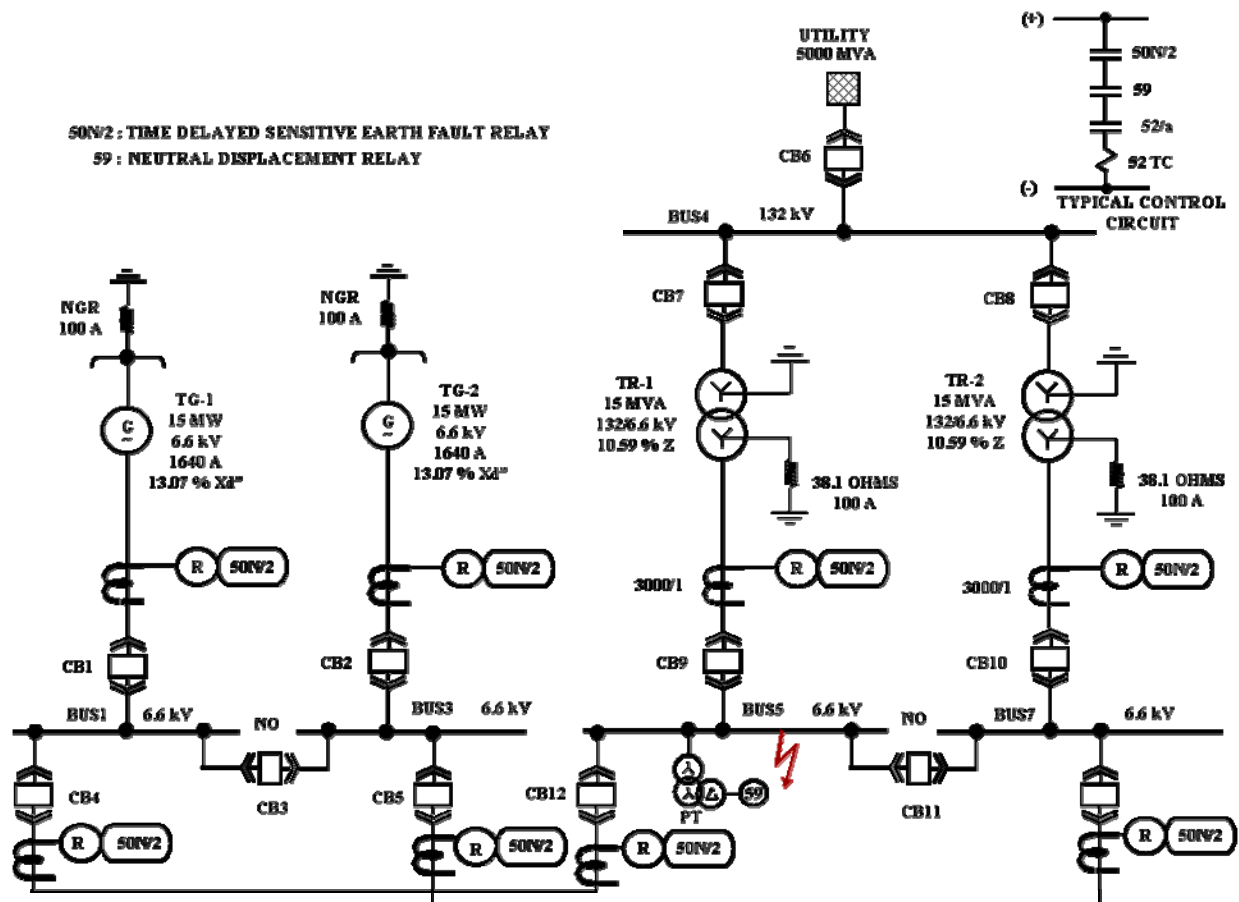


FIG. 6 INTRODUCTION OF NDR WITH SENSITIVE EARTH FAULT RELAY

CONCLUSIONS :

Two power source system with different grounding methods shall not be operated in parallel to protect the equipments connected to high resistance grounded system.

Grounding methods of two source needs to be rationalized for continuous parallel operation.

RECOMMENDATION :

It is always recommended to rationalize the grounding methods either by,

- a) Introducing Generator Transformer in Generator circuit, thus, retaining the secondary ground fault current magnitude and sensitivity of detecting ground fault current magnitude by existing earth fault protection scheme/relays.
In case, if this solution is not feasible then,
- b) Rationalize the existing source grounding method by replacing the existing grounding equipment by high resistance grounding equipment. With above type of grounding method rationalization, if earth fault current detection sensitivity is reduced than a high sensitivity earth fault relay shall be installed for isolation of low magnitude earth fault currents. Earth fault relay shall be protected against 3rd harmonic current and this relay also shall have high reset current.
- c) To prevent ma-operation of sensitive earth fault current, a contact of Neutral Displacement Relay is recommended in series with earth fault relay.

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