Investigation of Stray Voltage Problems Near a Low Voltage Distribution Station.

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Distribution Performance Engineering of Manitoba Hydro were informed of an issue related to Stray Voltage at the Windsor Park Swimming Pool. The Power Quality Section of Business Engineering Service Department was also actively involved to assess the nature of the problem. Various measurements at the Windsor Park Pool and also at other neighbouring commercial customers were recorded to further analyse the problem.

The pool is located around 100m from a distribution station and is fed from two 24 kV feeders. The station has two 8 MVA transformers and eight 4 kV feeders feeding the residential/commercial customers in the neighbourhood. Three 50 kVA 3-Phase Wye-Wye transformers located just outside the fence of the station feed the neighbouring school and swimming pool.

According to the initial measurements, the NEV was recorded around 1.9 Volts and earth current was recorded around 3A when the supply was cut off to the pool. Since some preliminary actions did not resolve the problem, a detailed PSCAD® study was undertaken. The field measurement values were used (specifically 4 kV feeder currents, neutral currents, harmonic content, earth currents and NEV) to verify the results of the PSCAD® model and tune the model to represent the distribution system accurately.

The PSCAD® study considered four possible mitigating methods. The study indicated that the 'Ronk Blocker' (Saturable Reactor) would be the most suitable and cost effective solution to the stray voltage problem at the pool. The total cost of installing the Ronk Blocker to the existing transformer is around $1,500.

Development of the PSCAD® Model

The development of the complete model of the system at Windsor Park can be identified in three stages.

- **Stage 1** - In the first stage, the Manitoba Hydro poles with 24 kV line and two 4 kV under-built systems were modeled. Since the feeders are too short, Pi (π) line models were created from the different pole configurations with correct feeder lengths (PSCAD® can generate the Pi model data for a given pole configuration).

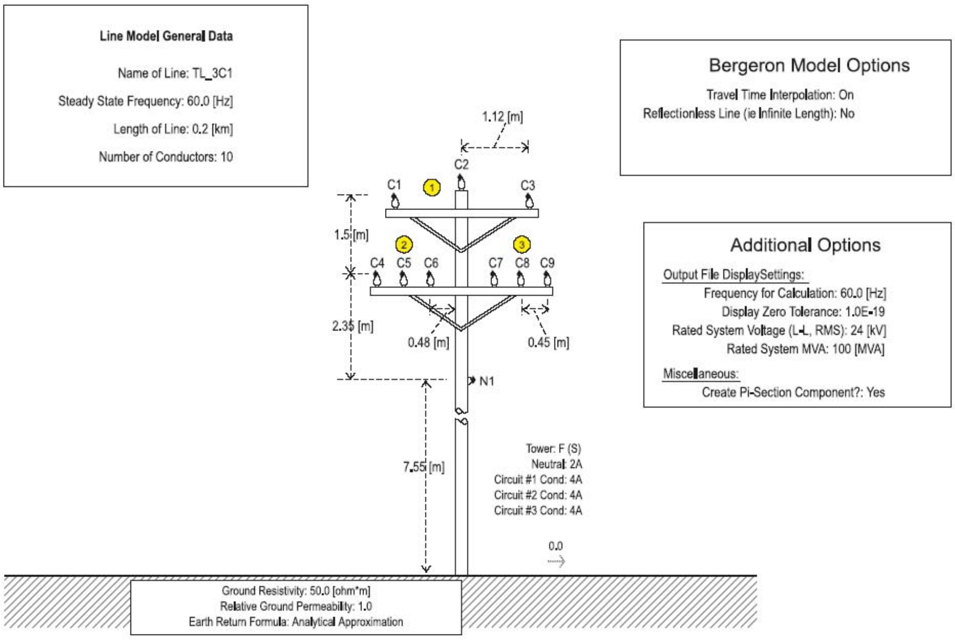

Figure 1: The use of three-scale autotransformer and open-close operations of 10sec periodicity to the propeller blade joystick.

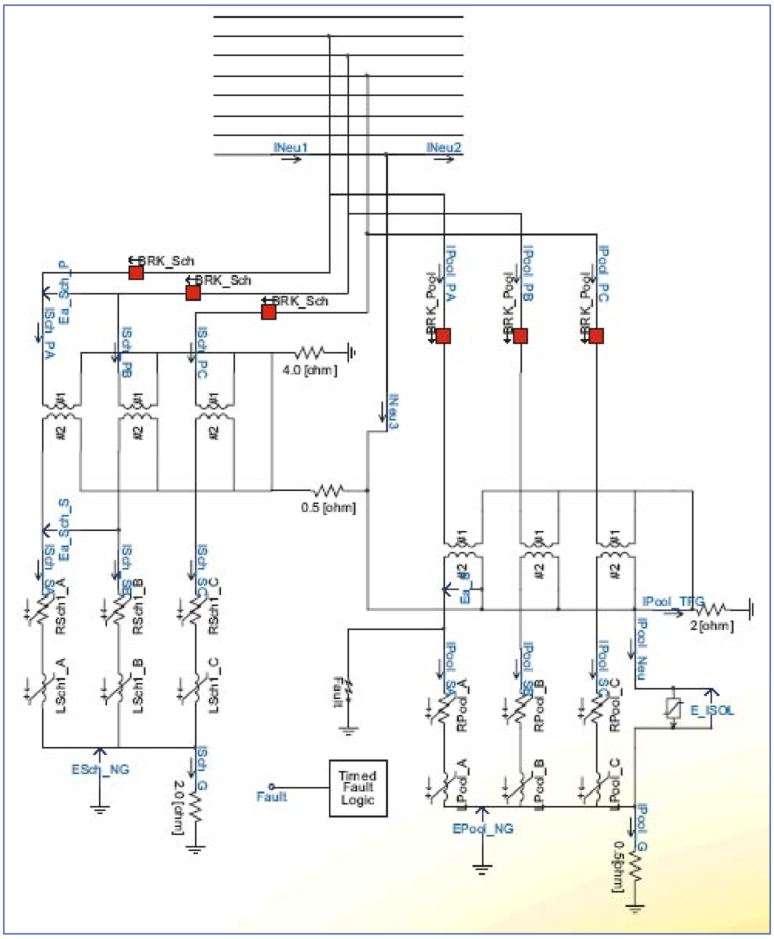

Figure 2: Part of the system model with the saturable reactor in place.

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The rest of the system was modeled using PSCAD® standard library components (Figure 1).

- **Stage 2** - It was determined during the investigation, that the system neutral carries a high amount of harmonic current (3rd harmonic and also other odd harmonics, especially 5th and 9th harmonics). It was assumed that the high harmonic content is due to the non-linear loads, such as power supplies, lighting (CFL lamps) and dimmer circuits. Single-phase, full-wave rectifier circuits were used to model the injection of harmonics to the system. Variable loads (inductors and resistors) were used to adjust the feeder currents until the values were matched with the measured currents. The system was fine tuned until proper load flow was achieved, including the measured stray voltage, ground and neutral currents at the pool (Figure 2 - system model).

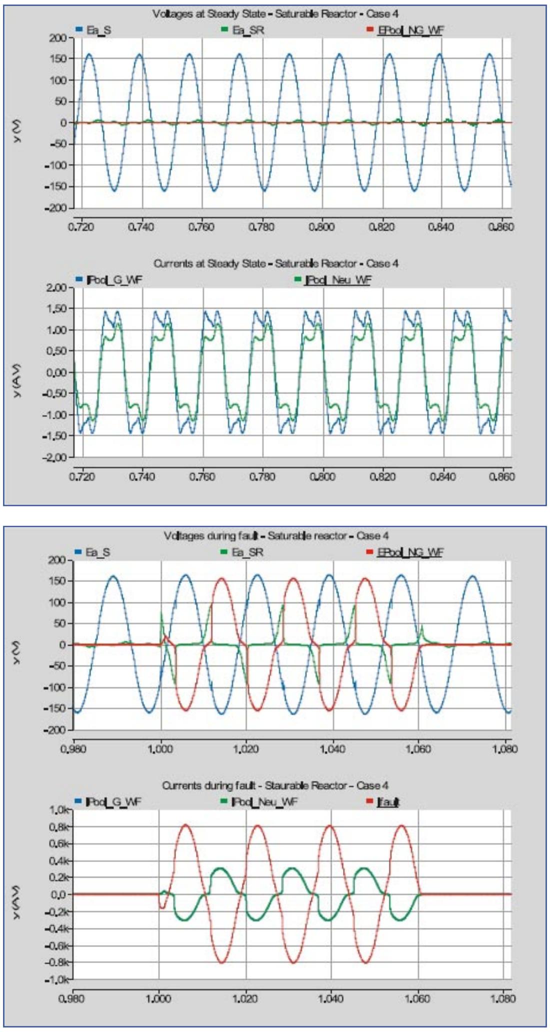

Figure 3: Steady state voltage and current waveforms near the pool with a saturable reactor.

- **Stage 3** - In this stage, four different cases were studied as mitigating methods to resolve the stray voltage issue. A brief description of these four cases is as follows:

Case 1 – *Replacing the existing Y-Y transformer by a Delta-Y transformer:* Distribution transformer at the pool was modeled as a Delta-Y transformer while keeping the transformer for the school as a Y-Y. The standard practice of Manitoba Hydro is to connect the secondary neutral of Wye winding to the system neutral. Once this connection is made, it will provide a path for the stray currents to return to the source, via system neutral. This will not eliminate the stray voltage problem at the pool, when the secondary neutral is tied to the system neutral.

Case 2 – *Connecting a series Current Balanced Transformer:* This proved not to be suitable for three-phase systems.

Case 3 – *Connecting an Isolator to the neutral wire, to isolate the system neutral from the customer neutral (open circuit under steady state, and short circuit during a fault):* The Isolator was modeled in PSCAD® as a surge arrester with arrester rated voltage to 45V.

Case 4 – *Connecting a Saturable Reactor to the neutral wire, to introduce high impedance during steady state and low impedance during a fault:* This device (Saturable Reactor) operates directly on the principle of magnetic saturation and does not depend on external or internal logic controls. Therefore, it responds instantaneously, providing immediate continuous protection.

To model a saturable reactor in PSCAD®, a single-phase transformer is used by enabling saturation. The saturation voltage is assumed as 11 Volts, to match the characteristics of Ronk Stray Voltage Blocker, produced by Ronk Electrical Industries.

The simulated current and voltage waveforms with the saturable reactor are shown in Figure 3.

System behaviour under steady state and fault conditions was analyzed for all four cases. Effect of the neutral isolator was also studied for Case1.

After careful consideration, the saturable reactor solution was implemented. The measurements at the pool site with and without the saturable reactor verified the solution method selected based on the PSCAD® study (Figure 4).

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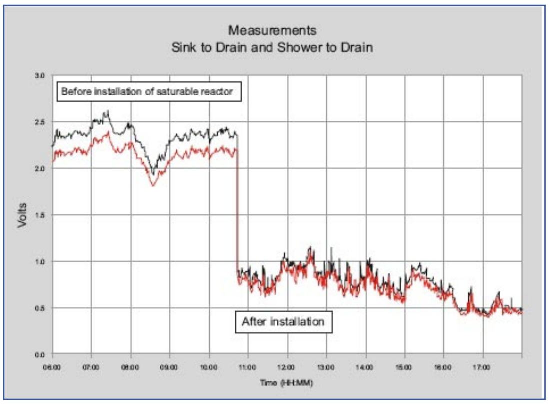

Figure 4: Stray voltage measurements with and without the saturable reactor.