# EARTH FAULT PROTECTION VIS-A-VIS GENERATOR GROUNDING SYSTEM

BY

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AT

**1ST INDIA DOBLE PROTECTION AND AUTOMATION CONFERENCE, NOV 2008**

GROUP

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# EARTH FAULT PROTECTION

# VIS-A-VIS

# GENERATOR GROUNDING

# SYSTEM

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- **IN AN ELECTRICAL SYSTEM,**

  **CLOSE TO 70% TO 80% OF FAULTS ARE EARTH FAULTS.**

  - **THE MAGNITUDE OF EARTH FAULT CURRENT IS DEPENDENT UPON:**
    - **SYSTEM (SOURCE) GROUNDING**
    - **VECTOR GROUP OF TRANSFORMER AND CORRESPONDING STAR NEUTRAL GROUNDING METHOD.**
    - **ARC RESISTANCE VALUE**

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- **GROUNDING METHODS**
  - **SOLID GROUNDING**
    - **FAULT CURRENT IN K AMPS**
  - **LOW (MEDIUM) RESISTANCE GROUNDING**
    - **FAULT CURRENT LIMITED TO 1000 AMPS TO 2000 AMPS**
  - **HIGH RESISTANCE GROUNDING**
    - **FAULT CURRENT LIMITED TO 100 AMPS**
  - **VERY HIGH RESISTANCE GROUNDING**
    - **CURRENT LIMITED TO LESS THAN 15 AMPS**

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- **GENERALLY GROUNDING METHOD OF TRANSFORMER RECEIVING POWER FROM GRID IS**
  - **SOLID GROUNDING OR**
  - **LOW RESISTANCE GROUNDING**
- **GROUNDING OF GENERATING SOURCE IS**
  - **HIGH RESISTANCE GROUNDING, OR**
  - **VERY HIGH RESISTANCE GROUNDING**

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- **CASE STUDY :**
  - **CEMENT PLANT**
    - **RUNNING SYSTEM OPERATION IS WITH SOURCE GROUNDED THROUGH LOW RESISTANCE GROUNDING AT RECEIVING END.**
    - **FAULT CURRENT MAGNITUDE IS LIMITED TO 1313 AMPS**

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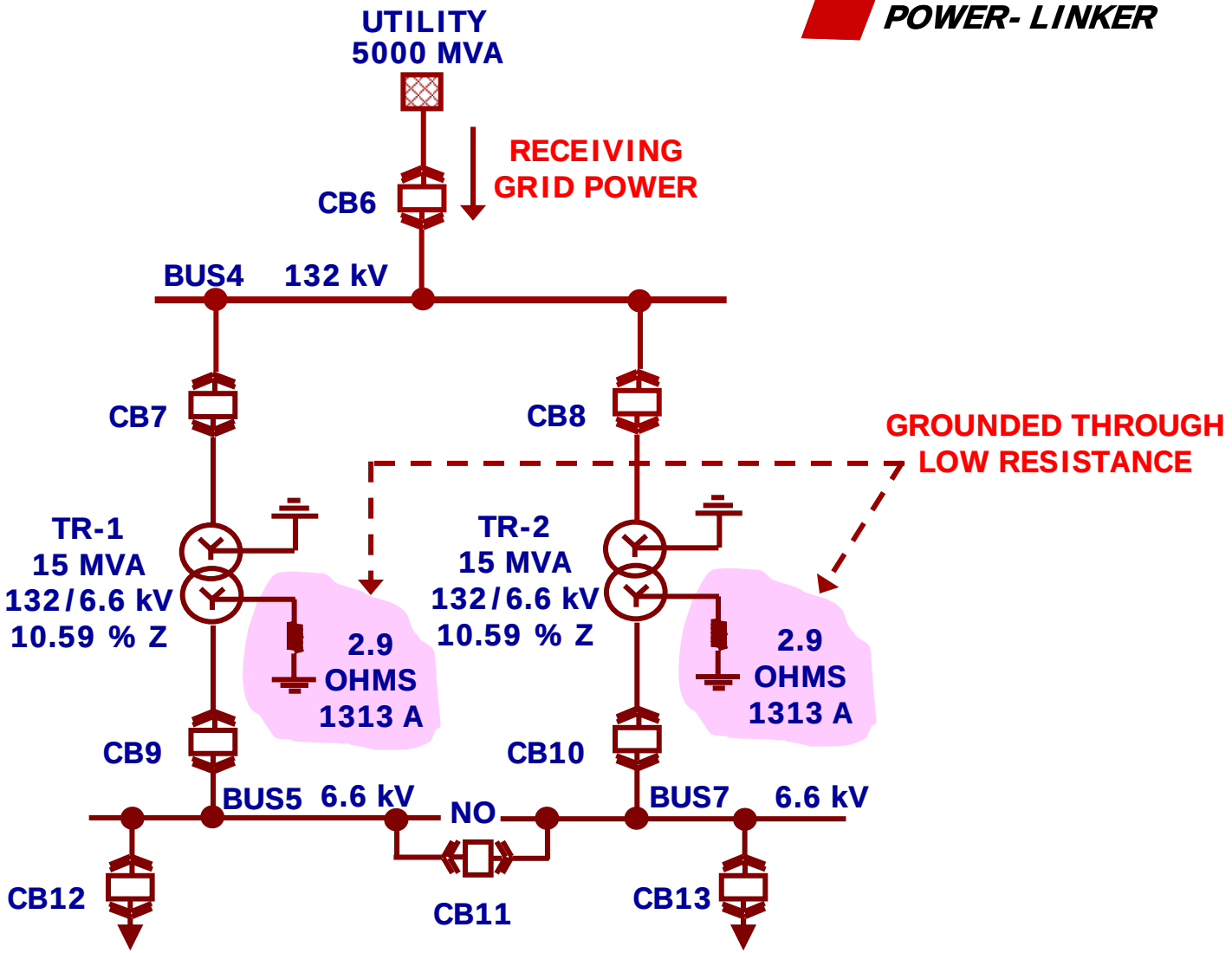


FIG 1: EXISTING SYSTEM SINGLE LINE DIAGRAM

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- **CASE STUDY :**

  - **OUTGOING FEEDER C.T. RATIO IS 2000/1**
    **ACCORDINGLY, EARTH FAULT PROTECTION RELAY SENSITIVITY IS GOOD.**

**PU = 10% = 0.1**

$$\text{SENSITIVITY} = \frac{\text{MIN.CURRENT FOR SENSING}}{\text{MAX. FAULT CURRENT}} = \frac{200}{1313}$$

**= 0.15 = 15 %**

**RELAYS OPERATE EFFICIENTLY FOR ALL EARTH FAULTS.**

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- **MODIFICATION IN SYSTEM :**
  - **CAPTIVE POWER PLANT GENERATORS ARE ADDED TO EXISTING ELECTRICAL DISTRIBUTION.**

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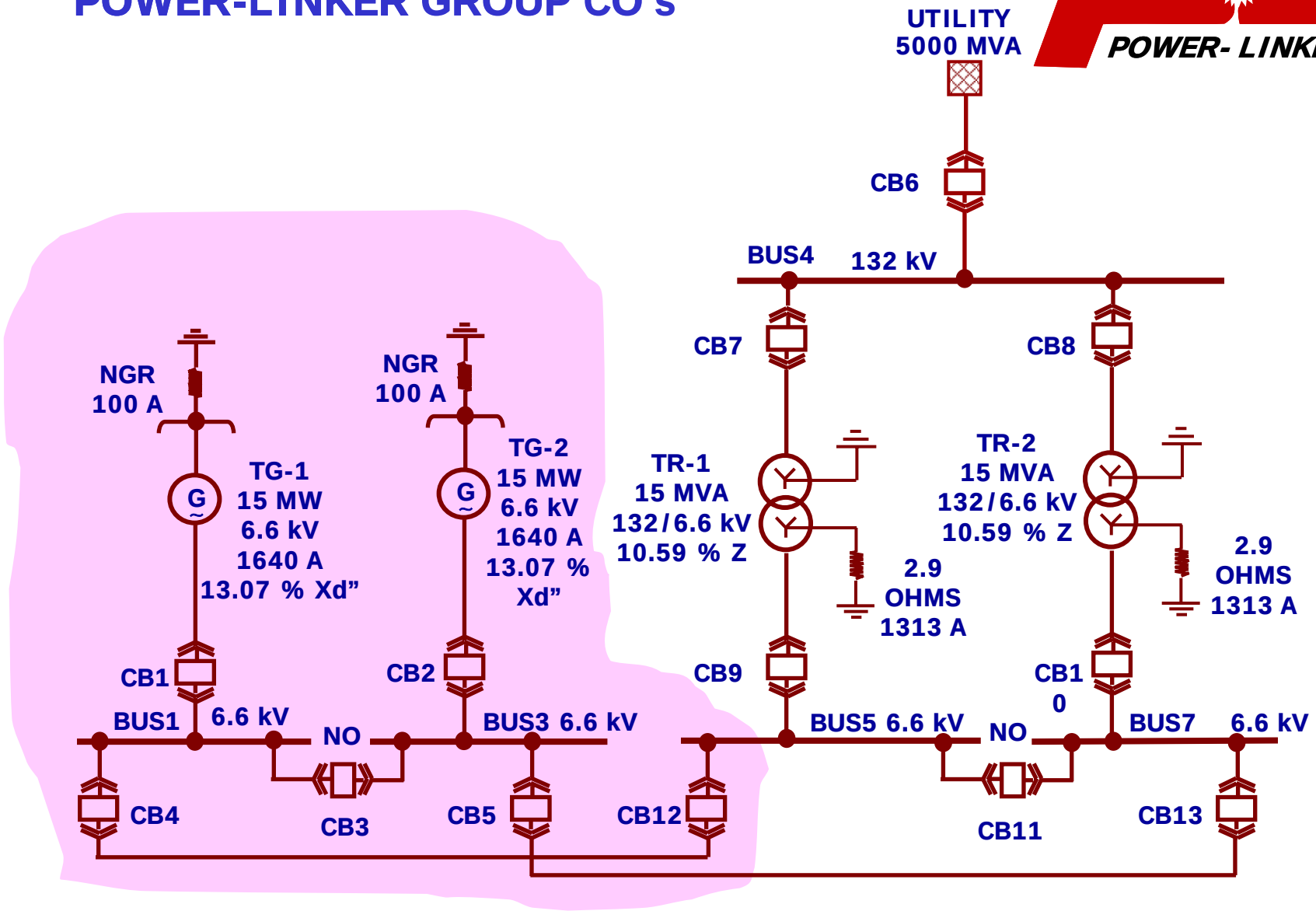


FIG. SLD AFTER ADDITION OF 2X15MW CAPTIVE POWER PLANT

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- GENERATORS ARE GROUNDED THROUGH HIGH RESISTANCE.
- CURRENT LIMITED TO 100 AMPS
- EARTH FAULT CURRENT CONTRIBUTION BY GENERATOR IS SMALL

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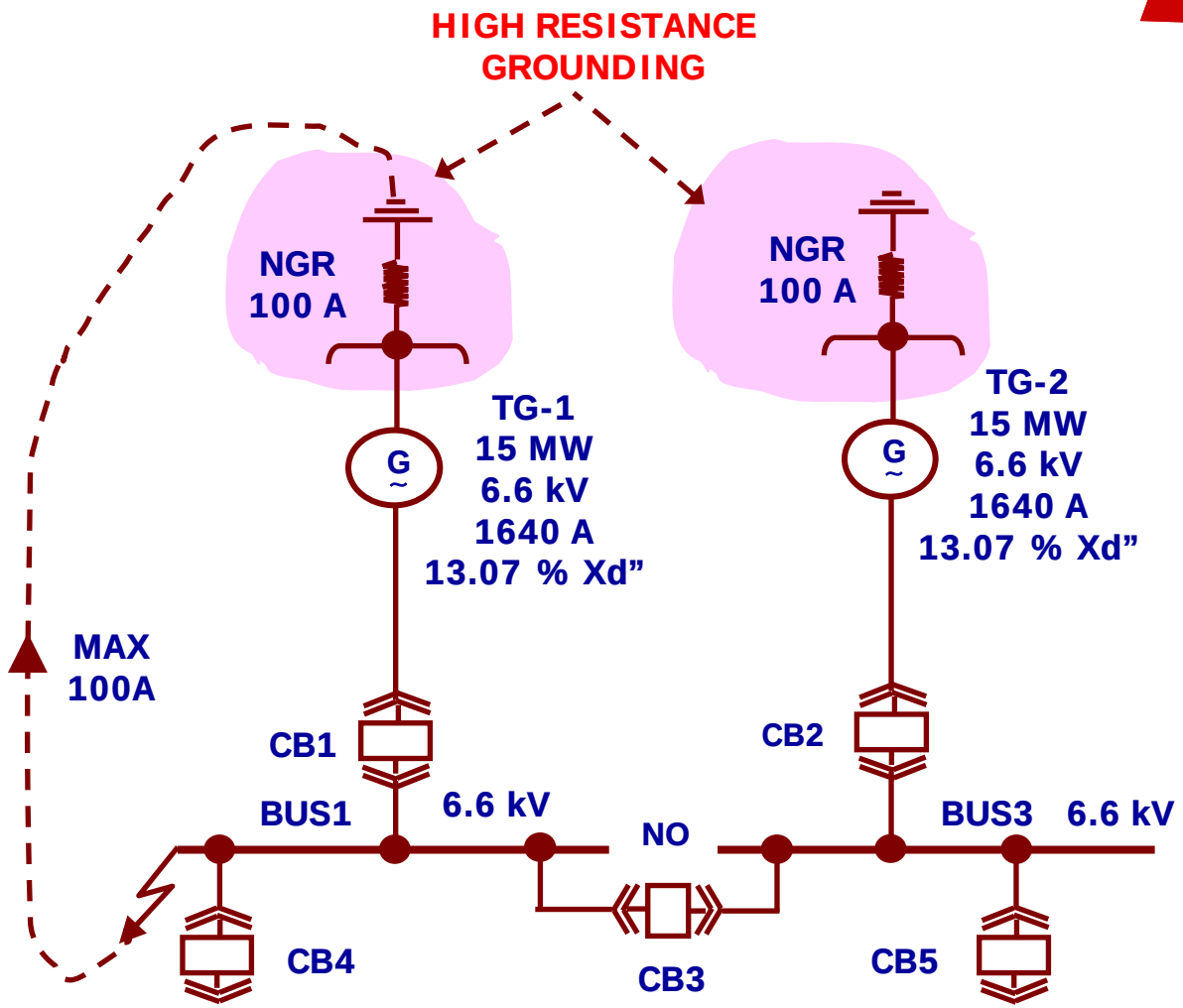


FIG. SLD AFTER ADDITION OF 2X15MW CAPTIVE POWER PLANT

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- **PROBLEMS :**
  - **GROUNDING METHODS ARE MIXED UP, HENCE,**
    - **GRID CONTRIBUTES HIGH CURRENT (1313 AMPS) TO GENERATOR FAULTS, AGAINST 100 AMPS LIMITATIONS ENVISAGED BY GENERATOR MANUFACTURER.**

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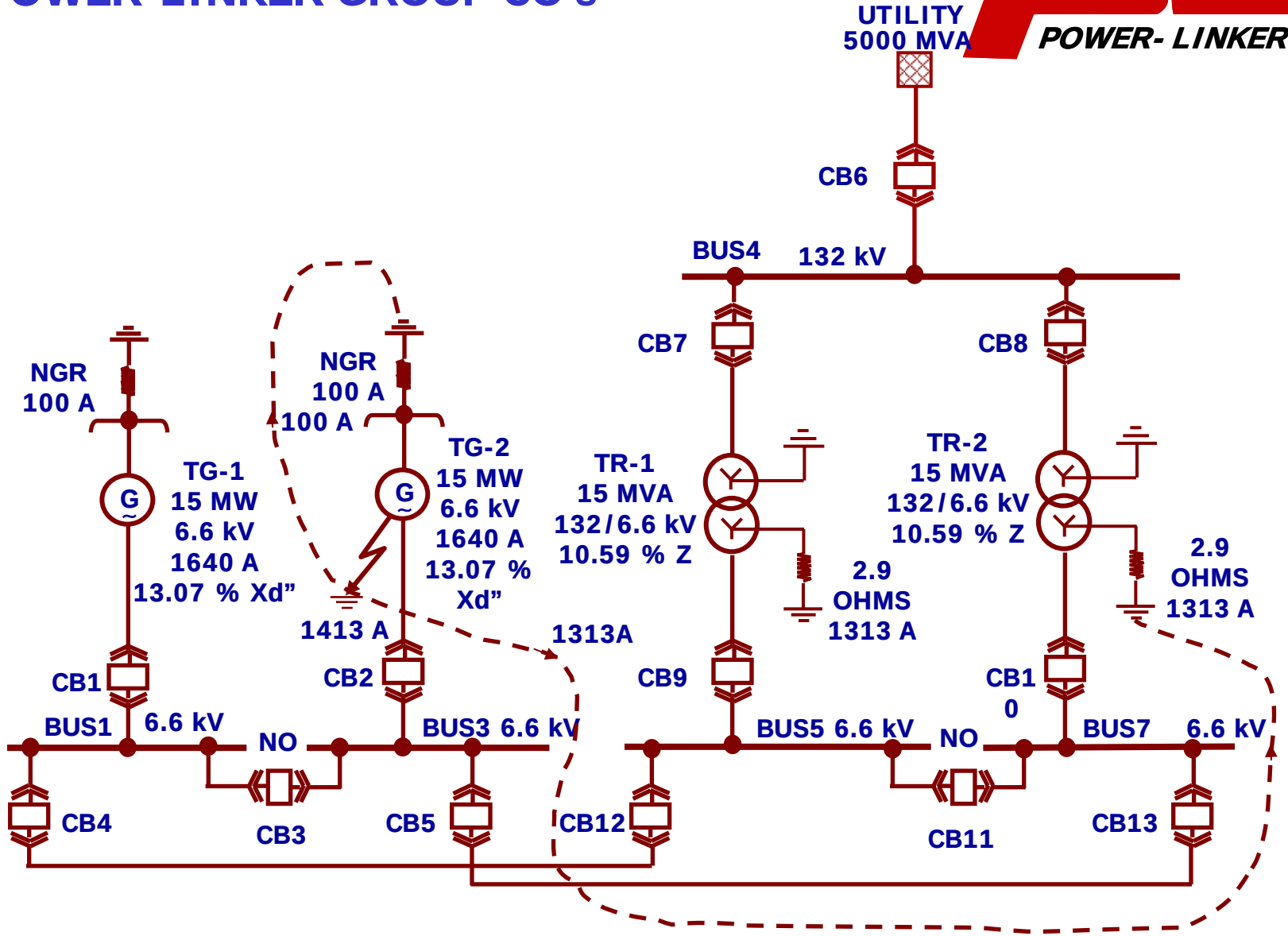


FIG. SLD AFTER ADDITION OF 2X15MW CAPTIVE POWER PLANT

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- **PROBLEMS :**

  - **THIS CAN DAMAGE GENERATOR WINDING & CORE**

    **GENERATOR CORE CAN WITHSTAND 100 A**

    **FOR APP = 0.7 SEC.**

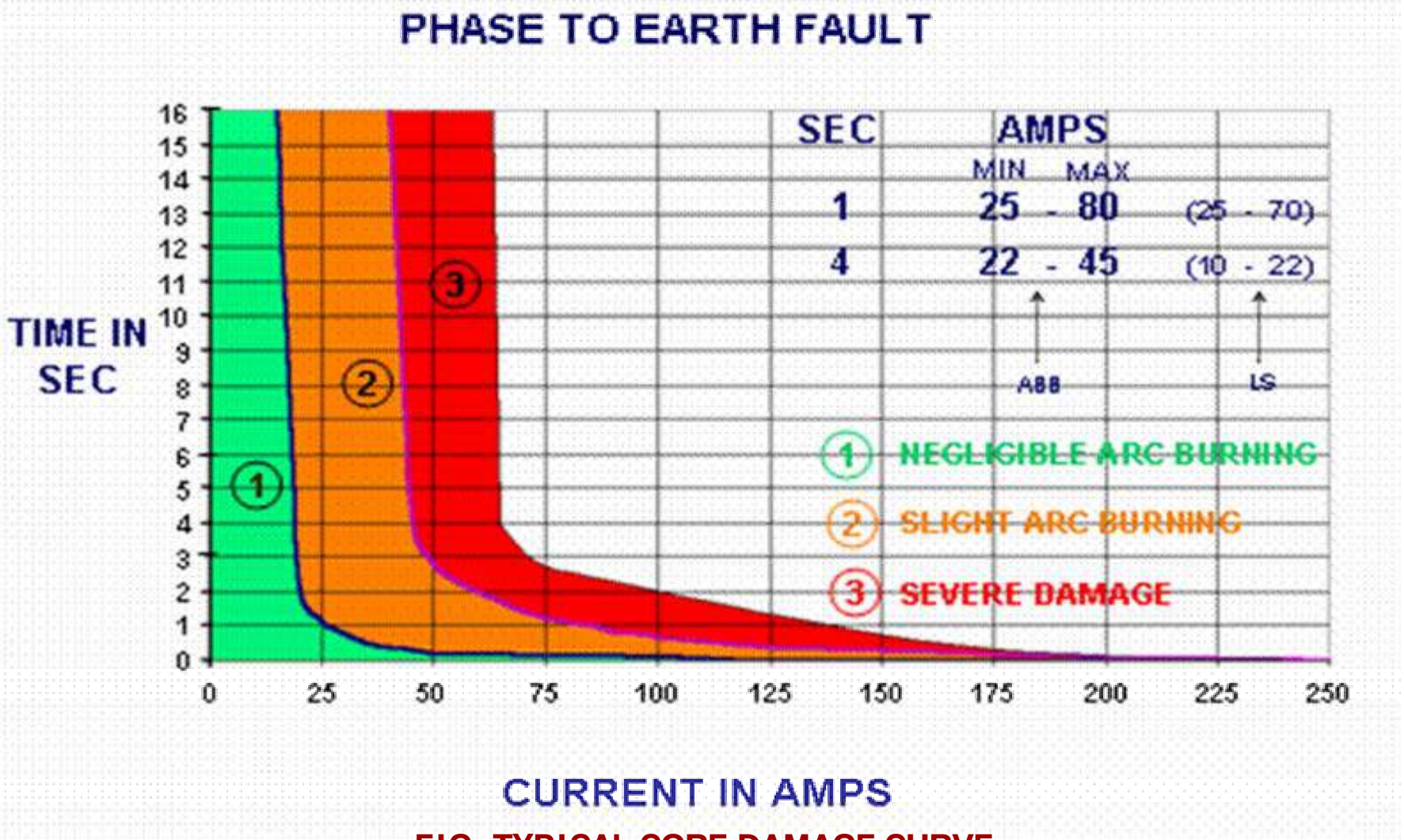


FIG: TYPICAL CORE DAMAGE CURVE

- VARIATION IN EARTH FAULT CURRENT FOR OUTGOING FEEDERS
  - WITH GRID (1313 A + 100 A)
  - WITHOUT GRID TRANFOFMER
    - WITH ONE GENERATOR-100A
    - WITH TWO GENERATORS (100 A +100 A).
  - A PROBLEM FOR PROTECTION RELAY SETTING
    - CHOOSE DMT CHARACTERISTICS

- FEEDER WITH HIGHER C.T RATIO AND EXISTING RELAYS MAY NOT PICK UP.
- FOR EARTH FAULT CURRENT MAGNITUDE OF 200 A WITH TWO GENERATORS IN OPERATION.
  - RELAY SETTING MIN 10%, CT RATIO = 2000/1

    $$\text{SENSITIVITY} = \frac{200}{200} = 1 \cong 100\%$$

    EQUIPMENTS NOT PROTECTED
  - IF FAULT HAS AN ARC RESISTANCE THEN RELAY MAY NOT PICK UP.

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- EARTH FAULT CURRENT ISOLATION SENSITIVITY REDUCED DRASTICALLY.
- WITH ONE GENERATOR, MAX. EARTH FAULT CURRENT = 100 A.
- RELAY DO NOT PICK UP. AS SENSITIVITY = $\frac{200}{100} = 200\%$
- DUE TO
  - MIX UP OF GROUNDING METHODS
  - REDUCED EARTH FAULT CURRENT SENSITIVITY
  - *PROPOSED SYSTEM DISRIBUTION NOT ACCEPTABLE*

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- **POSSIBLE SOLUTION :**
  - **RATIONALIZE GROUNDING SYSTEM**

**OR**

  - **EXISTING EARTH FAULT PROTECTION RELAYS TO BE REPLACED BY SENSITIVE EARTH FAULT PROTECTION RELAY.**

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- **RATIONALIZATION OF GROUNDING SYSTEM**
  - **SOLUTION : I**
    - **ADD GENERATOR TRANSFORMER (SOME TIMES UNIT RATIO TRANSFORMER : URT) IN SERIES WITH GENERATORS**
    - **VECTOR GROUP OF TRANSFORMER DELTA / STAR**

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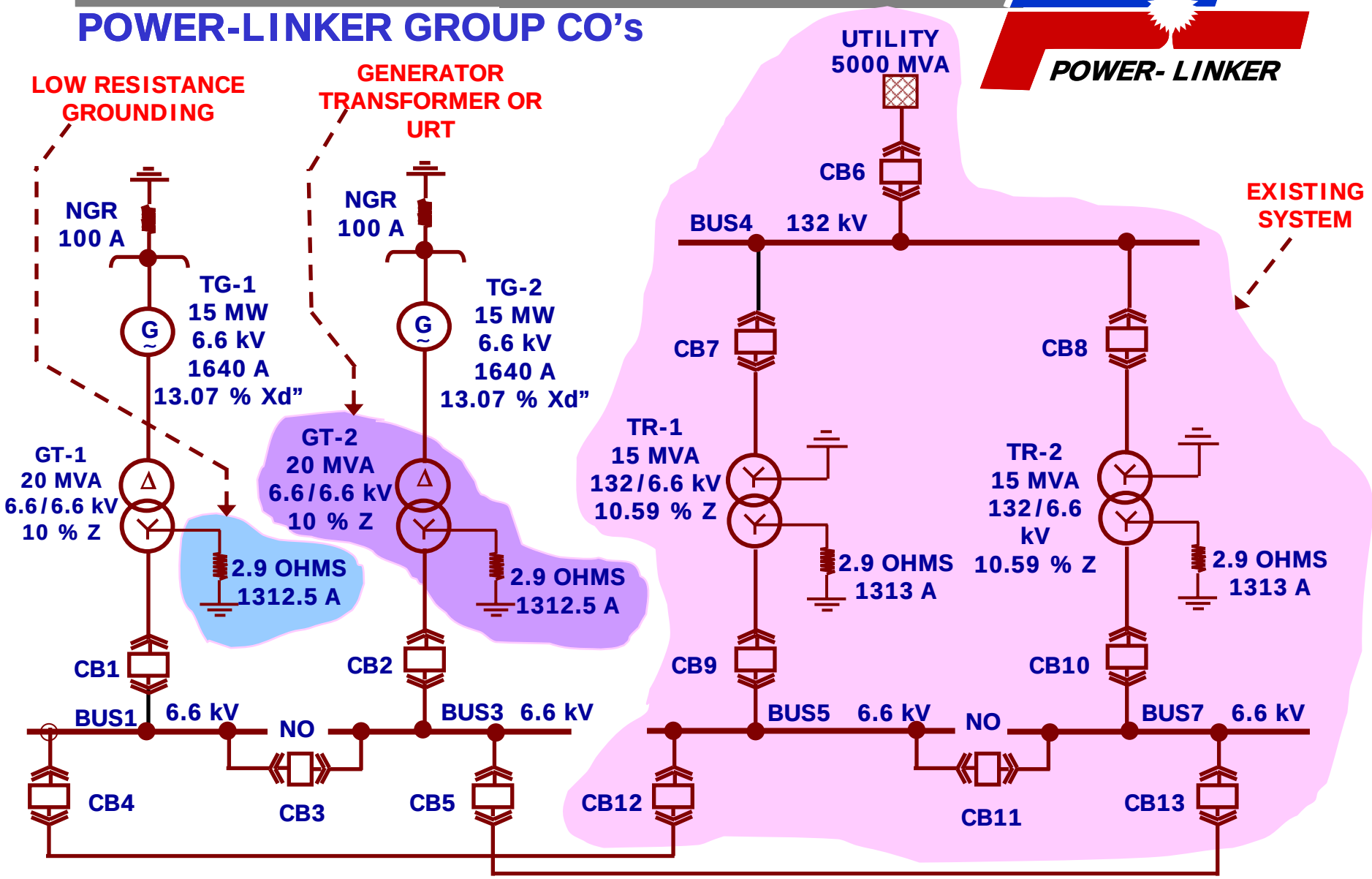


FIG. 4 RATIONALIZATION OF GROUNDING SYSTEM BY ADDITION OF UNIT RATIO GENERATOR TRANSFORMER

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- LOAD SIDE STAR WINDING IS GROUNDED THROUGH LOW RESISTANCE.
- NGR OF SAME RATING AS THAT OF GRID TRANSFORMER TO BE INTRODUCED.
- FAULT CURRENT LIMITED TO 1313 AMPS.

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- **ADVANTAGES WITH ADDITION OF GENERATOR TRANSFORMER (URT)**
  - EARTH FAULT CURRENT MAGNITUDE SUFFICIENT TO MAINTAIN HIGH EARTH FAULT CURRENT SENSITIVITY.
  - GENERATOR CORE AND WINDING PROTECTED AGAINST HIGH EARTH FAULT CURRENT FROM GRID TRANSFORMER
  - GENERATOR FAULT CURRENT LIMITED TO 100 A.

- **ADVANTAGES WITH ADDITION OF GENERATOR TRANSFORMER (URT)**
  - GENERATOR ISOLATED FROM DISTRIBUTION SYSTEM'S PHASE AS WELL AS EARTH FAULT CURRENT.
  - DISTRIBUTION SYSTEM FAULTS ARE NOT SEEN AS GENERATOR TERMINAL FAULTS.
- **DISADVANTAGES :**
  - NO DISADVANTAGES.
  - ONLY ADDITIONAL CAPITAL INVESTMENT ON GENERATOR TRANSFORMER

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- **SOLUTION : II**

  - **RATIONALIZATION OF GROUNDING SYSTEM BY MODIFYING EXISTING SOURCE GROUNDING.**

    - **CONVERTING EXISTING LOW RESISTANCE GROUNDING TO HIGH RESISTANCE GROUNDING.**
    - **REPLACE EXISTING NGR.**

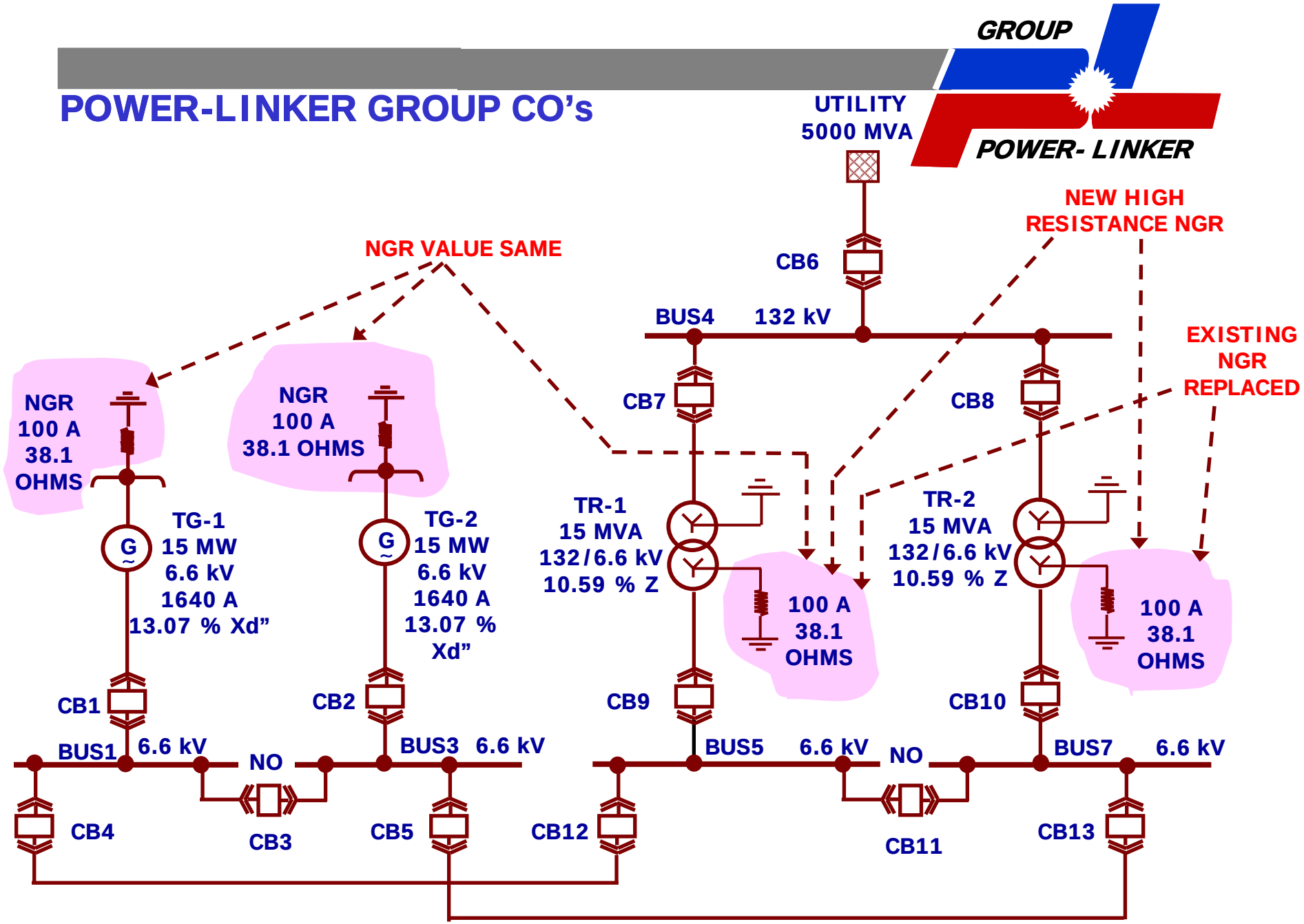


FIG. 5 RATIONALIZATION OF GROUNDING SYSTEM BY REPLACEMENT OF NGR

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- NEUTRAL GROUNDING RESISTOR OF GRID TRANSFORMER IS REPLACED.
- NEW NGR HAS THE SAME RATING AS THAT OF GENERATOR NGR, CURRENT LIMITED TO 100 AMPS.

- **PRECAUTIONS.**
  - **GRID TRANSFORMER GROUNDED THROUGH LOW RESISTANCE.**

    **NEUTRAL INSULATION CAN BE GRADED.**
    - **TO CHANGE TO HIGH RESISTANCE GROUNDING CHECK THAT TRANSFORMER NEUTRAL IS FULLY INSULATED. (PRACTICALLY UNGROUNDED SYSTEM INSULATION).**
    - **TRANSFORMER NEUTRAL, WITH GRADED INSULATION CANNOT BE HIGH RESISTANCE GROUNDED.**

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- THIS CEMENT PLANT CASE TRANSFORMER WAS 15 YEARS OLD, NOT FEASIBLE TO GET DESIGN DATA VERIFIED.
- MANUFACTURER LATER CONFIRMED THAT TRANSFORMER NEUTRAL WAS FULLY INSULATED .
- INSERTED HIGH RESISTANCE NGR, AS NEUTRAL WAS FULLY INSULATED.
- RATIONALIZED THE GROUNDING SYSTEM BY LIMITING THE EARTH FAULT CURRENT TO 100 AMPS FROM EACH SOURCE.

- **ADVANTAGES :**
  - EARTH FAULT CURRENT MAGNITUDE LIMITED TO 100 AMPS,
  - THUS IN CASE OF GENERATOR FAULT, DAMAGE TO GENERATOR WINDING & CORE IS LIMITED.
- **DISADVANTAGE :**
  - SENSITIVITY OF CLEARING EARTH FAULT CURRENT REDUCED.
  - CONDITION IS CRITICAL WITH ONE GENERATOR IN OPERATION.
  - MAXIMUM EARTH FAULT CURRENT IS 100 AMPS.
  - THIS REQUIRES REPLACEMENT OF EXISTING EARTH FAULT PROTECTION RELAYS.
- **SOLUTION TO PROBLEM :**

ADD SENSITIVE EARTH FAULT PROTECTION.

50N/2 : TIME DELAYED SENSITIVE EARTH FAULT RELAY

59 : NEUTRAL DISPLACEMENT RELAY

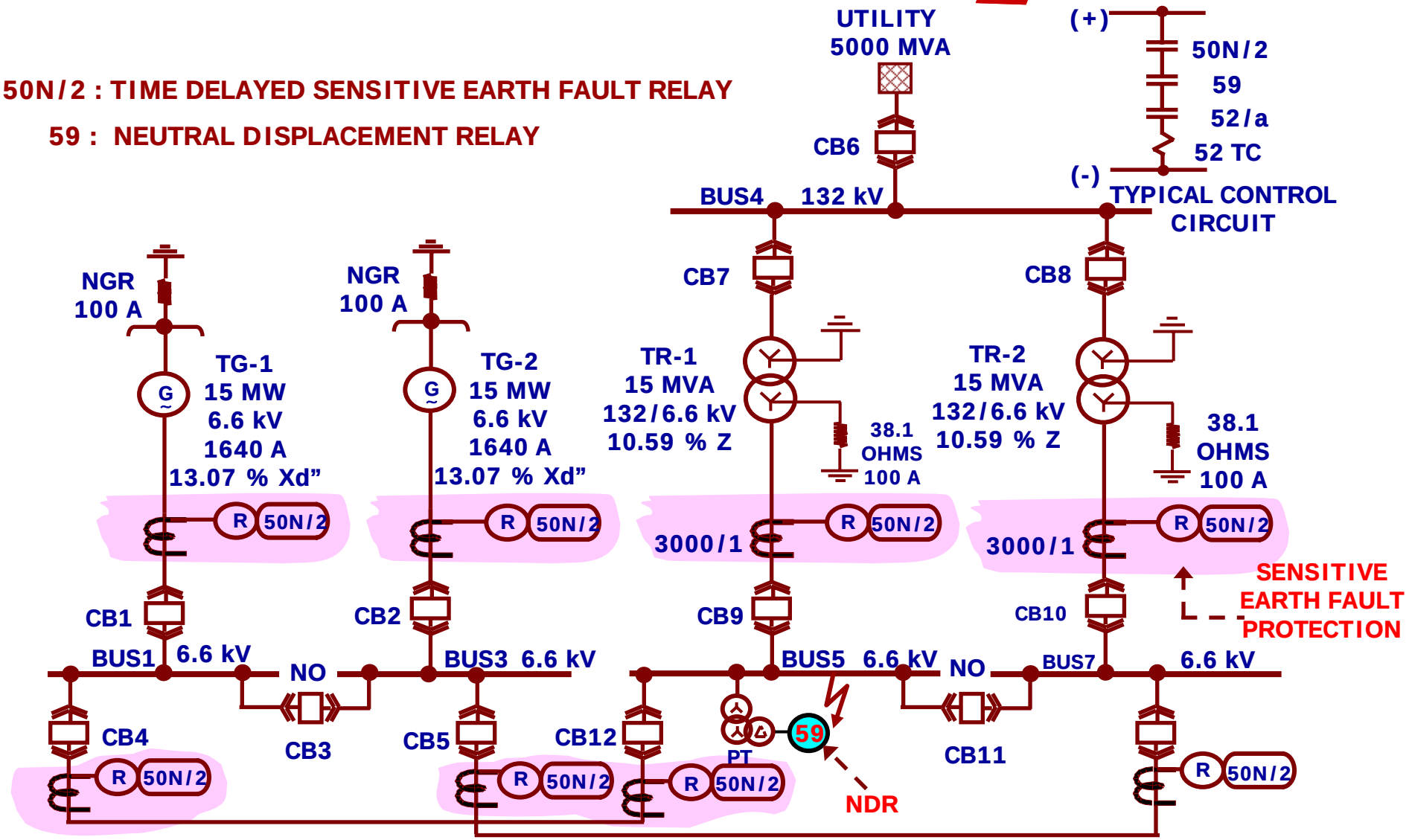


FIG. 6 INTRODUCTION OF NDR WITH SENSITIVE EARTH FAULT RELAY

- EARTH FAULT CURRENT MAGNITUDE LIMITED TO 100 AMPS.
- THE HIGHEST RATING FEEDER IS 2000 AMPS.
- MAXIMUM EARTH FAULT CURRENT WITH ONE GENERATOR = 100A.
- CT RATIO = 2000/1

  CT SECONDARY CURRENT = 100/2000

  MINIMUM PU < 0.05 A

  < 5%
- NEW SENSITIVE EARTH FAULT RELAY RECOMMENDED WITH
  - PICK UP (SENSITIVITY) <5%
  - BUILT IN FUTURE TO FILTER 3RD HARMONIC CURRENT
  - HIGH RELAY RESET CURRENT (GREATER THAN 95% OF OPERATING CURRENT)
  - SHORT TIME DELAY RANGE (0.1 – 9.9 SEC)

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- **SUSPECTED MALOPERATION :**
  - **SENSITIVE (VERY LOW) EARTH FAULT RELAY SETTING (<5%).**
  - **MAL-OPERATION OF THIS RELAY SUSPECTED DURING TRANSIENT CONDITION TO ENSURE RELIABILITY AND STABILITY.**
    - **NEUTRAL DISPLACEMENT RELAY RECOMMENDED**
    - **RELAY TO BE CONNECTED ON PT SECONDARY OPEN DELTA WINDING.**
    - **A CONTACT OF NDR WAS RECOMMENDED TO BE CONNECTED IN SERIES WITH EARTH FAULT RELAY.**

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- **CONCLUSION :**
  - o **TWO POWER SOURCES WITH DIFFERENT GROUNDING METHODS SHALL NOT BE OPERATED IN PARALLEL.**
  - o **THIS CAN DAMAGE THE EQUIPMENT GROUNDED THROUGH HIGH RESISTANCE GROUNDING SYSTEM.**
  - o **GROUNDING METHODS OF TWO SOURCES SHALL ALWAYS BE RATIONALIZED FOR CONTINUOUS PARALLEL OPERATION.**

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- **RECOMMENDATION :**

  - **RATIONALIZE GROUNDING SYSTEM OF SOURCES AT POINT OF COMMON COUPLING (PCC) BY**

    - **INTRODUCING GENERATOR TRANSFORMER, THUS RETAINING,**
      - **SECONDARY GROUND FAULT CURRENT MAGNITUDE SAME AS EXISTING &**
      - **SENSITIVITY OF DETECTING GROUND FAULT CURRENT MAGNITUDE BY RETAINING EXISTING EARTH FAULT PROTECTION SCHEME / RELAYS.**

**OR**

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- **RECOMMENDATION :**
  - REPLACE EXISTING SOURCE GROUNDING TO MATCH WITH THE EQUIPMENT GROUNDED THROUGH HIGH RESISTANCE.
  - PROVIDE HIGH SENSITIVITY EARTH FAULT RELAY TO DETECT LOW MAGNITUDE EARTH FAULT CURRENT.
  - TO PREVENT MAL-OPERATION,
    - RELAY SHALL HAVE PROTECTION AGAINST 3RD HARMONIC CURRENT.
    - SHALL HAVE HIGH RESET CURRENT.
    - PROVIDE CONTACT OF NEUTRAL DISPLACEMENT RELAY IN SERIES WITH SENSITIVE EARTH FAULT RELAY.

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# THANK YOU

# QUESTIONS ARE WELCOME NOW


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