ECEN 616 Project, Spring 2025

Instructions for the Project

For this project you will be building and simulating an EMTP model as described below. Turn in a maximum of 4 page report that includes the circuit diagram, study results, and answers to questions below. Be sure to include a few significant plots to illustrate your results. The report should be well-written and presented. The reports are due by email on Thursday, Apr. 24th, at 8am.

Description of System

For the project, we are modeling transients associated with three 500 kV transmission substations: Alfa, Bravo, and Charlie.

- At the Alfa substation, there is an equivalent source, with a three-phase short circuit strength of 5000 MVA and X/R ratio of 20.
- At the Bravo substation, there is a switchable capacitor bank installed, connected wye and solidly grounded, providing 70 Mvar of total three-phase reactive power to the system.
- At the Charlie Substation, there is a solar plant producing 200 MW of real power at 1.0 per-unit voltage. Assume ground return resistivity is 100 Ohm-meters.
- There is a 50 km, double-circuit transmission line connecting Alfa and Bravo substations. Each circuit is organized vertically, with the middle phase 18 m above the ground, and the phases separated by 5 m each. Each phase contains a bundle of two conductors, separated by 26 cm. The two circuits are separated horizontally by 9.6 m. There are two shield wires located 4 m above the top phases, centered and separated by 7.4m. Assume ground return resistivity is 100 Ohm-meters.
- There is another transmission line connecting Bravo and Charlie substations. This is a 10-km, single-circuit transmission line with horizontal configuration 20m above the ground, spaced 8m apart. Each phase contains a bundle of two ACSR conductors, separated by 26 cm. There are two shield wires located 5 m above phase wires, centered and separated by 12 m.
- Phase conductors for both lines are ACSR and have an outside diameter of 2.1 cm and a dc resistance of 0.137 Ohms/km. Shield wires for both lines are 0.945 cm in diameter, with a dc resistance of 3.375 Ohms/km. Assume ground return resistivity is 100 Ohm-meters for both lines. Use a frequency-dependent line model with validity from 0.1 Hz to 10 MHz.
- Lightning impulses are modeled as a standard 1.2/50μs pulse with peak current of 12 kA, injected into the bus at the Charlie substation.
- Add a switchable Metal-Oxide-Varistor (MOV) surge arrestor to the A-phase conductor at Bravo substation. To get the model for the MOV, in EMTP open the Example File

under Options -> ApplicationCases -> Lightning -> arrester_model -> Zno_OB_258kV. Then use the ZnO1 object as it is designed in the example file.

Solar Plant Modeling

You will try three different models for the solar plant inverter.

- Ignoring it. Just model the Charlie substation as an open circuit.
- Voltage source behind a R-L combination. In this case, approximate $R = 12\ \Omega$ and $L = 70\ \text{mH}$
- Detailed inverter model. Use your choice of inverter models from the EMTP library. For example, look in the library categories "Power Electronics" or "Renewables"

Questions to Answer

1. First set up your case with (1) no lightning pulse, (2) no surge arrester, (3) the capacitor bank switched out, (4) ignoring the solar plant. What is the maximum overvoltage when switching in the second circuit of the Alpha-Bravo line, assuming the other lines are already switched in? Which bus and phase does this maximum overvoltage occur at?
2. Next assume all transmission lines are in service. What is the maximum surge current when switching the capacitor bank in? Where does that maximum current occur?
3. Next assume all transmission lines and the capacitor bank are in service. What is the peak voltage level at each substation following the lightning pulse at Charlie?
4. Repeat #3 with the surge arrestor at Bravo in place. How much does the surge arrester help?
5. Repeat #1-4 with each of the two other solar plant models. What is the impact of the solar plant modeling? For the detailed inverter model, explain the choices you made in selecting and parameterizing your detailed model and how the models' characteristics relate to its transient performance in the simulations.