IEEE PES Test Feeders

Neutral-to-Earth Voltage (NEV) Test Case

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Objective

The purpose of this test case is not only to solve the Neutral-to-Earth Voltage (NEV) problem, which isn't necessarily computationally difficult, but to present a challenge to the various methods of describing circuits for distribution analysis. Believe it or not, this circuit was inspired by a real circuit near a major US university.

NEV analysis requires one of the most comprehensive circuit models of any type of power system analysis with the possible exception of lightning analysis. Not only does one have to model the phase conductors, but it is necessary to model all neutral and ground conductors explicitly. While most electromagnetic transients programs can handle this modeling task, they are not necessarily familiar to distribution analysts. This test feeder is presented as a benchmark for distribution system analysis tools to encourage development of tools capable of modeling nearly all aspects of steady-state frequency-domain analysis encountered on distribution systems.

NEVs are principally 3rd harmonic as well as fundamental frequency voltage. Therefore, the system must be solved at two frequencies. This will be a new capability for most distribution system analysis programs, although most are probably not far from being able to achieve that capability. However, the conventional ladder (forward/backward sweep) techniques may not converge for any frequency other than power frequency.

Description of the Test Case

The substation has a relatively large 3-winding transformer with a 0.3 ohm reactor in the neutral of the MV winding to limit fault current contributions. A 3-winding transformer is common in some areas where the transmission system might need additional ground strength.

Four feeders leave the substation on the same poles for 5 pole spans (75 m each span). The four circuits share one neutral wire. However, there are also 4 telecom circuits on the same poles, each suspended from a grounded messenger wire. The messenger wires are assumed to have similar electrical characteristics to #2 ACSR.

The feeders split off at the 5th pole from the substation. Two of the feeders travel on the same poles for 6 more spans before splitting off separately.

Most of the load on each feeder is modeled by lumping it at the end of each feeder with a 3-phase grounded-Y-Y connected equivalent. The low voltage side of these transformers is not of interest in this test case. The loads are unbalanced and are described by

1. kW demand

2. Power factor (PF)
3. % 3rd harmonic current (%I_3). All 3rd harmonic currents in the loads are assumed to be in phase with the Phase A-N voltage at each location.

On each of the 4 feeders there is one single-phase lateral branch circuit that originates on one phase of the main feeder. There is a detailed 1-phase residential load model at the end of each 1-phase lateral. The load model consists of a single-phase transformer connected line-to-neutral (not ground!), a center-tapped LV winding (120/240V), a length of triplex LV cable, two 120V equivalent loads, and one 240V equivalent load. The X2 bushing on the transformer is connected to the neutral at the top of the pole, as it would be in practice. The pole ground resistance is assumed to be 100 ohms while the house ground resistance, Rg, varies as specified in the data spreadsheet. One of the four single-phase feeders is tapped off the C phase of one of the circuits on the 4-circuit pole structure. Expressing this connection can sometimes be a challenge if the scheme is not well thought out.

The neutral conductors are connected together throughout the circuit.

The neutrals are grounded at each pole through a grounding resistance of 100 ohms. (NEV problems are most severe where it is difficult to obtain a good ground.) The inductance of 10m of downlead is approximately 12µH. The grounding resistance at the substation is assumed to be 2 ohms. The grounding resistances at the loads vary as specified.

Challenges Presented by This Test Case

The following issues are expected to present modeling challenges for distribution system analysis tools. If a program can accurately model these issues, there would be few circuit topology issues on the distribution system that the program could not handle.

1. Three-winding transformer in the substation.
2. The substation neutral reactor.
3. The four circuits on the same pole sharing a common neutral and four messenger wires for telecom circuits.
4. The single-phase lateral tapped off phase C of the 2nd circuit on the 4-circuit pole
5. Single-phase laterals tapped off different phases of the three-phase feeders
6. Explicit pole grounds and load grounds
7. Connecting the loads line-neutral rather than line-to ground.
8. Center-tapped single-phase transformers for 120/240V service
9. The triplex LV cable with all three conductors explicitly modeled
10. Mixing 120V and 240V loads in a typical North American residential service
11. 3rd harmonic currents
12. 3rd harmonic solution
13. Reporting currents in neutral conductors
14. Reporting voltages L-N and N-G
15. Handling all the additional nodes
16. Unbalanced loads
17. Unbalanced 3rd harmonic currents

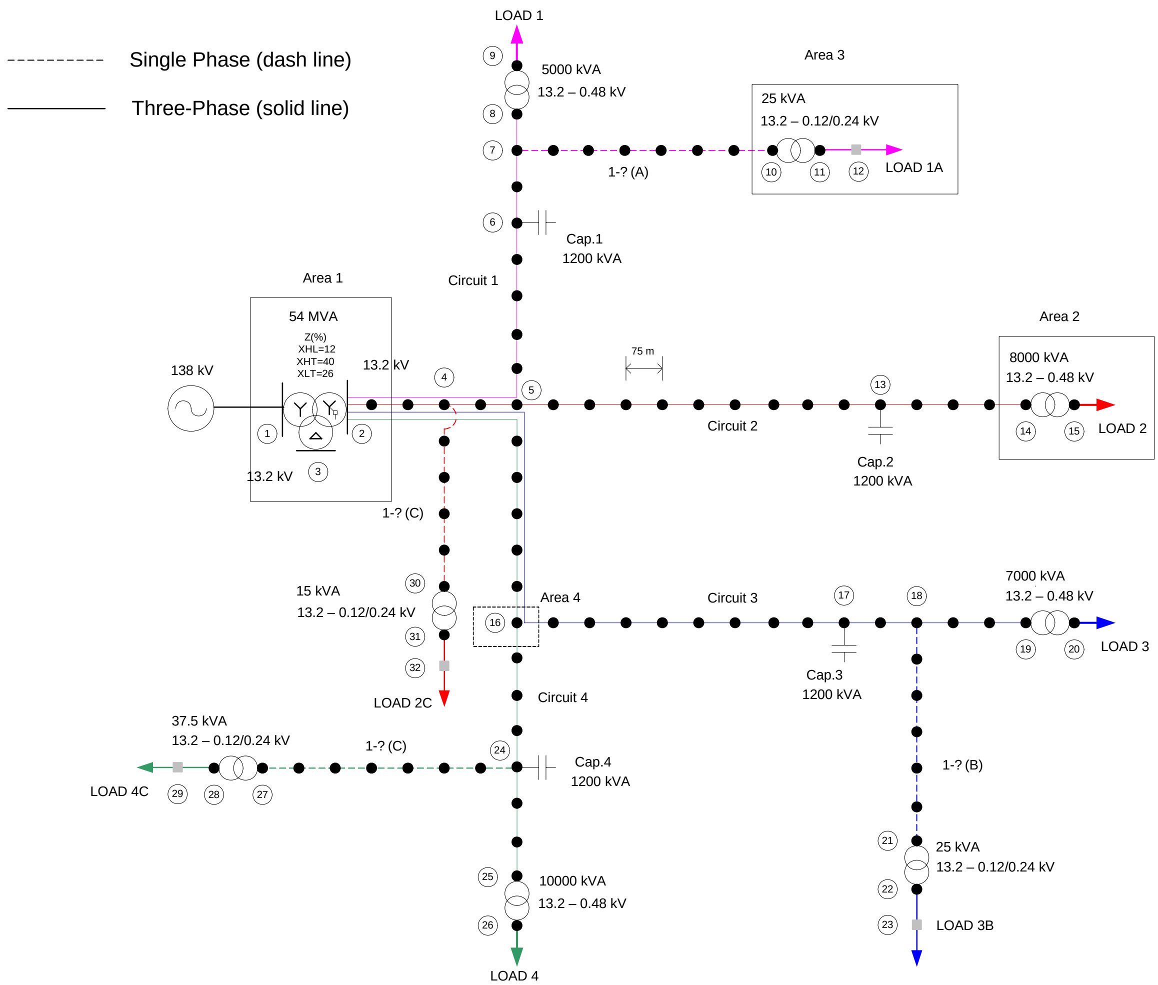

Figure 1. Overall circuit diagram

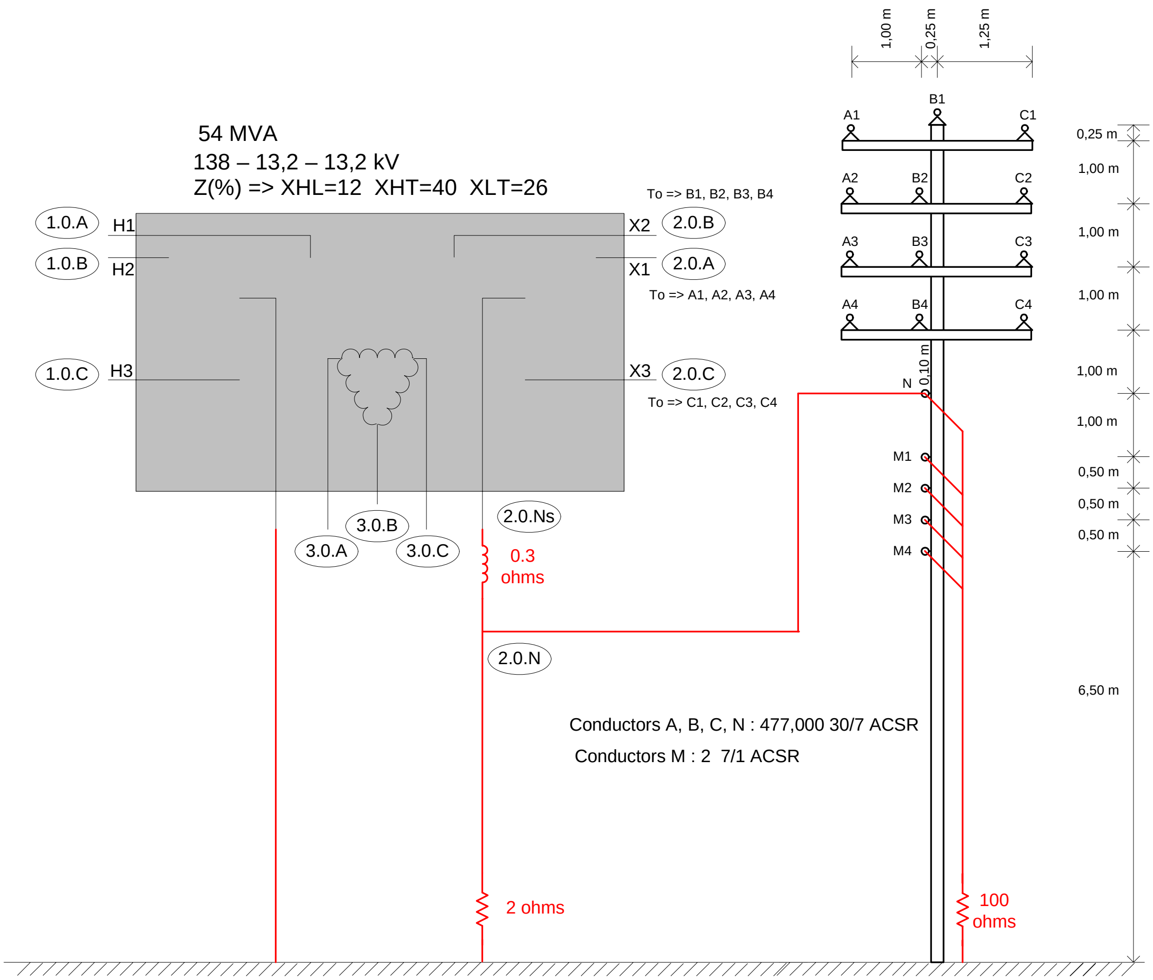

Figure 2. Detail on Area 1 (Substation and Quad-circuit Pole)

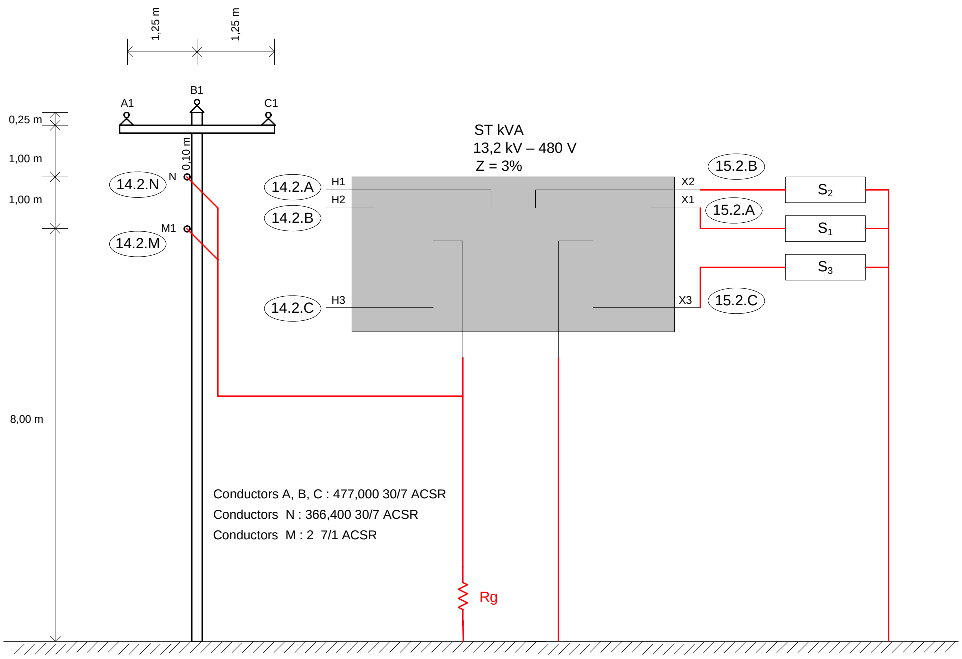

Figure 3. Detail on Area 2. Service to 480V 3-phase Load.

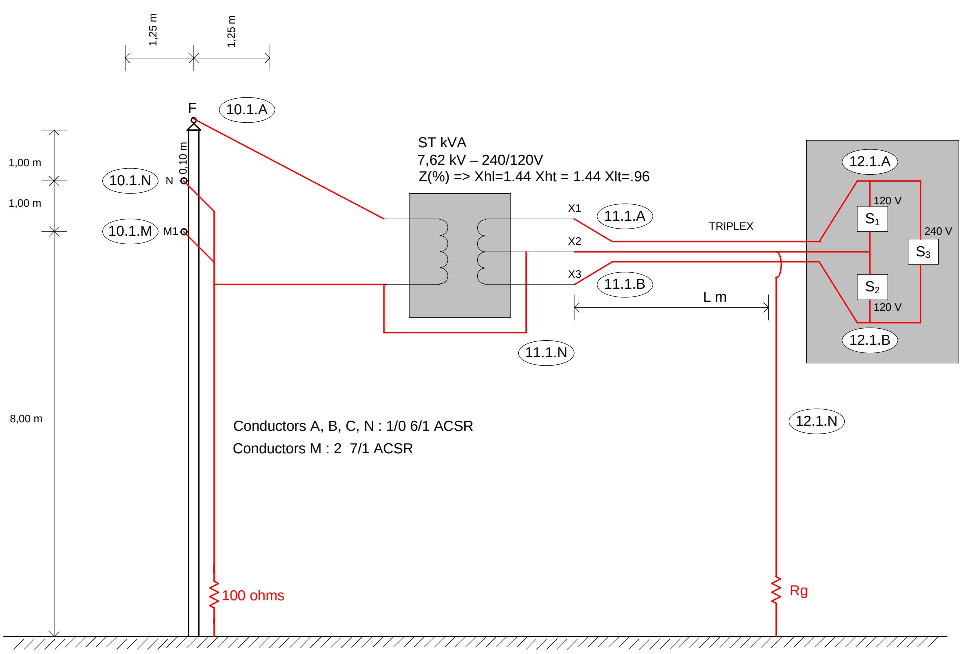

Figure 4. Detail on Area 3. Service to single-phase 120/240V Load.

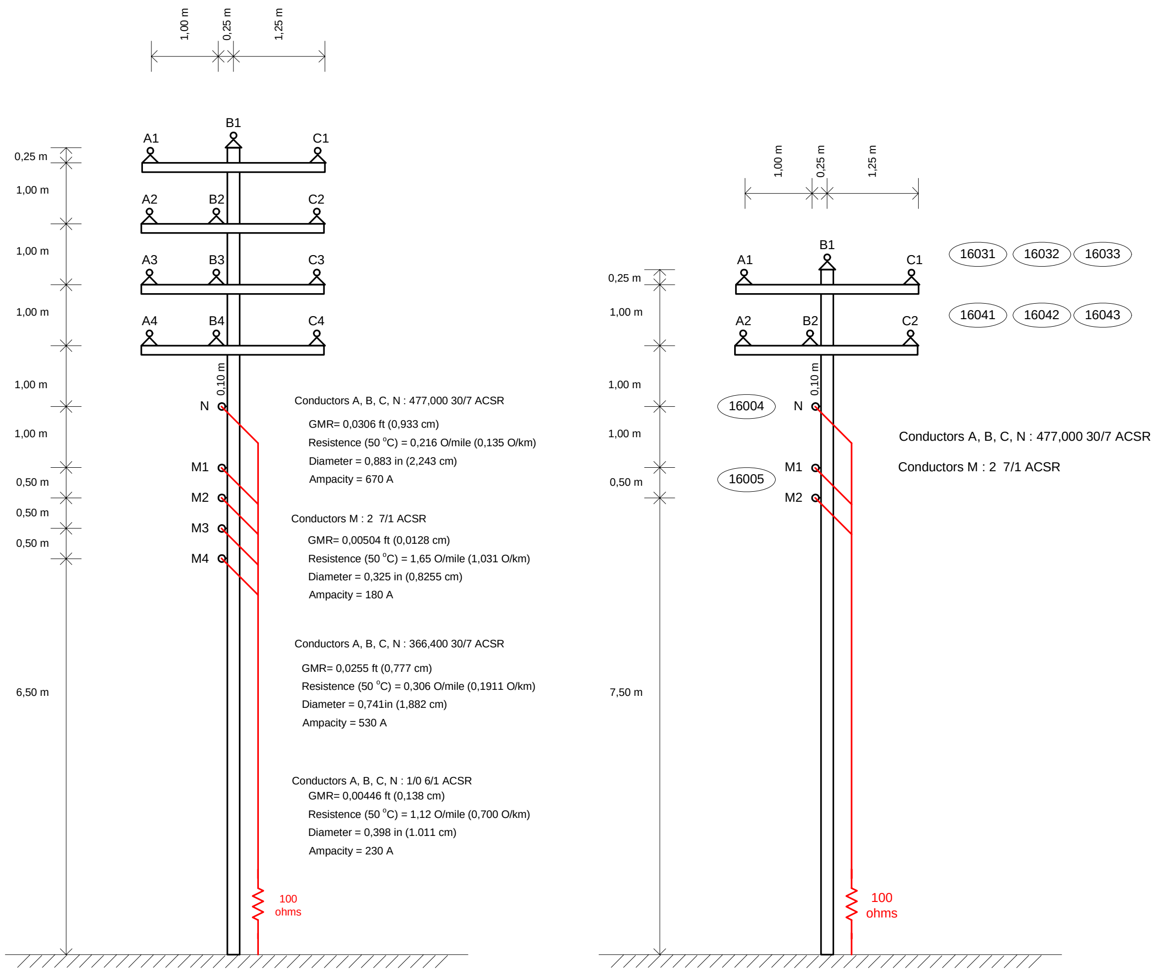

Figure 5. Detail on Quad-circuit and Double-circuit Poles.