

Performance of Lightning Arresters Considering the Frequency-Dependence of the Grounding System: A MoM-AOM Approach

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Outline

- **Introduction**
- **Frequency dependency of grounding systems**
- **Frequency domain treatment of lightning arrester**
- **Definition and solution of a simple case**
- **Conclusions**

Introduction

Lightning arresters;

- Are strong nonlinear loads and can be easily treated in time-domain.
- Are connected to a grounding system to carry the lightning impulse currents towards the earth.

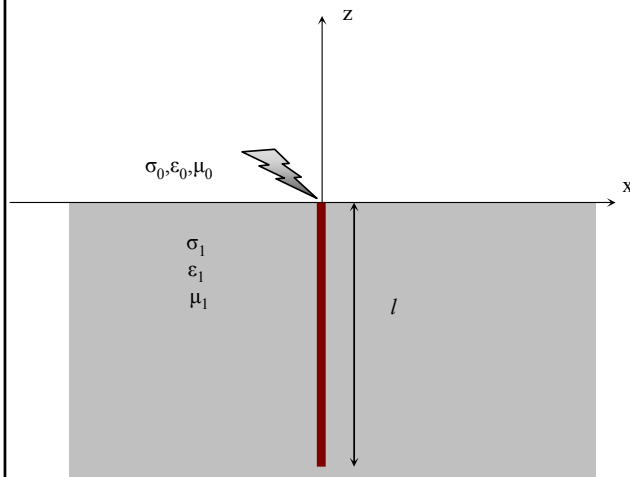


Introduction

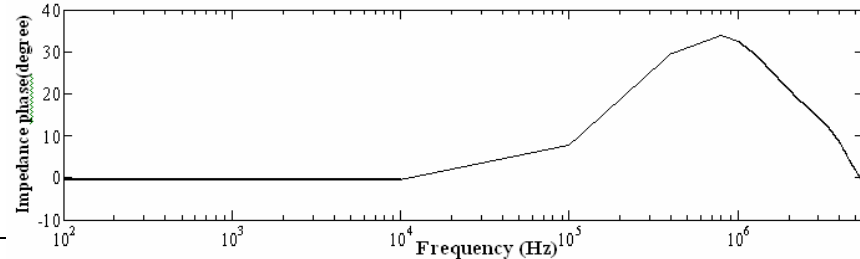
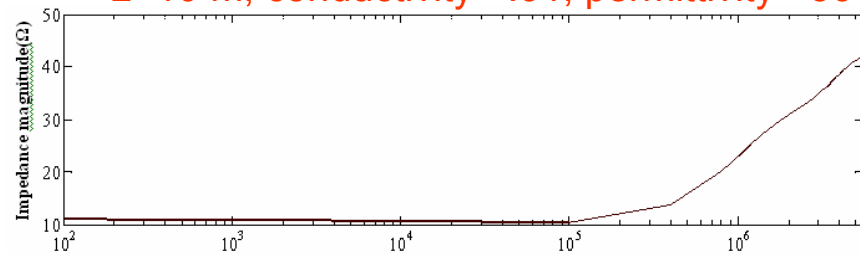
- **The associated grounding system plays an important role in the protection performance of the lightning arrester.**
- **Better understanding of the transient performance of the grounding system is achieved in the frequency domain, that enables one;**
 - To consider the effect of multilayer soil.
 - To consider the effect of soil conductivity.
 - To consider the frequency dependence of the grounding system.

Frequency dependency of grounding systems

- The grounding system has a frequency dependent behavior which is of great importance for transient analysis.



$L=10$ m, conductivity= .01, permittivity= 36



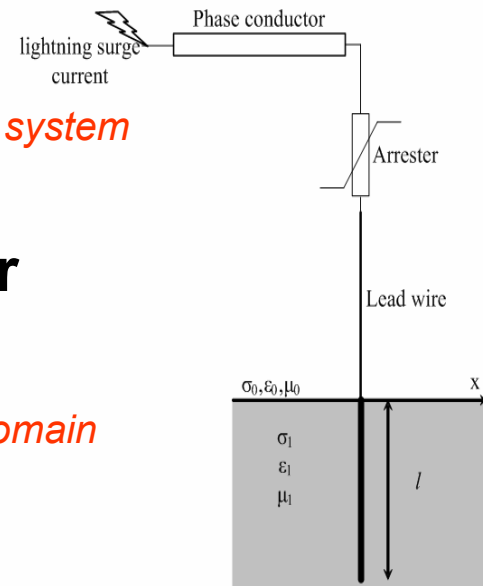
Solution approach

- We take the advantage of the MoM solution of the electrical field integral equations (EFIE) to,

Obtain the input impedance of the grounding system

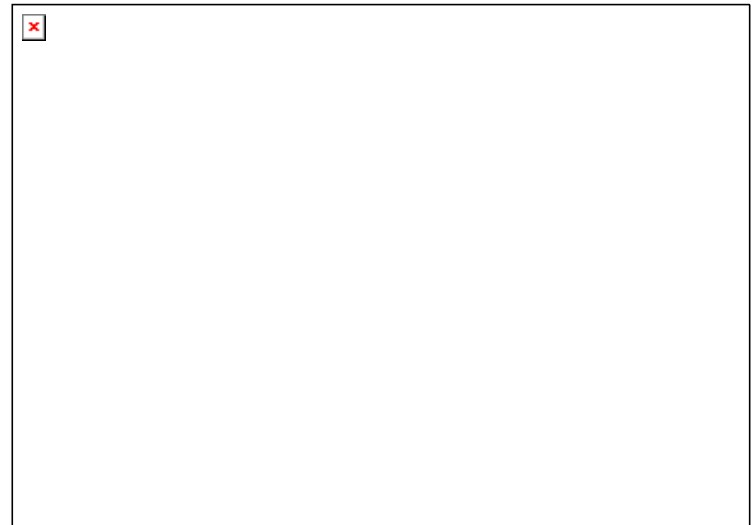
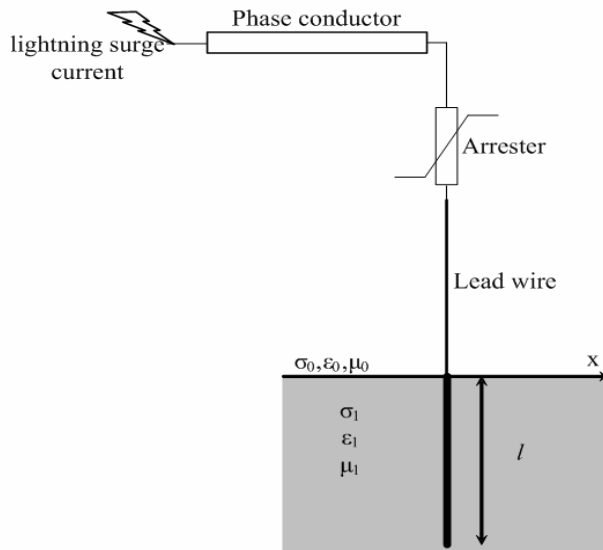
- We use Arithmetic Operator Method (AOM) to,

treat the arrester nonlinearity in frequency domain



Solution approach

- An equivalent nonlinear circuit is extracted for the problem and treated by use of AOM.



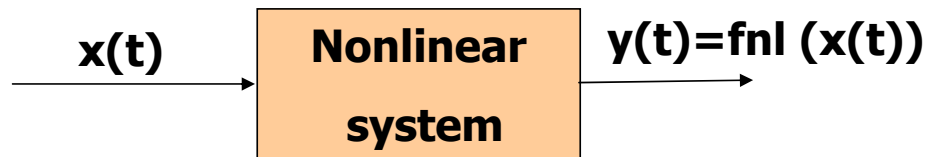
Arithmetic Operator Method

$$[x(t)]^n \stackrel{F}{\Rightarrow} \underbrace{X(f) * X(f) * \dots * X(f)}_{n \text{ times}}.$$

$X(f)$ can be represented in a discrete vector form

The convolution operation can be recast in matrix form.

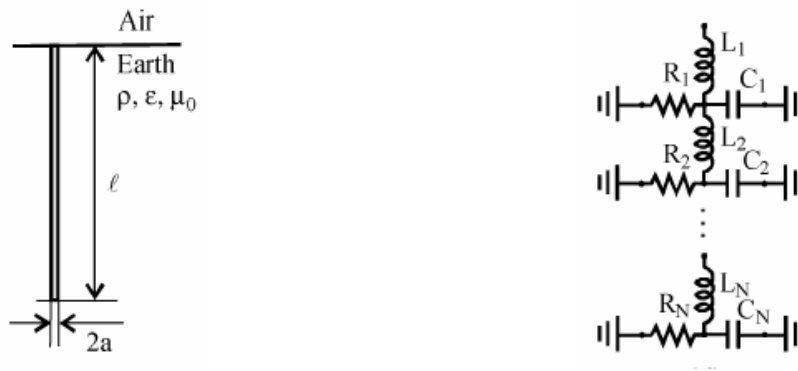
Example,



$$y(t) = [x(t)]^2 \longrightarrow Y(f) = X(f) * X(f) \equiv Y = T_x X$$

Verification

- The high frequency equivalent circuit is used to model the grounding system in EMTP.RV



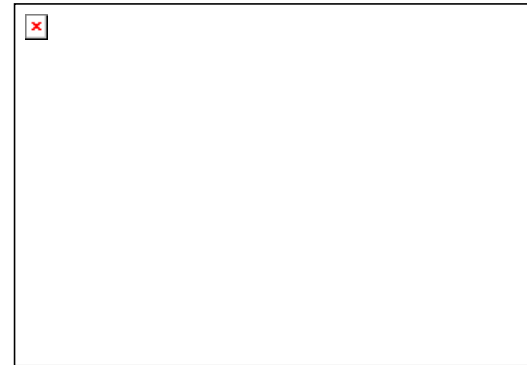
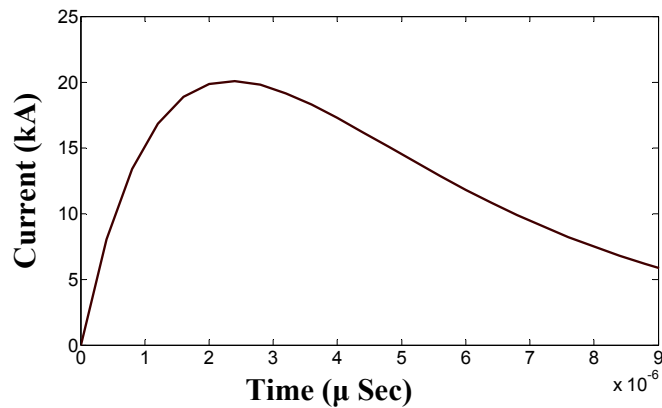
High-frequency distributed parameters circuit.

Example

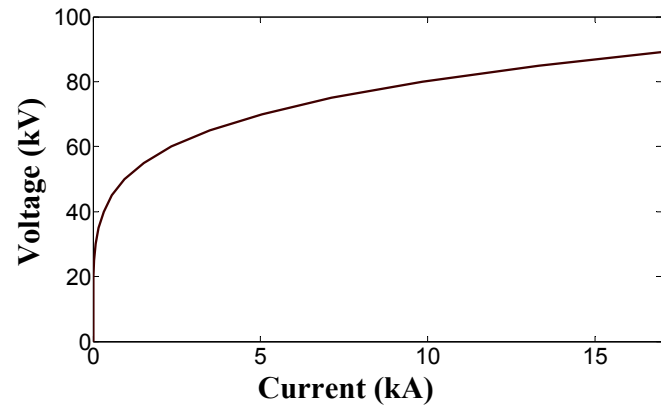
Grounding system Parameters:

$L=24$ m, resistivity=100 and permittivity= 36.

Lightning current

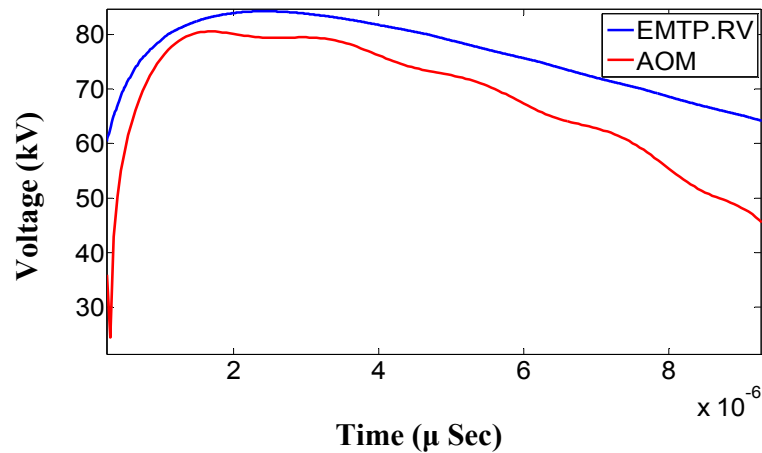


Arrester characteristics

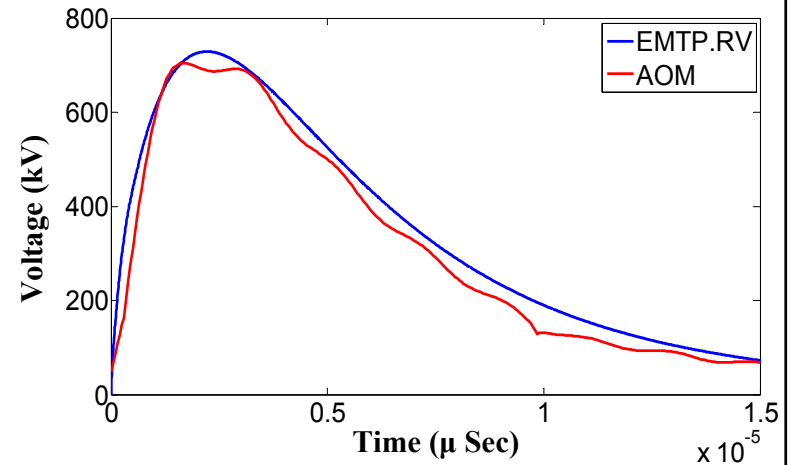


Results

Arrester residual voltage



System over-voltage



Conclusion

- **Arrester nonlinear characteristics is treated in frequency-domain.**
- **As opposed to the time-domain methods, frequency dependency of grounding system is well included in the analysis.**

Thanks