



User Manual

xEV Simulator

Version 6.0

Supervisor: Miyasaka san

NIDEC ADVANCE TECHNOLOGY CORPORATION

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Revisions:

Version	Primary Author	Description of Version	Date completed
6.0	Roywin Joel Monteiro	Initial Release	06-09-2024
	Pratheeksha		

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Table of Contents:

1	Introduction	
2	Installation and Setup	
3	Getting Started	
	3.1 Home Page	
	3.2 Introduction	
	3.3 Input Tab	
	3.3.1 Digital Twin	
	3.4 IPM Tab	
	3.4.1 IGBT	
	3.5 Drive Pattern Modelling Tab	
	3.5.1 Parameter Settings	
	3.6 Ploss Analysis by Torque	
	3.6.1 Ploss Analysis by Torque Next	
	3.7 Ploss Analysis by Current	
	3.7.1 Ploss Analysis by Current Next	
	3.8 Data Tab	
4	Detailed Explanation	

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1. Introduction

With the global rise of automobile electrification, it is essential to optimize the entire vehicle as a unified system. The xEV Simulator is designed to create and optimize a digital twin of the whole electric vehicle, rather than focusing solely on its individual components.

xEV Simulator is an integrated simulation tool to support the designing and analysis of xEV (electric vehicles). This tool simulates the entire electric vehicle during xEV development, incorporating the specific characteristics of the E-Axle, which includes an automotive drive motor, gear, inverter, and other components.

This function enables the tool's users to propose, among others, motors and components that match the vehicle's conditions and running environment, while shortening the time for motor test via detailed calculation, and improving the efficiency of the calculation-result gap analysis.

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2. Installation and Setup

Follow these steps to run the xEV Simulator web application:

1. Extract the Zip File:
 - Extract the contents of the attached zip file
2. Navigate to the Build Directory:
 - Go to the directory: [web v6.0/build/exe.win-amd64-3.12/](#)
3. Run the Server:
 - Run the [server.exe](#) file located in the directory.
4. Open the Application in a Browser:
 - Open a web browser and go to: <http://127.0.0.1:8050>

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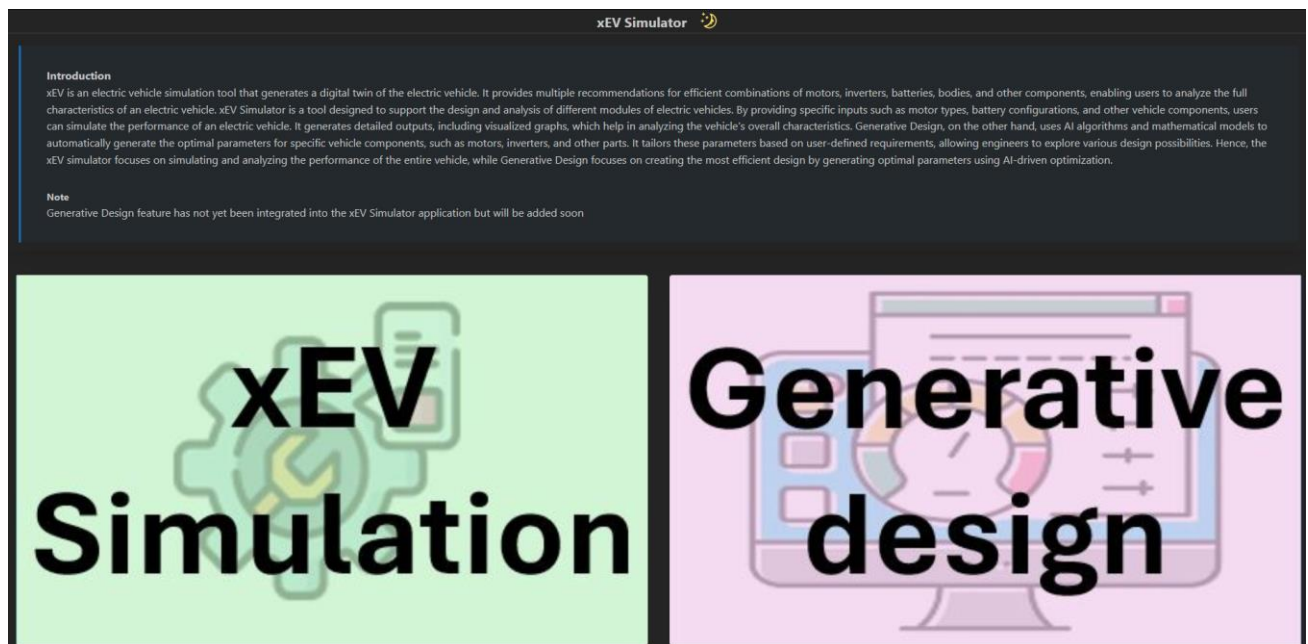
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3. Getting Started

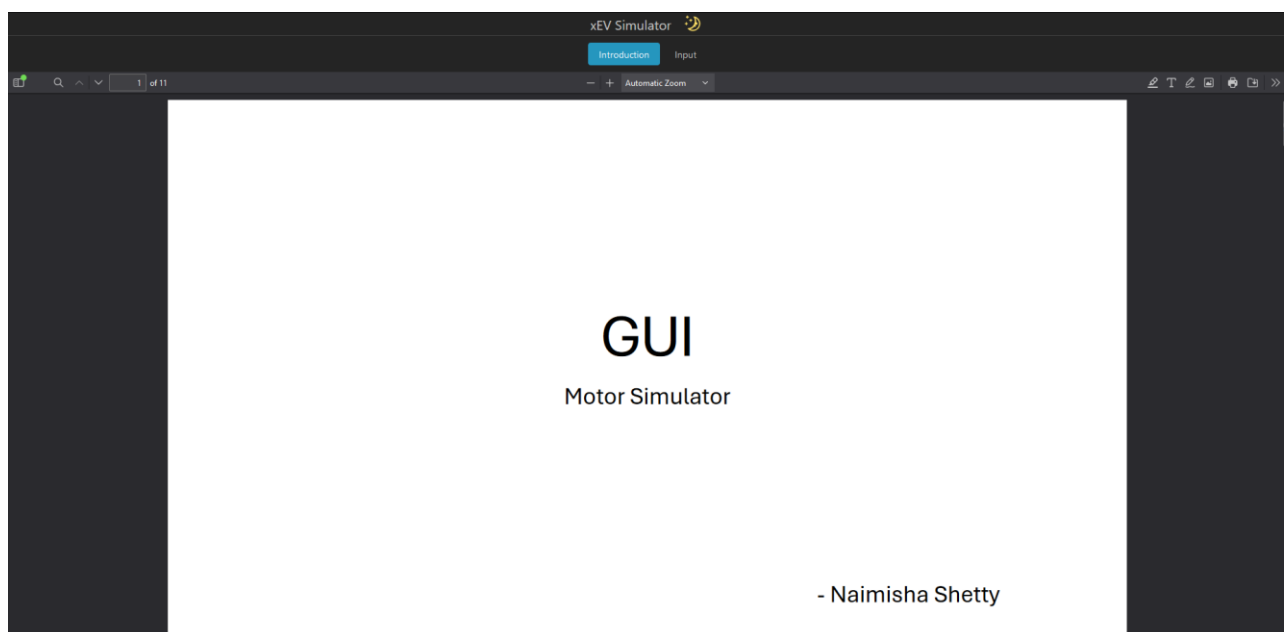
3.1 Home Page:

On this page, selecting the xEV simulator button starts the motor simulator application.



3.2 Introduction:

This page contains a Presentation for the motor simulator.



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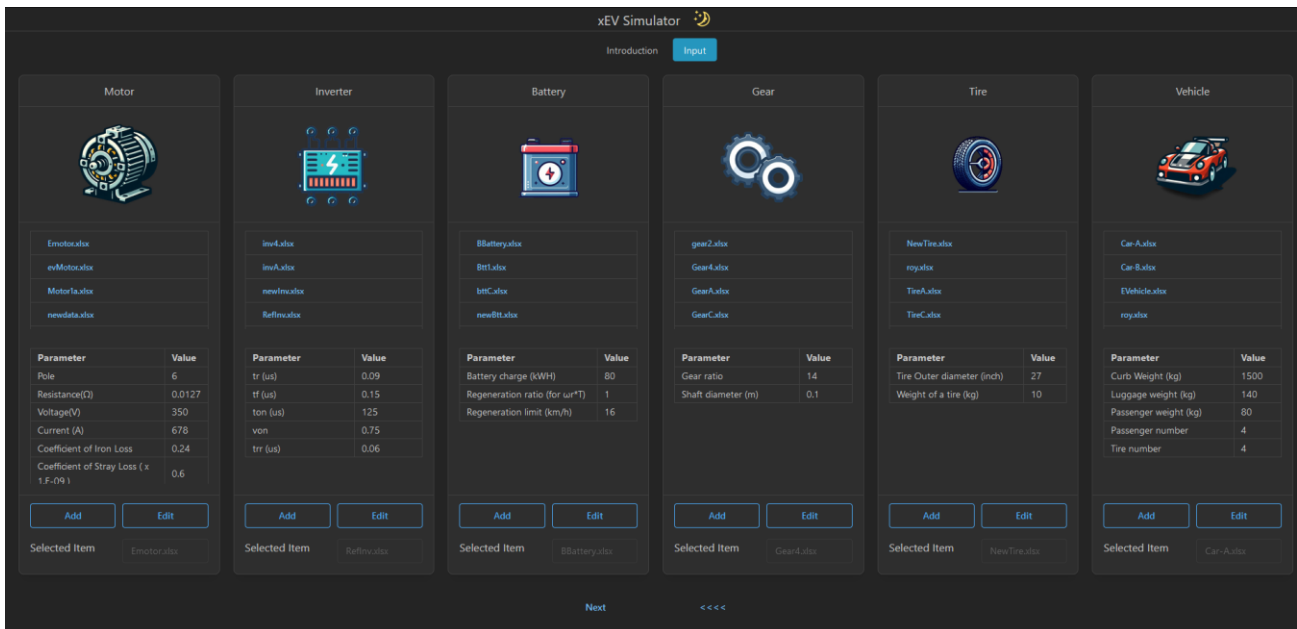
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3.3 Input Tab:

The Xev software has the main tab named the Input tab.

In this tab, parameters for Motor, Inverter, Battery, Gear, Tire and Electric Vehicle on the whole has to be selected. Upon clicking Next button, the following tabs will be available:

1. IPM Modeling
2. Drive Pattern
3. P-Loss Analysis by Torque
4. P-Loss Analysis by Current
5. Data



The screenshot shows the 'xEV Simulator' interface with the 'Input' tab selected. It displays six panels for different components, each with a list of files to select from and a table of parameters with their values.

Motor	Inverter	Battery	Gear	Tire	Vehicle																																																										
Files: Emotor.xlsx evMotor.xlsx Motor Ia.xlsx newdata.xlsx	Files: inv4.xlsx invA.xlsx newInv.xlsx RefInv.xlsx	Files: BBattery.xlsx Btt.xlsx bttC.xlsx newBtt.xlsx	Files: gear2.xlsx Gear4.xlsx GearA.xlsx GearC.xlsx	Files: NewTire.xlsx roy.xlsx TireA.xlsx TireC.xlsx	Files: Car-A.xlsx Car-B.xlsx Vehicle.xlsx roy.xlsx																																																										
<table border="1"> <thead> <tr> <th>Parameter</th> <th>Value</th> </tr> </thead> <tbody> <tr><td>Pole</td><td>6</td></tr> <tr><td>Resistance(Ω)</td><td>0.0127</td></tr> <tr><td>Voltage(V)</td><td>350</td></tr> <tr><td>Current (A)</td><td>678</td></tr> <tr><td>Coefficient of Iron Loss</td><td>0.24</td></tr> <tr><td>Coefficient of Stray Loss (× 1/F^{1/3})</td><td>0.6</td></tr> </tbody> </table>	Parameter	Value	Pole	6	Resistance(Ω)	0.0127	Voltage(V)	350	Current (A)	678	Coefficient of Iron Loss	0.24	Coefficient of Stray Loss (× 1/F ^{1/3})	0.6	<table border="1"> <thead> <tr> <th>Parameter</th> <th>Value</th> </tr> </thead> <tbody> <tr><td>tr (us)</td><td>0.09</td></tr> <tr><td>tf (us)</td><td>0.15</td></tr> <tr><td>ton (us)</td><td>125</td></tr> <tr><td>von</td><td>0.75</td></tr> <tr><td>trr (us)</td><td>0.06</td></tr> </tbody> </table>	Parameter	Value	tr (us)	0.09	tf (us)	0.15	ton (us)	125	von	0.75	trr (us)	0.06	<table border="1"> <thead> <tr> <th>Parameter</th> <th>Value</th> </tr> </thead> <tbody> <tr><td>Battery charge (kWh)</td><td>80</td></tr> <tr><td>Regeneration ratio (for ω⁺T)</td><td>1</td></tr> <tr><td>Regeneration limit (km/h)</td><td>16</td></tr> </tbody> </table>	Parameter	Value	Battery charge (kWh)	80	Regeneration ratio (for ω ⁺ T)	1	Regeneration limit (km/h)	16	<table border="1"> <thead> <tr> <th>Parameter</th> <th>Value</th> </tr> </thead> <tbody> <tr><td>Gear ratio</td><td>14</td></tr> <tr><td>Shaft diameter (m)</td><td>0.1</td></tr> </tbody> </table>	Parameter	Value	Gear ratio	14	Shaft diameter (m)	0.1	<table border="1"> <thead> <tr> <th>Parameter</th> <th>Value</th> </tr> </thead> <tbody> <tr><td>Tire Outer diameter (inch)</td><td>27</td></tr> <tr><td>Weight of a tire (kg)</td><td>10</td></tr> </tbody> </table>	Parameter	Value	Tire Outer diameter (inch)	27	Weight of a tire (kg)	10	<table border="1"> <thead> <tr> <th>Parameter</th> <th>Value</th> </tr> </thead> <tbody> <tr><td>Curb Weight (kg)</td><td>1500</td></tr> <tr><td>Luggage weight (kg)</td><td>140</td></tr> <tr><td>Passenger weight (kg)</td><td>80</td></tr> <tr><td>Passenger number</td><td>4</td></tr> <tr><td>Tire number</td><td>4</td></tr> </tbody> </table>	Parameter	Value	Curb Weight (kg)	1500	Luggage weight (kg)	140	Passenger weight (kg)	80	Passenger number	4	Tire number	4
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3.3.1 Digital Twin:

Digital Twin

Adjust
0
0
0

Select Digital Twin No.(1-6)

D-T
D-T
Speed Macro
Digital Twin range by A12 speed

	D.T	A* Ψ dmax	B* Ψ dmax	Ld	Lq	Ψ md	Ψ mq	a	STD(Nm)	STD(rpm)	Speed Macro	Min	Max
1	$\sin(V/(1+(a\omega)^2))$	0.137	0.211	222	323	0.085	0	1.28	0	0	806.2	0	0
2	$\tanh(a\omega)$	0.117	0.182	230	333	0.092	0	1.18	0	0	804.7	0	0
3	$A12-Vm/\omega \cdot \sin(\pi/\sqrt{1+(a\omega)^2})$	0	0	0	0	0	0	1	0	0	796.9	0	0
4	$\arctan(a\omega)$	0.106	0.161	276	403	0.1034	0	1.06	0	0	816	0	0
5	$1-\exp(-a\omega)$	0.151	0.225	250	366	0.0907	0	1.39	0	0	836.3	0	0
6	$A12-Vm/\omega \cdot \sin(\pi/\sqrt{1+(a\omega)^2})$	0.141	0.229	213	311.2	0.07296	0	1.41	0	0	807.3	0	0

1:LINEAR
2:POLYNOMIAL
1
1

1	$\sin(V/(1+(a\omega)^2))$	0	87	18
2	$\tanh(a\omega)$	0	88	13
3	$\arctan(a\omega)$	0	120	0
4	$\arctan(a\omega)$	0	100	20
5	$1-\exp(-a\omega)$	0	90	11
6	A12	0	76	0

Constant Ψ Ld,Lq
0

Type θ ld=0.1:AVR,2:MAX
2

Trc1=DQ,2=xEV
1

Pe
1

Profms
ON

Mode: 0=Off, 1=On, 2=Idq
0

Low
6800

High
15000

Vrn
350

3D
10

1

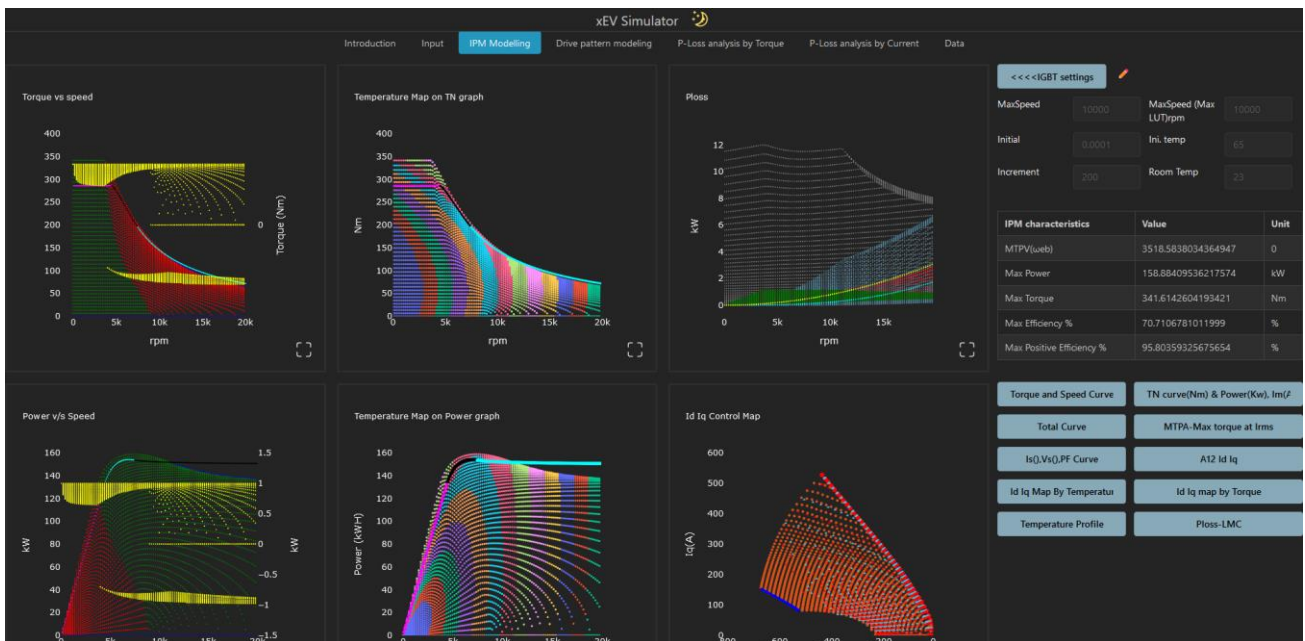
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3.4 IPM Tab:

IPM Modeling tab simulates the Interior Permanent Magnet Synchronous motor (IPMSM) by incorporating the control strategies specific to IPMSM. Major graphs of this tab include the torque vs speed, power vs speed and id-iq current maps. Within these graphs we can observe the different regions of the control namely MTPA(Maximum Torque per Ampere), MTPV(Maximum torque per voltage) and CPSR(Constant Power Speed Range). From these graphs we can obtain the maximum torque and power obtainable. Additionally, we can observe the temperature profile for different operating points of the torque vs speed and power vs speed graphs. This tab calculates the losses occurring within the motor and inverter for different speeds of operation. These motor losses include the copper loss, stray loss, iron loss friction loss windage loss. These losses are calculated based on the current map. By knowing these losses, efficiency of the system can be found.



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3.4.1 IGBT:

IGBT

IGBT/FRD Modeling				[H] 800A (150°C)
Inverter	DC Link	350	V	350
	Irms(A)	480	P-P(A)	679
	SW Frequency		Hz	6500
	Modulation			0.8
Power Factor(PF)				0.9
IGBT/FWD	Therma R	Rth(IGBT)	k/W	0.136
		Rth(Diode)	k/W	0.208
		Rth(IGBT-Diode)	k/W	0.041
IGBT	Vce(sat)	A1(rc)	V/A	0.0012
		A0(Vce0)	V	0.8965
		C3		3e-8
	Eon=C3*I^3+C2*I^2+C1*I+C0		C2	-0.00002
			C1	0.058
			C0	1.365
	Eon=C3*I^3+C2*I^2+C1*I+C0	On-loss at Ip	mJ	32.5680
	D3		7.4e-8	
	Eoff=D3*I^3+D2*I^2+D1*I+D0		D2	-0.00008
			D1	0.09
			D0	4.021
	Eoff=D3*I^3+D2*I^2+D1*I+D0	Off-loss at Ip	mJ	43.3607
	Vf=B1*I+B0	B1(rf)	V/A	0.0015
		B0(Vfo)	V	0.84

<<< IGBT settings

MaxSpeed

MaxSpeed (Max IUTrpm)

Initial

Im temp

Increment

Room Temp

IPM characteristics

Value

Unit

MTPV(veh)

3518.583034364947

0

Max Power

158.88409536217574

kW

Max Torque

341.6142604193421

Nm

Max Efficiency %

70.7106781011999

%

Max Positive Efficiency %

95.80359325675654

%

Torque and Speed Curve

TN curve(Nm) & Power(Kw), Imf

Total Curve

MTPA-Max torque at Irm

Is(Vs),PF Curve

A12 Id Iq

Id Iq Map By Temperature

Id Iq map by Torque

Temperature Profile

Phos-LMC

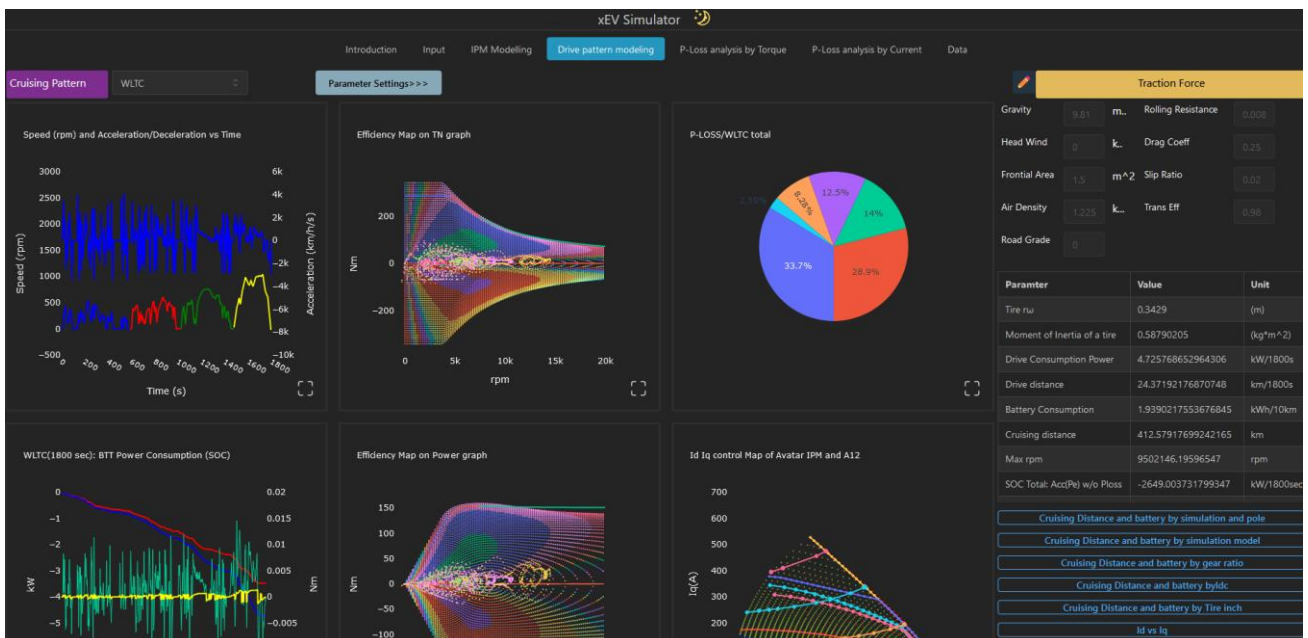
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3.5 Drive Pattern Modelling Tab:

The drive pattern tab simulates the vehicle dynamics by using the standard drive cycles namely WLTC (World Wide Harmonic Light Vehicle Test Cycle), CLTC(China Light-duty vehicle Test Cycle), NEDC(New European Driving Cycle) and FTP75(Federal Test Procedure). The power consumption at each point of the drive pattern is found. These points are added up to find the total energy consumption for the particular drive cycle selected. From this data, we obtain the battery power consumption per 10 km. By knowing the battery capacity that is provided as input, we can determine the cruising distance. The losses occurring in the motor and inverter are calculated in this tab, similar to that done in IPM tab, but this time accounting for the vehicle dynamics. Based on these losses, the efficiency is determined. The losses are depicted using a pie chart for better understanding. The drive pattern tab also comprises of the torque vs speed and power vs speed plots. The efficiency for different points on these graphs can be visualized. Other important graphs of this tab include the variation of cruising distance and battery consumption as a function of pole pairs, gear ratio, battery current and tire inch. The id-iq current maps are also included.



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3.5.1 Parameter Settings:

Driving Pattern

Zones

Low

1.2

Medium

1

High

1

Ex-High

1

Vehicle Dynamics

IPM characteristics

Temperature

A

0.004

B

0.0005

C

0.0566

MaxTemp

144.19874184

Ploss

Pcu

1

Pfe

2

Pstr

1

Pf

1

Pw

1

Pinv

2

Temp

1

Filter-1

Tn-50

50

15000

Tn-100

100

10000

Tn-200

200

5000

Tn-300

300

5000

Filter-2

S1-K

1000

S5-K

5000

S10-K

10000

S15-K

15000

Traction Force

Gravity

9.81

m/s

Head Wind

0

k

Frontal Area

1.3

m^2

Air Density

1.225

k

Road Grade

0

Rolling Resistance

0.008

Drag Coeff

0.25

Slip Ratio

0.15

Trans Eff

0.98

Parameter

Value

Unit

Tire nu

0.3429

(m)

Moment of Inertia of a tire

0.58790205

(kg*m^2)

Drive Consumption Power

4.725768652964306

kW/1800r

Drive distance

24.37192176870748

km/1800r

Battery Consumption

1.9390217553676845

kWh/10km

Cruising distance

412.57917699242165

km

Max rpm

9502146.19996547

rpm

SOC Total: Acc(Pe) w/o Ploss

-2649.003731799347

kWh/1800r

Cruising Distance and battery by simulation and pole

Cruising Distance and battery by simulation model

Cruising Distance and battery by gear ratio

Cruising Distance and battery bydc

Cruising Distance and battery by Tire Inch

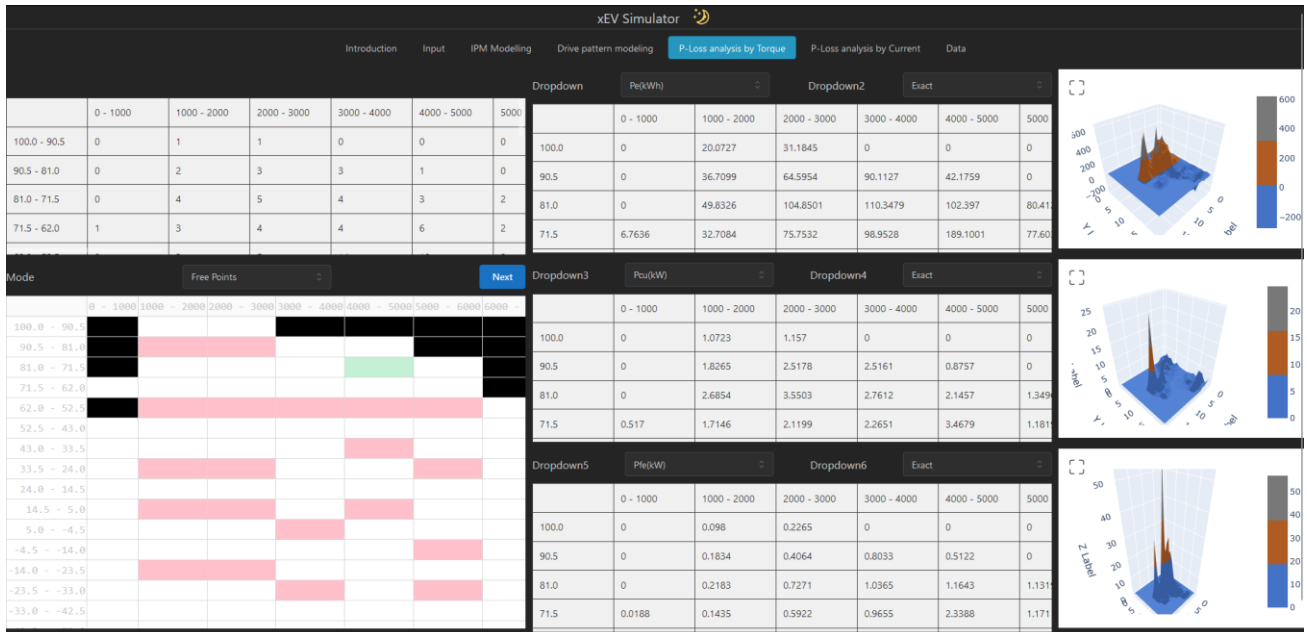
Id vs Ig

3.6 Ploss Analysis by Torque:

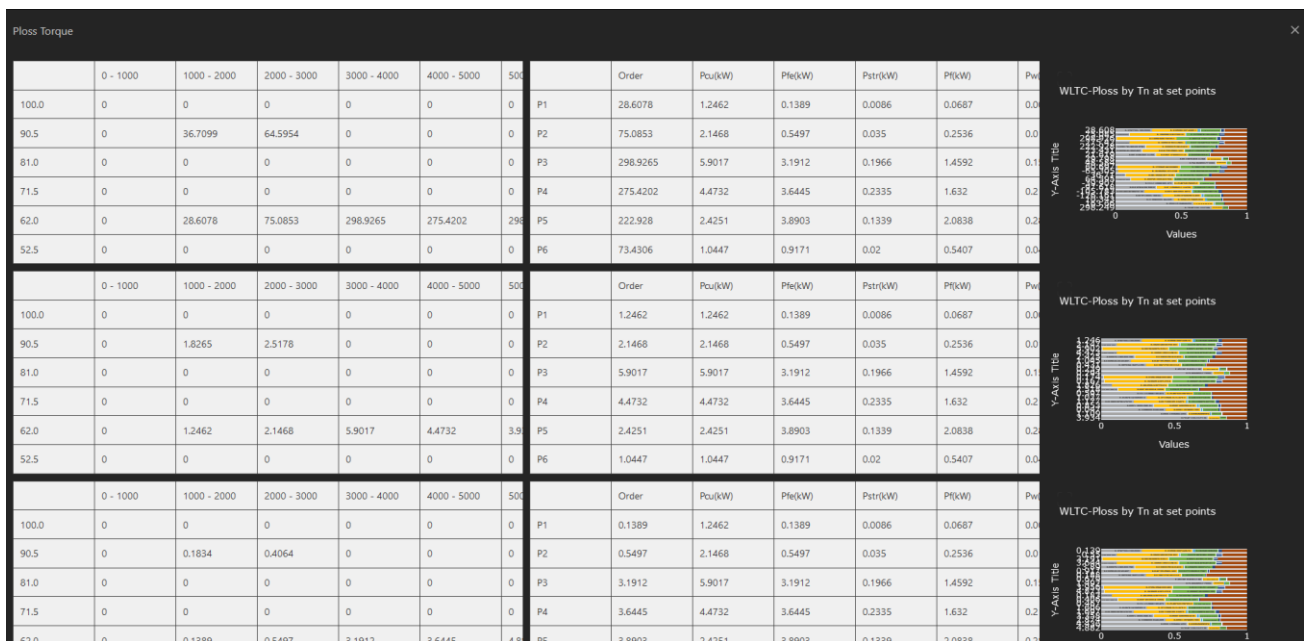
This tab has the frequency map table. The column header specifies the torque range and the row header specifies the speed range. The torque array calculated on the basis of the drive pattern, is divided into sets of ranges. This table specifies the number of points present in the torque and speed range. If no point lies in a particular torque and speed range, the corresponding cell holds the value, 0.

Below this table, there is a table named "Free points". In this table, 10 positive and 10 negative points have to be selected by checking 20 cells of the table. After selection of these cells, we need to click on the next button available below this table. This will enable 3 tables to appear on the right side of the tab. The column headers and row headers for these tables remain the same as for the frequency map table. The column headers being Torque range and row headers being speed range. These tables are provided with drop down where we can select different parameters which include motor power (P_e), motor power with regeneration (P_e with regeneration) having the units of kW/s and kWh each, temperature (Temp), efficiency ($\eta = P_e / P_{batt}$) and the loss values which include copper loss, iron loss, stray loss, friction loss, windage loss, inverter loss and the total loss (P_{cu} , P_{fe} , P_{str} , P_f , P_w , P_{inv} , sum Ploss) The table will hold the values corresponding to the parameter that is selected using the drop down. If P_{cu} is selected, each cell will hold the sum of copper loss for the points present in the torque and speed range corresponding to this cell. There is another dropdown provided for each of the 3 tables. This dropdown contains the average and exact fields. Suppose that a particular cell has no numerical value, then by selecting average this cell will hold the value of 0. If exact field is selected the cell will hold the value named "nan" which signifies that this cell would be omitted for plotting. It should be noted that all the 6 dropdowns must be selected in order to click the next button again. By clicking the next button we can visualize the bar chart of these tables.

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3.6.1 Ploss Analysis by Torque Next:



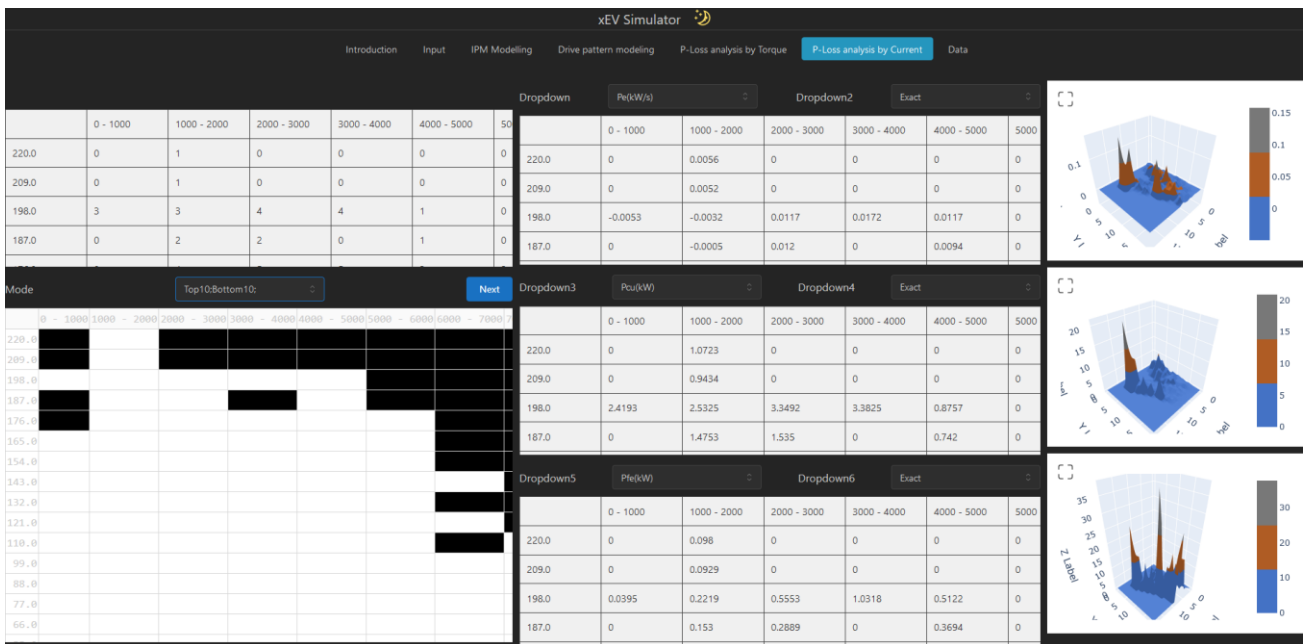
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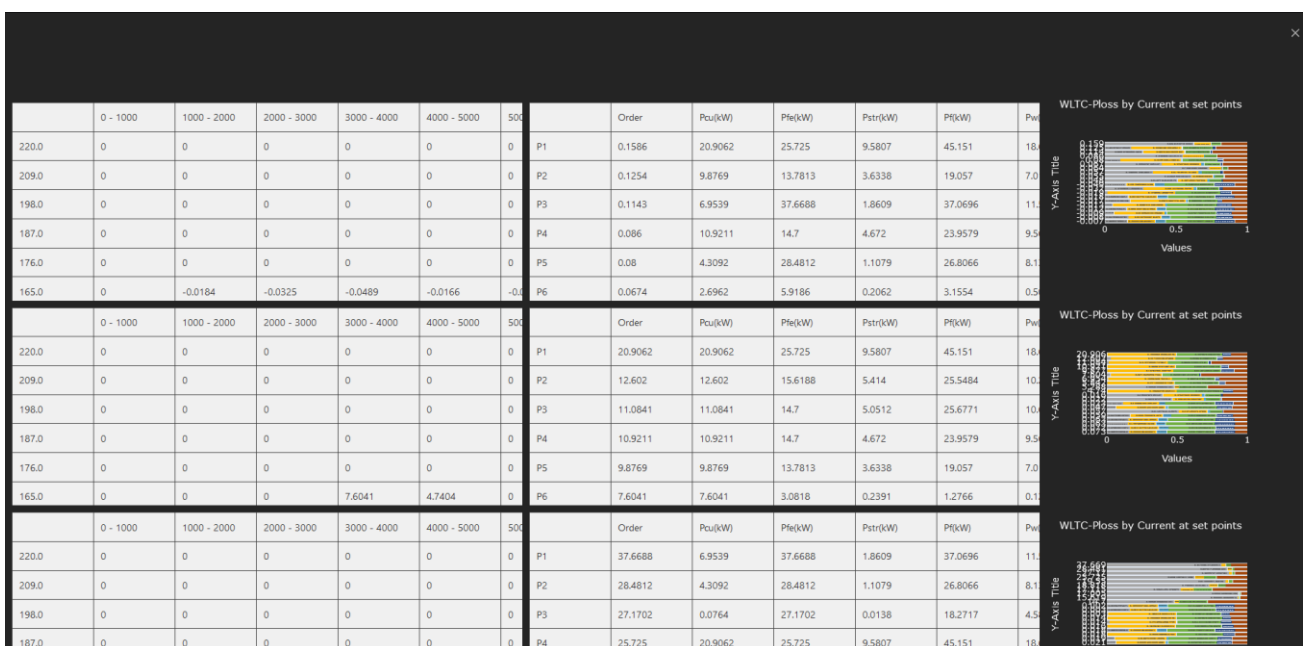
URL. <https://www.nidec.com/jp/nidec-advancetechnology/>

3.7 Ploss Analysis by Current:

This tab is similar to the Ploss Analysis by current tab with only difference being the column header for the table is current. This current refers to the peak stator phase current of the motor.



3.7.1 Ploss Analysis by Current Next:



3.8 Data Tab

This tab consists of several graphs which could be used for comparative analysis.

The first graph of this tab is the battery consumption vs battery capacity graph. This graph is used to compare the value of battery capacity and the battery consumption that our simulated model offers, along with that offered by other models. The other two graphs, present on the first row of the tab are similar to the first graph but are specific to the CLTC and WLTC drive cycles. They are battery consumption for cltc cycle vs battery capacity and battery consumption for wltc cycle vs battery capacity graphs. The battery consumption per 10 km is considered in all the 3 graphs. Next is the graph of loss vs speed in rpm. This graph has two curves which indicate the power loss of our motor model and that of Nissan Leaf.

Other two graphs are corresponding to the WLTC drive cycle. They are the first two graphs present in the second row of the data tab.

The first graph plots the power loss values due to 4 factors namely Aerodynamic drag (M1), Rolling resistance (M2), Drivetrain losses (M3) and Accessory power loss (M4). The power loss due to these 4 factors are found for the 4 phases of the WLTC drive cycle namely low, medium, high and extra-high. Hence from this graph, we can obtain the total loss corresponding to the WLTC drive cycle.

The second graph shows the electrical power (P_e), electrical torque (T_n), Reactance torque (in percentage), efficiency (in percentage) corresponding to M1, M2, M3 and M4.

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4. Detailed Functionality

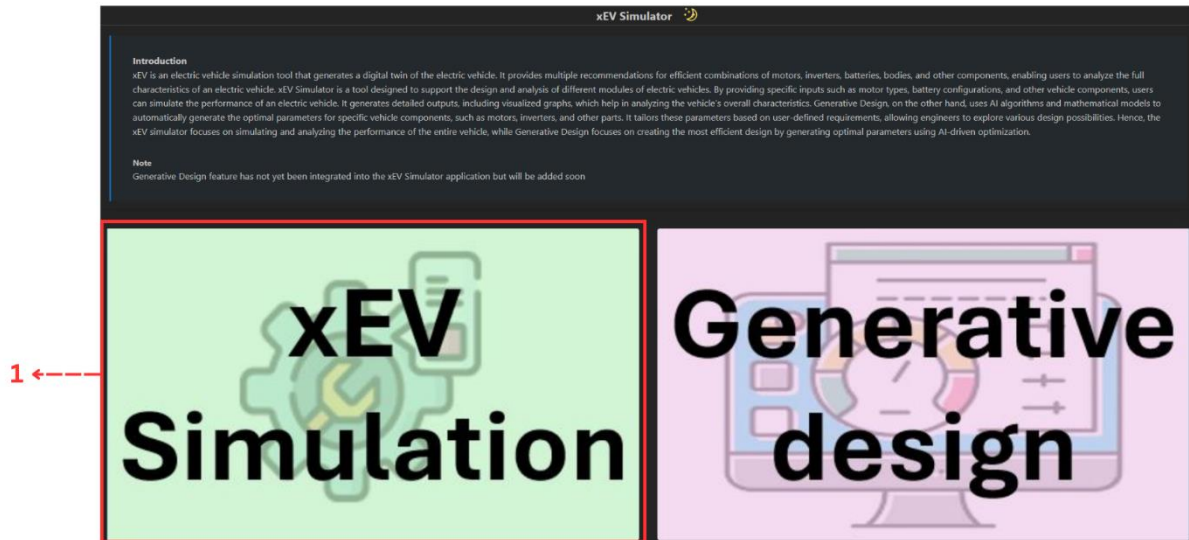


Figure 1 : Home Page

In Figure 1:

1 - xEV Simulator Button

Click button 1 to proceed with xEV simulator Application

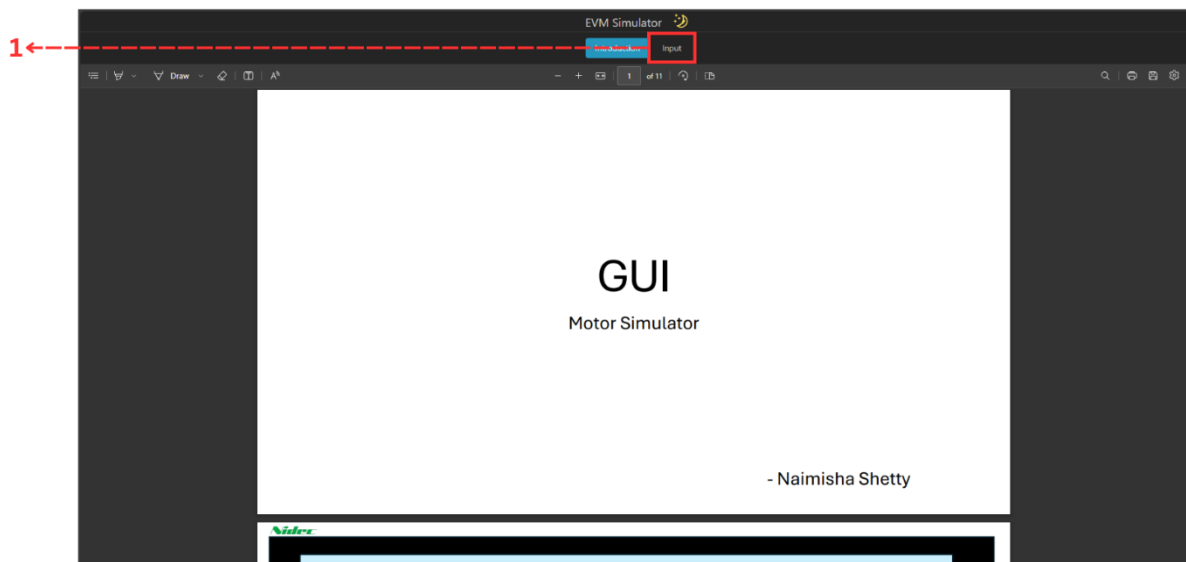


Figure 2 : Introduction Tab

In Figure 2:

1 - Input Tab Navigation

Click on 1 to navigate to input tab

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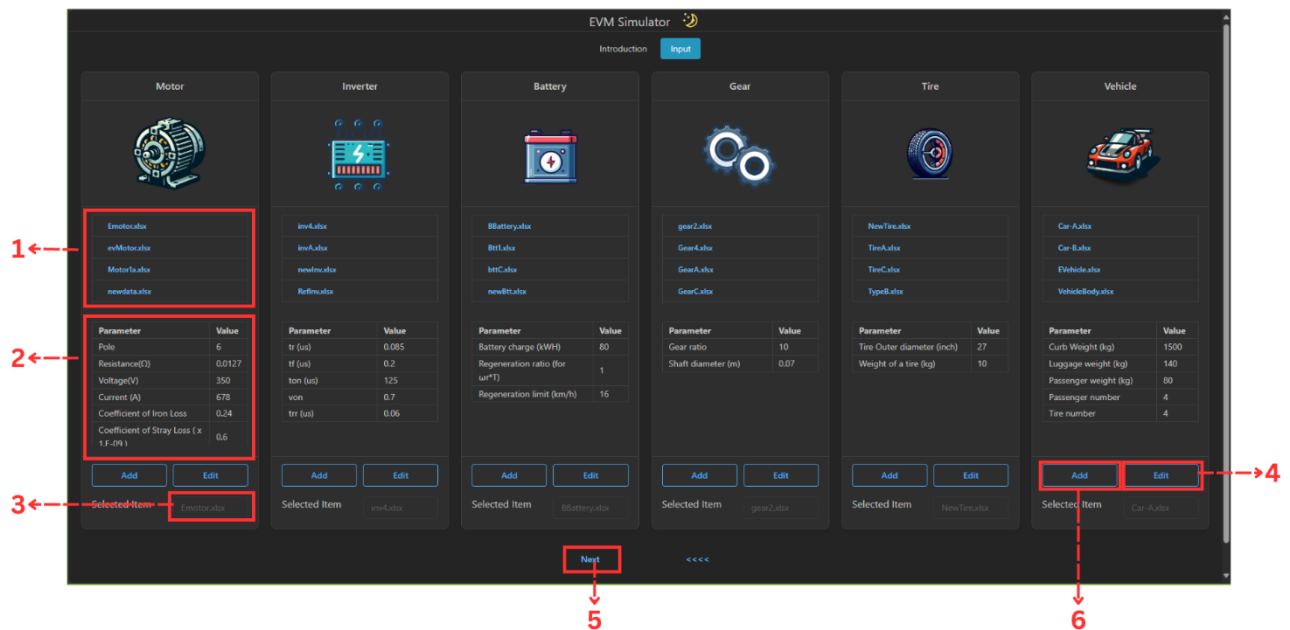


Figure 3 : Input Tab

In Figure 3 :

- 1- File list
- 2- Selected File content
- 3- Selected file name
- 4- Edit button
- 5- Next Button
- 6- Add button

Click on button 1 to select input file for all parameters. On 2 you can view the selected file contents. On 3 you can view the selected file name. Click on 4 to edit the file contents. Click on 6 to add a new file. After selecting files for each parameter click on 5 to display all the tabs for selected parameters.

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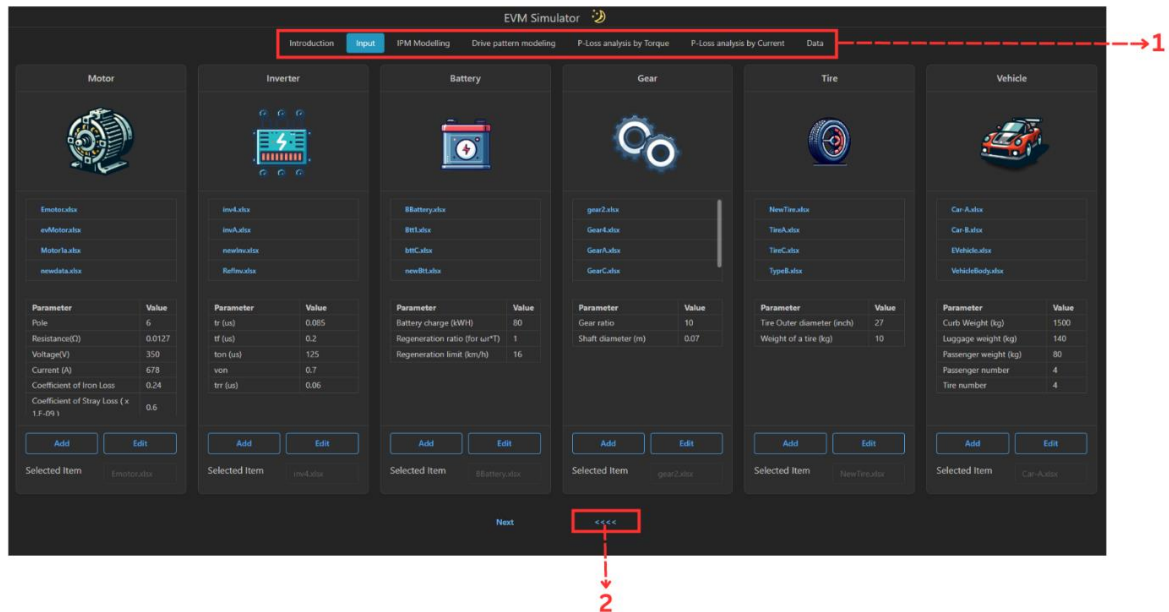


Figure 4 : Input Tab

In Figure 4

- 1 - Tab navigation
- 2 - Digital Twin button

Select the required tab by using 1. Click on button 3 to view Digital Twin tab.

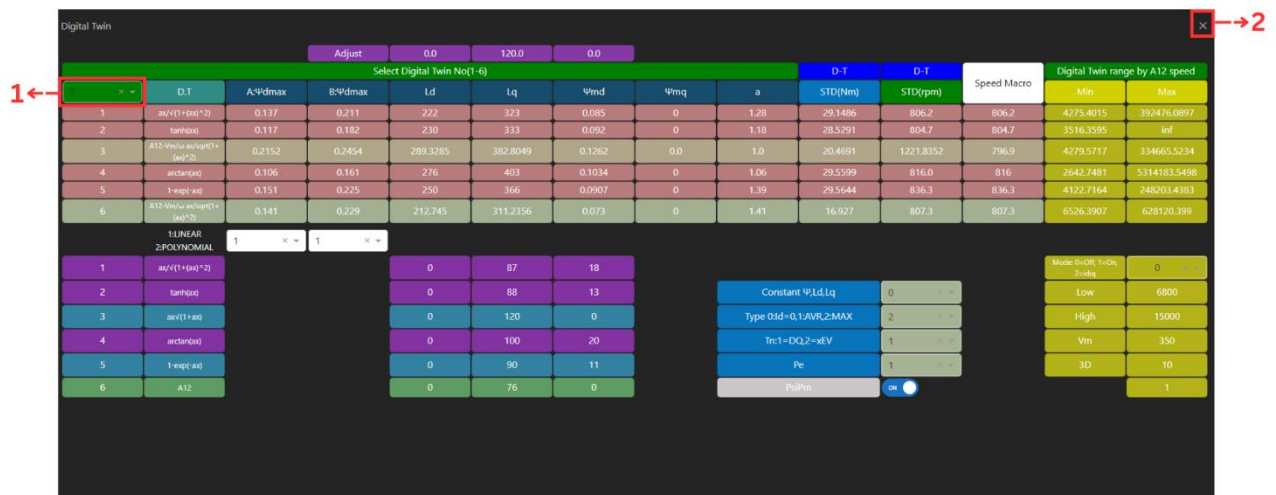


Figure 5 : Digital Twin

In Figure 5

- 1 - DTnum Dropdown
- 2 - Close button

Select the required value in drop down 1 which will result in the change of values in standard deviation for speed and torque based on 6 methods.

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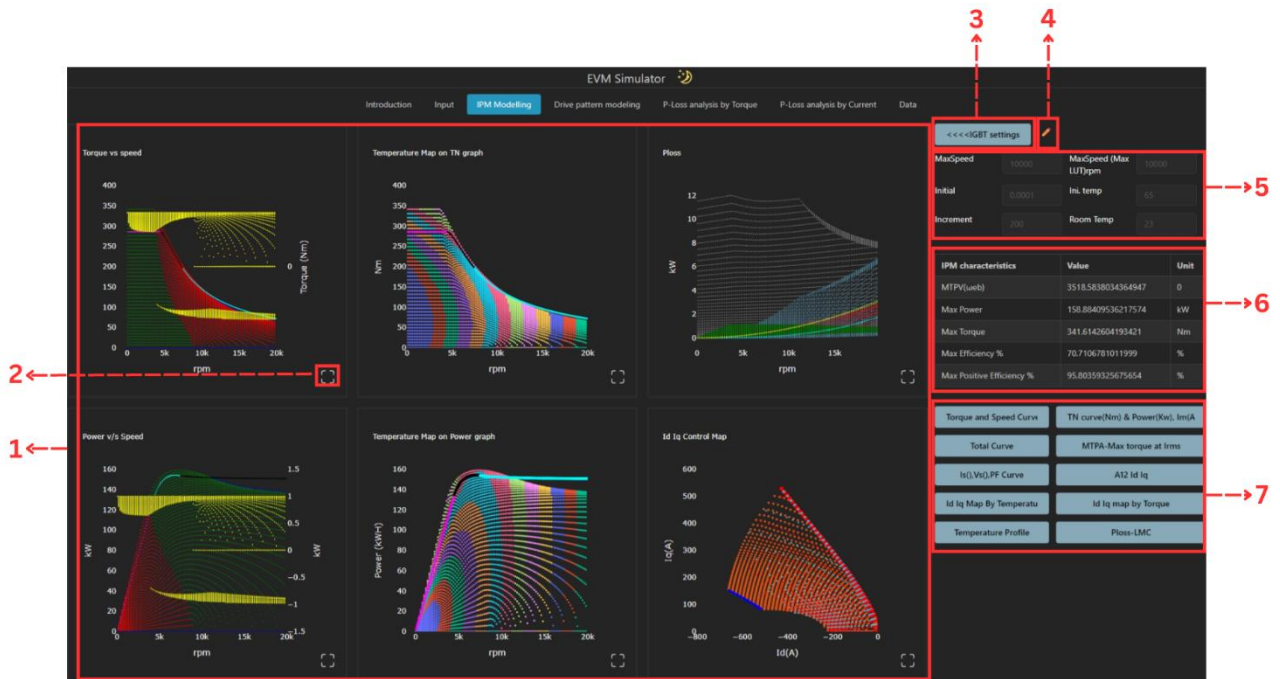


Figure 6 : IPM Modelling Tab

In Figure 6 :

- 1 – IPM Modelling graphs
- 2 - enlarge button
- 3 - IGBT settings button
- 4 - Edit/Confirm button
- 5 - Input Parameters
- 6 - Output Parameters
- 7 - Secondary graphs

On frame 1 you can view all the primary IPM graphs. On clicking 2 you can enlarge individual graphs. On clicking 3 you can view IGBT settings. Click 4 to edit input parameters on table 5. On 6 you can view the resulting output parameters. Select individual buttons on 7 to display secondary graphs one by one.

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IGBT					✕ → 1
IGBT/FWD	Therma R	V _{th} (V _{th})	V/W	0.136	
		R _{th} (Diode)	k/W	0.208	
		R _{th} (IGBT-Diode)	k/W	0.041	
IGBT	V _{ce} (sat)	A ₁ (r _c)	V/A	0.0012	
		A ₀ (V _{ce0})	V	0.8965	
	E _{on} =C3*I ³ +C2*I ² +C1*I+C0		C3	3e-8	
			C2	-0.000021	
			C1	0.058	
			C0	1.365	
	E _{on} =C3*I ³ +C2*I ² +C1*I+C0	On-loss at I _p	mJ	32.56805	
	E _{off} =D3*I ³ +D2*I ² +D1*I+D0		D3	7.4e-8	
			D2	-0.00008	
			D1	0.09	
			D0	4.021	
	E _{off} =D3*I ³ +D2*I ² +D1*I+D0	Off-loss at I _p	mJ	43.36073	
FWD	V _f =B1*I+B0	B ₁ (r _f)	V/A	0.0015	
		B ₀ (V _{f0})	V	0.84	
	Err=E3*I ³ +E2*I ² +E1*I+E0		E3	-2.9e-8	
			E2	0.000025	
			E1	0.034	
			E0	7.016	
	Err=E3*I ³ +E2*I ² +E1*I+E0	On-Loss at I _p	mJ	28.47663	
	Parasitic R	Bus-Bar Wiring-R	ohm	0.41	

Figure 7 : IGBT Parameters

In Figure 7:

1 - Close button

select 1 to close IGBT settings frame.



Figure 8 : Drive Pattern Modelling Tab

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In Figure 8:

- 1 - Drive Pattern graphs
- 2 - enlarge button
- 3 - Cruising Distance graph button
- 4 - Cruising Pattern dropdown
- 5 - Parameter Setting button
- 6 - Edit/Confirm button
- 7 - Input Parametrs
- 8 - Output Parameters

On frame 1 you can view all the primary Drive Pattern graphs. On clicking 2 you can enlarge individual graphs. Select required buttons on 3 to display the resulting graphs. Select dropdown 4 to change drive pattern graphs based on the selected dropdown. Click on 5 to view parameter settings. Click on 6 to edit input paramters on 7. Resulting output paramters will be displayed on 8

Driving Pattern

Zones

Low 1,2

Medium 1

High 1

Ex-High 1

Vehicle Dynamics ☒

IPM characteristics

Temperature

A 0.004

B 0.0005

C 0.0566

MaxTemp 144.19874184

Ploss

Pcu 1

Pfe 2

Pstr 1

Pf 1

Pw 1

Pinv 2

Temp

Temp 1

Filter-1

Tn-50 50 15000

Tn-100 100 10000

Tn-200 200 5000

Tn-300 300 5000

Filter-2

S1-K 1000

SS-K 5000

S10-K 10000

S15-K 15000

Close button (X) → 1

Figure 9 : Parameter Setting

In Figure 9:

- 1 - Close button
- select 1 to close Parameter Setting frame.

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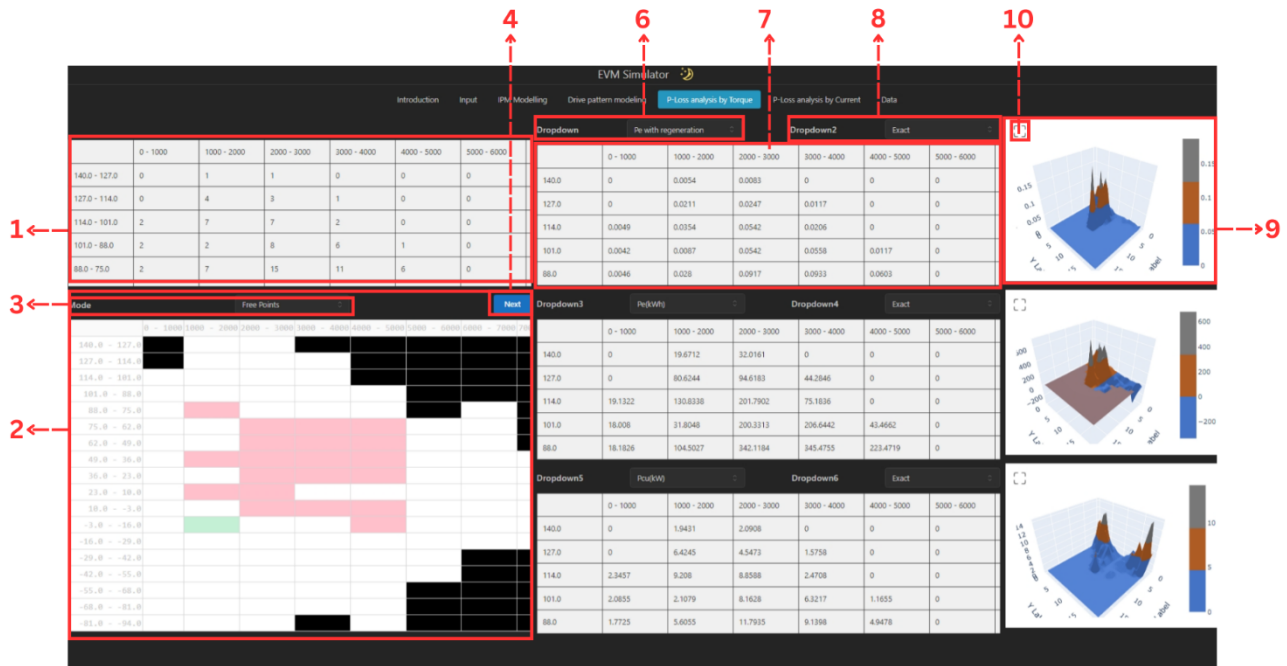


Figure 10 : Ploss Analysis by Torque Tab

In Figure 10:

- 1 - Tn Frequency table
- 2 - Tn Free points table
- 3 - Mode dropdown
- 4 - Next button
- 6 - Loss Dropdown
- 7 - Loss table
- 8 - Exact/Average drop down
- 9 - Loss graphs

Tn frequency table is displayed on 1. Select 20 points on table 2 when dropdown 3 is set at free points or set dropdown 3 to Top10: Bottom10. Click on dropdown 6 to view all loss options, after selecting three different loss options. Click on button 4 to view the resultant output tab. Select dropdown 8 to alter the loss tables between exact and average setting. View the resulting graphs in frame 9.

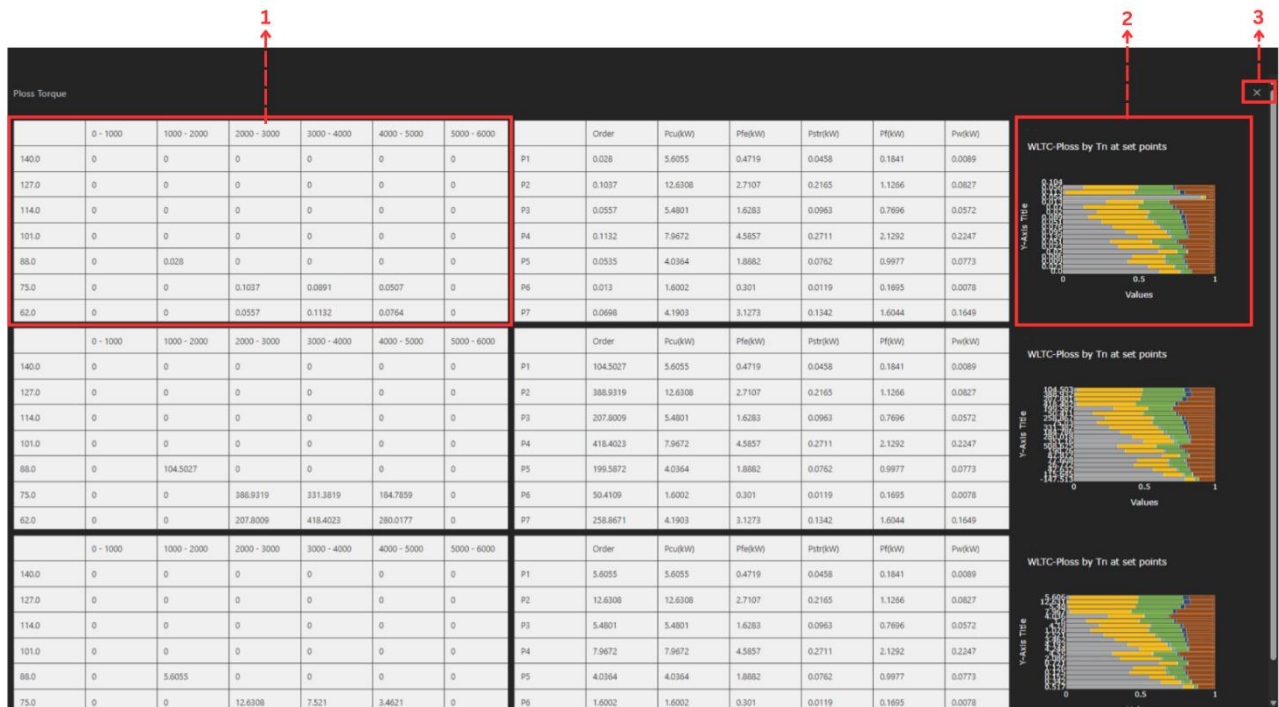


Figure 11 Torque Output

In figure 11:

- 1 - Output table
- 2 - Output graphs
- 3 - close button

View the resultant output values on 1. View the resulting output graphs on 2. Click on 3 to close the frame.

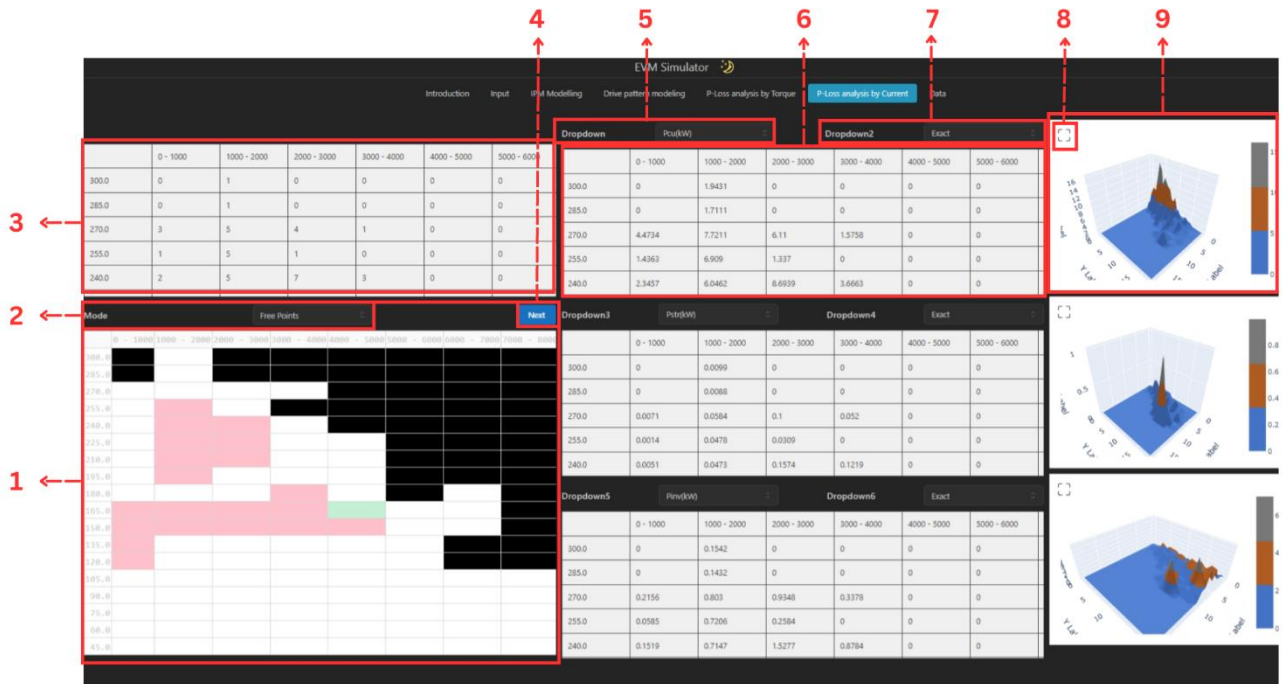


Figure 12 Ploss Analysis by Current Tab

In Figure 12:

- 1 - Im Frequency table
- 2 - Im Free points table
- 3 - Mode dropdown
- 4 - Next button
- 6 - Loss Dropdown
- 7 - Loss table
- 8 - Exact/Average drop down
- 9 - Loss graphs

Im frequency table is displayed on 1. Select 20 points on table 2 when dropdown 3 is set at free points or set dropdown 3 to Top10: Bottom10. Click on dropdown 6 to view all loss options, after selecting three different loss options. Click on button 4 to view the resultant output tab. Click on button 5 to clear all free points selected. Select dropdown 8 to alter the loss tables between exact and average setting. View the resulting graphs in frame 9.

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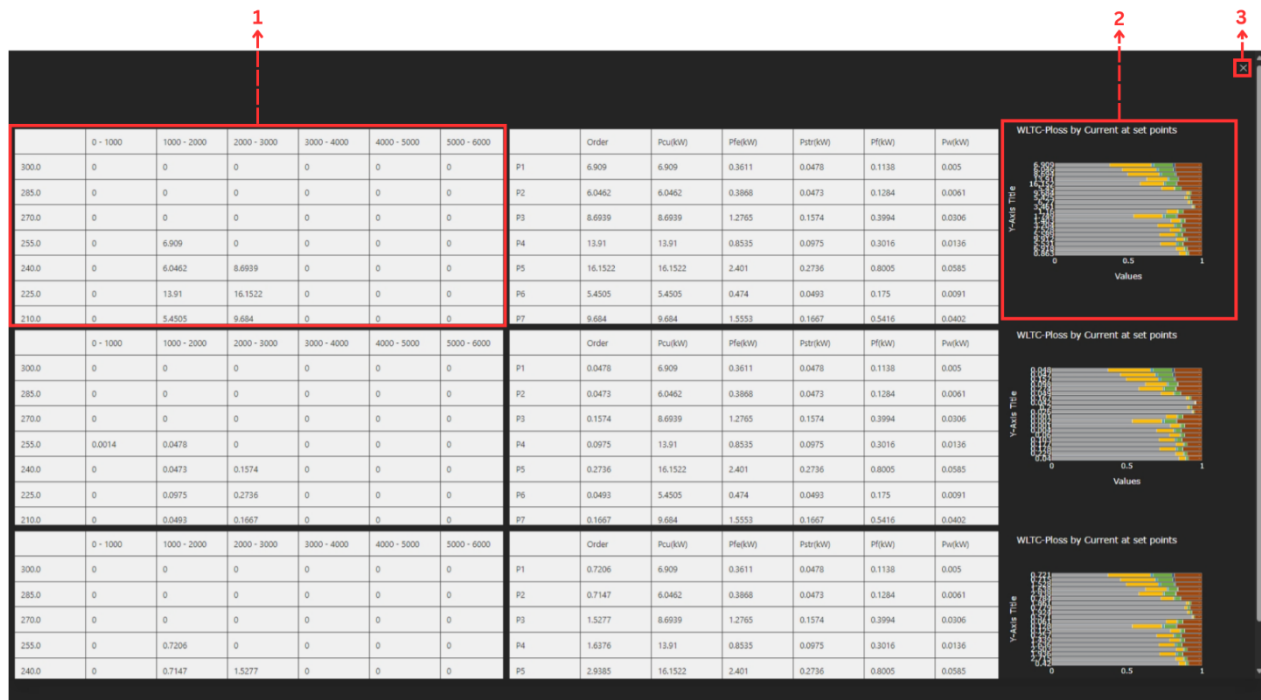


Figure 13: Current Output

In Figure 13

- 1 - Output table
- 2 - Output graphs
- 3 - close button

View the resultant output values on 1. View the resulting output graphs on 2. Click on 3 to close the frame.



Figure 14 : Data Tab

In Figure 14

1 - Data graphs

View Data graphs in frame 1



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