Accurate Electromagnetic Transient Modelling of Sector-shaped Cables

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Main Objectives:

- **To calculate frequency dependant parameters of sector-shaped cables using sub-conductor method**
- **To implement the effects of ground on the cable system**
- **To carry out a complete Electro-Magnetic Transient (EMT) simulation for a sector-shaped cable example**

Sector-shaped cable

Sector-shaped cable cross section

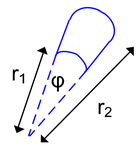
- **Widely used at medium & low Voltages**
- **Smaller cable diameter for the same conductor cross-section**

However,

- **EMT modelling is a challenge due to its shape**

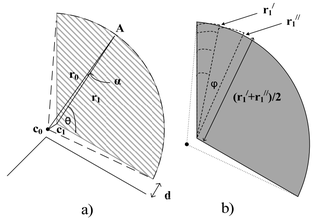
Subdivision Technique

- **Sub-conductor technique**
  - **Each conductor is approximated to be a collection of no. of smaller sub-conductors**
  - **Uniform current density is assumed inside a sub-conductor**
  - **Current flow in the filament is assumed to be longitudinal**
- **Elemental sub-conductor technique**
  - **Directly used only for circular cables**
  - **Has more accuracy than square & circular sub-conductor methods**



Elemental Shape

Subdivision of the Cable



a) b)

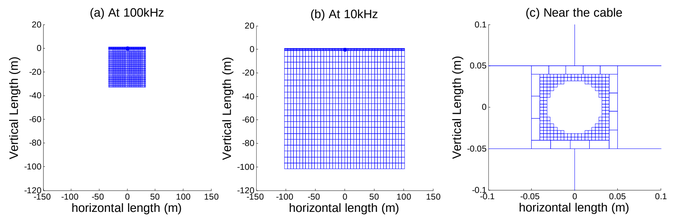
$$r_1 = \begin{cases} \dfrac{r_0}{\sin(120^0+\theta)}\sin(60^0-\theta-\alpha), & for\ \theta \neq 60^0 \\ r_0 - \dfrac{d}{2}\cos(30^0), & for\ \theta = 60^0 \end{cases} \qquad where,\ \alpha = \sin^{-1}\left[\dfrac{\frac{d}{2}\cos(30^0)}{r_0}\sin(120^0+\theta)\right]$$

Impedance Calculation

- **Initially, a fictitious return conductor is assumed**
- **Resistances and Inductances (R and L) for each sub-conductor is calculated using existing formulae**
- **Resulting large impedance matrix is reduced only to contain original conductor information**

Inclusion of Earth Return

- **Subdivision of ground**
  - **Similar to conductor subdivision, but using square sub-conductors**
  - **Skin depth vary from 5m to 5000m at 1Hz-1MHz range (for ρ=100 Ωm)**
  - **Subdivision was done depending on the skin depth at each frequency**

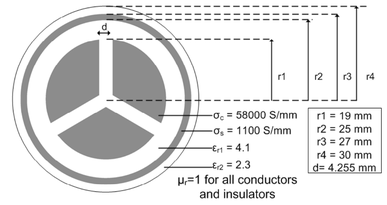


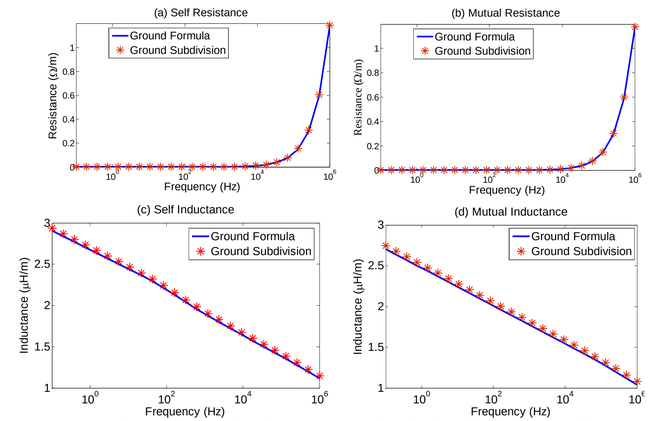
Ground subdivision

- **Using approximate ground formulae**
  - **Impedance matrix should be modified to include earth return impedance and impedance of the insulation.**

Results of a Case Study

Sector-shaped Cable Example

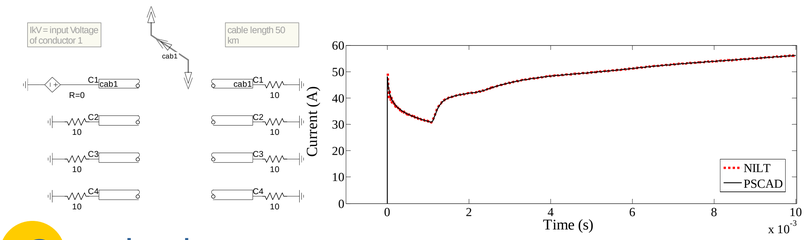




Resistance and Inductance calculation (with ground)

Time Domain Analysis

- **Admittance and propagation characteristics are fitted with rational functions in an EMT-type software (ULM in PSCAD/EMTDC)**



Conclusions

- **An approach based on sub-conductor technique is proposed to calculate resistances and inductances of sector-shaped cables.**
- **Time domain simulation is carried out and the results are validated using a numerical inverse Laplace approach.**
- **This method can be extended to model other cables with non-circular cross-sections.**