Generator Protection:
Differential and Split Phase for Machines with Three Windings per Phase

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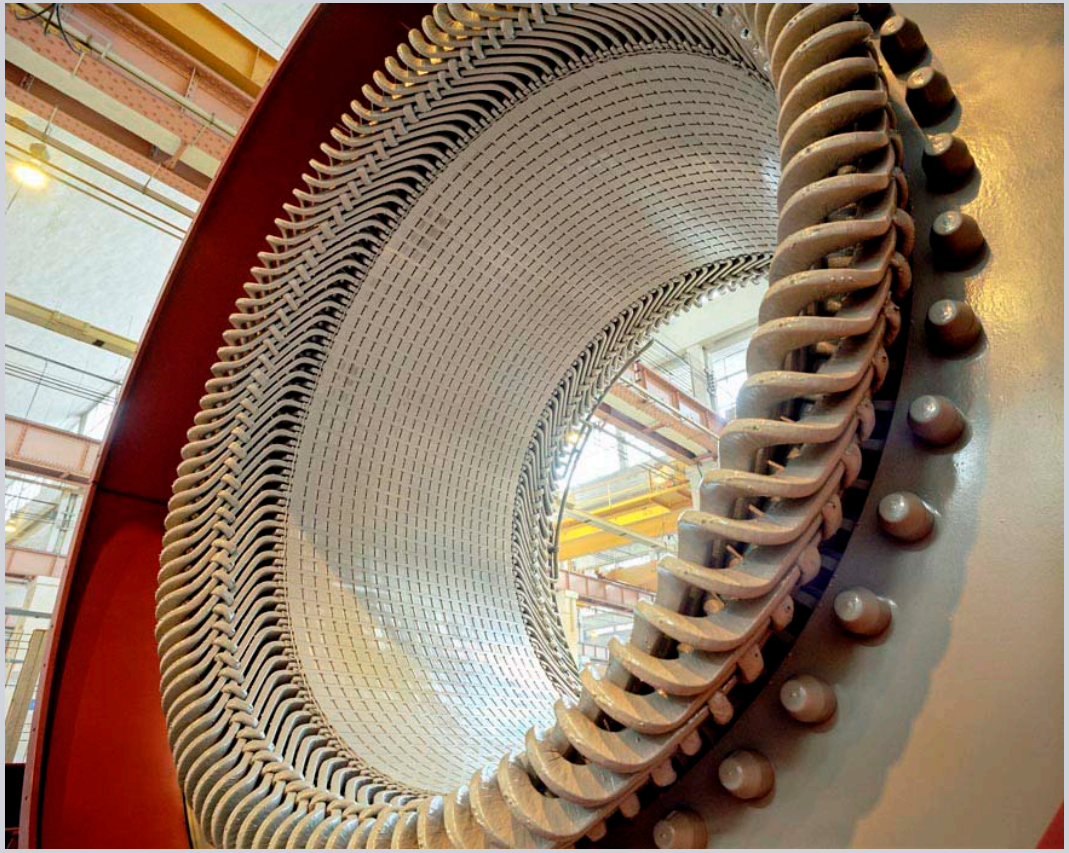
Introduction

- Brazil, 80% hydroelectric
- Split windings are becoming more common
- Reason: Cost Savings
- Objective: Maintain Cost Savings with Minimal CT’s



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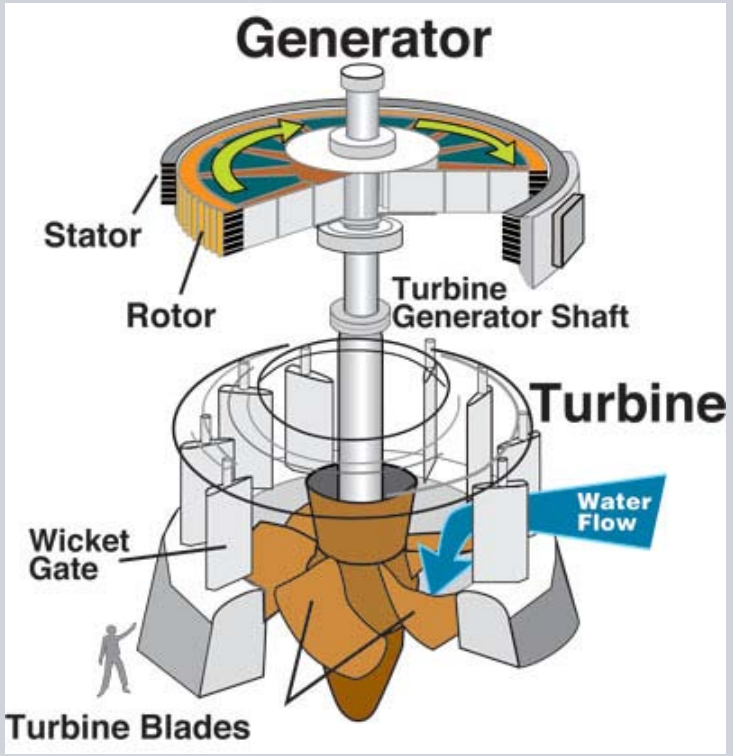
Location: Batalha Power Plant

Nearest City: between the municipalities of Crystalline-GO and Paracatu-MG

Number of Generators: 2

Types of turbines: Kaplan

Size each: 26.25MW



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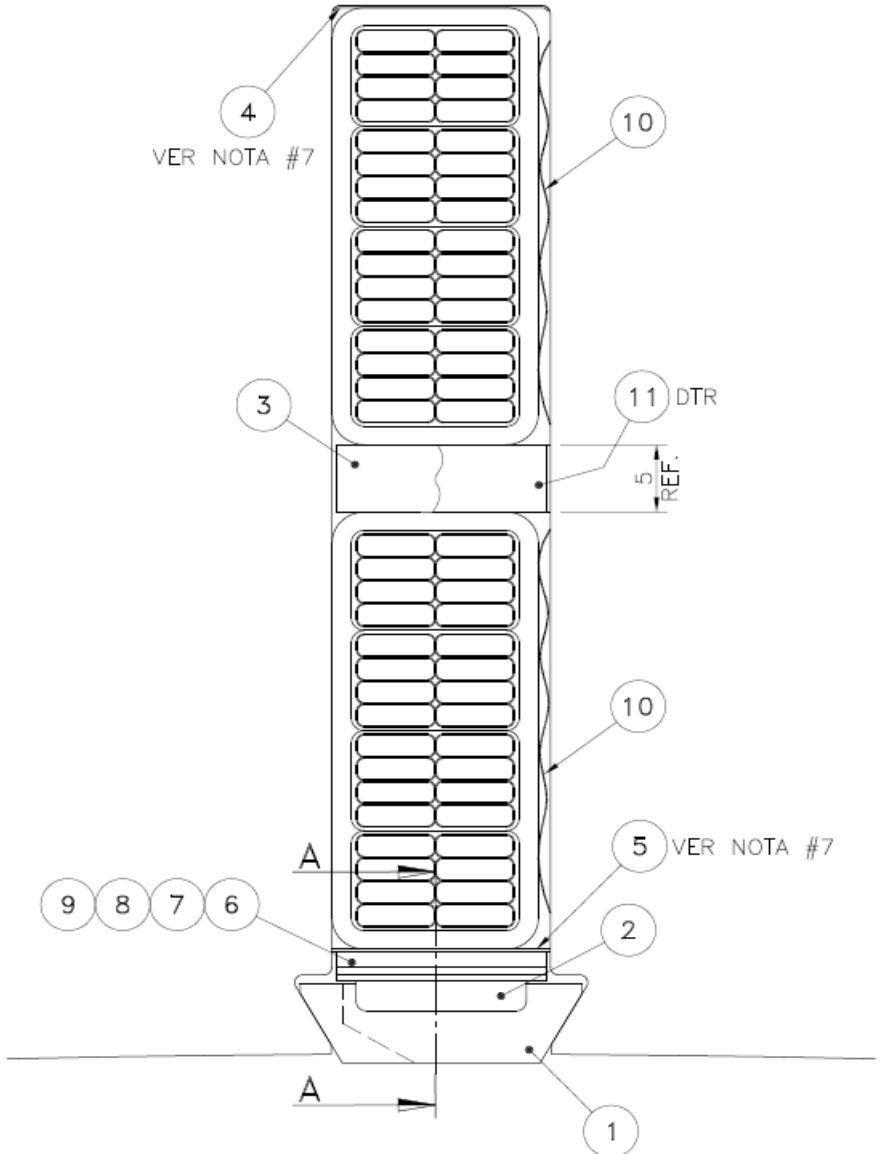
- **Cost Lower Based on Winding Type**
- **RTD temperature sensors where it would most likely for a fault to occur (**Over time the RTD can move, causing damage to the insulation system between the coils**)**
- **Sensors installed in positions 3 and 11 have a filler paste of conductive material causes it to be grounded to the housing of the generator (**see above**)**
- **Phase-to-phase fault Easy to detect**
- **Phase – Ground 100% Stator Ground Fault**



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- **Coils are mounted in the same slot and can be of the same or different circuit, including different phases**

- **The Differential relay settings are not sensitive enough for Turn – Turn Faults**

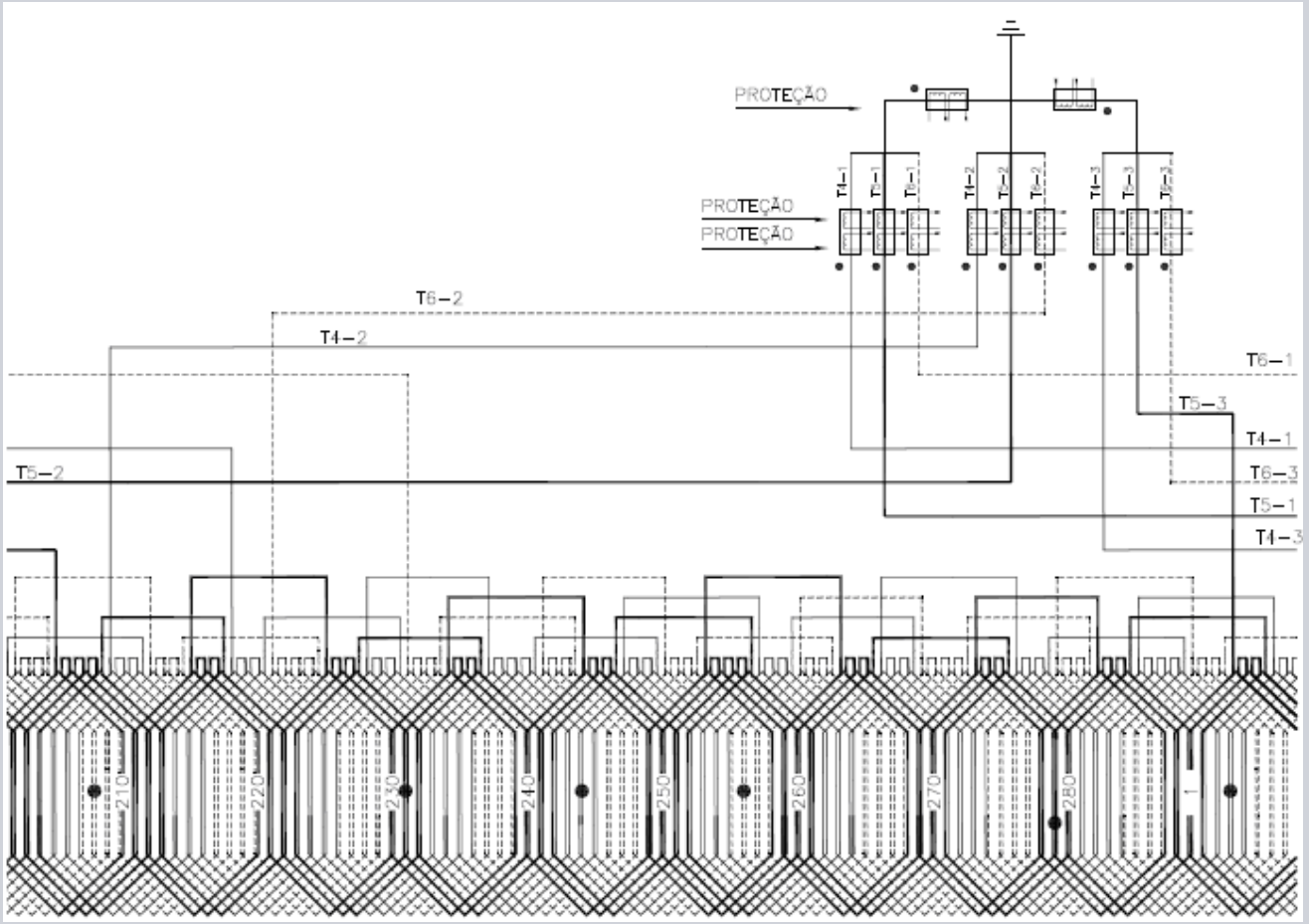

Fig 2-Example of a Split Winding diagram

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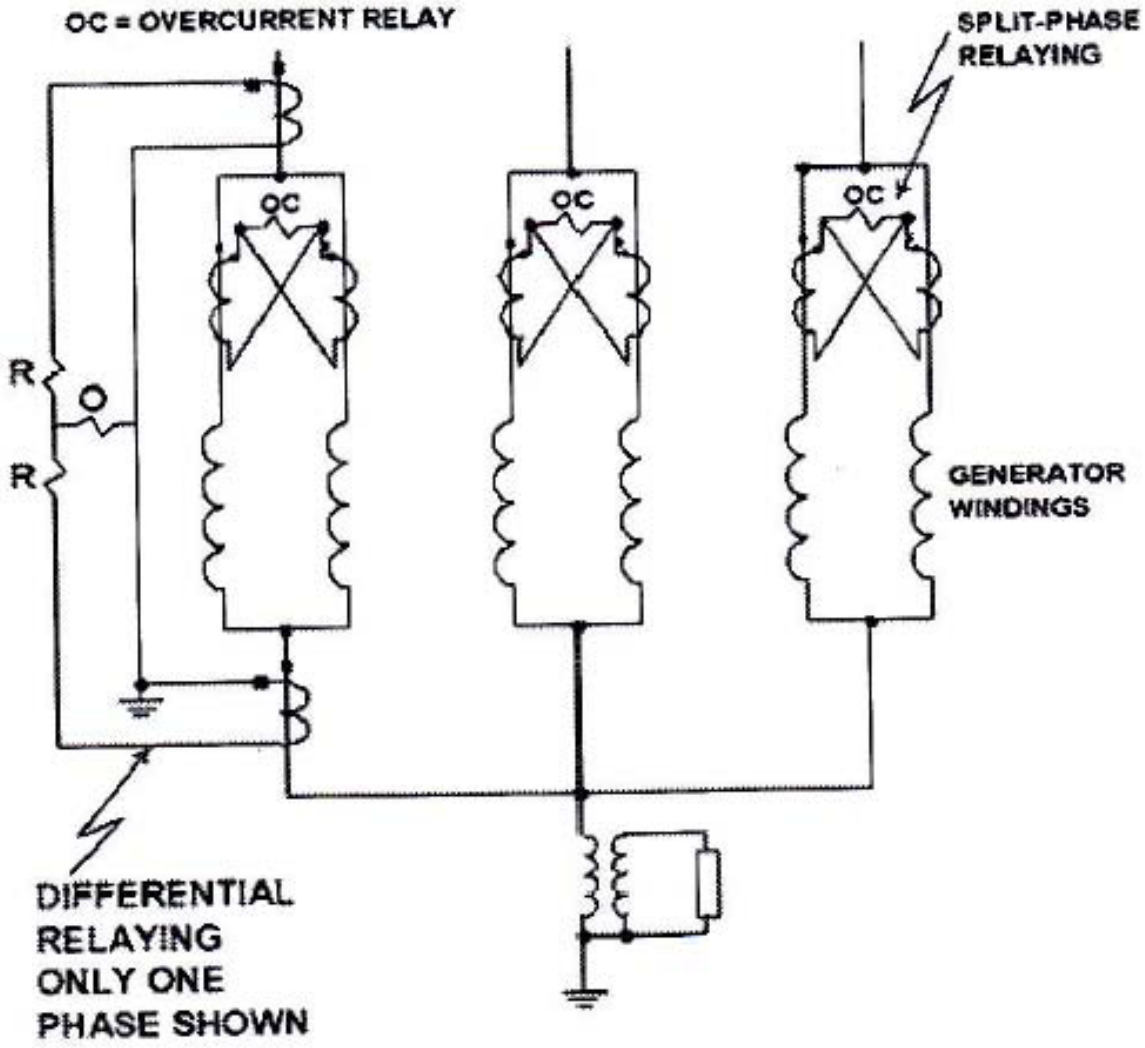
- **A likely point of failure is between the turns of the same coil**
- **Imbalance between circuits will only be approximately 1%.**

– Classical Method for two winding machine (Count CTs)



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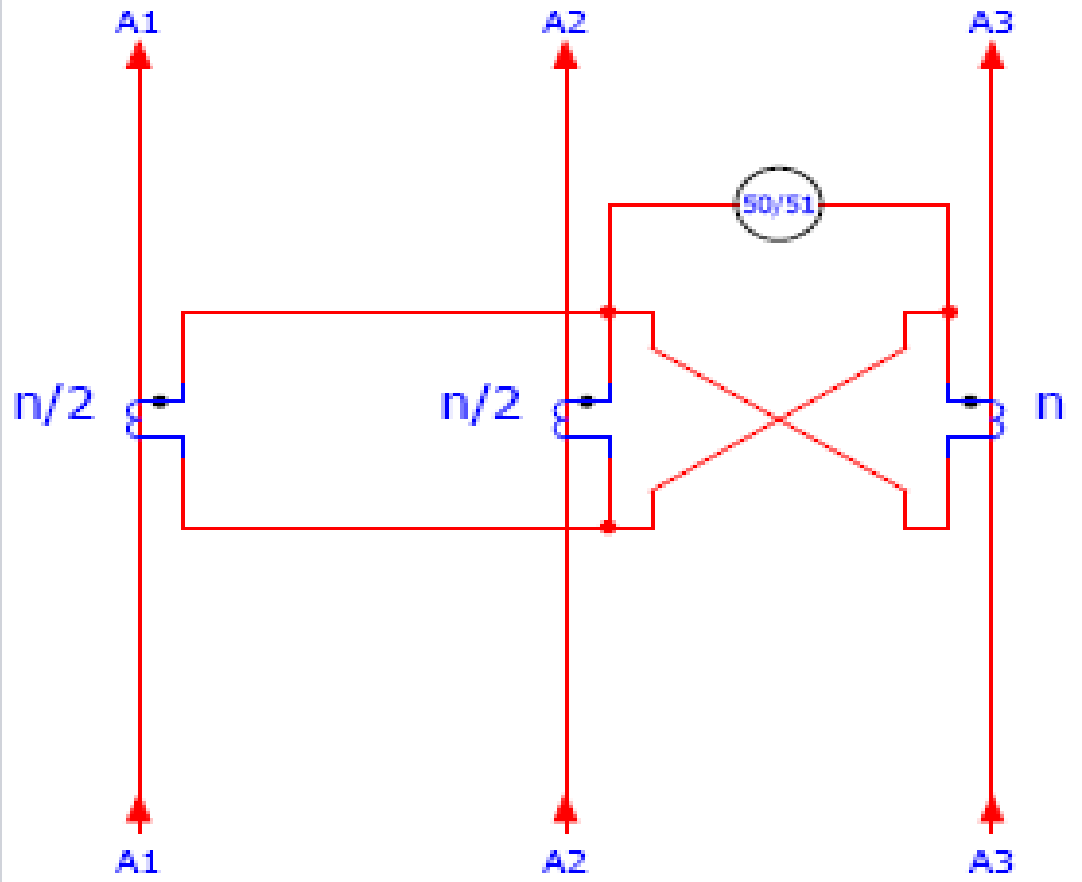
- **Requires the use of very inverse overcurrent relay**
- **Vulnerable to dynamic changes for external faults**
- **The result is misoperation of split-phase protection.**



Arrangement of CTs – Differential Protection and Phase Split (classic method)

n = Relação do TC

False Alarm Desensitizes Operators

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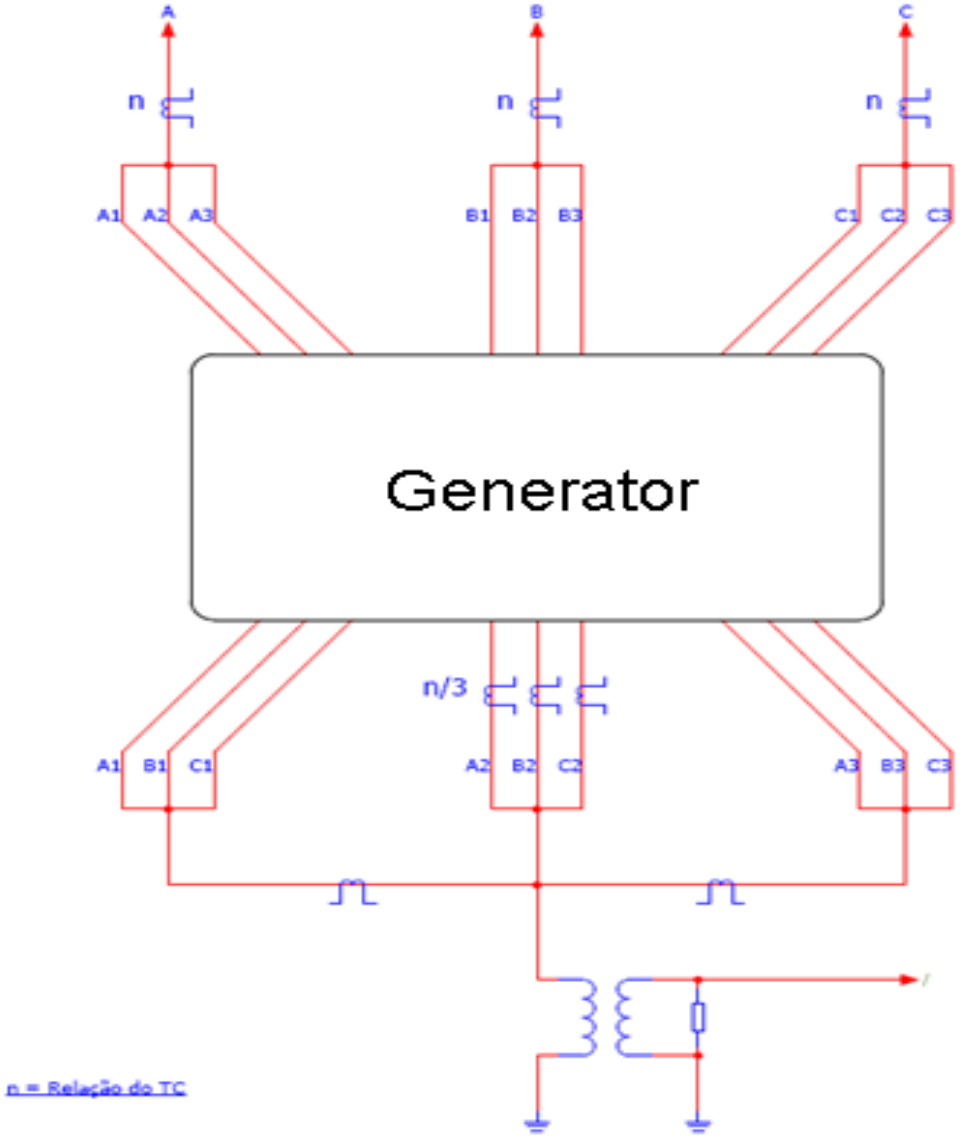
- **1/3 of the total current of the generator (see Fig. 5) is circulating in each neutral termination**
- **There was no need for installation of CT in all three neutral points, as the generator neutral grounding has high impedance and therefore the differential protection of the generator is specific for the detection of multi-phase faults**
- **Two additional CTs are installed after the connection of the neutral**



CT connection for Differential and Split Phase Protection (New method)

It’s All About Savings !!

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One Size Doesn’t Fit All

Conclusion

- **Any imbalance between circuits of the same phase will be detected by the current that circulates among those CTs. These CTs must be sensitive enough to detect the minimum fault current between turns and simultaneously withstand the maximum generator fault current.**
- **Classical Split phase protection is set as an alarm as this type of fault does not produce significant damage to the generator**
- **Reduces CTs as well as amount of copper in the output busses of the generator stator**

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Thank you for your attention!

Questions ?