

Open-Phase Study in Nuclear Power Plant



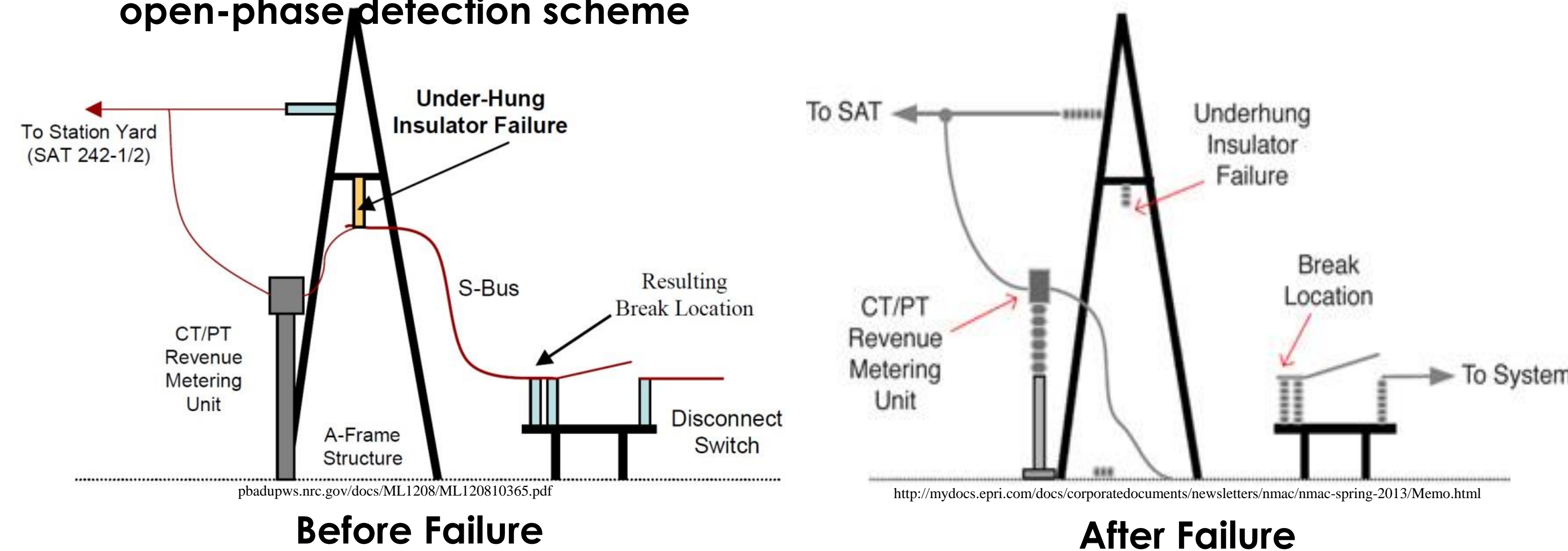
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Objective

To simulate and analyze open-phase conditions in the power generation stations

Introduction

- In January 2012, Byron Nuclear Power Plant (NPP) experienced a switchyard-side open-phase
- Open-phase was not detected correctly
- Incorrect relay tripped and open-phase fault was not removed from the system
- Nuclear Regulatory Commission requires all power plants to develop a reliable open-phase detection scheme



Requirements

- Simulation and analysis of open-phase model in EMT software in order to thoroughly understand conditions on medium and high voltage level equipment upon occurrence of an open-phase event.
- Common electrical quantities, such as unbalanced system measurements, for open-phase event simulations will be analyzed and identified.
- Written report which contains the overall approach to the project, the assumptions made, methods used, as well as input and output results obtained from EMT software.

Data Analysis & Conclusion

- Significant I_2 produced for all Cases and Loading Scenarios
- For Case 1 and Case 2, the three phase voltages are different
- For Case 3, the two unopened phase voltages (A and B) fall approximately 15%, while the opened phase (C) falls to about 50% of A and B
- For Case 4, all three phase voltages drop significantly (85% or more)
- Long motor acceleration times for Case 4

The following data were collected for all Open-Phase Cases on the Primary Side, ES bus and BOP bus:

- Phase Voltages
- Sequence Bus Currents

Steady State Condition under Normal Power Operation
20% (P=0.67kW, Q=0.32kVAr) Loading on ES Bus

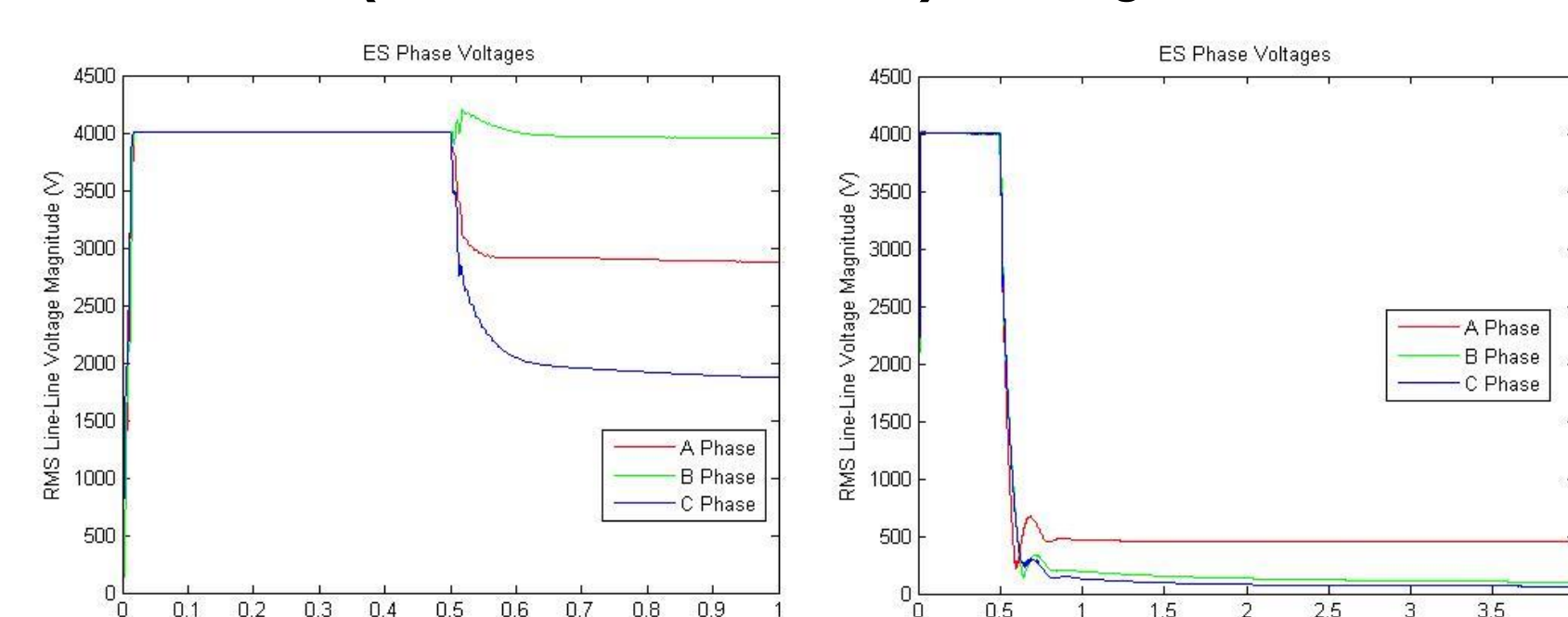


Figure 1. Case 1, Open-Phase on C at t=0.5 s for ES Phase Voltages

Steady State Condition under Normal Power Operation
20% (P=0.67kW, Q=0.32kVAr) Loading on ES Bus

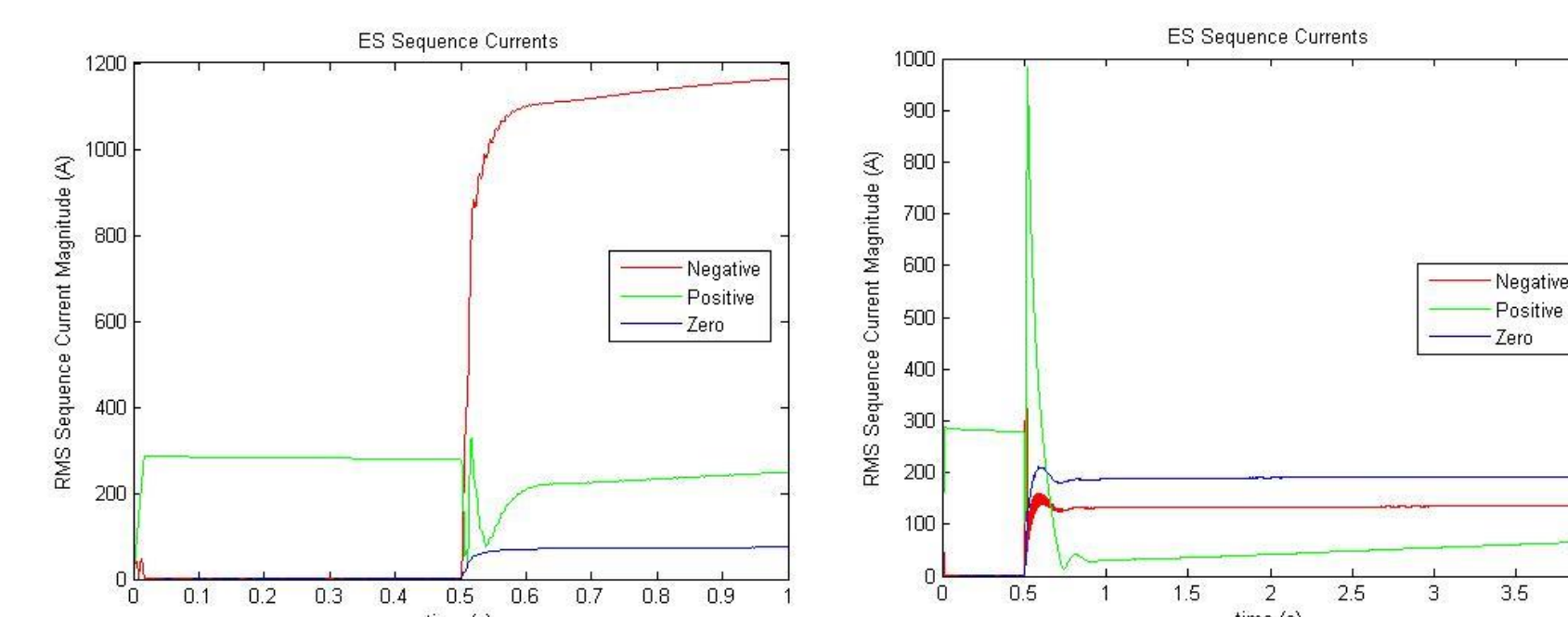


Figure 2. Case 4, Open-Phase on B & C at t=0.5 s for ES Sequence Currents

Steady State Condition under Normal Power Operation
100% (P=25.9kW, Q=12.6kVAr) Loading on BOP Bus

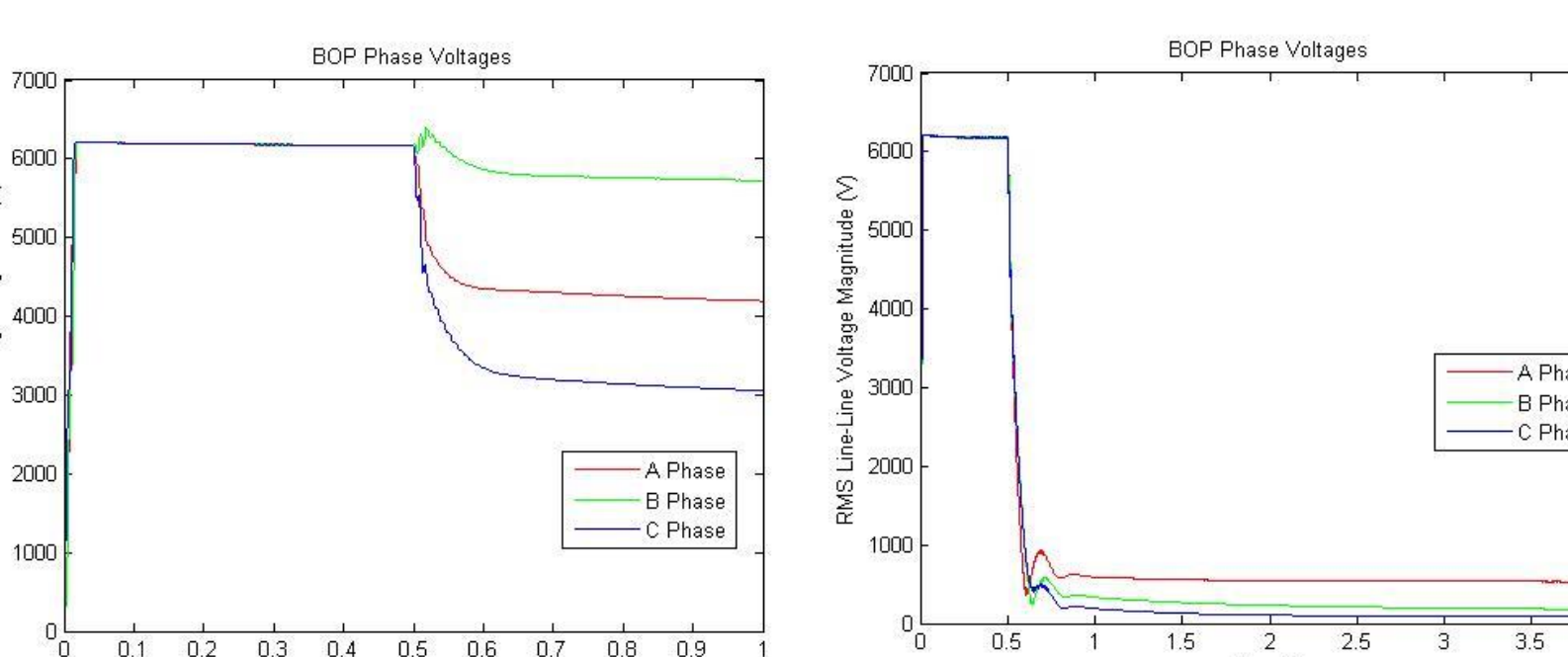


Figure 3. Case 1, Open-Phase on C at t=0.5 s for BOP Phase Voltages

Steady State Condition under Normal Power Operation
100% (P=25.9kW, Q=12.6kVAr) Loading on BOP Bus

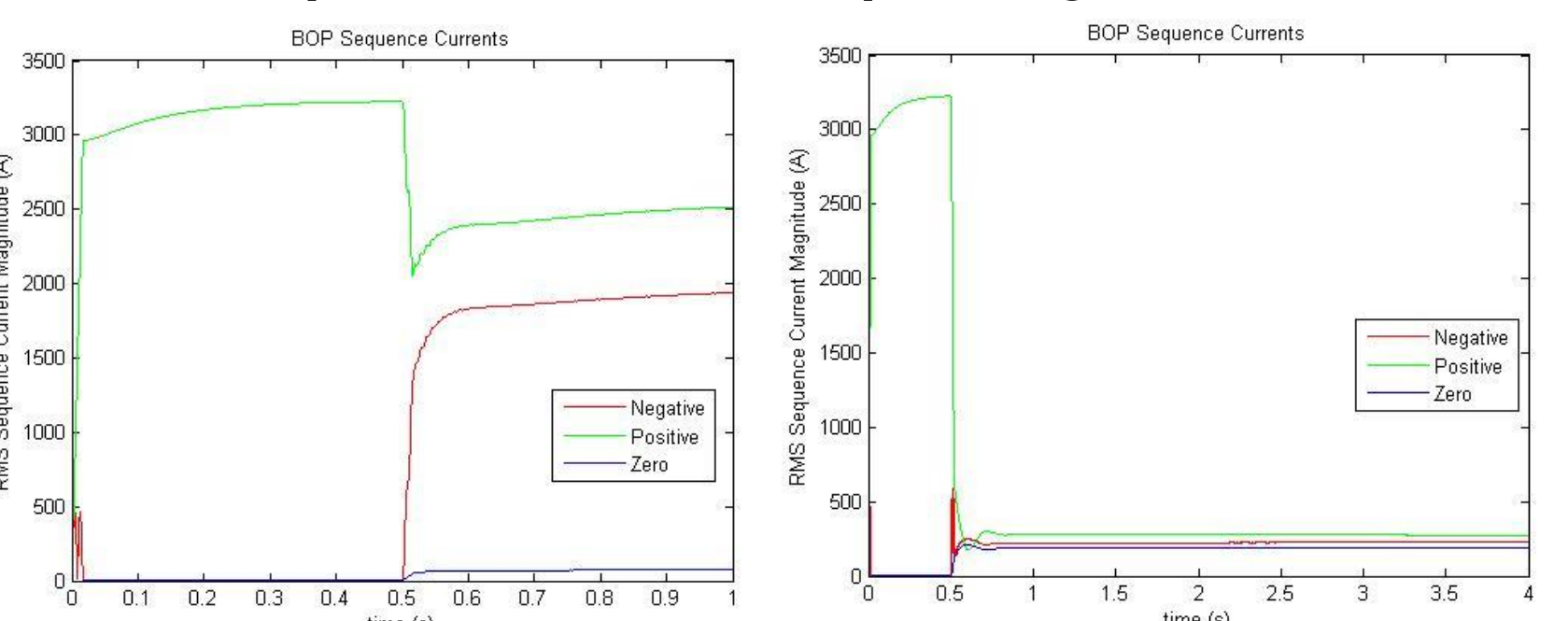
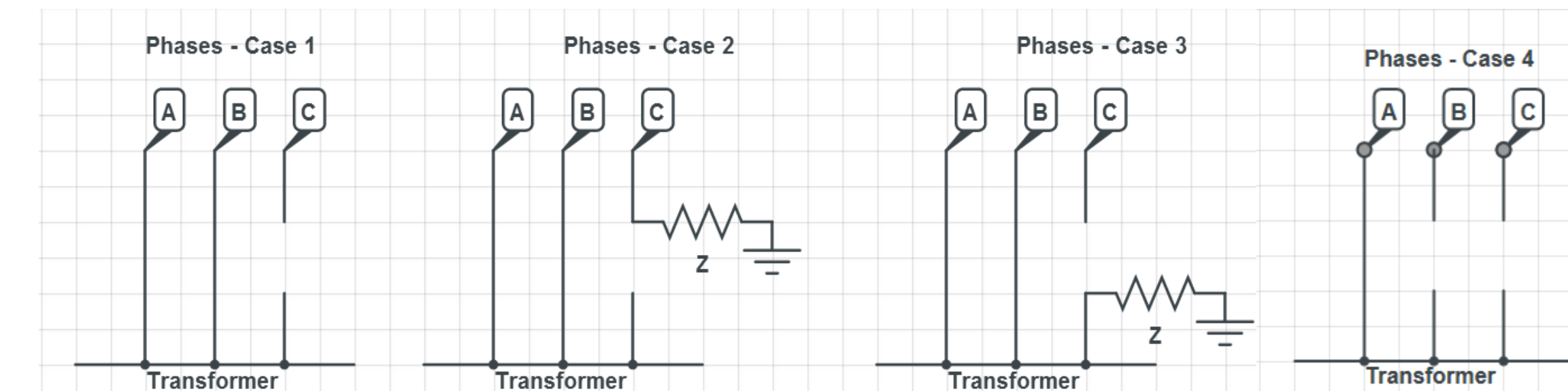


Figure 4. Case 4, Open-Phase on B & C at t=0.5 s for BOP Sequence Currents

Open-Phase Cases & Loading Scenarios

Four open-phase (on Primary, 40 MVA) cases were examined:

- Case 1 - Open-phase only
- Case 2 - Line to ground resistive open-phase from the grid
- Case 3 - Line to ground resistive open-phase on the high voltage side of transformer
- Case 4 - Two Open-phases



For the ground resistance Z, three preliminary resistance values will be used during testing: 0Ω, 100 Ω, and 400 Ω

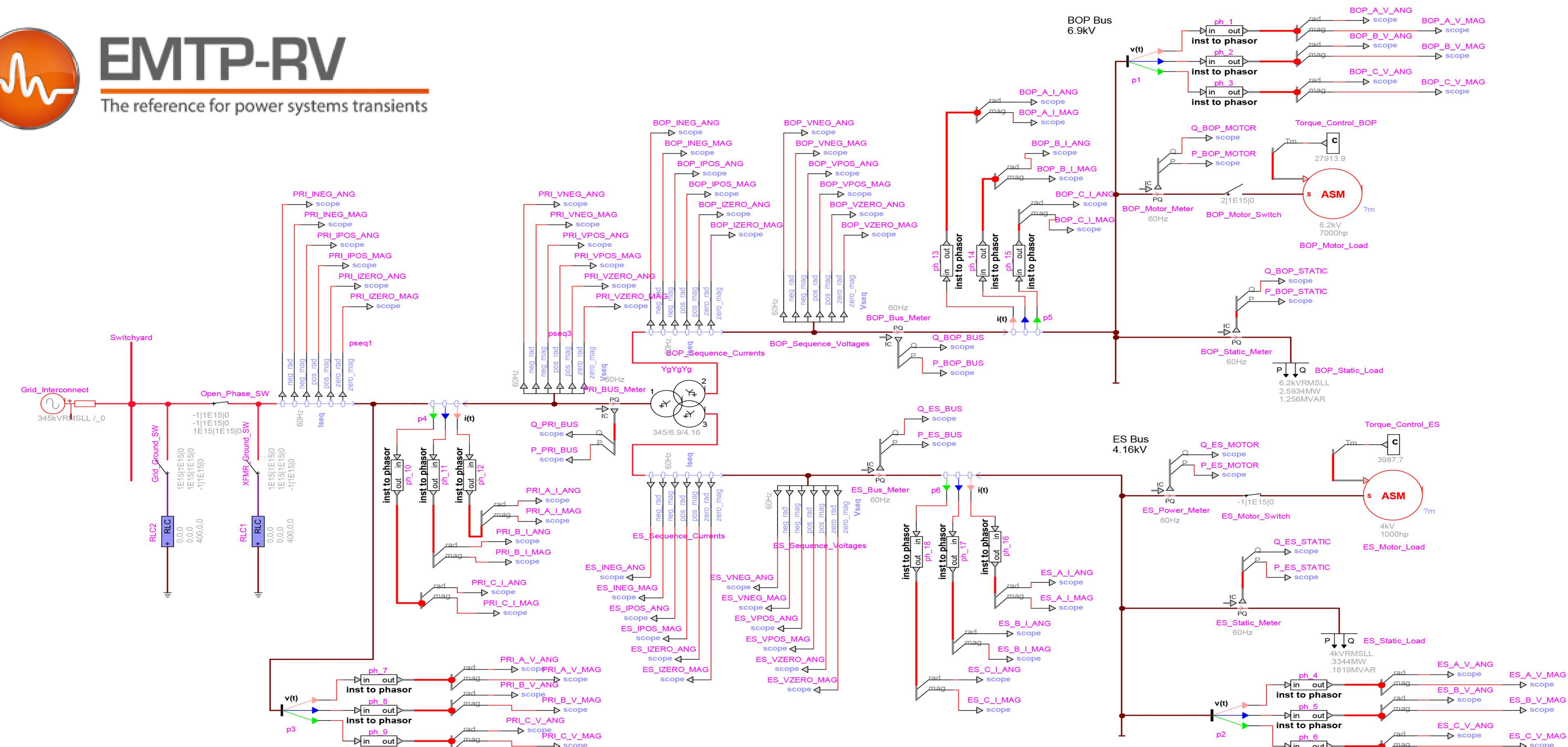
Steady State Conditions

Alignment/Percent Loading	Engineered Safeguard Bus	Balance of Plant Bus
Normal Power Operation	20%	100%
Refueling Outage	20%	20%
Accident	100%	80%
Minimum Loading	10%	10%

Motor Starting Conditions

Alignment/Percent Loading	Engineered Safeguard Bus	Balance of Plant Bus
Accident with Motor Start on ES	80%	80%
Minimum Loading with Motor Start on ES	10%	10%
Minimum Loading with Motor Start on BOP	10%	10%

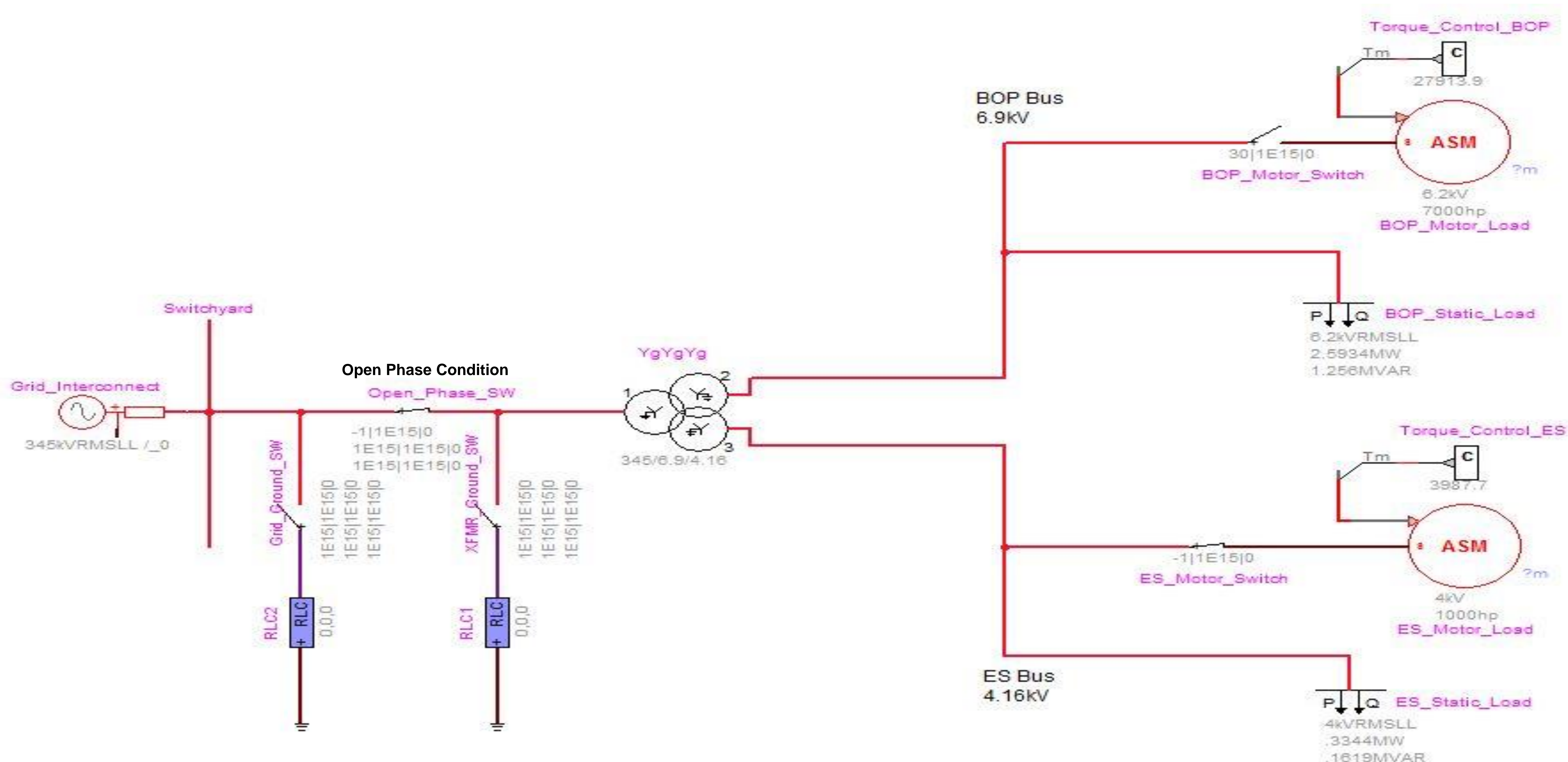
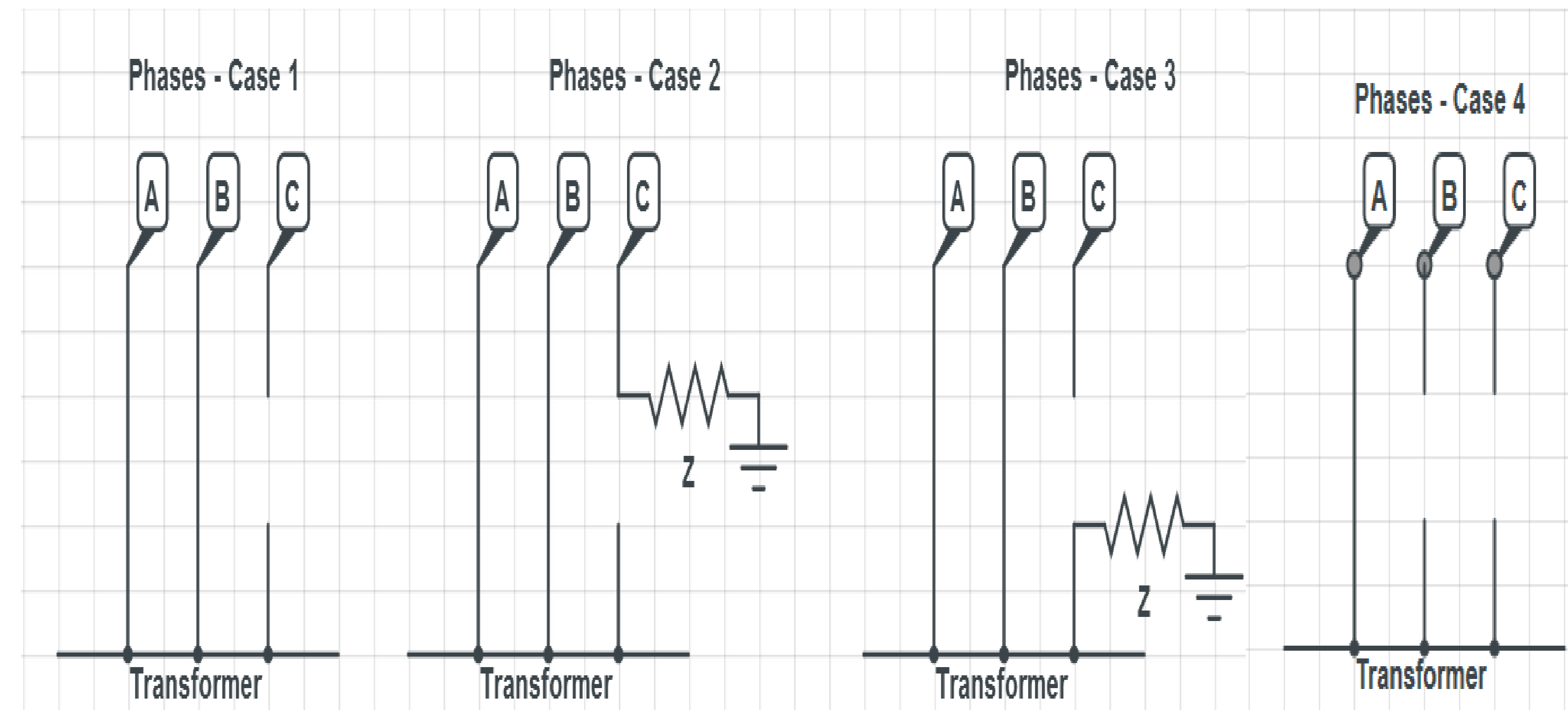
Three-Phase Power System Model



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