



2019 Grid of the Future Symposium

## **Comparing Static and Dynamic Analysis of Short Circuit Forces on Substation Rigid Bus: A Case Study**

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Presented By:

Paul Somboonyanon, Ph.D., P.E., P.Eng

# Outline

- Background
- Static vs. Dynamic Analysis
- Design Pros vs. Cons
- Case Study & Results
- Summary
- Q&A



# Background



# Background

- Short circuit force determination can be a complex analysis
- Increase in fault currents analyzed with new system upgrades/expansions
- Impact to project costs



# Static vs Dynamic Analysis

- Static analysis with IEEE 605-2008

*“IEEE Guide for Bus Design in Air Insulated Substations”*

$$F_{sc} = \frac{3.6 \Gamma I_{sc}^2}{10^7 D} \quad [\text{IEEE 605-2008 Eq. 15}]$$

$$F_{sc\_corrected} = D_f^2 K_f F_{sc} \quad [\text{IEEE 605-2008 Eq. 16}]$$



# Static vs Dynamic Analysis

- Dynamic analysis with CIGRE 105

*“The Mechanical Effects of Short Circuit Currents in Open Air Substations”*

$$i_{sc}(t) = \sqrt{2} i_{sc} [\cos(2\pi ft + \delta) - e^{-t/T_a} \cos(\delta)] \quad [\text{IEEE 605-2008 Eq. 17}]$$

$$F(t) = \frac{\mu}{4\pi r^2} i_1(t) i_2(t) [d_1 \otimes (u_r \otimes d_2)] \quad [\text{IEEE 605-2008 Eq. 16}]$$

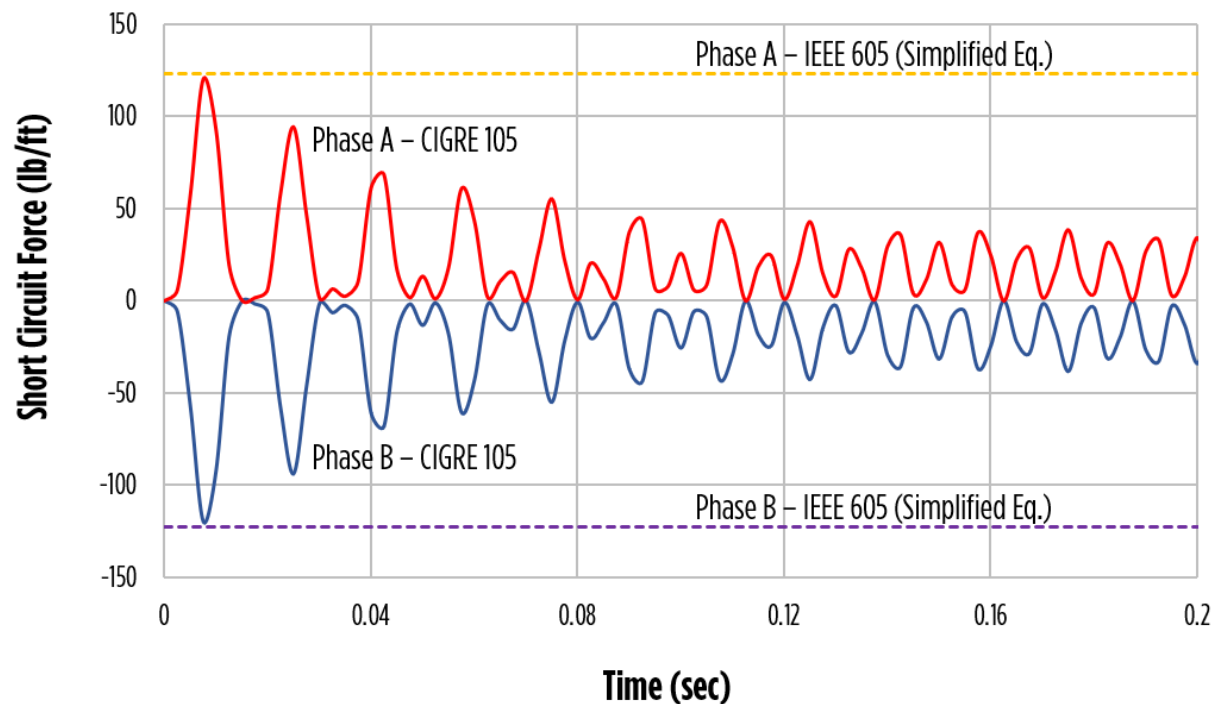
$$F_{sc}(t) = \frac{\mu_0}{2\pi} i(t) \sum_n \frac{i_n(t)}{a_n} \quad [\text{CIGRE 105 Eq. 1.7}]$$



Additional resources: CIGRE 214, and IEC 60865

# Static vs Dynamic Analysis

Short Circuit Force Function with Time



# Design Pros vs Cons

- Static Analysis – IEEE 605-2008

Pros:	Cons:
Minimal design time	More conservative analysis
Require fewer design parameters to run an analysis	Potentially require more support structures/foundations (higher project cost)
Reduce design complexity	Applicable with limited bus layout/configuration
Widely used by utilities with well-established design guideline	



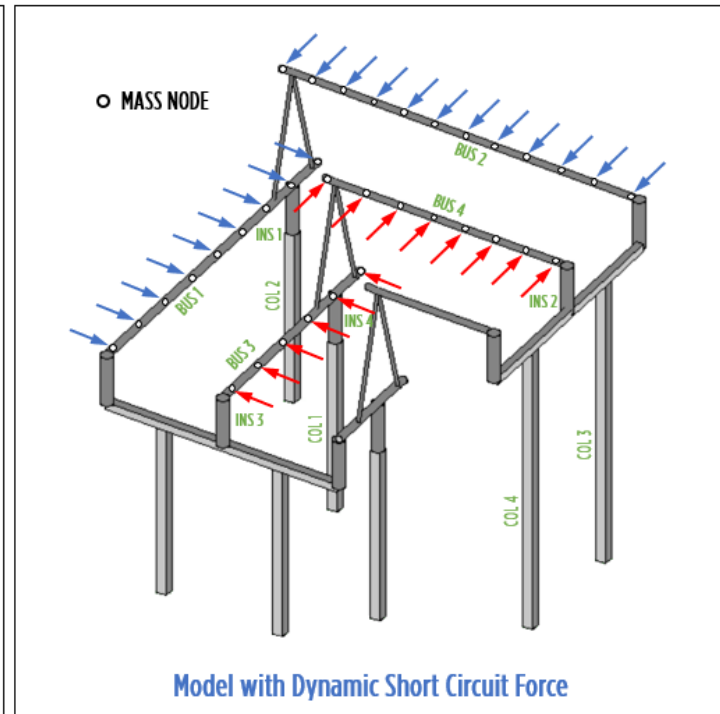
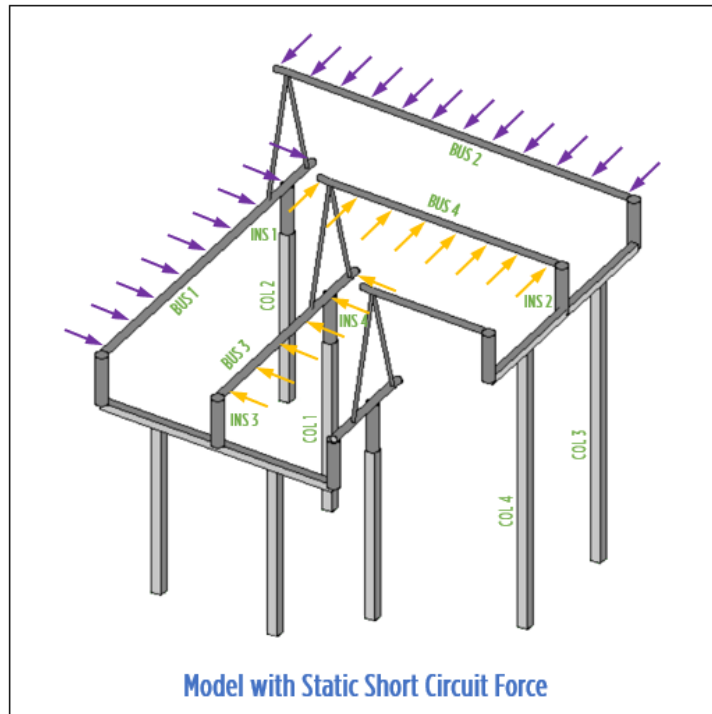
# Design Pros vs Cons

- Dynamic Analysis – CIGRE 105

Pros:	Cons:
More accurate analysis	Require extensive design time
Potentially requires fewer support structures/foundations (project cost saving)	Increase design complexity
Applicable with any bus layout or configuration	Require several more design parameters and considerations to run an analysis
	No industry established guideline available

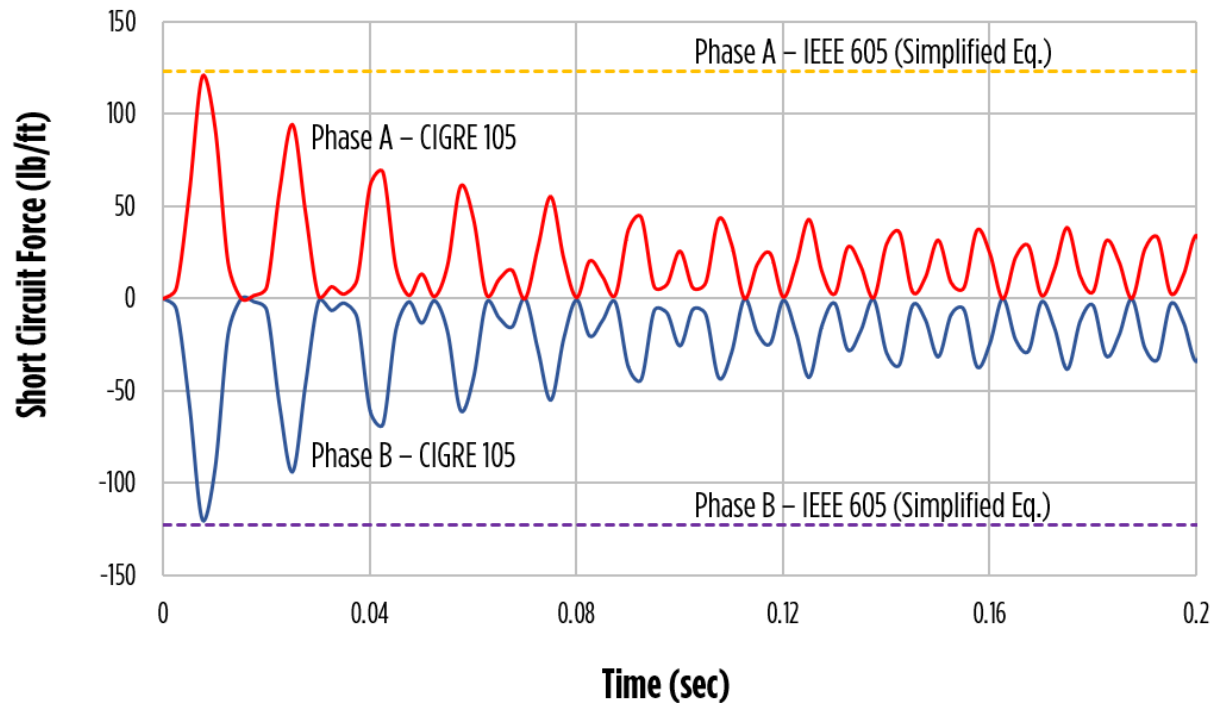
# Case Study

- Model analyzed for the case study



# Case Study

- Short circuit force function utilized

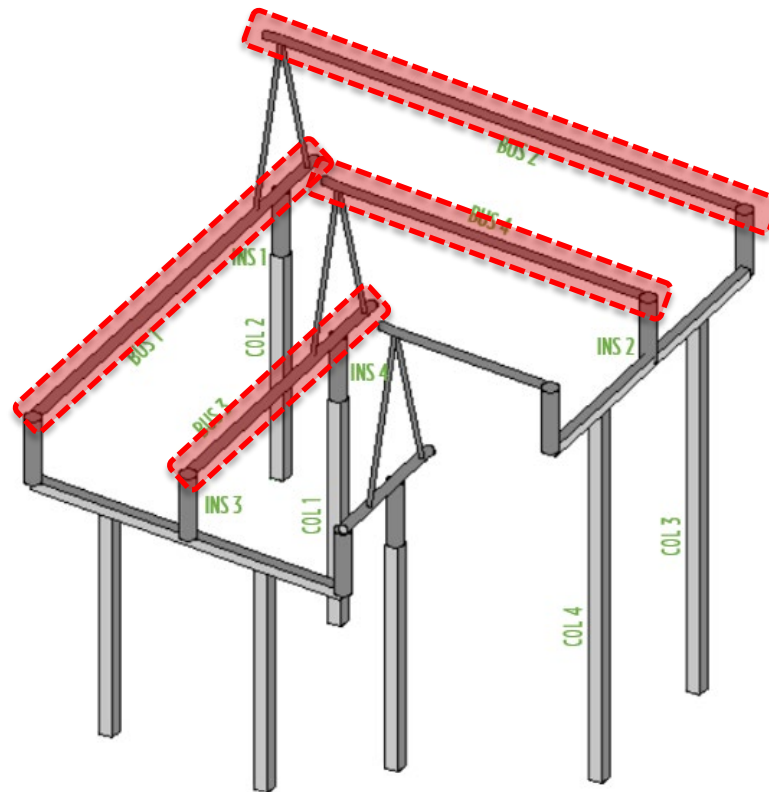


# Case Study

- Evaluated parameters:
  1. Bus conductor member stress
  2. Insulator cantilever force
  3. Structure column stress ratio

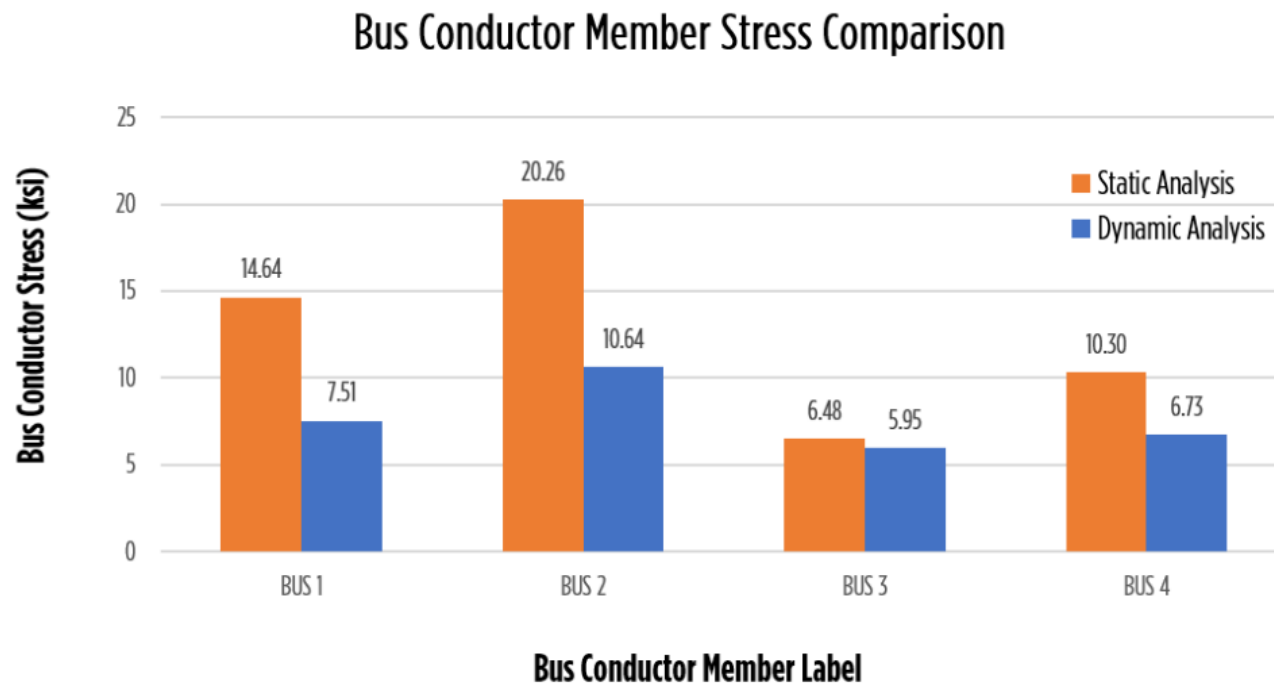
# Case Study

- Results – bus conductor member stress



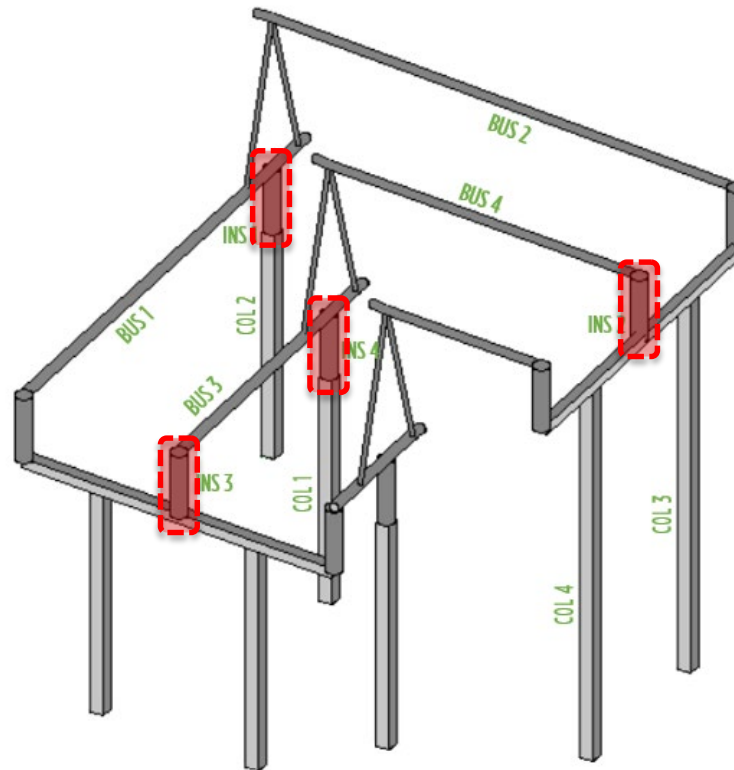
# Case Study

- Results – bus conductor member stress



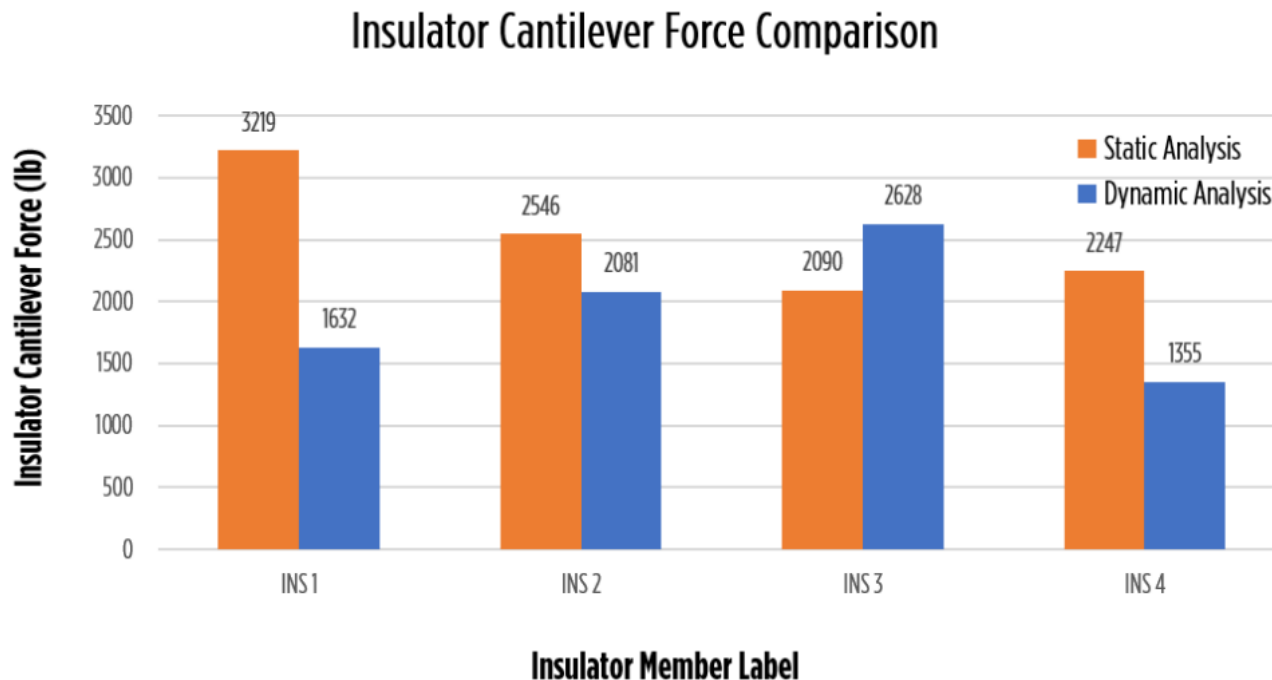
# Case Study

- Results – insulator cantilever force



# Case Study

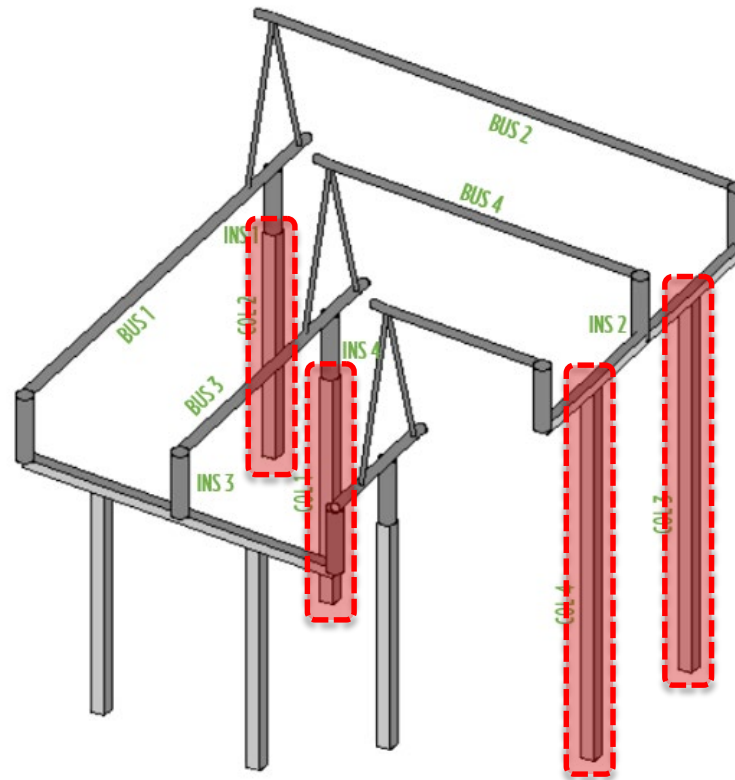
- Results – insulator cantilever force





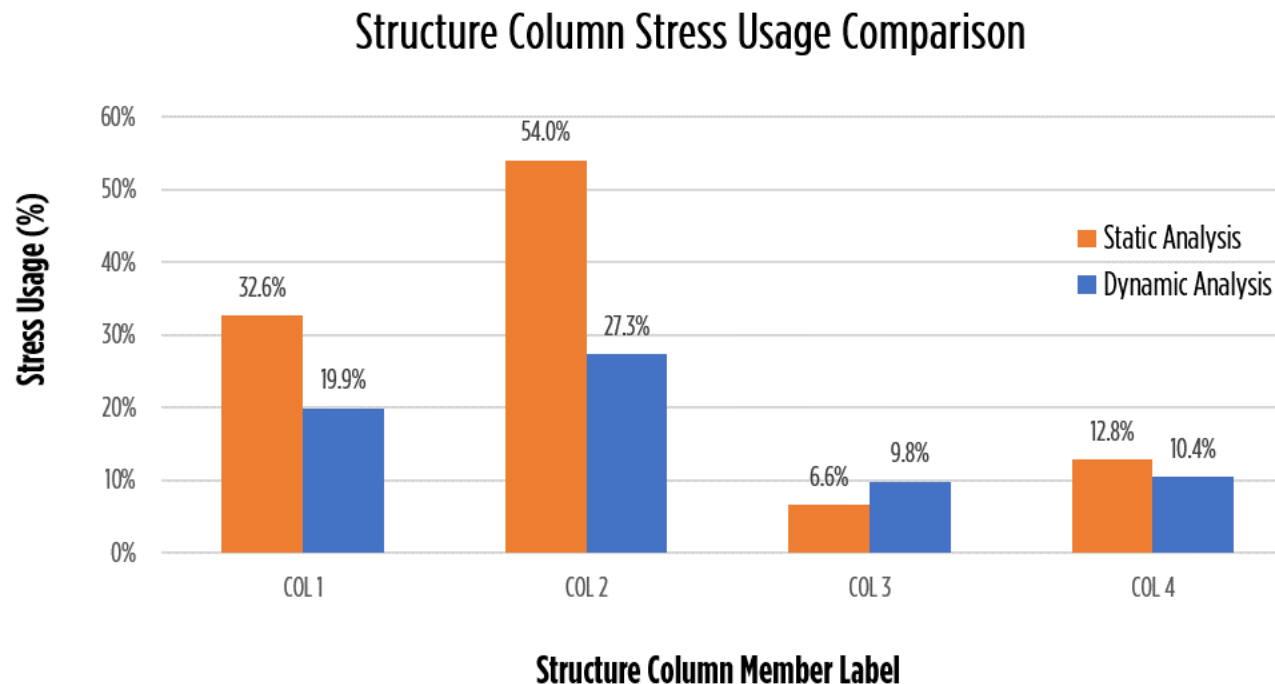
# Case Study

- Results – structure column stress ratio



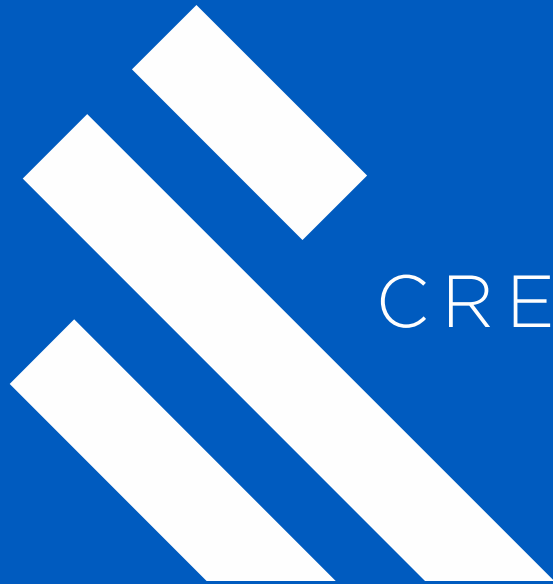
# Case Study

- Results – structure column stress ratio



# Summary

- Static analysis can be easily implemented but can be too conservative
- Dynamic analysis could be more complex but provides more accurate results
- Rigid bus design with dynamic analysis generally yielded lower stress on components compared to static analysis
- More flexible members are subject to higher load reduction with dynamic analysis



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