Ansys Maxwell Getting Started

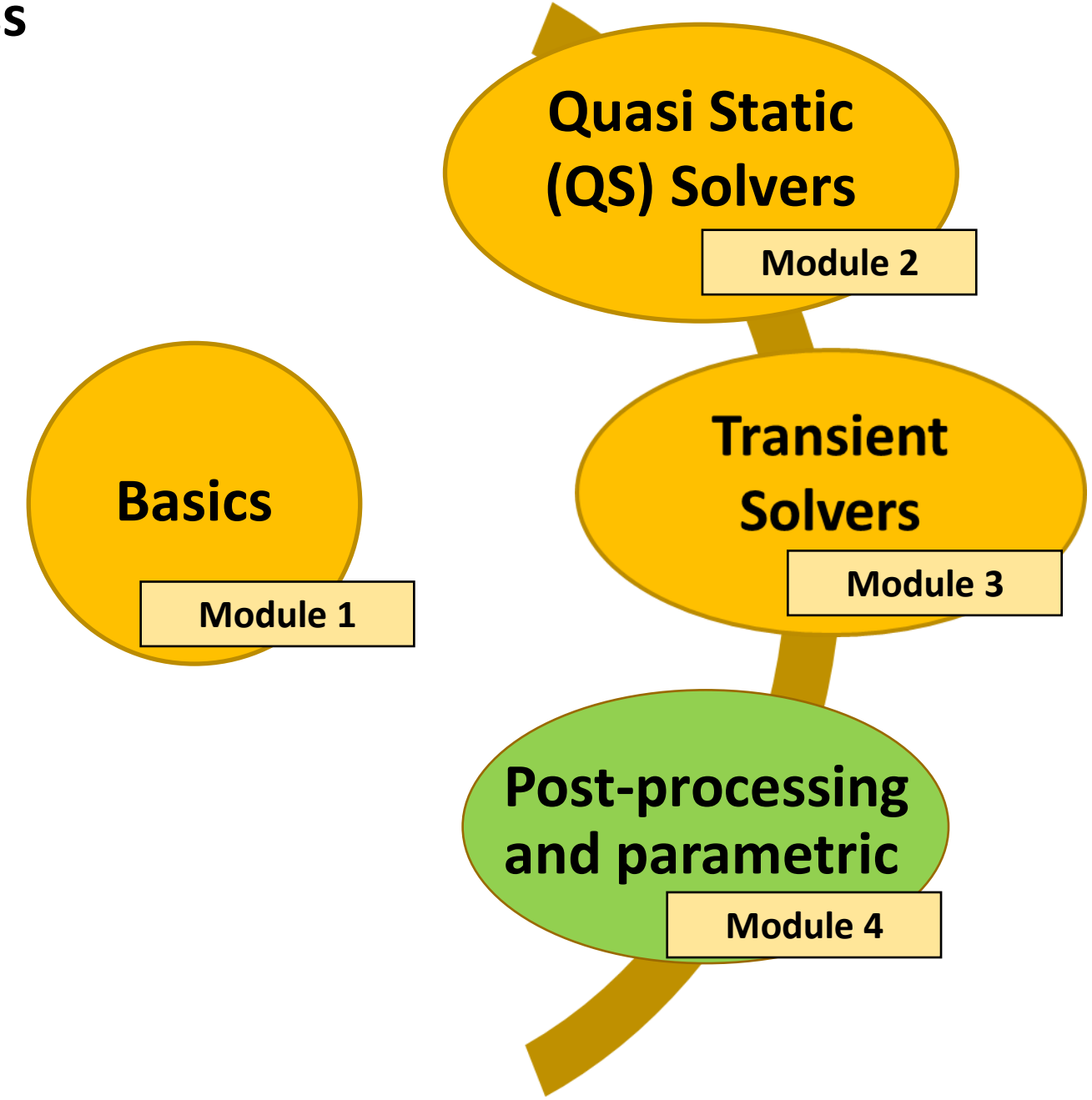
Module 04: Postprocessing and Parametric

Release 2020 R2

Overview

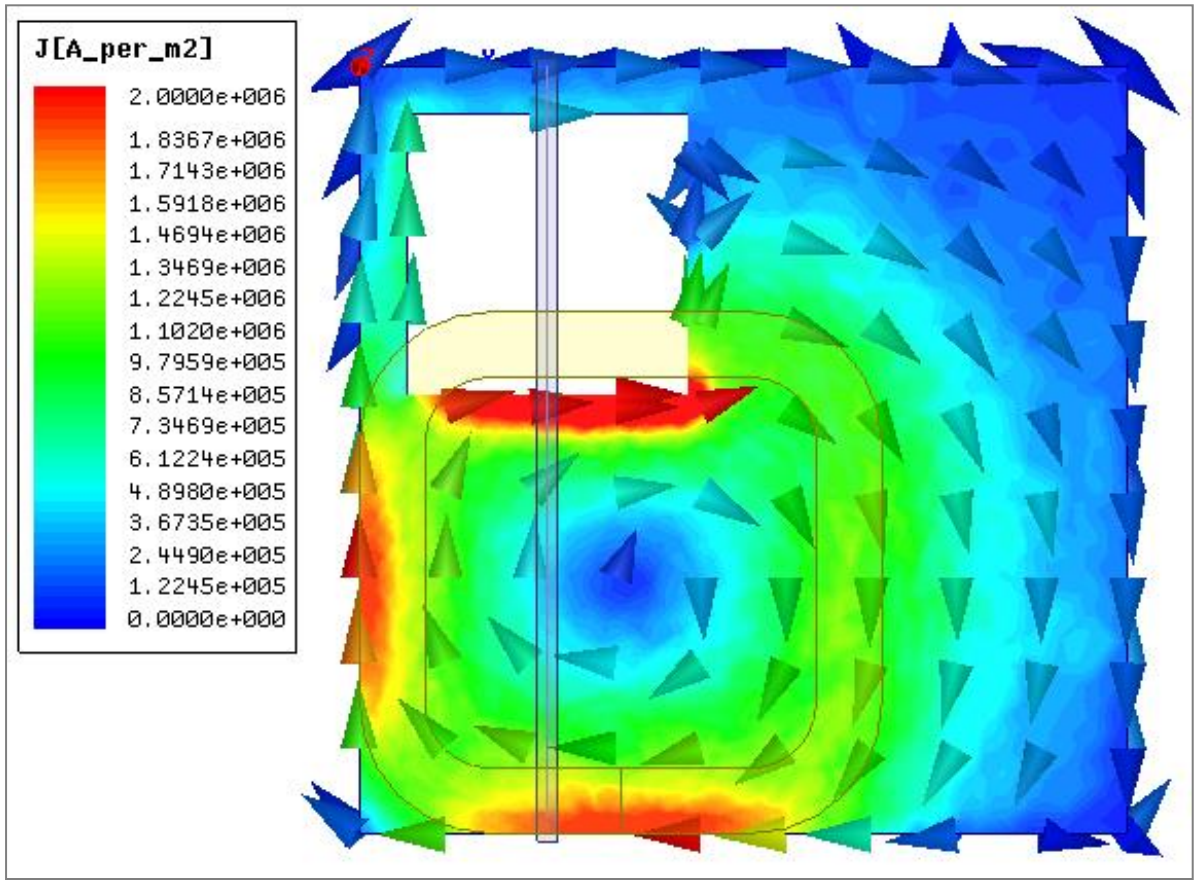
- Maxwell Postprocessing
- Reports and Solution Data
- Field Overlays
- Field Calculator
- Parametric, Optimization and Sensitivity
- Workshop 4.1: Postprocessing
- Workshop 4.2: Parametric Analysis

Overall Process



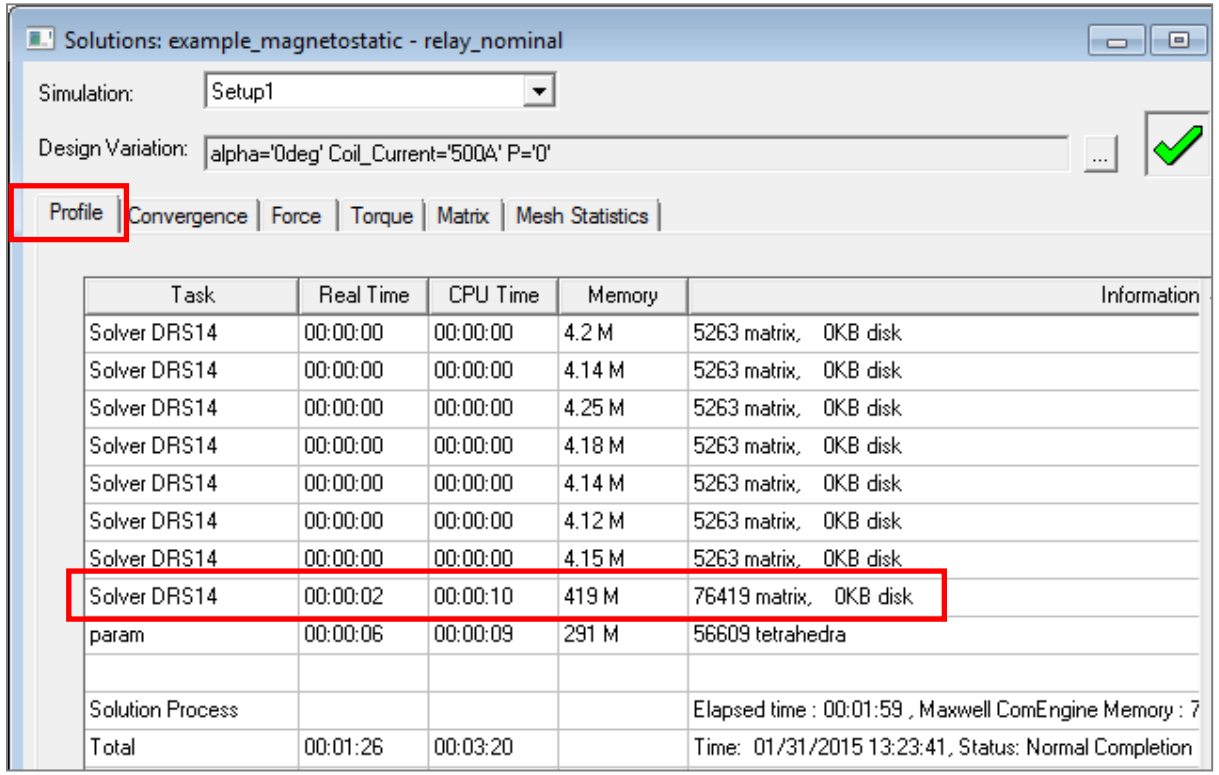
Maxwell Postprocessing

- Maxwell Postprocessing
  - ANSYS Maxwell has very powerful and flexible data management and plotting capabilities.
  - The following postprocessing options are discussed in detail in this Module
    - Field Overlays
    - 2D and 3D Report plot
    - Fields Calculator
    - Output Variables
    - Design Summary



Solution Data

- **Solution Data**
  - **Solution Data contains all the information related to executed solution process**
  - **The Solution Data window can also be opened while the solution process is running to check solution convergence**
  - **Can be accessed from menu item *Maxwell 2D/3D → Results → Solution Data***



Task	Real Time	CPU Time	Memory	Information
Solver DRS14	00:00:00	00:00:00	4.2 M	5263 matrix, 0KB disk
Solver DRS14	00:00:00	00:00:00	4.14 M	5263 matrix, 0KB disk
Solver DRS14	00:00:00	00:00:00	4.25 M	5263 matrix, 0KB disk
Solver DRS14	00:00:00	00:00:00	4.18 M	5263 matrix, 0KB disk
Solver DRS14	00:00:00	00:00:00	4.14 M	5263 matrix, 0KB disk
Solver DRS14	00:00:00	00:00:00	4.12 M	5263 matrix, 0KB disk
Solver DRS14	00:00:00	00:00:00	4.15 M	5263 matrix, 0KB disk
Solver DRS14	00:00:02	00:00:10	419 M	76419 matrix, 0KB disk
param	00:00:06	00:00:09	291 M	56609 tetrahedra
Solution Process				Elapsed time : 00:01:59 , Maxwell ComEngine Memory : 7
Total	00:01:26	00:03:20		Time: 01/31/2015 13:23:41, Status: Normal Completion

– **Profile Tab:**
  - **Contains log of tasks performed by Maxwell during solution process and time taken for each task**
  - **It reports peak physical memory used for each task**
  - **Listed tasks can be different based on type of solution being carried out**
  - **Tasks that can use HPC licenses also show the number of processors being used.**

Solution Data

- **Convergence Tab:**
  - Reports Adaptive Convergence information
  - Available only with Static Solvers
  - Can be viewed as a Table or Plot

Profile | Convergence | Force | Torque | Matrix | Mesh Statistics

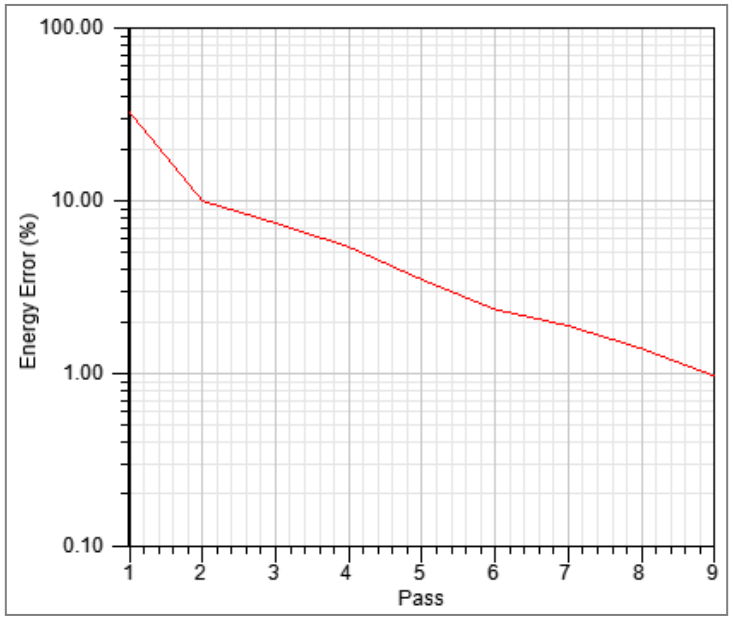
Number of Passes
Completed 9
Maximum 10
Minimum 2

Energy Error/Delta Energy (%)
Target (1, 1)
Current (0.97, 0.24766)

View: Table Plot

Export...

Pass	# Tetrahedra	Total Energy (J)	Energy Error (%)	Delta Energy (%)
1	6925	0.0073137	32.544	N/A
2	9006	0.0070874	9.9403	3.0947
3	11714	0.0069485	7.4082	1.9594
4	15233	0.0068706	5.3986	1.1221
5	19807	0.0068127	3.491	0.84167
6	25756	0.0067654	2.3529	0.69444
7	33488	0.0067348	1.8931	0.45276
8	43541	0.0067137	1.3988	0.3136
9	56609	0.006697	0.97	0.24766



- **Force, Torque and Matrix Tab:**
  - Reports computed parameters values

Profile | Convergence | Force | Torque | Matrix | Mesh Statistics

Parameter: frc_arm Force Unit: newton

Pass: 9

	F(x)	F(y)	F(z)	Mag(F)
Total	0.00070726	-0.17241	6.781	6.7832

- **Mesh Statistics Tab:**
  - Reports mesh information and statistics

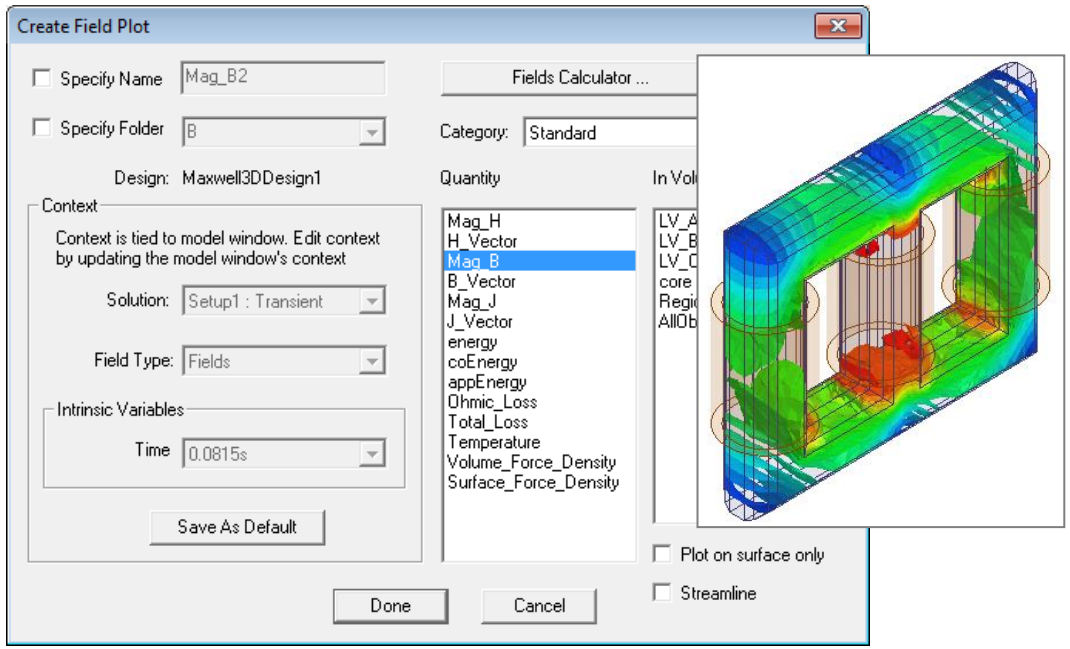
Profile | Convergence | Force | Torque | Matrix | Mesh Statistics

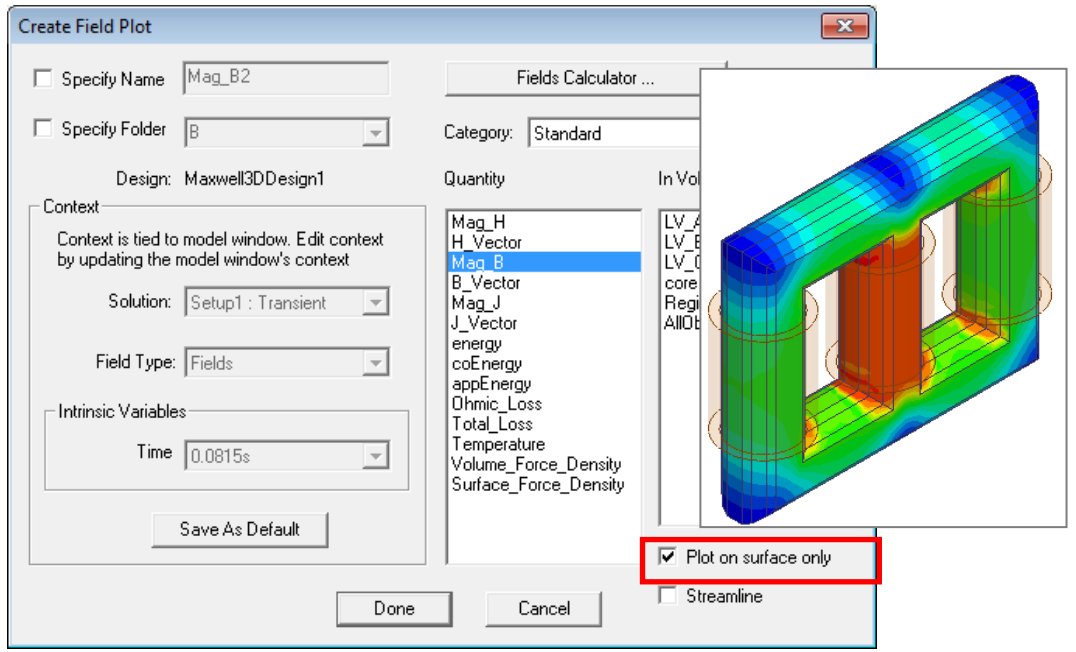
Total number of elements: 56609

	Num Tet...	Min edge len...	Max edge len...	RMS edge len...	Min tet vol...	Max tet vo...	Mean tet v...
armature	4682...	0.093326...	2.02271	0.788658	1.99997e-0...	0.350564...	0.0200986...
coil	6014...	0.39737	5.56725	1.77265	0.0025895...	3.9174...	0.238649...
core	2206...	0.275647...	3.97286	1.46459	0.0009330...	2.65256...	0.0735492...
region	37894...	0.105655...	20.7723	3.84229	1.84568e-0...	400.327...	4.69778...
yoke	5813...	0.120925...	3.78255	1.1414	0.0001216...	2.34904...	0.0626543...

Fields Overlays

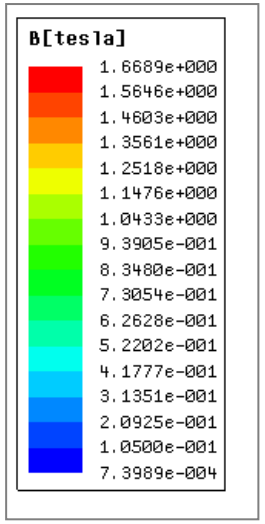
- **Field Plots**
  - **Field overlays are representations of basic or derived field quantities on surfaces or volumes. All the basic field quantities (B, H, J, E etc.) and in-built derived quantities (such as Ohmic Losses, Core Loss, Force Density etc.) can be directly used for plotting**
  - **A field plot can be a contour plot or a vector plot**
  - **Additional quantities can be derived using Fields Calculator and can be used for plotting**
  - **A field Plot can be created by selecting an object, then *Maxwell 2D/3D → Fields* and required quantity**

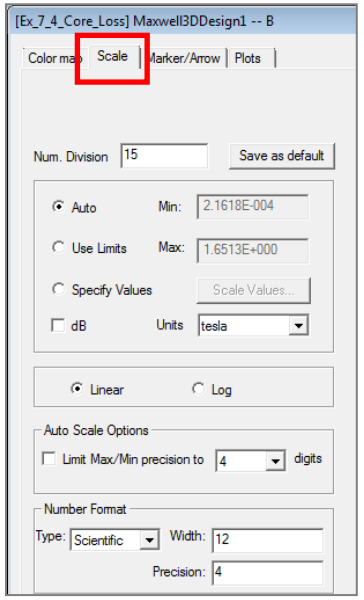


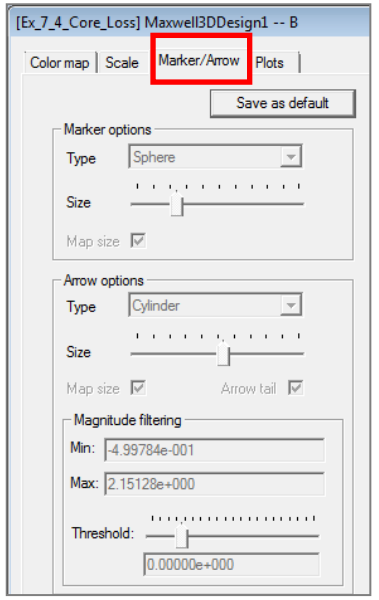


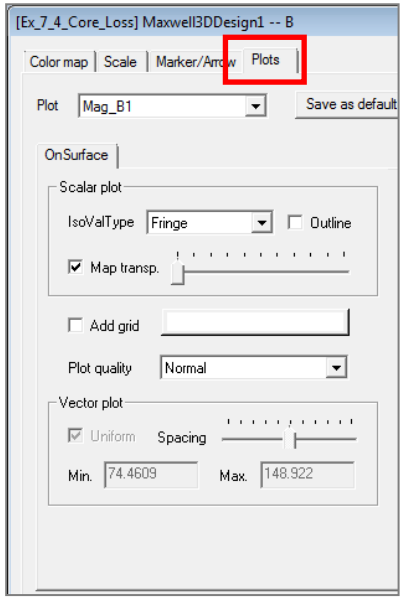
Plot Attributes

- **Modifying Plot Attributes**
  - Often changing the plot display attributes leads to better results viewing and analyze
  - After creation of the plot, double clicking on the legend (Colorkey) will open a dialogue box allowing to modify plot attributes
    - **Color Map Tab:** Sets predefined color schemes used for plot
    - **Scale Tab:** Sets range and Number of Colors of plot
    - **Marker /Arrow Tab:** Sets Size and style of arrows in vector plot
    - **Plots Tab:** Sets display style of contour plots and density of arrows for vector plot





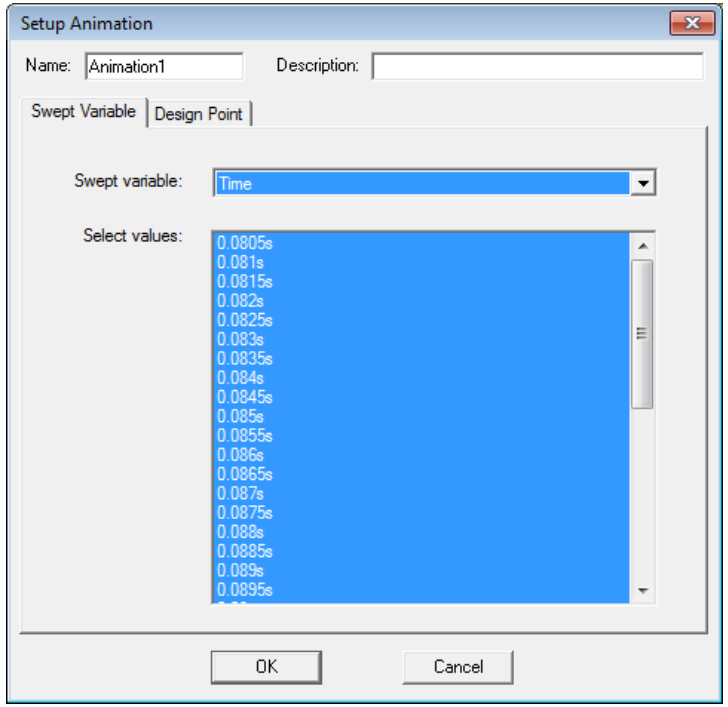


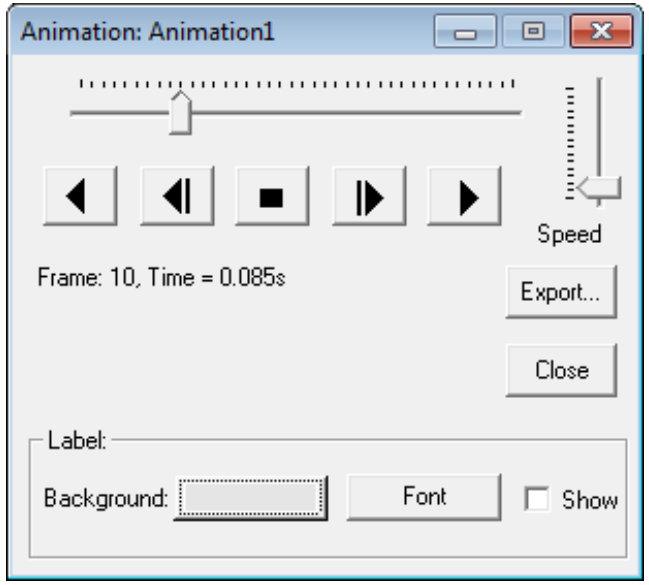


Fields Animation

- **Field Animation**
  - Field animation are useful to analyze changes in the field quantity with respect to time or any input parameters
  - Can be created by selecting an existing field plot and then ***RMB → Animate***

Note: Field animation for transient solutions must have Save Fields defined



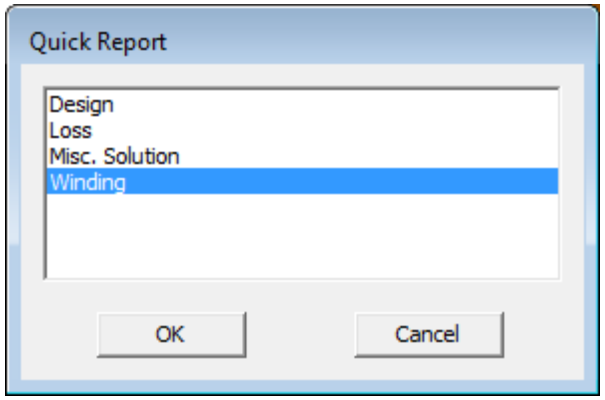


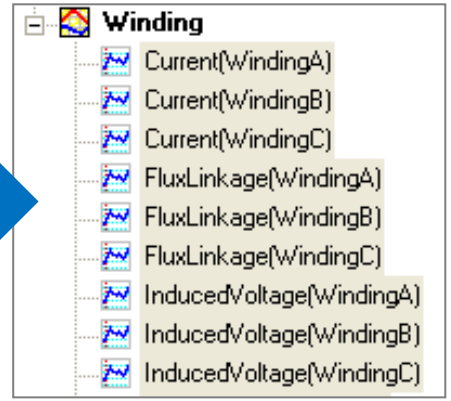
- **Animation window enables to Stop, Play or Rewind the animation**
- **Animation Speed can be controlled**
- **Export button exports the animation in AVI or GIF format**

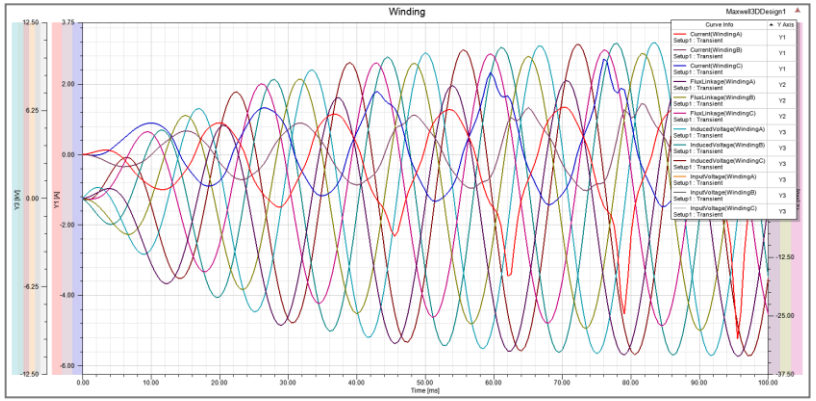
Animation can be setup by selecting swept variable values for which field is animated

Report Plots

- Report Plots
  - Report plots are used to analyze output quantities along a curve or vs any defined parameter such as Time
  - Can be created from menu item *Maxwell 2D/3D → Results → <Report Type > → <Plot Type>*
- Report Types
  - **Solver Specific Reports**
    - Plots for solver specific quantities such as core loss, assigned parameters or expression cache etc.
  - **Field Reports**
    - Plots any field quantities (such as Mag_B, Mag_H etc.) and calculator expressions
  - **Quick Reports**
    - Single click report generation for preset quantities such as assigned parameters, Losses, motion
    - X axis of plot will be Adaptive passes for Static solver while for transient solver it will be time

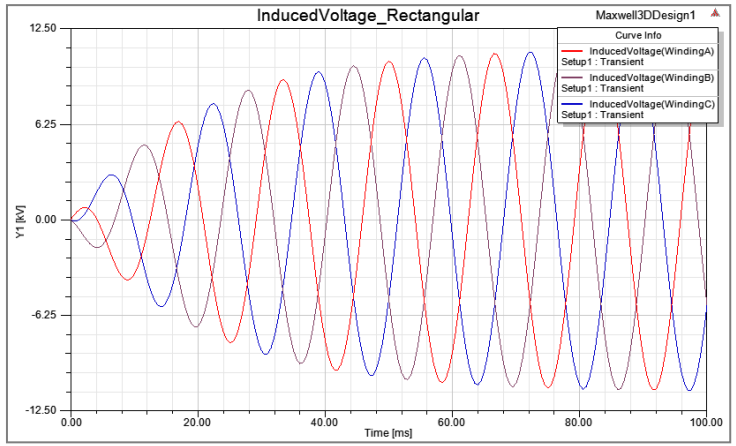




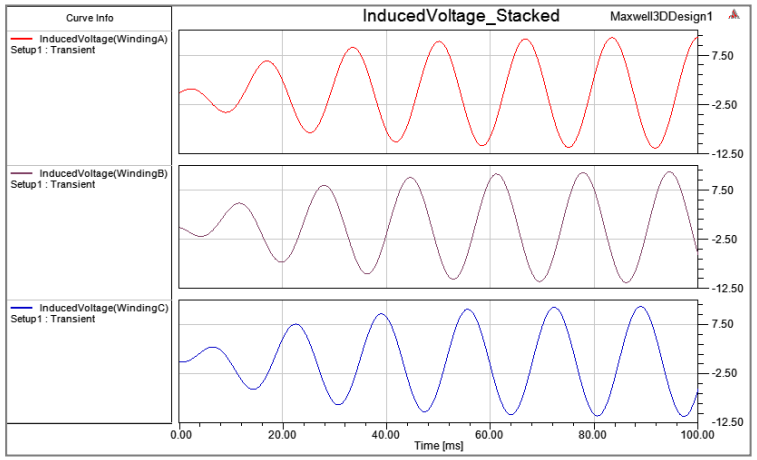


Report Plots

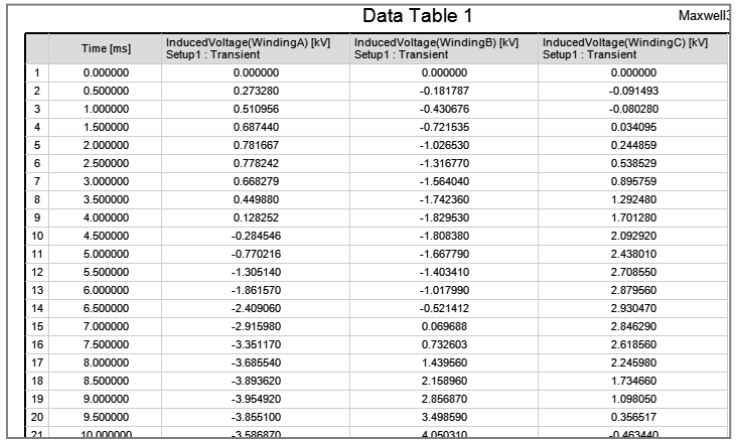
- **Plots Types**



Rectangular Plot:
Plots multiple traces overlaid in single Plot area

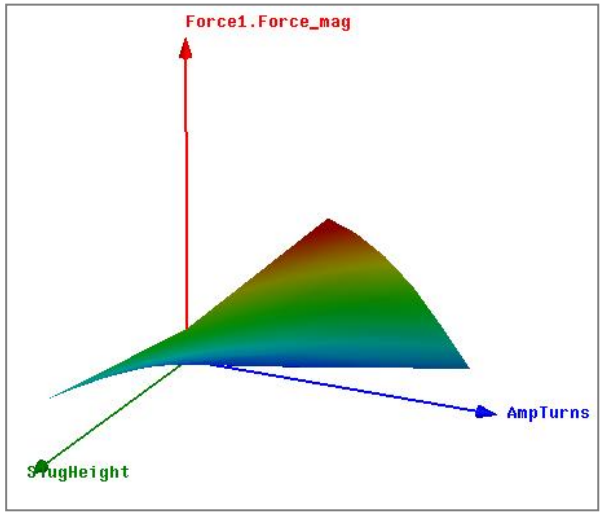


Rectangular Stacked Plot:
Plots multiple traces stacked vertically


Data Table 1

	Time [ms]	InducedVoltage(WindingA) [kV] Setup1 : Transient	InducedVoltage(WindingB) [kV] Setup1 : Transient	InducedVoltage(WindingC) [kV] Setup1 : Transient
1	0.000000	0.000000	0.000000	0.000000
2	0.500000	0.273280	-0.181787	-0.091493
3	1.000000	0.510956	-0.430676	-0.080280
4	1.500000	0.687440	-0.721535	0.034095
5	2.000000	0.781667	-1.026530	0.244859
6	2.500000	0.778242	-1.316770	0.538529
7	3.000000	0.668279	-1.564040	0.895759
8	3.500000	0.449880	-1.742360	1.292480
9	4.000000	0.128252	-1.829530	1.701280
10	4.500000	-0.284546	-1.808380	2.092920
11	5.000000	-0.770216	-1.667790	2.438010
12	5.500000	-1.305140	-1.403410	2.708550
13	6.000000	-1.861570	-1.017990	2.879560
14	6.500000	-2.409060	-0.521412	2.930470
15	7.000000	-2.915980	0.069688	2.846290
16	7.500000	-3.351170	0.732603	2.618560
17	8.000000	-3.685540	1.439560	2.245980
18	8.500000	-3.893620	2.158960	1.734660
19	9.000000	-3.954920	2.856870	1.098050
20	9.500000	-3.855100	3.498590	0.356517
21	10.000000	-3.586870	4.050310	-0.463440

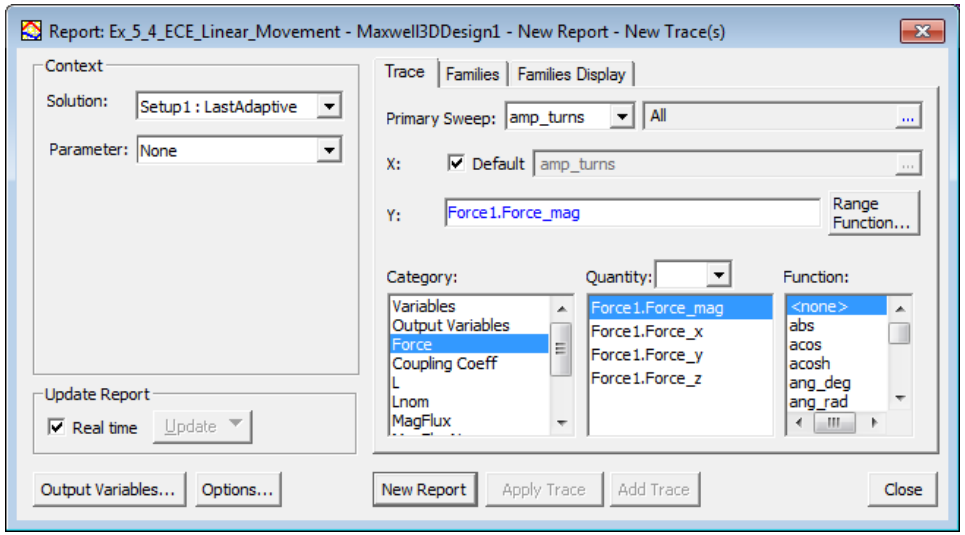
Data Table:
Plots traces in tabular form



3D Rectangular Plot:
Plots 3D surface of output against two inputs

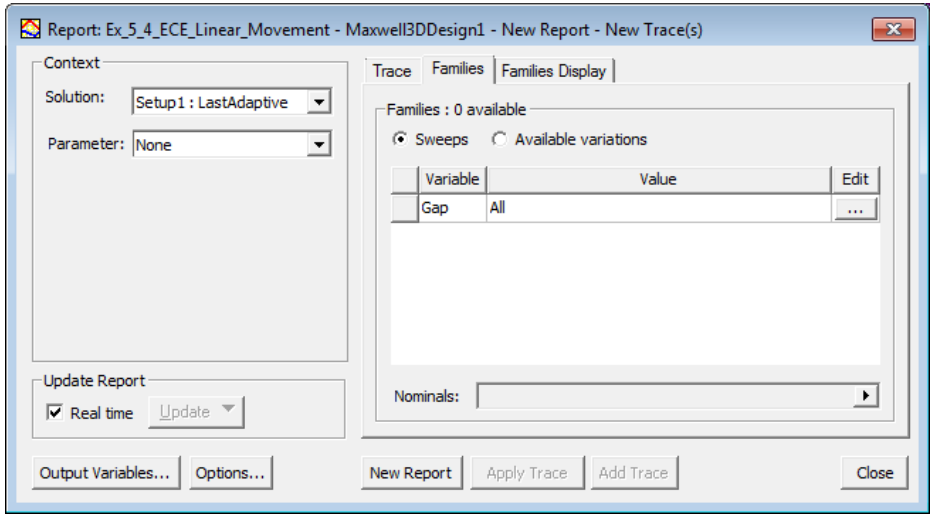
Report Plots

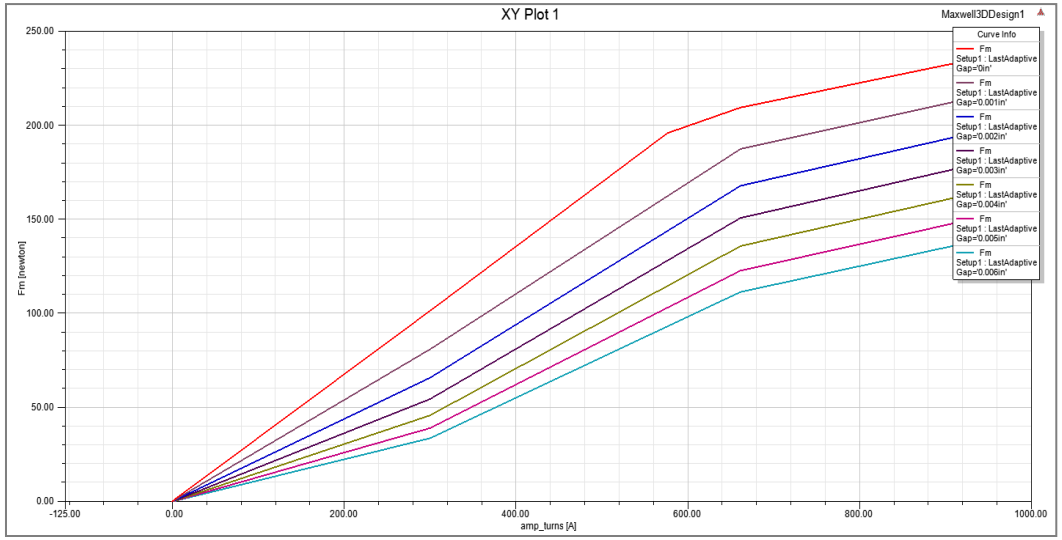
- Creating Rectangular Plot
  - Can be created from menu item *Maxwell 2D/3D → Results → <Report Type> → Rectangular Plot*
  - Context
    - Design: Choose from available designs within a project
    - Solution: choose from available setups or solution types
    - Geometry: if plotting Fields data, select an available Line or Point from the list
  - Trace Tab
    - Primary Sweep: controls the independent variable
    - X: controls any functional operator on the independent variable (set to Primary Sweep)
    - Y: select the value to be plotted
    - Category: Select the variable category
    - Quantity: Select the variable to plot
    - Function: To perform arithmetic operations on variable before plot



Report Plots

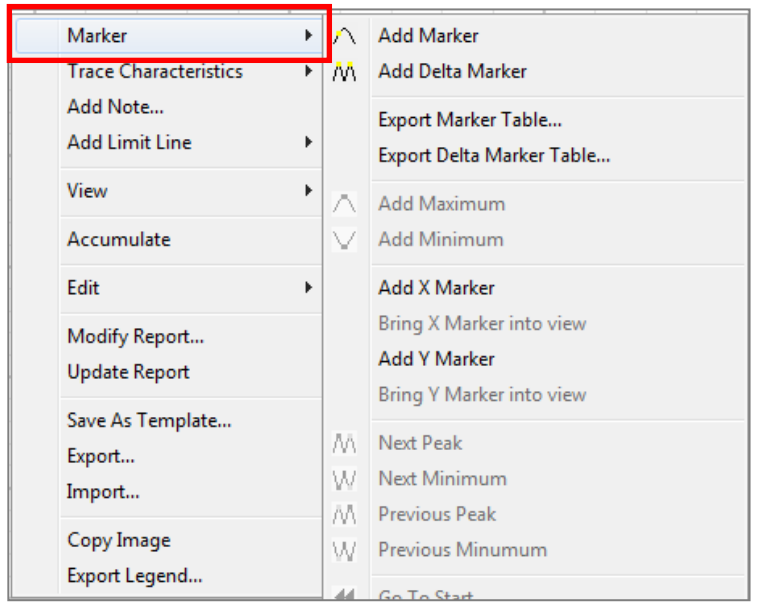
- **Families Tab**
  - Enables users to plot Separate Traces for each variable value from defined parametric sweep
- **Output Variables**
  - Opens Output variable definition window
- **New Report**
  - Creates a New XY Plot
- **Add Trace**
  - Adds defined trace to selected XY Plot
- **Apply Trace**
  - Modifies existing trace to the selected one



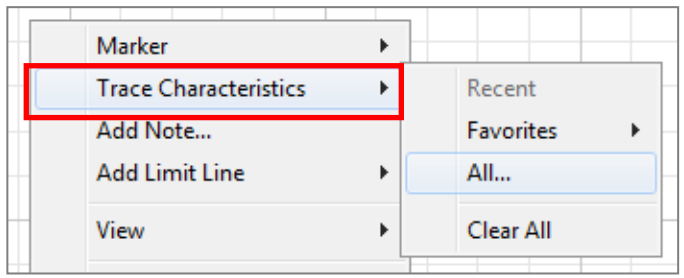


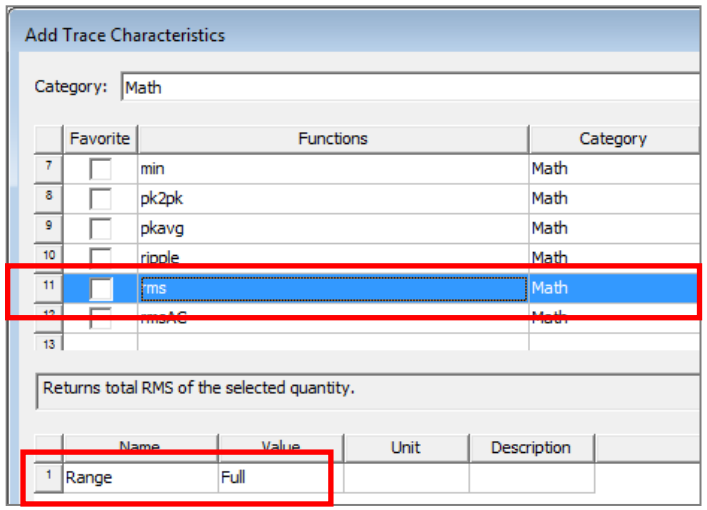
Report Analysis

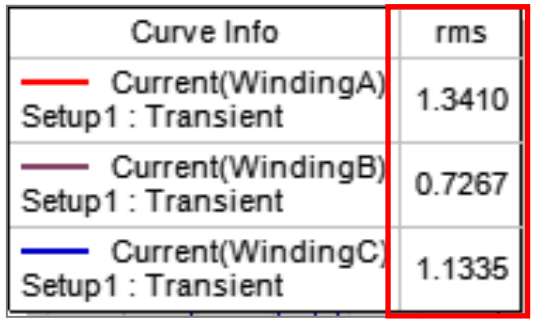
- **Markers**
  - **Markers help to analyze the plot data at various data points**
  - **Can be used to get the value of outputs at any input point, identify change in output over a range or get the slope of the curve between two points**
  - **Can be added by RMB on Report Plot area and selecting Marker**



- **Trace Characteristics**
  - **Trace Characteristics enable users to calculate signal characteristics on the plotted traces**
  - **Resulting value is displayed next to the trace**



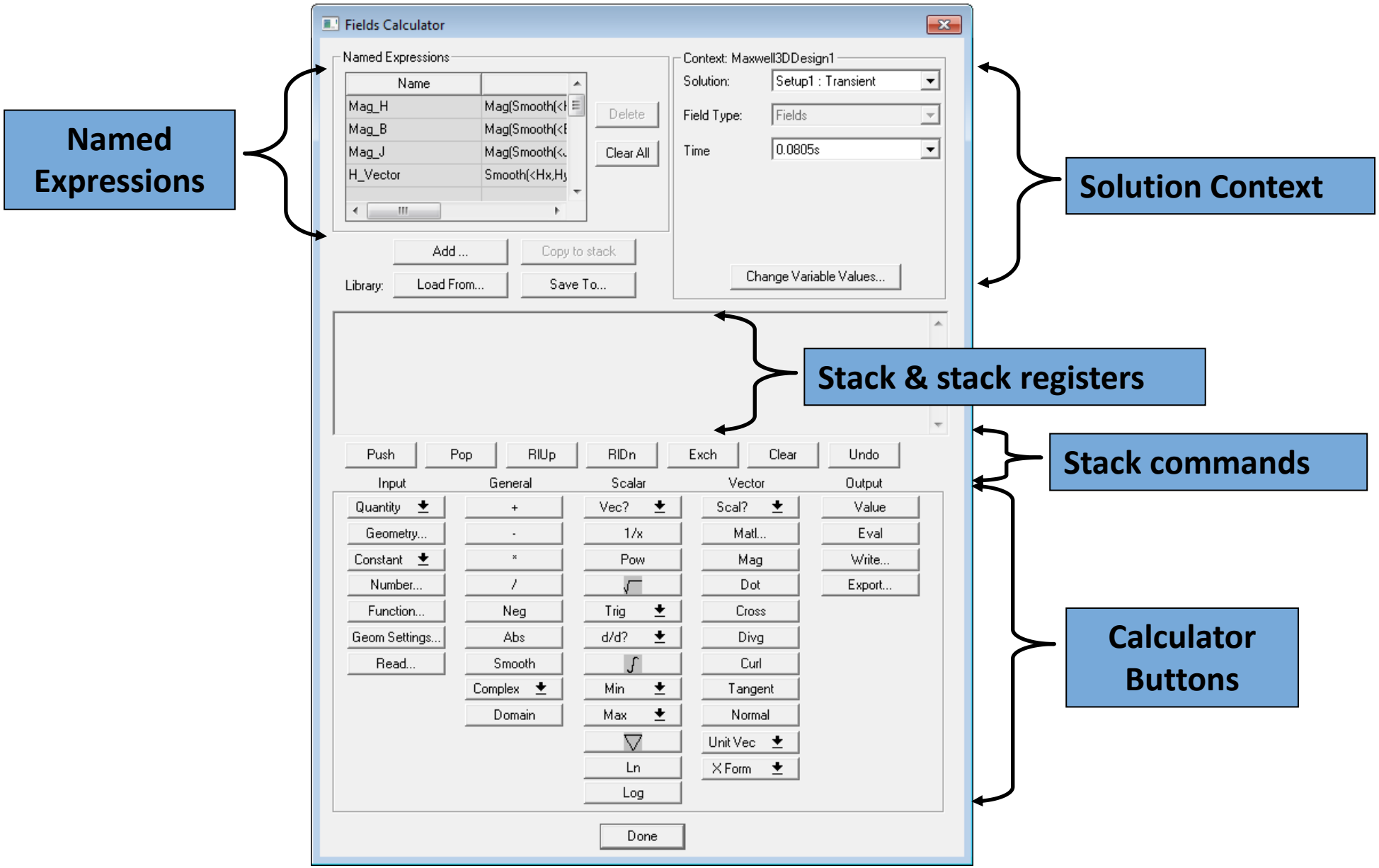




Fields Calculator

- Fields Calculator enables the user to build and postprocess customized expression directly from the basic field quantities
- It has the capabilities of performing vector algebra and calculus operations which can be used to build further complex quantities
- In addition Fields Calculator can also operate with geometry quantities for three basic purposes:
  - plot field quantities (or derived quantities) onto geometric entities
  - perform integration (line, surface, volume) of quantities over specified geometric entities
  - export field results in a user specified box or at a user specified set of locations (points)
- A Fields Calculator can be launched from the menu item *Maxwell 3D/2D → Fields → Calculator*
- Maxwell Help provides information on the operations for the entire calculator interface (press F1 and look in the Contents section *Post Processing → Using the Fields Calculator*)

Fields Calculator GUI



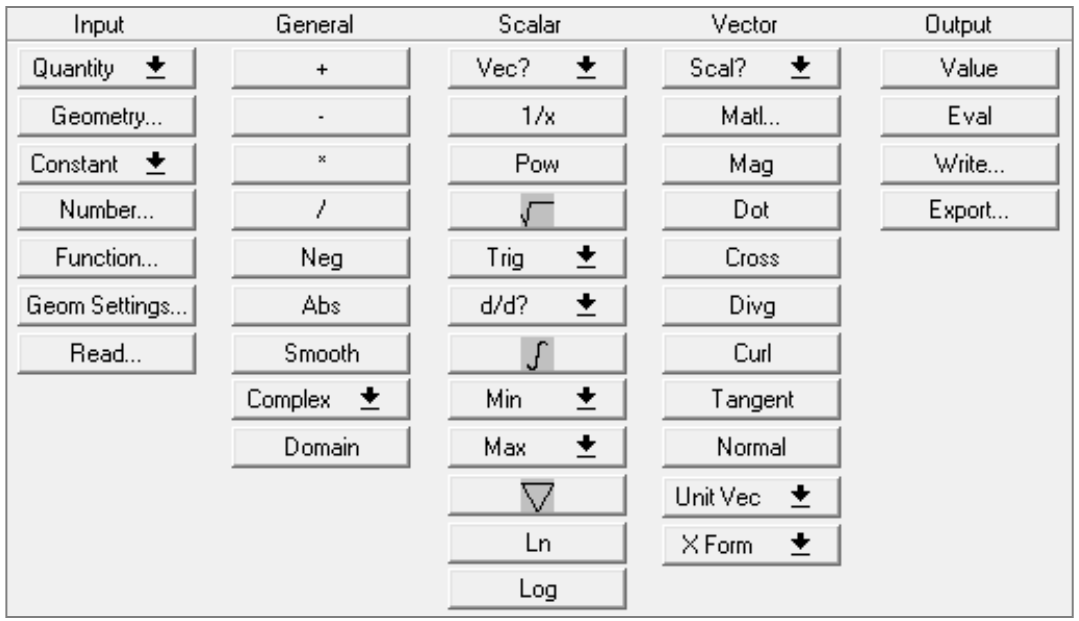
Fields Calculator GUI

- Calculator GUI
  - The Calculator GUI contains a stack holding the quantity of interest in stack registers
  - A number of operations are intended to allow users to manipulate the contents of the stack or change the order of quantities being held in stack registers
- Stack Commands

  - **Push**: Duplicates the content of the top stack register
  - **Pop**: Deletes the last entry from the stack (deletes the top of the stack)
  - **RlDn**: (Roll down) is a “circular” move making the contents of the stacks slide down one line with the bottom of the stack advancing to the top
  - **RlUp**: (Roll up) like RlDn on the other way around
  - **Exch**: (Exchange) exchanges the contents of the two top stack registers
  - **Clear**: Clears the entire contents of all stack registers
  - **Undo**: undo the most recent operation. It could be nested up to the level where a basic quantity is obtained

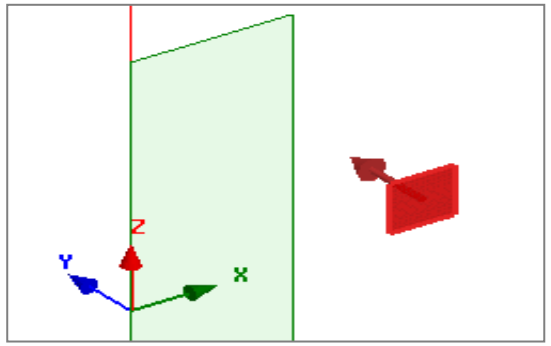
Fields Calculator GUI

- Calculator Buttons
  - **Input**:
    - Contains calculator buttons allowing the user to enter data in the stack
    - Sub-categories contain solution fields (B, H, J, etc.), geometry (point, line, surface, volume, coordinate system), scalar, vector or complex constants (depending on application)
  - **General**:
    - Contains general calculator operations applicable to “general” data (scalar, vector or complex)
    - The Operations being performed should be mathematically valid for inputs added in the stack
  - **Scalar**:
    - Scalar contains operations that can be performed on scalars such as Gradient, Integration etc.
  - **Vector**:
    - Contains operations that can be performed on vectors only such as cross/dot product, divergence, curl etc.
  - **Output**:
    - Contains operations resulting in data export, data evaluation, etc.



Integrate in 2D RZ

- Integrate Command in 2D RZ
  - Maxwell 3D and 2D XY offer single integration option which integrates the selected quantity over a volume or a surface
    - Integration in 2D XY will give results values per unit length in Z direction and needs to be multiplied by length of the model to get total values
  - Integration in 2D RZ offers two Options
    - Integral XY: Performs in plane integration of the quantity over the provided surface.
    - Integral RZ: Performs integration considering 360 degree of the geometry around Z axis. Thus integration is done over the volume of RZ geometry



Current Carrying coil in XZ Plane

Current through the coil can be calculated by performing XY integration of Current Density over the coil surface

```
Scl : 100.000000168651
Scl : Integrate(Surface(Coil), Real(ScalarPhi(<0,Jphi,0>)))
```

Ohmic loss over coil volume can be obtained by performing RZ integration of Ohmic Loss over the coil surface

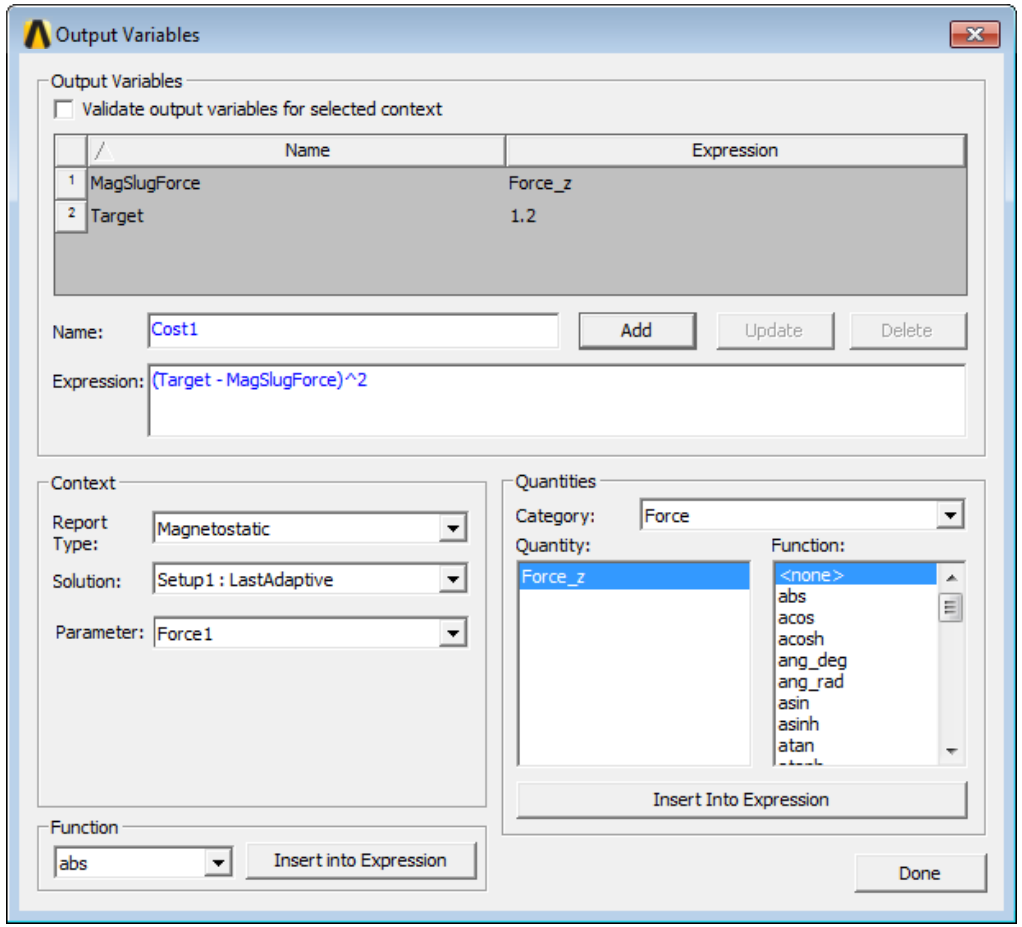
```
Scl : 3.82072139800439
Scl : RZIntegrate(Volume(Coil), Ohmic-Loss)
```

Fields Calculator Guidelines

- **Guidelines in Using Fields Calculator**
  - **Fields Calculator is a powerful tool to postprocess solution data in required form. The following points should be kept in mind while using Fields Calculator**
    - **Fields Calculator quantities do not include factors as Symmetry Multiplier or model depth. Users have to manually add scaling factors to account for full model when symmetry is used. All 2D XY integration results are in “per-meter”.**
    - **Some operations in Calculator require content of the stack to be in order**
    - **Integration require geometry term to be at the top and quantity to be integrated below it**
    - **Cross Product require second term at the top of stack while first term below it**
    - **Fields Calculator Operations are always performed with respect to Global CS and do not consider any active CS assigned**
    - **Fields Calculator values are always computed in SI [mks] units irrespective of the design units**

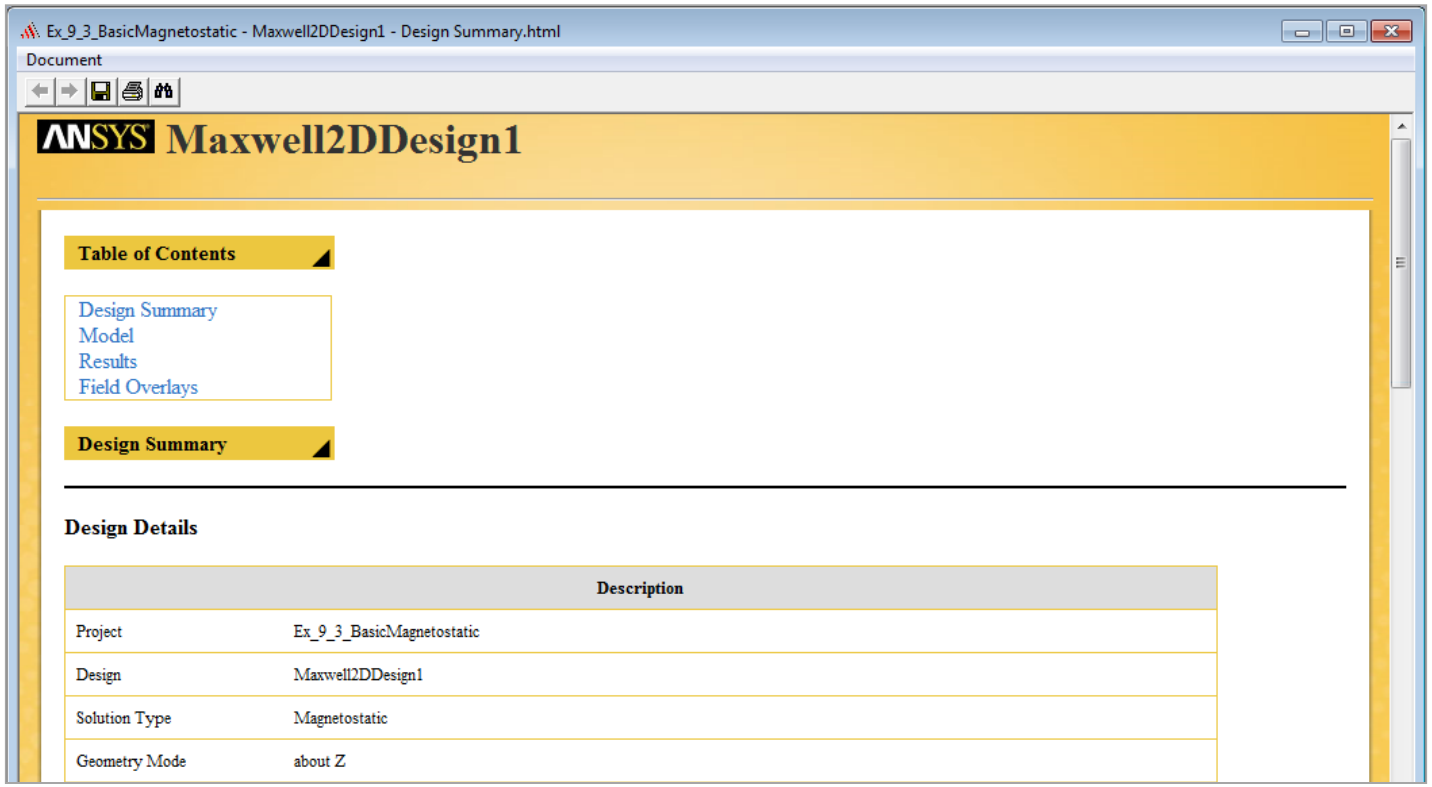
Output Variables

- Output variables are useful in the cases where parametric or optimization studies are required and additional calculations using output Quantities are needed.
- Can be created from the menu item *Maxwell 3D/2D → Results → Output Variables*
- **Output variables Section:**
  - Name and Expression for the Output variable to be created.
  - Pressing Add button adds defined variable to the list
  - Expression can be typed in or built using Quantity section
- **Context:**
  - Enables users to define Report Type, Solution and Parameters
  - All quantities related to these selection are displayed in Quantity section
- **Quantities:**
  - Helps users to build expressions
  - Can be selected along with a mathematical function
  - Insert Into Expression adds selected quantity to Expression field



Design Summary

- **Design Summary**
  - Design Summary allows users to summarize all Design information in a single document through a single click
  - Design Summary contains all postprocessed data such as Mesh plots, Field Overlays and Result plots
  - Resulting document can be saved in easily sharable HTML or PDF format
  - Design Summary can be created by selecting the menu item *Maxwell 2D/3D → Results → Create Document → Design Summary*



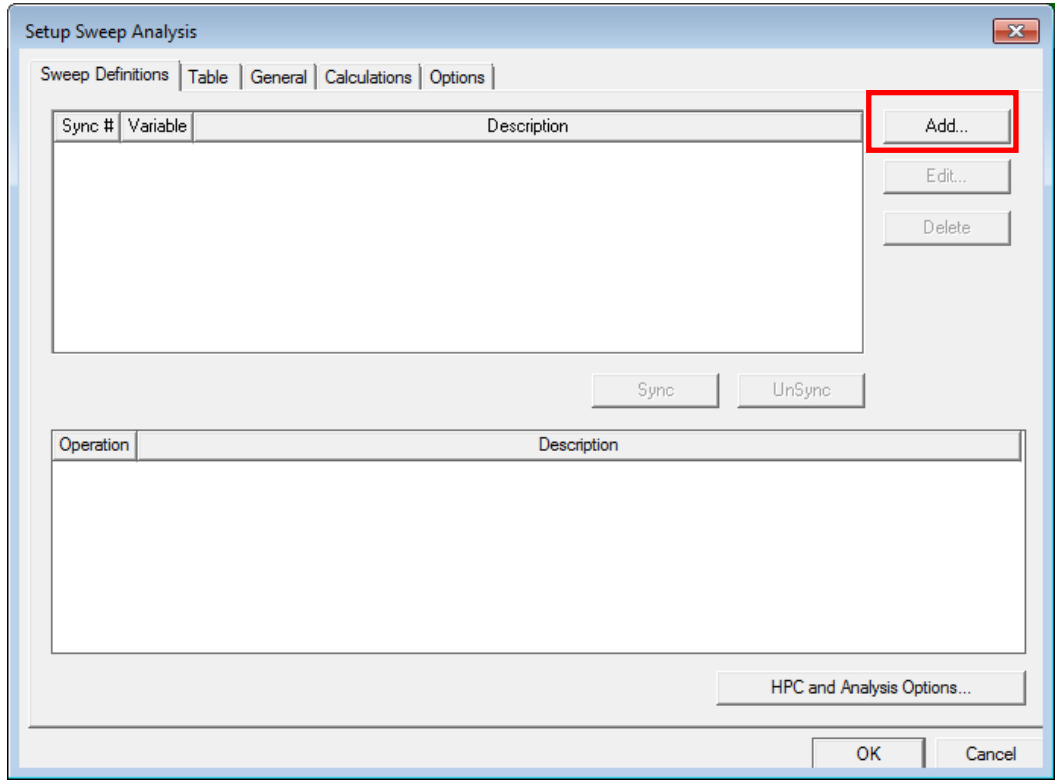
Optimetrics

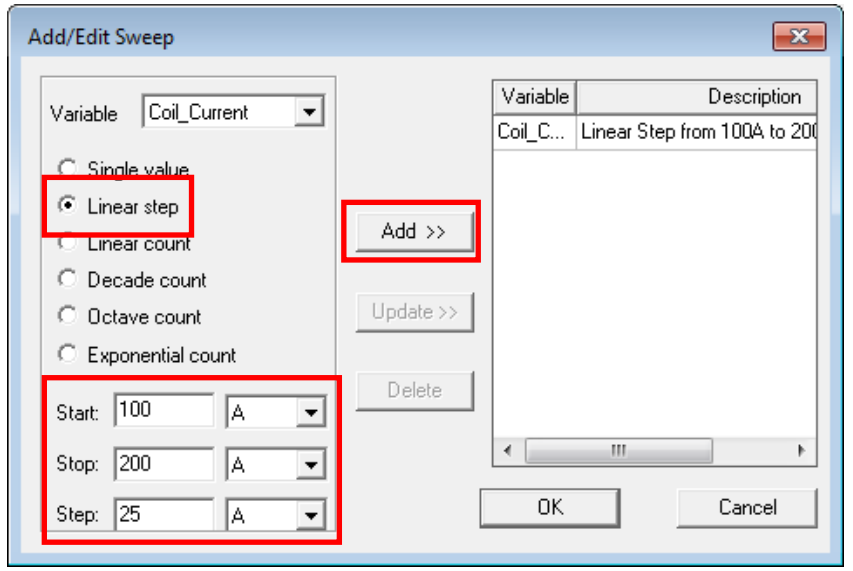
Optimetrics Analysis

- Optimetrics Analysis is used to perform studies where input variable variations affect the output
- Input parameters can be any geometrical or excitation parameter while output parameter can be any postprocessing quantity. The following analyses can be added under Optimetrics
  - **Parametric Analysis:**
    - Allows to set variation in single or multiple variables over specified range and assign output quantities
  - **Optimization:**
    - Allows users to define a goal of the analysis
    - Goal can be to minimize/maximize/seek targeted value of the output quantity
    - Input variables are varied in order to achieve the specified goal
  - **Sensitivity:**
    - Identifies which of the defined input variables have more influence in variation of Output
  - **Statistical:**
    - Allows to input statistical distribution of input variables and provides statistical distribution of Output quantities
  - **Tuning**
    - Can be used to fine tune the results of a parametric analysis
    - Allows users to change input parameters interactively while monitoring design performance

Parametric Analysis

- **Parametric Analysis**
  - **A Parametric Analysis can be added from menu item *Maxwell 2D/3D → Optimetrics Analysis → Add Parametric***
- **Sweep Definitions tab**
  - **Add: Clicking on Add button will open the Add/Edit Sweep window, enabling users to define the parametric sweep for all available parameters**

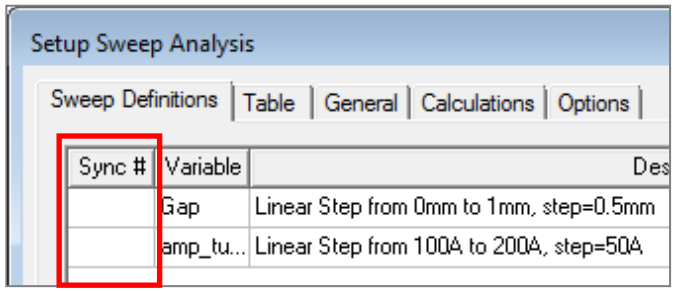




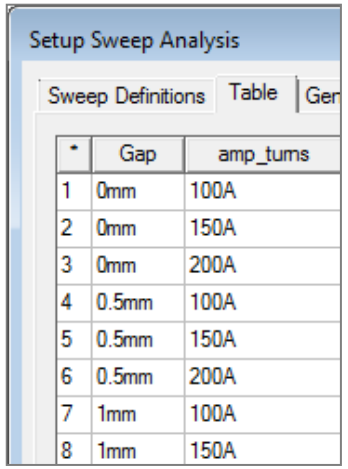
Add/Edit Sweep: enables to define start and end point, sampling method and sample size of parametric sweep

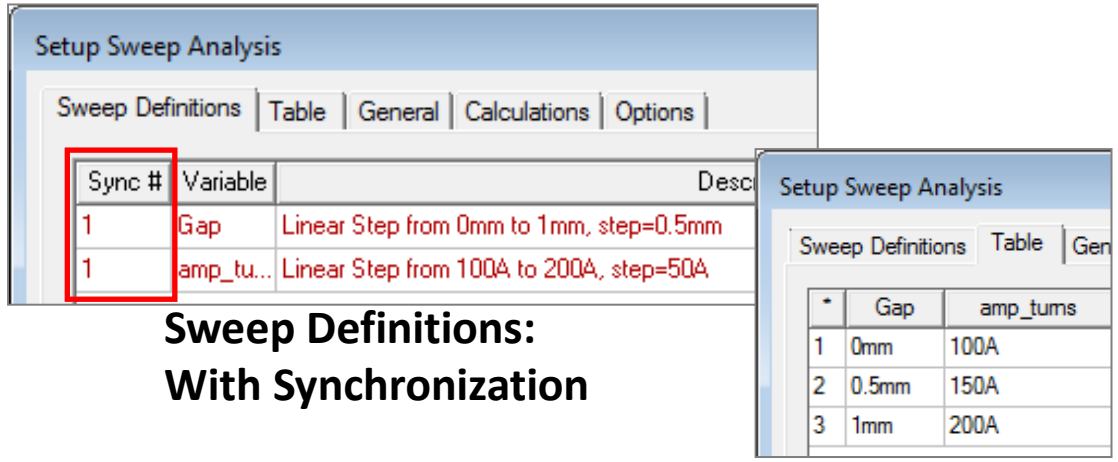
Parametric Analysis

- **Sweep Definitions tab**
  - Sync and UnSync:
    - By Default all assigned Sweep Definitions are nested
    - **Sync** button enables synchronizing the assigned sweep definitions
    - Number of Sample points in sweep definitions should be same for Synchronization
    - **UnSync** button removes the assigned synchronization and revert to nested behavior



Sweep Definitions: Without Synchronization



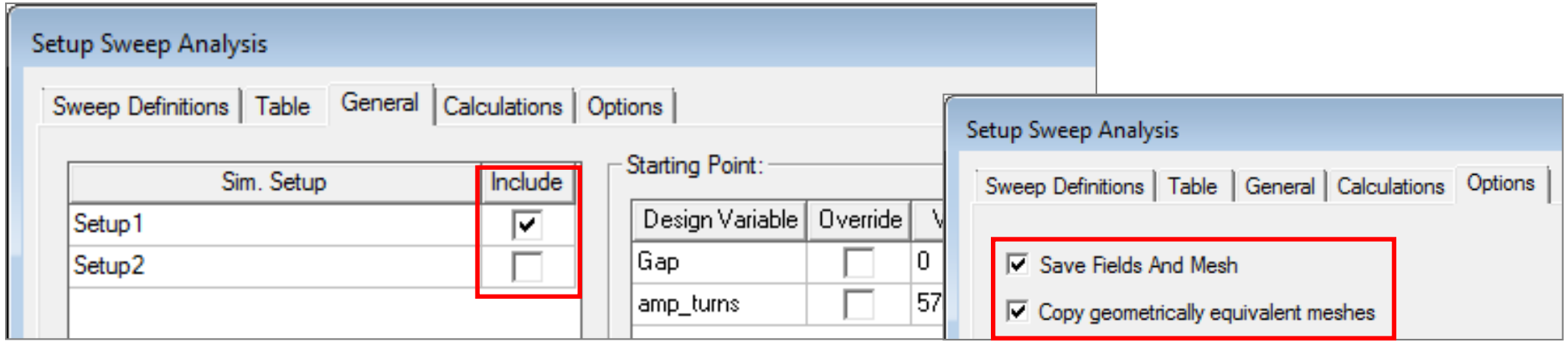


Sweep Definitions: With Synchronization

- **Table tab**
  - Lists all assigned design variations in a tabular form as shown in above image
  - Number of variations that will be solved by Maxwell can be checked from table tab

Parametric Analysis

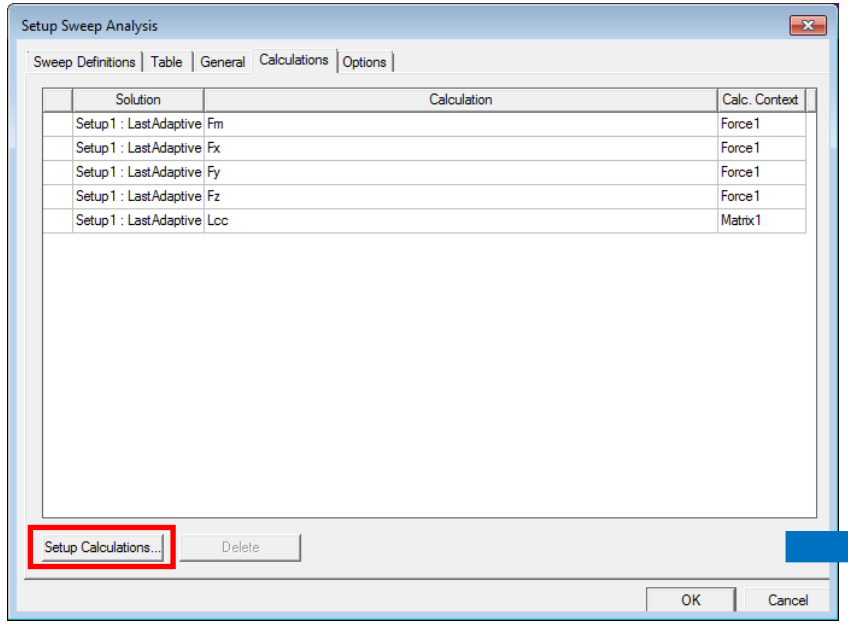
- **General Tab**
  - Sim. Setup:
    - Enables to select the required simulation setup for which parametric sweep needs to be assigned
    - Solver settings used in selected Simulation setup will be used to solve all design variations
  - Starting Point
    - Sets the start value of the design variables for running parametric sweep



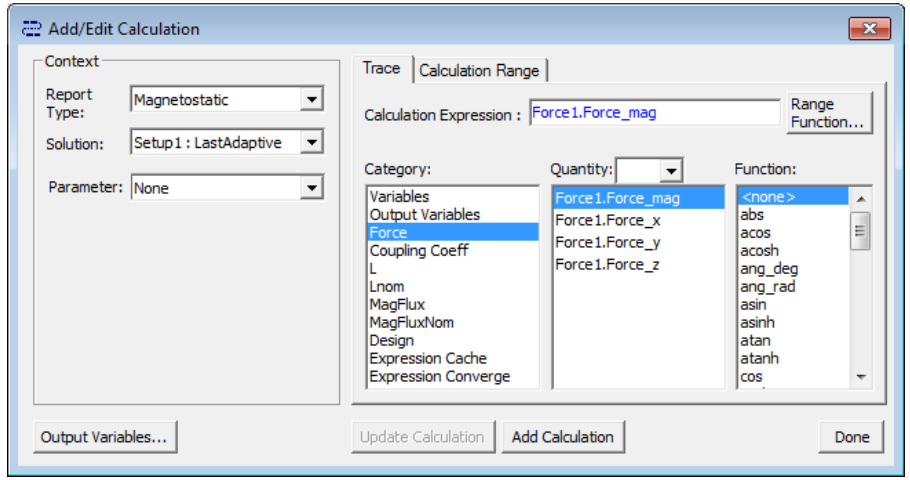
- **Options tab**
  - Save Fields And Mesh:
    - Saves fields and mesh data for all the solved design variations
    - Design variations can be postprocessed using all postprocessing options discussed earlier
  - Copy geometrically equivalent meshes
    - Avoids remeshing if changes in input variables does not affect the geometry

Parametric Analysis

- **Calculation tab**
  - Enables users to define Output parameters of Parametric Analysis to get required output without need to save fields at all design variations
  - Resulting value of output parameters must be a real scalar



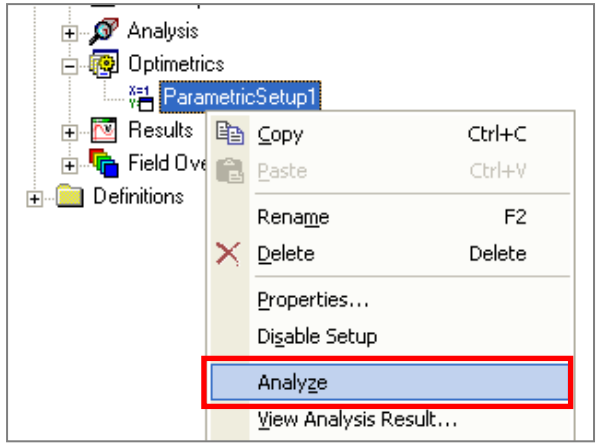
Clicking Setup Calculation button will open Add/Edit Calculation window

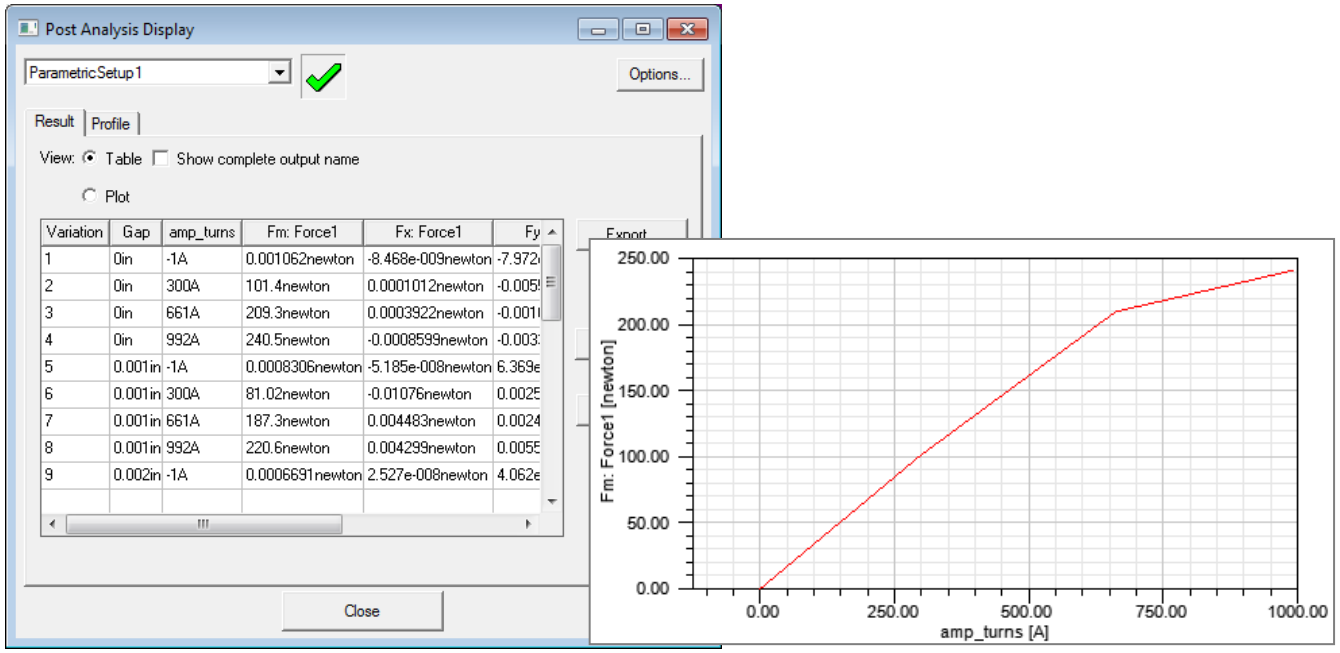


- **Add/Edit Calculations window:**
  - Enables users to select any of the output quantities
  - Clicking on Output Variables button will open Output variables window
  - Add Calculation button will add selected quantity to Setup Sweep Analysis window

Parametric Analysis

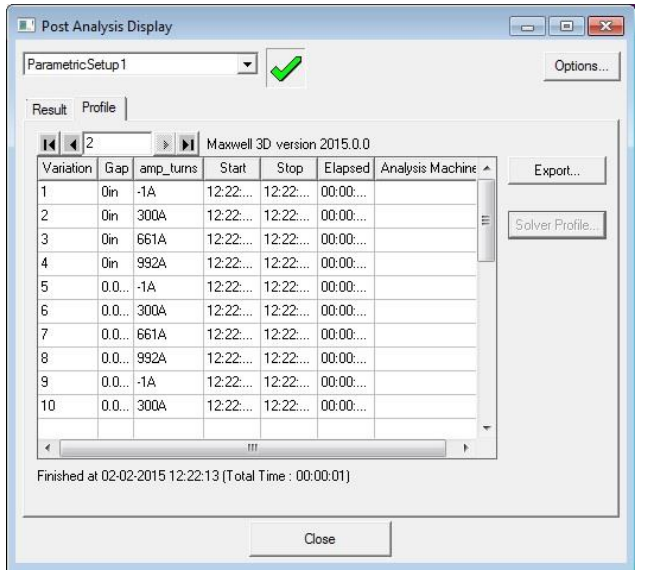
- **Running Parametric Analysis**
  - **Right clicking on added Parametric Setup from project Manager tree under Optimetrics and selecting “Analyze”**
- **Examine Results**
  - **Right click on Added parameter setup from Project Manager tree and select “View Analysis Results”**





Variation	Gap	amp_turns	Fm: Force1	Fx: Force1	Fy
1	0in	-1A	0.001062newton	-8.468e-009newton	-7.972
2	0in	300A	101.4newton	0.0001012newton	-0.005
3	0in	661A	209.3newton	0.0003922newton	-0.001
4	0in	992A	240.5newton	-0.0008599newton	-0.003
5	0.001in	-1A	0.0008306newton	-5.185e-008newton	6.369e
6	0.001in	300A	81.02newton	-0.01076newton	0.0025
7	0.001in	661A	187.3newton	0.004483newton	0.0024
8	0.001in	992A	220.6newton	0.004299newton	0.0055
9	0.002in	-1A	0.0006691newton	2.527e-008newton	4.062e

Results can be seen in Tabular or plot view

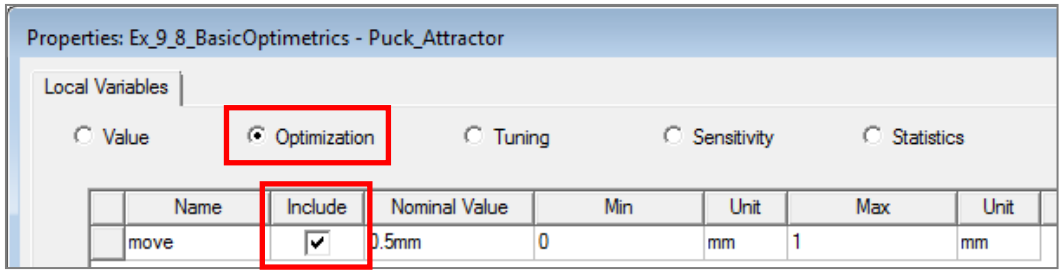


Variation	Gap	amp_turns	Start	Stop	Elapsed	Analysis Machine
1	0in	-1A	12:22:...	12:22:...	00:00:...	
2	0in	300A	12:22:...	12:22:...	00:00:...	
3	0in	661A	12:22:...	12:22:...	00:00:...	
4	0in	992A	12:22:...	12:22:...	00:00:...	
5	0.0...	-1A	12:22:...	12:22:...	00:00:...	
6	0.0...	300A	12:22:...	12:22:...	00:00:...	
7	0.0...	661A	12:22:...	12:22:...	00:00:...	
8	0.0...	992A	12:22:...	12:22:...	00:00:...	
9	0.0...	-1A	12:22:...	12:22:...	00:00:...	
10	0.0...	300A	12:22:...	12:22:...	00:00:...	

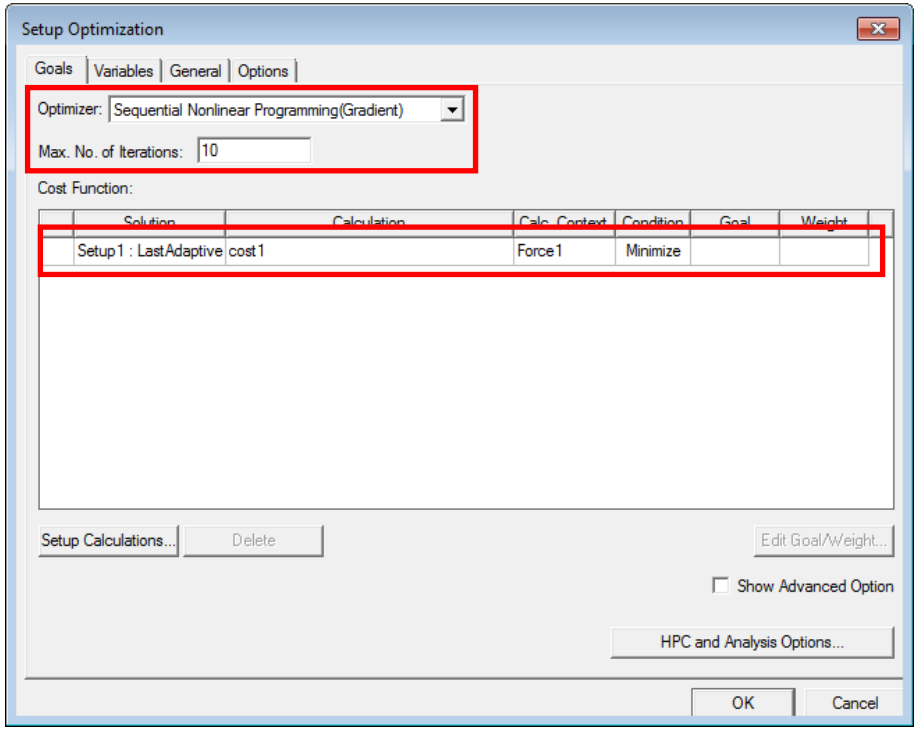
Profile window reports time taken for solving each design variation

Optimization Analysis

- **Setting Variables for Optimization**
  - **Before Optimization setup can be done, it is required to define the variables which will participate in the optimization process**
  - **Variables for Optimization can be assigned from *Maxwell 3D/2D → Design Properties***
- **Optimization Analysis**
  - **Optimization Analysis can be added from menu item *Maxwell 2D/3D → Optimetrics Analysis → Add Optimization***



Parameters for which Include is checked vary to achieve optimization Goal

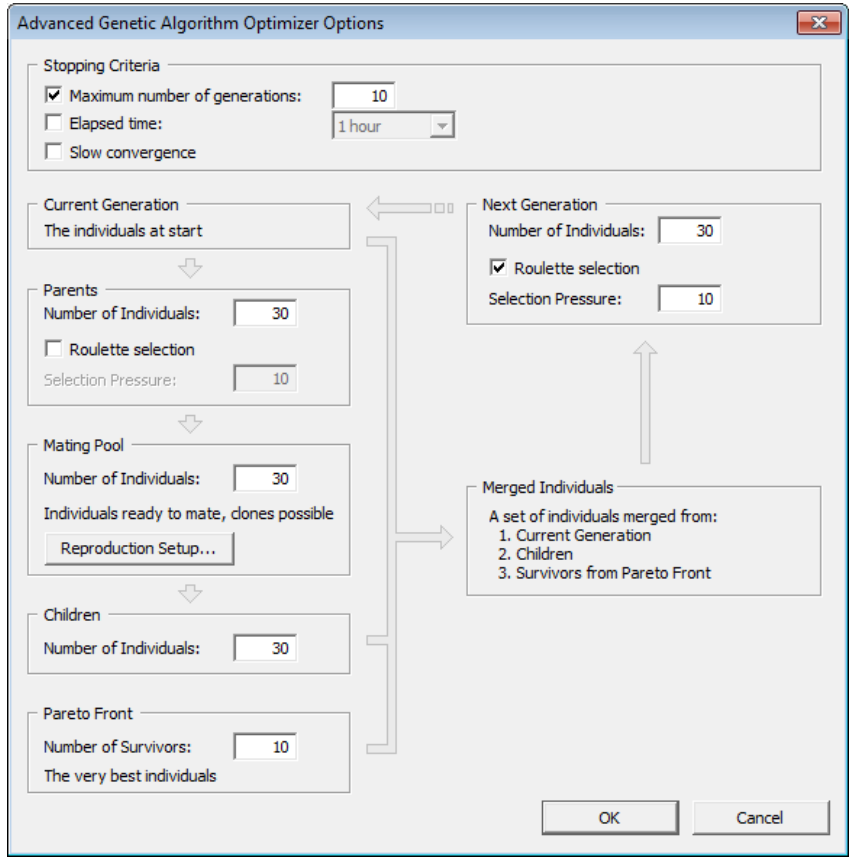


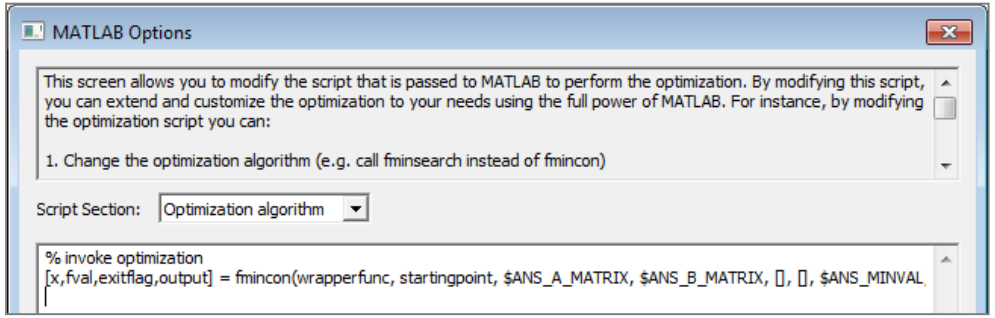
Optimization Analysis

- Goals tab
  - Optimizers: Sets Optimization algorithm used for analysis
  - **Sequential Nonlinear Programming (SNLP):**
    - Creates a Response Surface (RS) using a Taylor Series approximation from simulation results
    - RS is used to determine the gradients and thus the next step direction and distance
    - Numerical noise is assumed to be not significant
  - **Sequential Mixed Integer NonLinear Programming:**
    - Equivalent to SNLP except that Optimization variable can take only integer values
    - Can be used where discrete values of optimization are required (eg. Coil turns)
  - **Quasi Newton:**
    - finds minima or maxima of a cost function relating model variables to overall simulation goals
    - Can be used effectively when numerical noise is less and start values of optimization variables are near expected values
    - Should only be used when 1 or 2 variables are being optimized at a time
  - **Pattern Search:**
    - Performs a grid-based simplex search, based on triangles in 2D or tetrahedra in 3D
    - Can be used effectively when numerical noise is significant
    - Takes more iterations to achieve assigned goal

Optimization Analysis

- **Genetic Algorithm:**
  - Does not use cost function to determine where to further explore the design space.
  - Instead uses a random selection and applies it in a structured manner
  - Run more number of iterations and may be slow
  - Advanced Genetic Algorithm settings can be set by selecting Setup button that appears adjacent to Optimizer Selection
- **MATLAB**
  - Enables users to pass a script to perform MATLAB optimization
  - MATLAB must be installed on local system
  - MATLAB installation location must be specified under *Tools → General Options under Miscellaneous tab*



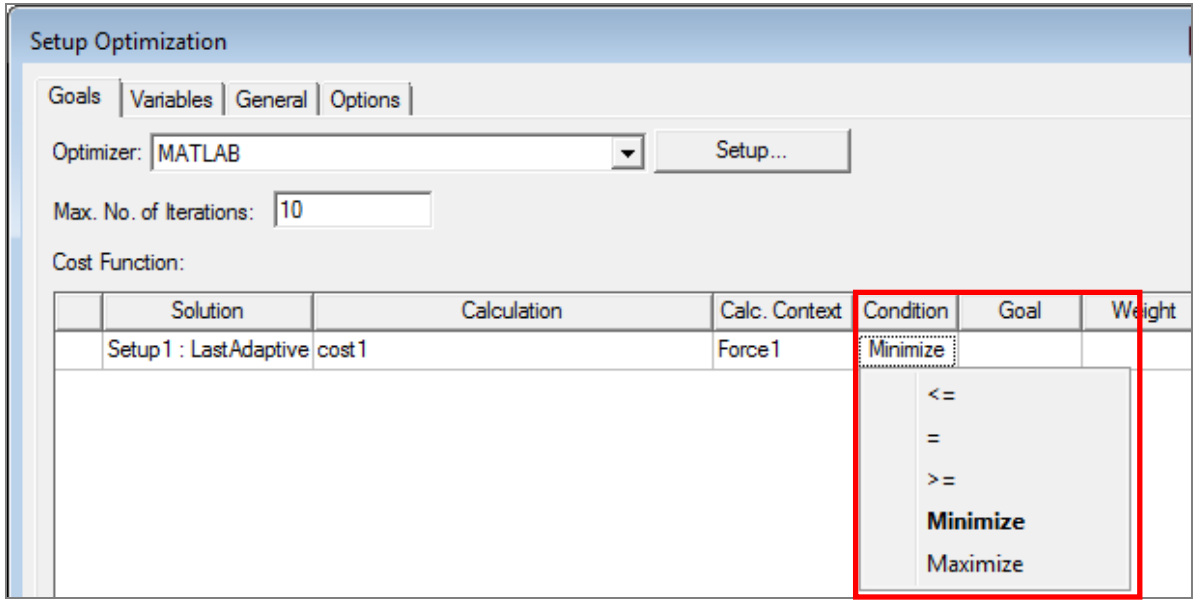


Note: For detailed information about each Optimizer, please refer to Maxwell Help

Optimization Analysis

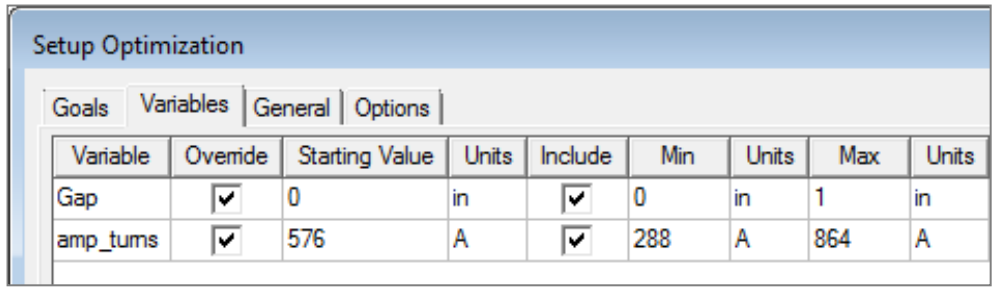
- Max. No. of Iterations:
  - Limits number of iterations to be conducted. Thus avoids solution runaway
- Setup Calculation:
  - Opens Add/Edit Calculation window Enables users to define the output quantity for which design needs to be optimized
  - Added Calculations will be listed under Cost Function

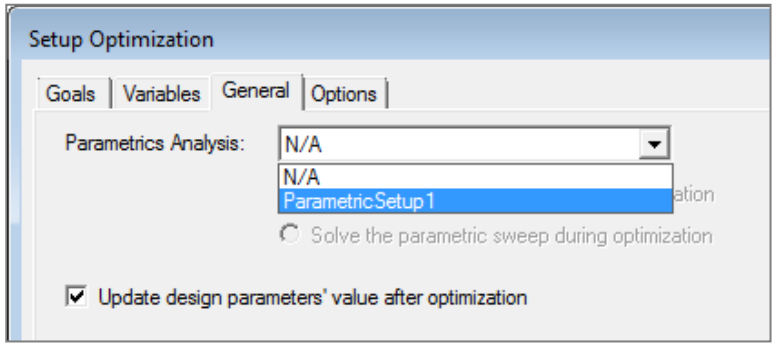
- Cost Function
  - Sets Goal of Optimization and weight to each goal
  - Goal with highest weight is given more importance
  - For Maximize or Minimize conditions, only single cost function is allowed
  - If “=”,“<=” or “>=” conditions are used, target value can be set in Goal field

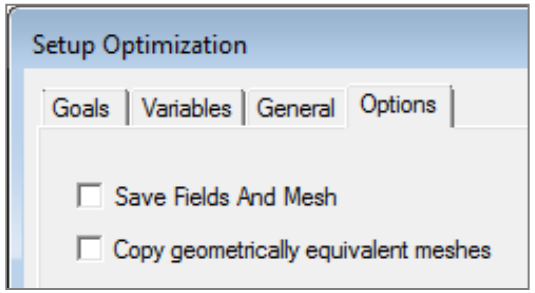


Optimization Analysis

- **Variables tab**
  - Starting Value: Values from which Optimization will start. If start value is close to optimization point, Optimization requires less iterations
  - Min & Max: Sets the range in which values of design variables will be varied
- **General tab**
  - General tab allows users to specify results of Parametric Analysis as an input to Optimization or run a parametric analysis as a part of Optimization
  - Selecting “Update design parameters’ value after optimization” will assign Optimized variable values to the nominal design,
- **Options tab**
  - Inputs on Options tab are same as Parametric Analysis

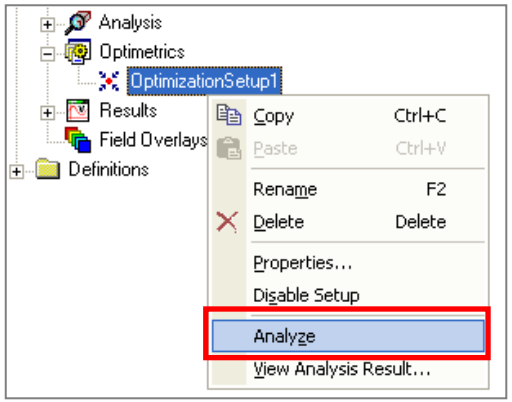


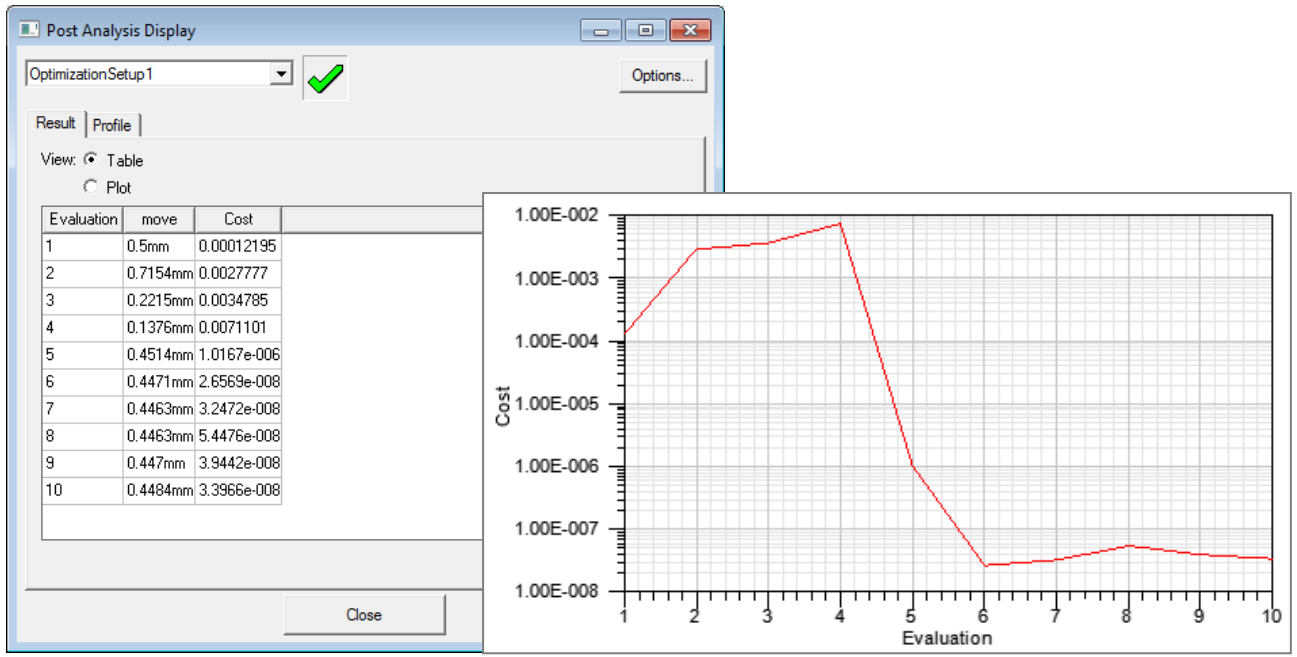




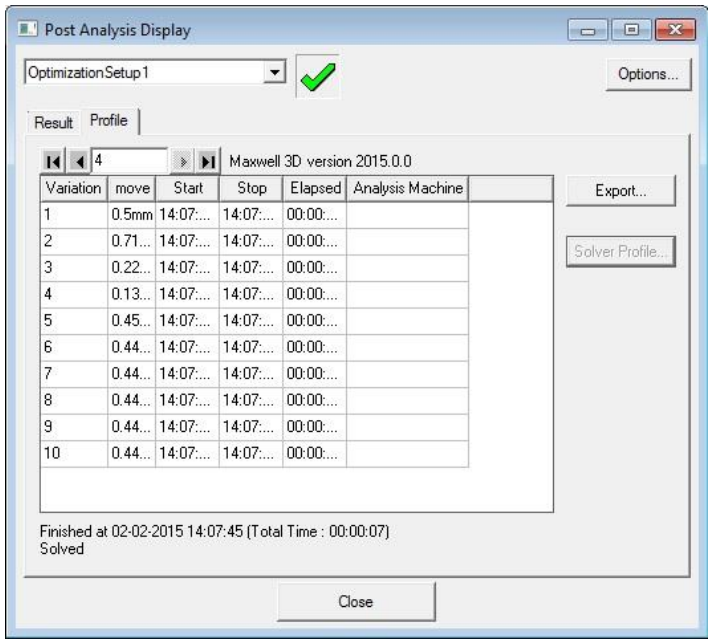
Optimization

- **Running Optimization**
  - **Right clicking on added Optimization Setup from project Manager tree under Optimetrics and selecting “Analyze”**
- **Examine Results**
  - **Right click on Added Optimization setup from Project Manager tree and select “View Analysis Results”**





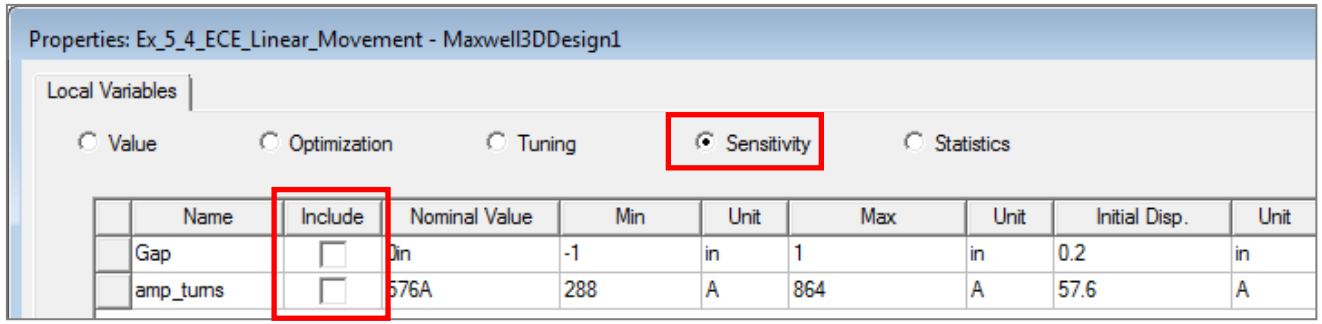
Results can be seen in Tabular or plot view



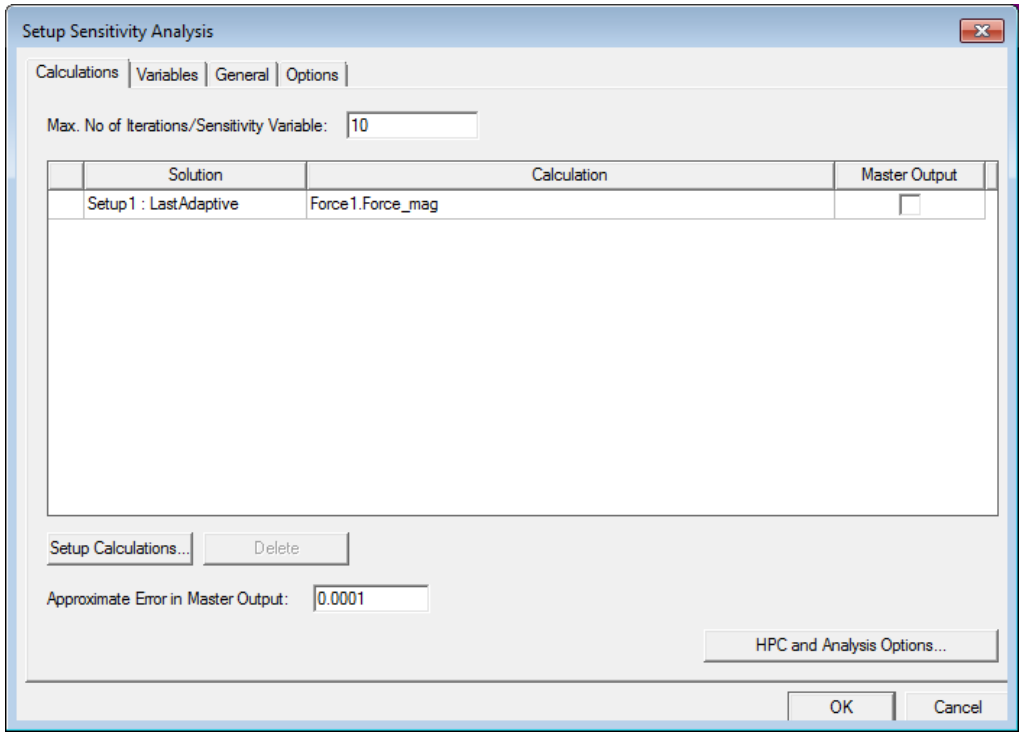
Profile window reports time taken for solving each design variation

Sensitivity Analysis

- **Setting Variables for Sensitivity**
  - **Before Sensitivity setup can be done, it is required to define the variables which will participate in the sensitivity analysis**
  - **Variables can be assigned from *Maxwell 3D/2D → Design Properties***
- **Sensitivity Analysis**
  - **Sensitivity analysis can be added from menu item *Maxwell 2D/3D → Optimetrics Analysis → Add Sensitivity***

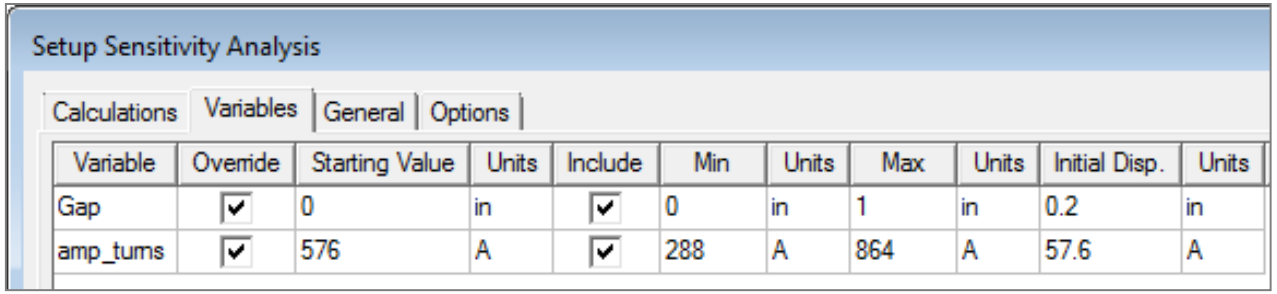


Parameters for which Include is checked will be used in Sensitivity analysis



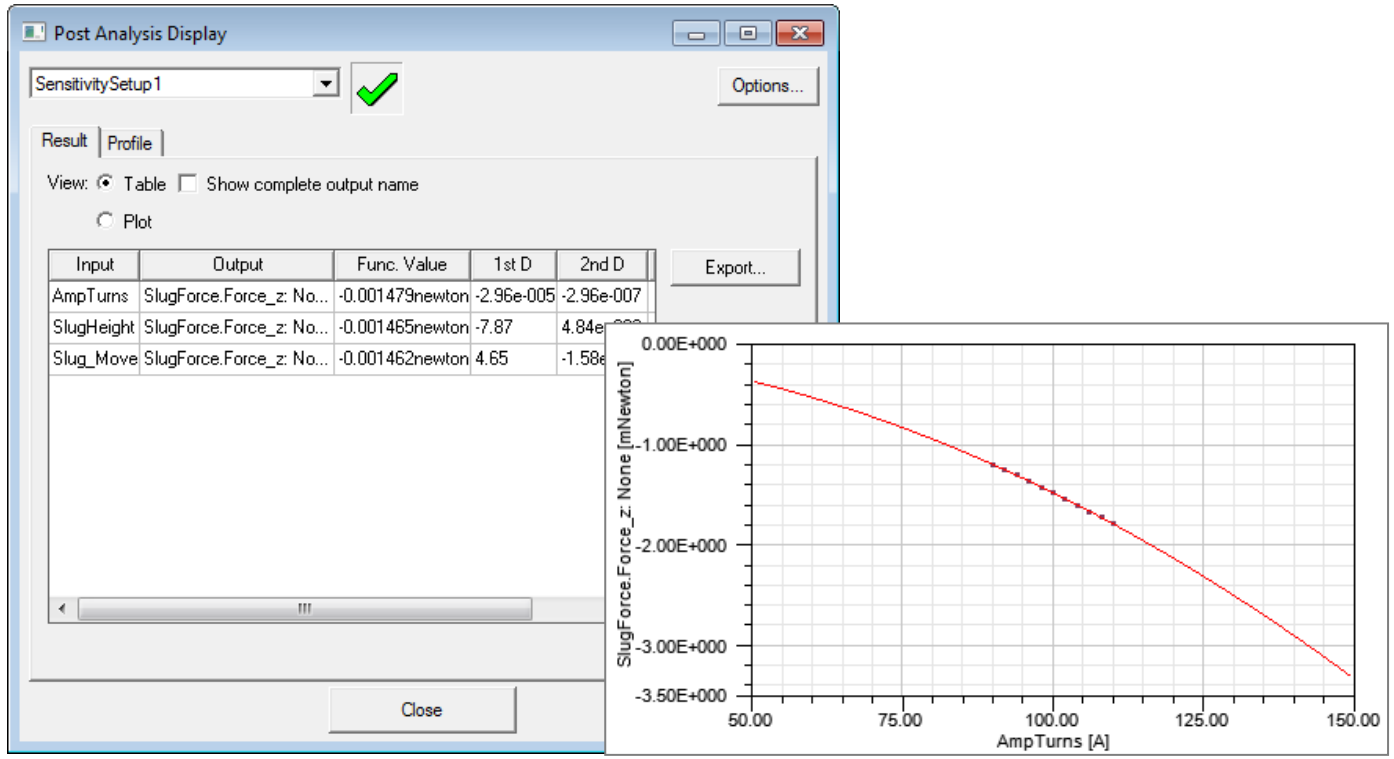
Sensitivity Analysis

- **Calculations tab**
  - Max. No. of Iterations/Sensitivity Variables: Sets maximum number of iterations for each variable value
  - Setup Calculation: Opens Add/Edit Calculation window Enables users to define the output quantity for which sensitivity analysis is done
- **Variables tab**
  - Starting Value: values from which analysis starts. It should be in between Min and Max specified
  - Min & Max: Sets the range in which values of design variables will be varied
  - Initial displacement: Sets the difference between a variable's starting value and the next solved design variation
- **General tab**
  - General tab allows users to specify results of Parametric Analysis as an input to Sensitivity analysis or run a parametric analysis
- **Options tab**
  - Inputs on Options tab are same as Parametric Analysis

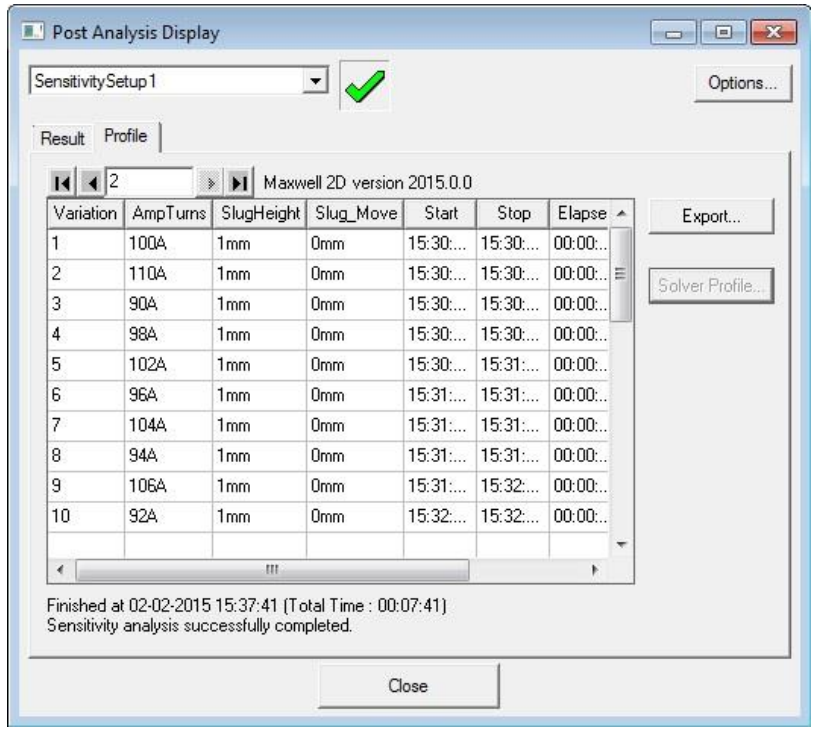


Sensitivity Analysis

- **Running Sensitivity**
  - **Right clicking on added Sensitivity Setup from project Manager tree under Optimetrics and selecting “Analyze”**
- **Examine Results**
  - **Right click on Added Sensitivity setup from Project Manager tree and select “View Analysis Results”**



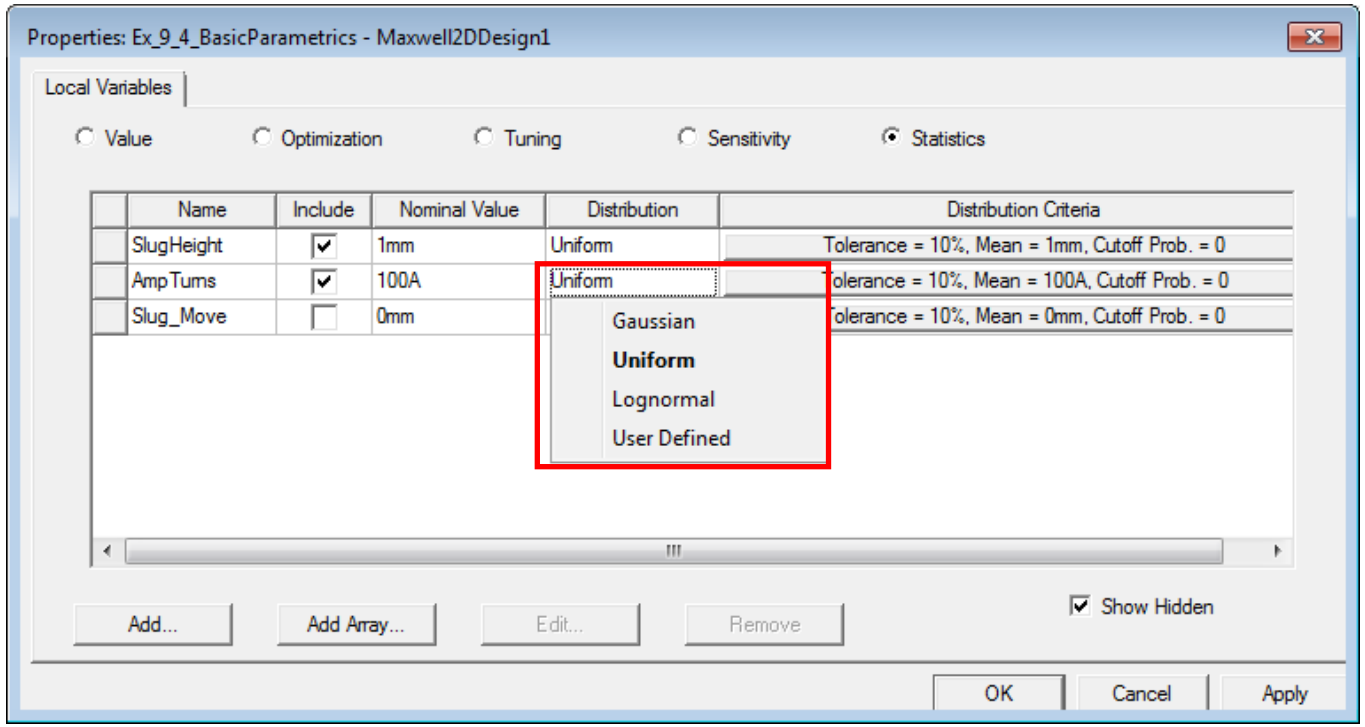
Results can be seen in Tabular or plot view

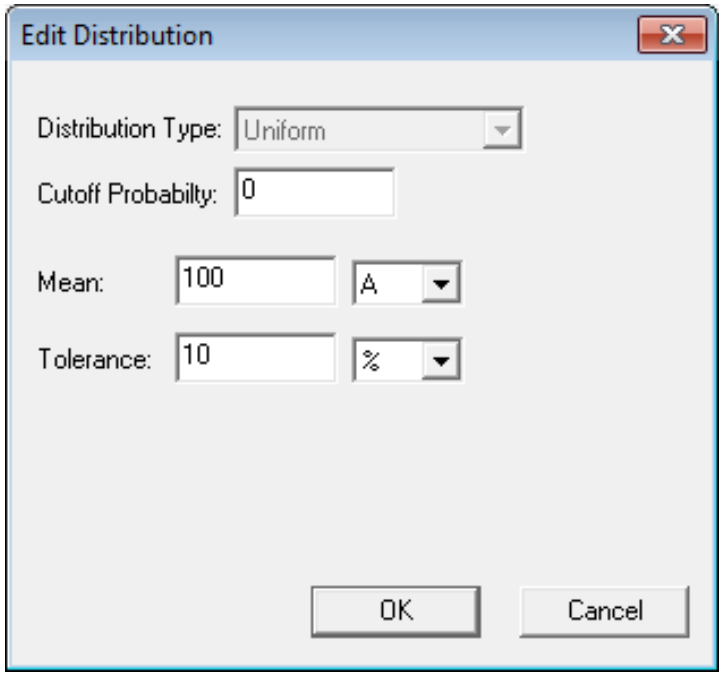


Profile window reports time taken for solving each design variation

Statistical Analysis

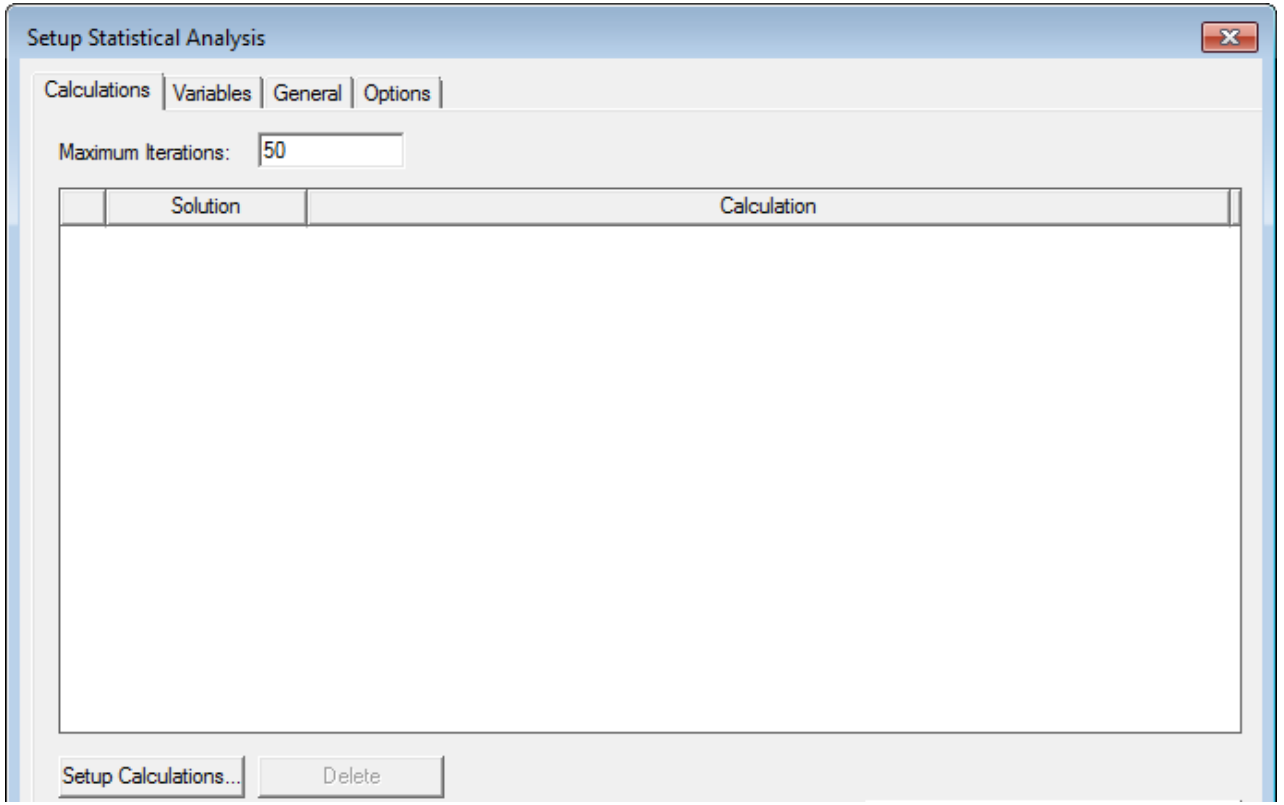
- **Setting Variables for Sensitivity**
  - Similar to Sensitivity, Statistical Analysis requires definition of variables for analysis
  - In Addition, users can set standard deviation for each variable
  - Variables can be assigned from ***Maxwell 3D/2D → Design Properties***
- **Statistical Analysis**
  - Sensitivity analysis can be added from menu item ***Maxwell 2D/3D → Optimetrics Analysis → Add Statistical***

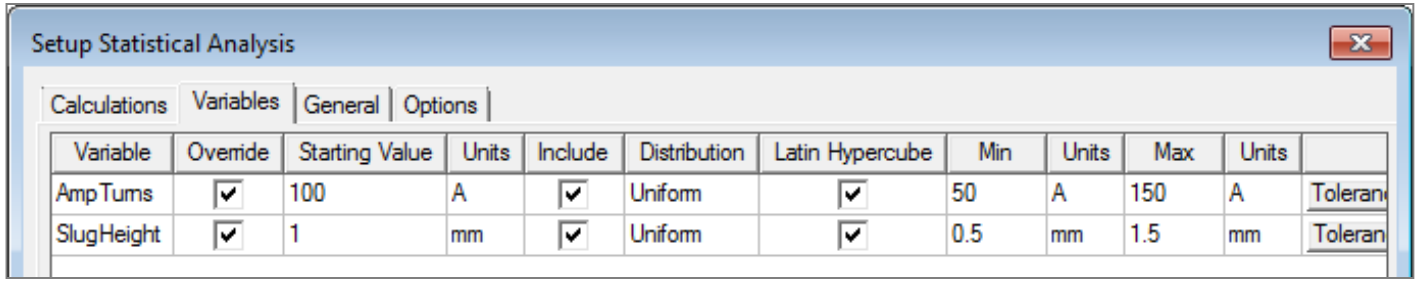




Statistical Analysis

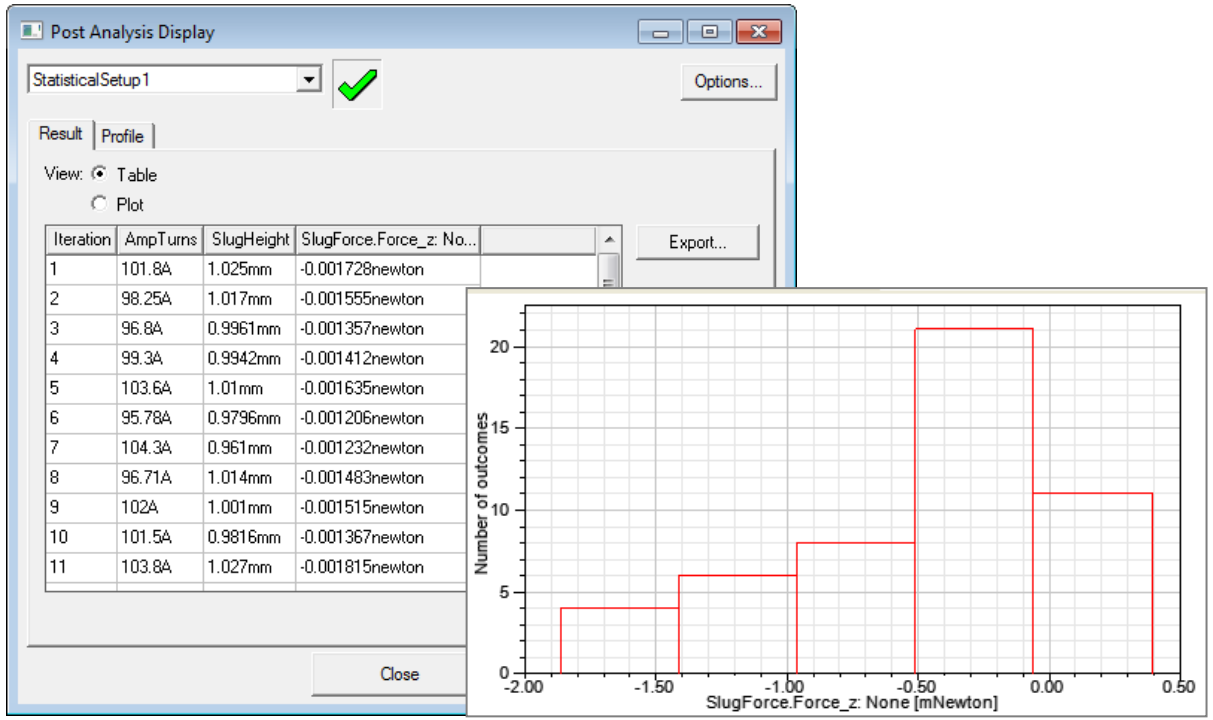
- **Calculations tab**
  - Max. No. of Iterations: Limits Maximum number of iterations carried out in statistical analysis
  - Setup Calculation: Opens Add/Edit Calculation window Enables users to define the output quantity for which statistical analysis is done
- **Variables tab**
  - Allows users to define, Starting values, Min and Max limits of variables
  - In addition users can define distribution criteria using Standard deviation or tolerance value
- **General tab**
  - General tab allows users to specify results of Parametric Analysis as an input to Statistical analysis or run a parametric analysis
- **Options tab**
  - Inputs on Options tab are same as Parametric Analysis





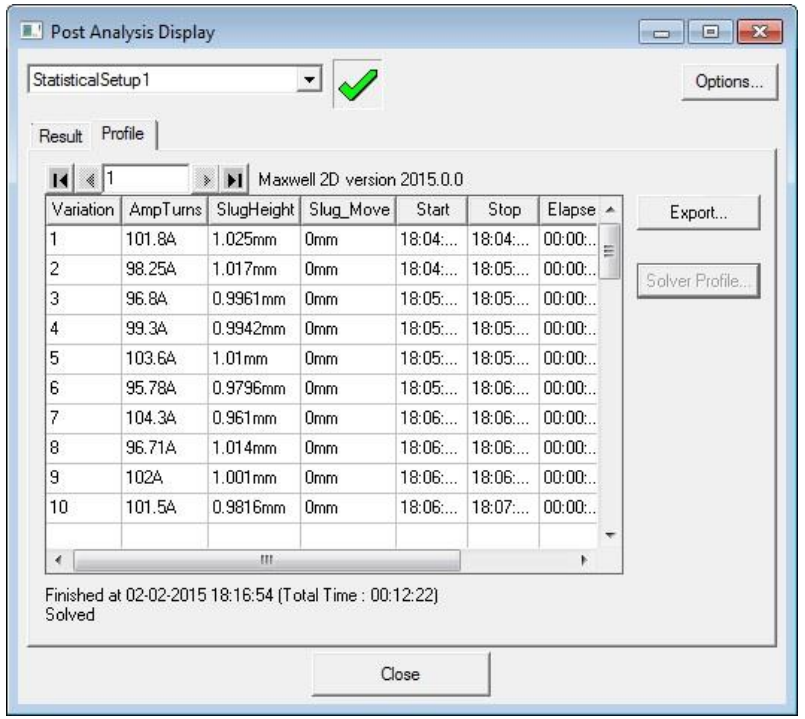
Statistical Analysis

- **Running Statistical Analysis**
  - **RMB on added Statistical Setup from project Manager tree under Optimetrics and select “Analyze”**
- **Examine Results**
  - **RMB on Added Statistical setup from Project Manager tree and select “View Analysis Results”**



Iteration	AmpTurns	SlugHeight	SlugForce.Force_z: No...
1	101.8A	1.025mm	-0.001728newton
2	98.25A	1.017mm	-0.001555newton
3	96.8A	0.9961mm	-0.001357newton
4	99.3A	0.9942mm	-0.001412newton
5	103.6A	1.01mm	-0.001635newton
6	95.78A	0.9796mm	-0.001206newton
7	104.3A	0.961mm	-0.001232newton
8	96.71A	1.014mm	-0.001483newton
9	102A	1.001mm	-0.001515newton
10	101.5A	0.9816mm	-0.001367newton
11	103.8A	1.027mm	-0.001815newton

Results can be seen in Tabular or plot view

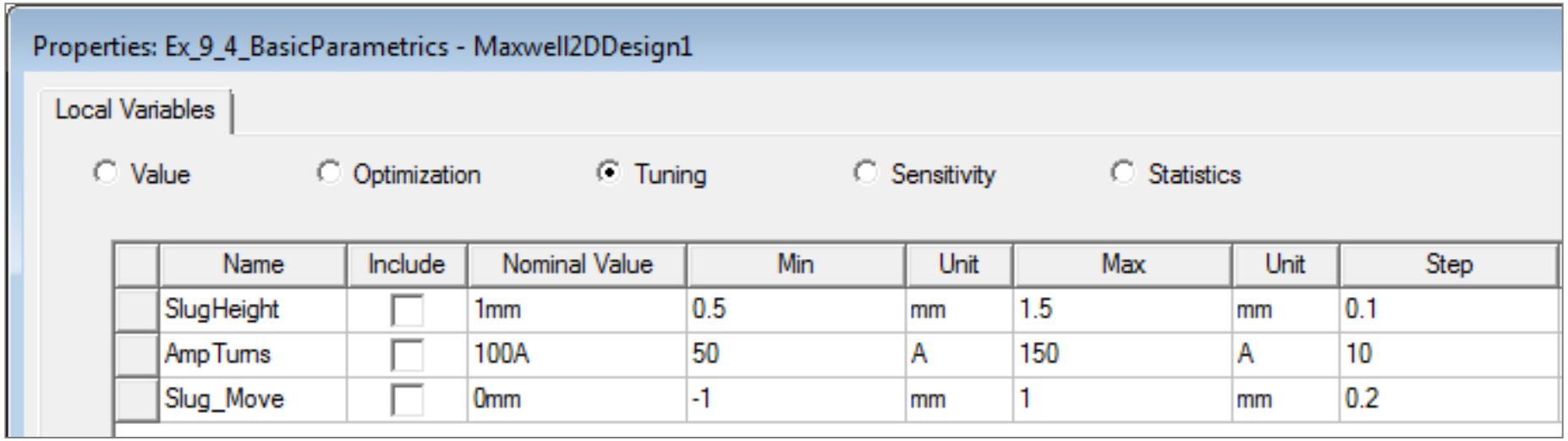


Variation	AmpTurns	SlugHeight	Slug_Move	Start	Stop	Elapse
1	101.8A	1.025mm	0mm	18:04:...	18:04:...	00:00:..
2	98.25A	1.017mm	0mm	18:04:...	18:05:...	00:00:..
3	96.8A	0.9961mm	0mm	18:05:...	18:05:...	00:00:..
4	99.3A	0.9942mm	0mm	18:05:...	18:05:...	00:00:..
5	103.6A	1.01mm	0mm	18:05:...	18:05:...	00:00:..
6	95.78A	0.9796mm	0mm	18:05:...	18:06:...	00:00:..
7	104.3A	0.961mm	0mm	18:06:...	18:06:...	00:00:..
8	96.71A	1.014mm	0mm	18:06:...	18:06:...	00:00:..
9	102A	1.001mm	0mm	18:06:...	18:06:...	00:00:..
10	101.5A	0.9816mm	0mm	18:06:...	18:07:...	00:00:..

Profile window reports time taken for solving each design variation

Tuning

- **Setting Variables for Tuning**
  - **Similar to Sensitivity, Tuning requires definition of variables for analysis**
  - **In Addition, users can set min and max limits of variable and step sizes used for Tuning**
  - **Variables can be assigned from *Maxwell 3D/2D → Design Properties***



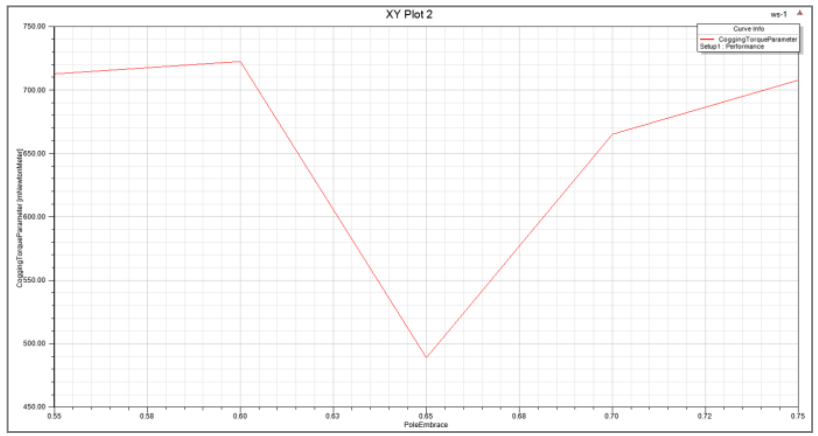
Name	Include	Nominal Value	Min	Unit	Max	Unit	Step
SlugHeight	☐	1mm	0.5	mm	1.5	mm	0.1
AmpTurns	☐	100A	50	A	150	A	10
Slug_Move	☐	0mm	-1	mm	1	mm	0.2

- **Tuning**
  - **Tuning is used to interactively study the impact of input variables on Output**
  - **Changing input variable will dynamically update the solution to new values and populate the results**
  - **Tuning can be added from menu item *Maxwell 2D/3D → Optimetrics Analysis → Tune***

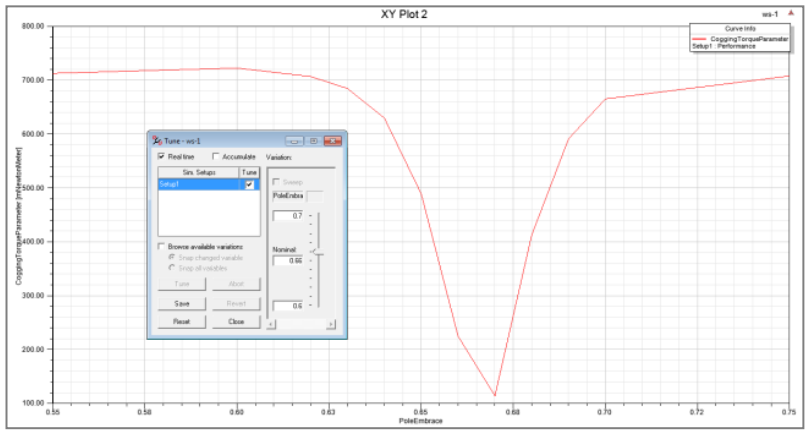
Note: It is advised that tuning should be carried out after Parametric Analysis to fine tune results

Tuning

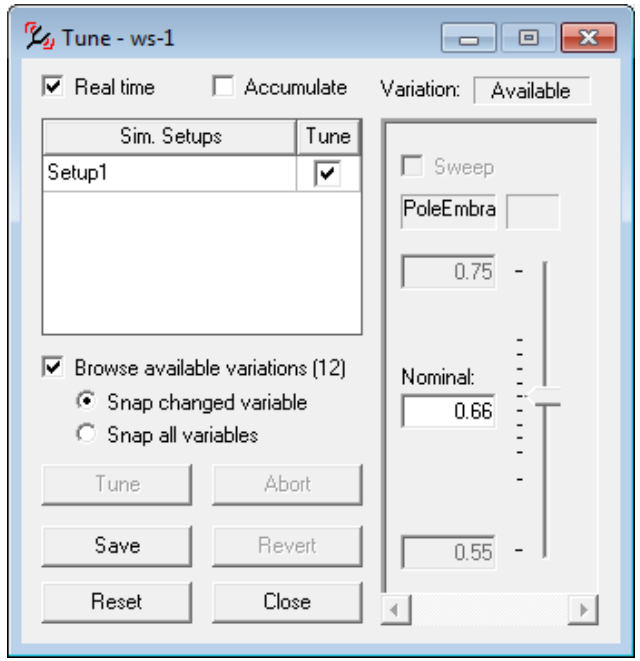
- **Variations**
  - Variation allow users to change the design variables using a slider
  - Min, Max and step sizes of slider are set from values defined in Design properties
- **Browse available variations**
  - Makes already solved variation available in Variations section. This option prohibits solving any new variation using Tuning
- **Tune**
  - Tune button will tune the results to selected slider position
  - If solution does not exist for select variation value, Maxwell computes it



Untuned Parametric Analysis Results

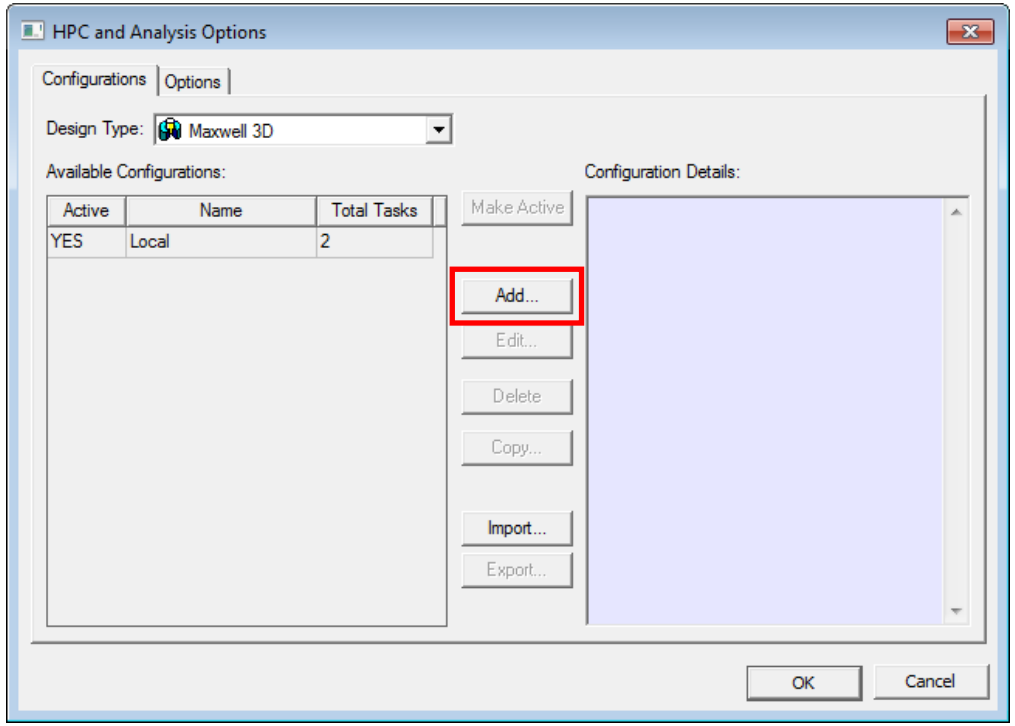


Results after Tuning



High Performance Computing (HPC, DSO)

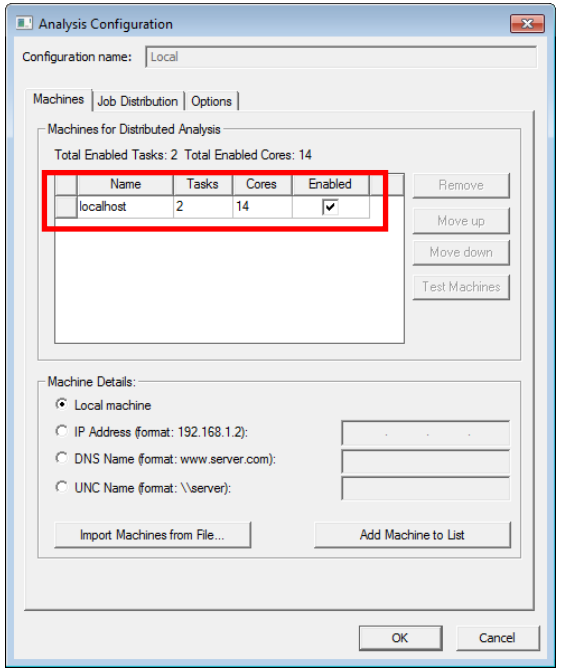
- HPC (High Performance Computing)
  - Requires additional license and it works for 3D only
  - Multiprocessing in our static solvers (MS, Eddy, ES)
  - SDM (Spectral Decomposition Method or Frequency sweeps) in eddy current solver.
  - Full parallelization in Transient solver with the possibility to turn on TDM (Time Domain decomposition Method)
  - The Multi-Threading includes:
    - Initial Tau Mesh
    - Non Linear Newton-Raphson Loop
    - Matrix Assembly
    - Matrix Solving
    - Matrix Postprocessing
  - Select the menu item *Tools → Options → HPC and Analysis Options*

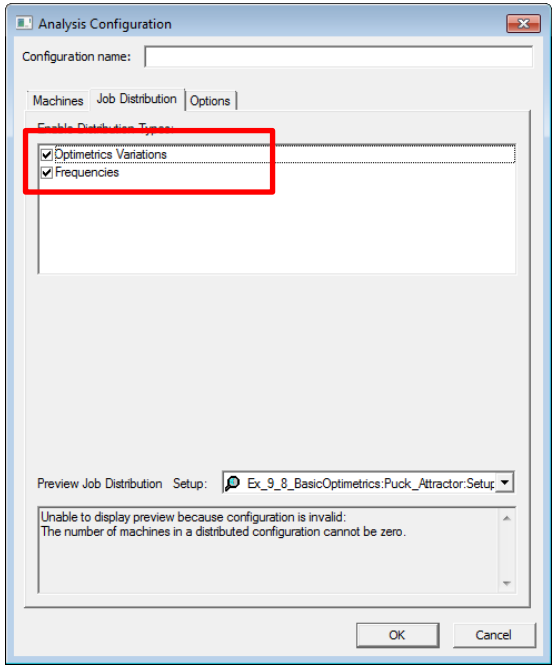


Note: The cores specified for HPC can be located over several processors but they have to share the same memory. Maxwell cannot run a single design simulation over a cluster but can distribute multiple designs over any number of computers with DSO

High Performance Computing (HPC, DSO)

- DSO (Distributed Solve Option)
  - Requires additional license
  - Enables to distribute parametric analysis
  - Highest level of parallel analysis providing best linearity and scaling
  - Optimetrics product is necessary
  - Select the menu item *Tools → Options → General Options*, choose Design Type, and select Distributed radio button, click on Edit Distributed Machine Configuration

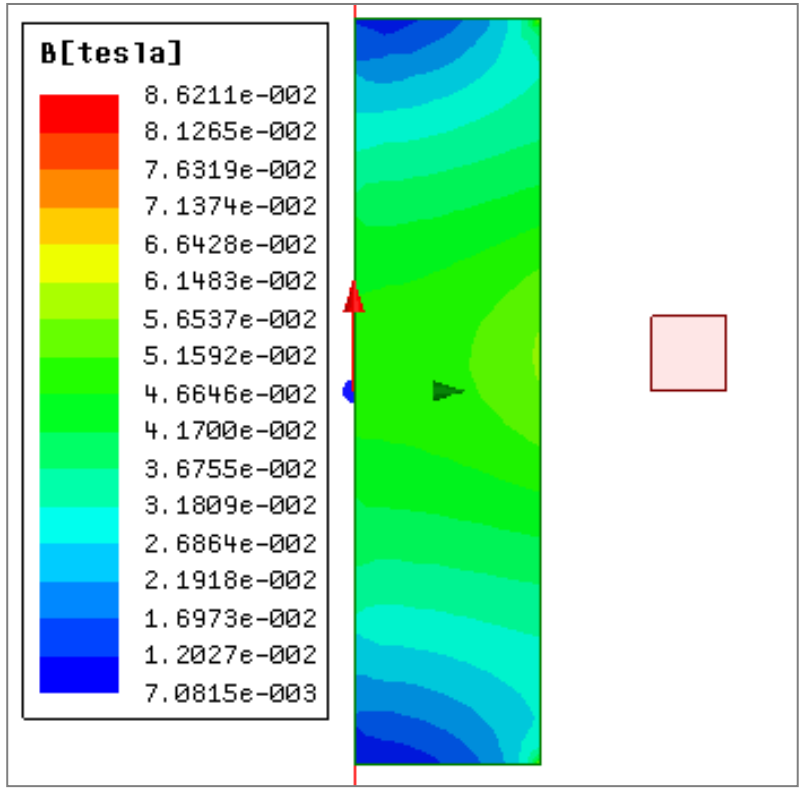


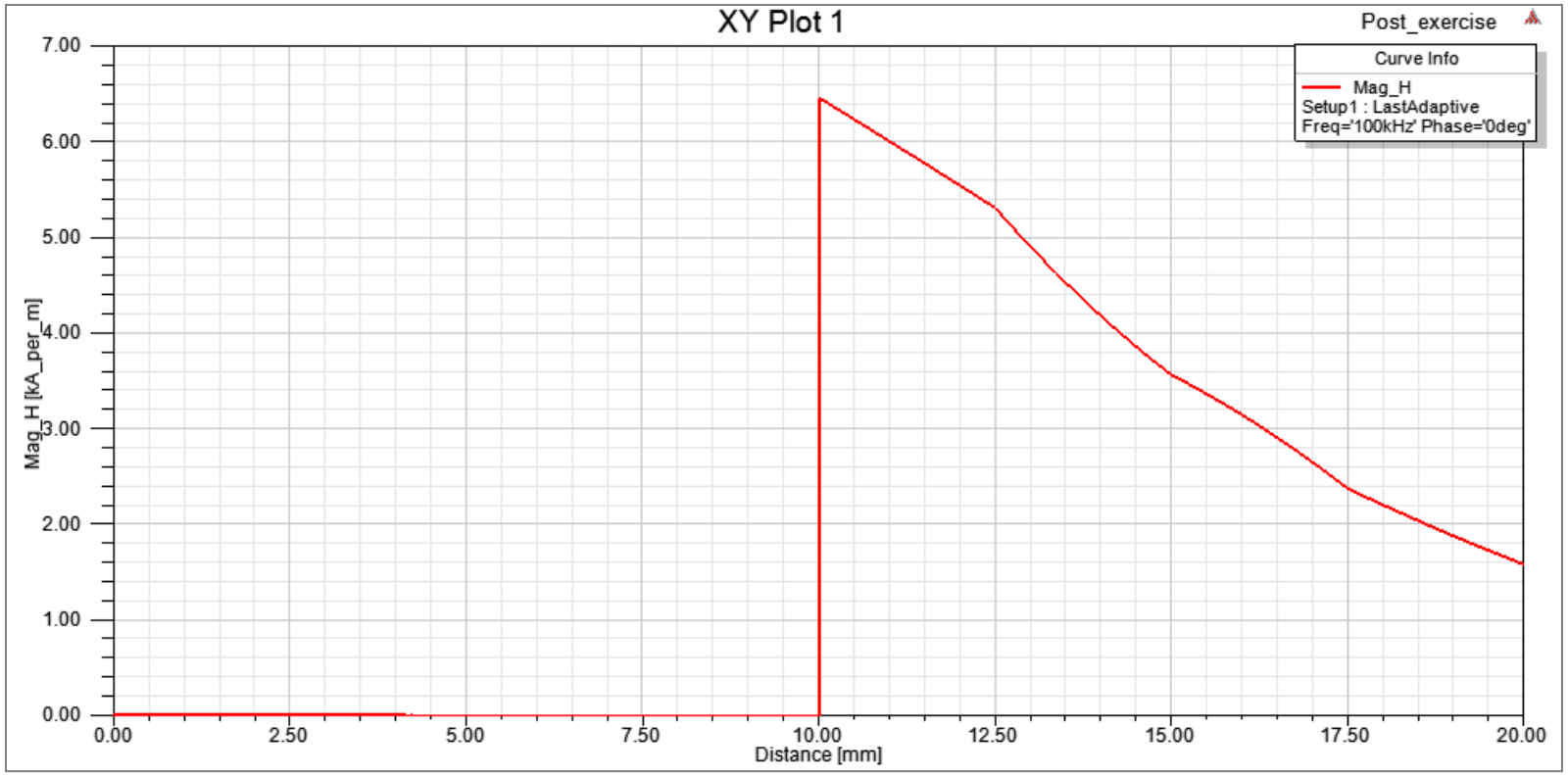


Summary

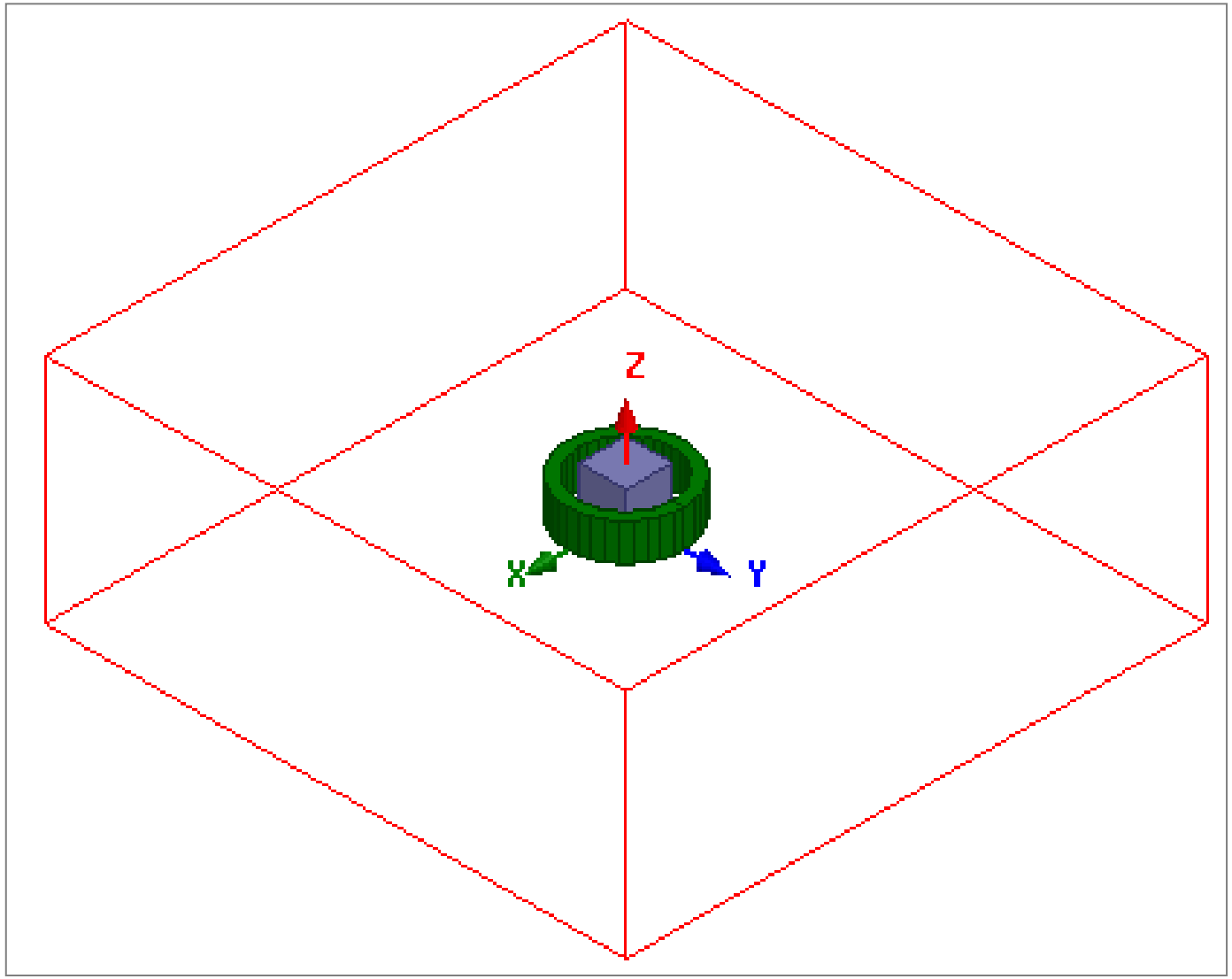
- What have we learned in this session?
  - Post-Processing
  - Fields Calculator
  - Parametric Analysis
  - Optimization Analysis
  - Sensitivity Analysis
  - Statistical Analysis
  - Tuning

Workshop 4.1 – Postprocessing Examples





Workshop 4.2 – Parametric analysis



End of Presentation