Elimination of Transformer Inrush Currents When Energizing Unloaded Power Transformers

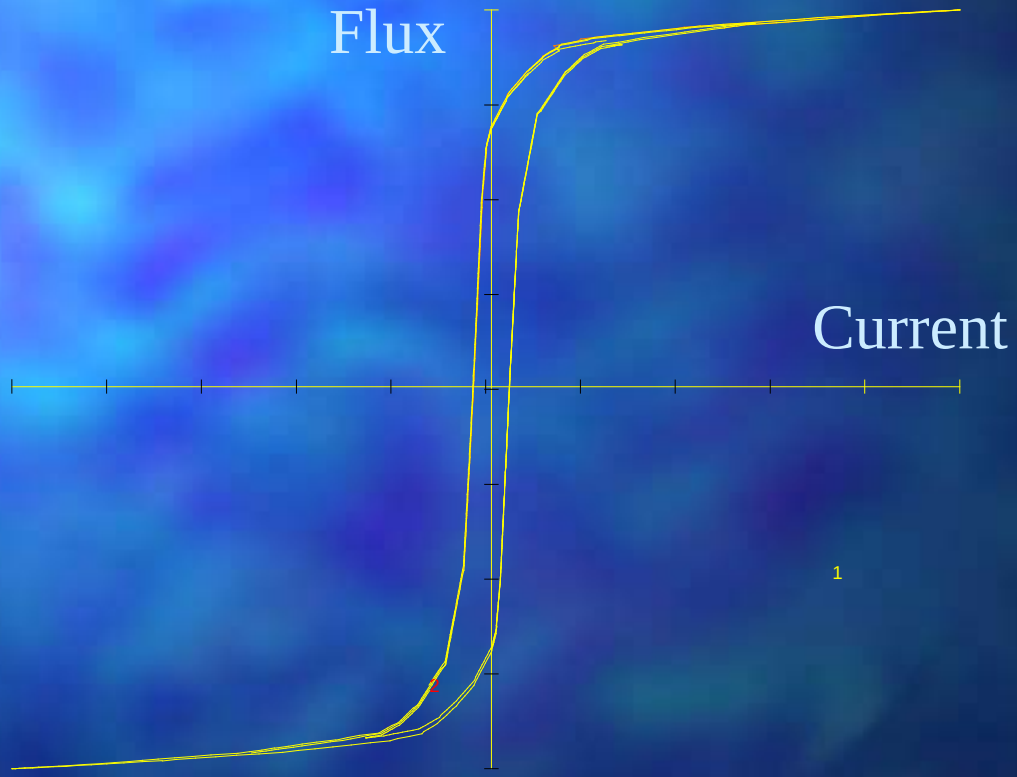
John H. Brunke

Eidgenössische Technische Hochschule Zürich

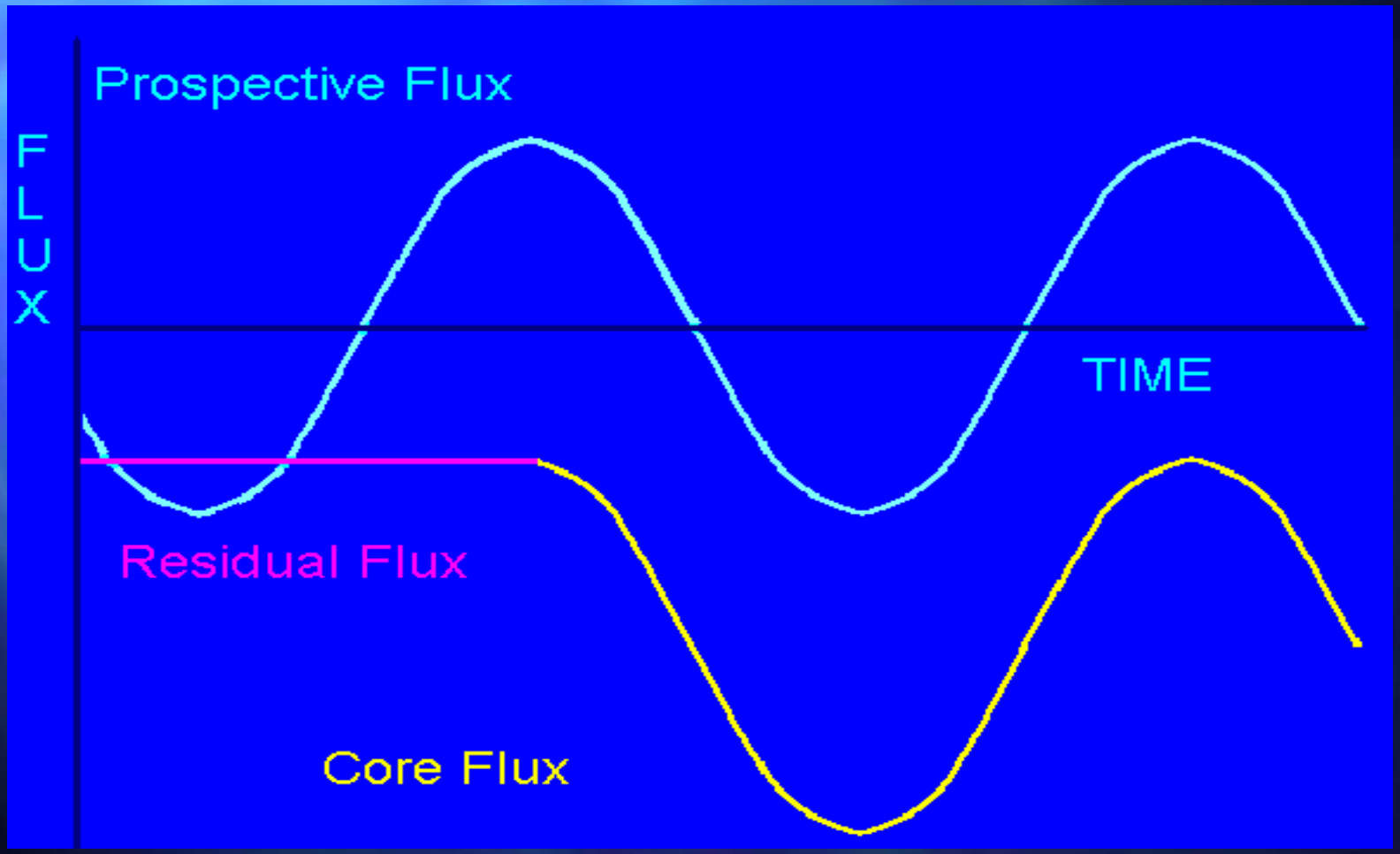
Presentation Outline

- Basics of transformer inrush transients
- Three phase transformer core flux transients based on model studies
- New controlled closing strategies
- Statistical performance

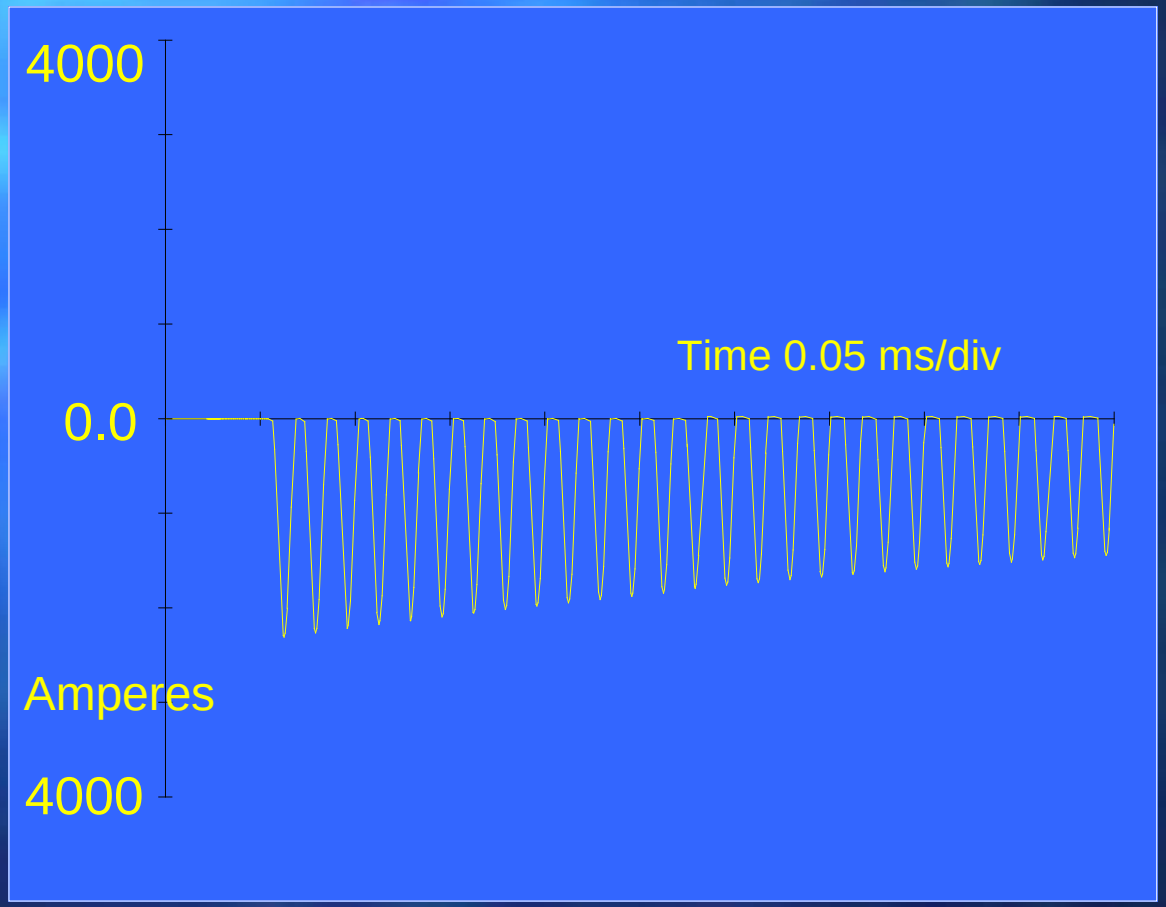
Transformer Core Characteristics



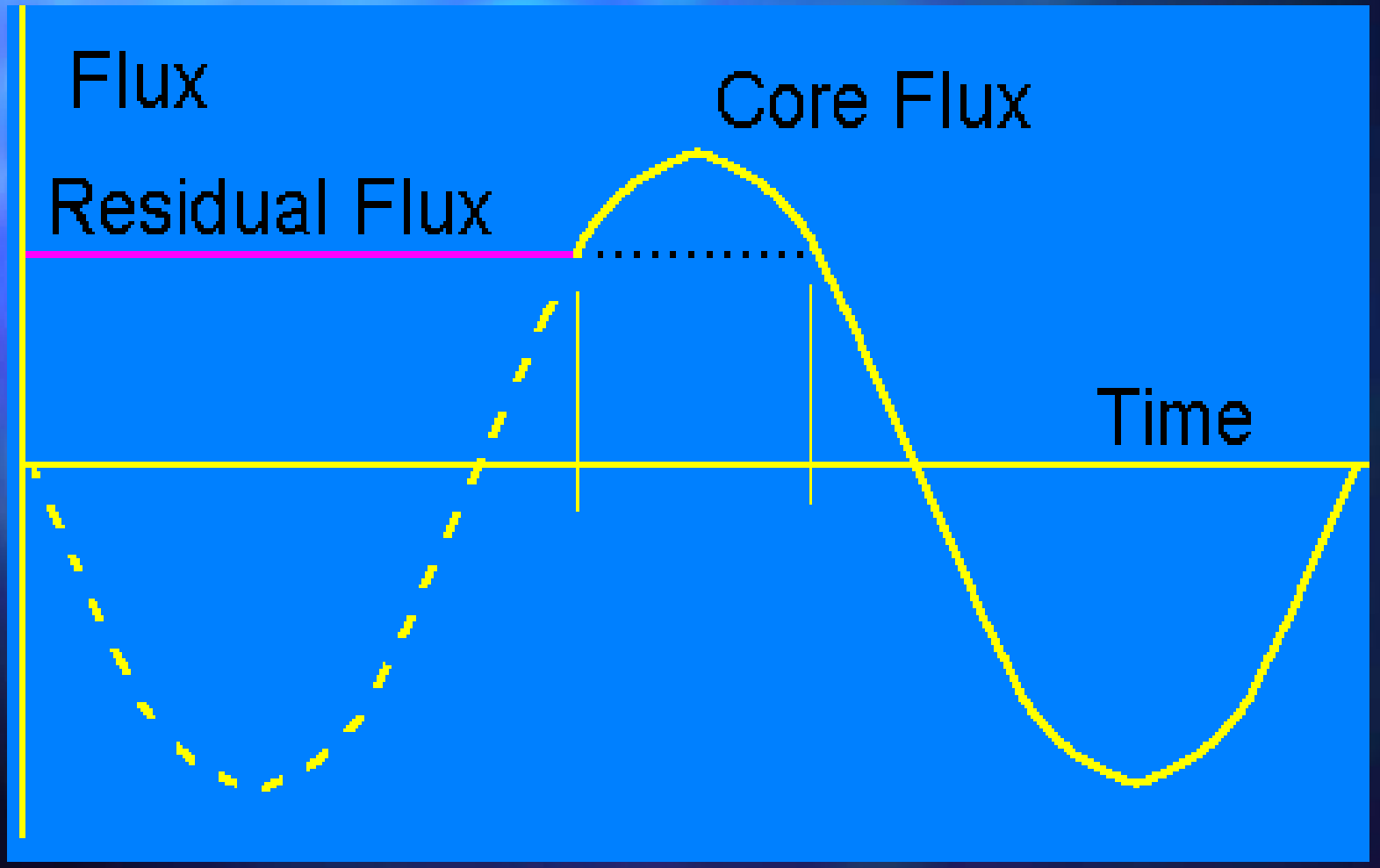
Energizing a Transformer



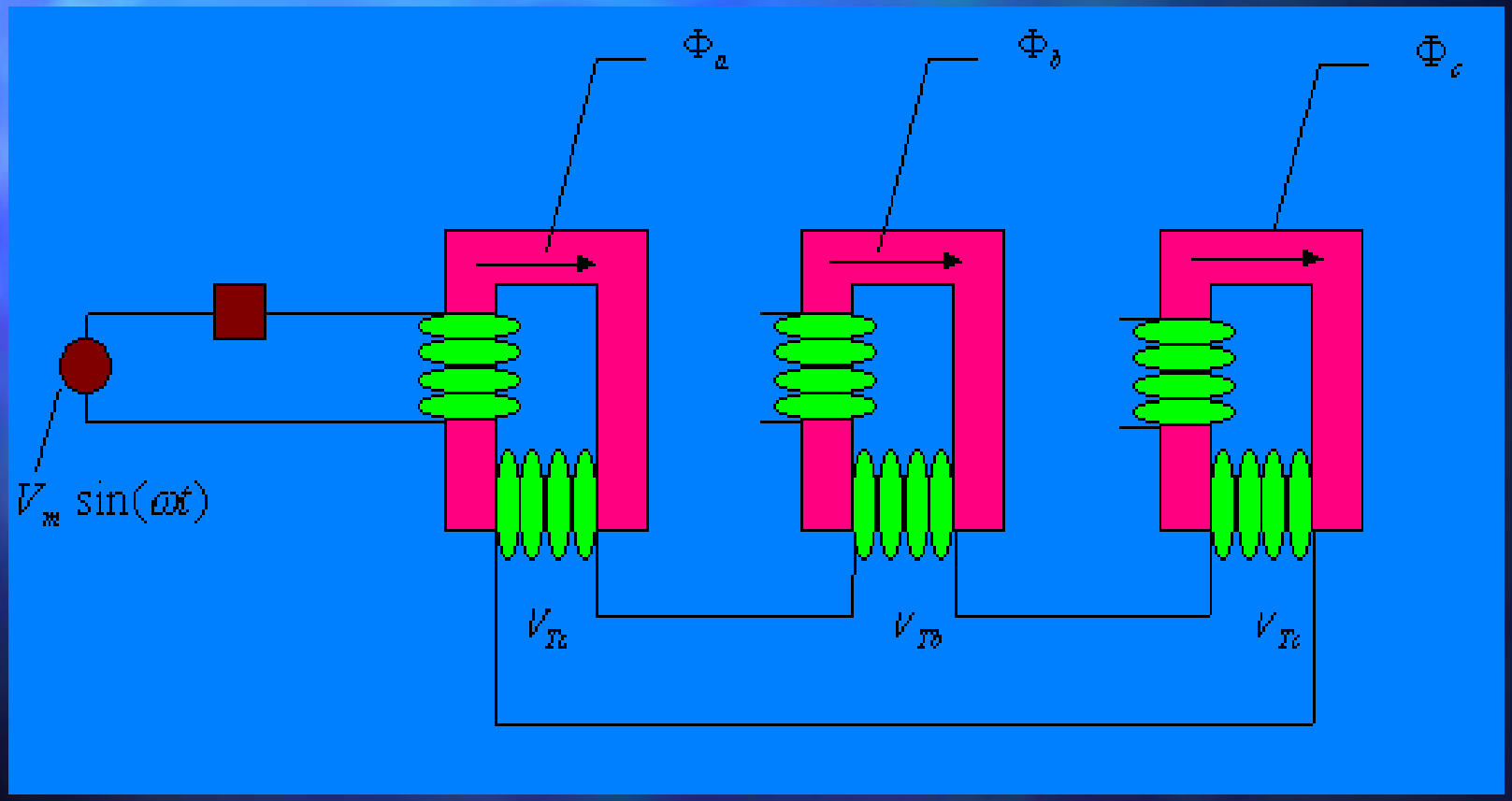
Transformer Inrush Current



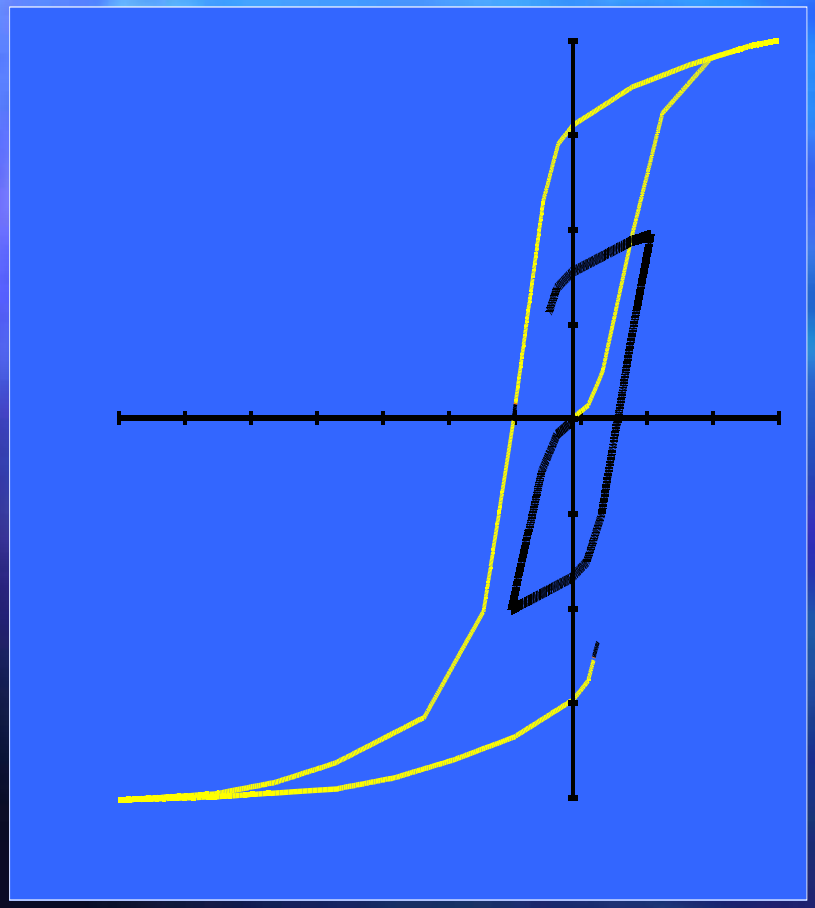
Optimal controlled closing

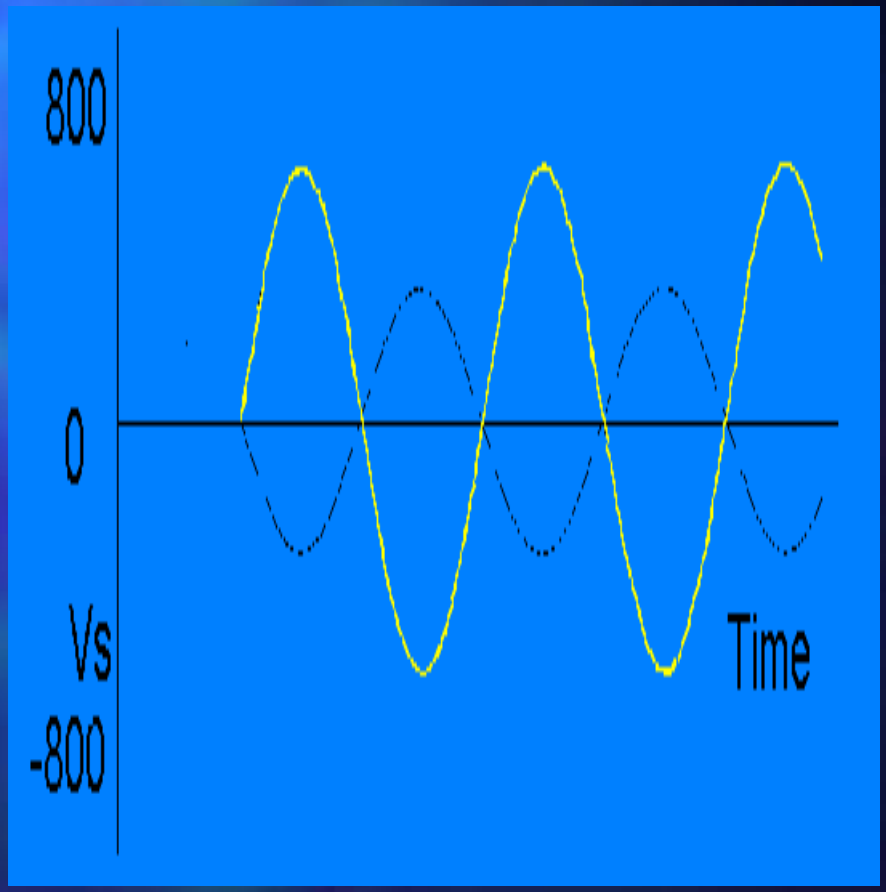


Three Phase Transformers

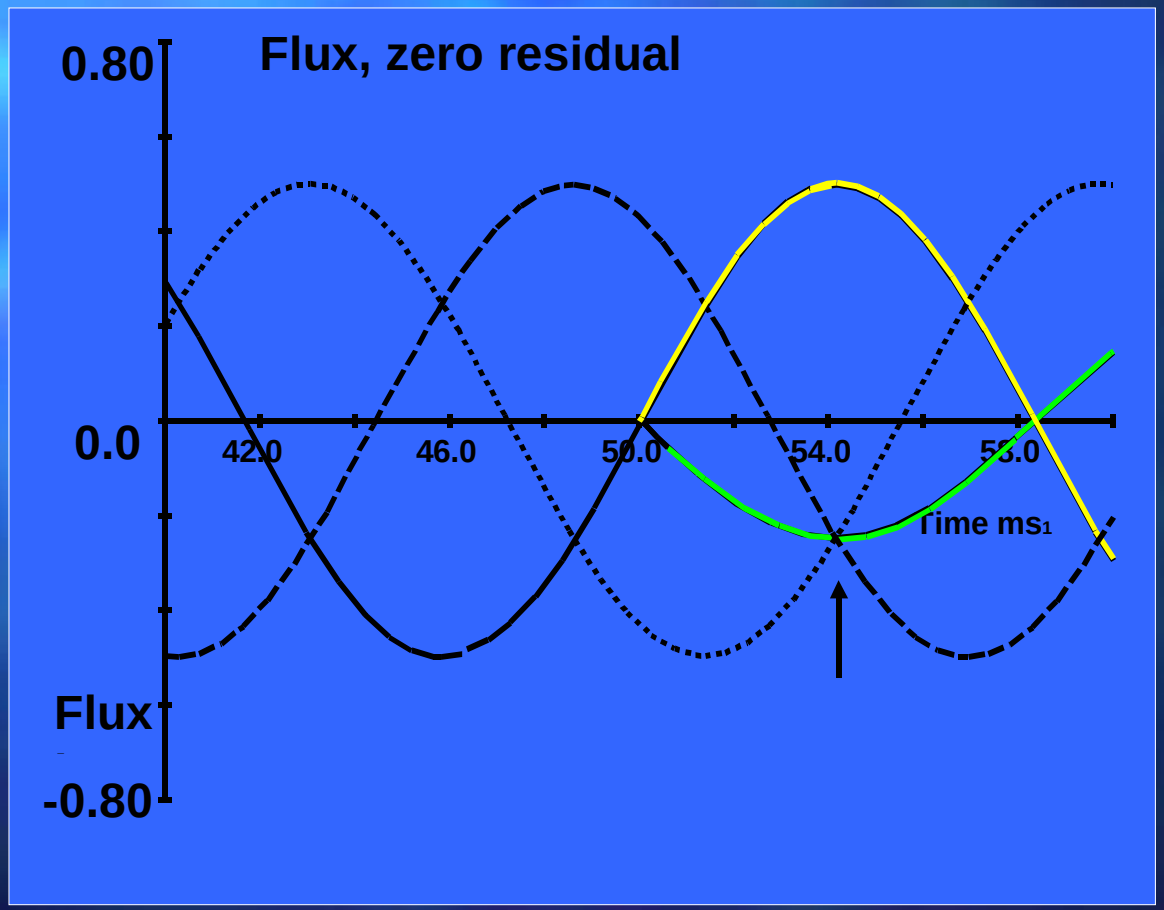


Core Flux - No residual

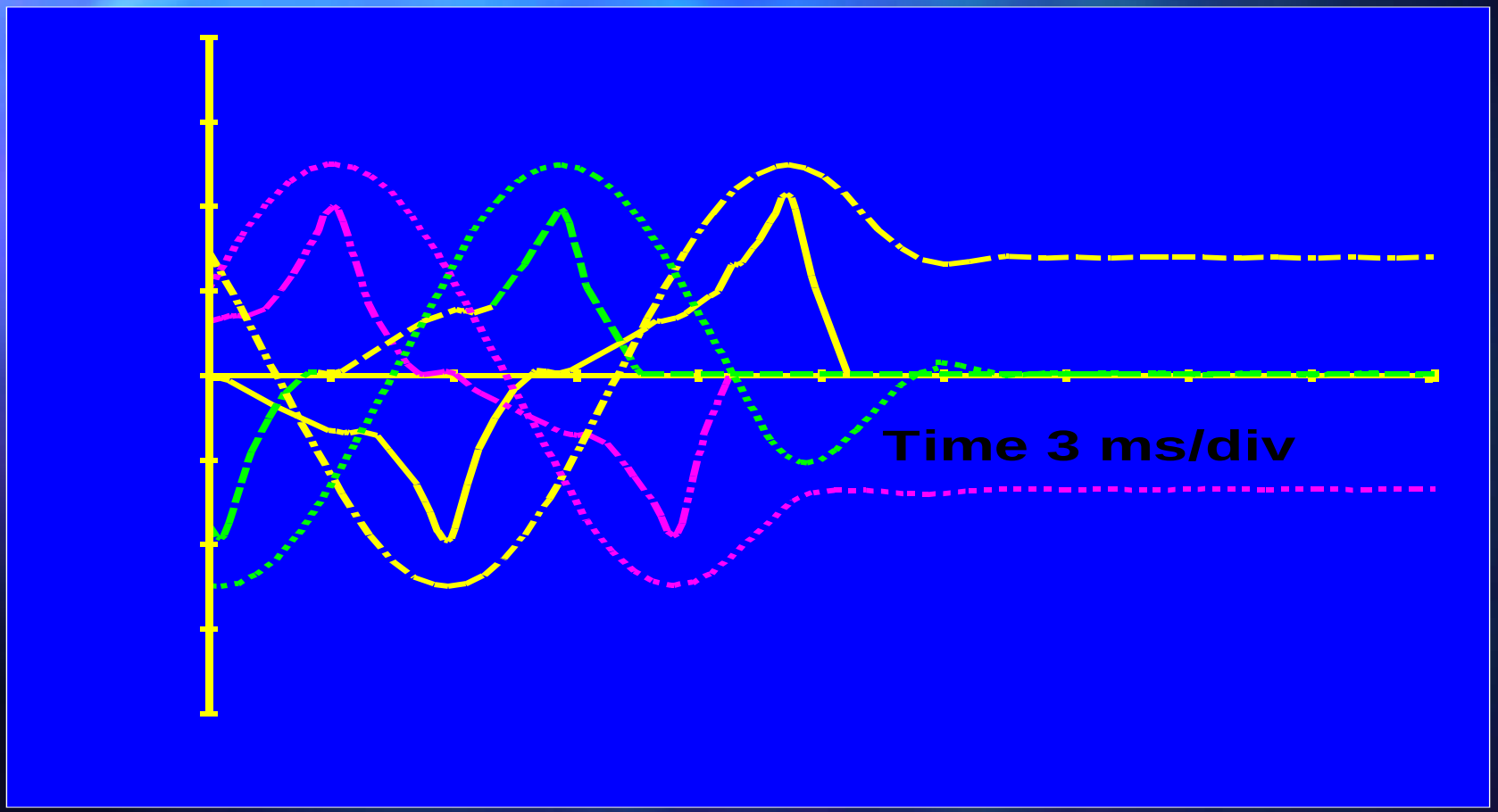




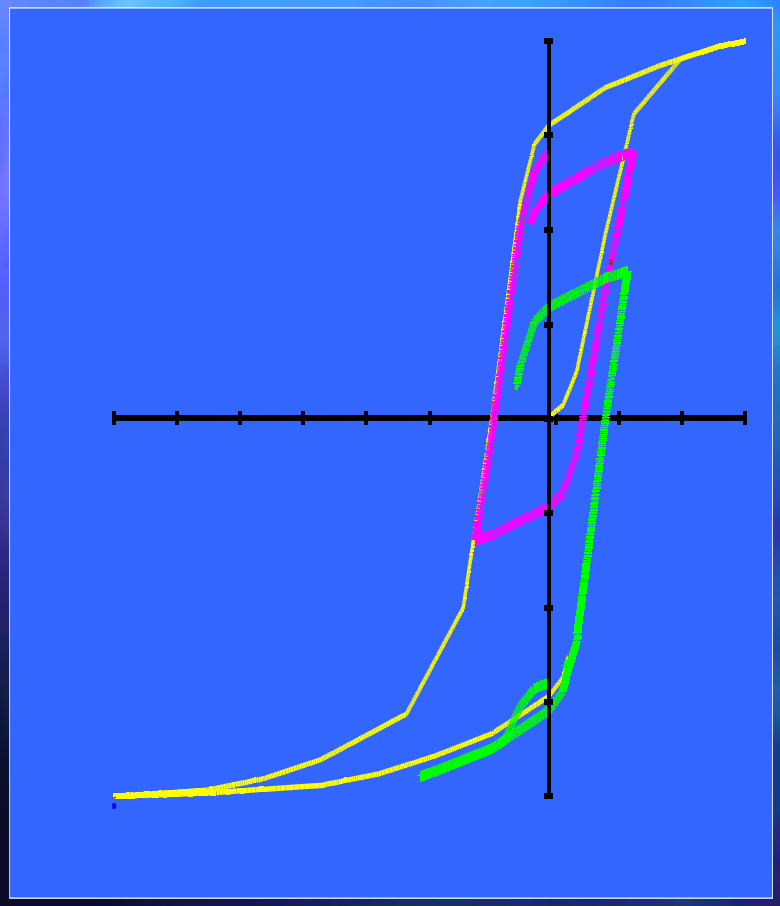
Prospective and Dynamic Flux

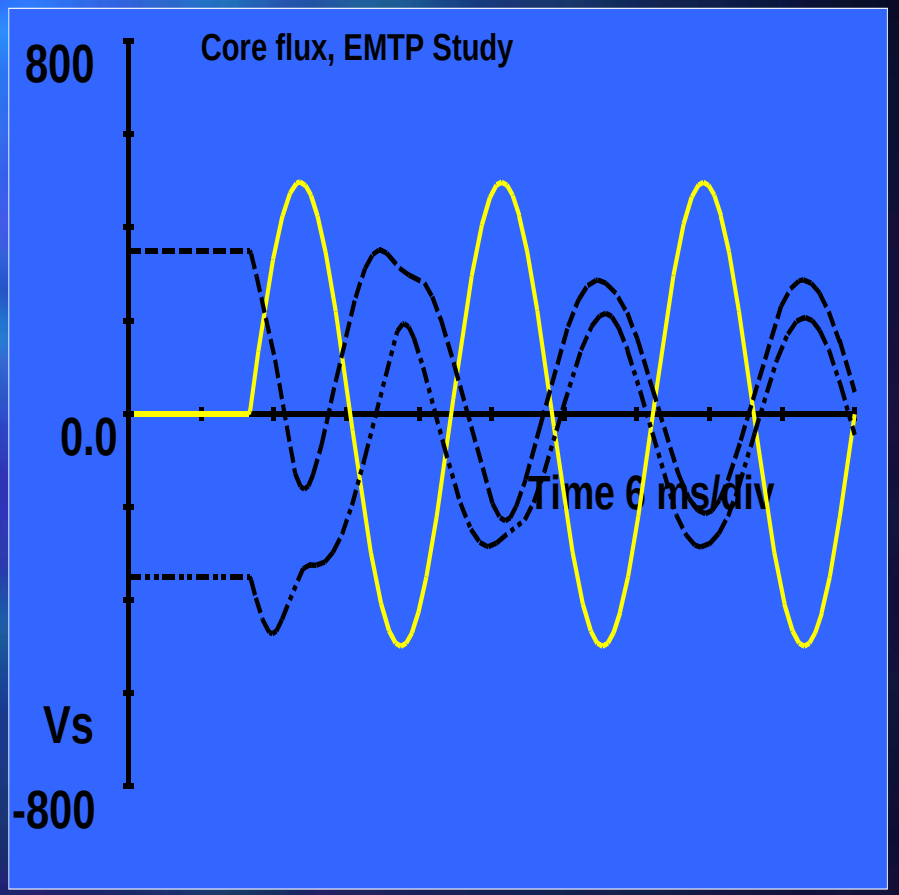


Three phase residual flux

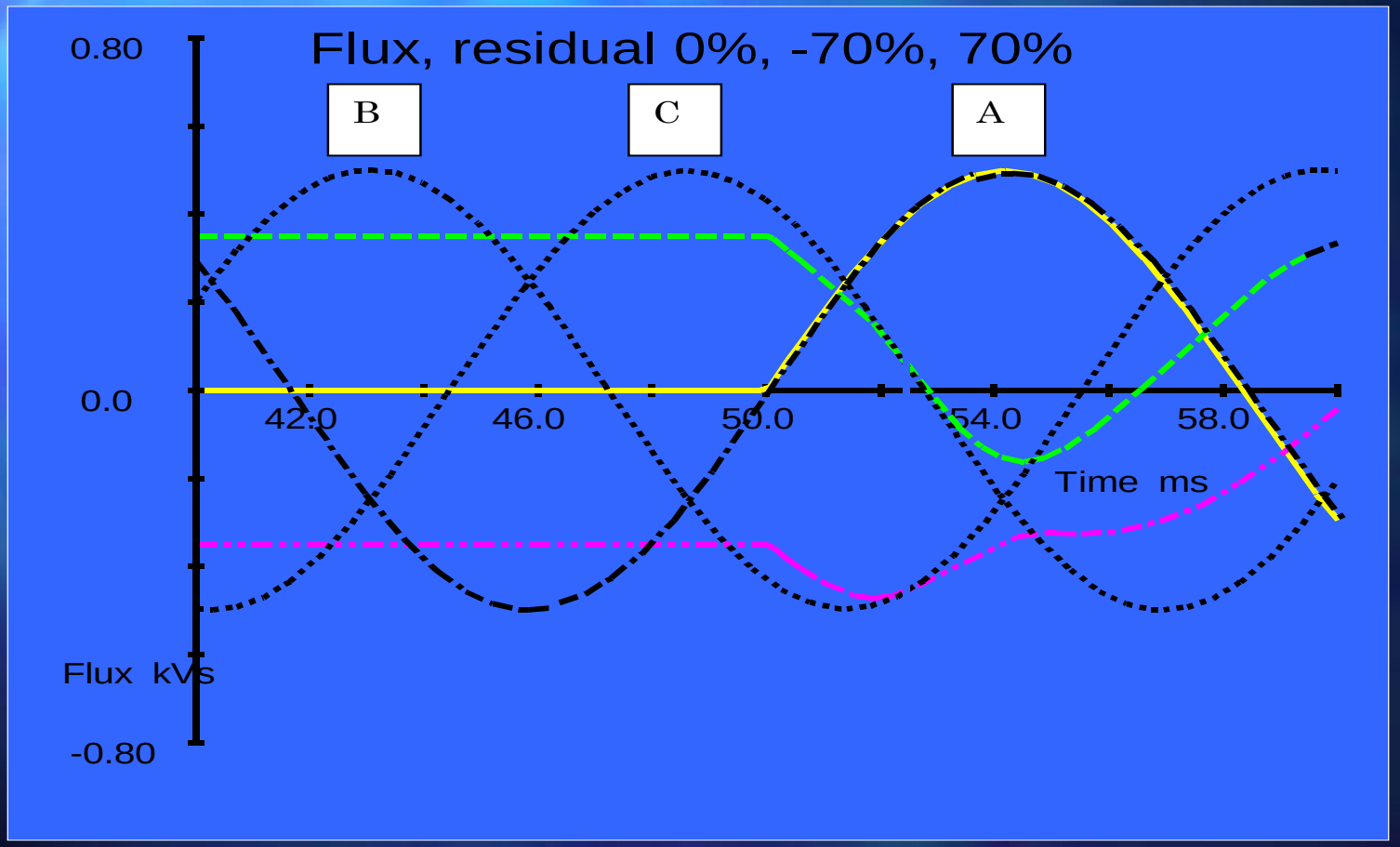


Core flux with residual flux

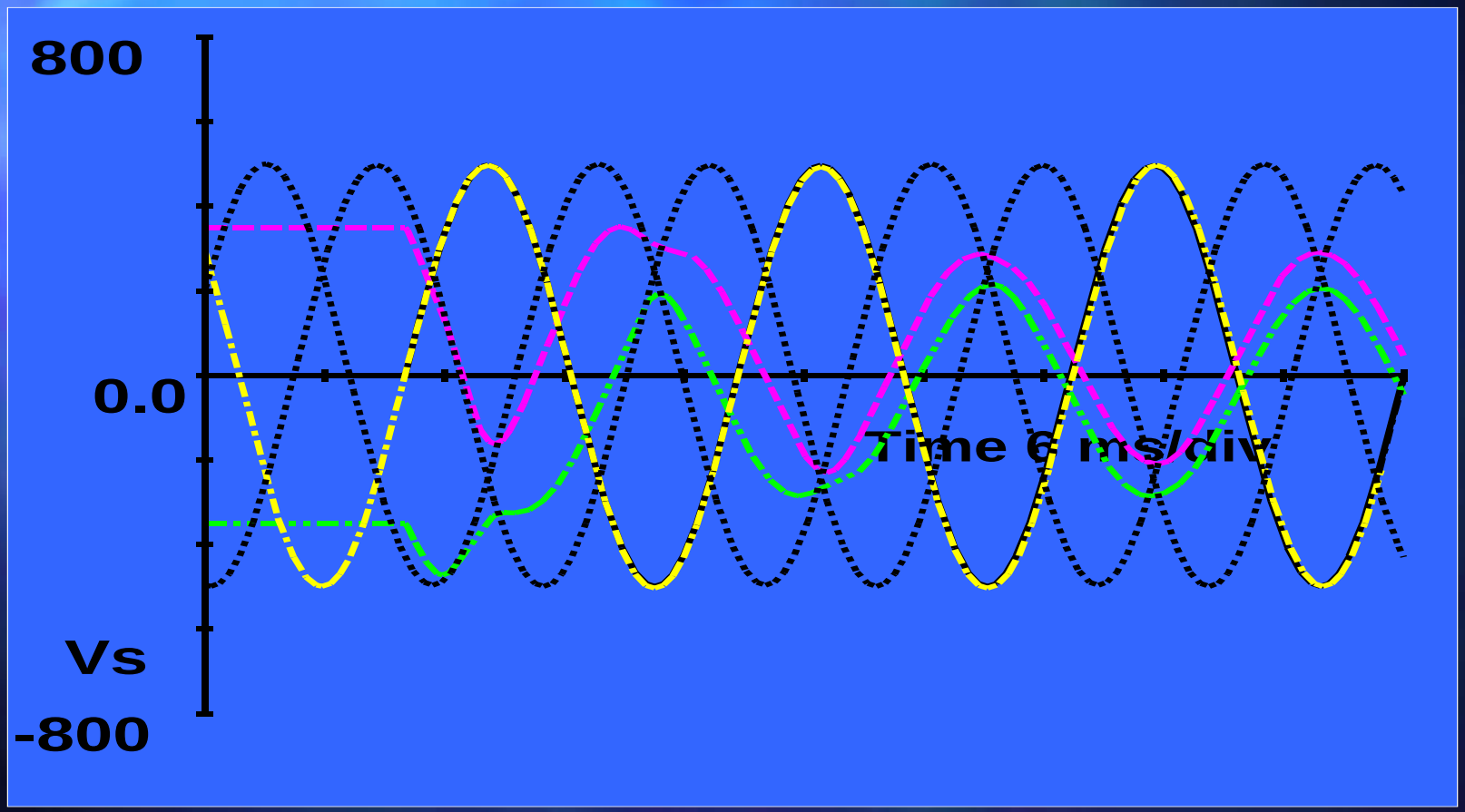




Prospective and Dynamic Flux



Prospective and Dynamic Flux

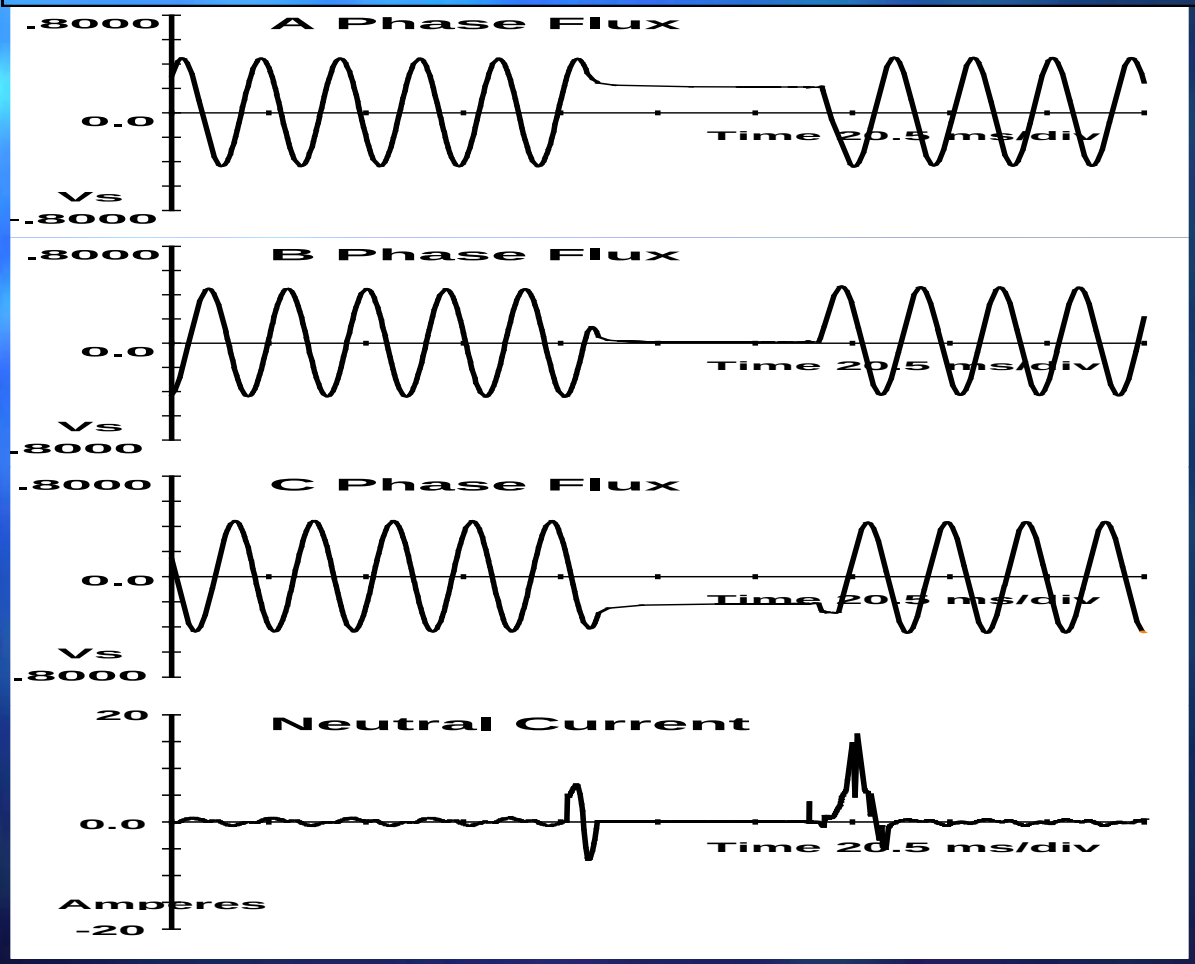


Closing Strategies

- Rapid closing strategy
  - Requires detailed transformer data and look up table
- Delayed Closing strategy
  - Generalized approach
- Three phase strategy
  - Limited to high residual flux scenarios

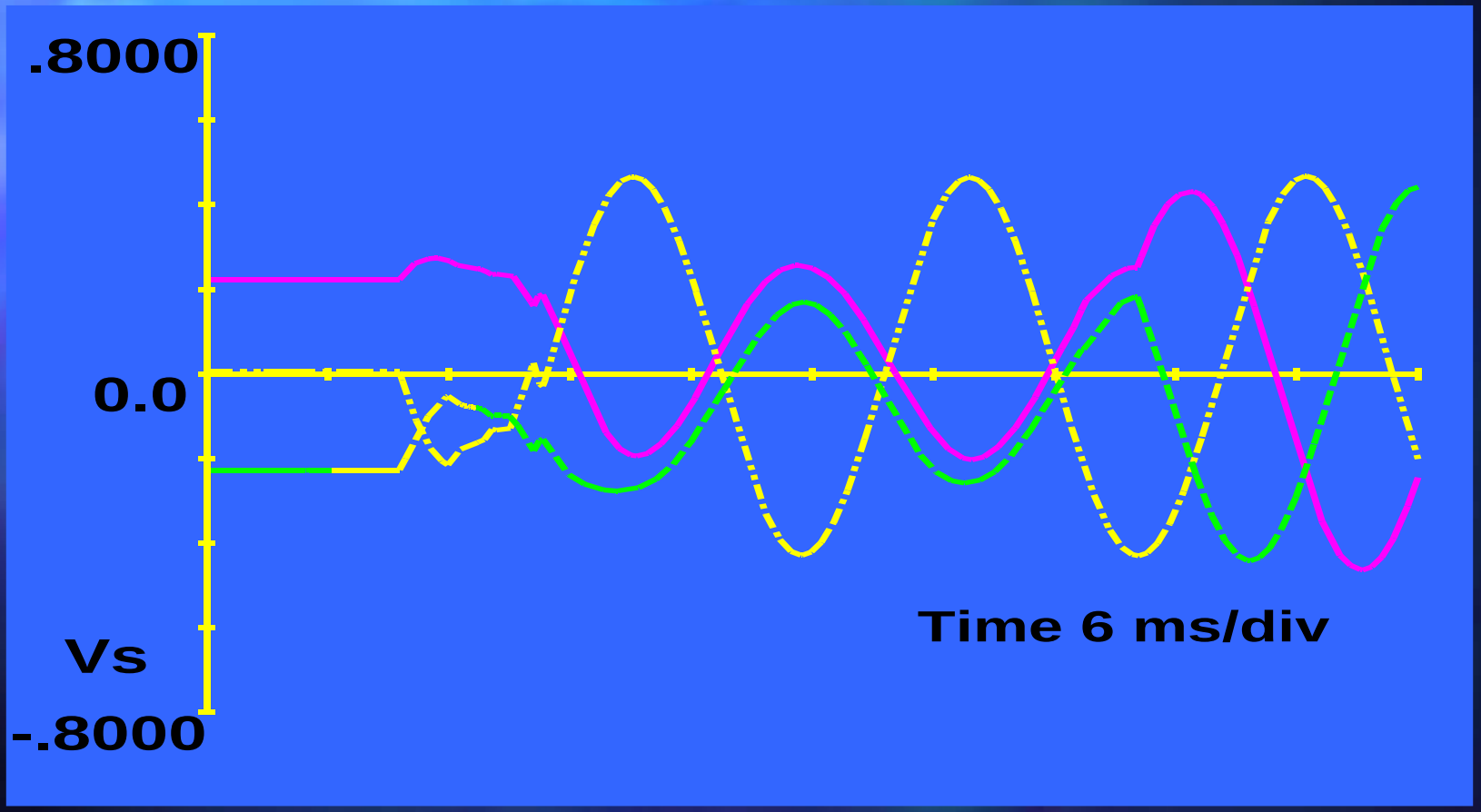
Verification - Laboratory Tests

Rapid Closing Strategy



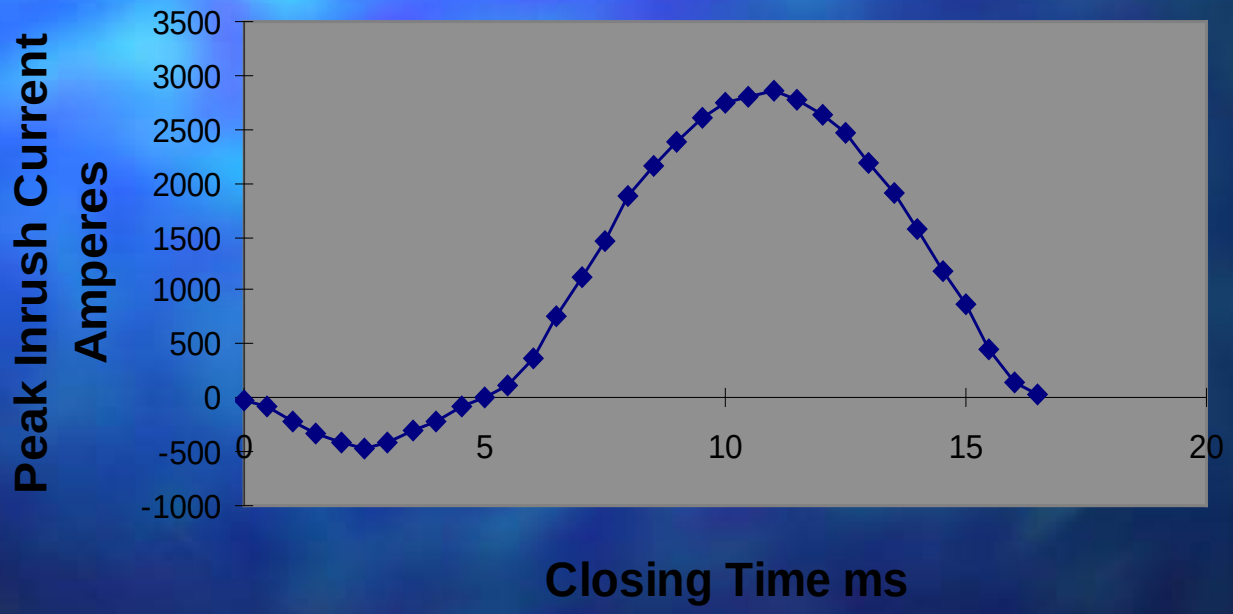
Verification - Laboratory Tests

Delayed Closing Strategy

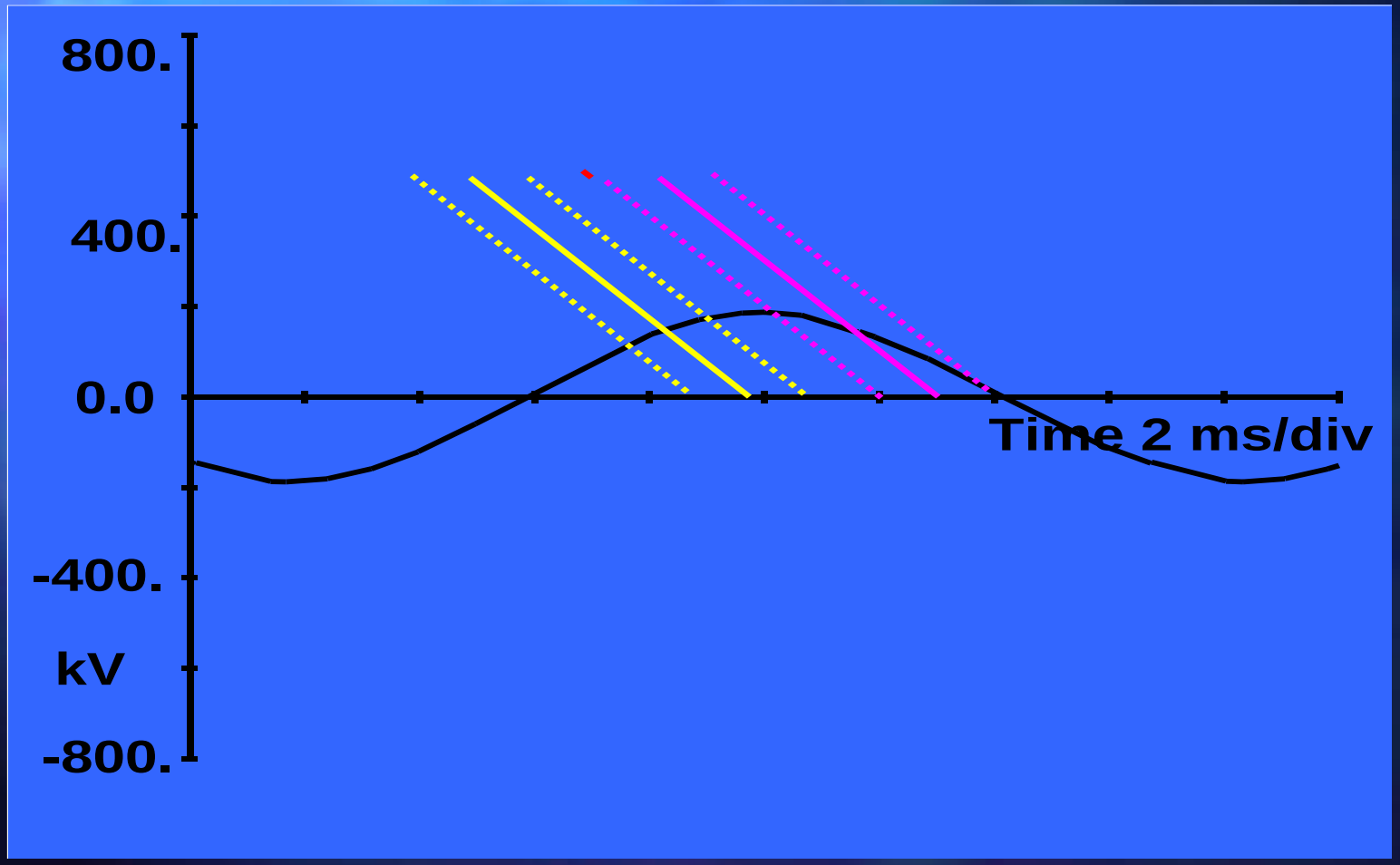


Effect of Closing Error

Model Study Results, Peak Inrush Current for a 70% Residual as a Function of Closing Angle



Prestrike



Statistical Studies

- Benchmarks - linear bias runs with statistical pole span 1000 studies/run
- Controlled studies - 200 studies/run 0.5, 1.0, 1.5, 2.0 ms timing error ranges

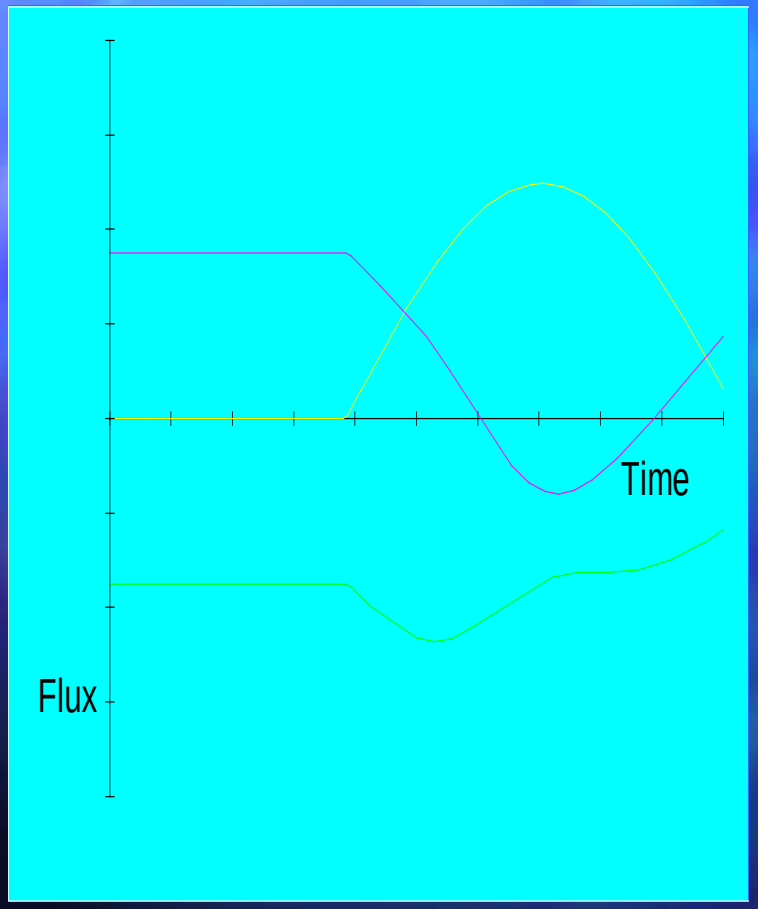
Statistical Performance

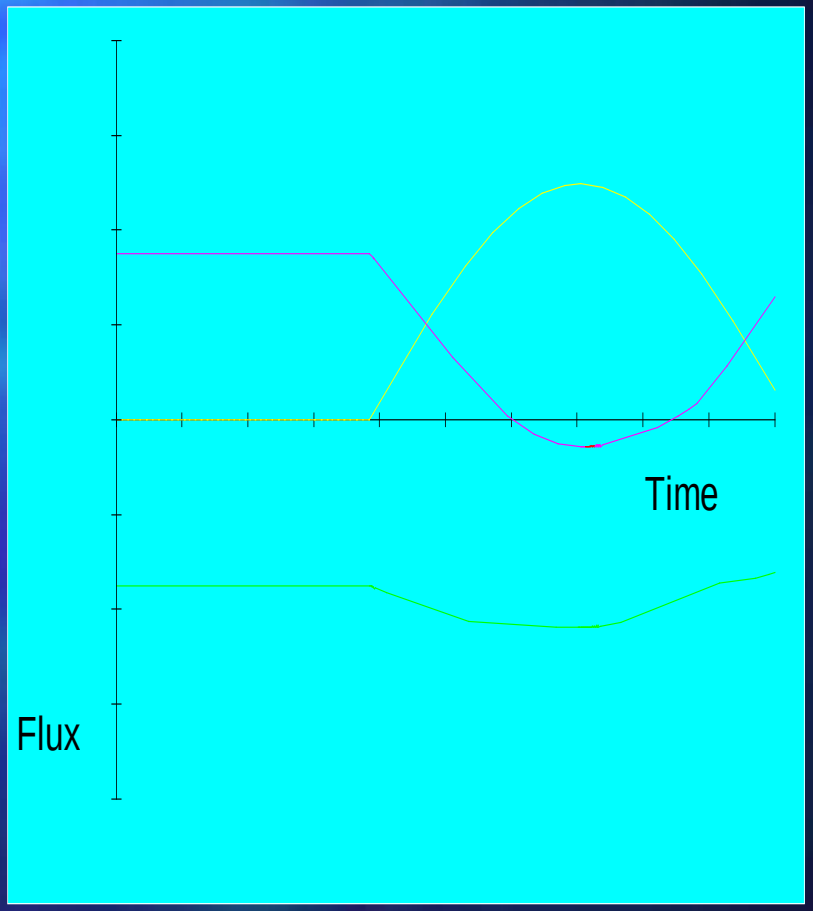
CLOSING TIME SCATTER, 3 SIGMA	LEVEL EXCEEDING 2% AMPERES	PERCENT REDUCTION FROM UNCONTROLLED 2% LEVEL
0.5	62	98%
1.0	140	95.3
1.5	350	88.3%
2.0	620	79.3

Table 5.3. The improvement in performance using controlled closing with a 70% residual flux. .

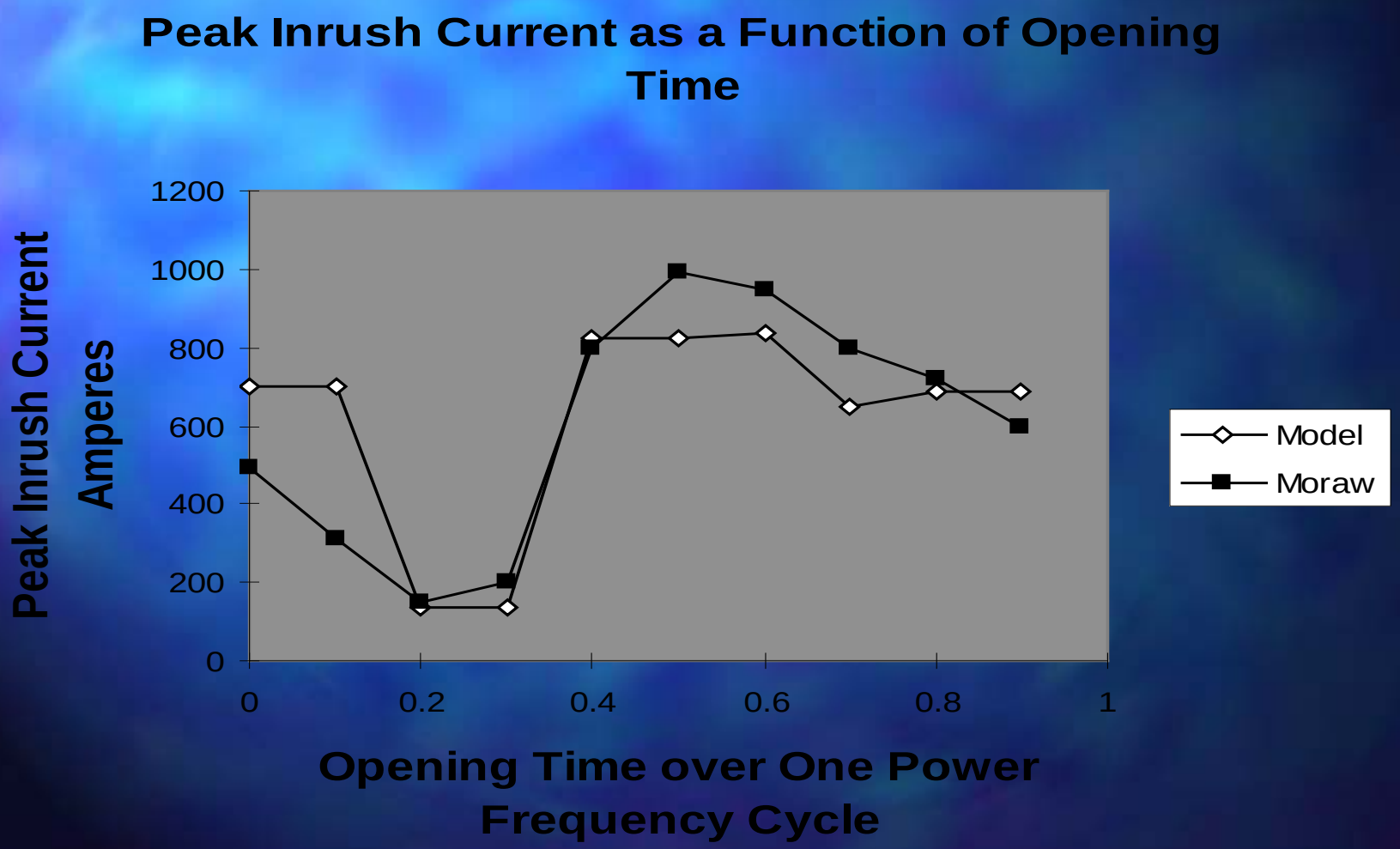
Transformer Model

Effect of Capacitance

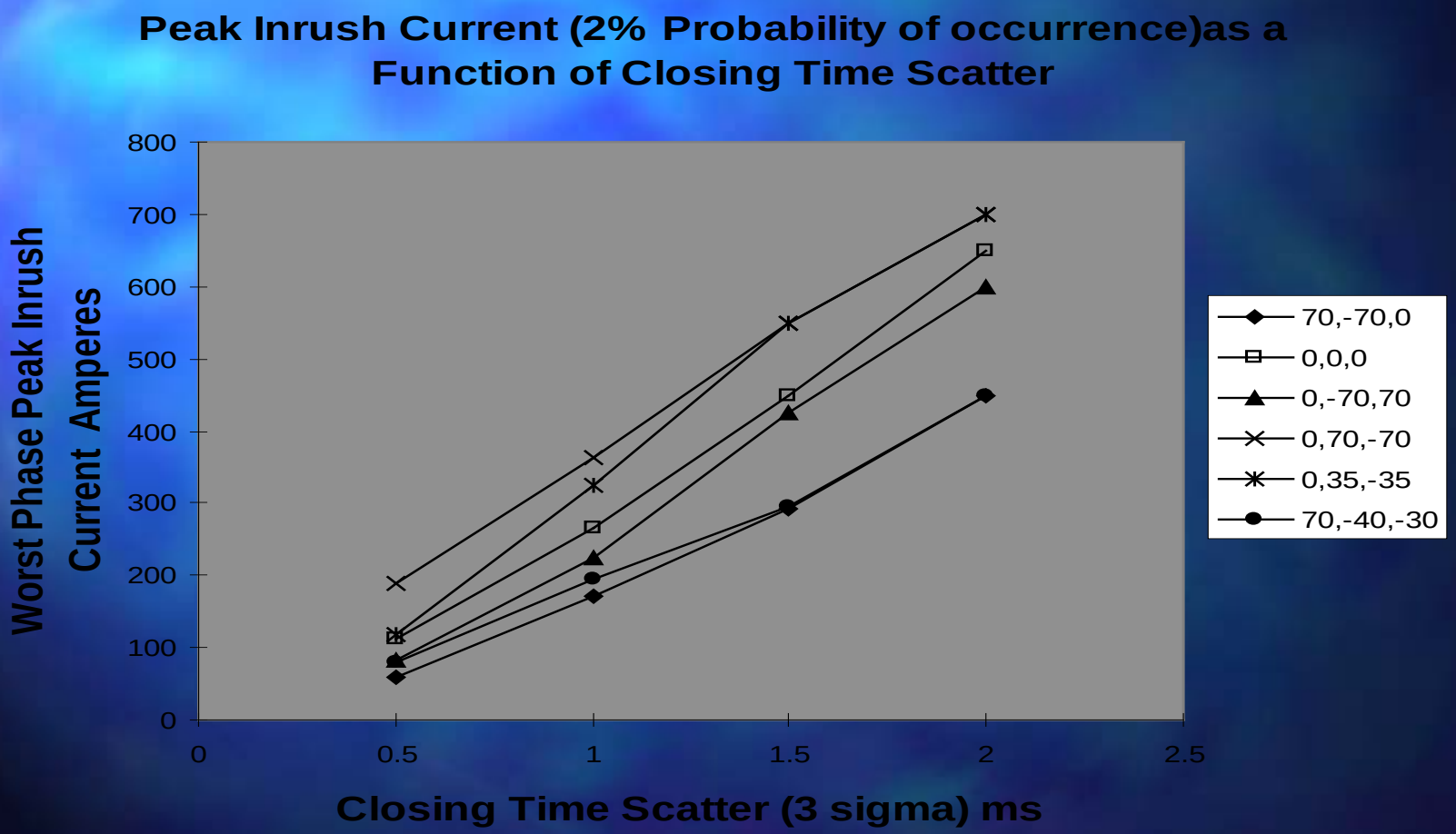




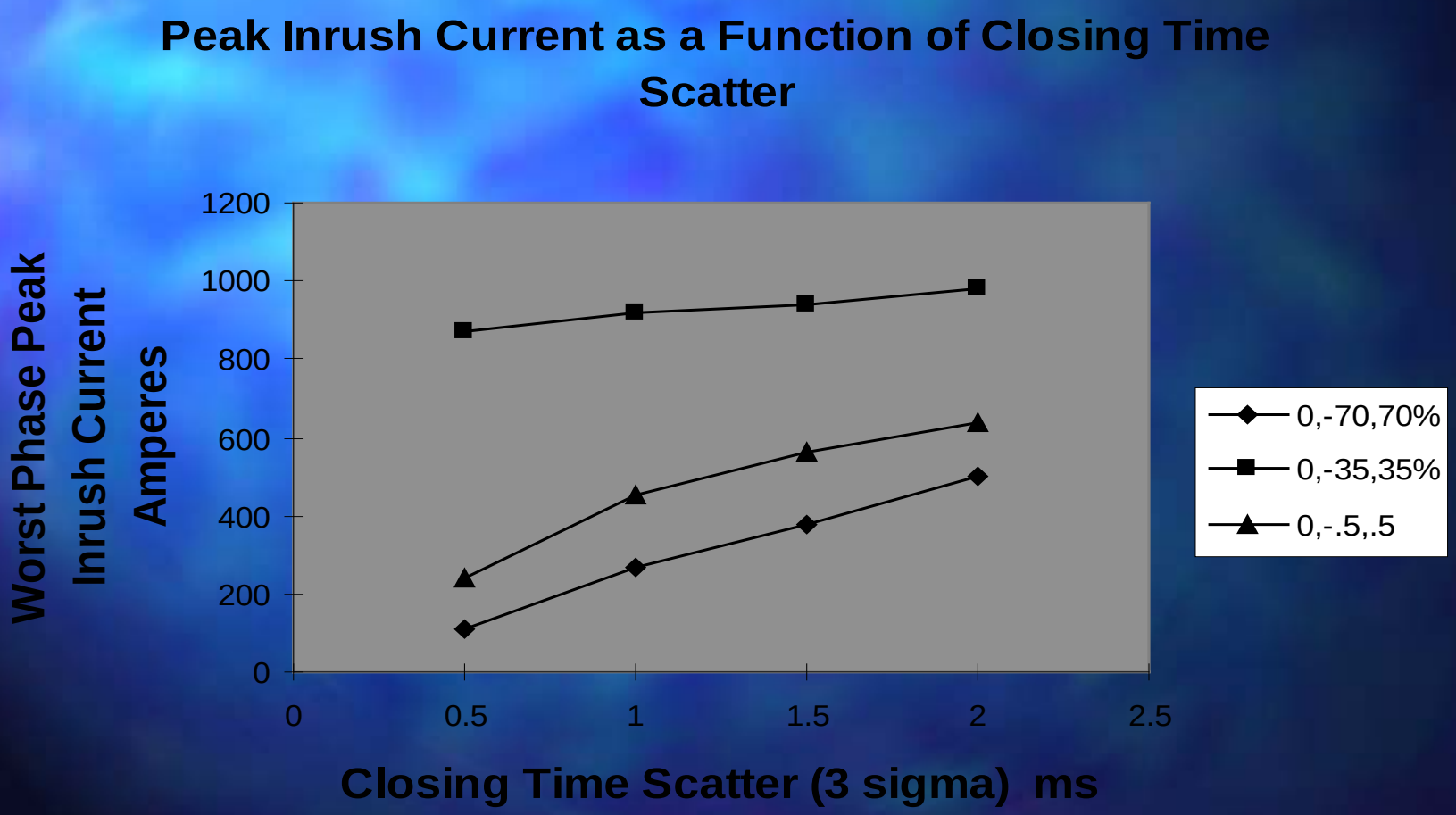
State of the Art



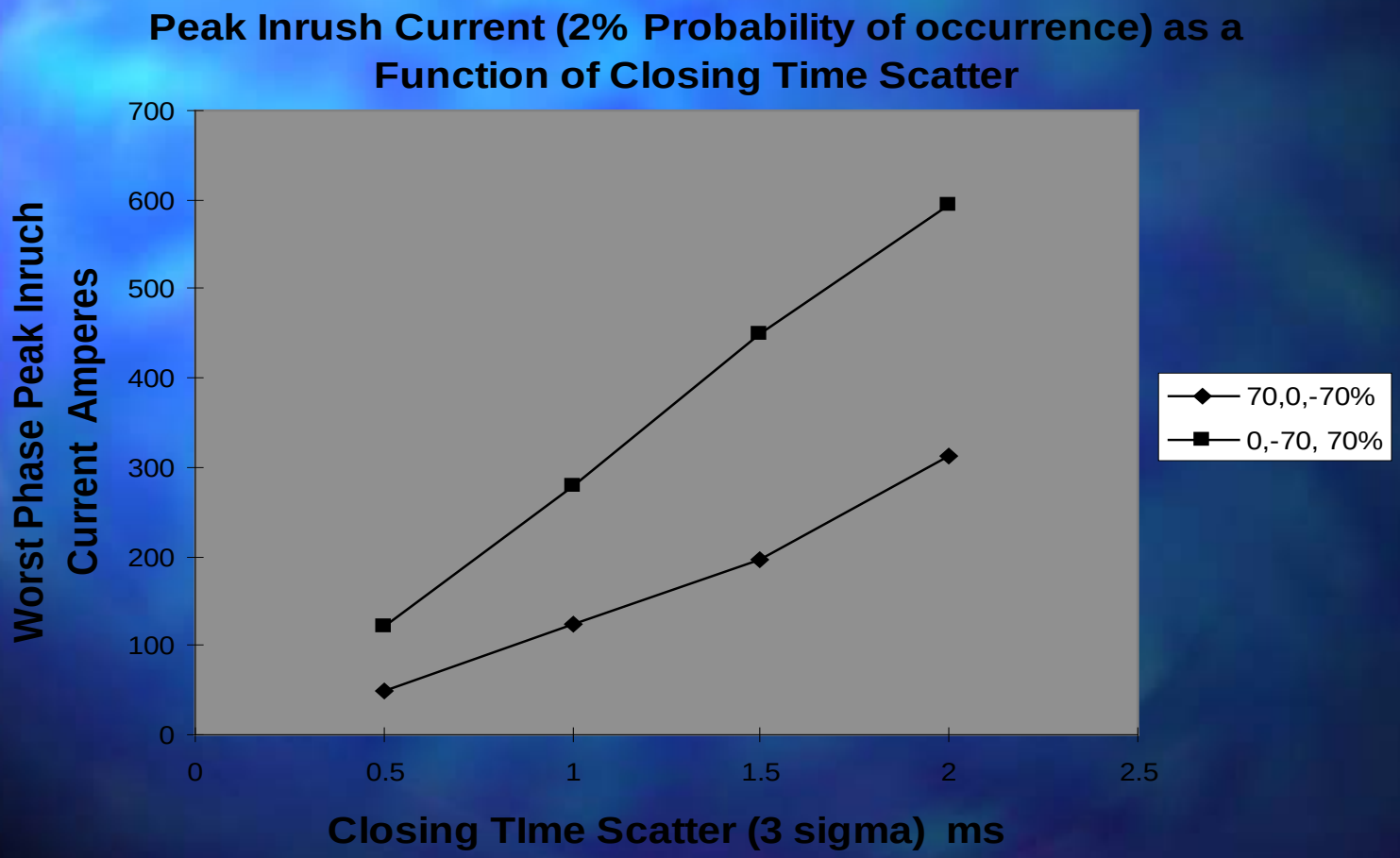
Delayed Performance



Three Phase Performance



Rapid Closing Performance



Conclusions

- It is possible, by considering residual flux together with the appropriate closing strategy, to eliminate transformer inrush currents in most transformer configurations
- With consideration of breaker closing scatter, a reduction of typically 90% of worst, can be achieved