

## Motor Parameter Estimation

### Induction Motor Dynamic Modelling (Where Optimization is seen to be required):

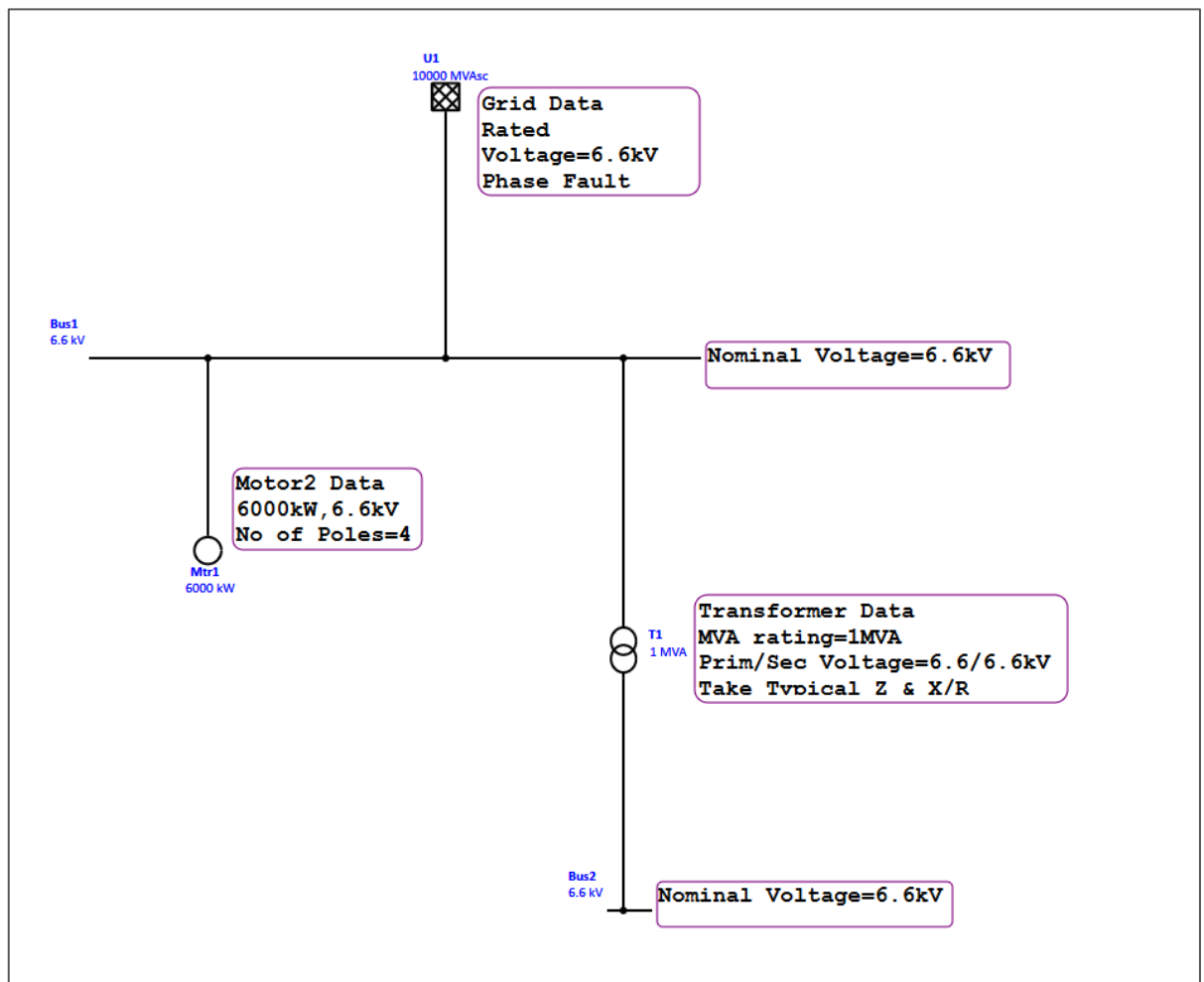
Using optimization technique for arriving of rotor (non-linear) impedance variation with slip. Optimization required where large difference exists in ETAP calculated (using linear impedance technique) values of torque-slip as compare to vendor declared values.

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:

**Step1:** Modelling of equivalent circuit model with few inputs such as Peak torque, LR torque, LR power factor, LR Current, FL power factor, FL efficiency & slip as specified in attached vendor datasheet.

1. As per given datasheet, model the motor connected to grid in ETAP.



## Motor Parameter Estimation

Induction Machine Editor - Mtr2

Cable/Vd	Cable Amp	Protection	Reliability	Remarks	Comment
Info	Nameplate	Imp	Model	Inertia	Load
1	530 kW 6.6 kV				

Ratings

FL 100 % 75 % 50 % NL 0 % OL 100 %

kW 530 kV 6.6 % PF 92.23 92.23 92.23 0 92.23

kVA 615.3 FLA 53.82 % Eff 93.4 93.4 93.4 0 93.4

Poles 2 RPM 3000 %FLA 100 75 50 0 100

% Slip 0.67 RPM 2980 SF 1

Library... None

Loading

Category	%	Loading		Motor Load		Feeder Loss	
		kW	kvar	kW	kvar	kW	kvar
1 Design	100	530	567.5	237.8	0	0	
2 Normal	90	477	510.7	214	0	0	
3 Brake	0	0	0	0	0	0	
4 Winter Load	0	0	0	0	0	0	
5 Summer Load	0	0	0	0	0	0	
6 FL Reject	0	0	0	0	0	0	
7 Emergency	0	0	0	0	0	0	
8 Shutdown	0	0	0	0	0	0	
9 Accident	0	0	0	0	0	0	
10 Backup	0	0	0	0	0	0	

Operating Load: 0 kW +j 0 kvar

Mtr2

- Go to model page & estimate the motor parameters.

Parameter Estimation - PE\_Mtr4

Parameters Curves

530 kW 11 kV

Motor Editor

Input Data

☒ Parameter Est. & Tuning Based on Nameplate Data Only

☐ Parameter Est. & Tuning Based on Nameplate and Characteristic Data

☐ Nameplate

☒ User-Defined

Initial Estimation Requirement

	Locked Rotor				Full Load				
	I	PF	T	Tmax	Slip	I	T	PF	Eff
Input	550	20	75	220	0.67	100	100	91	96
Calculated									
Deviation									

Solution Parameters

Max Deviation Precision 0.01 Acceleration Factor 0.25

Estimated Parameters

Rs Xs Xm Rc Xr Ir Xr fi Rr Ir Rr fi

Estimate Update Mtr4

Help Close Cancel

## Motor Parameter Estimation

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

Parameter Estimation - PE\_Mtr4

Parameters Curves

530 kW 11 kV

Motor Editor

Input Data

☒ Parameter Est. & Tuning Based on Nameplate Data Only

☐ Parameter Est. & Tuning Based on Nameplate and Characteristic Data

☐ Nameplate

☒ User-Defined

Initial Estimation Requirement

	Locked Rotor				Full Load				
	I	PF	T	Tmax	Slip	I	T	PF	Eff
Input	550	20	75	220	0.67	100	100	91	96
Calculated	550	20	75.01	220	0.67	99.99	100	91.01	96.01
Deviation	0	0	0.01	0.01	0	0	0	0.01	0.01

Solution Parameters

Max Deviation 0.01 Precision 0.01 Acceleration Factor 0.25

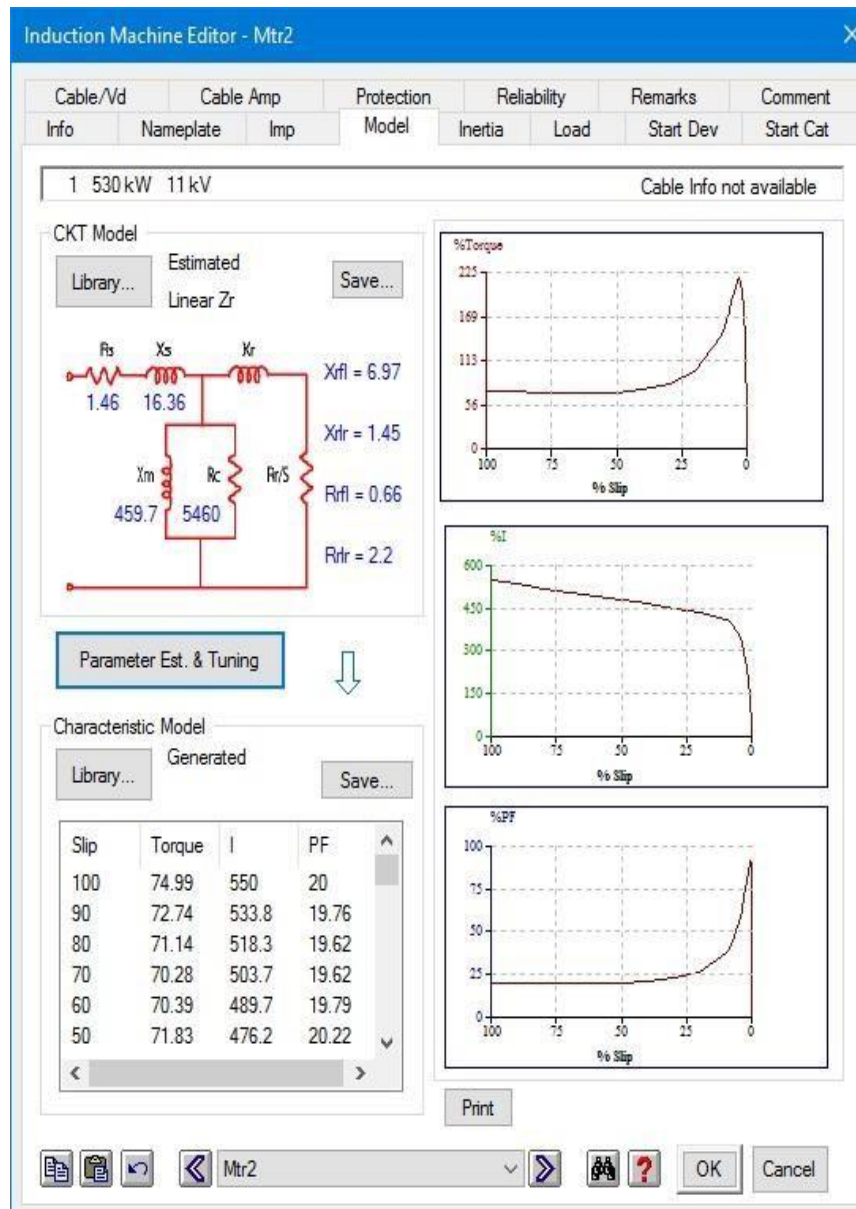
Estimated Parameters

Rs	Xs	Xm	Rc	Xr Ir	Xr fl	Rr Ir	Rr fl
1.452	13.79	460.71	5538.221	4.051	9.654	2.221	0.663

Estimate Update Mtr4 Help Close Cancel

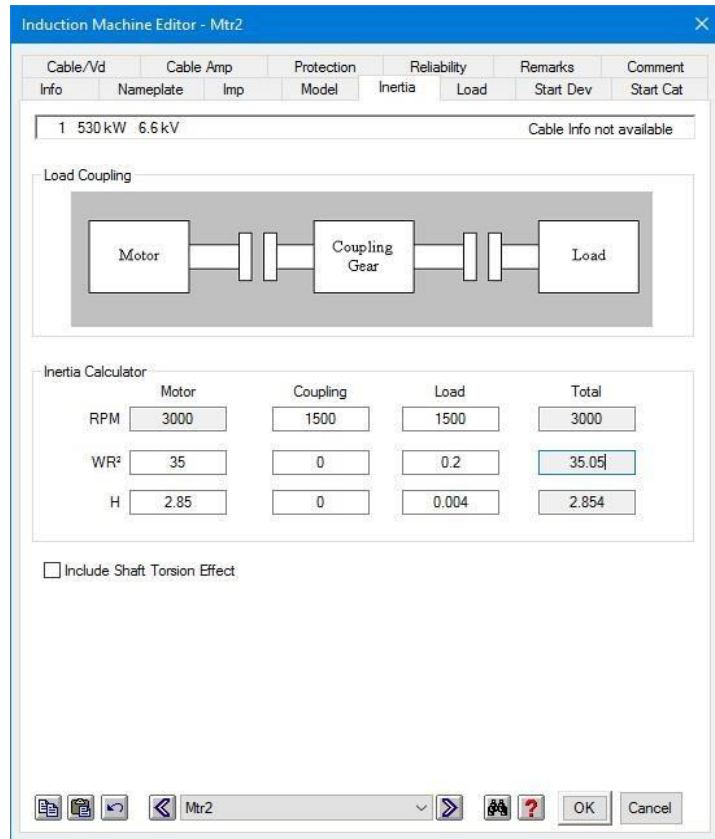
- Update the estimated values in motor. The ETAP estimated curves will appear as shown below.

## Motor Parameter Estimation



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

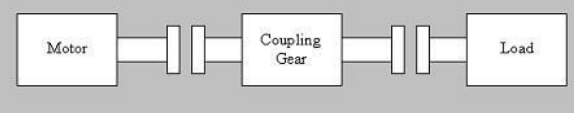
## Motor Parameter Estimation



Induction Machine Editor - Mtr2

Cable/V/d	Cable Amp	Protection	Reliability	Remarks	Comment
Info	Nameplate	Imp	Inertia	Load	Start Dev
1	530 kW	6.6 kV	Cable Info not available		

Load Coupling



Inertia Calculator

	Motor	Coupling	Load	Total
RPM	3000	1500	1500	3000
WR <sup>2</sup>	35	0	0.2	35.05
H	2.85	0	0.004	2.854

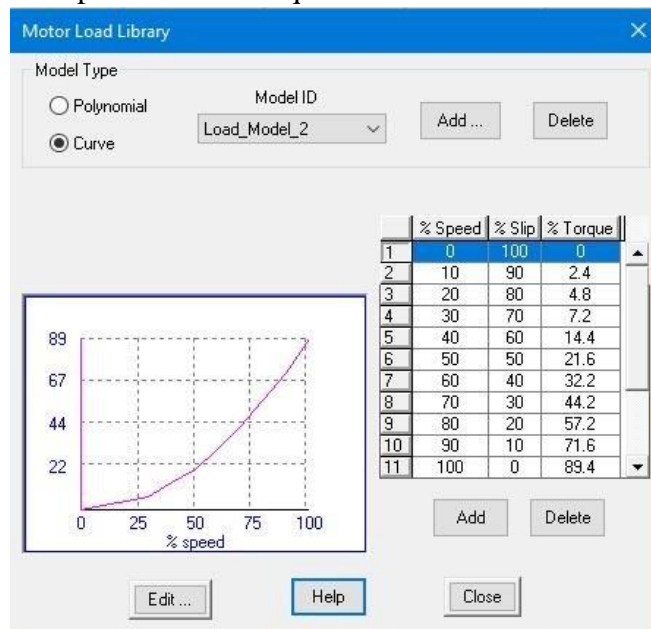
☐ Include Shaft Torsion Effect

Buttons: OK, Cancel

- Enter load curve points in ETAP library as shown below.

Go to library => Motor load model=> Add a new 'curve type' model with ID 'Load\_Model\_2'.

Enter the data of % Speed V/S % Torque for load curve as available in data sheet.



Motor Load Library

Model Type

☐ Polynomial ☒ Curve

Model ID: Load\_Model\_2

Buttons: Add..., Delete

	% Speed	% Slip	% Torque
1	0	100	0
2	10	90	2.4
3	20	80	4.8
4	30	70	7.2
5	40	60	14.4
6	50	50	21.6
7	60	40	32.2
8	70	30	44.2
9	80	20	57.2
10	90	10	71.6
11	100	0	89.4

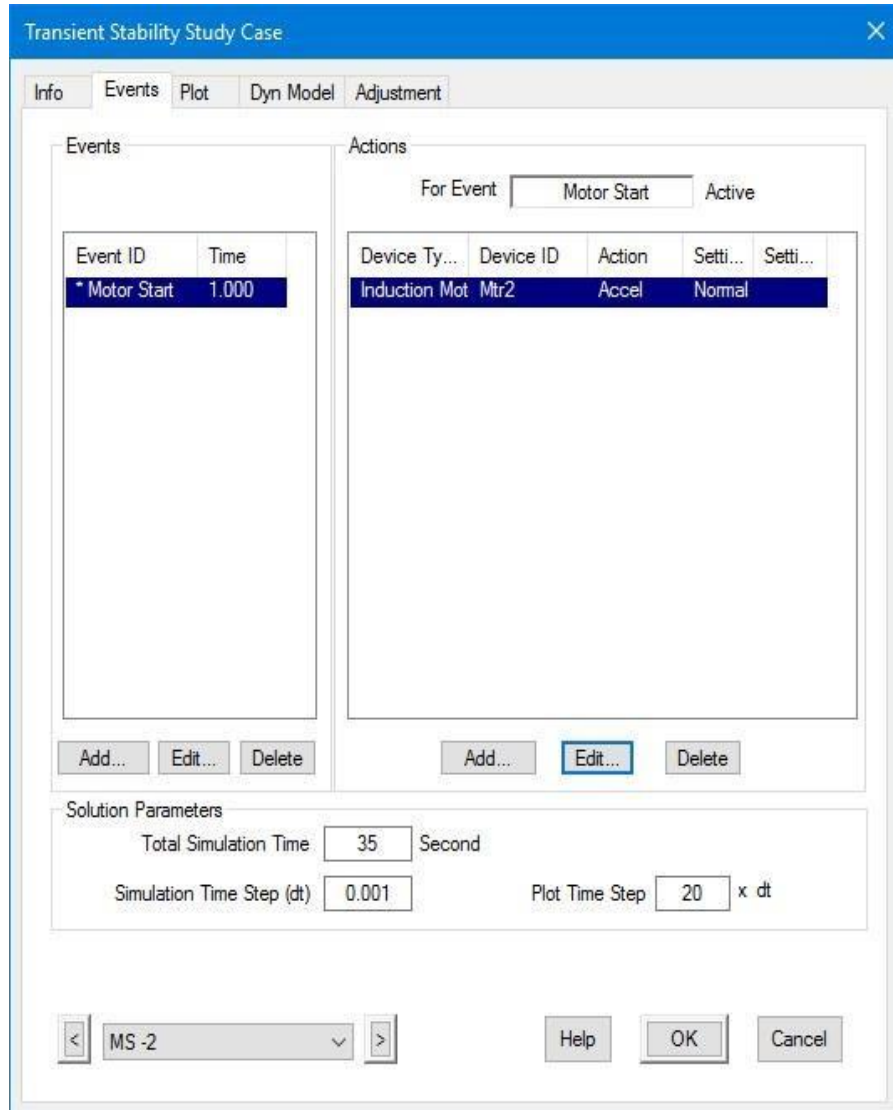
Buttons: Add, Delete

Graph: % speed vs % Torque

Buttons: Edit..., Help, Close

## Motor Parameter Estimation

6. Go to Induction motor => Load page & select above load model.
7. Now, go to transient stability module, make a new study as 'MS-2' and give the event to accelerate the motor 2.



The screenshot shows the 'Transient Stability Study Case' dialog box with the 'Events' tab selected. The 'Events' table contains one entry: 'Motor Start' at time '1.000'. The 'Actions' table shows the action 'Accel' for device 'Mtr2' of type 'Induction Mot'. The 'Solution Parameters' section shows 'Total Simulation Time' as 35 seconds and 'Simulation Time Step (dt)' as 0.001. The 'Plot Time Step' is set to 20 x dt. The study name 'MS-2' is entered in the dropdown at the bottom.

Event ID	Time
* Motor Start	1.000

Device Ty...	Device ID	Action	Setti...	Setti...
Induction Mot	Mtr2	Accel	Normal	

Solution Parameters

Total Simulation Time: 35 Second

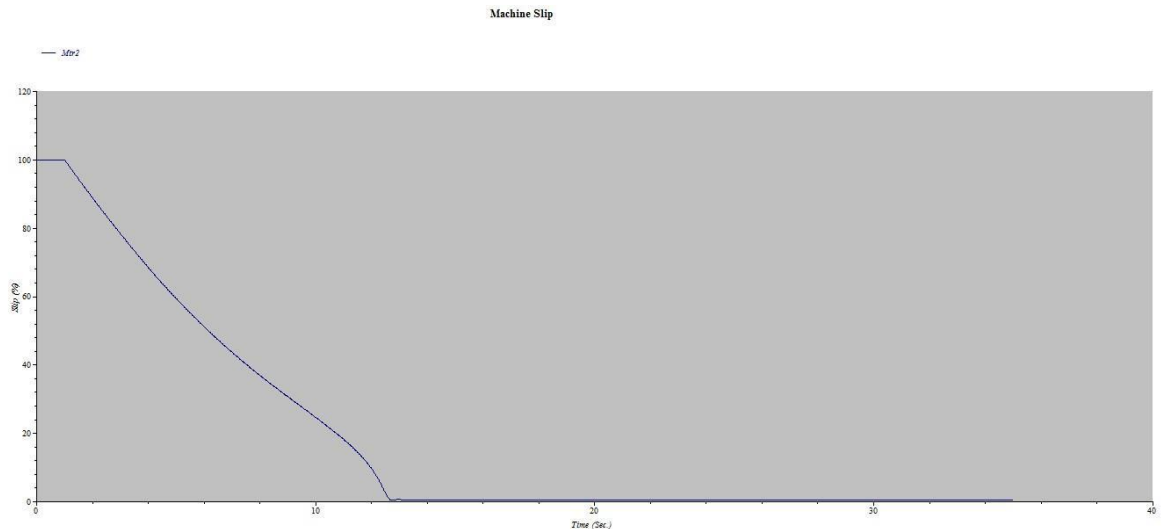
Simulation Time Step (dt): 0.001

Plot Time Step: 20 x dt

Study Name: MS-2

8. Plot bus and motor2.
9. Run the case & check the starting time of motor-2 by using plot option.

## Motor Parameter Estimation



10. **Starting time of motor as per vendor datasheet: 8.5sec at 100% voltage**  
& calculated Starting time of motor in ETAP is = 11.6 sec, which is not matching with starting time mentioned in vendor datasheet.
11. Now, compare the vendor declared Torque v/s Speed curve data with ETAP estimated data.

Speed (%)	Torque as per vendor datasheet (%)	Torque as per ETAP estimation (%)
0	75	74.99
20	82.2	71.14
40	87	70.39
60	97.6	75.41
80	114.4	99.45
Tmax	220	220

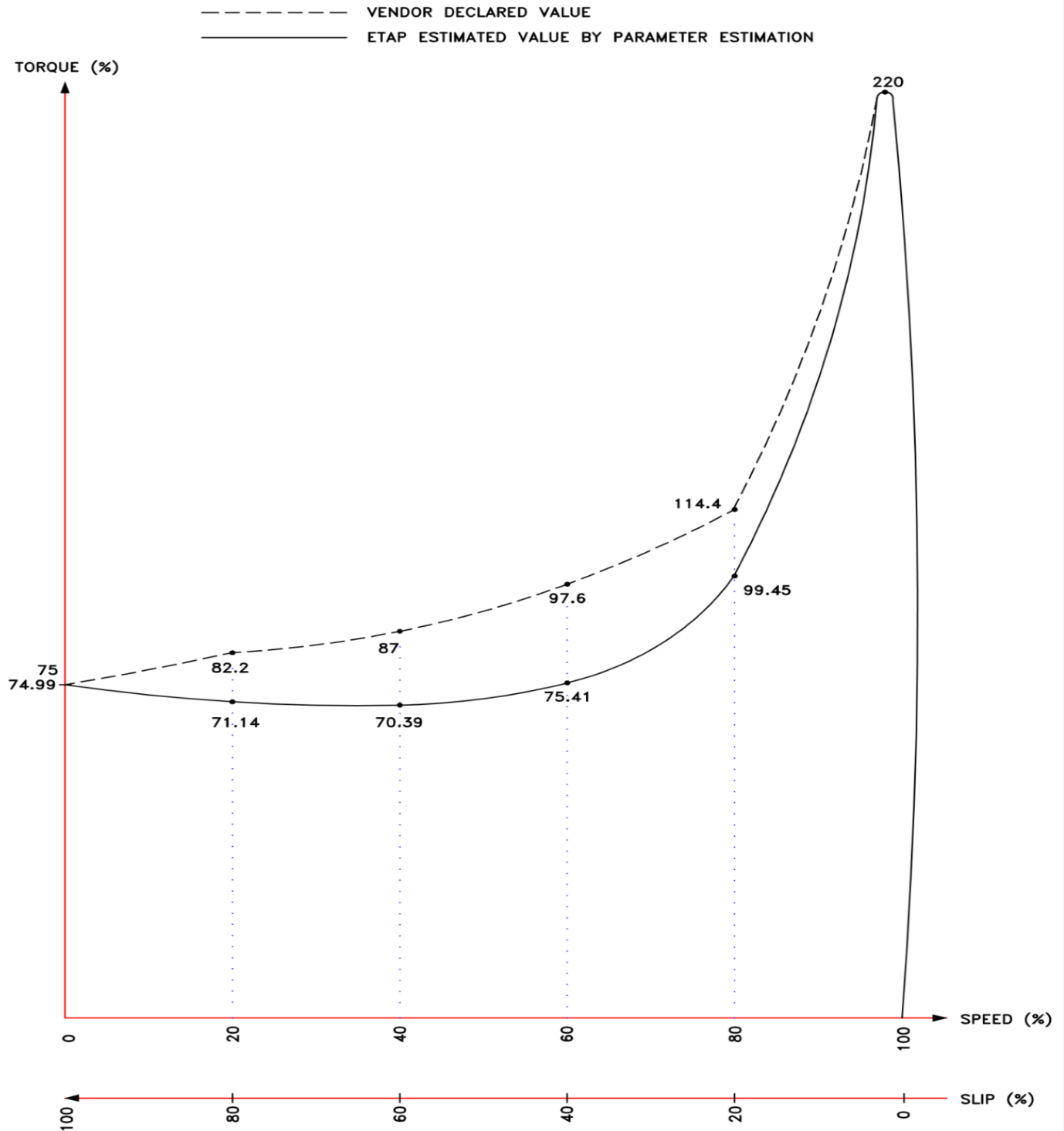
**Note:** There is significant difference between vendor declared & ETAP parameter estimated values of Torque v/s Speed.

This is because ETAP parameter estimation is based on few data points such as Locked rotor torque, Locked rotor current, Locked rotor power factor, Peak torque, Full load efficiency, Full load slip & Full load power factor, where ETAP uses linear rotor impedance (Z) variation with slip.

A more elaborate model estimates, when more data points are taken from Torque v/s Slip, Pf v/s Slip & Current v/s Slip curve for motor characteristics model library, which is first created and then used as input to parameter estimation.

In next points parameter estimation by characteristics model is explained

## Motor Parameter Estimation



**NOTE:-**

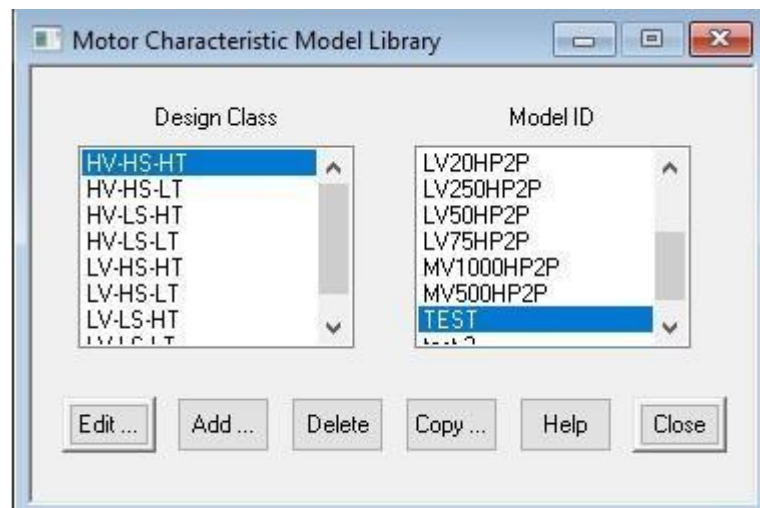
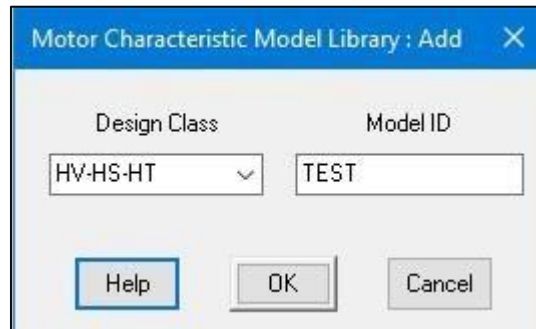
THERE IS SIGNIFICANT DIFFERENCE BETWEEN VENDOR DECLARED & ETAP ESTIMATED T V/S SPEED VALUES.



## Motor Parameter Estimation

**Step 2:** To perform optimization more torque, current & pf V/s slip points are need to be consider.

12. Go to library – “Motor characteristic Model”, then add new motor characteristics model named as ‘TEST’ as shown below.



13. Add the following points in the TEST model:

Slip	Torque	Current	Pf
%	%	%	%
100	74.8	549.3	20.02
90	77.9	543.7	19.78
80	80.7	540.5	19.64
70	83.5	533.2	19.63
60	87.3	525.2	19.8
50	92.9	516.3	20.23
40	97.6	502.6	21.1
30	103.8	485.7	22.81

Slip	Torque	Current	Pf
%	%	%	%
6	181.6	397	49.88
5	192.87	383.31	55.07
4	209.2	357.15	61.66
3	220.24	318.73	70.01
2	215.2	274	79.98
1.5	212.6	216.6	85.1
1	165.7	159.35	89.45
0.8	138.5	118.35	90.6

## ETAP Workshop Notes



### Motor Parameter Estimation

20	113.5	463.1	26.52
10	143.4	430.1	37.44
9	147.84	423.6	39.7
8	156.04	416	42.43
7	169.29	407	45.75

0.67	101.5	99.91	91
0.6	93.79	89.55	91
0.4	88.96	59.70	90.25
0.2	78.28	29.85	89.78
0.01	75.4	1.49	89.21

The screenshot shows the 'Motor Characteristic Model Library Editor' window. On the left, there are two lists: 'Design Class' and 'Model ID'. The 'Model ID' list includes 'TEST'. Below these lists are buttons for 'Edit...', 'Add...', 'Delete', 'Copy...', 'Help', and 'Close'. On the right, a table titled 'Torque Slip Curve' is displayed, showing data for 'ID : TEST'. The table has columns for Slip, Torque, I, and PF. The data points are as follows:

	Slip	Torque	I	PF
1	100	74.8	549.3	20.02
2	90	77.9	543.7	19.78
3	80	80.7	540.5	19.64
4	70	83.5	533.2	19.63
5	60	87.3	525.2	19.8
6	50	92.9	516.3	20.23
7	40	97.6	502.6	21.1
8	30	103.8	485.7	22.81
9	20	113.5	463.1	26.52
10	10	143.4	430.1	37.44
11	9	147.8	423.6	39.7
12	8	156	416	42.43
13	7	169.3	407	45.75
14	6	181.6	397	49.88
15	5	192.9	383.3	55
16	4	209.2	357.1	61.66
17	3	220.2	318.7	70.01
18	2	215.2	274	79.98
19	1.5	212.6	216.6	85.1
20	1	165.7	159.3	89.45
21	0.8	138.5	118.3	90.6
22	0.67	100.5	99.9	91
23	0.6	93.79	89.6	91
24	0.4	88.96	59.7	90.25
25	0.2	78.28	29.9	89.78
26	0.01	75.4	1.5	89.21
27				

**Note:** The points can be traced using Didger software as well for accurate results.

- Now, go to Model page of motor & select the saved characteristic Model from library as shown below:

## Motor Parameter Estimation

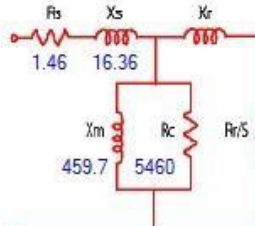
Induction Machine Editor - Mtr2

Cable/Vd	Cable Amp	Protection	Reliability	Remarks	Comment
Info	Nameplate	Imp	Model	Inertia	Load
				Start Dev	Start Cat
1	530 kW	11 kV			

Cable Info not available

CKT Model

Library... Estimated Linear Zr Save...



$R_s = 1.46$   
 $X_s = 16.36$   
 $X_m = 459.7$   
 $R_r = 0.66$   
 $X_r = 6.97$   
 $R_{lr} = 1.45$   
 $R_{lr}/S = 2.2$

Parameter Est. & Tuning

Characteristic Model

Library... Generated Save...

Slip	Torque	I	PF
100	74.99	550	20
90	72.74	533.8	19.76
80	71.14	518.3	19.62
70	70.28	503.7	19.62
60	70.39	489.7	19.79
50	71.83	476.2	20.22

Library Quick Pick - Characteristic Model

Torque Slip Characteristic Model Library


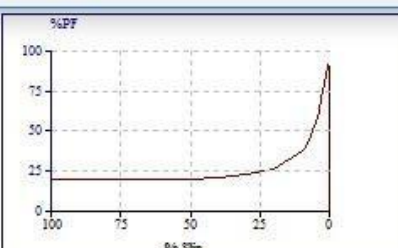
Design Class

Model ID

HV-HS-HT  
 HV-HS-LT  
 HV-LS-HT  
 HV-LS-LT  
 LV-HS-HT

LV75HP2P  
 MV1000HP2P  
 MV500HP2P  
 TEST

OK None Cancel Help

Print

Mtr2

OK Cancel

- Again estimate and update the motor parameters with TEST characteristics model.

# Motor Parameter Estimation



## ETAP Workshop Notes

Motor Parameter Estimation and Tuning - PE\_Mtr7

Parameters Curves

530 kW 11 kV Motor Editor

☐ Parameter Est. & Tuning Based on Nameplate Data Only  
☒ Parameter Est. & Tuning Based on Nameplate and Characteristic Data

Initial Estimation Requirement

	Locked Rotor				Full Load				
	I	PF	T	Tmax	Slip	I	T	PF	Eff
Input	549.3	20.02	74.8	220.2	0.67	100	100	91	95.86
Calculated	549.3	20.02	74.8	220.2	0.67	99.99	100	91	95.85
Deviation	0	0.01	0	0	0	0	0	0	0.01

Solution Parameters

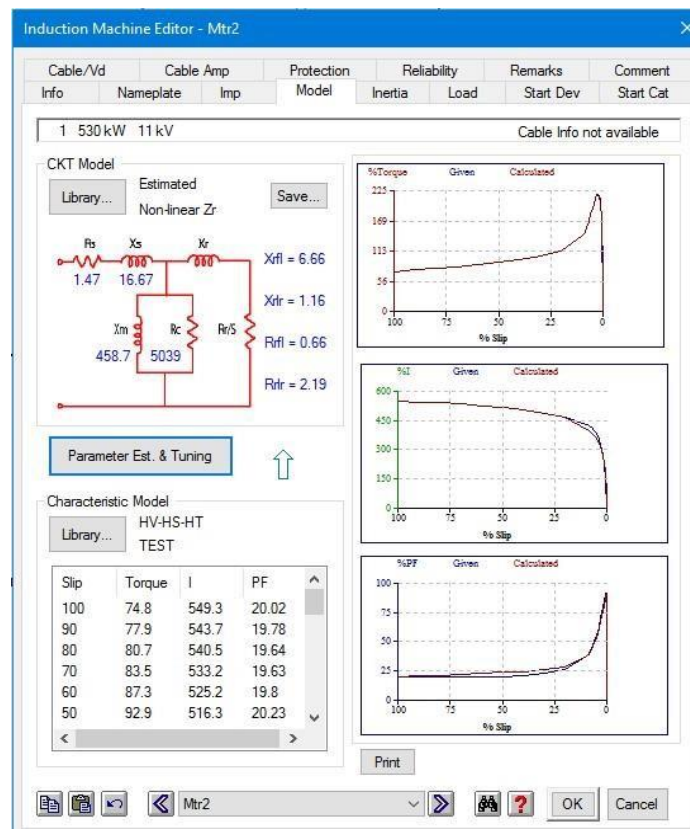
Max Deviation 0.01 Precision 0.01 Acceleration Factor 0.25

Estimated Parameters

Rs	Xs	Xm	Rc	Xr lr	Xr fl	Rr lr	Rr fl
1.466	16.668	458.738	5039.424	1.163	6.656	2.19	0.655

Adv. Setting Estimate Update Mtr7 Help Close Cancel

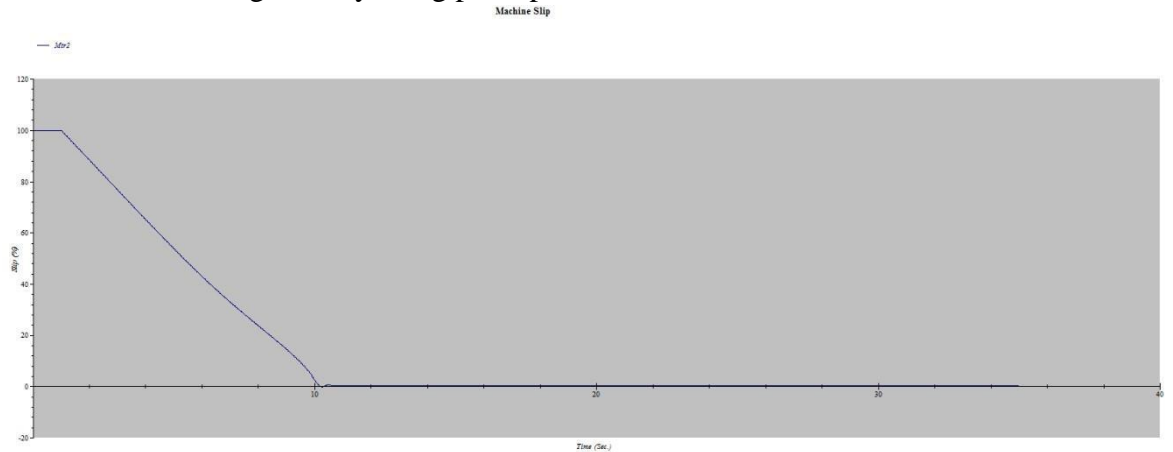
16. The deviation in the manufacturer curves (entered in library) and ETAP estimated curves are shown below.



## Motor Parameter Estimation



17. The difference between two curves can be reduced by changing weighting factor specified in Advance settings.
18. Now, go to transient stability module and run the same case to accelerate motor 2.
19. Check motor starting time by using plot options.



Starting time of motor is reduced from 11.6 sec to 9.2 sec.