Effect of GIC and GIC Capability of EHV Power Transformers

– A Case Study on an AEP 765 kV Power Transformer Design

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Outline

- GMD Impacts on Transformers
- GIC Profile for the Evaluation of the GIC Impacts on Power Transformers
- Impact of GIC on a 750 MVA, 765/345/34.5 KV, 1-phase, Auto-transformer Design
- GIC Capability of the 765 KV, 1-Phase Transformer Design
- Conclusion and Future Studies

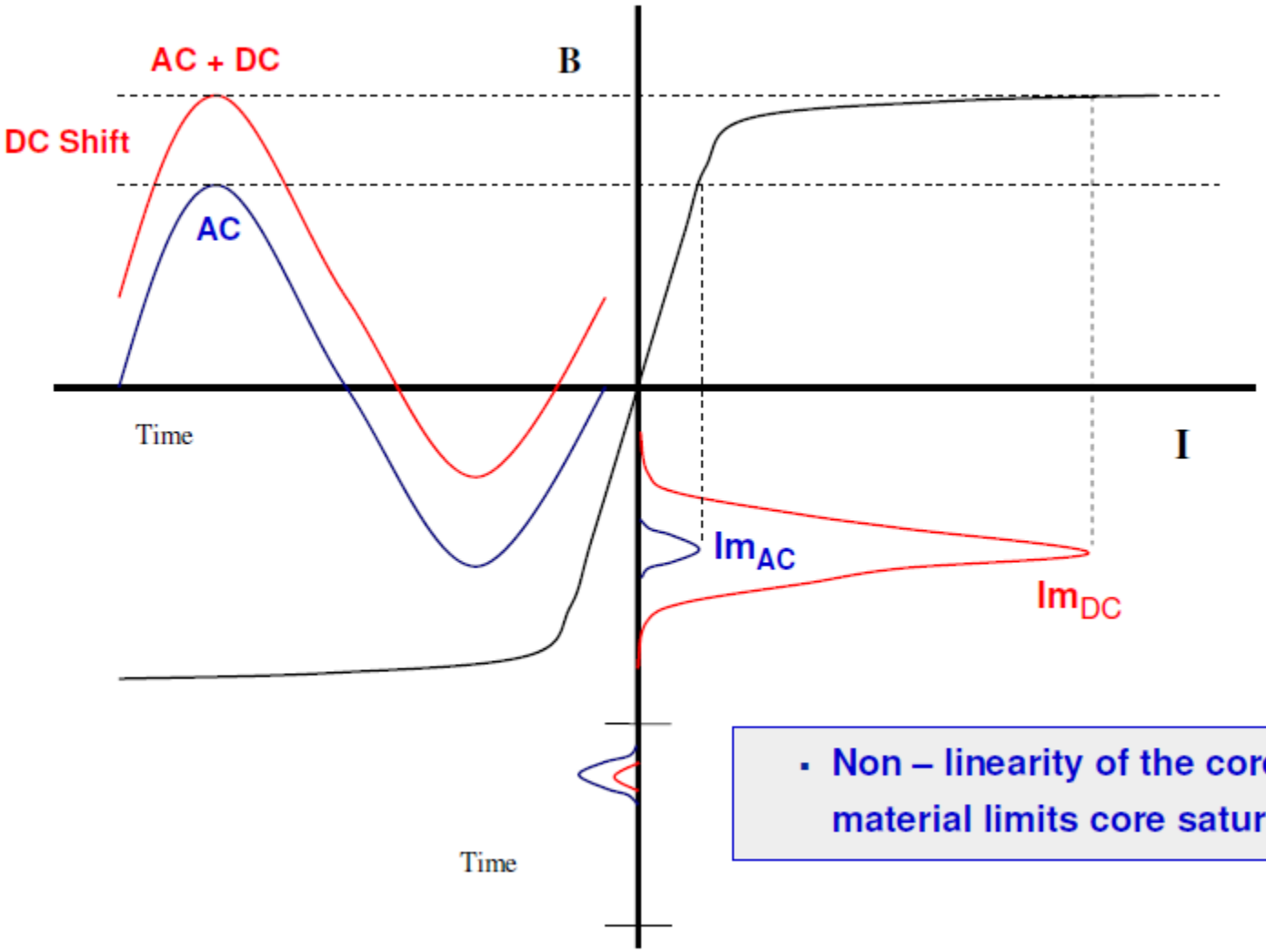
Geomagnetic Disturbance Impacts on Power Systems

- The solar storm impacts on power systems depend on many factors, including:
  - Intensity of solar storm activity
  - Whether and where the mass of particles ejected during a solar storm strikes Earth
  - The facilities' geography (proximity to Earth's poles) and local geology
  - Length and orientation of lines and the winding connection of connected transformers
  - **The design of connected transformers and their power loading during the GMD**

GMD Impacts on Transformers

- GMD Impacts on Transformers Depend on
  - Transformer design, including core type
  - Magnitude and duration of the GIC pulse
- Effects of GIC on a transformer
  - If sufficient in intensity and duration, these quasi-DC currents may cause transformer part-cycle core saturation and overheating
  - Unidirectional core flux density shift
  - A short duration high peak magnetizing current pulse one per cycle
    - Significant increases in core loss, core noise, and load loss
    - Hot spot temperature rises of the windings and structural parts
    - In the extreme, it can lead to transformer damage or failure
      - Failure of a GSU transformer in Salem nuclear plant on 3/13/1989

GMD Impacts on Transformers



- Non – linearity of the core material limits core saturation

AEP Approach on Transformer GMD Impact Assessment

- Working with transformer vendors:
  - To evaluate the GIC impacts on selected in-service and new EHV transformers
  - To determine the GIC capability of representative EHV transformers is to identify potential transformer vulnerabilities
- These studies provide necessary technical support in developing/refining GMD operating procedures and GMD mitigation plans.
- The results of these studies, such as reactive power demands, and current harmonics, due to GIC flow can be incorporated into AEP's GIC system impact studies such as voltage stability and protection & control impact studies.

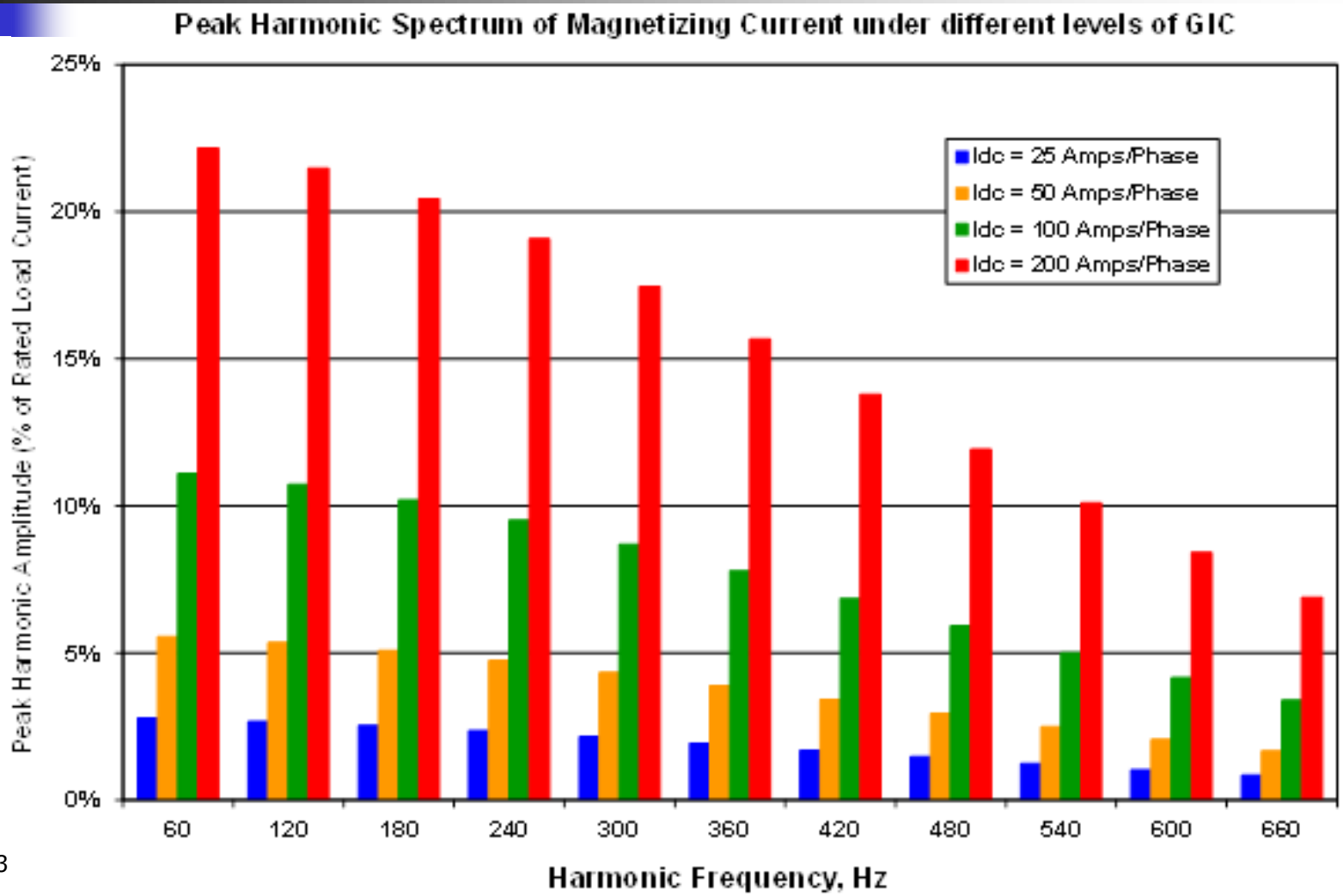
Scope of Transformer GMD Impact Assessment

- Calculations of the transformer performance parameters subjected to a range of GIC levels
  - Calculate magnitude and wave-shape of the resulting magnetizing current pulse, and the associated additional VAR demand and harmonics
  - Calculate the increase in core losses, load losses, and core noise level
  - Calculate the increase in the hot spot temperatures of windings and structural parts
- Evaluation of transformer GIC capability study
  - Estimate the combinations of load current and magnitude of GIC that the transformer would operate at without exceeding loss of life of the transformer insulation beyond what is allowed by Industry Standards

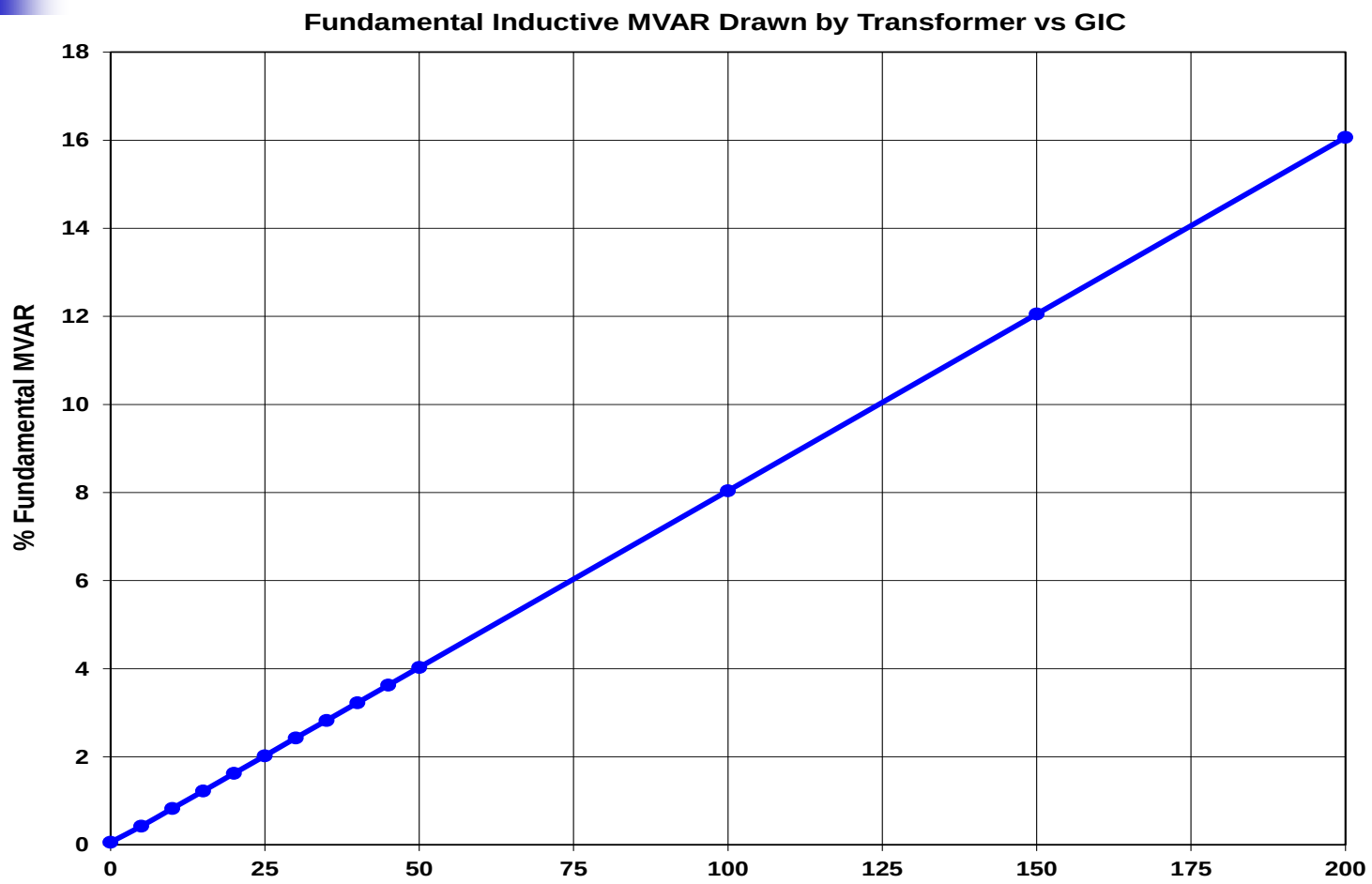
GIC Profile for the Evaluation of the GIC Capability

- AEP design and performance requirements of new EHV 765 kV single phase transformers
  - GIC profile of six 5-minute on/5-minute off cycles of 120 A/phase DC in the common and series windings, the transformer would not exceed the dissolved gas values listed in the AEP Specification
- For the GIC Capability evaluation of 765 kV transformers
  - AEP specifies that the magnitudes of GIC used are 50, 100, and 200 A/phase for a 5-minute duration

Harmonics% Vs. GIC Levels



Fundamental MVAR% Vs. GIC Levels



Calculated Increases of Core Loss & Core Noise

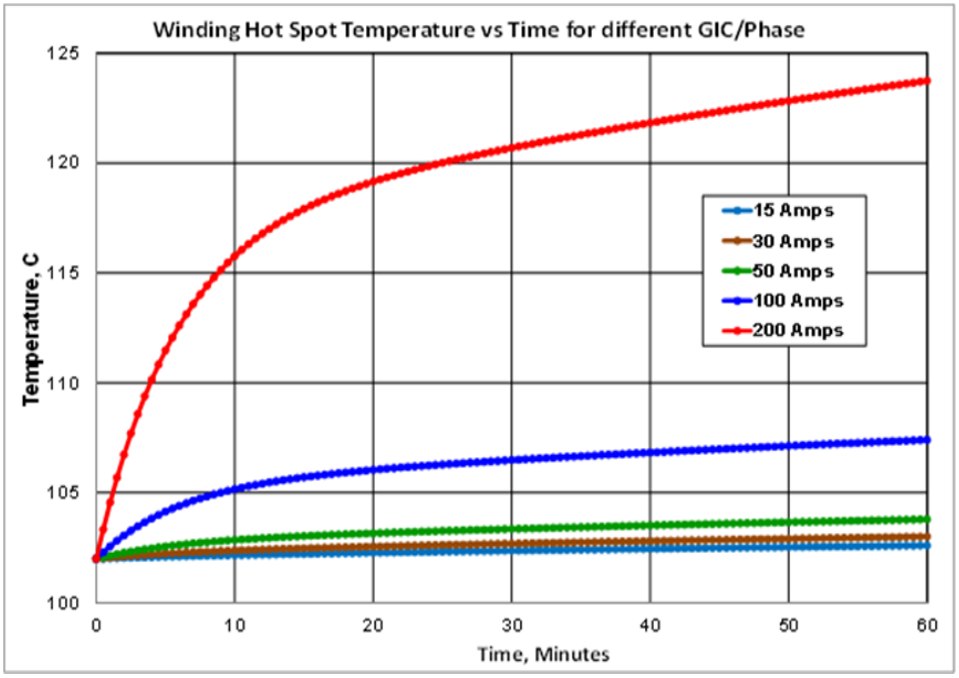
GIC (A/Phase)	Core Loss Increase	Core Noise level Increase (dB)
15	29.0%	29.6
20	31.5%	31.2
30	35.3%	33.7
40	38.1%	35.4
50	40.4%	36.9
100	48.2%	41.6
200	56.9%	46.7

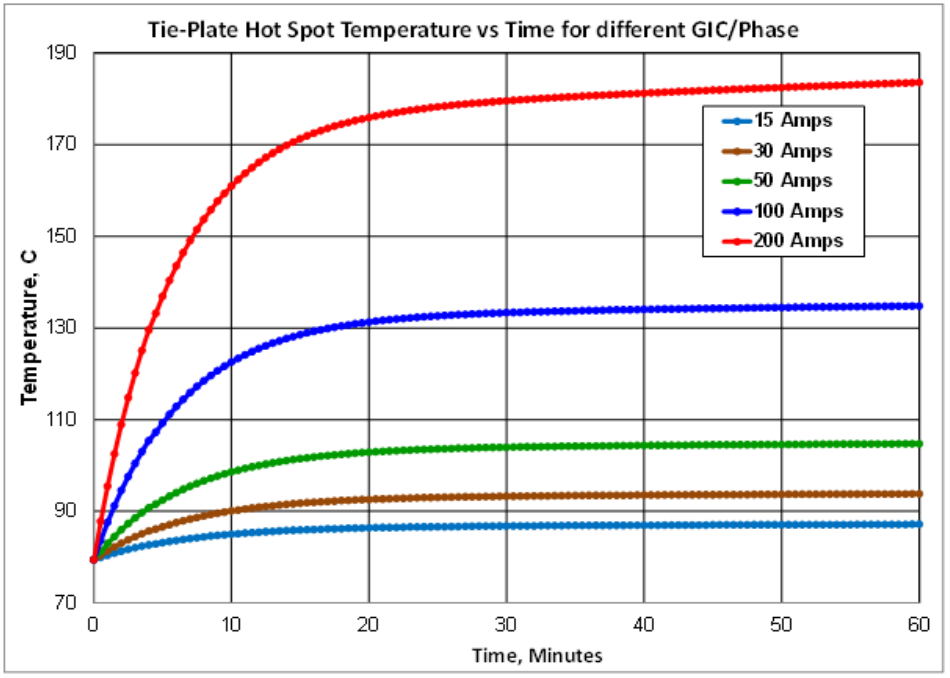
Calculated Increases of Load Loss vs. Levels of GIC

GIC (A/Ph)	Loss Increase In Windings			Loss Increase in Structural Parts	Increase in Total Load Losses
	Ohmic	Eddy Current	Windings		
15	0.05%	0.9 %	0.2%	0.1%	0.2%
20	0.1%	1.6%	0.4%	0.2%	0.33%
30	0.2%	3.7%	0.8%	0.5%	0.76%
40	0.3%	6.6%	1.4%	0.8%	1.35%
50	0.5%	10.3%	2.2%	1.4%	2.13%
100	2.1%	41.7%	9.1%	5.3%	8.55%
200	8.4%	169.5%	36.7%	21.4%	34.7%

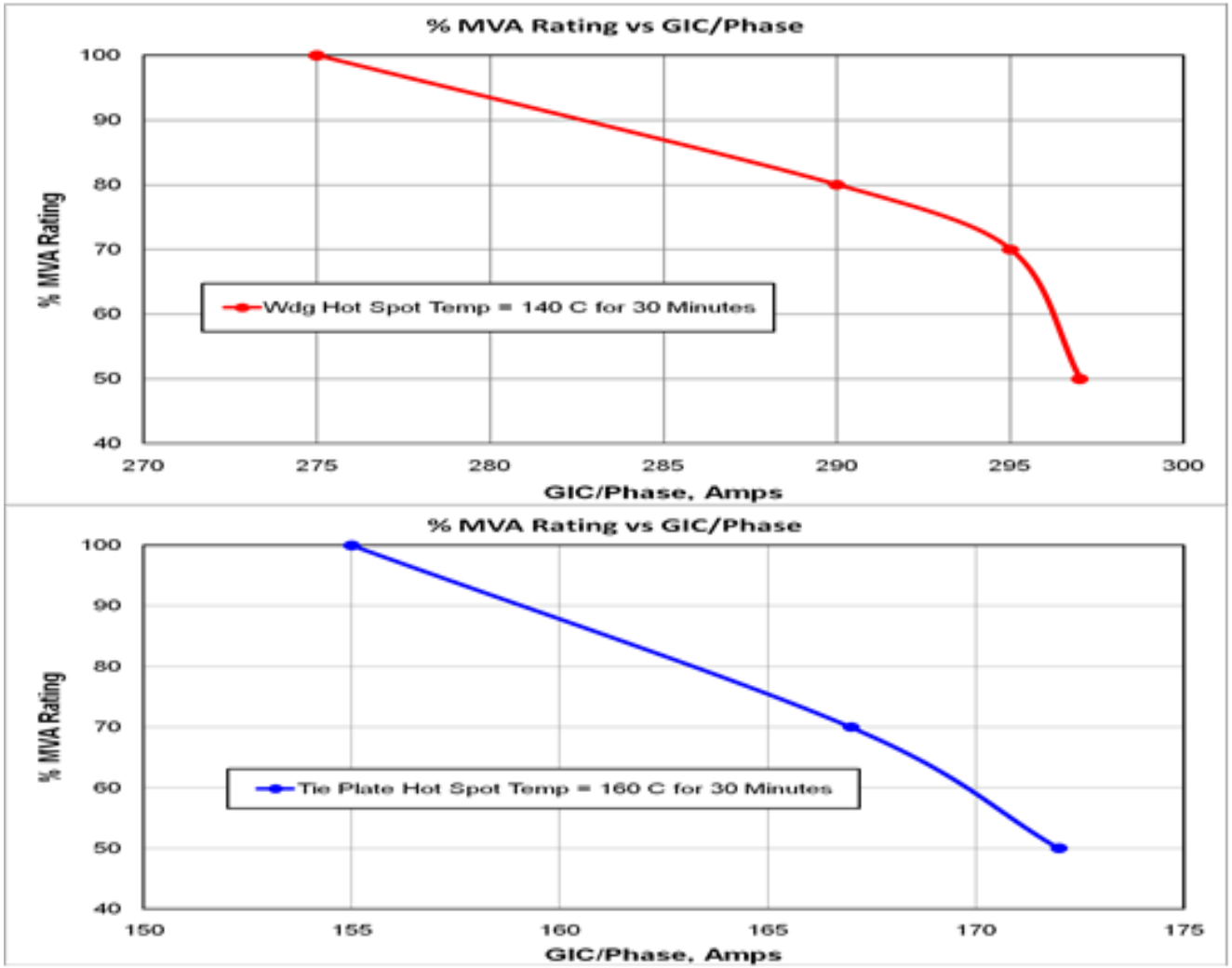
Calculated Hot Spot Temperatures Vs. Time for Various GIC Levels

- Calculated temperatures of the windings and structural
  - The transformer is fully loaded
  - Subjected to 5 different levels of GIC currents for a 60-minute period





GIC Capability of the Transformer Design



Conclusion and Future Studies

- Effect of GIC on transformers
  - Significant increases in core loss, core noise, and load loss
  - Generation of high current harmonics
  - Significant VAR demand during a severe GMD storm
- GIC capability curves confirm that transformers of this design can be subjected up to 155 amps/phase of GIC for a duration of 30-minute without the need for reducing their load.
- To validate the calculations based on the measurements from fiber temperature probes at the winding and tie-plate hot spots, as well as the reactive power loss measurements during a storm

Questions?