Purpose

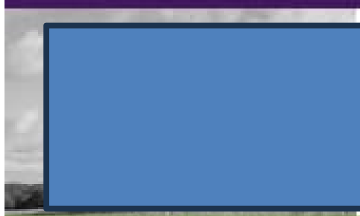
Accurate estimation of short circuit loads and methods of analysis to produce safe and economical structural designs for structures in substations

Current Approach

- Typically the design of gantries and bus supports in substations relies on the use of static load techniques, primarily including gravity, wind and conductor tensile loads.

- There is a significant load due to short circuit forces present under fault conditions and is **dynamic** in nature depending on response of the supporting structure in terms of stiffness.

- Currently this dynamic load is applied as a static load to the system and design is carried out by most utilities.



Types of Arrangements in Substations

- Flexible Conductor Arrangement

  Comprising of a flexible conductor arrangement connected with strain insulators to structures.

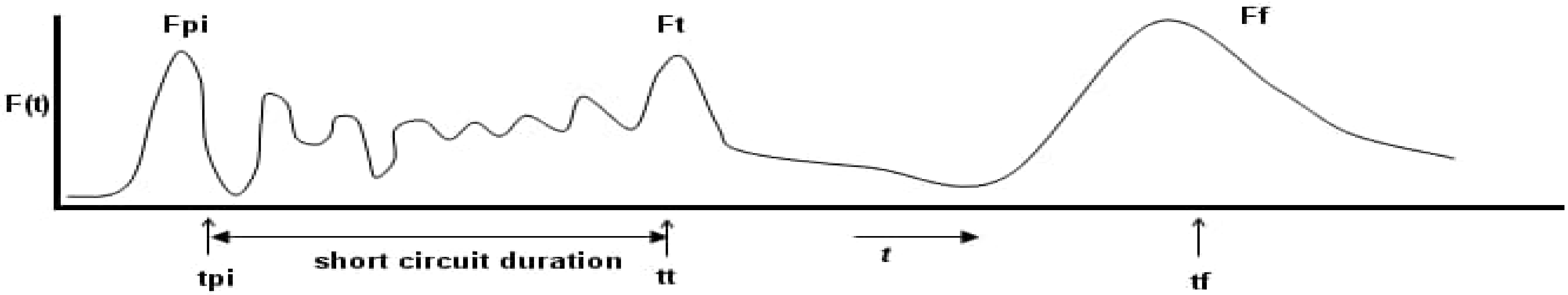
Ref [1] Western Power Northern Terminal 330kV Gantry

- Rigid Conductor Arrangement

  Conductor arrangement - tubular or rectangular profiles mounted on supporting structures mainly composed of insulators and steel structures

Short Circuit Tensile Forces

- Pinch force, F_{Pi}
  - In the case of bundled conductors, when the sub-conductors clash
- Short circuit force, F_T
  - During a short circuit current flow,
- Drop Force, F_f
  - After the end of a short circuit, conductor drops from its highest point



Short Circuit Duration

- Short Circuit Duration, Tk1 is based on the protection time which is generally **0.355secs** for a 132kV Substation and **0.310secs** for a 330kV Substation.

Test on Slack Cable Conductor by EDF

Cable:	2x570 mm^2
Distance between subconductors:	400 mm
Distance between supports:	9 m
Distance between spacers:	3 m
Initial sym. short-circuit current:	50 kA
Duration of short-circuit current:	245 ms

Test on Rigid Conductor by FGH Mannheim

Tube (E-AlMgSi 0.5 F22):	120mm/5mm
Distance between conductors:	1.0 m
Distance between supports:	11.5 m
Initial sym. short-circuit current:	39 kA
Peak short-circuit current:	103 kA
Duration of short-circuit current:	300 ms

Methods of Analysis

IEC 865 – 1, CIGRE Brochure 105

Simplified Method

Advanced Method

Simplified Method

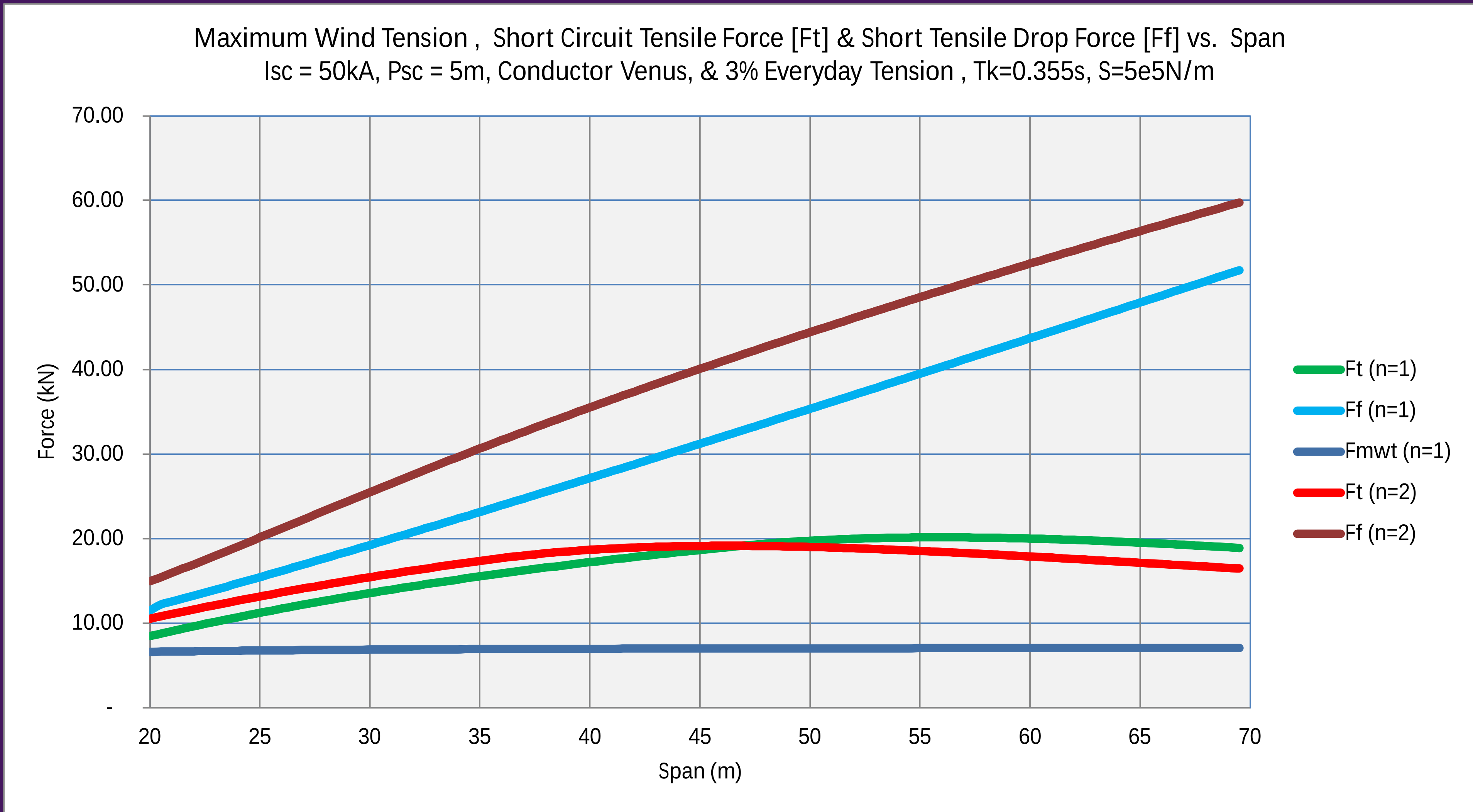
- No information about **time history** or evolution of the phenomena available.

- Requires,
  - *Span Length*
  - *Static Tension*
  - *Distance between phases*
  - *Structure Stiffness*
  - *Cable Data*
  - *Short Circuit Current & duration*

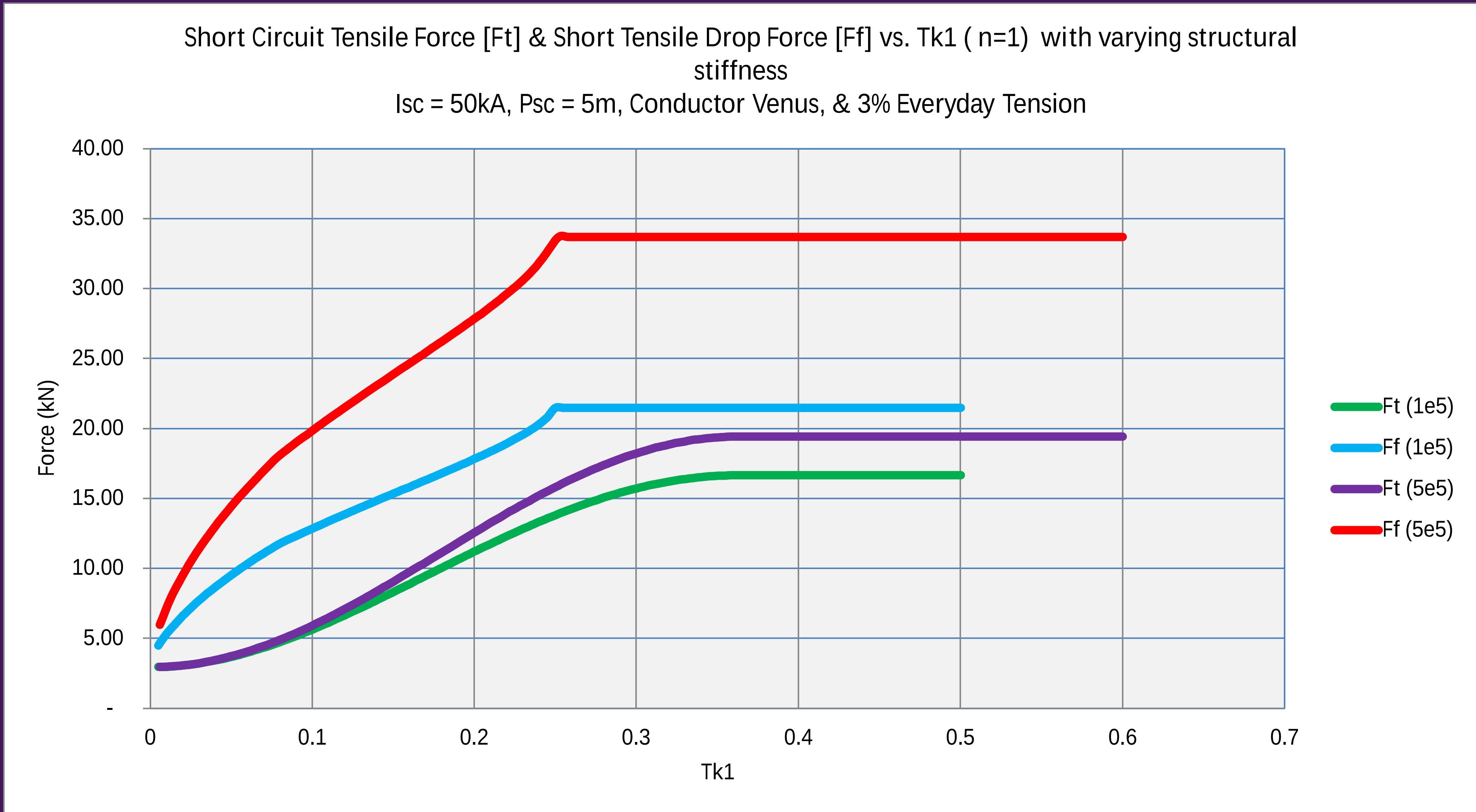
Simplified Method Parametric Studies

- Parametric studies were carried out to understand the mechanical effect of short circuit forces on landing spans.
- Case studies analyzed were as follows;
  - Conductor "Venus"
  - Stringing tension varied
  - Stiffness varied
  - Span varied
  - Tk1 varied

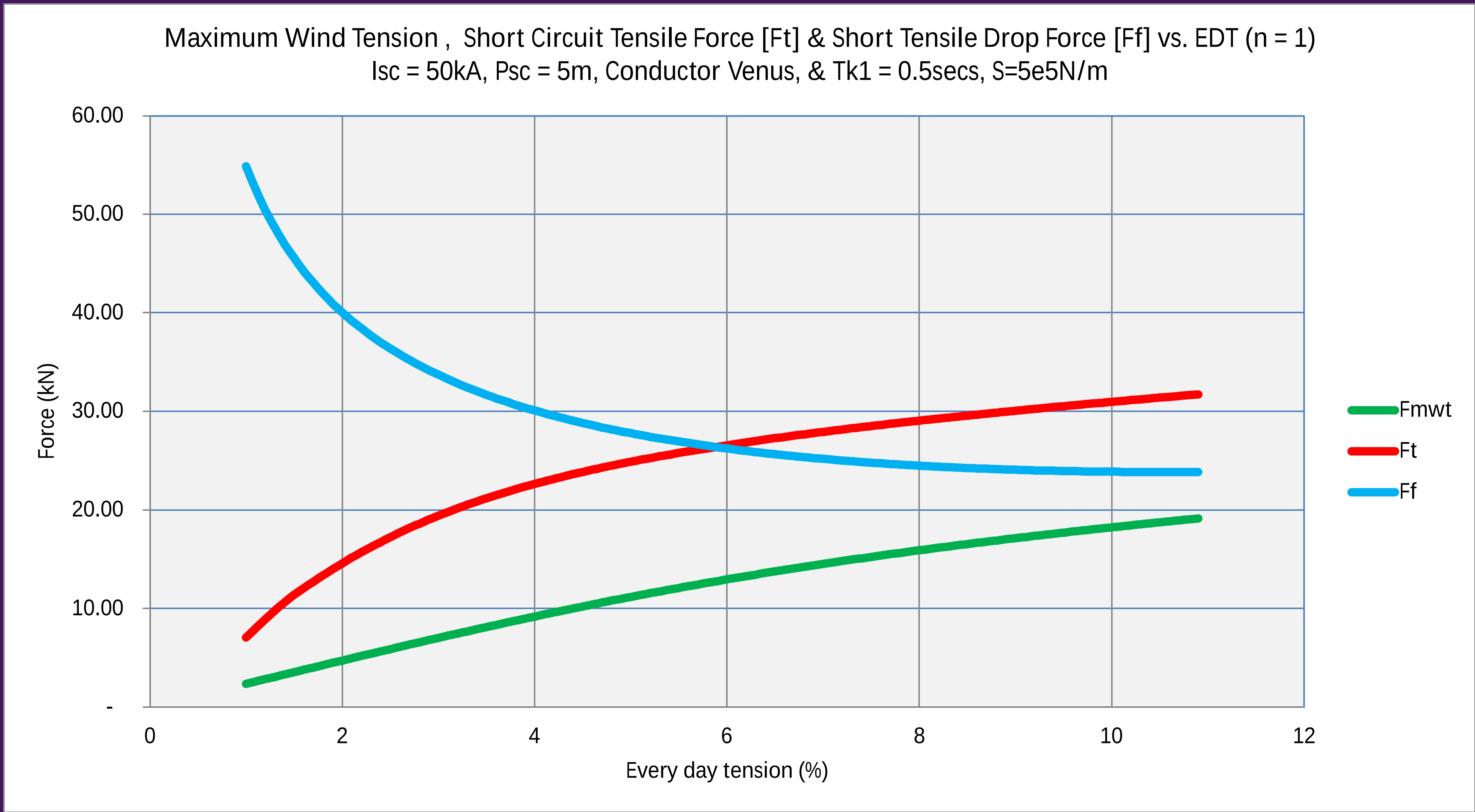
Parametric Studies - 1



Parametric Studies - 2



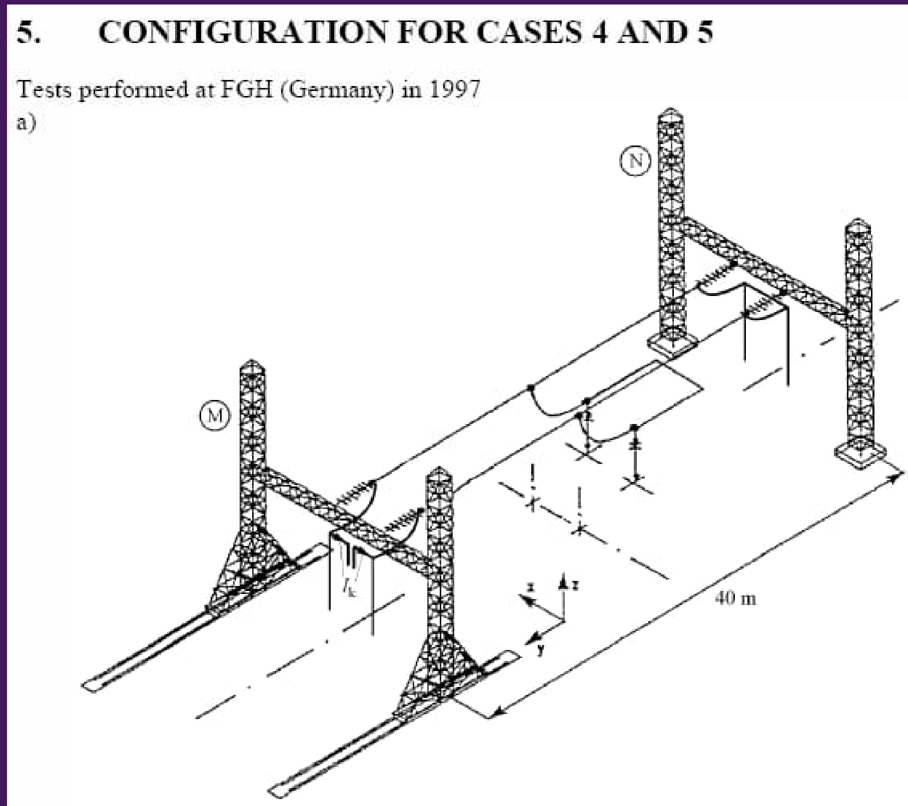
Parametric Studies - 3



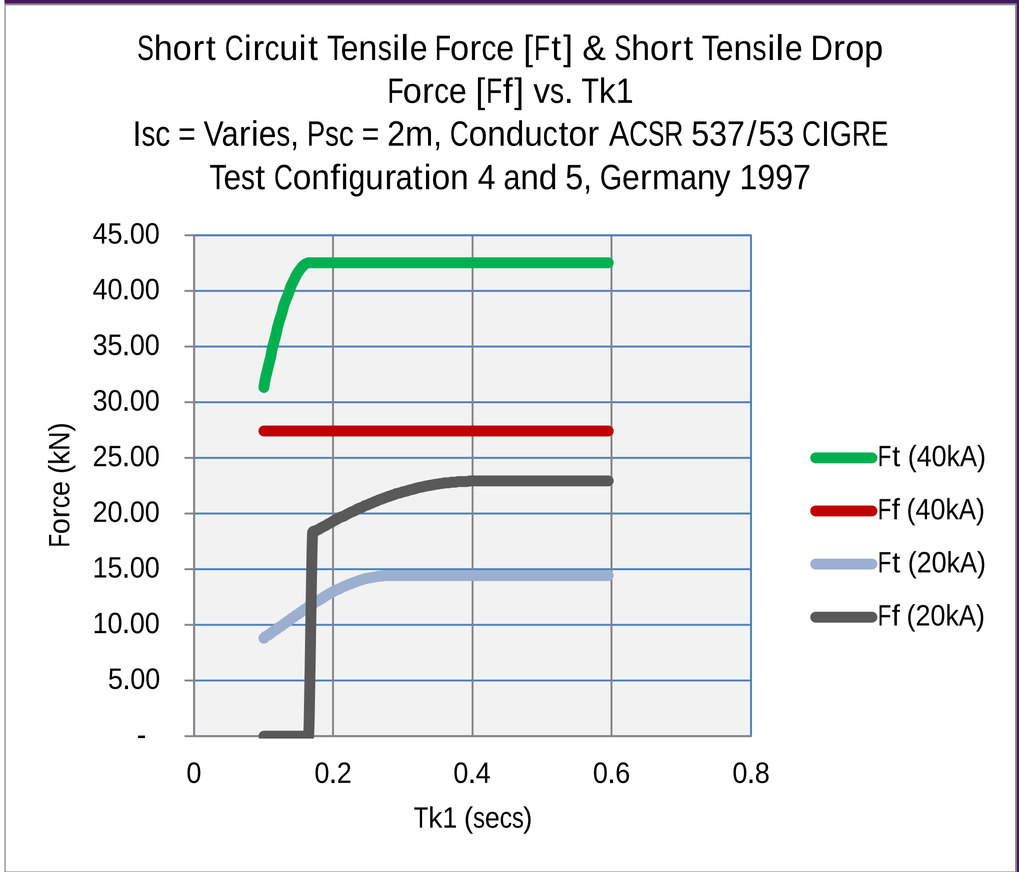
Dropper Effect

- To appreciate the effect of droppers note the test results from CIGRE test configurations 4 and 5, Germany 1997

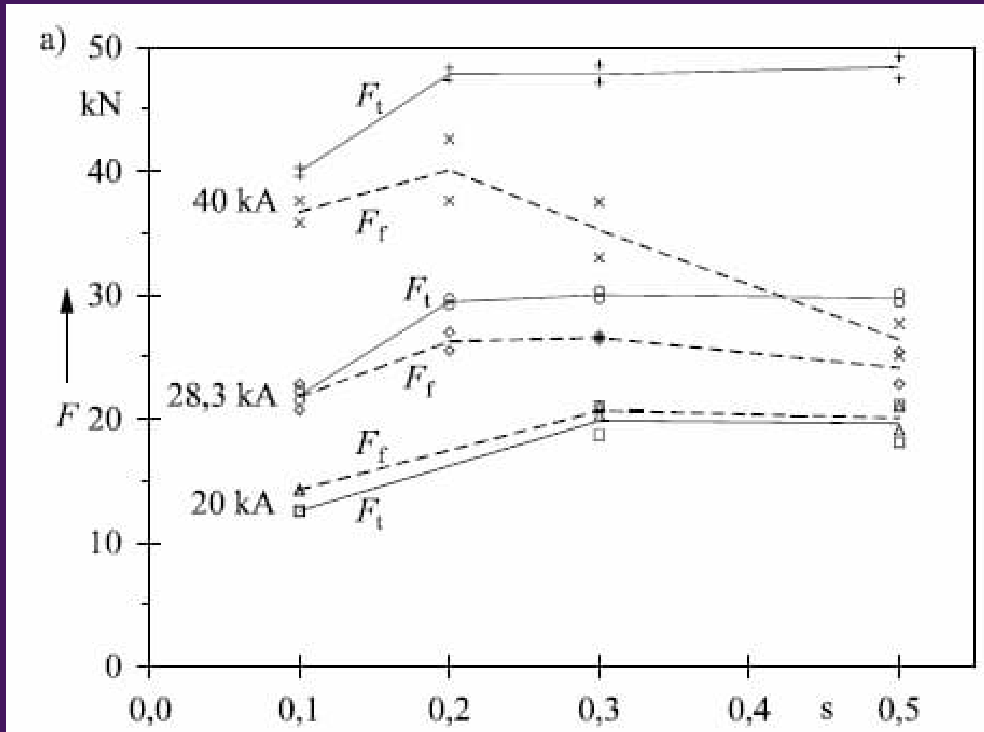
- Conductor ACSR 537/53
- $A=590mm^2$
- Diameter=32mm
- Mass=1.937kg/m
- Youngs modulus=69GPa



Dropper Effect - 1

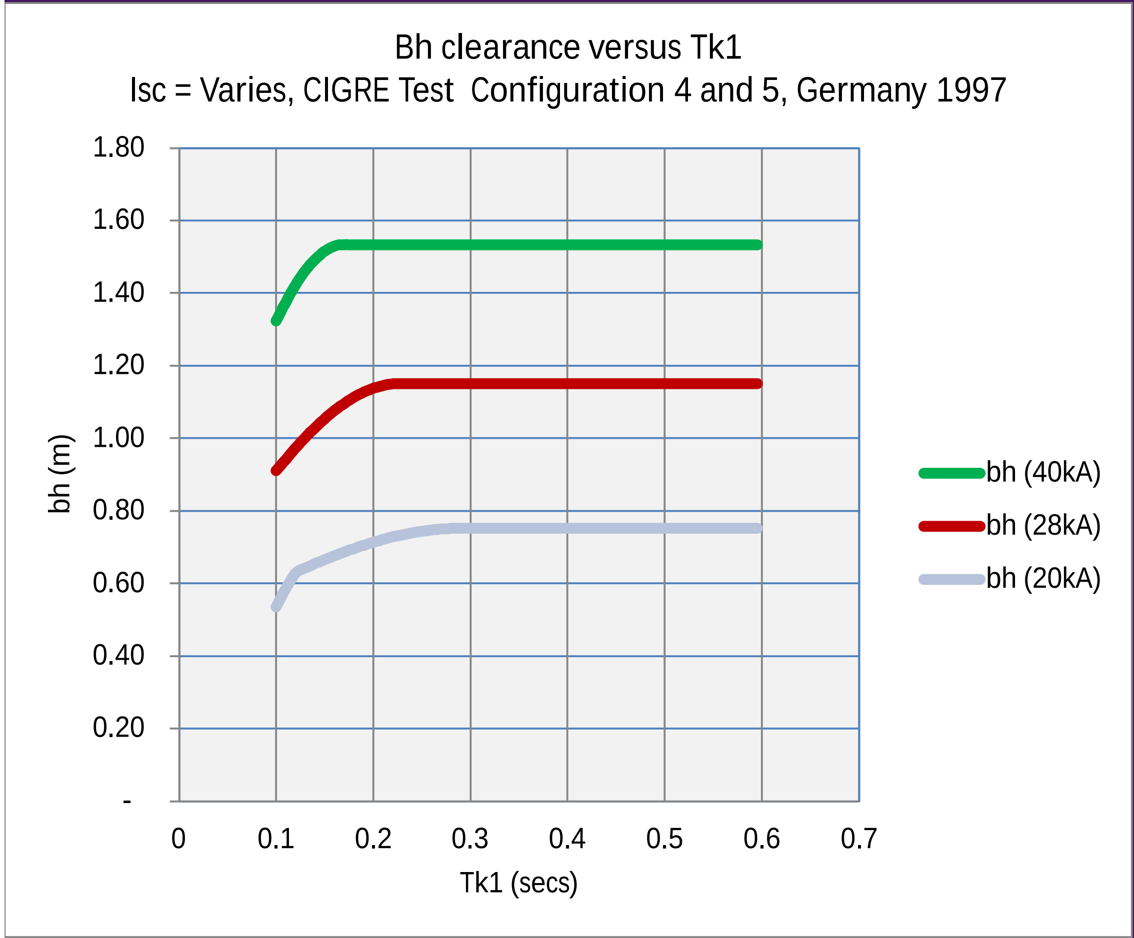


Calculated by Simplified Method

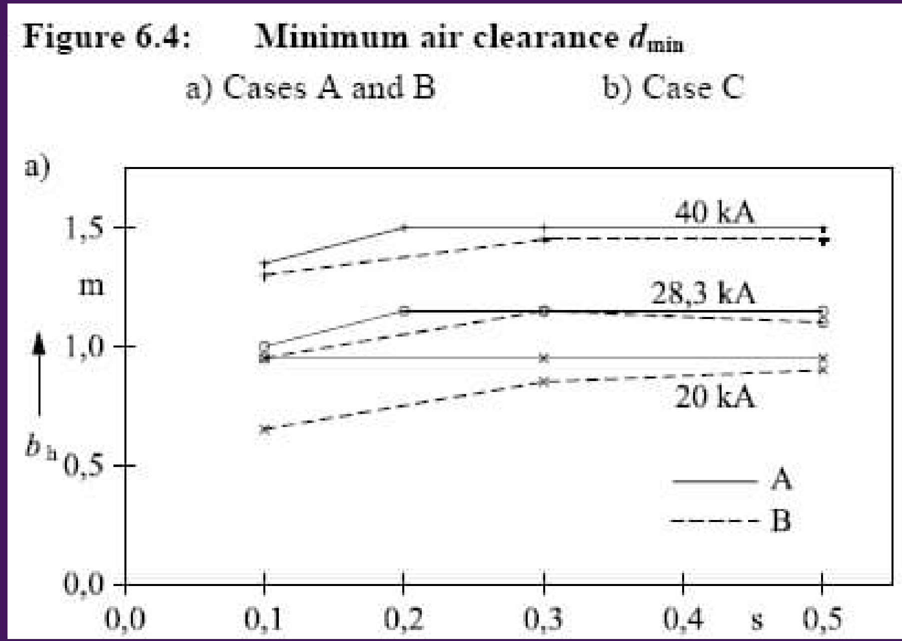


Test result in Germany

Dropper Effect - 2



Calculated by Simplified Method



Test result in Germany

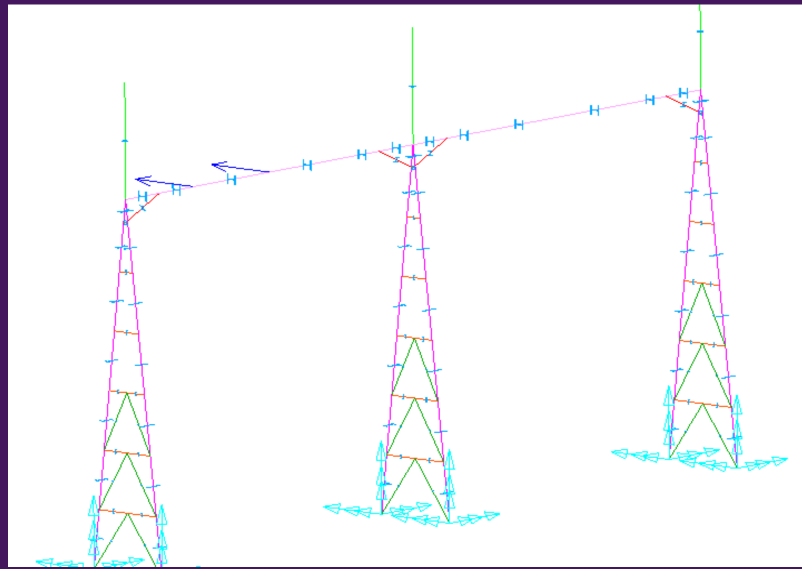
Methods of Analysis

Advanced Method

- This approach is accurate modeling of the structure using finite element approach for the conductors and supporting structures.
- Dynamic response of the structures is computed with time evolution of the phenomena.

Case Study: Dynamic Analysis

- Case Study
  - Short Circuit force, 50kN
  - Applied statically
  - Applied dynamically in 0.35secs



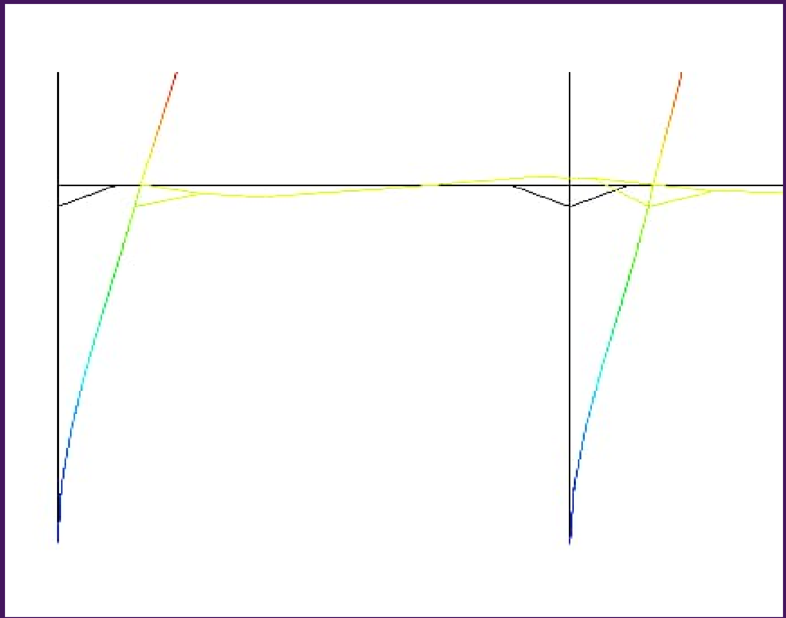
330kV Gantry – Neerabup Terminal, Western Power

- Software used = I-deas

- Purpose
  - To study amplifications in structural bending moments and displacements due to dynamic effects caused by short circuit forces in the conductors

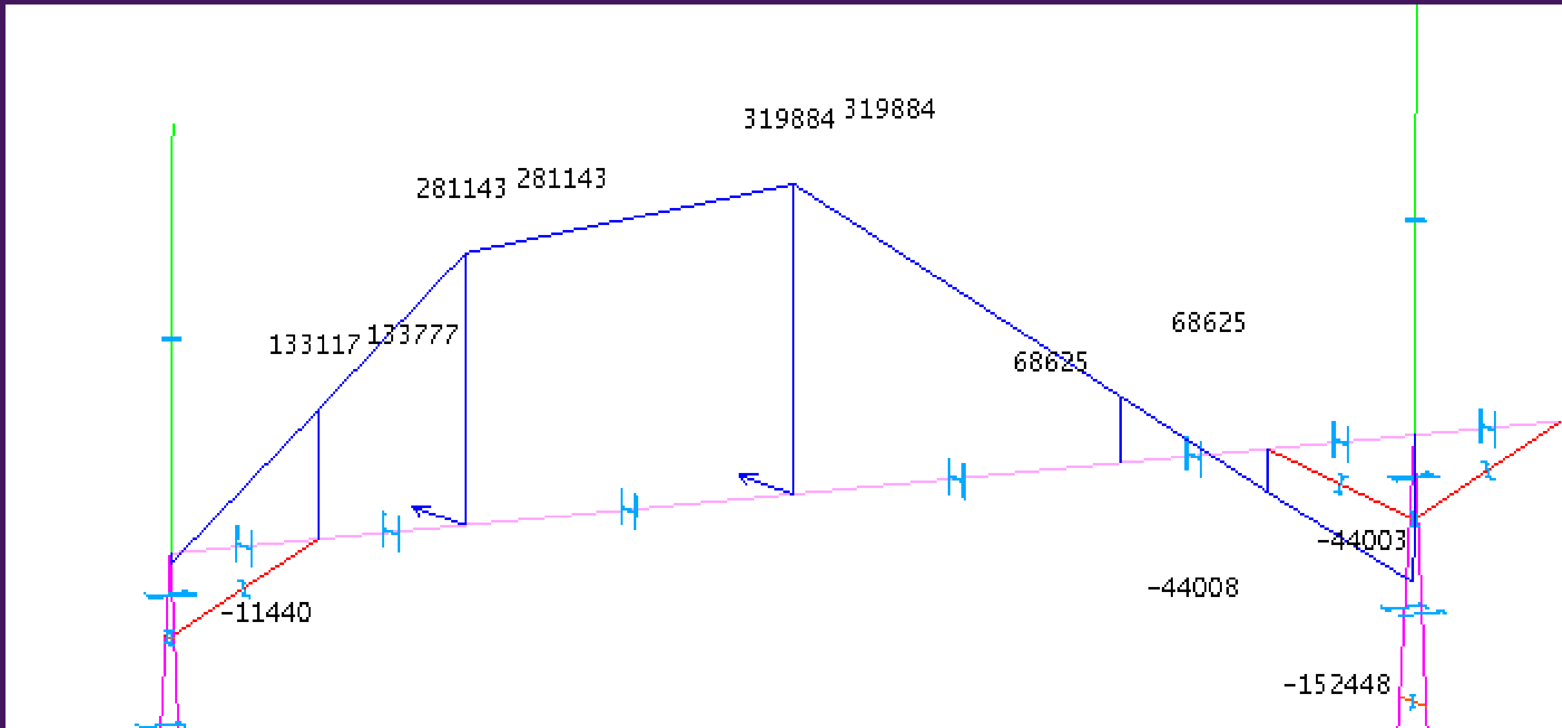
Structure frequencies

Vertical Bending Mode at 1.472 Hz (First Natural Frequency)



The second natural frequency - 3.42 Hz, lateral bending mode

Comparison of bending moment



Peak **static moment** was 320 kN.m.

Peak **dynamic moment** was lower at 294 kN.m

Case Study Results

Where it can be established that the frequency of the short circuit forcing function falls well below the resonance frequencies of the gantry structure, there is potential to reduce static amplification factors used in the design of these gantry structures.

Dynamic amplification is negligible - gantry frequency is 3.4 Hz. Forcing frequency is 0.7 Hz. Any dynamic amplifications already applied to the code will lead to conservative design.

For optimal design, recommended to model the short circuit forces, conductors and gantry in a finite element model and use the resulting moments to design the structure.

Load Combinations

Maximum Wind Tension, F_{MWT}

- As per ENA Cb1 2006, **$1.0\ W_n + 1.1\ G_s + 1.25\ G_c + 1.5\ F_{MWT}$**

Pinch Force, F_{pi}

Short Circuit Tension, F_T

Drop Force , F_f

- **$1.1\ G_s + 1.25\ G_c + 1.3\ F_{pi}$**
- **$1.1\ G_s + 1.25\ G_c + 1.3\ F_T$**
- **$1.1\ G_s + 1.25\ G_c + 1.3\ F_f$**

References

- IEC 865-1 Short Circuit Currents
- CIGRE Brochure 105
- CIGRE Committee 23-03 Volume 1 and 2
- Tests and calculations of short circuit forces and displacements in high voltage substations with strained conductors and droppers

  [N Stein, W Meyer, A Miri – 10 June 2000]
- Mechanical characteristics related to fault currents in bundle conductors [Makoto H, Takayuki K, Kouji Y, Yasuo S – 1994]
- Guidelines for seismic design of flexible buswork between substation equipment [Jean-Bernard Dastous – 05 July 2006]