Design, Selection and Application of Transmission Line Arresters

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Gathering Data

- Tower information:
  - All dimensions incl. phase conductors plus location and length of insulators
  - Shield wire dimensions and position, if used
  - Tower footing impulse resistance
  - Location of mechanical dampers
  - Maximum phase conductor movements
  - CFO/BIL of line insulators
- System parameters:
  - Reclosing time
  - Short-circuit currents at point of installation
  - Targeted trippings per year for lightning protection
  - Decisive TOV requirements
  - Data for substation arresters
  - (Targeted maximum switching voltage along the line for switching protection)
- Environmental data:
  - Ground flash density and/or number of thunder days per year

Selection of NGLA for Different Applications

- Minimise tripping due to lightning.
  - Protection of shielded lines.
  - Protection of unshielded lines.

- Compact line with reduced withstand levels.
  - Building a new line.
  - Upgrading an existing line.

- Control switching overvoltages along the line.
  - Substitute for reclosing resistors (works well together with controlled switching).

- Extended station protection e. g. for GIS substations.

- Temporary NGLA for hot line work.

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System Aspects

- Total outage time of transmission lines are measured including both maintenance and line trippings.
- This gives certain requirements for LSA installations:
  - Have clear targets of allowed trippings per year.
  - Usage of disconnectors to facilitate fast reclosing.
  - Ensure that if arrester unit is overloaded the tower does not have a reduced insulation level in that tower.
  - Indication of an overloaded arrester

Source: National Grid

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Matching Disconnector Operation with Line Protection Scheme

- Which protection scheme is used?
  - How fast is it?
  - What is the short-circuit currents at the installation?

- Electrical characteristics.
  - When the disconnector shall operate.
  - When the disconnector shall not operate.

Source: Lightning on transmission lines - IEEE Acapulco 2004

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Important Disconnector Characteristics.

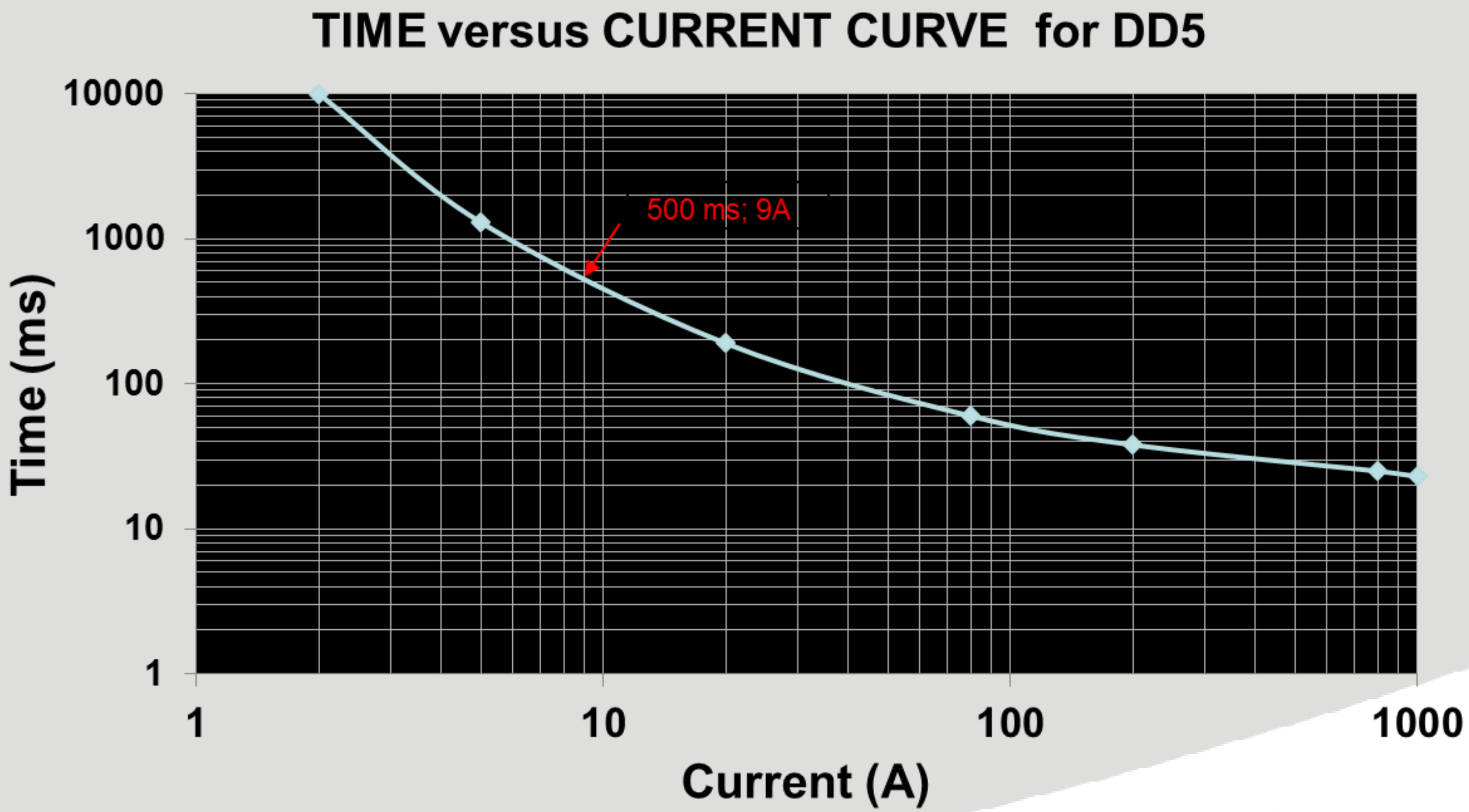
- The disconnector shall always continue its opening operation once it is triggered to operate even if the system voltage trips.

- A disconnector typically reacts on heating from power frequency currents. It cannot distinguish between TOV currents that the arrester withstands or real short-circuit currents.
  - It is thus important to always select a high enough rated voltage so that the NGLA do not see TOV stresses that can interfere with its disconnector operation.

Matching Disconnector and NGLA Characteristics

Typical disconnector curve showing opening time versus current

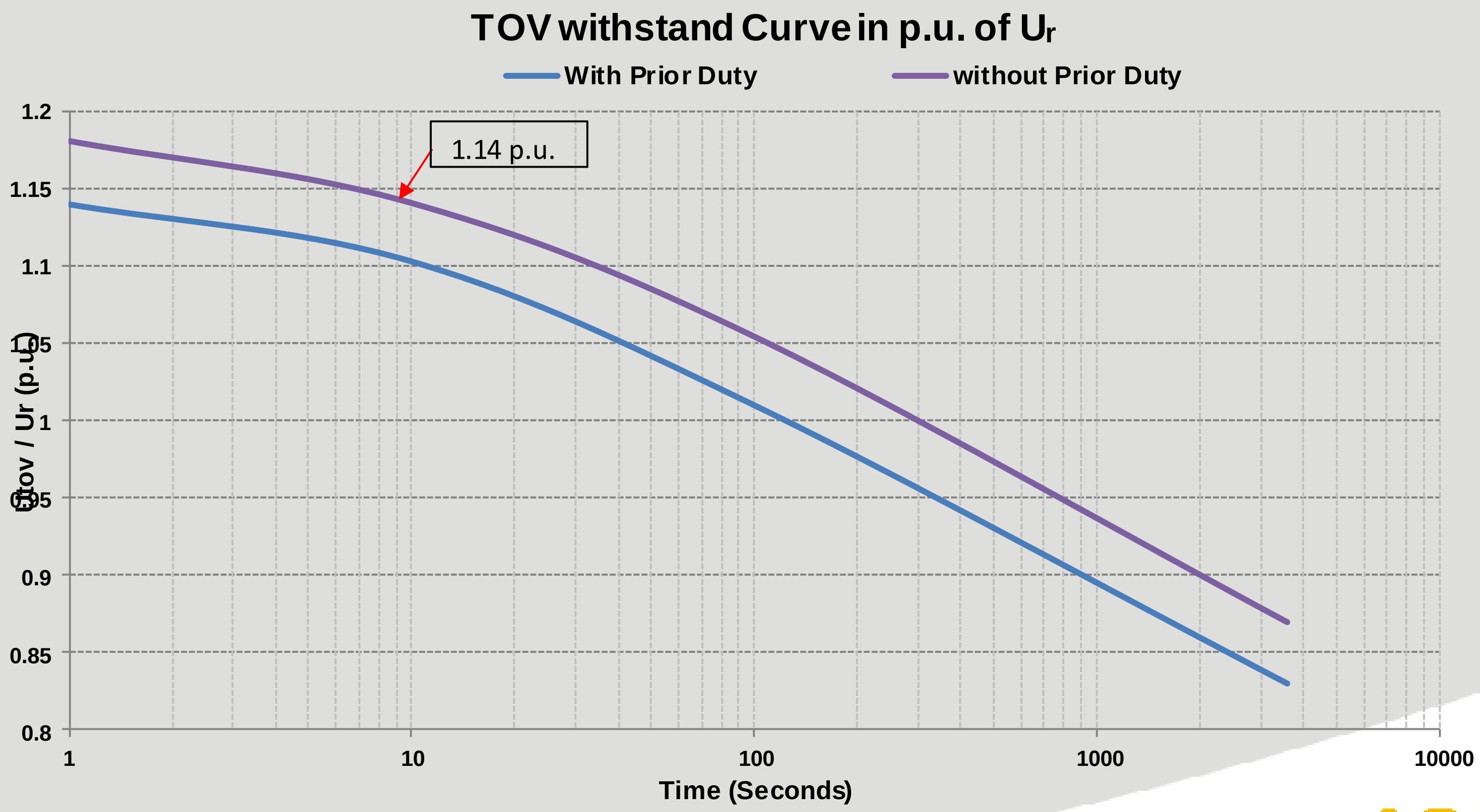
- Reclosing time 500ms
- Decisive TOV 150kV during 1s. Substation arresters 132kV



Matching Disconnector and NGLA Characteristics.

Typical arrester TOV withstand curve showing voltage versus time of U_r

- ➢ Reclosing time 500ms
- ➢ Decisive TOV 150kV during 1s. Substation arresters 132kV



Selection of Rated Voltage for NGLA

- Reclosing time 500ms
- Decisive TOV 150kV during 1s. Substation arresters 132kV

TOV currents in A							
NGLA / Disconnector	TIME/ Voltage p.u.	Voltage kV or p.u.	1 s (A)	Voltage kV or p.u.	10 s (A)	Voltage kV or p.u.	40 s (A)
NGLA	prior energy	1.14	8	1.11	6	1.05	0.4
	no energy	1.175	15	1.14	12	1.09	1.6
Ur = 132	no energy	155	15	**150**	**12**	144	1.6
Ur = 138	no energy	162	15	157	12	**150**	**1.6**
SYSTEM TOV (kV)		150					
Disconnector current		9A					

- Typically a higher rated voltage than the substation arresters.
  - This also limits TOV stresses and possible reduction of grading ring.

Proper Disconnector Coordination if Overloaded LSA.

- **Disconnector operates before the line trips**. This depends how quick the disconnector operates plus how quickly it can quench the arc during falling out, which will be strongly weather dependent. This is then a race between the line protection scheme and the disconnector and may vary from incident to incident. No tripping occurs.

- **Disconnector operates before fast reclosing of the line.** This means that once triggered the disconnector shall continue to disconnect even if the power supply is switched off. This should be a repeatable operation depending on coordination of the line protection scheme including fast reclosing time and the disconnector opening time.

Faulty Disconnector Operation if Overloaded LSA

- **Disconnector has not completed its operation when reclosing occurs.** This should be avoided as this leads to a system disturbance and also leads to a second short-circuit stress on the NGLA which significantly increase the risk of complete disintegration of the arrester with larger pieces coming down.

- **Another scenario is that the disconnector operates but the arrester is not overloaded or failed**. This should not occur and indicates a disconnctor not matching the arrester characteristics

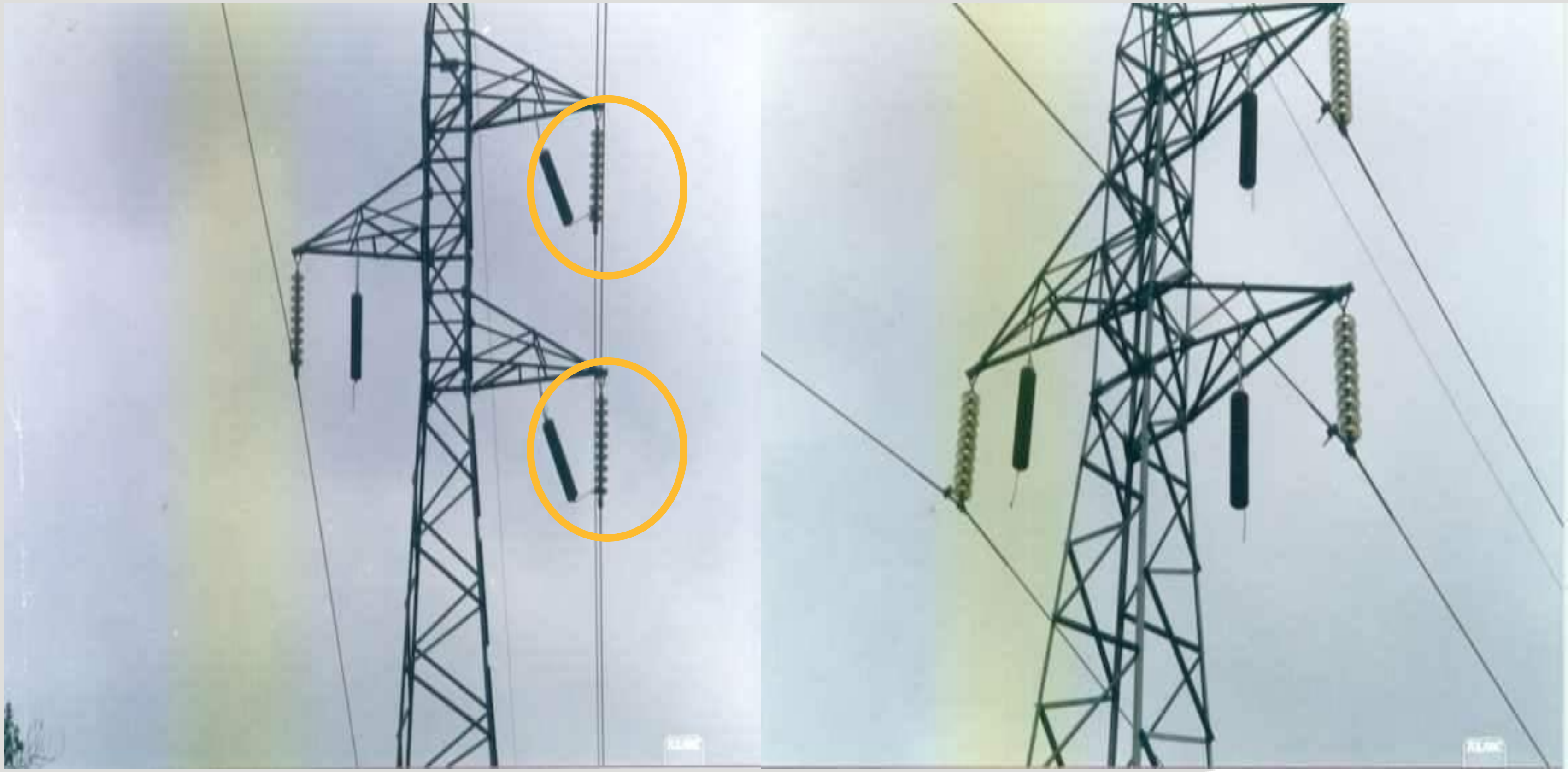
Mechanical Considerations for LSA

- Why is the vibration damper located where it is?
  - Aeolian vibration dampers are placed in specific locations to dissipate energy.
  - If a weight is placed beside them, they are no longer effective

Install another damper outside the arrester.

Mechanical Considerations for NGLA

- Allow enough free movement of disconnector cable.



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Selection of Number of NGLA per Tower & Number of Towers

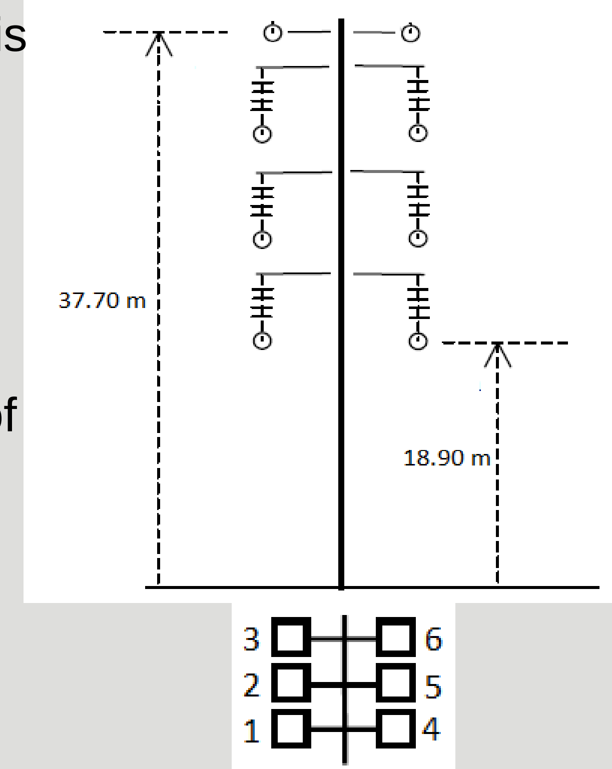
- Which outage rate is the target?
  - Are we to reduce or eliminate line trippings
    - Including shielding failures or not?
  - Typically not needed in all phases to get a significant reduction of trippings
  - Areas with high tower footing resistance are first targets.
  - NGLA in 2-4 towers with "normal" footing resistance on each side always need to be protected as the overvoltage will be "pushed" there.
- Double circuits where simultaneous tripping is not accepted.
  - All phases in one circuit will eliminate this and also reduce the number of trippings on the unprotected circuit.
  - Two NGLA in one circuit and one NGLA in the most exposed phase of the second circuit may give an even lower outage rate for the two circuits together and still get very close to zero risk for a double circuit tripping. (System studies will show which are the most exposed phases.)

Target Definition needed for Optimum Selection

245 kV Example

Case Study: Shielded 245 kV Double Circuit OHL

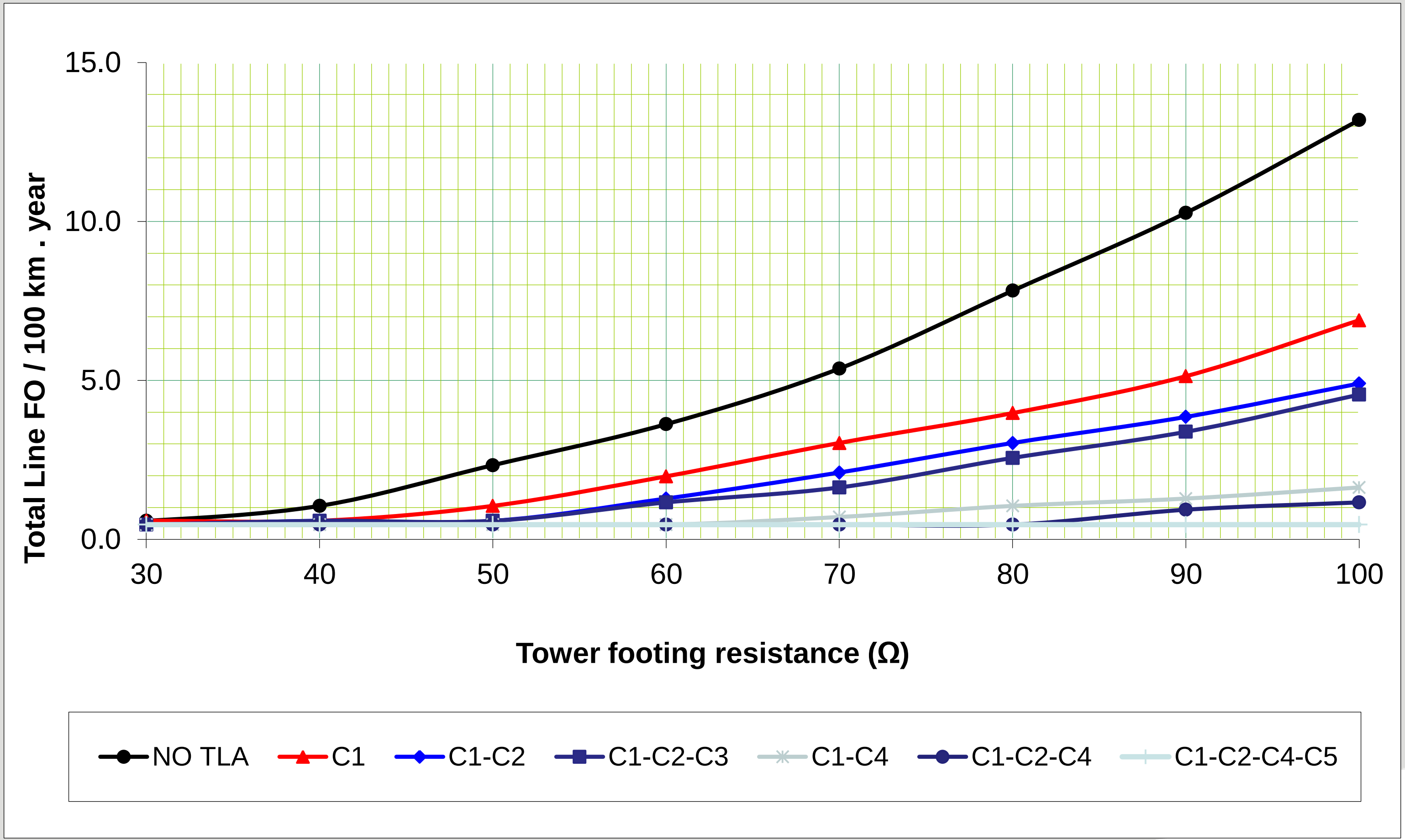
- Selected line parameters
  - The line insulation Critical Flashover Voltage is 1,040 kV.
  - The Ground Flash Density is 6.7 strokes per km² per year.
  - The evaluated section has an average soil resistivity of 1,500 Ω.m.
  - The evaluated section has an average span of 320 m.
  - Tower surge impedance is 198 Ω.
  - NGLA rated voltage is 198 kV.



- Three different targets possible
  1. Reduce the total number of trippings for the line to a target level.
  2. Reduce or eliminate double circuit tripping.
  3. Reduce number of shielding failures

Selection of Number of NGLA per Tower

Case 1: Reduce Total number of Trippings



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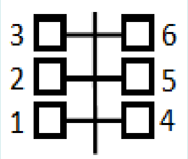
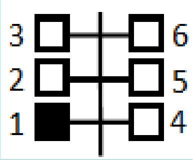
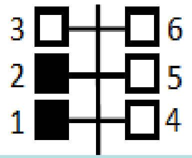
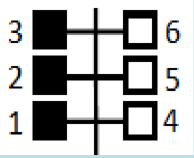
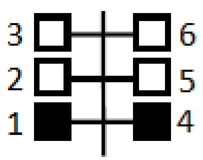
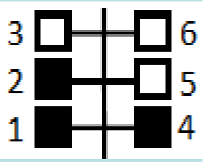
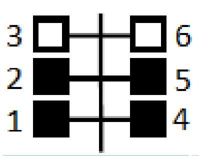
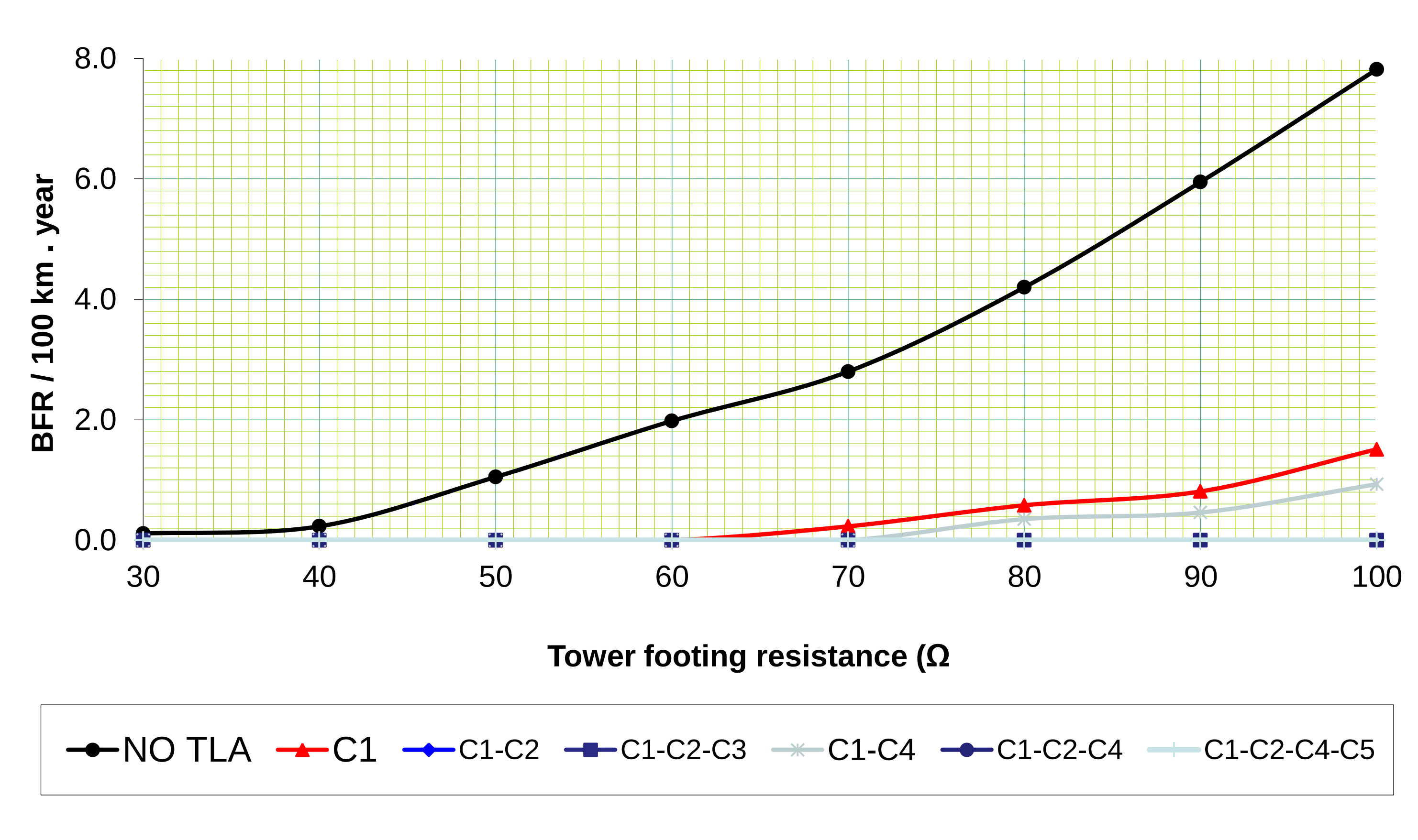
Selection of Number of NGLA per Tower

Case 1: Reduce Total number of Trippings

R(Ω)							
20	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
40	**0.58**	**0.11**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
60	**3.15**	**1.51**	**0.81**	**0.70**	**0.00**	**0.00**	**0.00**
80	**7.35**	**3.50**	**2.56**	**2.10**	**0.58**	**0.00**	**0.00**
100	**12.73**	**6.42**	**4.43**	**4.08**	**1.16**	**0.70**	**0.00**

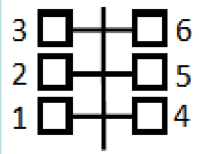
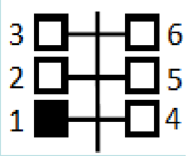
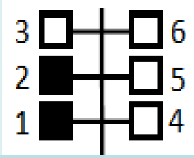
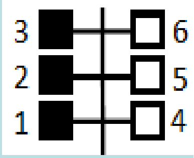
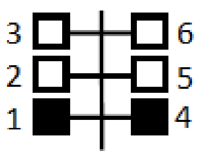
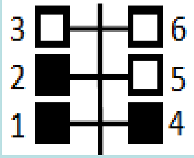
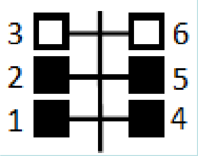
Selection of Number of NGLA per Tower

Case 2: Reduce Double Circuit Trippings



Selection of Number of NGLA per Tower

Case 2: Reduce Double Circuit Trippings

R(Ω)							
20	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
40	**0.23**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
60	**1.98**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
80	**4.20**	**0.58**	**0.00**	**0.00**	**0.35**	**0.00**	**0.00**
100	**7.82**	**1.51**	**0.00**	**0.00**	**0.93**	**0.00**	**0.00**

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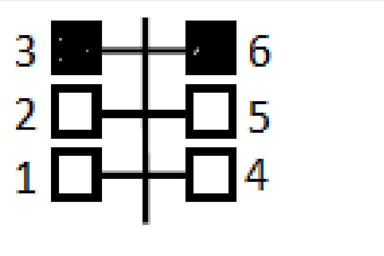
Selection of Number of NGLA per Tower

Case 3: Reduce Shielding Failures

- ➢ The highest risk for shielding failures is for the top phases.
  - – This is due to that with the phases in vertical configuration the top phases actually shields the lower phases from direct strikes.



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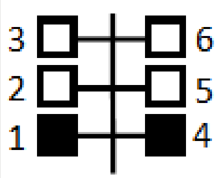
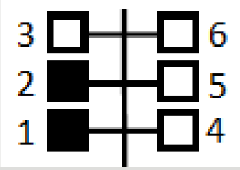
Different Targets – Different Solutions

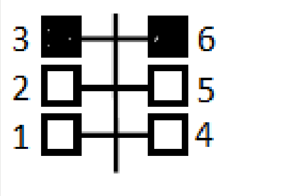
- ➢ If the target is to minimize the total number of flashovers select
- C1 & C4 solution for two arrester per tower.



- ➢ If the target is to minimize the number of double circuit tripping select
- C1 & C2 solution for two arrester per tower.



- ➢ If the target is to minimize the number of shielding failures select
- C3 & C6 solution for two arrester per tower.



Thanks for you time

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