Simulation of PD EM Wave Propagation in a Medium Voltage Bus Bar Chamber

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Introduction / Aim of project

- Optimum position for UHF partial discharge (PD) sensors in switchgear bus bar chambers not well understood.
- PD EM wave propagation characteristics in air-insulated switchgear still requires to be understand [1].
- Main aim to optimise development of PD online condition monitoring system for MV bus bar compartments.

Methods / Tools

- 3-D finite element (FEM) bus bar chamber model in Comsol Multiphysics created.
- Simulations of EM wave propagation due to PD within chamber performed [2].

Bus bar chamber model

- Bus bar chamber comprises, bus bars, bus bar supports, side walls (see Fig. 1).
- PD source implemented as lumped port, representing position where PD energy enters chamber space.
- May be positioned on insulation, supports or bus bars.

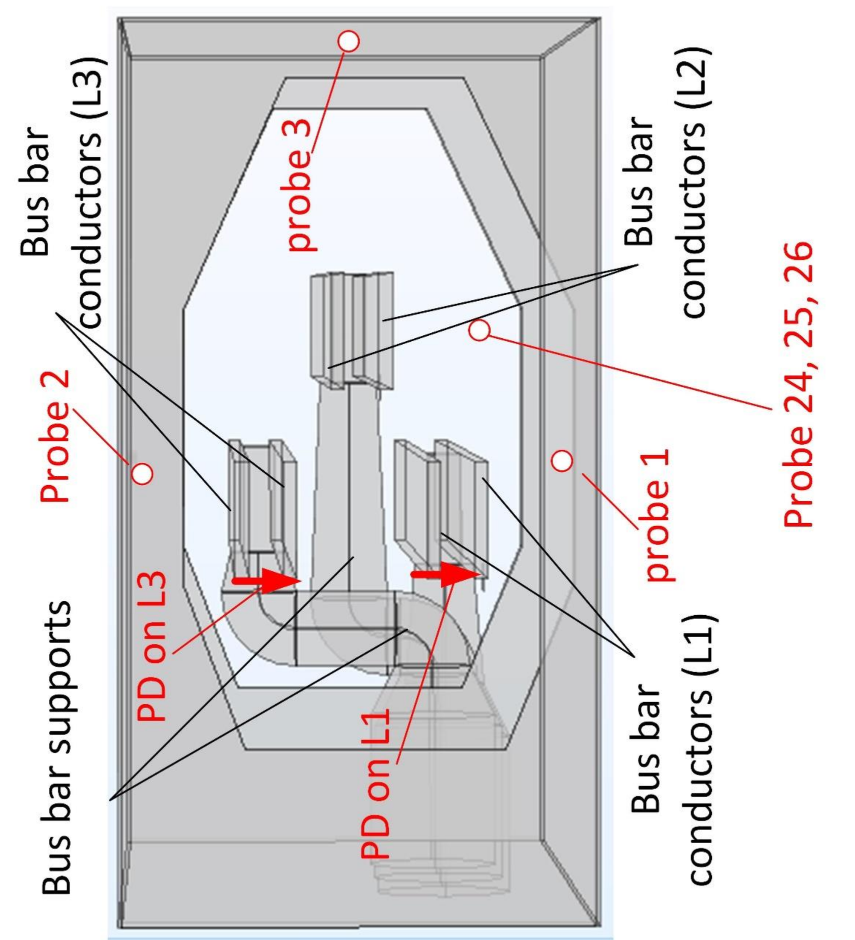

Fig. 1: 3-D FEM bus bar chamber model

- PD pulse based on Gaussian impulse described in (1) [3].

$$i_{PD}(t) = I_0 * e^{-\left[\frac{(t-t1)^2}{2*\tau^2}\right]} \qquad (1)$$

- Peak current impulse (I_0) arbitrarily set to 1 A, time occurrence of peak (t_1) set from 5 to 7.5 ns, pulse width (τ) determines discharge rise and fall times.

Simulation results

- PD sources on bus bar supports with particular discharge current orientation applied (see Fig. 2).
- COMSOL EM frequency probes applied at top and side walls of compartment.
- In Fig. 2, propagation of electric field shown, E_{norm} defined as stated in following:

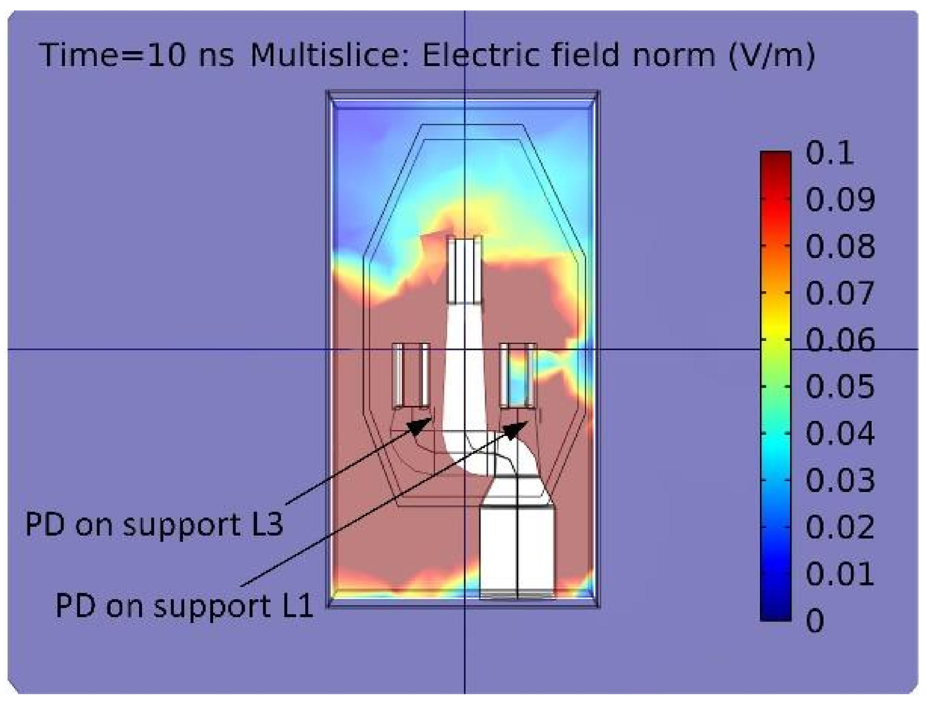

Fig. 2: PD source on support L1 and L3 and E-Field propagation at 10 ns

$$E_{norm} = \sqrt{E_x^2 + E_y^2 + E_z^2} \quad (2)$$

- Ex, Ey and Ez are spatial electric field components.
- Fig. 3 shows detected electric field for case of PD on phase L1 with Ex component from probe 1 with highest amplitude.

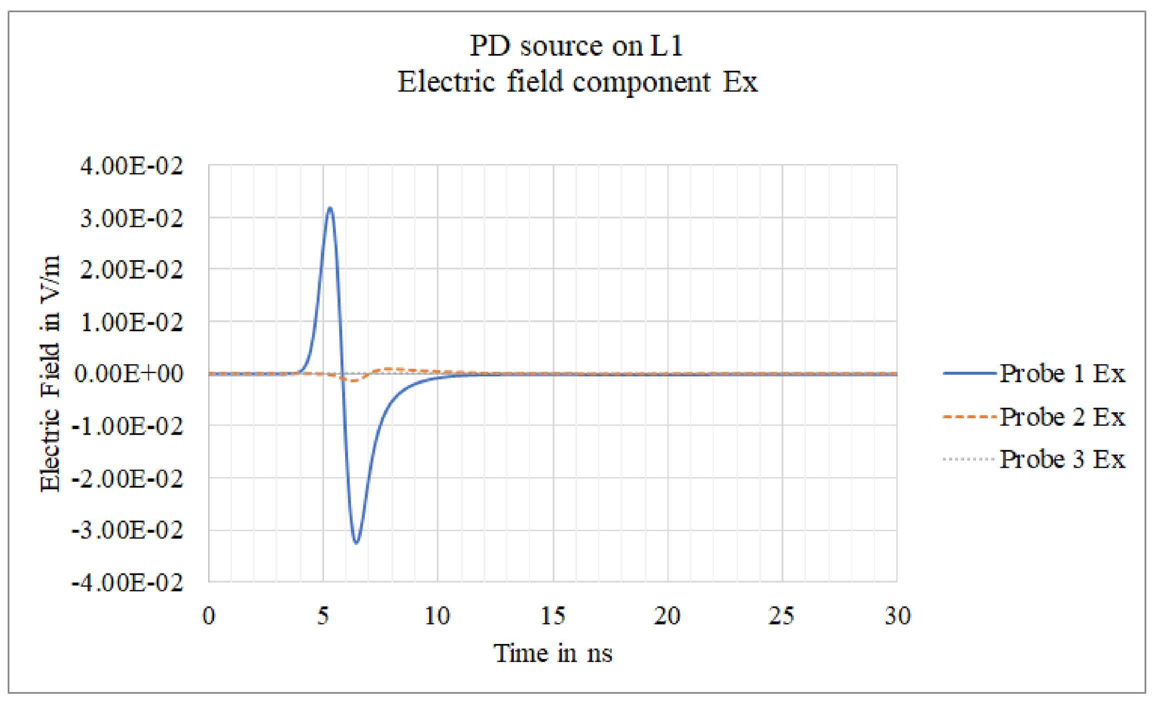

Fig. 3: Detected electric field for case of PD on L1

- Fig. 4 shows probe signals for case of PD on L3
- Due to vicinity of probe from PD source, it shows highest amplitude

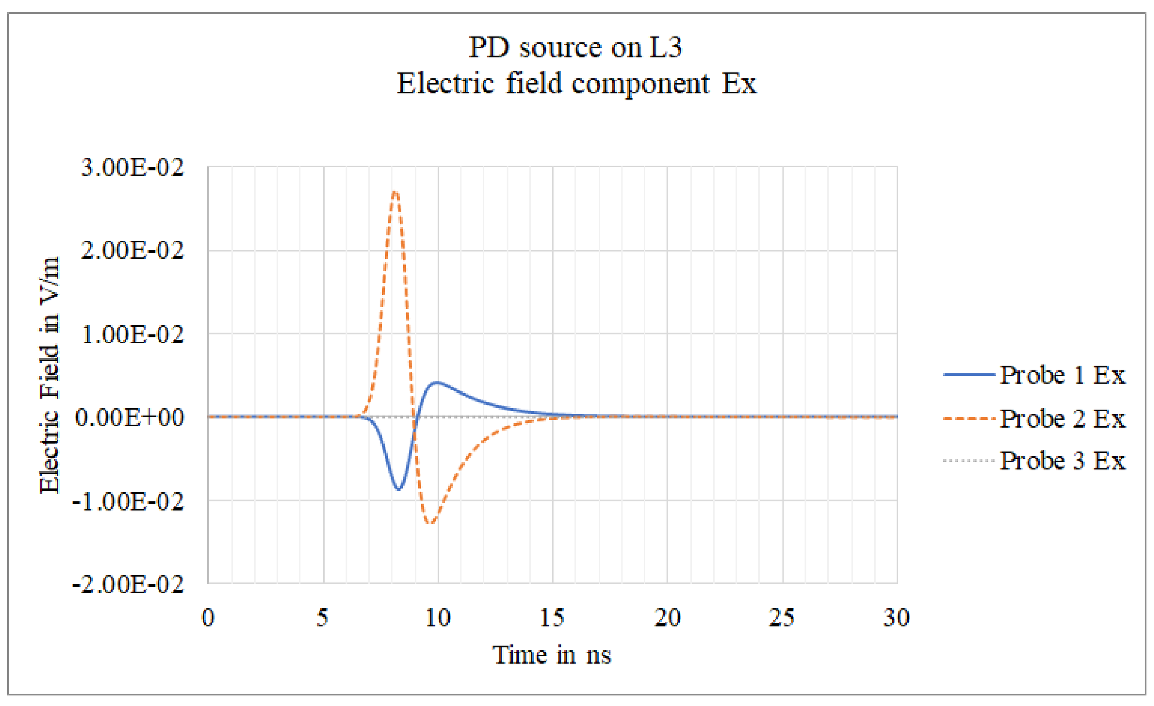

Fig. 4: Detected electric field in case of PD on L3

- Fig. 5 shows probe signals for case of PD on L1 with t_1 = 5 ns and PD on L3 with t_1 = 7.5 ns

- Superposition of PD sources recognised, when comparing with Fig. 3 and 4.

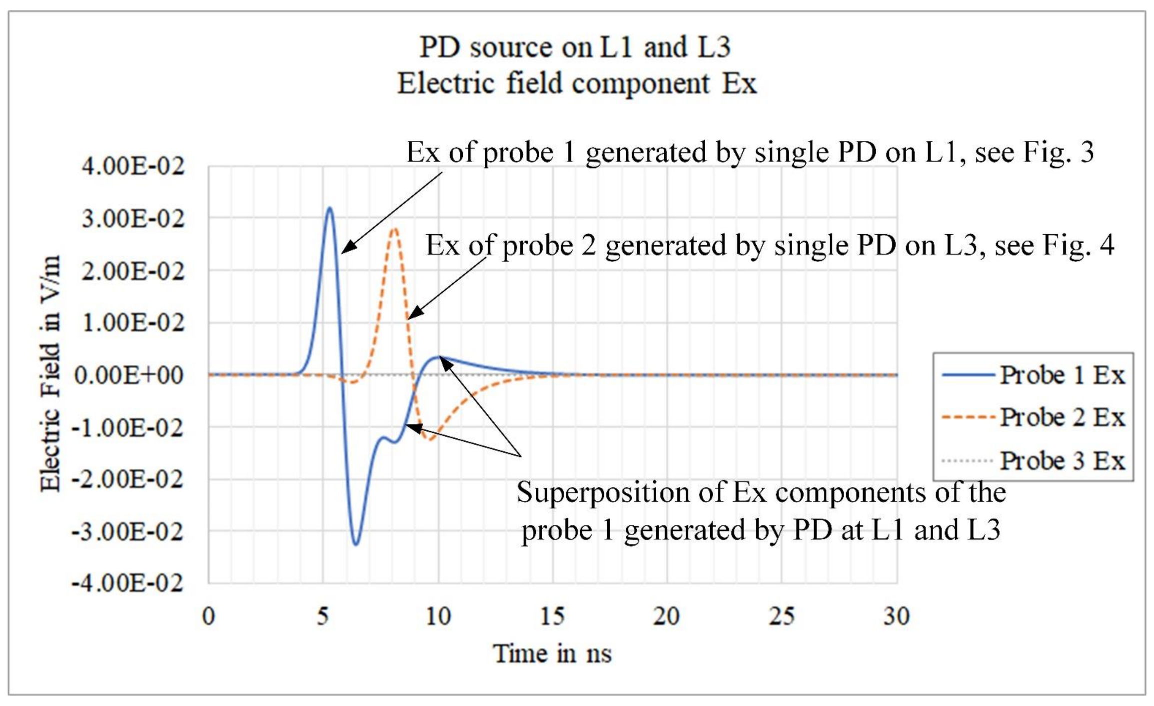

Fig. 5: Detected electric field in case of both PD sources, with a slight delay, on L1 and L3.

- Fig. 6 shows probe signals for case of PD on L1 with different pulse widths of 0.1ns, 0.2ns and 0.4ns
- The shorter the PD pulse width the higher the amplitude of detected signal and the faster the rise time
- Signal reflections inside chamber more easily recognisable for narrower pulse widths

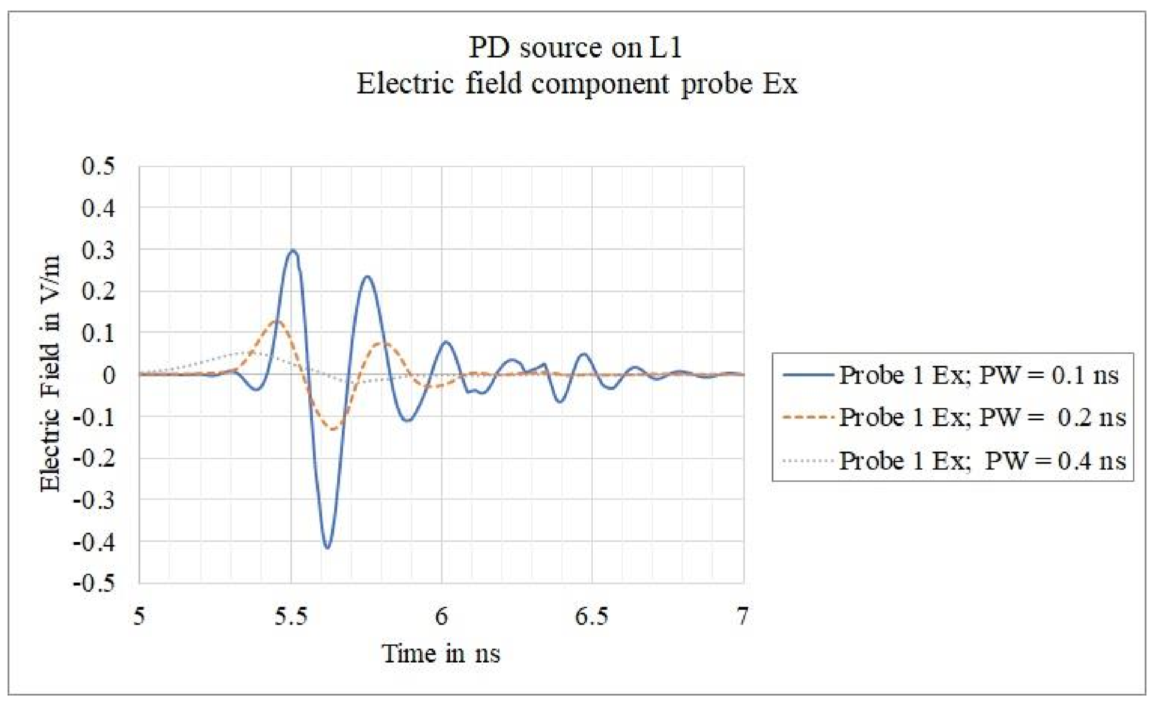

Fig. 6: Detected electric field in case of PD source on L1 with different pulse widths.

Conclusions

- Depending on PD source position and PD discharge current orientation, different wave shapes generated.
- Based on wave shapes PD source recognition may be possible
- EM field distribution generated from different PD sources with different current injection and orientation may be further studied.
- Optimised position of RF sensors possible for key PD source locations.

References
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[2] M. Miljanovic, M. Kearns, B.G. Stewart, "Simulation of Partial Discharge Electromagnetic Wave Propagation in a Switchgear Compartment,"
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[3] T. Zhao, M.D. Judd, B.G. Stewart, Time Dependent Simulation of PD Electromagnetic Wave Propagation, Annual Conference on Electrical Insulation and Dielectric Phenomena (2020): CEIDP 2020.

Acknowledgments
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