



UFSA: Closing the Nanosecond Protection Gap for Utilities

Dr. William Joyce

Michael Brown

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Export Control / ITAR

- Certain AFS technologies and performance characteristics are subject to U.S. export control regulations.
- Today's presentation is limited to:
 - High-level functional descriptions
 - Performance behavior under fast-front transients
 - Utility-relevant applications and operational impacts
- This presentation does not address:
 - Underlying physics of operation
 - Methods of manufacture
 - Controlled technical data Identify potential and implement major product design changes due to certification requirements before producing production quantity tubes



Agenda

1. The protection gap
2. Fast-front physics
3. Transformer vulnerability
4. UFSA concept
5. Test evidence
6. Utility integration
7. Summary



The Utility Protection Gap

Utilities face a protection gap: nanosecond transients from

- VCB (Vacuum Circuit Breaker) reignition
- HEMP (High Altitude Electromagnetic Pulse)
- IEMI (Intentional Electromagnetic Interference)
- E1 from HEMP or IEMI pulses will reach transformers before lightning arresters devices react.
- Ultra Fast Surge Arresters (UFSA) supply immediate nanosecond clamping, improving transformer protection, reducing insulation stress, and supporting resilient, reliable operation across modern microgrids and distribution systems.

Why Lightning Arresters Miss Fast Fronts

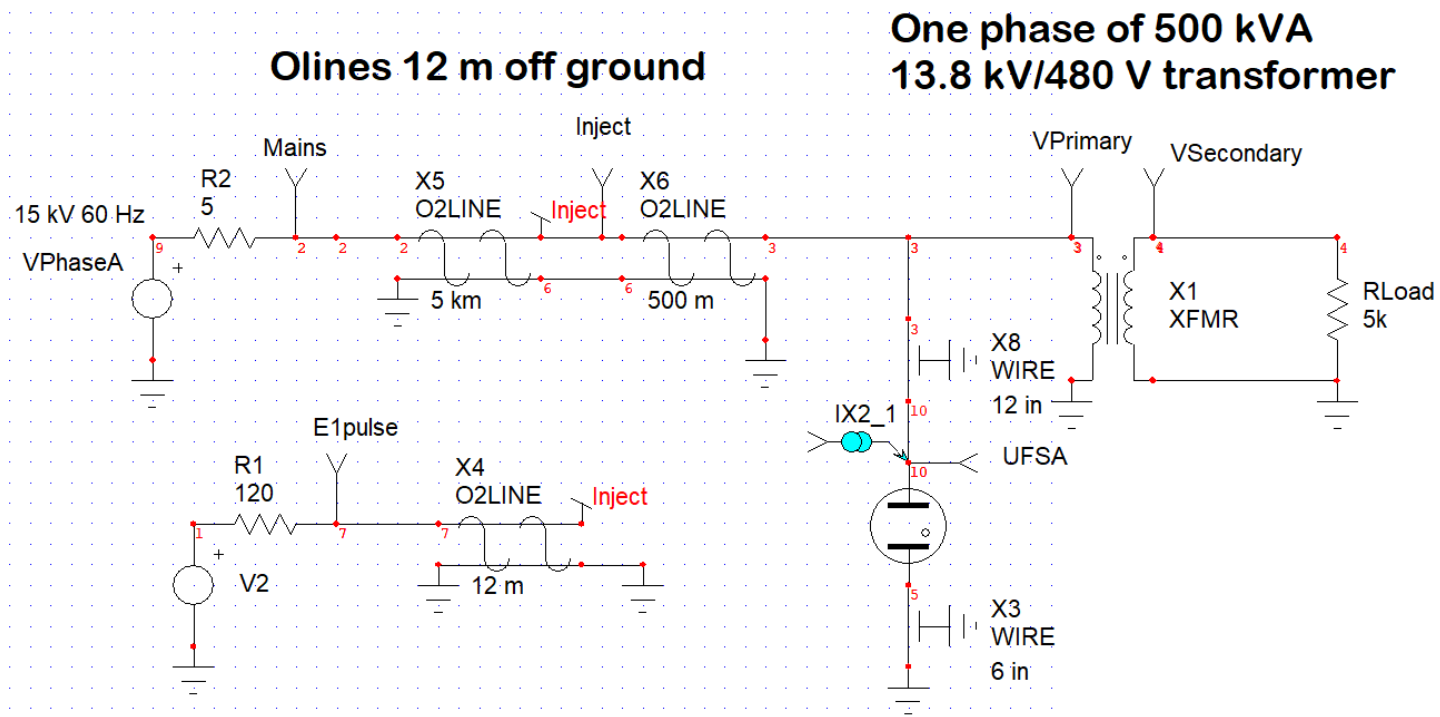
- MOV turn-on delay
 - MOVs respond on the microsecond scale, not the nanosecond scale
 - Fast-front surges outrun the conduction mechanism, allowing the initial spike to pass before the MOV fully conducts
- Inductive behavior
 - Lead and internal inductance slow the arrester's response to fast-front surges
 - Even small inductances create significant voltage overshoot during nanosecond events
- No E1 fast-front test data in LSA datasheets
 - Standard arrester tests use microsecond-scale impulses, not nanosecond events
 - FOW ratings describe a measurement point on a slow impulse, not true fast-front performance

Modeling Assumptions (Representative Local Transient Scenario)

- **Fast-front transients couple locally, so the last meter of cable dominates the overshoot**
- **The cable is treated as a short line segment with realistic surge impedance**
- **The transformer is modeled with a simple turns ratio for this comparison**
- **A full high-frequency transformer model (including winding capacitance and leakage inductance) would show even higher fast-front stresses**
- **The objective is to compare with vs. without UFSA, not to predict exact failure probability**

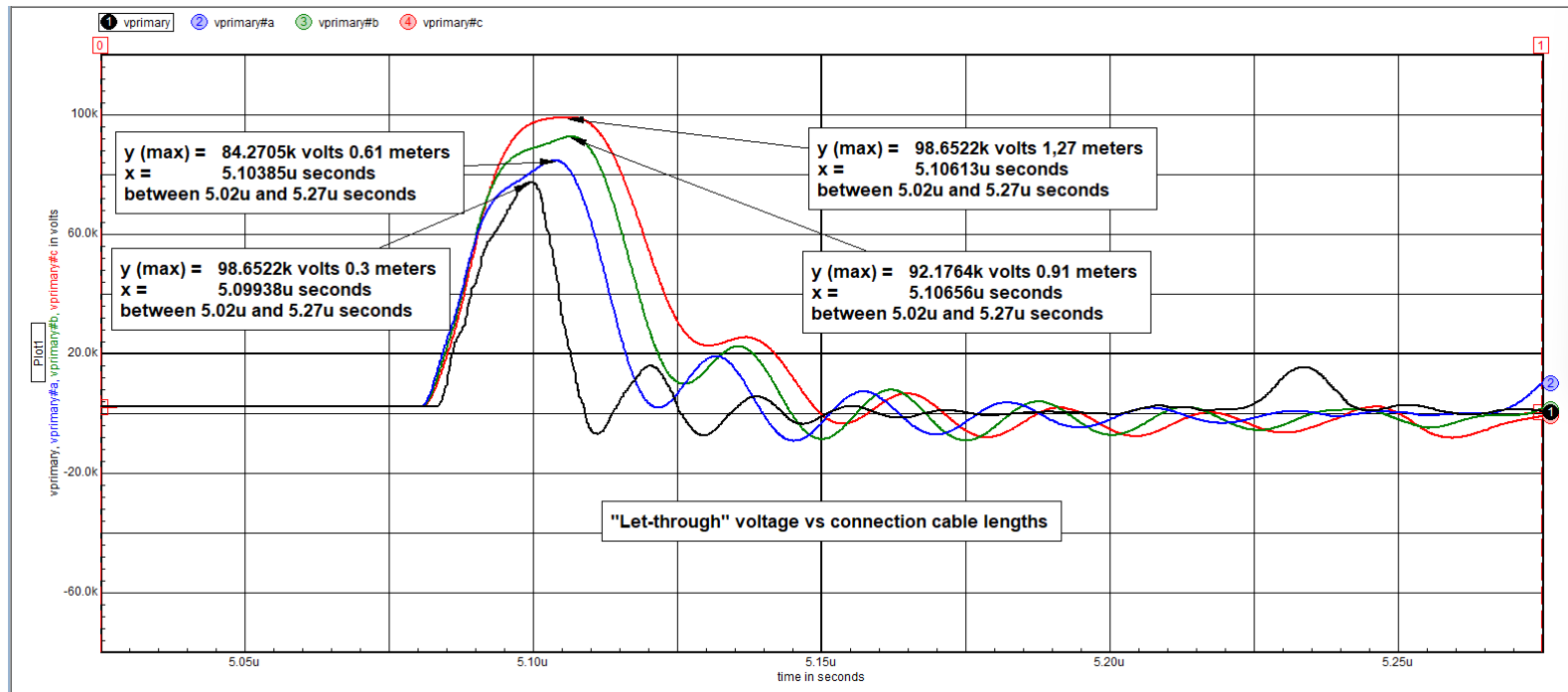
Transformer Vulnerability

Spice model



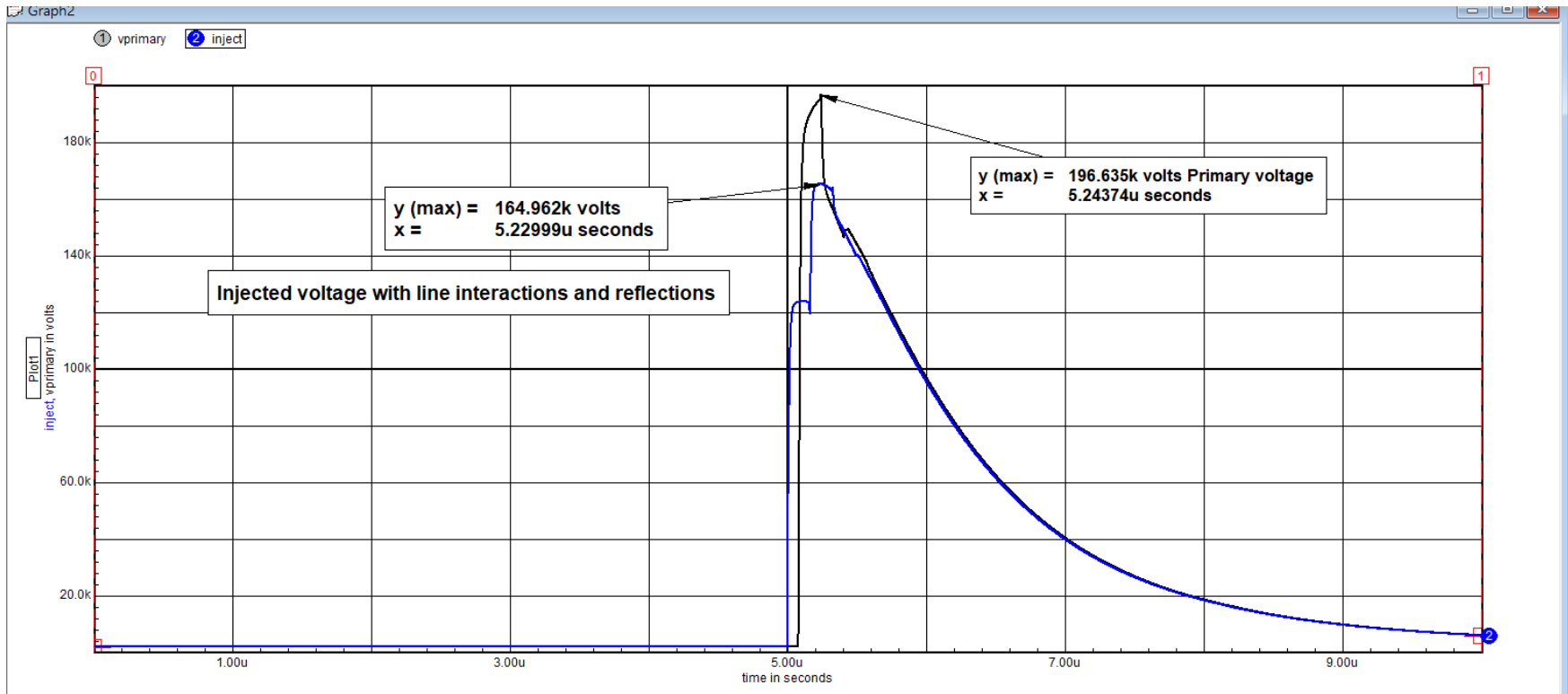
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Simulation with UFSA and Cable Length Sensitivity



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Simulation: Without UFSA



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Simulation results:

Cable length (m)	Peak Voltage	Time to peak (nS)	Rating	BIL	% Margin (protection)	% Margin w/o protection
0.3	76.9	19.13	15	110	0.89682	1.78764
0.61	84.27	22.93	18	110	0.89682	1.78764
0.91	92.17	25.68	36	200	0.49325	0.98320
1.27	98.65	25.69	72	350	0.28186	0.56183
	196.64	140.74				

System Voltage Rating (KV)	Basic Impulse Level (KV)
2.5	60
5.0	75
8.0	95
15.0	110
25.0	150
35.0	200
69.0	350
138.0	650



UFSA Concept

- Advanced Fusion Systems' Ultra-Fast Surge Arrester (UFSA) EMProve® - E1 is a Medium Voltage grid protection device designed to shunt the induced current to ground that is generated from the voltage transient from an E1 HEMP or IEMI event.
 - High voltage transients from EMP signals between 150 and 350 kV on top of the 60 Hz mains will exceed the BIL voltage ratings of systems below 72 kV rating which causes stresses in the system leading to degradation and failure.
 - With the UFSA installed the residual voltage at the asset will limit the stress below damaging levels
- Nanosecond response
- Installation is similar to LSAs and Complements LSA operation.



National Lab and Third-Party Testing

- E1 testing into single phase pole transformer at Boeing Little Mountain facility to Mil-188-125 Appx B
- Lightning testing at NTS
- Partial Discharge testing at Doble Engineering
- From INL/Sandia:
 - Do no harm - complete
 - Corner-case testing (abnormal induced faults) – complete
 - E1 injected into live grid – in process
- E1 pulser development – estimated by Q4
- UFSA is the only device undergoing full-scale E1 testing on a live grid.



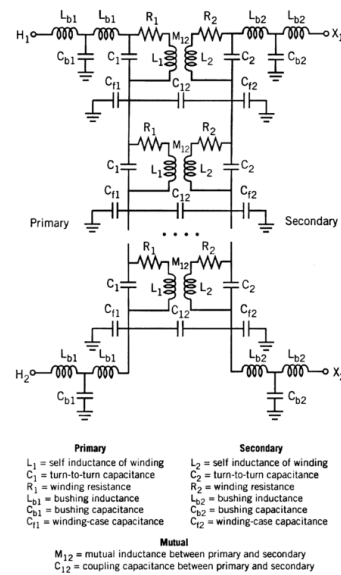
Summary

- Use your EMP deck summary:
- UFSA keeps transients below BIL
- Protects 72 kV and below
- Complements LSAs
- Available ratings 6 kV through 15 kV
 - 18 and 36 kV estimated Q3/Q4 2026

References and supporting data

- At high frequencies a transformer is more than turns ratios:

Figure 2. A High-frequency Transformer Model



At high-frequencies

- It is necessary to consider R, L and C parameters distributed throughout the transformer.
- This is similar to R' , L' , G' and C' of a transmission line
- This model - while accurate is not useful, since we do not know these parameters