SNC • LAVALIN

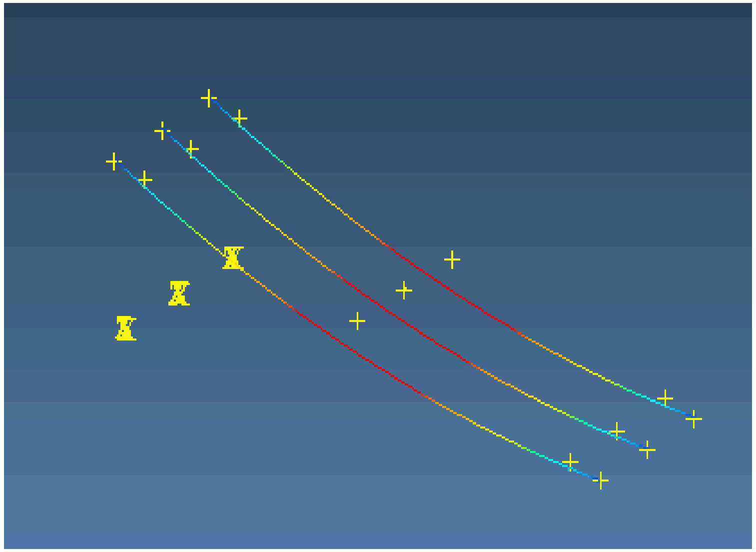
Impact of High Short-Circuit Current on Air Insulated Station Strain Bus Design

2016 CIGRE-IEC Colloquium

Montreal, QC, Canada

JAY TAILOR & BHARAT BHATT
Hydro and Power Delivery
SNC LAVALIN Inc.,
Canada

Characteristics of SC Forces on Strain Bus Systems



Nature

- Oscillatory & non-linear:
  - Instantaneous SC Current value
  - Ever-changing phase-phase clearance
  - Elastic and Thermal expansion of conductors
  - Tensile Forces in the conductors
  - Poor rigidity compared to Rigid Bus

Effects

- Tensile Forces in the conductors, terminations and associated hardware
- Elastic or Plastic deformation of conductors
- Structure deflection
- Conductor oscillations – Can compromise minimum clearances

Types of SC Forces on Strain Bus Systems

Pinch Effect Force

- Tensile Force due to attraction between bundled conductors

Shor-Circuit Force

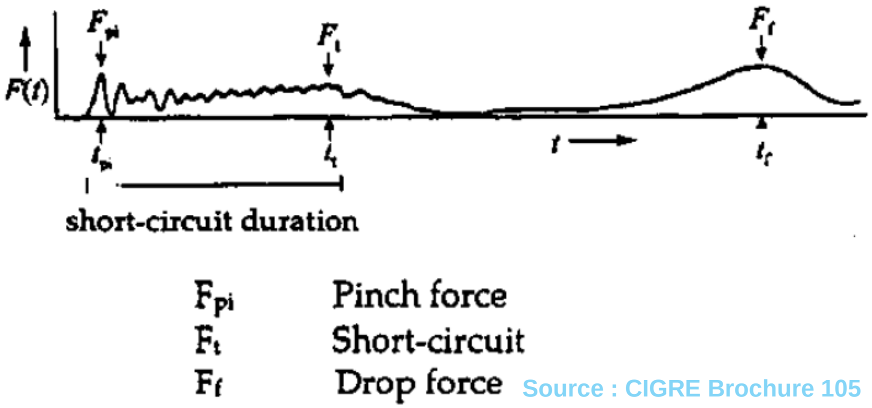
- Tensile Force due to attraction or repulsion between Phase conductors

Dropback Force

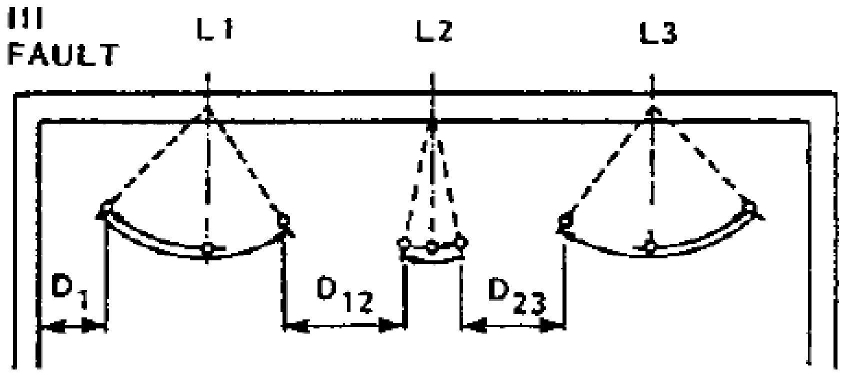
- Tensile Force when conductor drops back after clearance of short circuit

Horizontal Displacement

- Maximum displacement (swing) of phase conductors from the resting position



Source : CIGRE Brochure 105

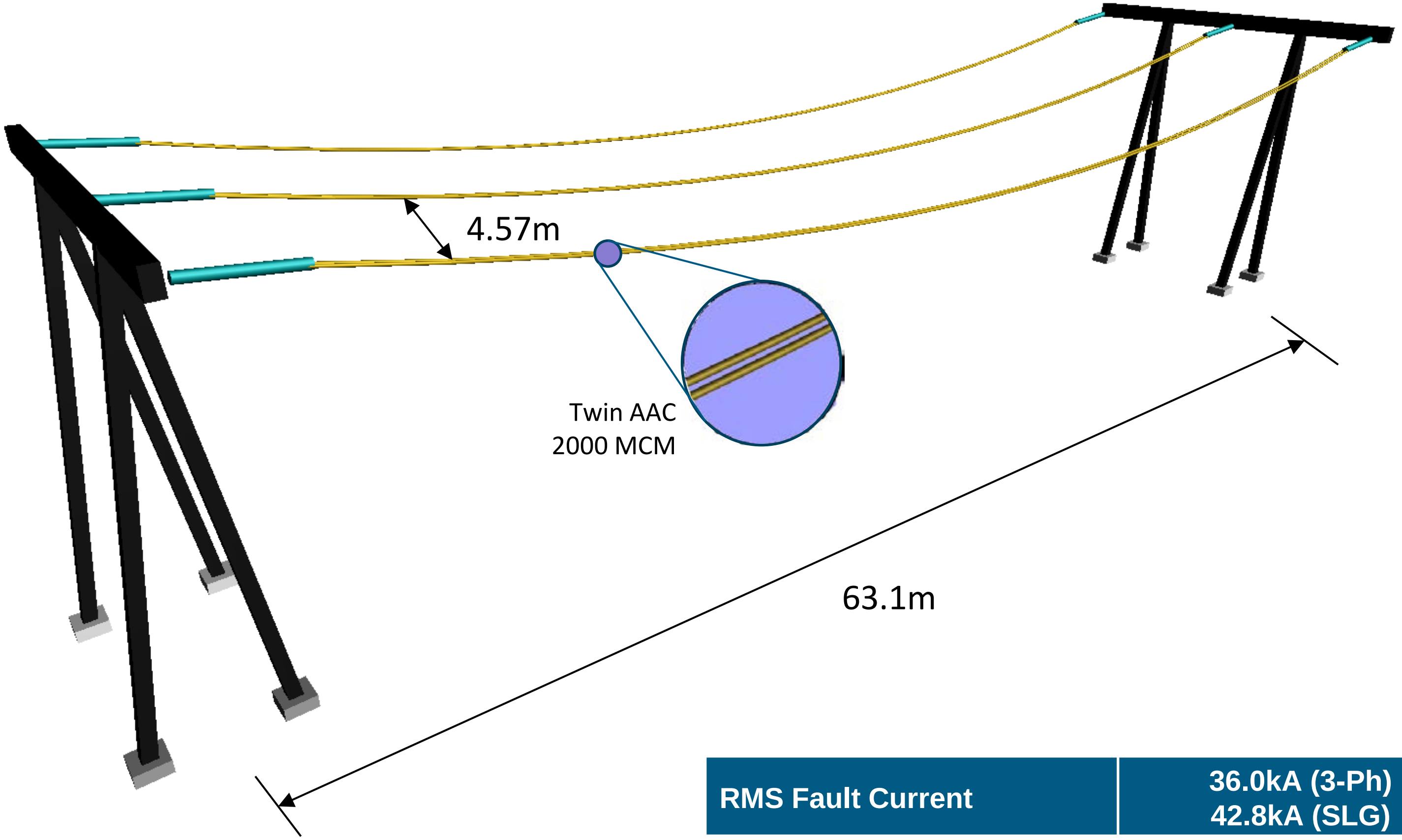


Source : CIGRE Brochure 105

Available Tools for Analysis

1. Simplified Hand Calculations – IEC 60865-1
2. Simplified Hand Calculations – IEEE 605-2008
3. Finite Element Analysis

230kV Strain Bus Study Case Details



RMS Fault Current	36.0kA (3-Ph) 42.8kA (SLG)
Fault current duration	0.484 seconds
System Frequency	60 Hz
X/R ratio	42.1

Source: ABB

Results

Short Circuit Forces	Temperature	IEEE 605 (N)	FEA (N)	IEC 60865 (N)
Maximum tensile short circuit force during fault current, F_t (N)	-20˚C	30,846.2	29,000	30,193.4
	-50˚C	38,807.4	40,100	37,612.9
	90˚C	18,753.7	18,125	18,612.9
Maximum tensile short circuit force when conductors drop back, F_f (N)	-20˚C	130,135.1	55,500	90,037.1
	-50˚C	121,057.6	74,375	88,588.1
	90˚C	149,505.1	26,250	95,335.1
Maximum tensile force caused by Pinch effect F_{pi} (N)	-20˚C	101,884.9	Indeterminate	65,836.6
	-50˚C	107,339.3	Indeterminate	74,185.1
	90˚C	94,723.8	Indeterminate	54,621.0

Diplacements	Temperature	IEEE 605 (m)	FEA (m)	IEC 60865 (m)
Maximum horizontal displacement within a span, b_h (m)	-20˚C	1.01	1.3	1.04
	-50˚C	0.815	1.13	0.866
	90˚C	1.542	2.0	1.556
Minimum phase to phase clearance during fault condition, a_{min} (m)	-20˚C	2.552	3.1	2.482
	-50˚C	2.939	3.5	2.838
	90˚C	1.487	2.3	1.459

Results (Contd.)

Required Ratings	**Per IEEE 605**	**Per IEC 60865**	**Per FEA**
ANSI/IEC Strength Class of Strain Insulator	CS-13 (150 KN)	CS-11 (111 KN)	CS-8 (80 KN)
Maximum Design Force to be considered for Support Structure design	450 KN	202 KN	160 KN

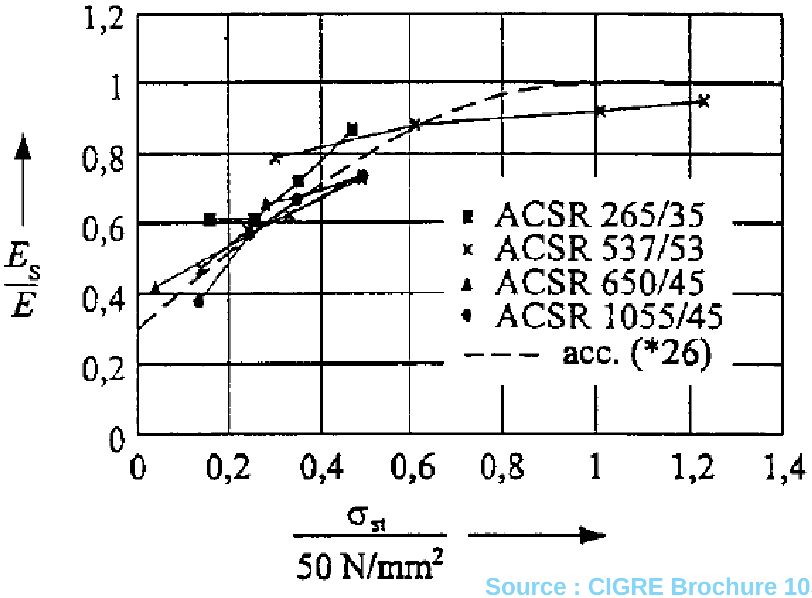
Which one to follow?

Observations

- Short Circuit Forces (F_t) matches well among all three methods
- Phase clearances are found to be larger in FEA; IEC and IEEE results are consistent
- Significant difference in Dropback forces
- Although not so close, FEA results are closer to IEC than IEEE
- Designing systems according to IEEE forces maybe challenging and uneconomical
- IEEE method derived from IEC 60865 – Apparently not so!

Differences between IEEE and IEC methods

1. Conductor Flexibility: IEEE assumes a Constant Young’s Modulus unlike IEC according to which Young’s modulus is non-linear.



Source : CIGRE Brochure 105

This means the conductor are more elastic for lower stresses thus can absorb relatively more forces.

Differences between IEEE and IEC methods (contd.)

2. Support Structure Flexibility:

IEC considers Supports to be Flexible; IEEE considers Supports to be Rigid

$$N = \frac{1}{S\,l} + \frac{1}{n\,E_{\text{eff}}\,A_{\text{s}}}$$

IEC

Support Structure Stiffness

This means the Support structure absorbs some of the forces in IEC methodology. Not so in IEEE methodology.

$$\left.\begin{aligned} N &= \frac{1}{k_{eq}\,l} \\ \frac{1}{k_{eq}} &= \frac{1}{k_c} + \frac{2}{k_i} \end{aligned}\right\}$$

IEEE

Differences between IEEE and IEC methods (contd.)

3. Selection of design Forces for Support Structures:

IEC Methodology: Twice the largest of (F_t , F_f , F_{pi}) + One times Static tensile force

IEEE Methodology: Thrice the largest of (F_t , F_f , F_{pi})

Much stronger Support structure required in IEEE methodology

Closing Remarks

- The paper presents a comparison of IEEE, IEC and FEA methods for Short circuit forces
- Fundamental differences were found between how two methods treat some parameters
- Difference between IEEE and IEC results are large – IEEE results are generally of larger magnitude
- It is recommended that IEEE 605 methodology be harmonized with IEC 60865

Questions??