



CIGRE / US NATIONAL COMMITTEE

GRID OF THE FUTURE (GOTF) SYMPOSIUM, OCTOBER 29, 2018, PAPER SESSION 1A

GIC Magnetic and Thermal Assessment of TVA's fleet of 500 kV Transformers

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Outline of Presentation

- § Requirements of the TPL 007-1 Standard
- § Results of the DC system modelling
- § Results of the GIC Susceptibility study
- § Results of the GIC Magnetic Fleet assessment
- § Results of the GIC Thermal Fleet assessment

Requirements of the NERC TPL 007 – 1 Standard

- A **GMD Vulnerability Assessment** of the system for its ability to withstand a Benchmark GMD Event without causing a wide area blackout, voltage collapse, or damage to transformers
- A **Transformer thermal impact assessment** to ensure that all high-side, wye grounded transformers connected at $\geq 200\text{kV}$ will not overheat based on the Benchmark GMD Event.

Tasks to comply with TPL 007 – 1 Requirements

1. **Calculate magnitude of GIC** that different transformers in the fleet would be subjected to under the Benchmark GMD event proposed by NERC
2. Perform Magnetic modeling of Transformers to **calculate additional Reactive Power absorption & Current harmonics** corresponding to these GIC levels
3. **Perform GIC vulnerability assessment of the power system**
4. **Develop Corrective Action Plan** addressing how performance requirements of the power system will be met during the Benchmark GMD storm
5. **Perform Thermal Assessment of Transformers** to be subjected to ≥ 75 A / phase

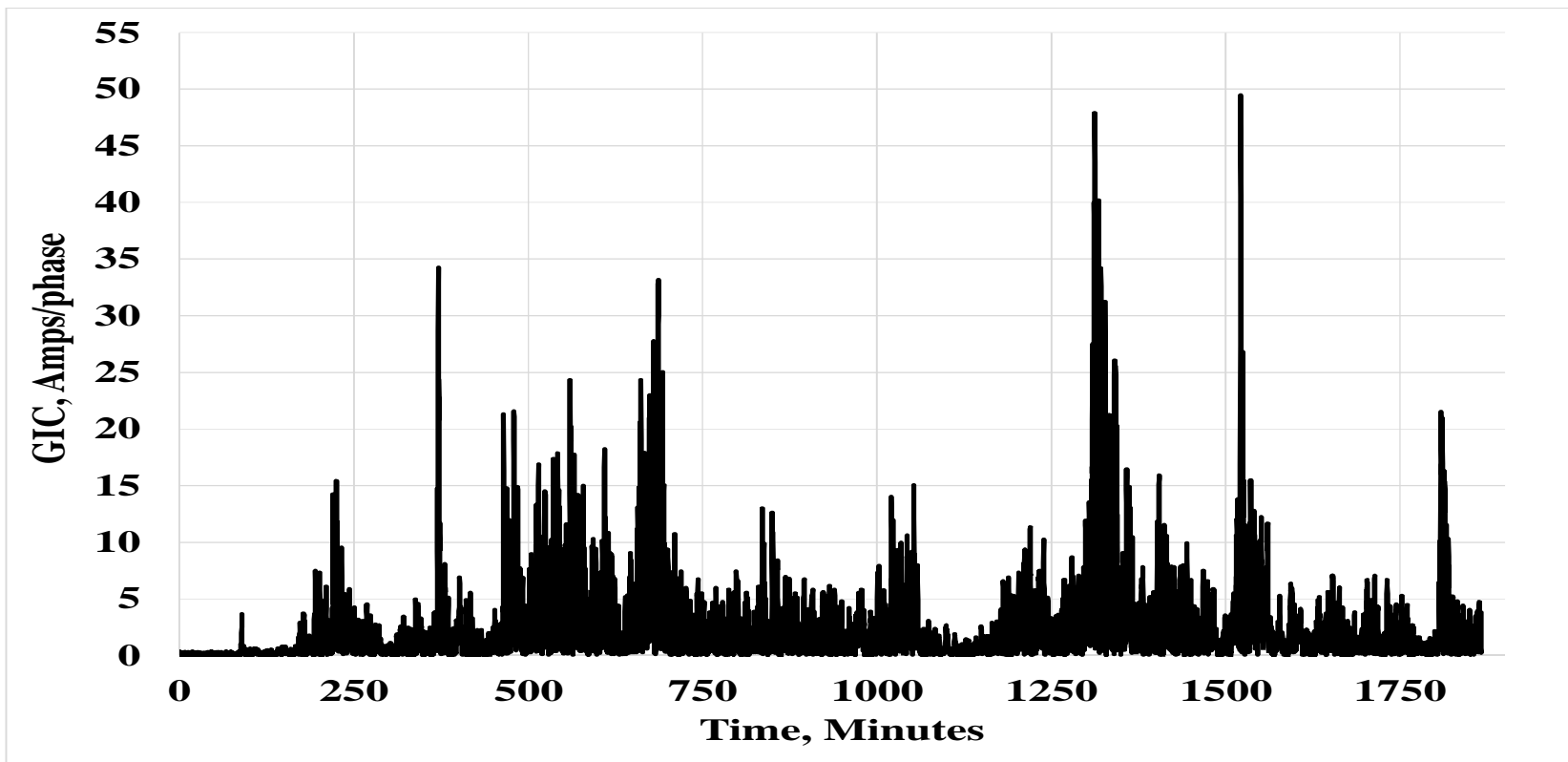
DC System Modelling *

- Winter 2016 base case
- Solve AC power flow
- Input substation/transformer/earth resistivity scaling region data
- Calculate GIC Values:
 - ∅ Constant electric field strength (8V/km), varying storm direction 0-360 degrees in 5 degree steps
 - ∅ Constant storm direction (15 degrees), increasing field strength up to 20V/km in 1V steps
 - 15 degrees was determined from step 1 to be worst case with all-ties-closed

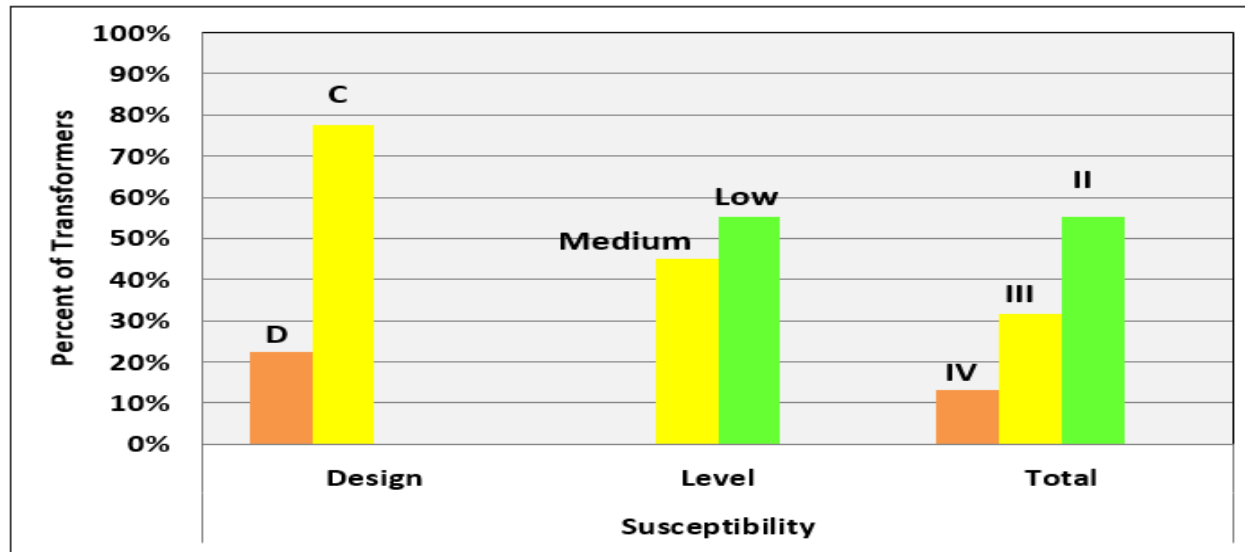
* Assessment of the Impact of GMD on the TVA 500 kV Grid & Power Transformers Part I: GIC Modelling and Initial Studies Gary Kobet and Ian Grant with Scott Dahman, PowerWorld Corporation USA

Results of DC system modeling performed by TVA

§ Highest levels of GIC, and GIC Signature, to be expected under Benchmark GMD event for all 500 kV transformers on the fleet

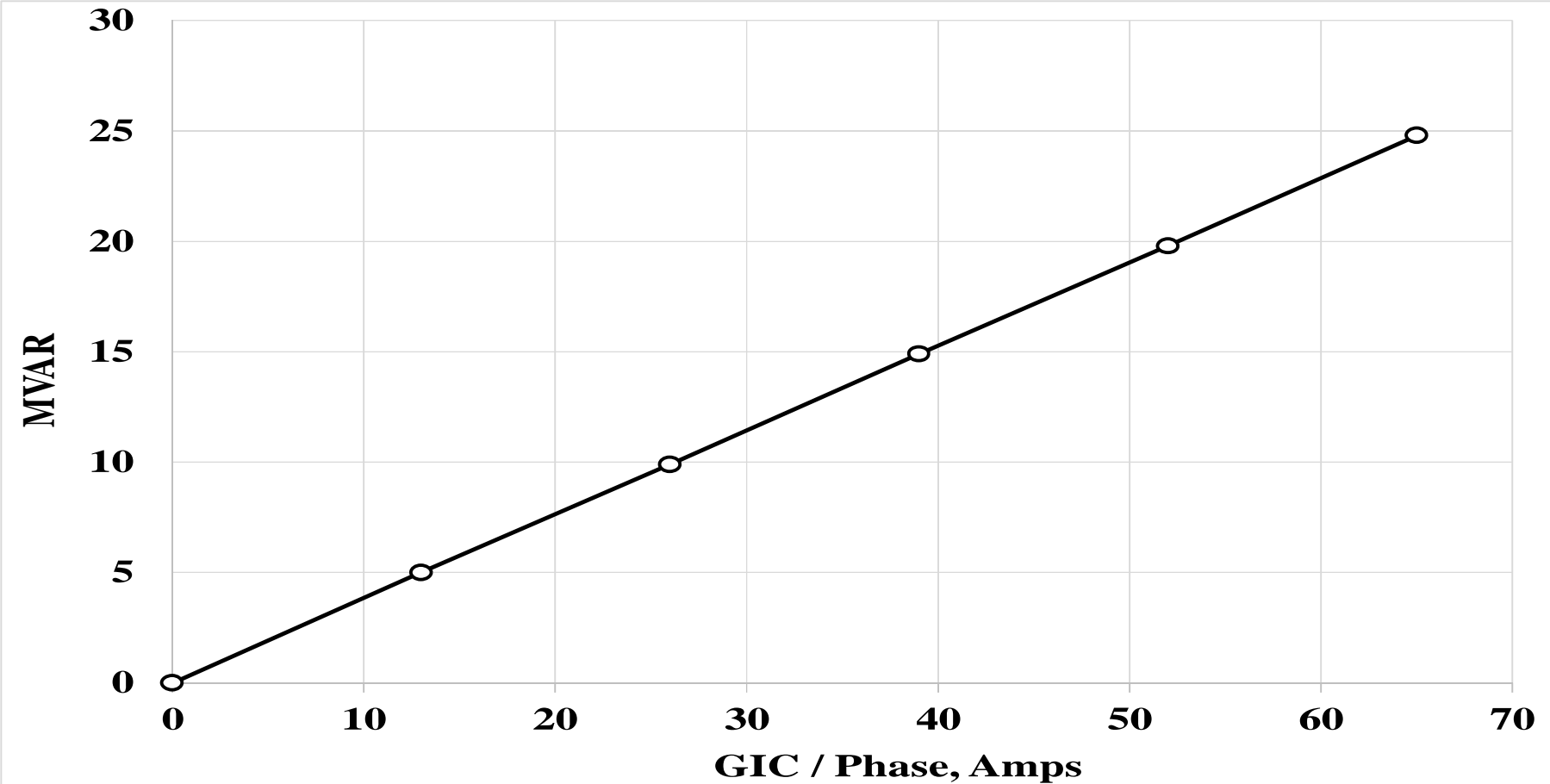


Results of the Assessment of susceptibility of the TVA transformers to effects of GIC

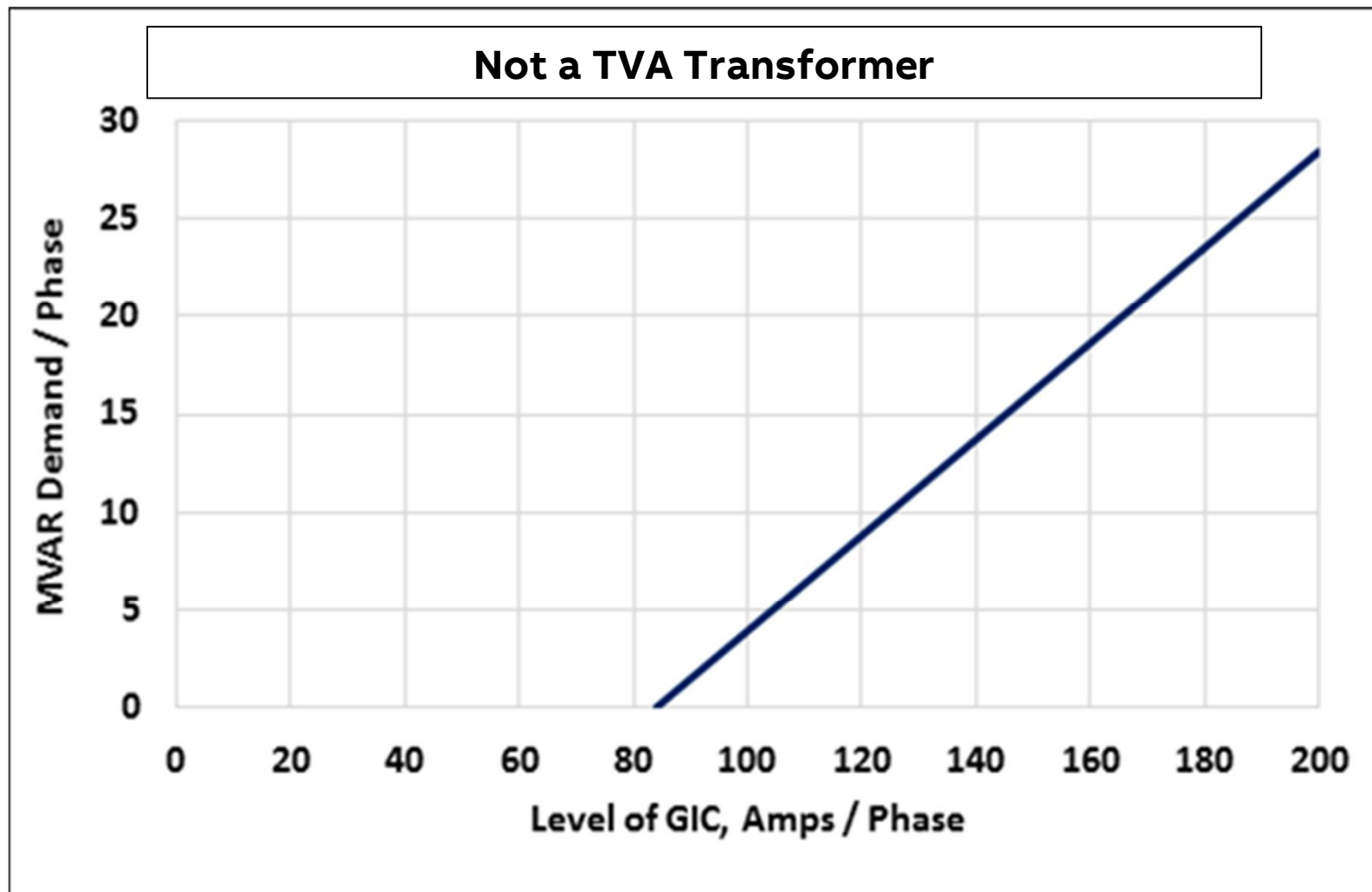


| Number of transformers | Total Susceptibility Categories | | | | |
|------------------------|---------------------------------|-------|-------|-----|-------|
| | IV | III | II | I | Total |
| Actual Count | 27 | 65 | 113 | 0 | 205 |
| % of Total | 13.2% | 31.7% | 55.1% | 0 % | 100% |

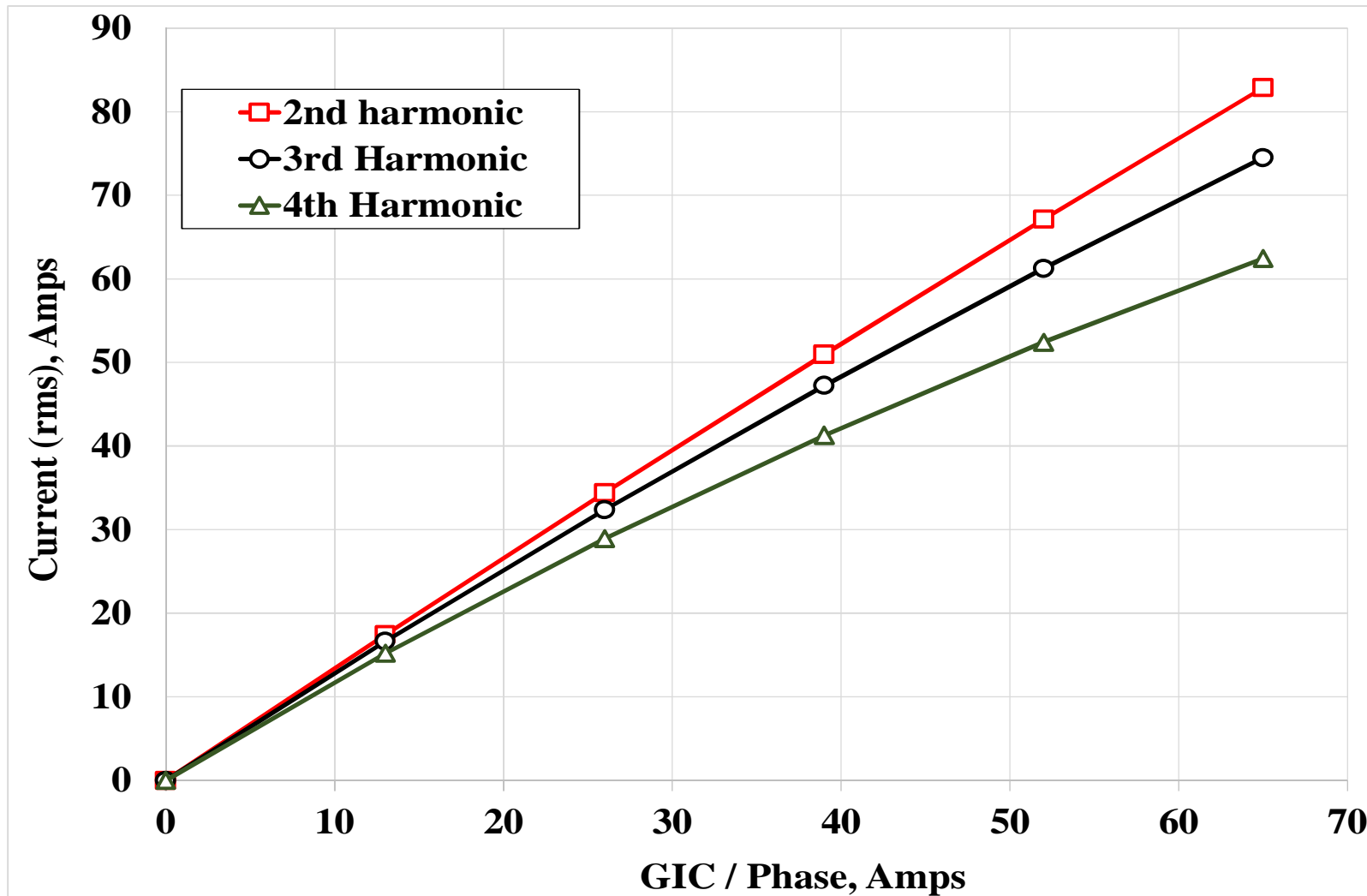
Calculated additional VAR demand – 500 / 22.5 kV, 470 MVA, 1-Ø



Calculated additional VAR demand – 345 / 18.5 kV, 360 MVA, 3-Ø



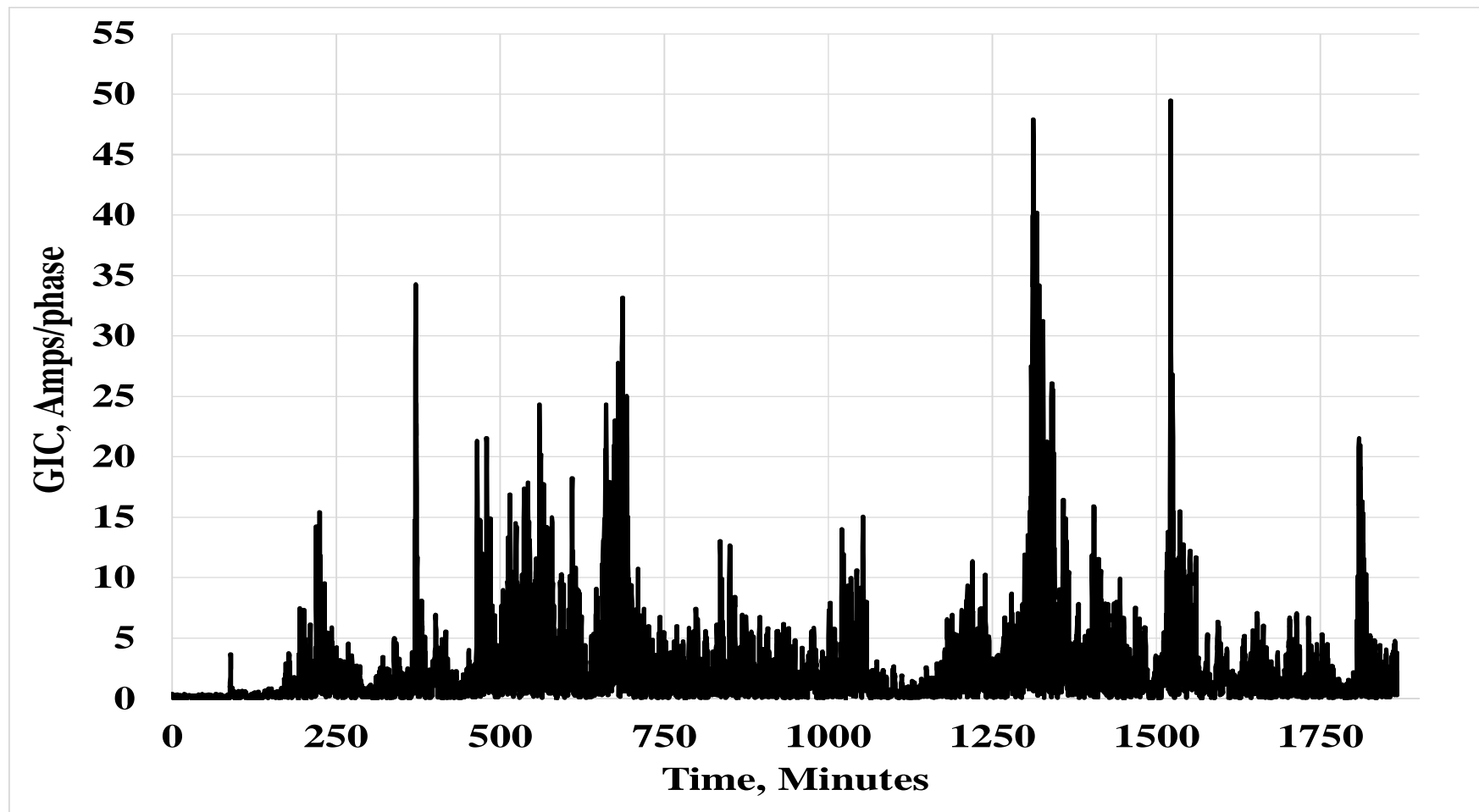
Calculated harmonic currents – 500 / 22.5 kV, 470 MVA, 1-Ø



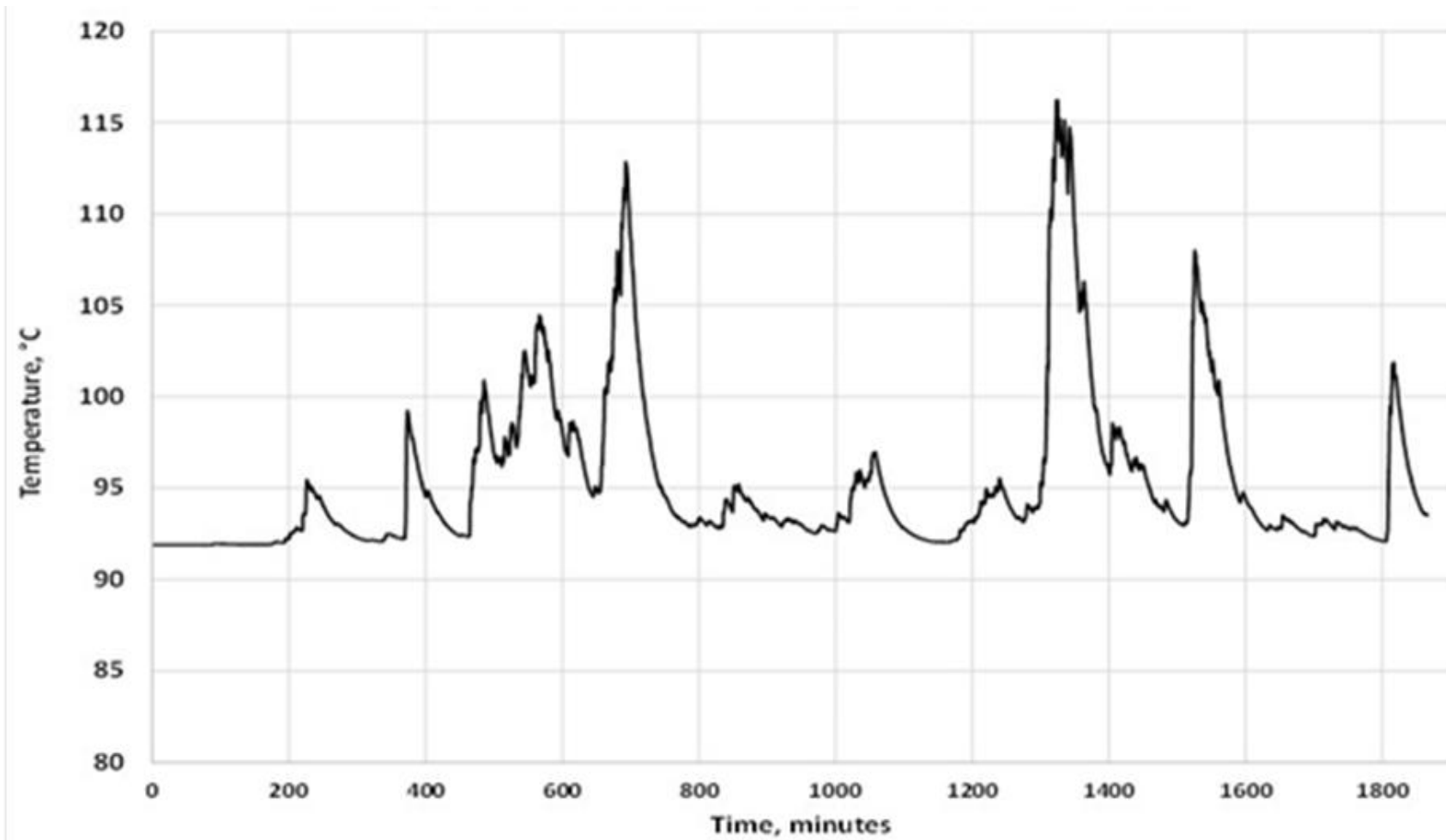
Results of Magnetic Assessment of the TVA 500 kV fleet – Sample

| Substation | MVA | Rated HV voltage, kV | Highest measured GIC current, Amps / Phase | Calculated | | | | |
|------------------------|------------|----------------------|--|-------------|-------------|------------------------|-----------------|-----------------|
| | | | | MVAR demand | K-factor | Harmonic Current, Amps | | |
| | | | | | | 2 nd | 3 rd | 4 th |
| Benton Magnolia | 360 | 500 | 24 | 0 | -- | 0 | 0 | 0 |
| Bradley | 448 | 500 | 15 | 5.7 | 1.31 | 19.9 | 18.8 | 17.1 |
| Bull Run | 448 | 500 | 41 | 16.0 | 1.31 | 53.0 | 48.7 | 42.2 |
| | 400 | 500 | 41 | 15.6 | 1.29 | 65.9 | 58.2 | 47.1 |

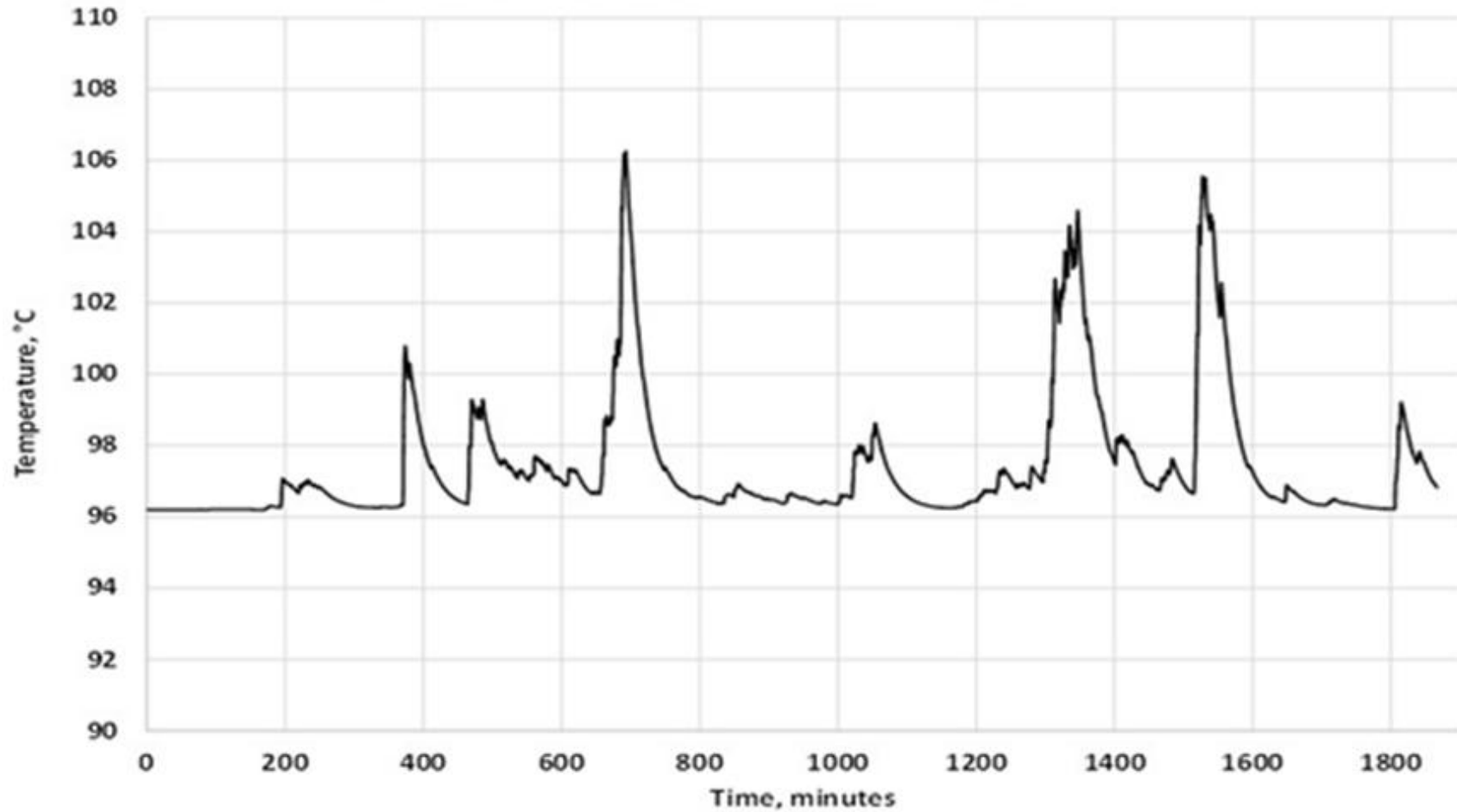
GIC Signature to be expected under Benchmark GMD event for one of the 500 kV transformers on the fleet



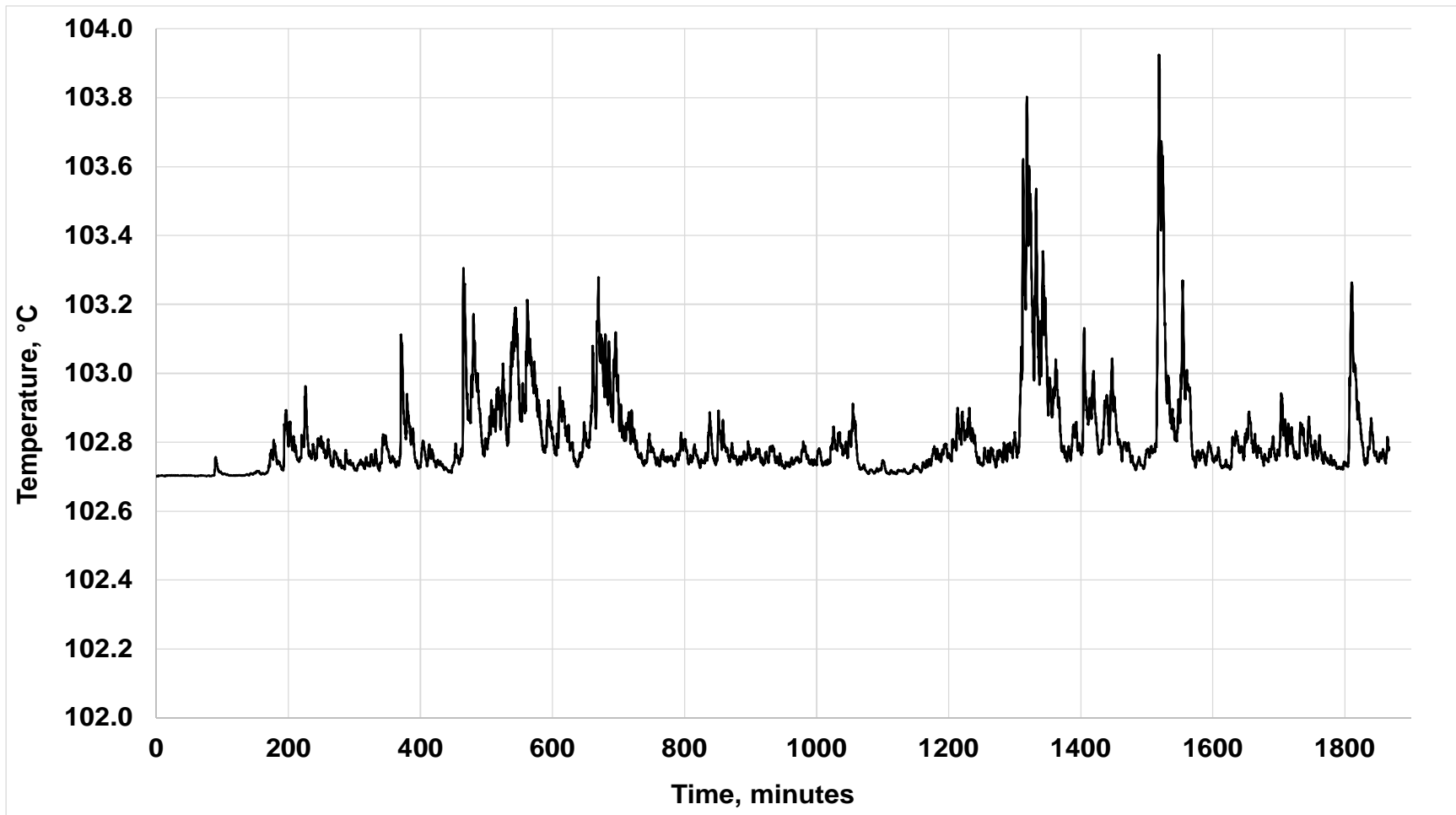
Calculated Fitch plate hot spot temperatures of transformers at one Generating station corresponding to Calculated GIC Signature



Calculated Tank wall hot spot temperatures of Shell form transformers at one Substation corresponding to Calculated GIC Signature



Calculated Winding hot spot temperatures of transformers at a Generating station corresponding to Calculated GIC Signature



Results of Thermal Assessment of the TVA 500 kV fleet – Sample

| Transformer | Location | MVA | HV Rated, kV | GIC, A / Ph | Maximum Hot Spot Temperature, °C | |
|-------------|------------|-----|-----------------|----------------|----------------------------------|------------------|
| | | | | | Windings | Structural Parts |
| BUR1 | Bull Run | 448 | 500 | 37.9 | 100.6 | 113.3 |
| BUR2 | | | | | 100.0 | 106.0 |
| EP1 | East Point | 250 | 500 | 22.9 | 106.2 | 130.1 |
| EP2 | | | | | | |
| EP3 | | | | | | |
| EP4 | | | | | | |
| M1 | Maury | 448 | 500 | 32.5 | 97.0 | 124.9 |
| M2 | | | | | | |
| M3 | | | | | | |
| M4 | | | | | | |

