ETAP Dynamic Motor Modelling and Testing

Theoretical Concepts

The most widely recognized and studied effect of motor-starting is the voltage dip experienced throughout an industrial power system. Available accelerating torque drops appreciably at the motor terminal bus voltage drops, extending the starting interval and affecting, sometimes adversely, overall motor-starting performance. Acceptable voltage for motor-starting depends on motor and load torque characteristics. Requirements for minimum starting voltage can vary over a wide range, depending on the application. (Voltages can range from 80% or lower to 95% or higher).

Several other problems may arise on the electrical power system due to the voltage dips caused by motor-starting. Motors that are running normally on the system, for example, will slow down in response to the voltage dip occurring when a large motor is started. The running machines must be able to reaccelerate once the machine being started reaches operating speed. When the voltage depression caused by the starting motor is severe, the loading on the running machines may exceed their breakdown torque (at the reduced voltage), and they may decelerate significantly or even stall before the starting interval is concluded. The decelerating machines all impose heavy current demands that only compound the original distress caused by the machine that was started. This result can lead to the loss of all load.

Other types of loads, such as electronic devices and sensitive control equipment, may be adversely effected during motor-starting. There is a wide range of variation in the amount of voltage drop that can be tolerated by static drives and computers. Voltage fluctuations may also cause objectionable fluctuations in lighting.

By industry standards, AC control devices are not required to pick up at voltages below 85% of rated nameplate voltage, whereas dc control devices must operate dependably (i.e., pick-up) at voltages above 80% of their rating. Critical control operations may, therefore, encounter difficulty during motor-starting periods where voltage dips are excessive. A motor-starting study might be required to determine if this is a problem with thoughts to using devices rated at 110 V rather than normal 115 V nominal devices.

Table summarizes some critical system voltage levels of interest when performing a motor starting study for the purpose of evaluating the effects of voltage dips.

Voltage drop location or problem	Minimum allowable voltage (% rated)
At terminals of starting motor	80%[a]
All terminals of other motors that must reaccelerate	71%[a]
AC contactor pick-up (by standard) (see 9.8, NEMA standards)	85%
DC contactor pick-up (by standard) (see 9.8, NEMA standards)	80%
Contactor hold-in (average of those in use)	60–70%[b]
Solid-state control devices	90%[c]
Noticeable light flicker	3% change
NOTE—More detailed information is provided in Table 51 of IEEE Std 242-1986.	

[a]Typical for NEMA design B motors only. Value may be higher (or lower) depending on actual motor and load characteristics.
[b]Value may be as high as 80% for certain conditions during prolonged starting intervals.
[c]May typically vary by ±5% depending on available tap settings of power supply transformer when provided.

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Purpose and Description

The purpose of this exercise is to model the dynamic motor & study its effects during the motor start using software.

Input data

3 Unit — Three–Phase Induction Motor with Laminated Squirrel Cage Rotor

Type:	1SJ1808–4JE60–Z	Mounting:	IMB3	Enclosure:	IP54 Sliprings —
Standard:	DIN VDE0530/IEC34	Cooling System:	IC611	Ex–Protect.:	ExnAIIT3
Rotation:	ccw	Thermal Class:	F	Ex–Stand.:	IEC79–15
				Service Altitude <=	1000 m
Duty:		Insul. System:	Micalastic	Required Inertia:	tm²
Drivefor:	Turbo–Compressor	Type:		Required Power:	5628 kW

Operating Data:

	Unit		Rated Point	
Output	kW/HP		6000 /	
Voltage	V		6000	⅄
Variation	%	±	6.0 / 6.0	
Current	A		669	
No–Load Current	A		86	
Power Factor			0.89	
Frequency	Hz		50	
Range	%	±	5.0 / 5.0	
Speed/Over–Speed	min^{-1}		1489 / 1500	
Cooling Temp. sec./prim.	°C		40 / 58	
Wdg. Limit Temp. Stator	°C	<=	120	(R)
Duty Type			S1	
Servicefactor				

Starting Data

	Unit		
External Reactance	p.u.		
Voltage	p.u.	1.00	0.80
Locked Rotor Torque	p.u.	0.59	0.36
Pull–up Torque	p.u.	–	–
Breakdown Torque	p.u.	1.7	1.03
Locked Rotor Current	p.u.	4.2*	3.26
Starting Time	s	11	25
LR–Thermal Limit Time cold/hot	s		
Permissible Starts	cold/hot	3 / 2	3 / 2

Method of Starting: direct–on–line

Moment of Inertia Mach./Ext. 0.345 / 1.000 tm²

Counter–Torque

Speed p.u.	T p.u.
1.0	0.465
0.8	0.340
0.6	0.230
0.4	0.150
0.2	0.090
0.0	0.140

TN 38.48 kNm

Efficiency / Power Factor

Load	P.F.	Efficiency (%)
1.00	0.89	97.0
0.75	0.90	97.1
0.50	0.89	96.6

x Marked Losses are Included in the Efficiency
Stator Lamination M350–65A 3.5 W/kg at 1.5 T

Losses at Rated Load [kW]

x	Bearing Friction		8
x	Windage		46
x	Core		20
x	I^2R_{DC}–Stator	95 °C	35
x	I^2R_{DC}–Rotor	95 °C	45
x	Additional		31
	Brushes		
	Separated Fan Power		

Resistances and Reactances in p.u. Ref. to ZN = 5.178 Ω/Ph.

	F=0	F=FN		s=0	s=1
R1	0.0050	0.0055	XS1	0.171	0.111
R2'	0.0069	0.0297	XS2'	0.1919	0.124
			XM	7.741	8.723
Comm. React. / System (F = Hz)			XK		

Time Constants in s at 95 °C

T0	TG
T(3K)	T(2K)

MagneticForces

Therm.TimeConstants

Running	15 min
Standstill	300 min
OverCurrentFactor	1.10

SuddenShortCircuitTorqueinp.u.

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Motor parameters from motor data sheet are tabulated as shown:

Operating Data			**Rated Point**						
Output	KW/HP		6000 /						
Voltage	V		6600	star					
Variation	%	±	6.0 / 6.0						
current	A		669						
No - Load current	A		86						
Power Factor			0.89						
Frequency	HZ		50						
Range	%	±	5.0 / 5.0						
Speed/Over-Speed	min^{-1}		1489 /1500						
Cooling Temp Sec/Prim	°C		40 /58						
Wdg. Limit Temp. Stator	°C		120	(R)					
Duty type			S1						
Service factor									
Starting Data							**Counter Torque**		
External Reactance	p.u						Speed	P.u	T P.u
Voltage	p.u		1.00		0.80			1.0	0.465
Locked Rotor Torque	p.u		0.59		0.36			0.8	0.340
Pull up Torque	p.u		--		--			0.6	0.230
Breakdown Torque	p.u		1.7		1.03				
Locked Rotor current	p.u		4.2		3.26			0.4	0.150
Starting time	s		11		25			0.2	0.090

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LR Thermal Unit time	cold/hot							0.0	0.140
Permissible Starts	cold/hot		3 / 2					TN	38.48 kNm
Method of starting	direction-line					Moment of Inertia Mach/Ext		0.345 /1.000 $1m^2$	

Efficiency / Power Factor							**Losses at Rated Load (kW)**		
Load	**PF**				**Efficiency (%)**		X Bearing Friction		8
1	0.89				97.0		x Windage		46
0.75	0.90				97.1		x Core		20
0.50	0.89				96.6		x RROC Stator 95°C		35
							x RROC Rotor 95°C		45
							x Additional		31
x Marked Losses are included in the Efficiency							Brushes		
Stator Lamination M350-55A 3.5 W/kg at 1.5T							Separated Fan power		
Resistances and Reactance in p.u Ref. to ZN = 5.178 □/ph							Time constant in S at 95°C		
	F=0		**F= FN**		**S=0**	**S=1**	T0	TG	

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R1	0.0050		0.0055	XS1	0.171	0.111	T(3K)	T(2K)	
R2	0.0069		0.0297	XS2'	0.1919	0.124			
				XM	7.741	8.723			
Comm. React / System (F=Hz)				XK					
Magnetic Force				Therm. Time Constant			Sudden short circuit Torque in p.u		
					Running	15 min			
					Standstill	300 min			
					Overcurrent factor	1.10			

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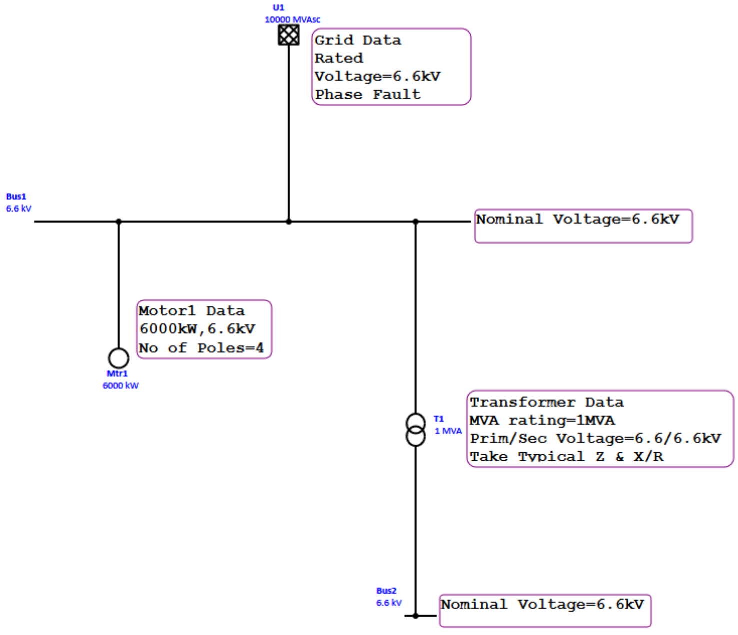
Purpose and Description

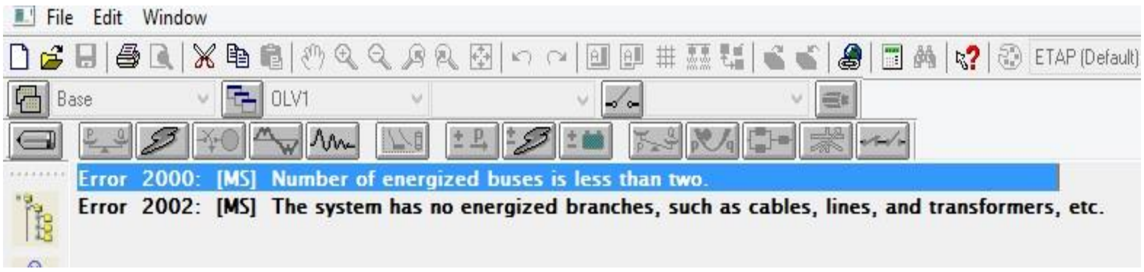
This exercise involves creating the below shown SLD and entering the corresponding data. The detail modelling of the SLD is shown in the subsequent pages.

Procedure

1. Drag and place buses, transformer & grid on OLV and connect them. Proceed to enter the input data as shown below.



Note: Transformer and bus are required to run the ETAP. Otherwise, ETAP shows the following message.



2. Connect Induction machine to Bus1, double click on the Induction machine and enter kW rating & No of Poles.

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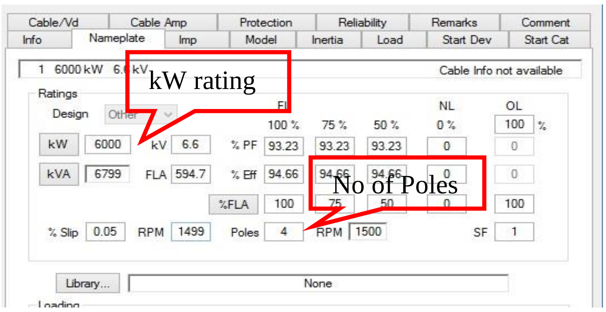
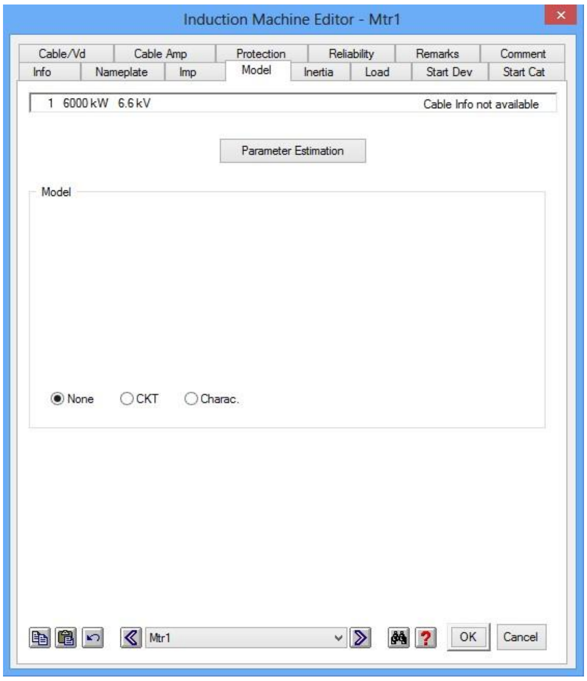


3. Go to Model page, click on “Parameter Estimation” tab.



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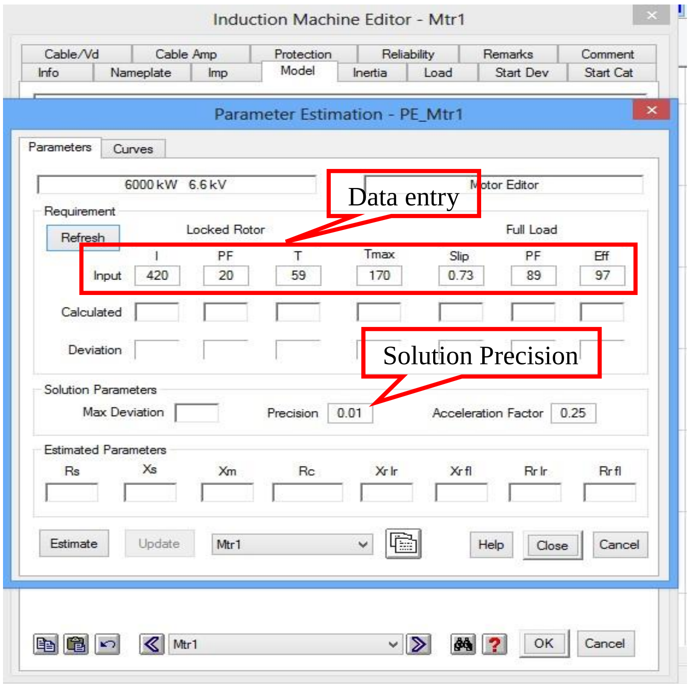
4. In Parameter Estimation**,** enter the locked rotor and full load data from Induction machine data sheet & set the solution parameter precision to 0.01.



Note: Locked rotor power factor is assumed to be 20%.

5. Click on Estimate button. Check estimated motor parameters.

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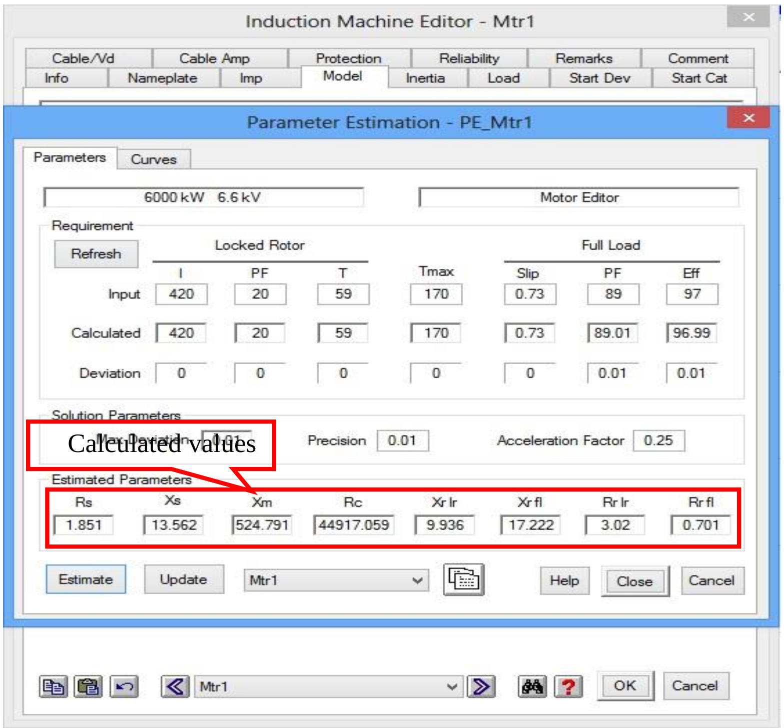
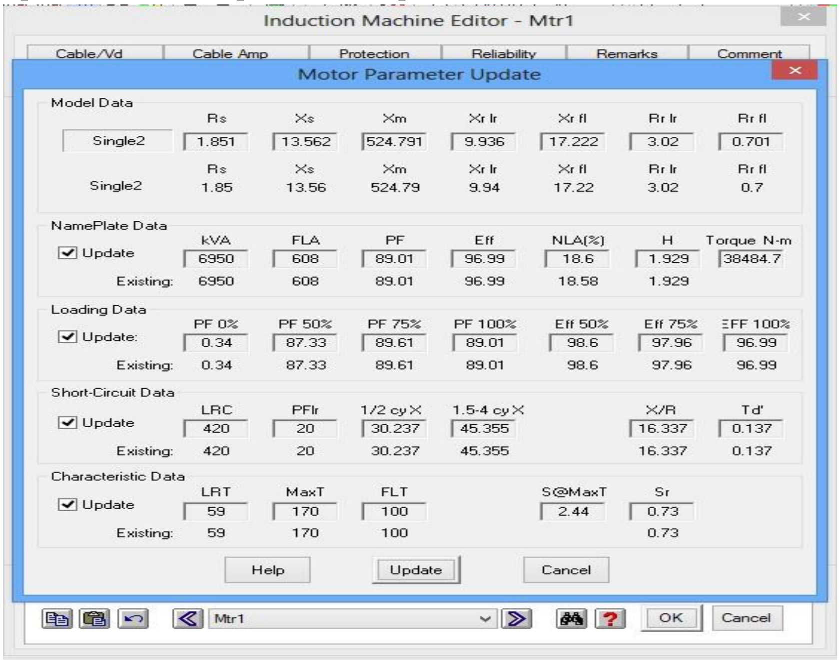


6. Click on update button to update motor parameters.



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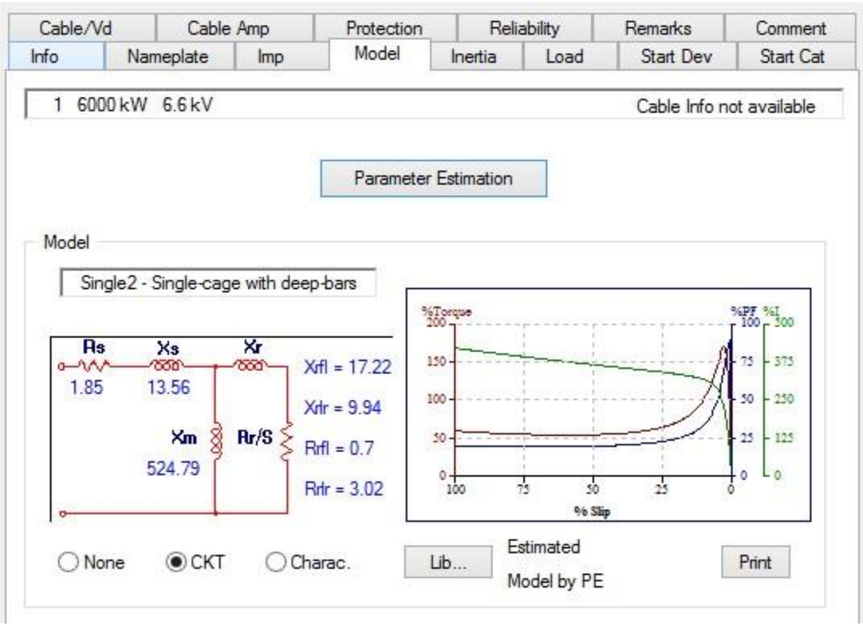
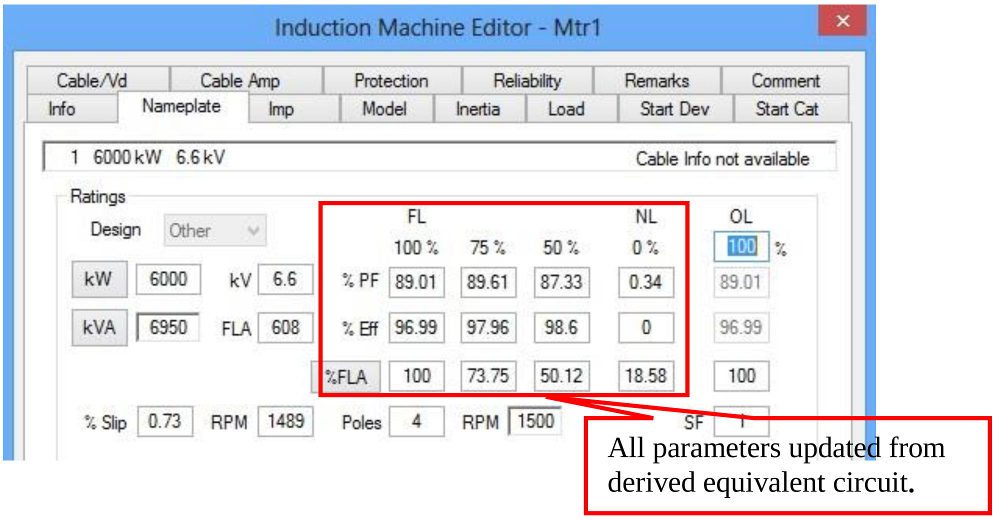
7. Check for equivalent circuit parameters updated in to motor model.



Note: Parameter estimation is an iterative process, the results of your calculation might be slightly different.

8. Also check updated name plate, where, % Efficiency, % PF are updated from ETAP parameters estimated.



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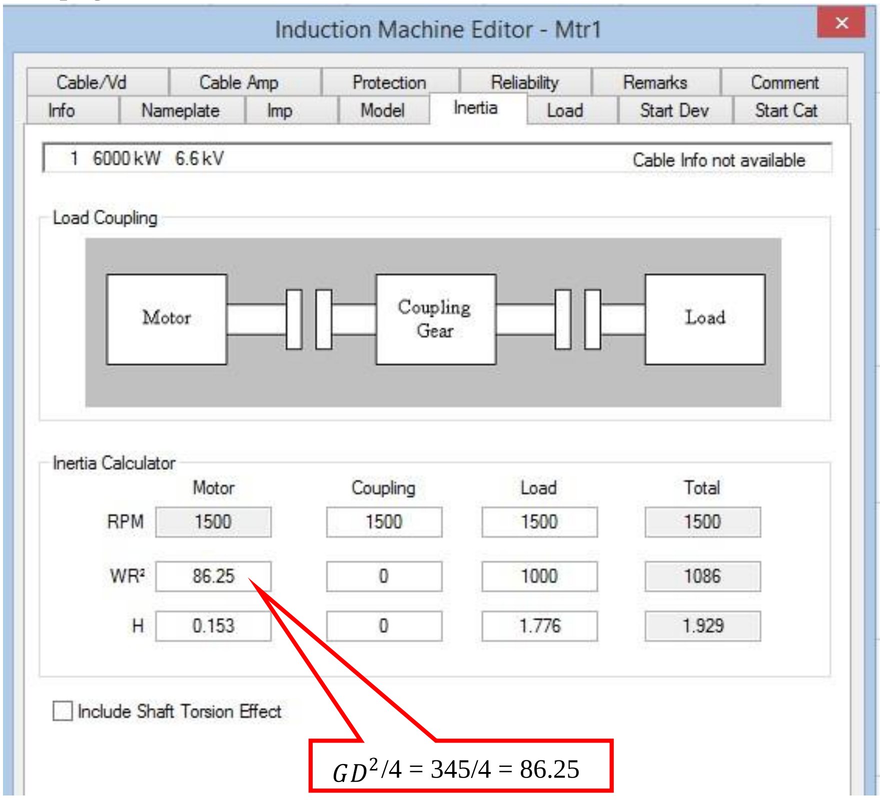
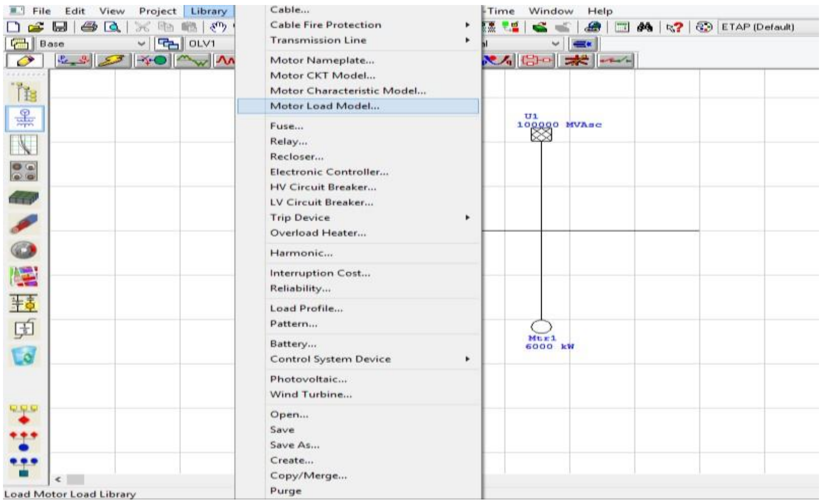
9. Go to Inertia page, enter inertia data for motor & load model from motor data sheet.



10. Go to library, select Motor load model.



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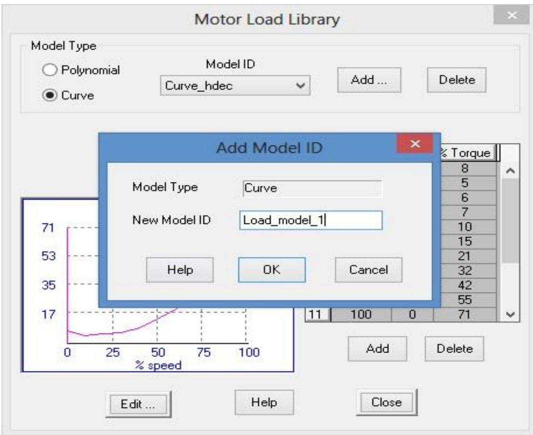
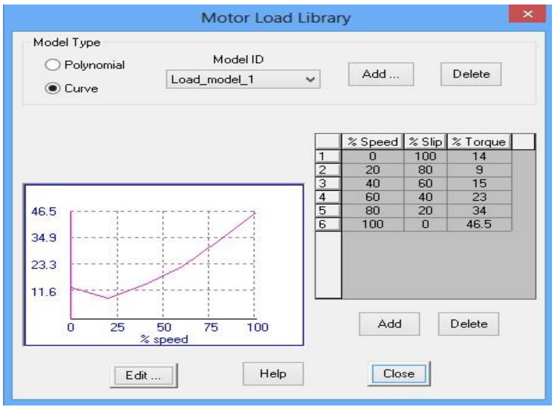
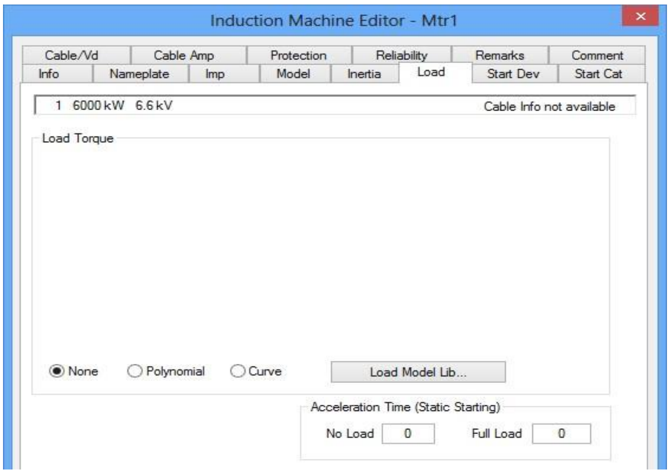
11. Check the curve radio button. Click on Add and give a name for motor model as Load_model_1.



12. Enter the data of (% Speed vs % Torque) or (%Slip vs %Torque) as available in data sheet and delete other rows.



13. Double click on Induction motor, go to Load page.



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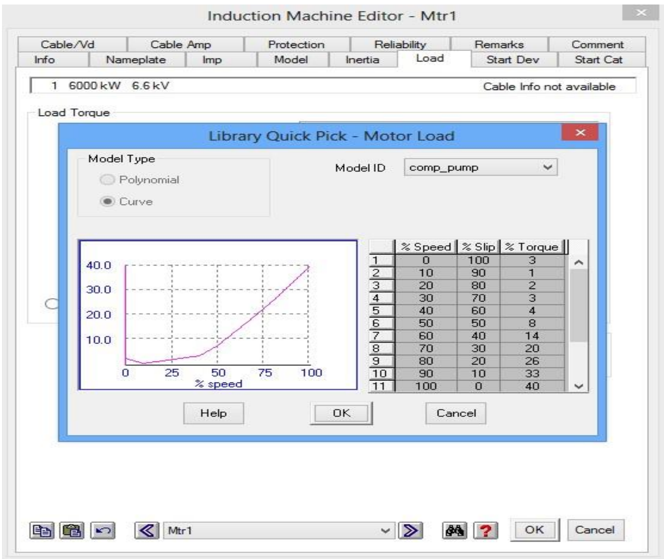
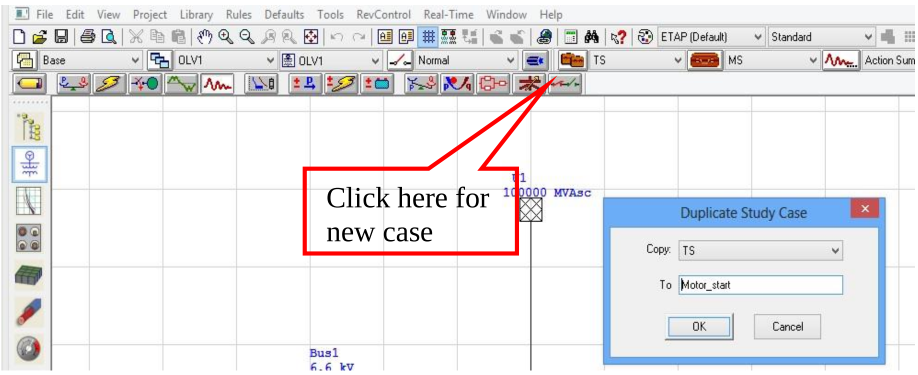
14. Select the radio button for curve model and select load_model_1.



15. Go to Transient Stability Analysis module, create New Study Case and create new case with case ID as Motor start.



16. Select study case ID "Motor start" from drop down menu. Then click on Edit study case for editing study events and for other settings.
17. Go to Events page click on Add button in events box, enter Event ID as Motor Start and Time = 1 sec.

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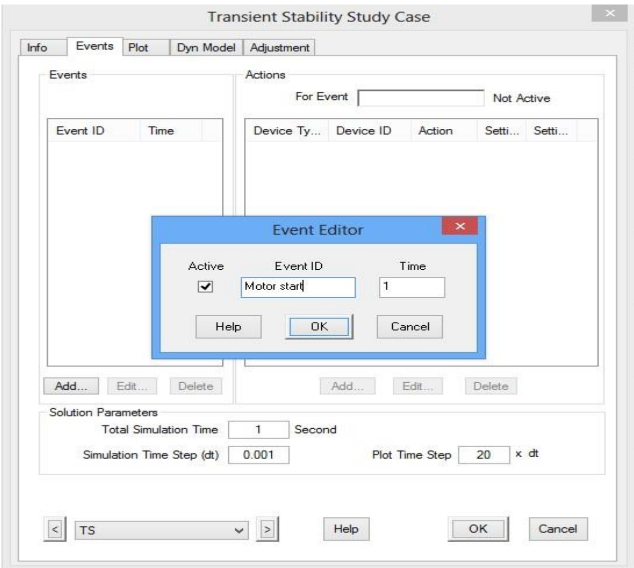
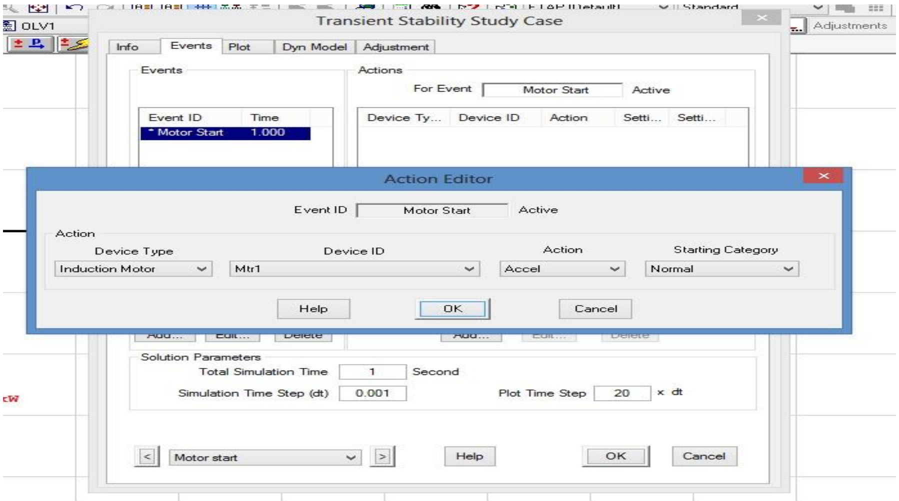


18. Click on Add button in Actions box. In the Action editor window select Device type as "Induction motor", Device ID as "Mtr 1", Action as "Accel" and Starting Category as "Normal".



19. Set the Total Simulation time as 35 second. Simulation time step as 0.001, Plot time step as 20 x dt.

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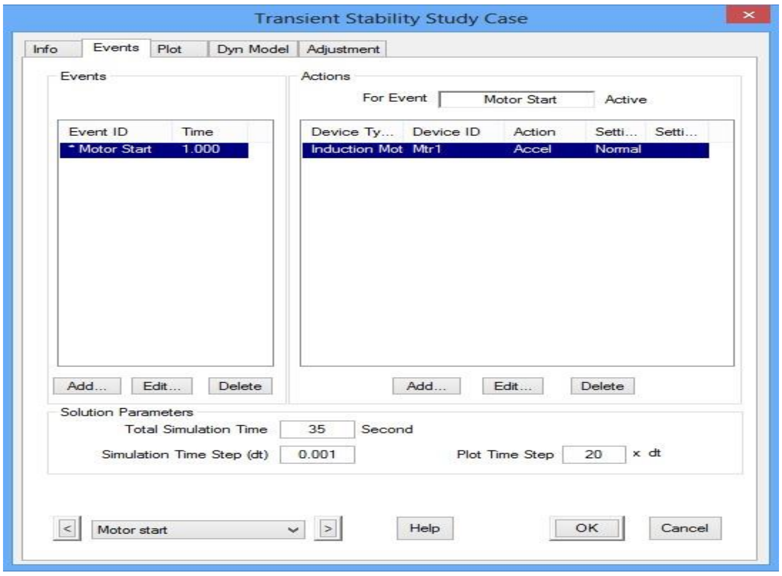
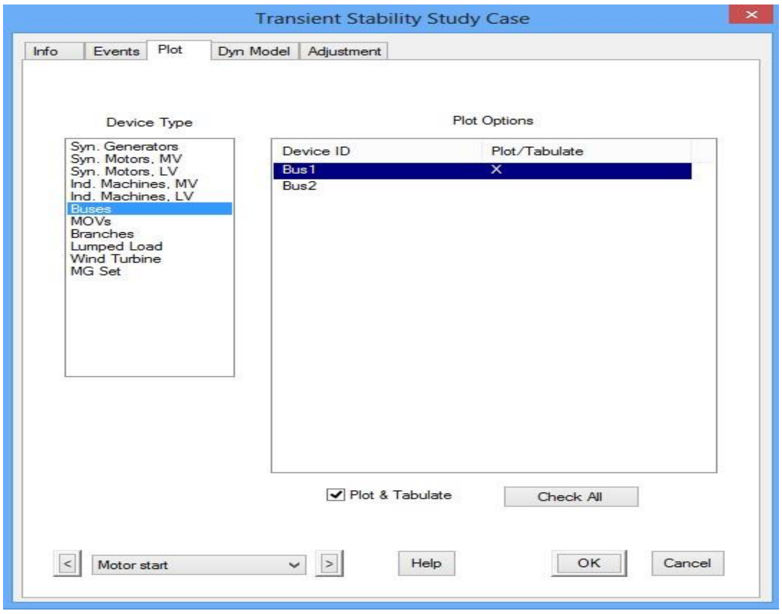


20. Go to Plot page, select motor terminal bus from Buses in device type and Induction motor from Ind. Machines, MV.



21. Go to Dyn Model page perform following actions
    - Select Ind Machines, MV check radio button with model machines larger or equal to “0” HP/KW to model all the MV motors dynamically.
    - In Dynamic modelling during simulation (time>0), uncheck both Include LTC action and Include starting device.

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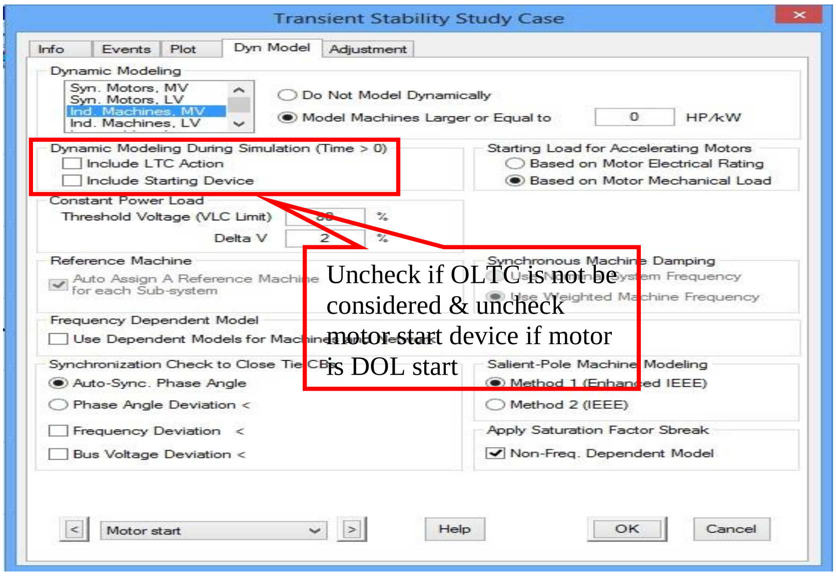
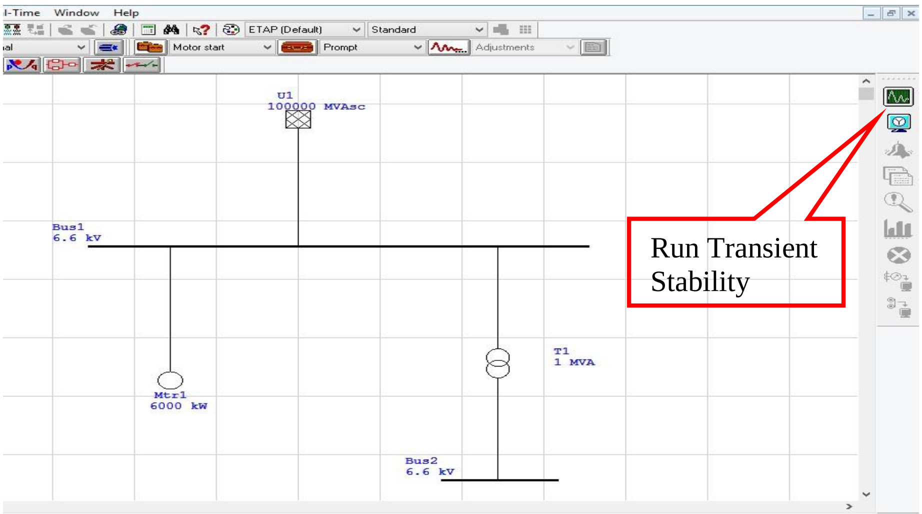
- In starting load for acceleration motors, check radio button Based on motor mechanical load.



22. Click on the Run Transient stability button in Transient study toolbar.



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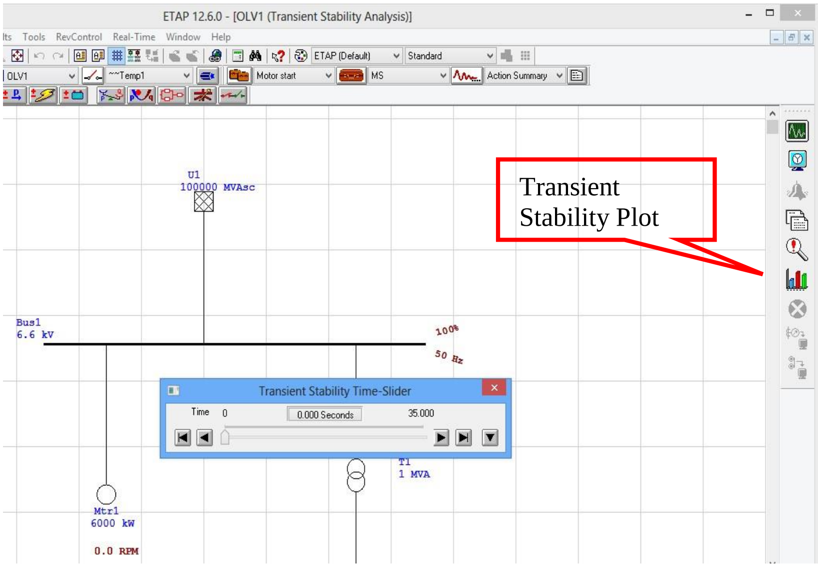
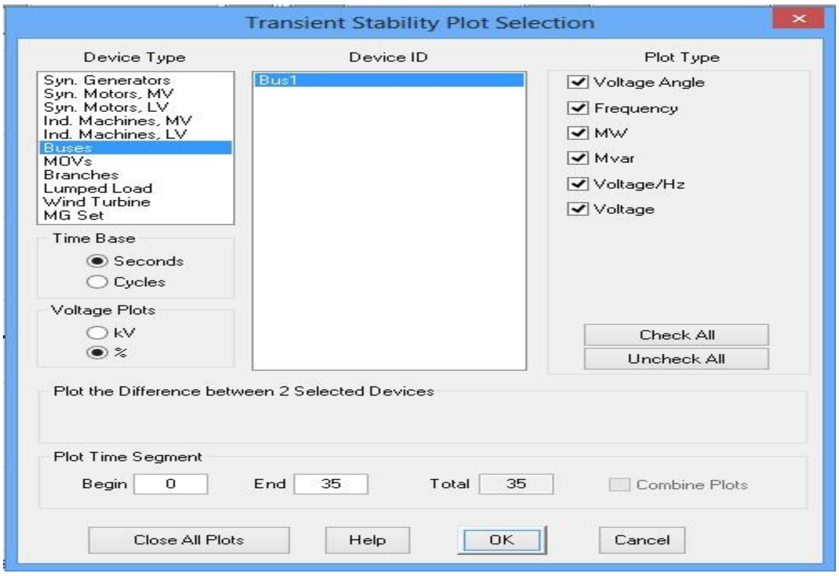
23. Click on the Transient Stability Plots, to plot the results.



24. Select Buses in Device type, Bus1 in Device ID and uncheck all in Plot type other than voltage and frequency. Check the results.



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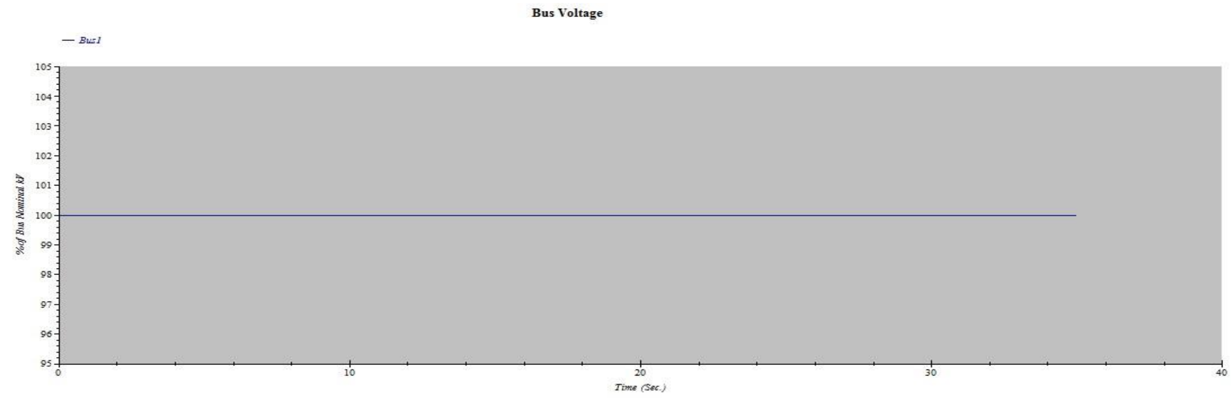

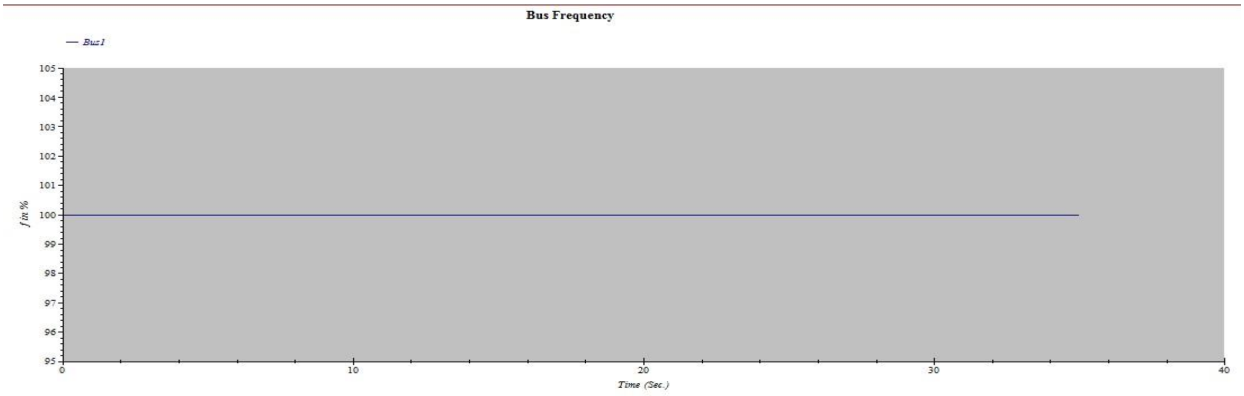

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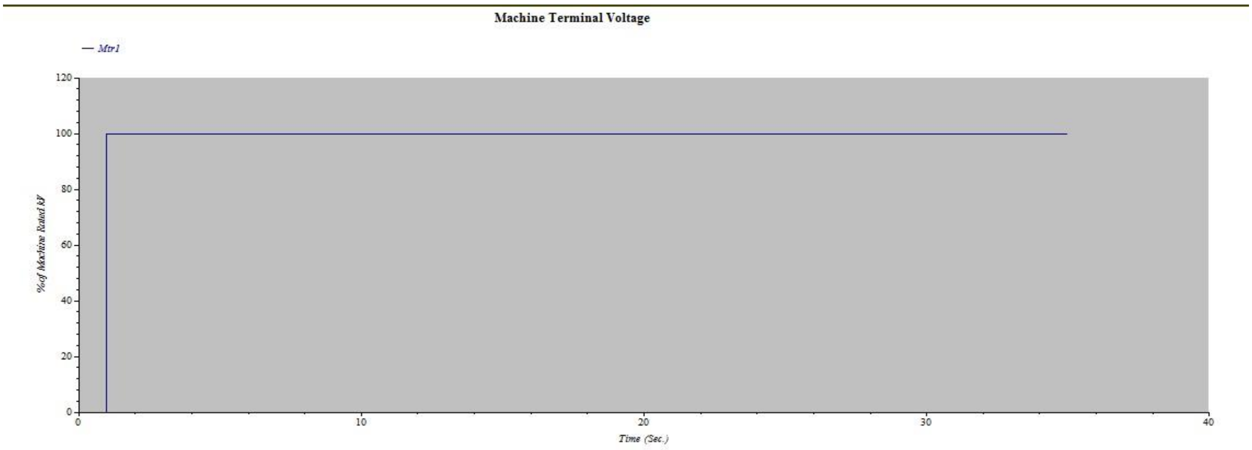
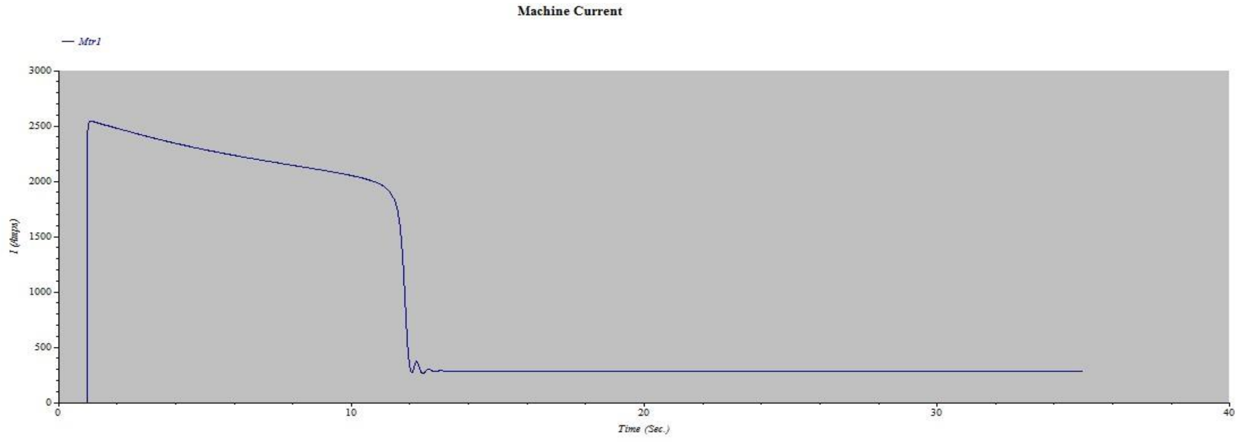
25. Select Ind. Machines, MV in Device type, and Mtr1 in Device ID and uncheck all in Plot type other than slip, MWe, MVAr, Current and terminal voltage. Check the results.





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