

Transient Analysis

Description

This document gives a brief description of how to set up a Motor-CAD model for a transient analysis. The Motor-CAD duty cycle options allow for simple transient, duty cycle and soak-back transient calculations.

Machine Geometry

For this example the standard machine will be used as shown below.

The screenshot shows the Motor-CAD v5.3.2.9 software interface. The main window displays a cross-section of a motor with a cyan rotor, a green stator, and a red housing with yellow segments. The interface includes a menu bar (File, Options, Defaults, Editors, View, Results, Tools, Help), a toolbar, and a parameter table.

Stator Dims.		Rotor Dims.	
Data	Data	Data	Data
Slot Number	18	Pole Number	6
Housing Dia	140	Magnet Thickness	4
Stator Lam Dia	130	Magnet Arc [ED]	140
Stator Bore	80	Airgap	1
Tooth Width	7	Banding Thickness	0
Slot Depth	18	Shaft Dia	25
Slot Corner Radius	0	Shaft Hole Diameter	0
Slot Opening	3		
Tooth Tip Depth	1		
Tooth Tip Angle	30		
Sleeve Thickness	0		
Fin Extension	10		
Fin Thickness	2		
Fin Pitch/Thick	5		
Fin Pitch [Calc]	10		
Corner Cutout [%]	40		
Corner Cutout Add	0		
Plate Height	350		
Plate Width	350		
Stator Ducts	0		

Below the table is a 'Redraw' button and checkboxes for 'Draw plate' and 'Draw base'. The status bar at the bottom shows 'Length (-54.12,81.48) mm 17 July 2009 www.motor-design.com'.

Setting the machine losses

The losses of the machine are defined in the losses page as shown below. The default losses are used in this example.

There are different loss models allowing for the losses to vary with speed, temperature and load.

Loss Variation with Speed:

$P[\text{speed}] = P[\text{input}] \times \left[\frac{\text{Shaft Speed}}{\text{Speed[REF]}} \right]^{\text{coef[A]}}$

Speed Dependant Losses
 Shaft Speed [rpm] 3000

Single value of Speed[REF] [rpm] 3000

Component	P[input]	Speed[REF]	coef[A]	W/kg	P[speed]
Units	Watts	rpm		W/kg	Watts
Loss [Stator Copper]	120	3000	0	87.29	120
Loss [Stator Back Iron]	30	3000	1.5	16.29	30
Loss [Stator Tooth]	40	3000	1.5	24.44	40
Loss [Magnet]	0	3000	0	0	0
Loss [Rotor Back Iron]	0	3000	0	0	0
Loss [Friction - F Bearing]	2	3000	1	0	2
Loss [Friction - R Bearing]	2	3000	1	0	2
Loss [Windage]	10	3000	3	0	10
Loss [Windage] [Ext Fan]	0	3000	3	0	0
Power Injected [Endcap Front]	0	3000	0	0	0
Power Injected [Endcap Rear]	0	3000	0	0	0
Power Injected [Feet]	0	3000	0	0	0
Power Injected [Shaft Active]	0	3000	0	0	0
Power Injected [Shaft Front]	0	3000	0	0	0
Power Injected [Shaft Rear]	0	3000	0	0	0
Power Injected [EWdg Front]	0	3000	0	0	0
Power Injected [EWdg Rear]	0	3000	0	0	0
Power Injected [Plate]	0	3000	0	0	0
Power Injected [Wdg Outer]	0	3000	0	0	0
Power Injected [ESpace Front]	0	3000	0	0	0
Power Injected [ESpace Rear]	0	3000	0	0	0

Copper Loss Variation with Temperature

Copper Losses Vary with Temperature
 Winding Temperature at which Pcu Input: 20

Loss Variation with Temperature & Load:

Losses Vary with Temperature & Load
 Constant Torque or Constant Current
 Constant Torque Constant Current

Winding Temperature - $T_w(i/p)$: 120
 Magnet Temperature - $T_m(i/p)$: 80
 Shaft Torque [Nm] (@Pcu defined): 15
 Motor Current [Ams] (@Pcu defined): 8.114
 Torque Constant [Nm/A]: 1.849
 Torque & Current Multiplier: 1
 Rph @ $T_w(i/p)$: 0.45
 Magnet Temperature Coefficient Br: -0.06667
 Iron Loss Flux To Power Ratio: 1.5
 Phases: 3

Check Data

Length mm 17 July 2009 www.motor-design.com

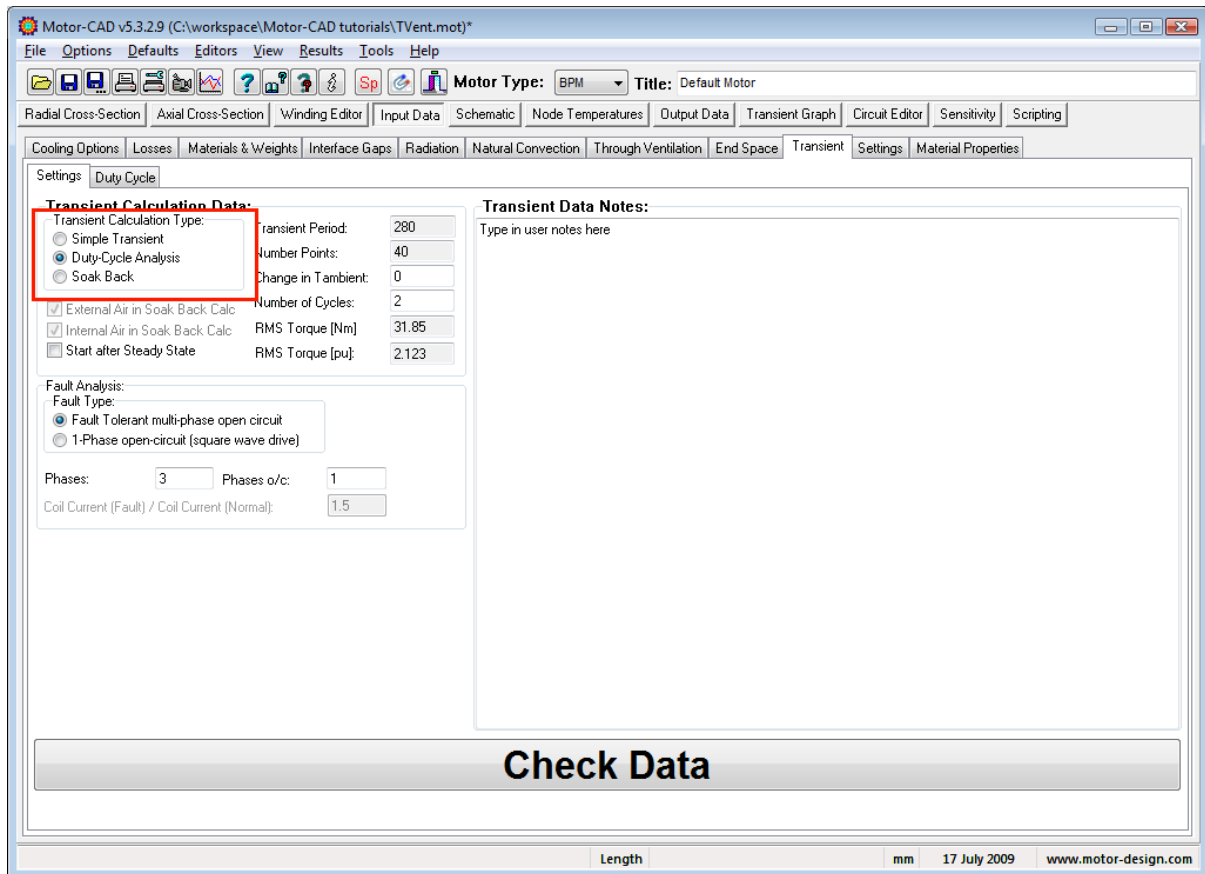
Transient Analysis

You can also run a transient analysis on the machine to model the thermal performance over complex duty cycles.

There are 3 different duty cycle options available:

- Simple Transient – where the machine runs with a fixed load.
- Duty Cycle – where the load and losses of the machine vary over time
- Soak back – where the forced convection flow rate is removed when the machine is switched off.

In this case select to run a complex duty cycle as shown below.



The duty cycle is then specified using the pu (per unit) values of the losses given in the losses editor as shown below. The use of the pu values allows the losses to vary as given in the duty cycle and also to take into account the variation in losses with speed and temperature.

Duty Cycle Data Table:

Period	Time	Points	Stator Copper	Stator Back Iron	Stator Tooth	Magnet	Rotor Back Iron	Friction Front Bearing	Friction Rear Bearing	Windage	Windage Exterior Fan	Speed [Start]	Speed [End]	Fault
Units	secs		pu	pu	pu	pu	pu	pu	pu	pu	pu	rpm	rpm	
1	20	4	1	1	1	1	1	1	1	1	1	0	3000	<input type="checkbox"/>
2	20	4	5	1.5	1	1	1	1	1	1	1	3000	3000	<input type="checkbox"/>
3	20	4	0.6	1	1	1	1	1	1	1	1	3000	0	<input type="checkbox"/>

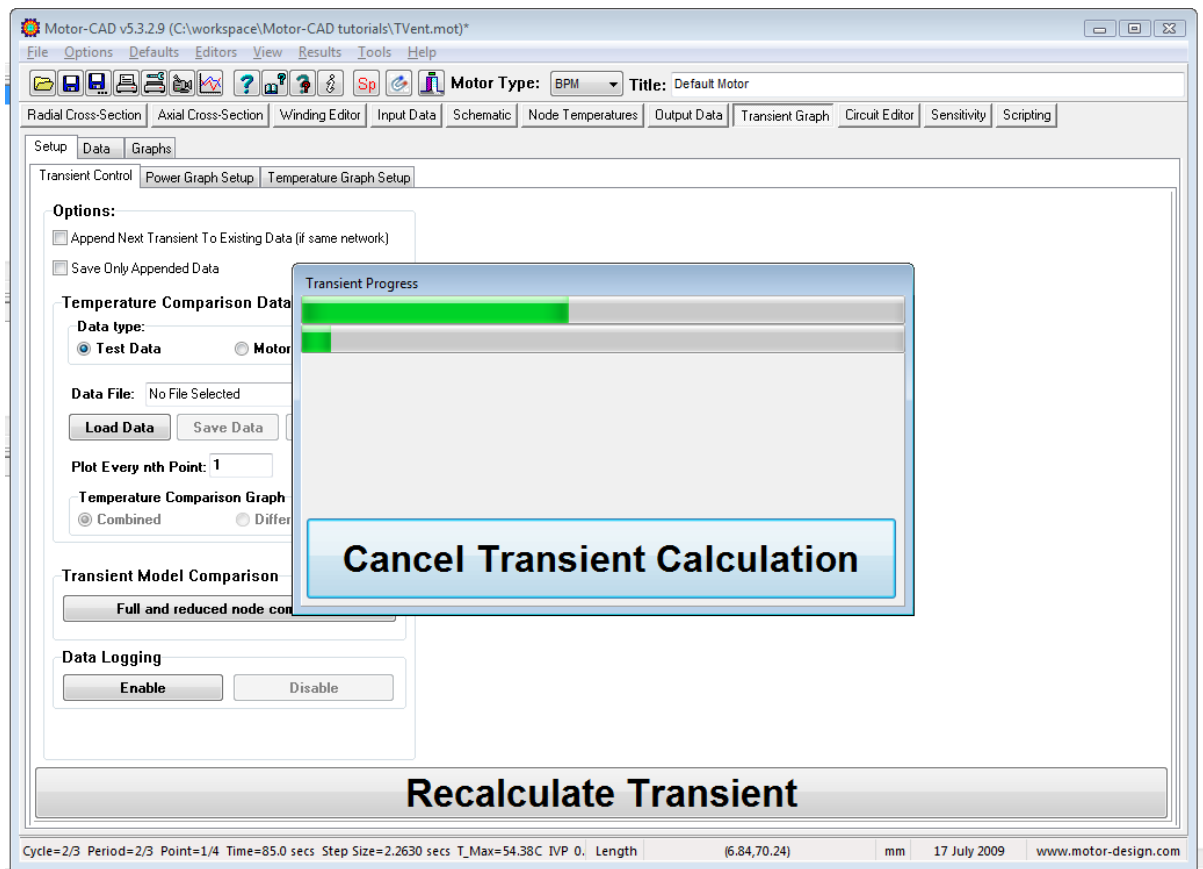
Duty Cycle Control:
 Add Period Remove Period
Check Data

Duty Cycle Data Definition:
 Torque-Speed Loss-Speed

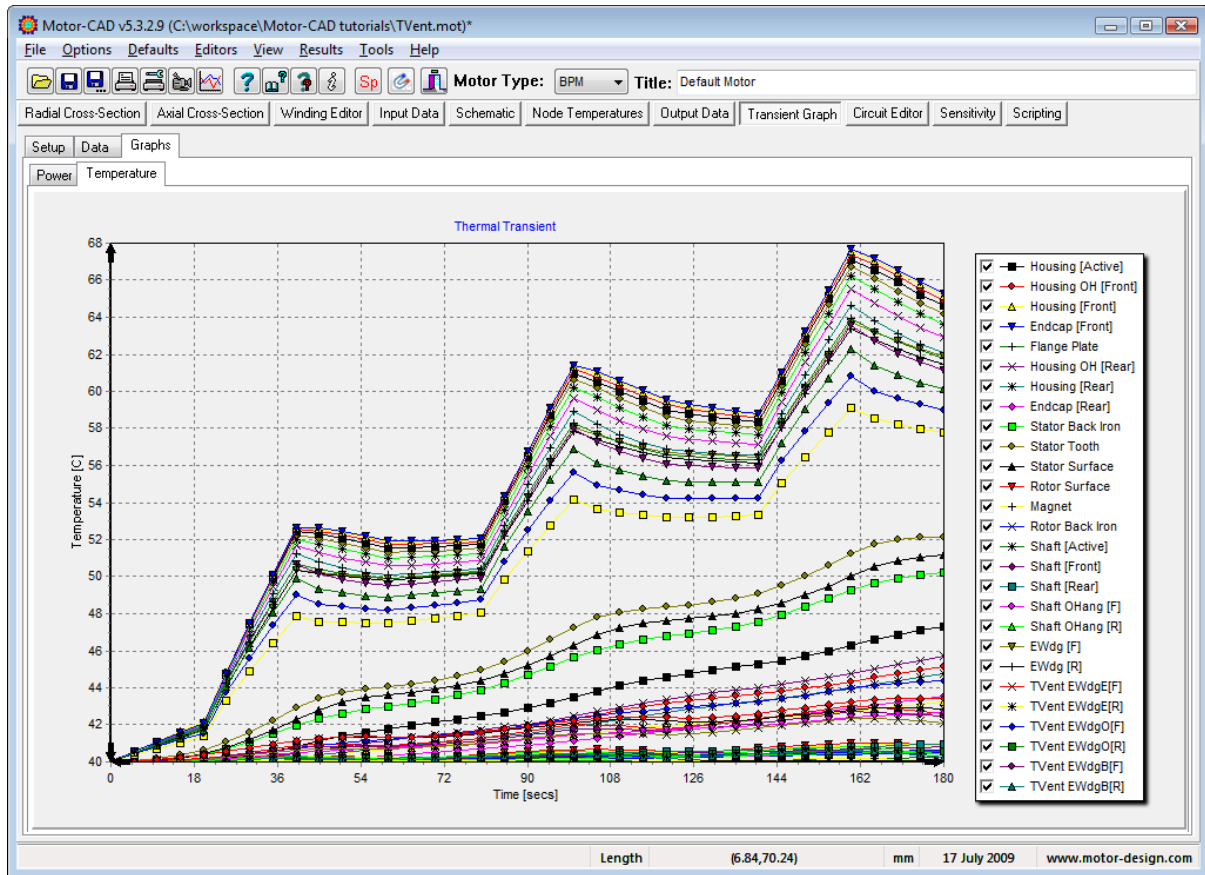
Duty Cycle pu or Value Input:
 pu Value

External Duty Cycle Data:
 File: No Datafile Selected
 Load Data Save Data Clear Data

The transient calculation is then started by selecting the 'Transient Graph' tab as shown below.



The transient results graph will be displayed as shown below. This has all the nodes in the model.



The interested nodes can be selected to view and the graph setup modified in the 'Temperature Graph Setup' tab as shown below.

Motor-CAD v5.3.2.9 (C:\workspace\Motor-CAD tutorials\TVent.mot)*

File Options Defaults Editors View Results Tools Help

Motor Type: BPM Title: Default Motor

Radial Cross-Section Axial Cross-Section Winding Editor Input Data Schematic Node Temperatures Output Data Transient Graph Circuit Editor Sensitivity Scripting

Setup Data Graphs

Transient Control Power Graph Setup **Temperature Graph Setup**

Chart Titles:

Automatic Titles

Chart Title: Thermal Transient

X-Axis Title: Time [secs]

Y-Axis Title: Temperature [C]

Graph Limits:

Automatic Scale

X-Axis Limits

Min: 0 Max: 180 Inc: 18

Y-Axis Limits

Min: 40 Max: 68 Inc: 2

Custom Graph Settings:

Use Custom Graph Settings

Settings File: No File Selected

Load Settings Save Settings

Select/Deselect all nodes

Drawing Options

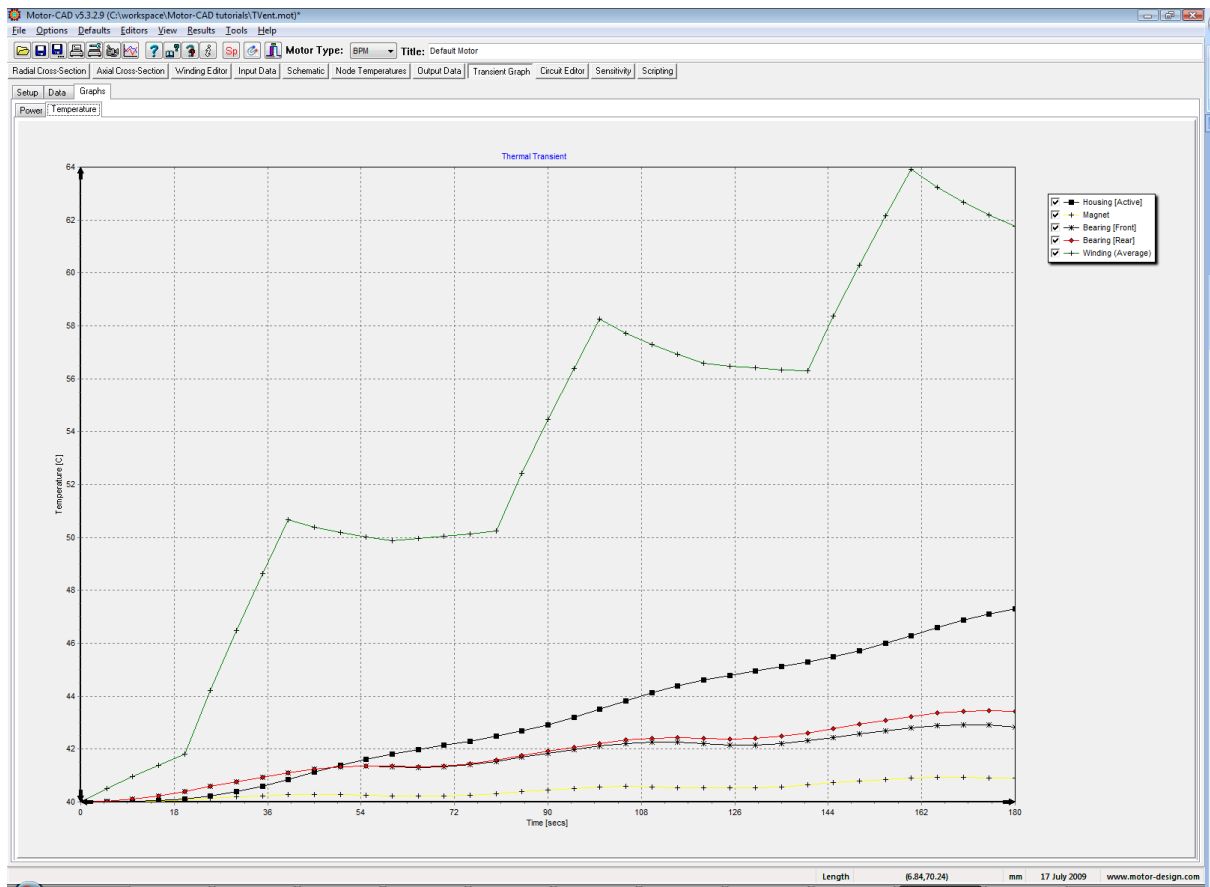
Draw Lines

Draw Points

Show Legend

Node	Graph Legend	Graphed	Point Type	Line Colour
Housing [Active]	Housing [Active]	<input checked="" type="checkbox"/>	Rectangle	Black
Housing OH [Front]	Housing OH [Front]	<input type="checkbox"/>	Circle	Red
Housing [Front]	Housing [Front]	<input type="checkbox"/>	Triangle	Yellow
Endcap [Front]	Endcap [Front]	<input type="checkbox"/>	DownTriangle	Blue
Flange Plate	Flange Plate	<input type="checkbox"/>	Cross	Green
Housing OH [Rear]	Housing OH [Rear]	<input type="checkbox"/>	DiagCross	Purple
Housing [Rear]	Housing [Rear]	<input type="checkbox"/>	Star	Cyan
Endcap [Rear]	Endcap [Rear]	<input type="checkbox"/>	Diamond	Pink
Stator Back Iron	Stator Back Iron	<input type="checkbox"/>	Rectangle	Lime
Stator Tooth	Stator Tooth	<input type="checkbox"/>	Circle	Olive
Stator Surface	Stator Surface	<input type="checkbox"/>	Triangle	Black
Rotor Surface	Rotor Surface	<input type="checkbox"/>	DownTriangle	Red
Magnet	Magnet	<input checked="" type="checkbox"/>	Cross	Yellow
Rotor Back Iron	Rotor Back Iron	<input type="checkbox"/>	DiagCross	Blue
Shaft [Active]	Shaft [Active]	<input type="checkbox"/>	Star	Green
Shaft [Front]	Shaft [Front]	<input type="checkbox"/>	Diamond	Purple
Shaft [Rear]	Shaft [Rear]	<input type="checkbox"/>	Rectangle	Cyan
Shaft OHang [F]	Shaft OHang [F]	<input type="checkbox"/>	Circle	Pink
Shaft OHang [R]	Shaft OHang [R]	<input type="checkbox"/>	Triangle	Lime
EWdg [F]	EWdg [F]	<input type="checkbox"/>	DownTriangle	Olive
EWdg [R]	EWdg [R]	<input type="checkbox"/>	Cross	Black
TVent EWdgE[F]	TVent EWdgE[F]	<input type="checkbox"/>	DiagCross	Red
TVent EWdgE[R]	TVent EWdgE[R]	<input type="checkbox"/>	Star	Yellow
TVent EWdgO[F]	TVent EWdgO[F]	<input type="checkbox"/>	Diamond	Blue
TVent EWdgO[R]	TVent EWdgO[R]	<input type="checkbox"/>	Rectangle	Green
TVent EWdgB[F]	TVent EWdgB[F]	<input type="checkbox"/>	Circle	Purple
TVent EWdgB[R]	TVent EWdgB[R]	<input type="checkbox"/>	Triangle	Cyan
TVent S Duct	TVent S Duct	<input type="checkbox"/>	DownTriangle	Pink
TVent R Duct	TVent R Duct	<input type="checkbox"/>	Cross	Lime
TVent Airgap	TVent Airgap	<input type="checkbox"/>	DiagCross	Olive
Bearing [Front]	Bearing [Front]	<input checked="" type="checkbox"/>	Star	Black
Bearing [Rear]	Bearing [Rear]	<input checked="" type="checkbox"/>	Diamond	Red
Winding Layer1	Winding Layer1	<input type="checkbox"/>	Rectangle	Yellow
Winding Layer2	Winding Layer2	<input type="checkbox"/>	Circle	Blue
Winding Layer3	Winding Layer3	<input type="checkbox"/>	Triangle	Green
Winding Layer4	Winding Layer4	<input type="checkbox"/>	DownTriangle	Purple
Winding Layer5	Winding Layer5	<input type="checkbox"/>	Cross	Cyan
Winding Layer6	Winding Layer6	<input type="checkbox"/>	DiagCross	Pink
Winding Layer7	Winding Layer7	<input type="checkbox"/>	Star	Lime
Winding Layer8	Winding Layer8	<input type="checkbox"/>	Diamond	Olive
Winding Layer9	Winding Layer9	<input type="checkbox"/>	Rectangle	Black
Winding Layer10	Winding Layer10	<input type="checkbox"/>	Circle	Red
Winding Layer11	Winding Layer11	<input type="checkbox"/>	Triangle	Yellow
Winding Layer12	Winding Layer12	<input type="checkbox"/>	DownTriangle	Blue
Winding [Average]	Winding [Average]	<input checked="" type="checkbox"/>	Cross	Green

The temperature graphs below show the different node temperatures vary during the duty cycle.



Similarly the power graph shows how the losses in the machine vary with the duty cycle losses, speed and temperature of the winding.



After solving the transient the final transient circuit can also be viewed in the 'Schematic' tab as shown below.

