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CAPACITOR SWITCHING STUDIES IN EMTP

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7/21/2022



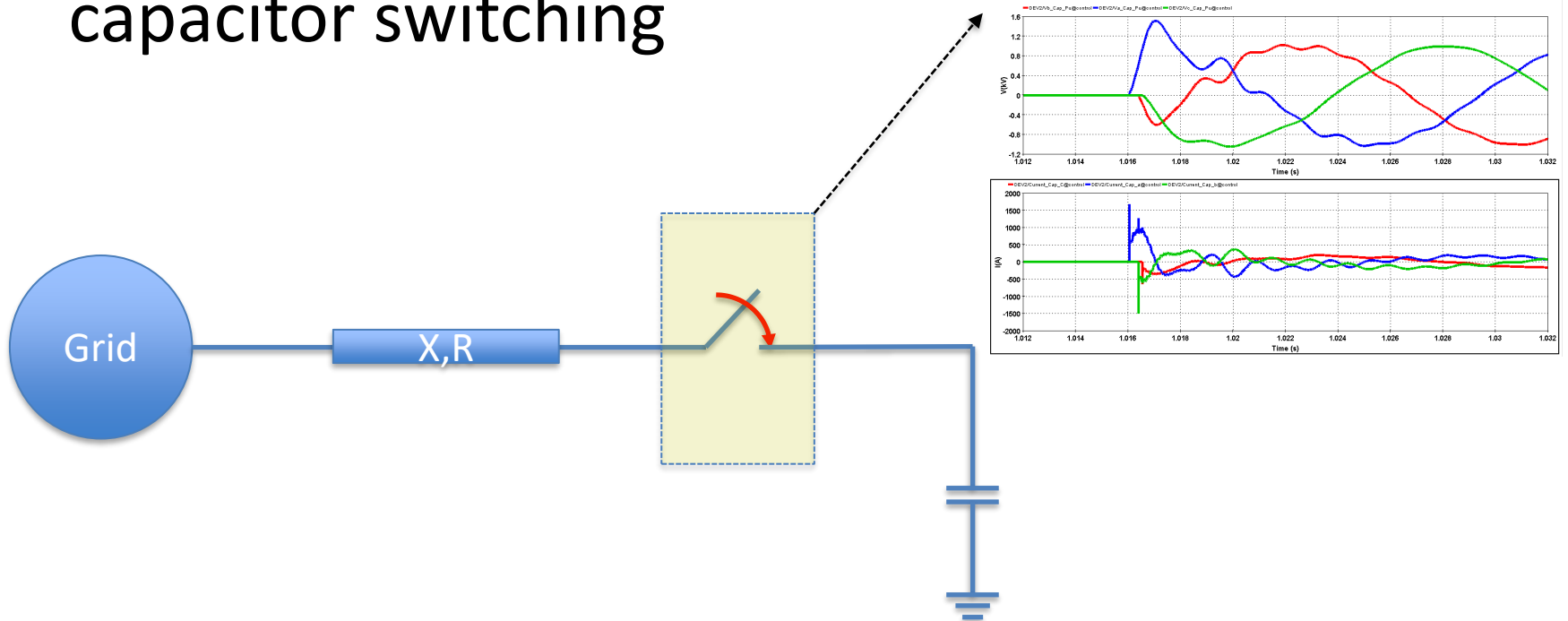
WHY EMTP SOFTWARE?

- Phasor domain simulation
- Electro Magnetic Transient (EMT) simulation
- EMTP can do both!
- Conversion tool from PSSE software
- Plotting the result without loosing the frame settings
- Statistical evaluation of the results



CAPACITOR SWITCHING STUDY

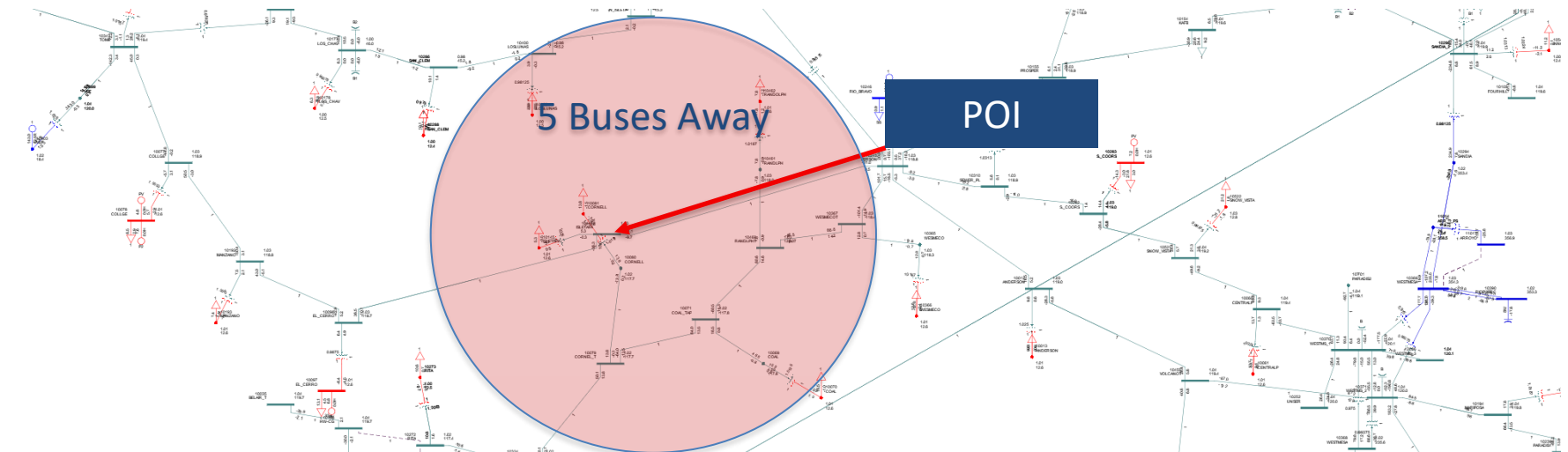
- The inrush current and transient voltage due to capacitor switching





NETWORK CONVERSION

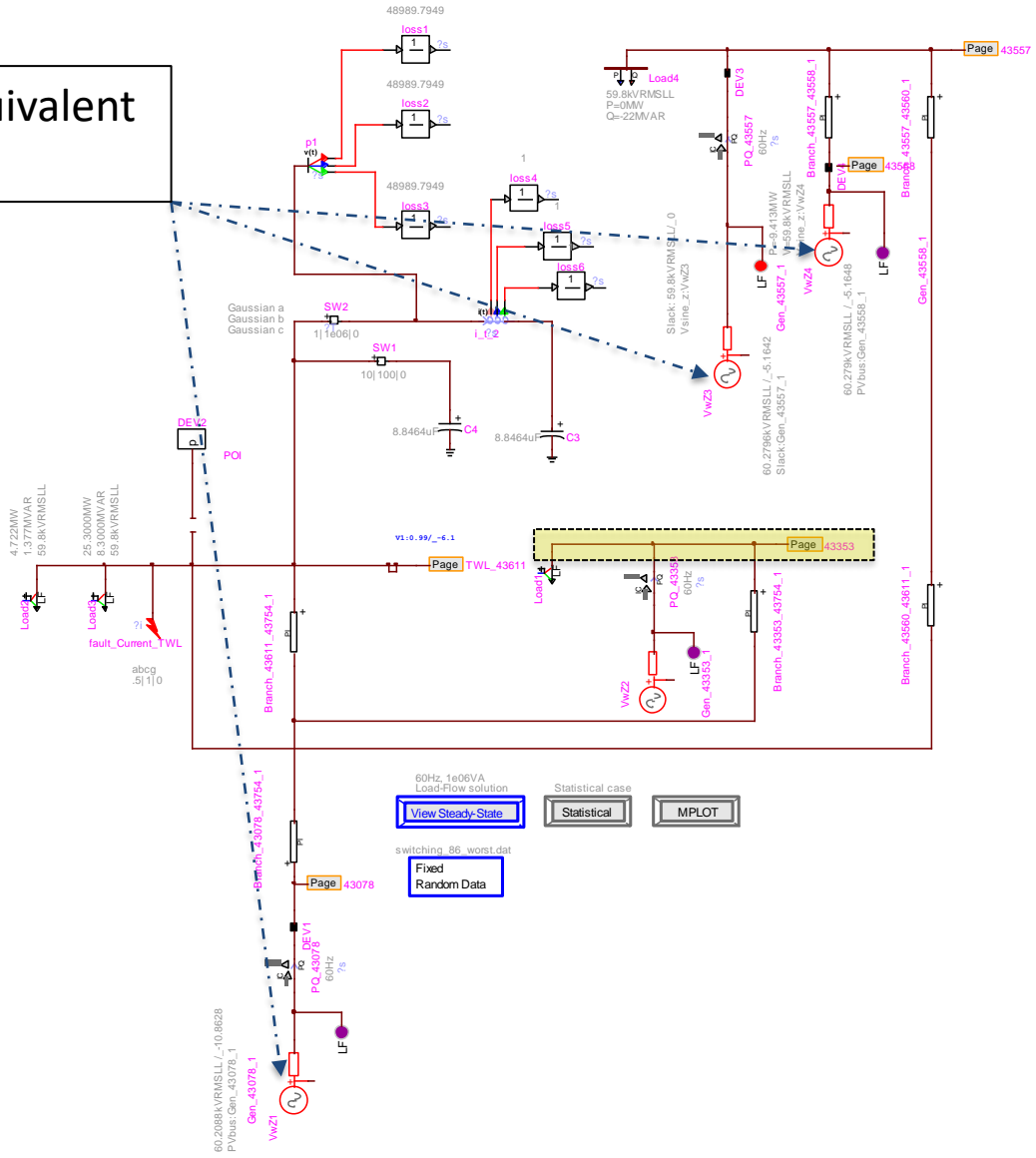
- System Conversion from PSSE
 - Requires extensive manual work but can be done with one click in EMTP software





NETWORK CONVERSION

Modeled as an equivalent
Thevenin sources





NETWORK CONVERSION

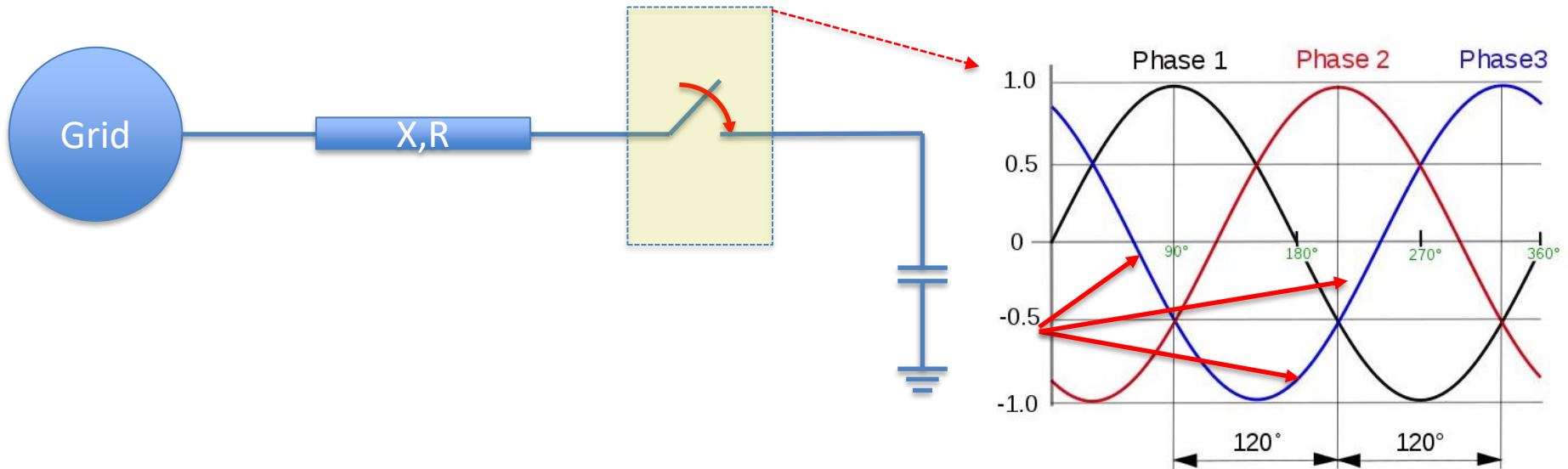
- Benchmarking Load flow and Short circuit
 - The error of less than 2% achieved for all the buses

Buses	V(EMTP)	V(PSSE)	Error	Isc (EMTP)	Isc (PSSE)	Error
4166	1.023	1.024	0.0978%	12.32	12.43	0.89%
4167	1.023	1.021	0.1955%	11.87	11.73	1.17%
4178	1.018	1.019	0.0982%	13.34	13.2	1.04%
4039	1.022	1.021	0.0978%	12.14	12.3	1.31%
4038	1.021	1.021	0.0%	12.14	12	1.15%



PERFORMING THE STUDY

The study must be performed on various breaker closing point (1-360 degree). At least 100 points of wave to be considered





PERFORMING THE STUDY

EMTP Options Tap

The screenshot displays the EMTP software interface. On the left, a circuit diagram is shown on a grid background. It includes components such as a generator (Gen_43353_1), a load (Load), a branch (Branch_43353_43754_1), and another generator (Gen_43353_1). The diagram is labeled with 'Page 43353'. Below the diagram, there are several buttons: 'View Steady-State' (highlighted with a blue box), 'Statistical' (highlighted with a grey box), 'MPLOT' (highlighted with a grey box), and 'Fixed Random Data' (highlighted with a blue box). The text '60Hz, 1e06VA Load-Flow solution' and 'Statistical case' is visible above the buttons. The file name 'switching_86_worst.dat' is shown at the bottom left of the diagram area.

On the right side, a vertical menu is open, listing various options and categories. The 'Options' category is expanded, showing the following items:

- Control
- Control Functions
- DC
- Exciters And Governors
- Flip Flops
- FMI
- Lines
- Load Models
- Machines
- Meters
- Nonlinear
- Options**
 - Data converter
 - DLL
 - Extra Frequency points
 - Fixed Random Data
 - Input Impedance
 - Input Output files
 - Link
 - Load-Flow
 - MPLOT
 - Run a case
 - ScopeView
 - Show Load-Flow
 - Show Simulation Web
 - Simulation Options
 - Simultaneous switching
 - Start EMTP
 - Statistical Options
 - View Steady-State
- Phasors
- Power Electronics
- Protection
- Pseudo Devices
- Renewables
- RLC Branches
- SimulinkDLL
- Sources

At the bottom of the menu, the FMI section is visible, showing the file path: C:\Program Files (x86)\EMTPWorks 4.2.1\Toolboxes\FMI\the\FMI.cif



PERFORMING THE STUDY

Statistical analysis

Properties for Ideal switch: Breaker Symbol Cap_4

Data Random data Scopes Observe Attributes Help

Random data

Phase A Random data law Gaussian

Dependency Master

Reference switch name

Random Closing time

Mean 1 s

Standard deviation .001 s

Number of steps 5

Phase B Random data law Gaussian

Dependency Master

Reference switch name

Random Closing time

Mean 1 s

Standard deviation .001 s

Number of steps 5

Phase C Random data law Gaussian

Dependency Master

Reference switch name

Random Closing time

Mean 1 s

Standard deviation .001 s

Number of steps 5

100 Display Scale

Statistical analysis options

Study Options Output Help

Study options

Study type Statistical

Time of dice roll

Computer defined

User defined 0

Number of simulations 100

Do all systematic combinations

Seed for random numbers Random

Maximum multiple of standard deviation 4 Enforce

Special delay for "Ideal switch" devices

T_{offset} closing delay

D_{min} 0 degrees

D_{max} 360 degrees

Frequency 60 Hz

Scope T_{offset}

100 Display Scale

OK Cancel

Page 43353

Branch_0_43754_L1

60 Hz, 1e0kVA Load-Flow solution

View Steady-State

Statistical analysis

Not used

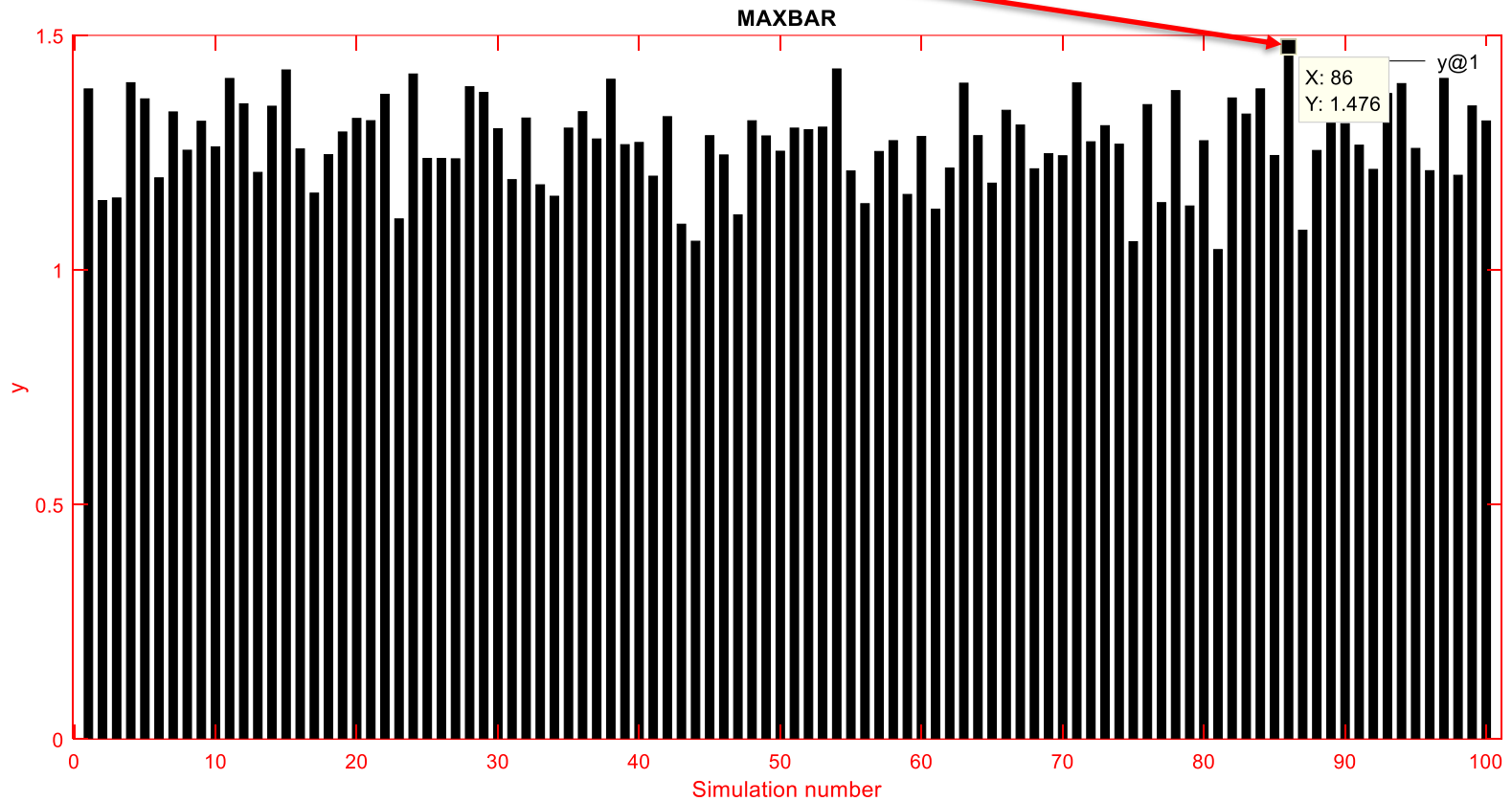
Fixed Random Data

Page 43357



PERFORMING THE STUDY

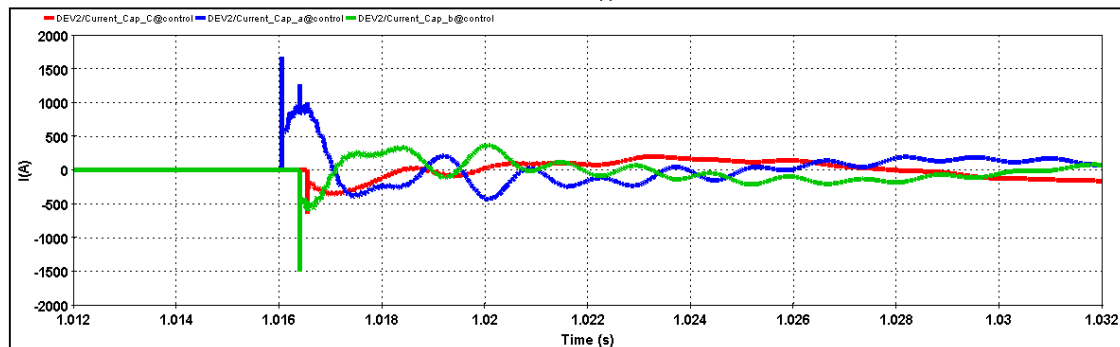
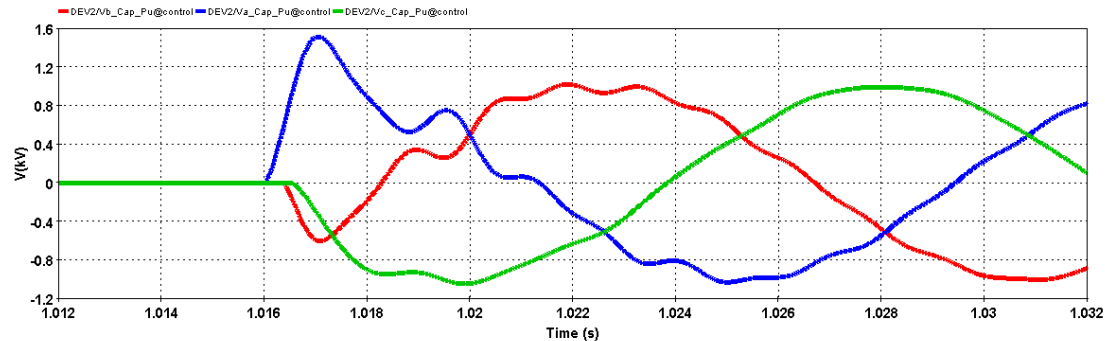
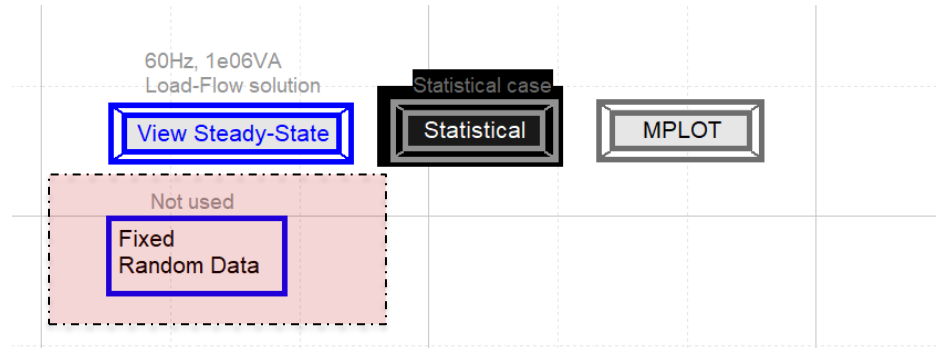
Statistical analysis/Worst Case





PERFORMING THE STUDY

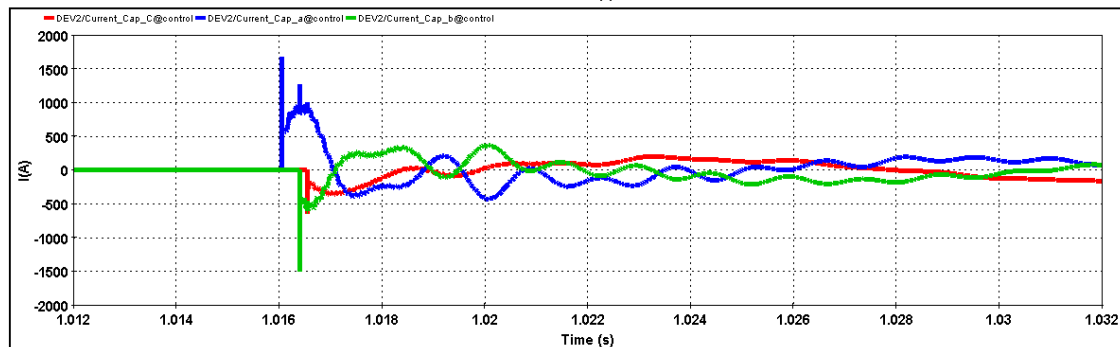
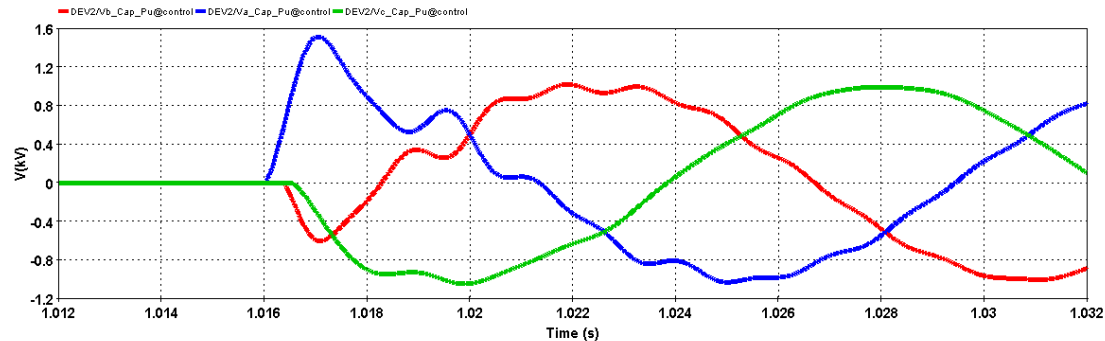
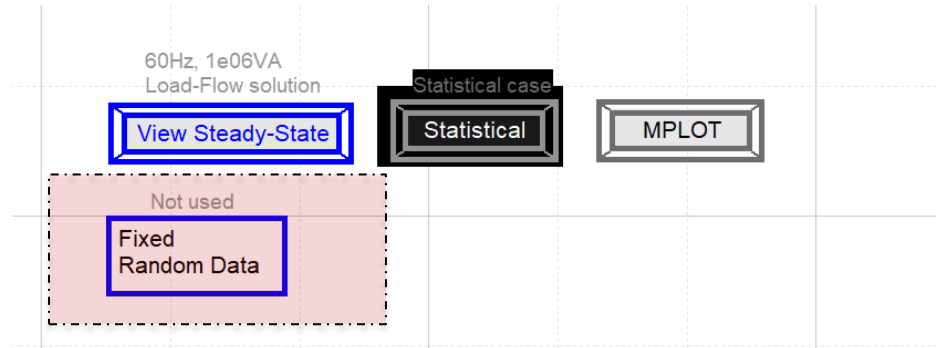
Statistical analysis/Worst Case





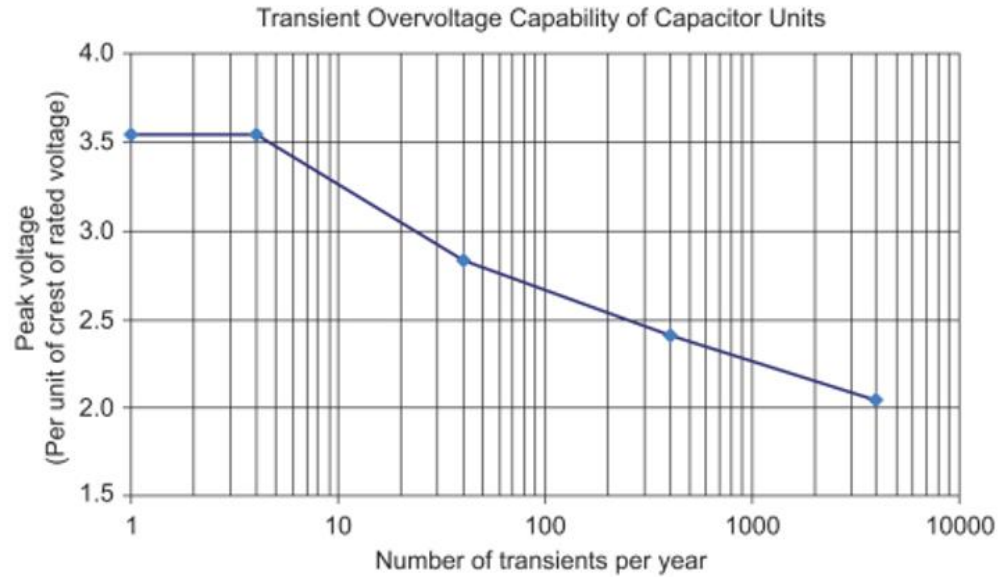
PERFORMING THE STUDY

Statistical analysis/Worst Case





EVALUATION OF THE RESULTS



NOTE—This curve is based on straight line segments between the following points on semi-log coordinates: $(1.0, 5/\sqrt{2})$, $(4.0, 5/\sqrt{2})$, $(40, 4/\sqrt{2})$, $(400, 3.4/\sqrt{2})$, and $(4000, 2.9/\sqrt{2})$.

IEEE C37.06, the product of the peak magnitude and the maximum frequency of the outrush current must be limited to values less than 20 kA·kHz



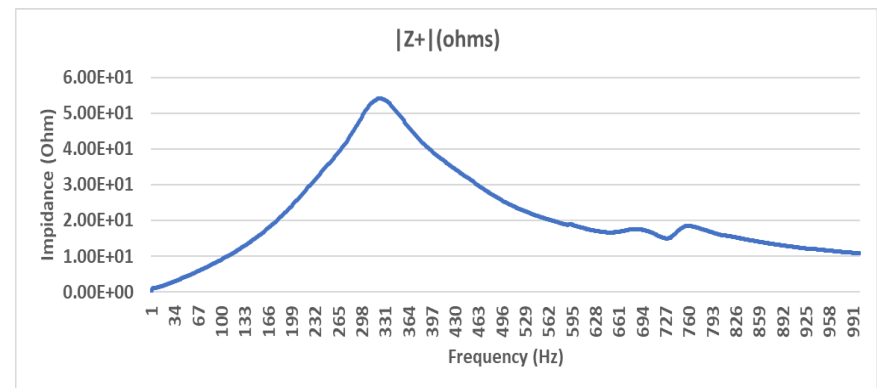
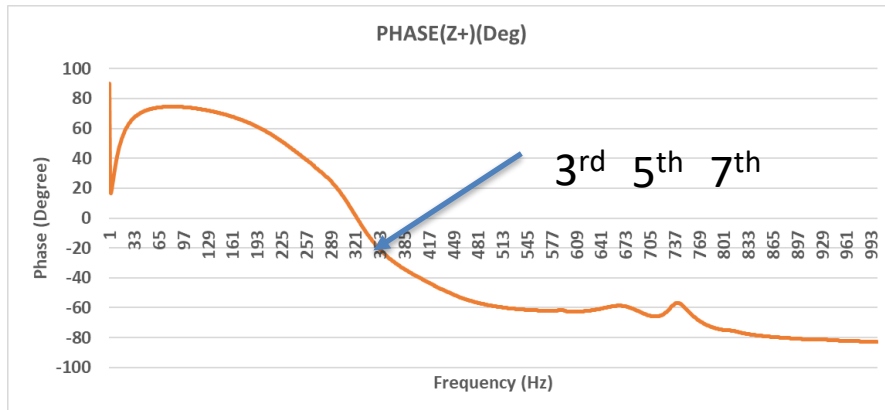
MITIGATION METHODS

- Staged capacitor switching
- Special operation criteria
- Current Limiting reactor
- Point of Wave (POW) devices



FREQUENCY SCAN OF THE SYSTEM

- Frequency scan analysis at the POI
- The conversion of the system to 5-10 buses away
- Indicates if the addition of cap bank will result in harmonic or transformer switching





SUMMARY OF THE EXPERIENCE WITH EMTF SOFTWARE

- Powerful conversion tool with high accuracy
- Generates an acceptable SLD after conversion
- Easy process to generate a sub-systems
- Powerful plotting tool (can be used as a benchmarking tool with other software)
- Accurate power flow tool
- Relatively fast simulation time
- Useful tools for Statistical evaluation and post data processing



QUESTIONS

