PATH Users Group Workshop

Overview of PSCAD/EMTDC

October 18, 1999
Knoxville, TN

Introduction to PSCAD/EMTDC

PSCAD/EMTDC is a general-purpose time domain simulation tool for studying transient behavior of electrical networks. First developed in 1976, the EMTDC simulation program has been constantly evolving in its scope and capabilities. The software features a graphical interface called PSCAD, which supports all aspects of conducting a simulation including circuit assembly, run-time control, analysis, and reporting.

PSCAD/EMTDC comes with a comprehensive library of models encompassing all aspects of AC and DC power systems and controls. New models and libraries can be developed using the built-in graphical Component Workshop.

Engineers working with circuits consisting of power electronic switches such as thyristors and GTOs will benefit from EMTDC's Interpolated Network Solution and Chatter Removal technology. This permits study of circuits that would be impractical or almost impossible to simulate using other tools, and ensures a highly accurate solution in the least amount of time.

PSCAD has many advanced features to boost productivity, including intelligent data forms, interactive control and feedback, up-to-date documentation of the circuit along with plots and comments, context sensitive help, hierarchical designs, and multiple levels of zooming.

This seminar will focus on an overview of PSCAD/EMTDC, including features and processes for developing models. Plenty of opportunity will exist for attendees to build and run cases of their own.

Agenda

- History of PSCAD/EMTDC
- Features and Functionality
- Comparison with ATP and EMTP
- Software Usage Overview
- Sample Cases
- Building and running of sample cases by attendees
- Questions and Wrapup

Instructors:
Surya Santoso, Electrotek Concepts
Garth Irwin, Manitoba HVDC Research Centre

PSCAD/EMTDC Seminar

October 18, 1999

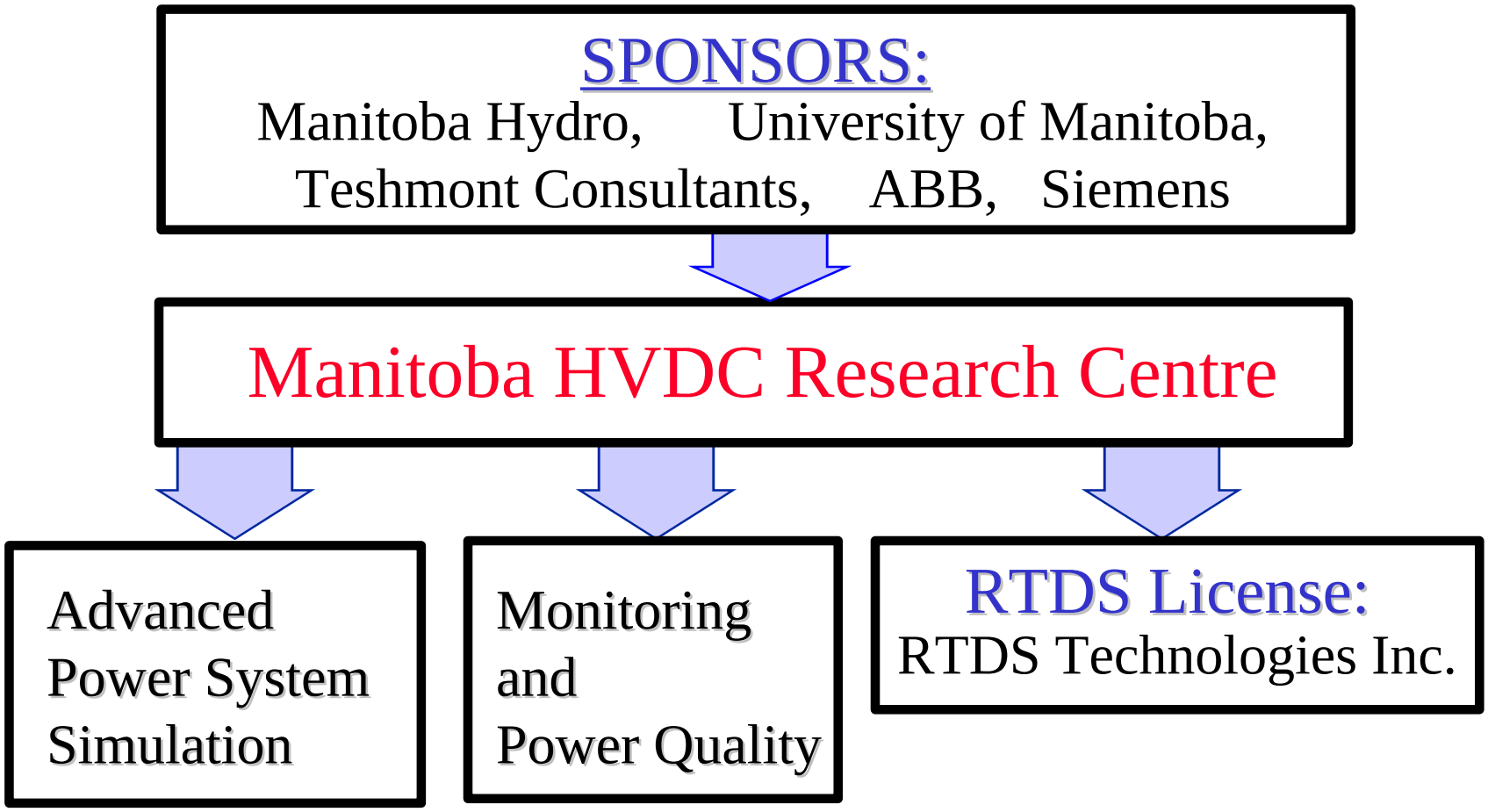
Garth Irwin

Manitoba HVDC Research Centre

Agenda

- History of PSCAD/EMTDC
- Major Features
- Comparison with ATP/EMTP
- Demonstrations, Questions and Discussion
- Power Quality Examples/Demonstrations

Manitoba HVDC Research Centre



Digital Simulation

- PSCAD/EMTDC Transient Simulation Program
- RTDS (Real Time Digital Simulator)
  - License to RTDS Technologies Inc. in 1994
- RTP (Real Time Playback)
  - PC Card for open loop powerful arbitrary waveform generator for testing hardware
  - Uses Comtrade or PSCAD input waveforms
  - GPS timing for synchronization between units

PSCAD/EMTDC - History

EMTDC “Electro-Magnetic Transients for DC”

- 1975 - Dennis Woodford (Manitoba Hydro)
  - Separate Program (not derived from EMTP!)
  - Originally on mainframes (Vax, Prime, Amdahl..)
  - Code re-structured for modern computers
  - Originally for DC (Nelson River), but now a general transients tool with all models
  - Significantly different algorithm compared to EMTP

PSCAD/EMTDC - History

PSCAD “Power Systems Computer Aided Design”

- Version 2
  - Unix (Sun, HP, IBM, DEC, SGI, Linux...)
  - Approx. 1500 licenses worldwide (manufacturers, power utilities, consultants, universities)
- Version 3.0.1
  - Released May, 1999
  - PC Windows: NT 4.0 / 95 / 98
  - Unix support designed but not yet available
  - > 1,100 downloads of PSCAD V3 PE since May 1999

PSCAD V2 - V3 Comparison

PSCAD V2

- Unix platforms only
- Many program modules (Draft, Runtime, Tline…)
- Many files (tlb, dft, rtb,mpb..)
- Textual component design
- Non-standard GUI look/feel
- Drawings on single pages

PSCAD V3

- Multi-platform design (Unix platform not yet complete)
- 1 integrated program
- Case saved into 1 file (.psc)
- Graphical comp. workshop
- Standard windows look/feel
- Full hierarchical page structure

PSCAD V2 - V3 Comparison (Continued)

PSCAD V2

- Limited help system
- Problems with big cases:
  - Slow data generation
  - Slow recompile of DSDYN
- Re-run cases for more output
- Difficult library management
- Fixed zoom level

PSCAD V3

- Integrated HTML on-line & fly-by help (printable)
- Incremental building of cases
  - Only changed pages require generation of data
  - .map file to link pages
- Outputs saved, fly-by output
- Integrated library management
- Multiple zoom levels

PSCAD V2 - V3 Comparison (Continued)

PSCAD V2

- Fortran and C interface for custom models
- Inefficient asymptotic curve fitting for line/cable constants
- Printing used non-standard Postscript (& HPGL) driver
- Limited multiple run facility

PSCAD V3

- Fortran, C, C++, Matlab and soon MODELS interface
- New weighted least squares optimum fitting method
- Print/embedding using any standard Windows drivers.
- Enhanced m-run features
- Can directly load V2 cases
- Multiple language support designed but not yet available

EMTDC V2 - V3 Comparison

EMTDC V2

- Hard-coded dimensions (F77)
- Switch resistance > 0.005
- Voltage sources must have Z
- Tline/cable models req'd constant Ti approximation
- Few exciter/gov/stab. models
- Basic transformer models

EMTDC V3

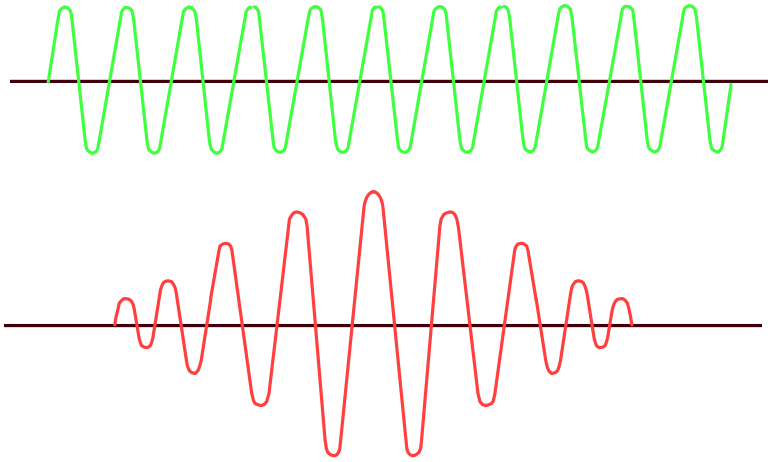
- F77 or F90 (dynamic dimensioning)
- Ideal switches (ie R=0)
- Ideal sources (ie Z=0)
- New phase domain model
- All IEEE standard models
- UMEC transformer models for each core type

Distribution & Support

- CD-ROM for major releases
- New WWW site for downloads
- Strict version control and documenting
  - PSCAD V3.0.2 …..
  - List of changes (changes.log)
  - Automatic synchronization with source code control system (CVS)

PSCAD/EMTDC Live Demos

- PSCAD V3 - Features and Demo



PSCAD/EMTDC - Key Features

- Phase domain line model
- Ideal switch algorithm (series, parallel, loops…)
- Interpolation switching algorithm
- Chatter Removal and Root Matching
- PSCAD GUI: case management, data generation, error checking, on-line monitoring/control, output preparation...

PSCAD/EMTDC
Key Features (Continued)

- UMEC core transformer
- Fortran/C/C++/Matlab interface for user-written controls (multiple time step, event driven, direct translation…)
- All controls are coded and optimized by a compiler
- Speed and memory savings (F90)
- Multiple Run Facility

Comparison of EMTDC with EMTP/ATP

- Original EMTP from BPA has many derivatives:
  - EMTP (EPRI/DCG)
  - ATP (Alternate Transients Program)
  - MicroTran (UBC EMTP)
- EMTDC developed independently in 1975 by Dennis Woodford

PSCAD/EMTDC - Comparison to EMTP/ATP

Description	PSCAD/EMTDC	EMTP/ATP	PSCAD Comments
1. Graphical Data Input	100%	ATPDraw	Excellent GUI
2. Graphical Interaction During Run	Yes	No	Modify settings.. On-Line
3. Plotting	On and Off Line	Off Line	Active X Coming Soon
4. Speed of Solution	Faster	Slower	Subsystems and Optimal Switch Ordering
5. Initialization Procedure	Lock Rotors, Start from 0.0 Until Snapshot	Initialization from Load-flow for AC cases	Initialization not possible or too time consuming for complex cases
6. Supported Computers	PC's and Unix	PC's and Unix	PSCAD V3 for PC's, V2 for Unix
7. Switching Accuracy	Continuous switch instants via Interpolation	Switching limited to time step only	Interpolation essential for many Power Electronics

PSCAD/EMTDC - Comparison to EMTP/ATP

Description	PSCAD/EMTDC	EMTP/ATP	PSCAD Comments
8. Transformer Models	- External Taps - UMEC Model	- Fixed Turn Ratio	New UMEC Core/Flux Models
9. Tline Models	- Bergeron - Constant Ti - Phase Domain	- Bergeron - Constant Ti	Recent “State of the Art“ Phase Domain Model
10. Line/Cable Constants Programs	- Built-in with GUI - Optimal Curve Fitting (W-LSQ) - Coax-Cables	- Separate Program - Non-optimal fitting - Pipe-type cables	Weighted Least Squares Curve Fitting
11. Memory Usage	Less	More	Dimensions set dynamically (F90)
12. Controls Modeling	More Accurate (Exact) and Fast	TACS, MODELS - Less Accurate, Slow	Manufacturers directly translate multiple time step digital controls.

PSCAD/EMTDC - Comparison to EMTP/ATP

Description	PSCAD/EMTDC	EMTP/ATP	PSCAD Comments
13. Control of Numerical Oscillations in inductive nodes or capacitive loops	Chatter Removal	ATP – none EMTP96 - CDA	CDA is less accurate
14. Integration Methods	- Trapezoidal - Root Matching	- Trapezoidal	Root Matching only when >1 element per branch(ie RL..)
15. Electrical Branch Collapsing	- GUI collapses series and parallel branches	None	Collapsing where internal V or I not monitored.
16. Series/Parallel Switches	Unlimited	Not allowed, must insert extra nodes	Less nodes required
17. Series Voltage Sources	Unlimited	Not allowed	

PSCAD/EMTDC - Comparison to EMTP/ATP

Description	PSCAD/EMTDC	EMTP/ATP	PSCAD Comments
18. FDNE	Not direct	Available	
19. High Frequency Transformer Model	Simple Model	Detailed FD Model	

Areas for Further Research

- New numerical methods and techniques: code tuning, compiler technologies, parallel processing on a network,real time processing….
- New GUI features:
  - Plots, SLD, OLE compliant…
  - Interface electromagnetic and electromechanical transient solutions
  - …..

Areas for Further Research

- Detailed power electronic modeling (i.e. Spice-like simulations)
- Load-flow and high speed stability
- Integration of EMTDC with stability programs
- PSCAD/Distribution, Protection and Power Electronics libraries

PSCAD/EMTDC Support Contact Information

- Manitoba HVDC Research Centre

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  Winnipeg, Manitoba, Canada, R3T 2G5

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  Fax: (204) 453 - 5074

  pscad@hvdc.ca

  www.hvdc.ca

  ftp.hvdc.ca/pub

- Electrotek Concepts

  408 North Cedar Bluff Road

  Knoxville, TN 37923

  Phone: (423) 470-9222

  Fax: (423) 470-9223

  pscad@electrotek.com

  www.pqnet.electrotek.com/pathmemb/path.htm

PSCAD/EMTDC User's Group

- Non-profit organization, free to all users
- Headed by Dr. Ani Gole
  - University of Manitoba
- E-mail server (emtdcug@ee.umanitoba.ca)
- WWW and anonymous FTP site
  - www.ee.umanitoba.ca/~hvdc/ (PSCAD V2)
  - ftp.ee.umanitoba.ca/pub/PSCAD_EMTDC
- Northern European User's Group (NEUG)

Courses and Training

- PSCAD/EMTDC Training
  - Introduction to PSCAD/EMTDC
  - Advanced HVDC concepts
  - FACTS, STATCOMs and controls
  - SVC and reactive power compensation
- Custom model development contracts
- Sponsorship of university and industry research

PSCAD/EMTDC V3

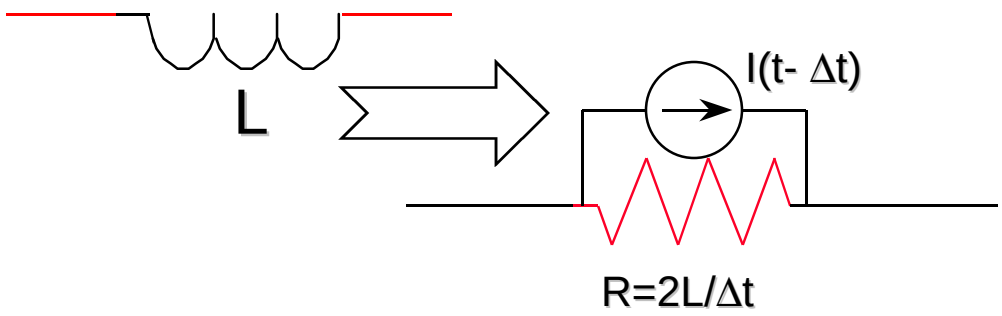
- Personal Edition - FREE!
  - Register and download from www.hvdc.ca
  - 15 node limit
- Educational Edition
  - Discounts for universities
  - 200 node limit
- Commercial Edition
  - Unlimited size of system

Topics for Discussion

- Root matching technique
- Internal solution techniques
- Speed of EMTDC versus EMTP/ATP
- Phase domain line model
- Details of interpolation
- Details of chatter removal

Electro-Magnetic Transients Simulation - Basic Algorithm

- Formulation of differential equations as a difference equation via trapezoidal integration (Dommel et al)

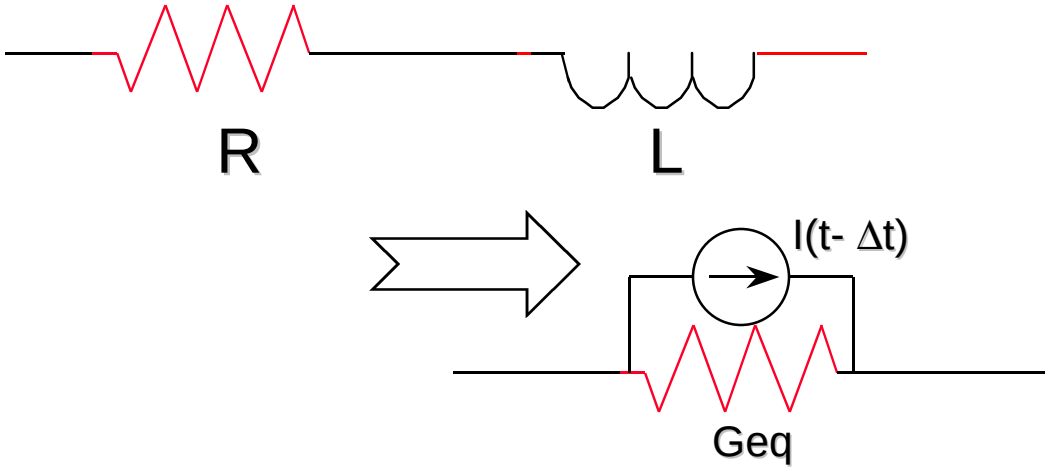


Main Solution Equation

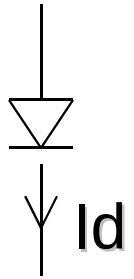
- [Geq] . [V(t)] = [I (t-Ät)]
  - Geq is an NxN Matrix of Real #'s (G=1/R)
  - I is Input Current Injection Vector (ie History Terms)
  - V is Vector of Unknown Node Voltages
- Direct Sol'n by Sparse Gaussian Elimination
  - Special Optimal Ordering for Switch Nodes
  - Use of Sub-Systems (ie Multiple Simultaneous Eqn's)

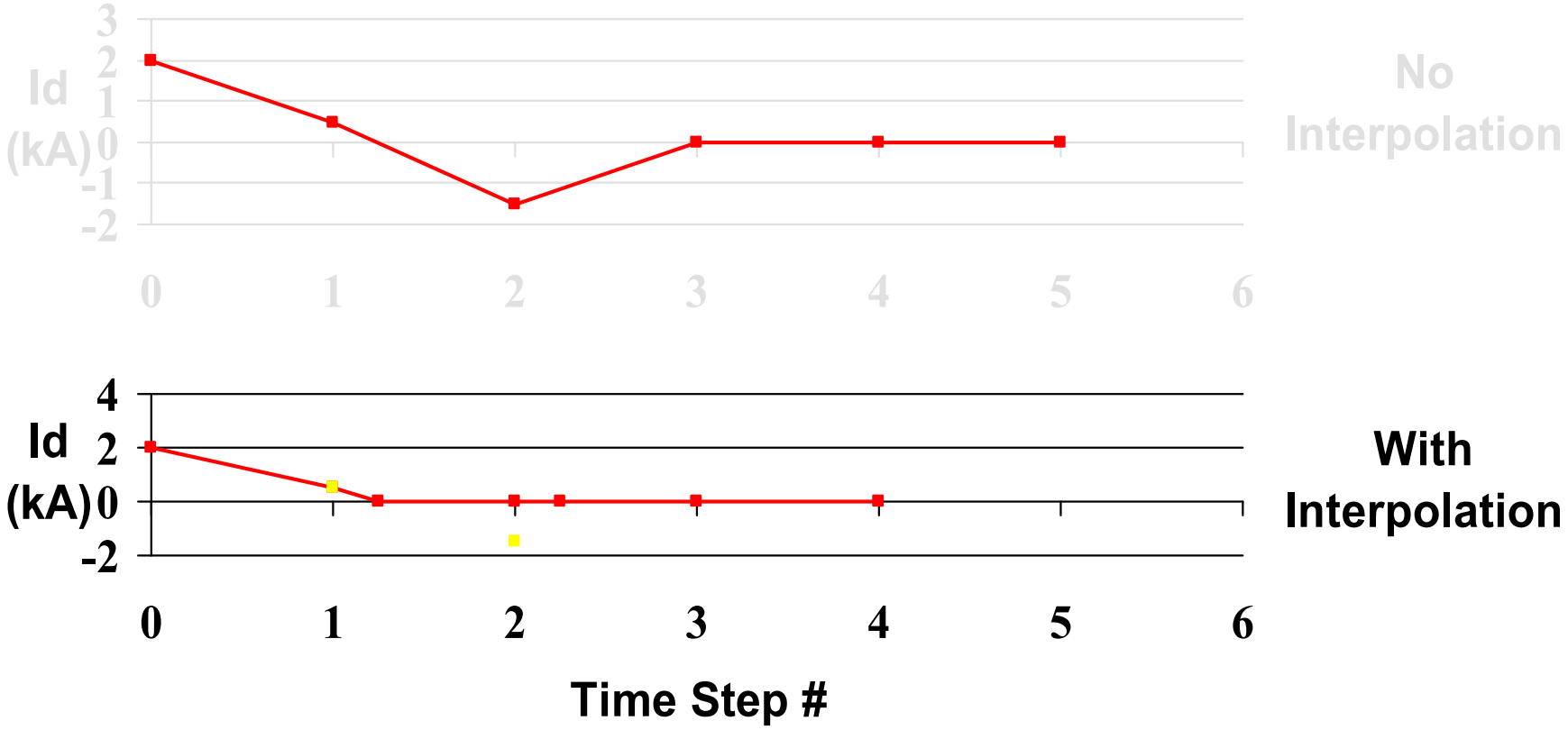
Electro-Magnetic Transients Simulation - New Algorithm

- Formulation of Differential Equations as a Difference Equation via Root Matching

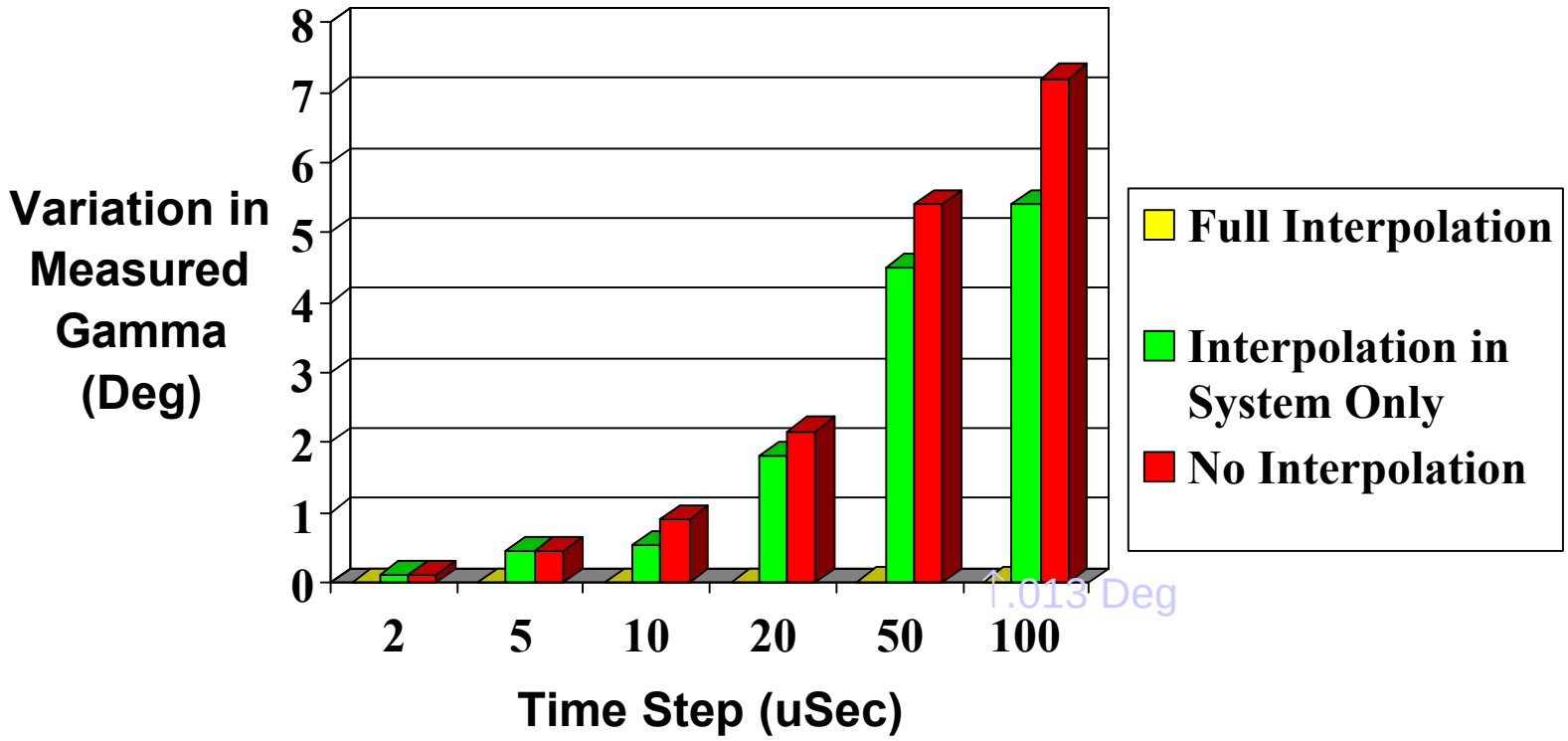


Interpolation Example

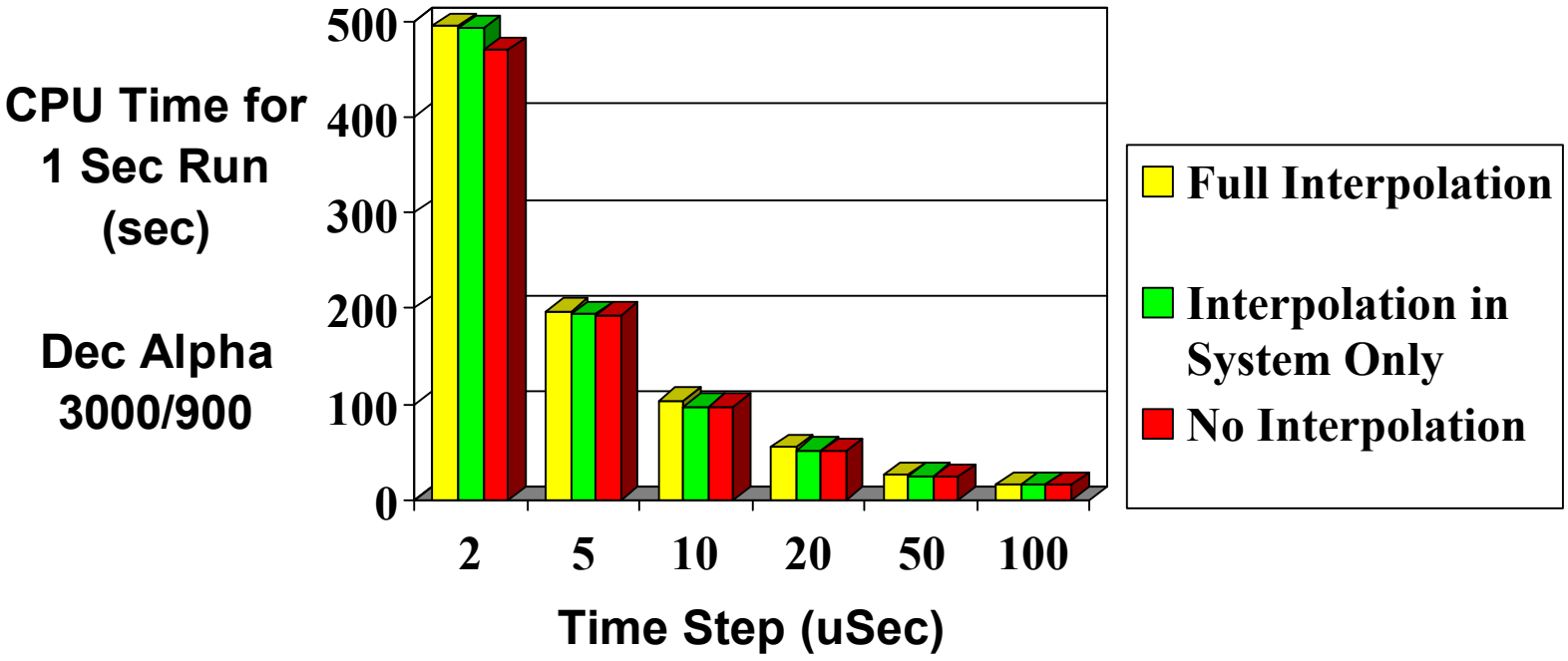




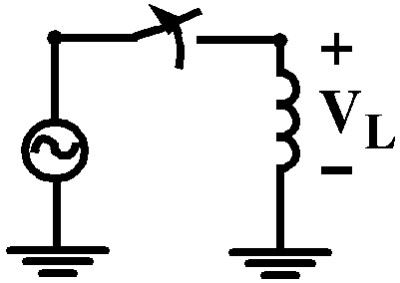
Effect of Interpolation (CIGRE HVDC Benchmark)

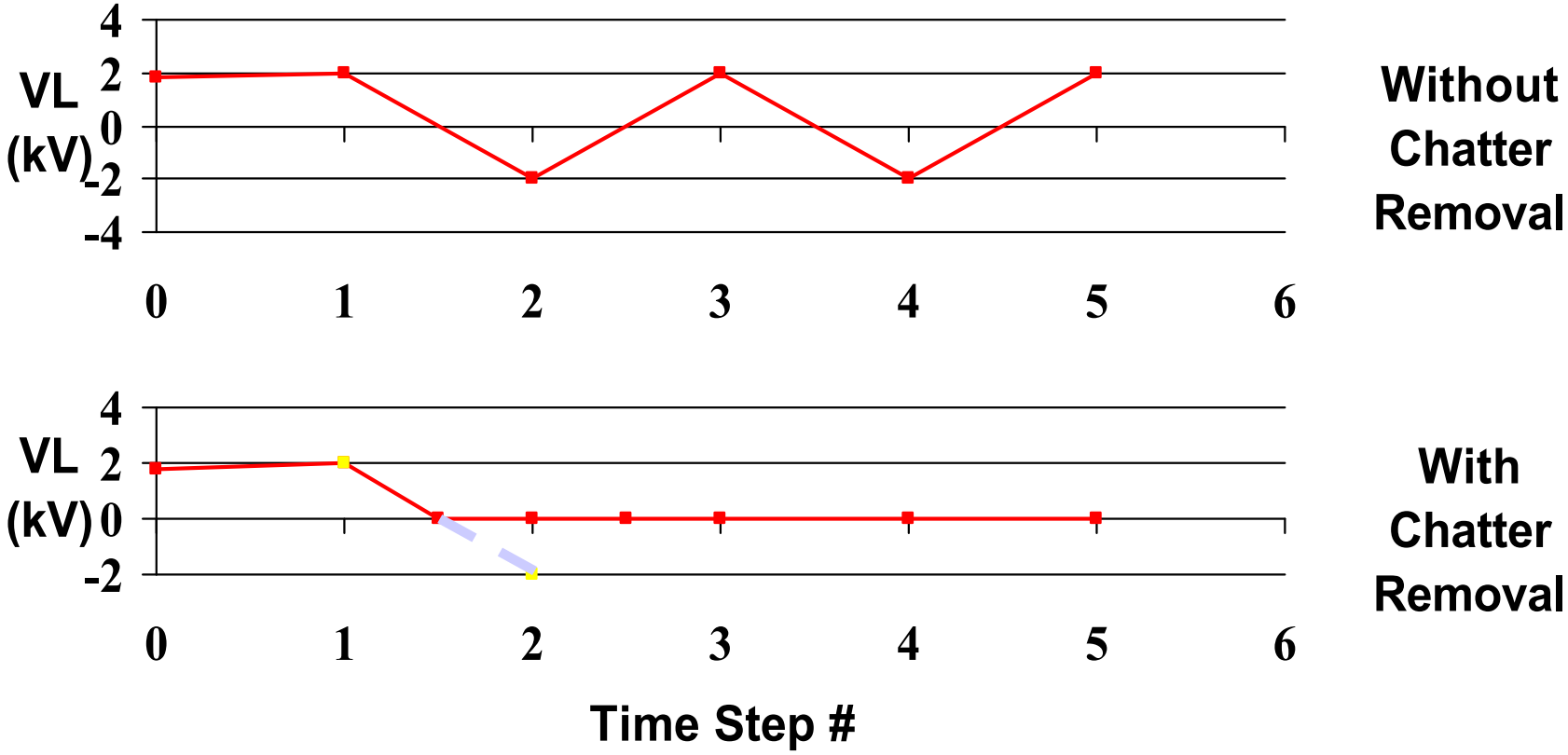


CPU Time Comparison (CIGRE HVDC Benchmark)

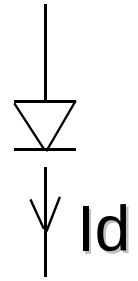


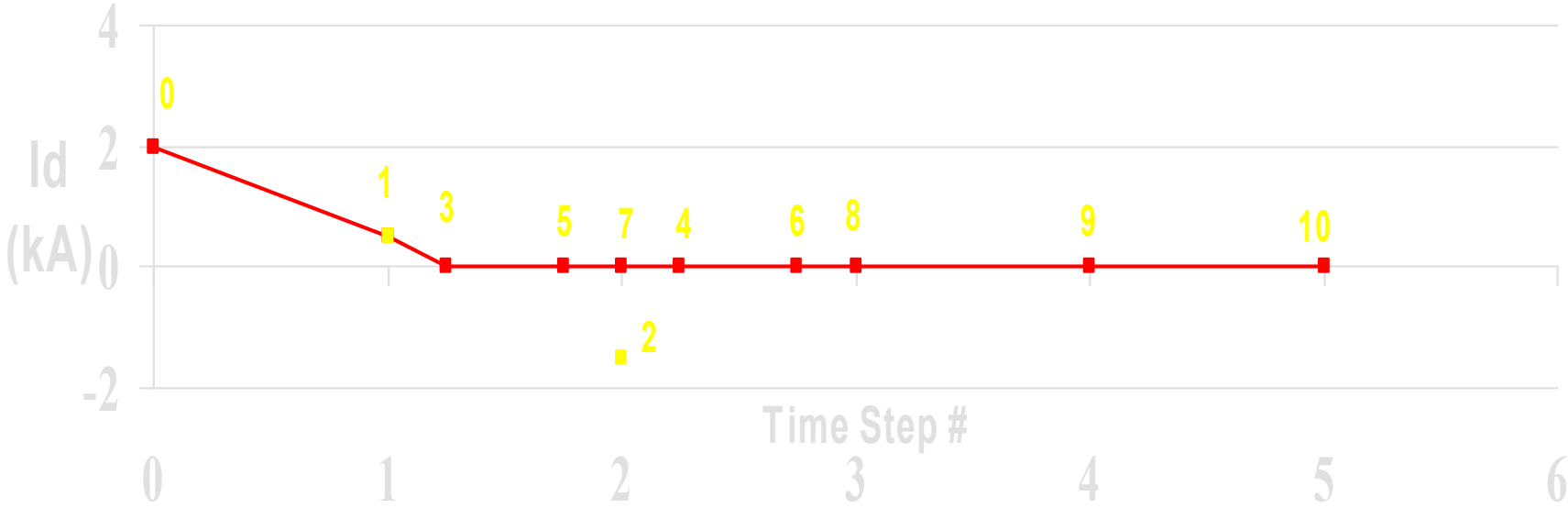
Chatter Removal





Interpolation Details





1 - Delt Forward
2 - Delt Forward
3 - Interpolate to 0 Crossing
4 - Delt Forward
5 - 1/2 Step Chatter Removal
6 - Delt Forward
7 - Interpolate to Regular Grid
8 - Delt Forward
9 - Delt Forward
10 - Delt Forward