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Eletropaulo

On the Analysis and Evaluation of a Transmission Line Upgrading Assisted by Line Arresters

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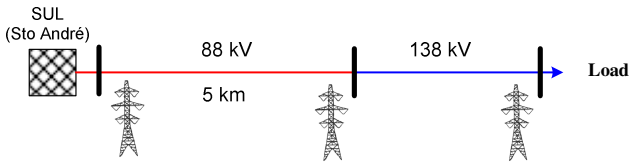
Introduction

- Constant increase of demand in existing networks claim for either:
  - construction of new TLs (often unfeasible)
  - upgrade existing ones (attractive alternative)
- It is the case of a TL located in SE region of Brazil.
- Currently, TL operating at 88 kV → soon upgraded to 138 kV.
- Past reports also state that this TL showed ↑ rate of transient "disconnections" caused presumably by lightning.



- So, main scope: analyse upgrading method of TL, select appropriate TLA + find right location to install first units.

Introduction

Amongst methods of line upgrade using existing structures:

i. Reconductoring
ii. Addition of conductors (bundled configuration)
iii. Cross-arm substitution by bigger ones
iv. Retension of existing conductors → higher temperature operation
v. Increase line voltage using existing conductors

Main reasons for choosing (i) and (iv):

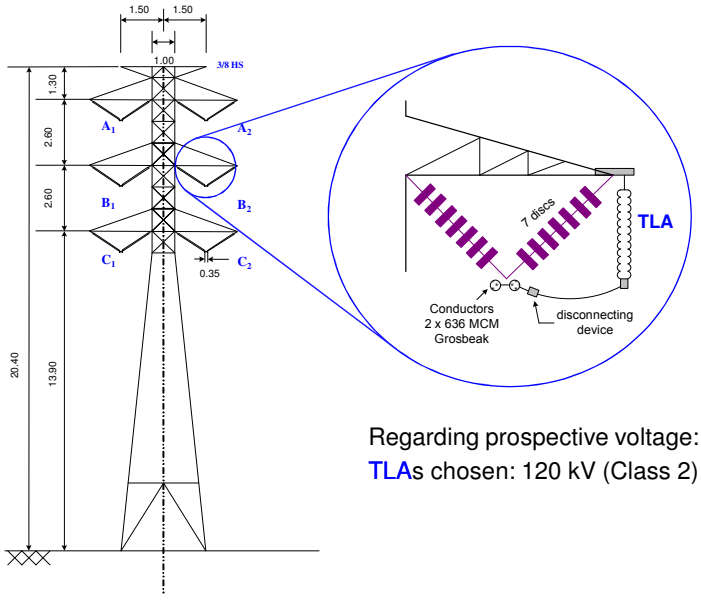
- Width of R-O-W can NOT be expanded a single inch (urban area).
- Loads (industrial area) can ONLY be interrupted short period of time (weekend, holiday).
- Decided to maintain number of insulators in string (7).
- 88 kV segment reconductored. Used same type of conductor, though new one → thermo-resistant (conveys ⇧ power).

Introduction

Other aspects to be checked up:

- **Line-to-line + line-to-ground clearances, insulator swing.**
- **Risk of disconnections + operative voltage analysis.**
- **Check out if under 88 kV, number of outages still occur after installing TLAs (their efficiency).**
- **Aside of protecting against lightning surges, TLAs should also support line's BSL.**

SV Type Tower Used



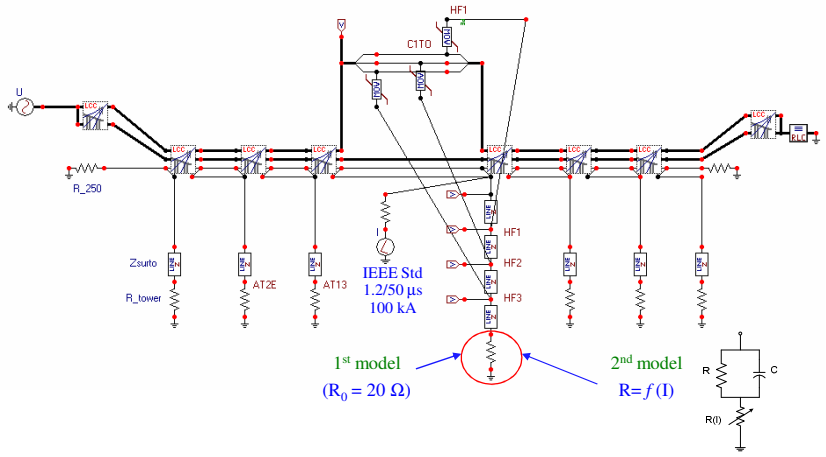
Regarding prospective voltage:
TLAs chosen: 120 kV (Class 2)

Elementary System Used (1)

Incidence of Lightning

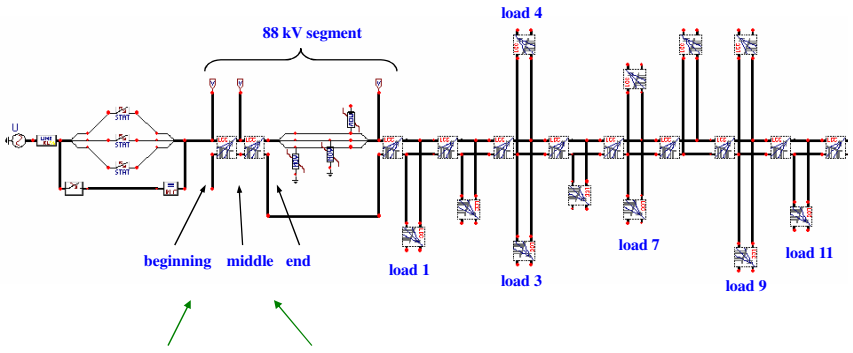
Tower Foot Model (2 cases):

1. **TFR = 20 Ω (equiv. linear resistance) → tests performed (worst case)**
2. **Using TFI (Model based on non-linear resistance & capacitor) lower voltage reflexions**



Elementary System Used (2)

Analysed also case of energization + high speed reclosing, responsible for overvoltages in line:

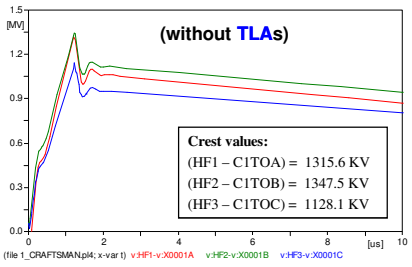


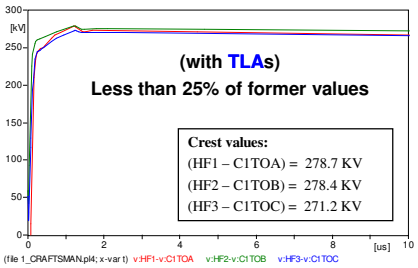
Mean overvoltage + Standard Deviation (σ) useful to analyse risk analysis.

some results …

Results

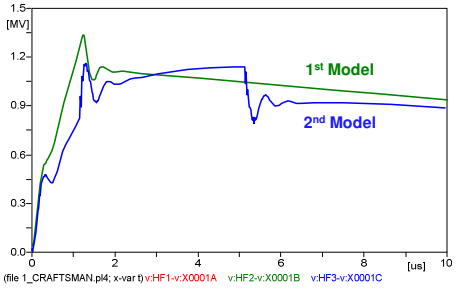
Ph-to-G voltages induced due to lightning

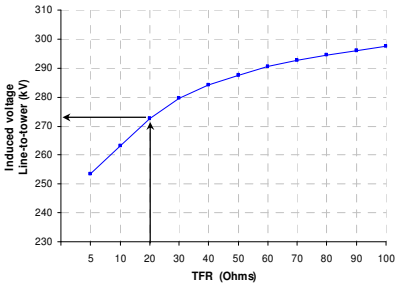




Results

Overvoltages induced with 2 Tower Foot Models





Variation of induced line-to-tower voltage with TFR (phase C)

Risk Analysis for Energisation & Reclosing

From σ and mean overvoltages obtained:

Risk of Fault (disconnection) Without TLAs

Voltage (kV)	Risk of Fault (pu)	
	Reclosing	Energization
138 (Case 1)	9.3 E-1	1.3 E-9

Risk of Fault Disconnection (Reclosing) With TLAs

Case	Voltage	Location of TLAs, Risk of Fault (pu)		
		Beginning	Middle	End
Case 1	138 kV	2.27 E-2	7.09 E-6	2.64 E-12
Case 2		5.45 E-3	5.03 E-6	6.68 E-12

- Risk of fault ⇩ if TLAs connected at end of segment (i.e. far from S/E).
- Minimum clearances (conductor-tower) ≈ 1.0 m. Thus, fault risk analysis used a switching withstanding of 475 kV.
- Shown that using TLAs amidst + end-of-line, fault risk improved !!. This is important → supports tower clearances issue.

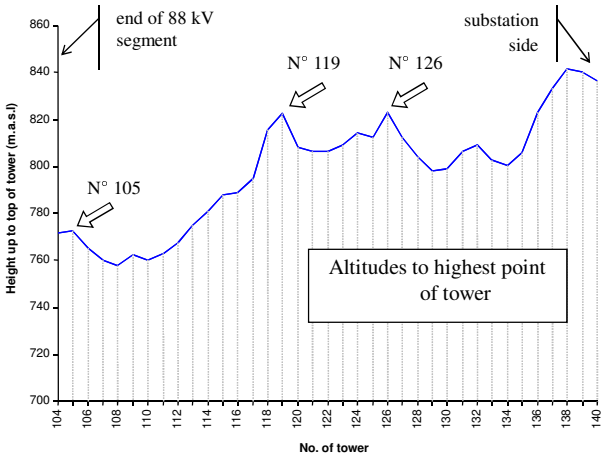
Key Aspects

Operative Voltage Analysis:

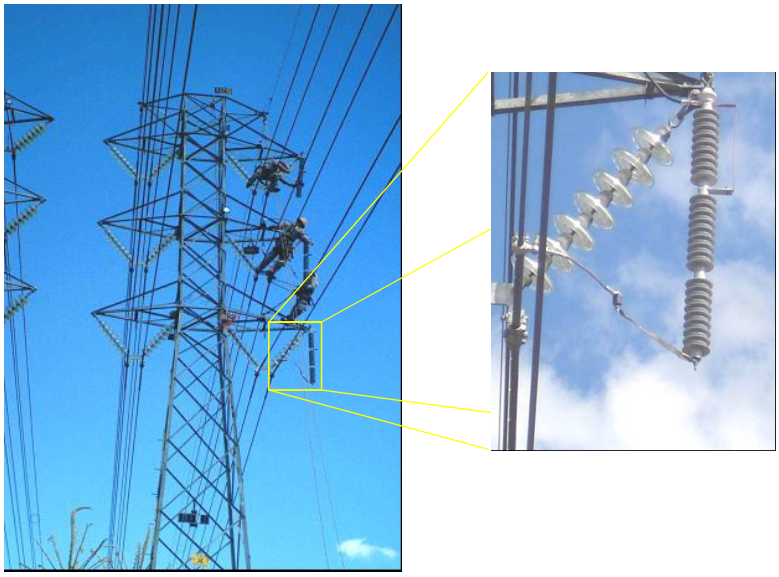
- Found out that with new 138 kV (7 insulators), creepage distance (pollution level withstanding) diminishes from 25 mm/kV (up to 1000 m of altitude) down to ≈ 19 mm/kV.
- This fact may jeopardize behaviour of operative voltage especially if region possesses high pollution levels.
- So, under new voltage, critical to keep all insulators clean + in good conditions.
- Analysis on energisation + fast reclosing enabled obtention of suitable places to install TLAs.

Towers selected for the Installation of TLAs

- Since incidence of lightning (direct strokes) more frequent in towers at hills, initial candidate towers located there.
- This should be corroborated with risk analysis performed.



Installation of TLAs



Conclusions

- Studied upgrading of TL → showed feasibility regarding limitations e.g. space of corridors + construction of new TLs.
- Observed that overvoltages stemming from lightning + switching effectively diminished by TLAs installed.
- With TLAs → line's operative voltage + insulation level kept within certain safe ranges.
- Combination of risk analysis + altimetry analysis defined suitable towers for installing TLAs.
- Meanwhile System Operator OKs switching to new voltage, TLAs operating at 88 kV (jumper "on" + equalizing ring removed).

Thank you !!