



#### **DC MOTOR ANALYSIS**

#### FLUX 2D APPLICATION NOTES

March 2021, Altair Valorization and Support Team

# **GENERAL PRESENTATION OUTLINE**





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- Flux 2D project: initiation
  - Create a new Flux 2D project

ер	Action	Altair Flux <sup>™</sup> 2D Skew 3D PEEC C ALTAIR
1	Open Flux supervisor	New project Use to sorting data (2), Sex, Sor (HC)
2	Select the [2D] simulation context	Open project Open example Upen
3	Click on [New project]	Python scripts (#NAND) 
4	Select the working path : "~/DC_Motor"	Image: State of the state o
5	Click on [Start a new project]	b         MOD_PHOTOR           0         MOD_PHOTOR           0         MOD_PHOTOR           0         MOD_PHOTOR           0         MOD_PHOTOR           0         Presend           0         Presend           0         Security_Liver           0         Security_Liver           0         Security_Liver           0         Security_Liver           0         Security_Liver
		Skit & Her project Command - Skit & S
		Physical memory 20.54 GB(63.75 GB Allocable memory 20.54 GB(64.75 GB Diduspect 1.271 10); 12 TD



- Flux 2D project: initiation
  - Close the Sketcher 2D Context



- Flux 2D project: create geometry
  - Load Overlay

			<u></u> v⊡ ∞ 3R mi	Na Y AP	• 🔽 🛛 🕰		
Step	Action	Open project Ctrl-0     Gose			Graphic		
1	Click on [Project] – [Overlays] – [Load a certified overlay]	Save Ctrl-S Save as Command file Marro		Choose the over	lav to load		×
2	Select the Overlay "Permanent_MagnetDC _MotorV2.PFO" in the folder "Flux2D"	Overlay       Import       Export       Print       Exit	Load a certified overlay Load a user overlay Unload Run	Look In: Flux2	manent_Magnet_Motors_V11.1.PFO manent_Magnet_Outer_Rotor_Motor	rs_V11.1.PFO	
3	Click on [Open]			Induction_Mo	tors_V11.1.PFO		$\overline{}$
				Permanent M Switched_Rel File Name: Perm Files of Type: User	agnet_DC_Motors_V2.PF0 2 uctance_Motors.PF0 anent_Magnet_DC_Motors_V2.PF0 overlays		Copen Cancel

View

Display

Select Tools Extensions

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Help

Application

Geometry

Mesh

Physics 



- Flux 2D project: create geometry
  - Run Overlay



7

- Flux 2D project: create geometry
  - Run Overlay





• Flux 2D project: create geometry

#### Run Overlay

Step	Action
1	Set values for the motor parameters

	MotorE
*B* New Motor DCM Name * MotorDCM_1 General Rotor Stator \ Airgap \ Winding \ rotor Slots \ General \	Gene rotor- Slo Roto 52 Shaf 14
Rounded Tooth width (Tw) * 3.5 Slot depth (SD) * 15.575	Slot 12 Roto 0.0
Slot opening (SO) * 4 Depth of slot opening (TGD) * 1.425 Slot opening angle (TGAng) * 15	

OK

Cancel

Picture



 $\times$ 

# **GEOMETRY AND MESH**

Flux 2D project: create geometry

#### $\sim$ .

• Ri	in Overlay		rew Motor DCM	Name *	P. GL
			Name *	MotorDCM_1	DCM motor
Step	Action	Sew Motor DCM	MotorDCM_1	General \ Rotor \ Stator \ Airgap Winding \ Winding	Winding - coils position
1	Set values for the motor parameters	Name * MotorDCM_1 General \ Rotor Stator \ Nirgap \ Winding \ stator PIISide time fmagnet (Betall) 1	General ( Kotor \ Stator Argap \ Winding \ excentricityNo periodicity* no Rotating airgap number (bdr) *	Winding Coils position in slot * adjacent Threw * 3	superimposed
2	Click on [OK]	143.48	two_layers_airgap		
		Frame width (WFrame) * 3.05 Magnet length (Lm) * 4.4 Pole number (Npole) * 4	OK Cancel Picture	OK Cancel Picture	
1		OK Cancel Picture			

International In

- Flux 2D project: create geometry
  - Run Overlay





- Flux 2D project: create mesh
  - Mesh domain



Number of elements not evaluated		U	-
Number of excellent quality elemen	ts :	97	-
Number of good quality elements	:	3	-
Number of average quality elements	:	0	•
Number of poor quality elements	:	0	-
meshDomain executed			



- Flux 2D project: create mesh
  - Mesh domain





- Flux 2D project: complete geometry and mesh
  - Unload Overlay





- Flux 2D project: complete geometry and mesh
  - Save project





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- Why brush angle determination?
- One difficulty with collector is the way to set the brush angles
  - We propose to run a specific computation at constant speed (close to the working speed)
  - With no stator, and no magnet ( they are defined as air or vacuum region )
  - With a specific variable for initial brush angle
  - The goal is to display the animation of flux density line and to check where they are compared to the stator flux density
  - According to theory, the rotor flux density should be in quadrature with stator flux density in order to get the maximum torque available



- Flux 2D project: initiation
  - Save project





- Flux 2D project: define physics
  - Define physics application

Step	Action
1	Click on [Application] – [Define] – [Magnetic] – [Transient Magnetic 2D]
2	Define the physics parameter setting
3	Click on [OK]





$\frac{1}{20}$ Define Transient Magnetic 2D application X					
Definition <sup>7</sup> Colls Coefficient Symmetry & Periodicity ⇒ Coefficient for colls flux computation     Automatic coefficient (Symmetry & Periodicity taken into account)					
OK Cancel					

Definition \ Coils	Coefficien Transient initialization	/
Type of initialization	on ————	
Initialized by stati	c computation	-
	h -	
😥 ОК	Cancel	



- Flux 2D project: define physics
  - Create materials

Stop	Action	Project Application Geometry Mesh	Physics Parameter/Quantity Solving Display Vie	w Select Tools Extensions Help	
Step 1	Action Click on [Physics] – [Material] – [New]	Data Tree General data B General data B Mesh	Privide Parameter /Quantity Solving Display vie     Markenial     Markenial		1
		B - Call Physics B - Call Parameter/Quantity C - Call Post processing B - Call Post processing B - Call Extensions	Point region Line region Face region Face region Circuit Assign regions to geometric entities Assign coll conductor components to regions Assign solid conductors components to regions Assign solid conductors components to regions Display arrows on magnet Display arrows on magnet Detec Arrows Load and run physics macro Check physics Alt-P Check circuit		v



- Flux 2D project: define physics
  - Create material: MAGNET

Step	Action
1	Create the material "MAGNET"

428 New Material	×
Name of the mathematical strength of the mathmathematical strength of the mathematical strength of the mathem	<b>Magnetic property</b> permanent magnet unidirectional magnetization linear approximation
Magnetic property Linear magnet described by the Br module  Remanent flux density (D *	μ <sub>r</sub> relative permeability of material
0.7 f0 Relative permeability *	$\mu_0 = 4\pi 10^{\circ} \text{H/m}$ permeability of vacuum B [TT]
1.22 N	B <sub>r</sub> ↓↓6↓↓ H [A/m] 0



- Flux 2D project: define physics
  - Create material: MU\_LIN

Step	Action
1	Create the material "MU_LIN"

🖏 New Material	×
Name of the mathematical strength         MU_LIN           Comment         Image: Strength           [B(H)]\/_W(F)\/_D(F)\/_K(T)\/_RCP(T)\/_Mass_density\/_Iron losses.\	Magnetic property isotropic soft magnetic material linear approximation
Magnetic property           Linear isotropic <td><math>\mu_r</math> relative permeability of material <math>\mu_0 = 4\pi 10^{-7} H/m</math> permeability of vacuum</td>	$\mu_r$ relative permeability of material $\mu_0 = 4\pi 10^{-7} H/m$ permeability of vacuum
	в [T]
	μομ
	0 H [A/m]
OK Cancel O Picture	



- Flux 2D project: define physics
  - Create mechanical sets





- Flux 2D project: define physics
  - Mechanical set: STATOR

		(1)
tep	Action	We Mechanical set
1	Create the mechanical set STATOR	STATOR STATOR Comment Type of mechanical set



- Flux 2D project: define physics
  - Mechanical set: ROTOR

Step	Action
1	Create the mechanical set ROTOR

Vilok  with the second coordinate  yee of mechanical set  totation around one axis  Rotation Axis  Rotation Axis  Rotation around one axis parallel to Oz  Coordinate system *  XY1  Pivot point  Pivot point  Formula or Value  0  10  Formula or Value  10  Formula or	chanical set name *			
yee of mechanical set totation around one axis  Rotation Axis Rotation Axis Rotation around one axis parallel to Oz  Socrafinate system * XY1  Pivot point Prot point First coordinate 0	mment			
ype of mechanical set otalion around one axis Arallel to Oz Rotation Axis Rotation axis Rot				
otation around one axis Avis Vainematics Avis Vainematics Avis Vainematics Avis Value Rotation Axis Rotation around one axis parallel to Oz  Coordinate system * XY1  Prvot point  Prvot point  Prvot point  Prvot point  O I() Second coordinate O I()	pe of mechanical set			
Avis \ Knematics \ Rotation Avis Rotation avis parallel to Oz Scordinate system * XY1 Pivot point Formula or Value irst coordinate 0 10 Second coordinate 0 10 Secon	otation around one axis			-
Rotation around one axis parallel to Oz  Coordinate system * XY1  Pivot point Pivot point Pormula or Value  irst coordinate 0 10 10	Axis \ Kinematics \			
Activation and one axis paramento O2 V Scoordinate system * XY1 V V Privot point Formula or Value First coordinate 0 10 Second coordinate 0 10 0 10 10 10 10 10 10 10 10 10 10	Rotation Axis			_
Avriance system *  VY1  VY1  Pivot point  Pivot point  0  formula or Value  10  formula or Value 10  formula or Value 10  formula or Value 10  formula or Value 10  formula or Value 10  formula or Value 10  formula or Value 10				
Prvot point Formula or Value First coordinate 0 100 Second coordinate 0 100 F(0)	XY1			- D
irst coordinate 0 100000 1000 1000 1000 1000 1000 100	Divet point		Formula or Valua	
Second coordinate	First coordinate	0	Tornial of Value	f()
	Second coordinate	0		f()



×

#### **BRUSH ANGLE ANALYSIS**

- Flux 2D project: define physics
  - Mechanical set: ROTOR

- 🔂 I	Jew Mechanical set	×
Mech	anical set name *	
ROT	OR	
Com	ment	
ГТур	a of mechanical set	
Rot	ation around one axis	-
A	is Kinematics	
Γ <sup>T</sup> )	pe of kinematics	
In	iposed Speed	•
117	General \ Internal characteristics \ External characteristics \ Mechanical stops \	
V	elocity (rpm) *	
l l l	2000	f()
F	osition at time t = 0s. (deg) *	
		f()

	Mechanical set name *
	ROTOR
New Machanical set	Comment
chanical set name *	Type of mechanical set
ITOR	Rotation around one axis
nment	Axis Kinematics
	Type of kinematics
be of mechanical set	Imposed Speed 👻
tation around one axis	General Internal characteristics External characteristics Mechanical stops
Axis Kinematics	
ype of kinematics	Type of load
mposed Speed 🔹	Inertia and resistive torque
General Internal characteristics External characteristics Mechanical stops	Moment of inertia (kg.m2) *
	0 f0
Type of load	Resistive torque (N.m)
Inertia and resistive torque	Expression (constant or evolving formula) *
Moment of inertia (kg.m2) *	0 0
0 f0	
Resistive torque (N.m)	
Expression (constant or evolving formula) *	
0 <u>f0</u>	
OK Cancel 🔞	

👶 New Mechanical set

ALTAIR

#### **BRUSH ANGLE ANALYSIS**

• Flux 2D project: define physics

#### Load Macro

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		Dpen project Ctrl-O			Graphic	
Step	Action	Close Recent projects			🖗 🔍 🔍 🖾 📰 🕭 💼 😵	
1	Click on [Project] – [Macro] – [Load]	Save     Ctrl-S       Save as         Command file				
2	Select the macro "Circuit_Collector_2D.PFM in the folder "Macros_Flux_Circuit"	"Macro       "Overlay       "Import       "Export       "Print	Load Run Unioad Update	,		
3	Click on [Open]	137 LAR ARTY	r			
	Choose the macro to load Look [n: Macros Macros_ChangeMaterial Macros_FieldLine Macros_FieldLine Macros_FieldZD_Physics Macros_FieldZD_Physics Macros_FieldZD_Physics FieldMacros_FieldZD_Physics FieldMacros_FieldZD_Postproc FieldZD_Postproc_FieldZD_Postproc FieldMacros_FieldZD_Postproc FieldMacros_FieldZD_Postproc FieldMacros_FieldZD_Postproc FieldMacros_FieldZD_Postproc FieldZD_Postproc_FieldZD_Postproc FieldMacros_FieldZD_Postproc FieldZD_Postproc_FieldZD_Postproc FieldZD_Postproc_FieldZD_Postproc FieldZD_Postproc_FieldZD_Postproc FieldZD_Postproc_FieldZD_Postproc_FieldZD_Postproc FieldZD_Postproc_FieldZD_Postproc_FieldZD_Postproc_FieldZD_Postproc_FieldZD_Postproc_FieldZD_Postproc_FieldZD_Postproc_FieldZD_Postproc_FieldZD_Postpro	Macros_Flux30_Geometry Macros Macros_Flux30_Mesh Macros Macros_Flux30_Physics Macros Macros_Flux30_Postproc Macros Macros_FluxMotor Macros Macros_FluxMotor Macros Macros_FluxPEEC_Geometry Macros Open	FluxPEEC_Miscelle FluxPEEC_Miscelle FluxPEEC_Miscelle FluxPEEC_PostPre FluxSkewed_Post JimportMateriale			

Project Application Geometry Mesh Physics Parameter/Quantity Solving Display View Select Tools Extensions Help

- Flux 2D project: define physics
  - Run Macro

Step	Action
1	Right click on the Data Tree [Extensions] – [Macros] – [CIRCUIT_COLLECTO R_2D], click on [Run]
2	Set the macro parameters
3	Click on [OK]

Data Tree				
🖃 🗝 General data				i .
Geomet     Geomet	try ter/ oces	Quantity sing		
	cros	Edit Edit array	Ctrl-E Ctrl-F	
	 	Run Unload Update Display PyFlux command Find usages XML export Python export TXT export Excel export Copy to clipboard		1

C
Circuit_Collector_2D
Id for parameters and components*** *
Number of slots (NSlot) * 12
Number of coils per slot (Ncslot, accepted values 1 or 2) <sup> *</sup> 2
Throw (ignored if Ncslot=1)**
Commutator pitch (bar nb between go and return coil) (comPitch)* .
Number of brushes (NBrush) <sup>*</sup>
Value of voltage supply (DCVoltage) [Volt] * 11.5
Resistance in serie with voltage supply (Resistance) [Ohm] * 1.0E-6
Inductance in serie with voltage supply (Inductance) [Henry] * 1.7E-6
Resistance of each coil (RCoil) [Ohm] * 0.012
Angular opening of brush (TetaBrush) [degree] * 29
Angular opening of bars (TetaBar) [degree] * 20.69
On state resistance between brush and bar (RonBarBrush) [Ohm] * 1.0E-4
Initial position first coil versus first brush (Tetalni) [degree] * 0.0
Cancel
(3)



- Flux 2D project: define physics
  - Verify circuit







- Flux 2D project: define physics
  - Verify circuit

		(1)					
04.000		At View Select Tools Help	No. 2 Lat 10 A				
Step	ACTION	Data Tree	- Graphic				_ 0
		General data     House and the second s	💌 🖉 🔍 🖓 🖓 🖉 👗 🗶 🔊 🕬 भ	· 神砂球的的时时时 14	н		
1	Click on the icon 🔀 to close the circuit editor context	<ul> <li>⊕ Volgepärrett ources</li> <li>⊕ Ter Gouge components</li> <li>⊕ SindhelgemacroAutors</li> <li>⊕ SindhelgemacroAutors</li> <li>⊕ Bagedential</li> <li>⊕ Industrial</li> </ul>	-150 -100 -50 0 50 1		0 400 450 500 550 .	. 590 590 790 890 890	900 950 1000 1050 1100 1150 120 400 450
			-303	qq qq qq	qq qq qq	qq qq qq qq	
			-159 -109 -59 0				
			50 -150 -100 -50 0 50 1	00 150 200 250 300 350	0 400 450 500 550	600 650 700 750 800 850	800 850 1000 1050 1100 1150 122 50 53.228
			Components \Potentials \ Type  In Iname	Parameters state	Connection state	Graphic state	Potentials of terminals
			CO_BRUSHSEGMENT_1	V Defined	✓ Connected	Valid	CO_EQUIPOT_BRUSHGROUP_1
			CO_BRUSHSEGMENT_10	V Defined	V Connected	Valid	CO_EQUIPOT_BRUSHGROUP_3
			CO_BRUSHSEGMENT_11	V Defined	<ul> <li>Connected</li> </ul>	Valid	CO_EQUIPOT_BRUSHGROUP_3 CO_EQUIPOT_BRUSHES_V
			CO_BRUSHSEGMENT_12	V Defined	V Connected	Valid	CO_EQUIPOT_BRUSHGROUP_3 CO_EQUIPOT_BRUSHES_IND
				V Defined	Connected	Vaid	CO_EQUIPOT_BRUSHERCUP_4
		<b>6</b>	.,				A



- Flux 2D project: define physics
  - Face region definition

Step	Action
1	Modify the following face regions - Magnets - Rotor / Stator

ldit Face region[MAGNET_1,MAGNET_2,MAG	GNET_3, MAGNET_4	4]			×
Entities	Modify all	MAGNET_1	MAGNET_2	MAGNET_3	MAGNET_4
🖃 📵 Face region					
Name *		MAGNET_1	MAGNET_2	MAGNET_3	MAGNET_4
Comment	Initial values	MAGNET POLE1	MAGNET POLE2	MAGNET POLE3	MAGNET POLE4
🖃 🕒 Transientmagnet *					
🖃 💿 Sub types	Initial values	Air or vacuum r			
Air or vacuum region		Air or vacuum r			
🕒 Color	Initial values	Red	Green	Red	Green
Visibility *	Initial values	VISIBLE	VISIBLE	VISIBLE	VISIBLE
Mechanical set	STATOR	STATOR	STATOR	STATOR	STATOR
OK Apply Cancel					

恭 Edit Face region[ROTOR,SHAFT,STATOR]				×
Entities	Modify all	ROTOR	SHAFT	STATOR
E 🕒 Face region				
Name *		ROTOR	SHAFT	STATOR
Comment	Initial values	ROTOR	SHAFT	STATOR
Transientmagnet *				
🖃 💿 Sub types	Initial values	Magnetic non conducti	Magnetic non conducti	Air or vacuum region
Air or vacuum region				Air or vacuum region
Magnetic non conducting region		Magnetic non conducti	Magnetic non conducti	
Material *	Initial values	MU_LIN	MU_LIN	
Color	Initial values	Blue	Yellow	Blue
Visibility *	Initial values	VISIBLE	VISIBLE	VISIBLE
Mechanical set	Initial values	ROTOR	ROTOR	STATOR
OK Apply Cancel				



- Flux 2D project: define physics
  - Face region definition: Air

Step	Action
1	Modify the following face regions

ldit Face region[INFINITE,ROTATING_AIRGAP,RC	Edit Face region[INFINITE,ROTATING_AIRGAP,ROTOR_AIR,STATOR_AIR,WEDGE]								
Entities	Modify all	INFINITE	ROTATING_AIRGAP	ROTOR_AIR	STATOR_AIR	WEDGE			
E Face region									
Name *		INFINITE	ROTATING_AIRGAP	ROTOR_AIR	STATOR_AIR	WEDGE			
Comment	Initial values	Infinite region	ROTATING AIRGAP	ROTOR_AIR	STATOR_AIR	WEDGE			
Fransientmagnet *									
🖃 💿 Sub types		Air or vacuum region	Air or vacuum region	Inactive region	Air or vacuum region	Air or vacuum region			
Air or vacuum region		Air or vacuum region	Air or vacuum region		Air or vacuum region	Air or vacuum region			
Inactive region				Inactive region					
Color	Initial values	Turquoise	Yellow	White	White	White			
Visibility *	Initial values	VISIBLE	VISIBLE	VISIBLE	VISIBLE	VISIBLE			
🕞 Mechanical set		STATOR	ROTOR		STATOR	ROTOR			
OK Apply Cancel									



- Flux 2D project: define physics
  - Face region definition: Phase

tep	Action	Edit Face region[PHASE_NEG_1,PHASE_NEG_2,I	PHASE_NEG_3,PH	ASE_NEG_4,PHASE_	NEG_5,PHASE_NEG	_6]			
		Entities	Modify all	PHASE_NEG_1	PHASE_NEG_2	PHASE_NEG_3	PHASE_NEG_4	PHASE_NEG_5	PHASE_NEG_6
	Modify the following	🖃 🕒 Face region							
1	face regione	Name *		PHASE_NEG_1	PHASE_NEG_2	PHASE_NEG_3	PHASE_NEG_4	PHASE_NEG_5	PHASE_NEG_6
	Tace regions	Comment	Initial values	PHASE NEG	PHASE NEG				
		Transientmagnet *							
		🖃 💿 Sub types	Initial values	Coil conductor re	Coil conductor				
		🖃 📵 Coil conductor region		Coil conductor re	Coil conductor				
		G Conductor *							
		Component *	Initial values	CO_COIL_1N	CO_COIL_2N	CO_COIL_3N	CO_COIL_4N	CO_COIL_5N	CO_COIL_6N
		Turn number *	Initial values	7	7	7	7	7	7
		🖃 🚫 Sub types	Initial values	All the symmetric	All the symme				
		All the symmetrical		All the symmetric	All the symme				
		Compute coil losses	Initial values			ĺ	ĺ		
		Conductor material *	Initial values	MAGNET	MAGNET	MAGNET	MAGNET	MAGNET	MAGNET
		Sub types	Initial values						
		🖃 🔘 Sub types	Initial values	Positive orientati	Positive orient				
		Positive orientation for		Positive orientati	Positive orient				
		Color	Initial values	COIL_NEG_1	COIL_NEG_2	COIL_NEG_3	COIL_NEG_4	COIL_NEG_5	COIL_NEG_6
		Visibility *	Initial values	VISIBLE	VISIBLE	VISIBLE	VISIBLE	VISIBLE	VISIBLE
		B Mechanical set	Initial values	ROTOR	ROTOR	ROTOR	ROTOR	ROTOR	ROTOR
		OK Apply Cancel							



- Flux 2D project: define physics
  - Face region definition: Phase

Step	Action
1	Modify the following face regions

Edit Face region[PHASE_NEG_7,PHASE_NEG_8,P	HASE_NEG_9,PHASE	E_NEG_10,PHASE_N	EG_11,PHASE_NEG_	12]			×
Entities	Modify all	PHASE_NEG_7	PHASE_NEG_8	PHASE_NEG_9	PHASE_NEG_10	PHASE_NEG_11	PHASE_NEG_12
E Face region							
Name *		PHASE_NEG_7	PHASE_NEG_8	PHASE_NEG_9	PHASE_NEG_10	PHASE_NEG_11	PHASE_NEG_12
Comment	Initial values	PHASE NEG	PHASE NEG				
Transientmagnet *							
🖃 🔘 Sub types	Coil conductor reg	Coil conductor region	Coil conductor reg				
Coil conductor region		Coil conductor reg	Coil conductor reg	Coil conductor reg	Coil conductor reg	Coil conductor region	Coil conductor reg
🕒 material							
🖃 🕒 conductor *							
Component		CO_COIL_7N	CO_COIL_8N	CO_COIL_9N	CO_COIL_10N	CO_COIL_11N	CO_COIL_12N
Turn number *	7	7	7	7	7	7	7
Fill factor (0 < Cf < 1)	false	false	false	false	false	false	false
E Series or parallel *							
🖃 🔘 Sub types	All the symmetrica	All the symmetrical	All the symmetrica				
All the symmetrical a		All the symmetrica	All the symmetrica	All the symmetrica	All the symmetrica	All the symmetrical	All the symmetrica
🖃 💿 Sub types	Positive orientatio	Positive orientatio					
Positive orientation for t		Positive orientatio	Positive orientatio				
Color	Initial values	COIL_NEG_7	COIL_NEG_8	COIL_NEG_9	COIL_NEG_10	COIL_NEG_11	COIL_NEG_12
Visibility *	Initial values	VISIBLE	VISIBLE	VISIBLE	VISIBLE	VISIBLE	VISIBLE
Mechanical set	ROTOR	ROTOR	ROTOR	ROTOR	ROTOR	ROTOR	ROTOR



R

0

- Flux 2D project: define physics
  - Face region definition: Phase

OK

Apply

Cancel

Step	Action
1	Modify the following face regions

Edit Face region[PHASE_POS_1,PHASE_POS_2,P	HASE_POS_3,PHAS	E_POS_4,PHASE_PO	S_5,PHASE_POS_6]				×
Entities	Modify all	PHASE_POS_1	PHASE_POS_2	PHASE_POS_3	PHASE_POS_4	PHASE_POS_5	PHASE_POS_6
E Face region							
Name *		PHASE_POS_1	PHASE_POS_2	PHASE_POS_3	PHASE_POS_4	PHASE_POS_5	PHASE_POS_6
Comment	Initial values	PHASE POS					
🖃 🕞 Transientmagnet *							
🖃 🔘 Sub types	Coil conductor reg	Coil conductor reg	Coil conductor re	Coil conductor reg	Coil conductor re	Coil conductor reg	Coil conductor re
Coil conductor region		Coil conductor reg	Coil conductor re	Coil conductor reg	Coil conductor re	Coil conductor reg	Coil conductor re
() material							
G conductor *							
Component		CO_COIL_1P	CO_COIL_2P	CO_COIL_3P	CO_COIL_4P	CO_COIL_5P	CO_COIL_6P
() Turn number *	7	7	7	7	7	7	7
Fill factor (0 < Cf < 1)	false						
🖃 🕞 Series or parallel *							
🖃 💿 Sub types	All the symmetrica	All the symmetrica	All the symmetric	All the symmetrica	All the symmetric	All the symmetrica	All the symmetric
All the symmetrical a	e	All the symmetrica	All the symmetric	All the symmetrica	All the symmetric	All the symmetrica	All the symmetric
🖃 💿 Sub types	Positive orientatio	Positive orientatio.					
Positive orientation for the second secon	t	Positive orientatio	Positive orientatio.				
Color	Initial values	COIL_POS_1	COIL_POS_2	COIL_POS_3	COIL_POS_4	COIL_POS_5	COIL_POS_6
Visibility *	Initial values	VISIBLE	VISIBLE	VISIBLE	VISIBLE	VISIBLE	VISIBLE
🕞 Mechanical set	ROTOR						



- Flux 2D project: define physics
  - Face region definition: Phase

Step	Action
1	Modify the following face regions

Entities	Modify all	PHASE POS 7	PHASE POS 8	PHASE POS 9	PHASE POS 10	PHASE POS 11	PHASE POS 12
E Face region							
F Name *		PHASE_POS_7	PHASE_POS_8	PHASE_POS_9	PHASE_POS_10	PHASE_POS_11	PHASE_POS_12
Comment	Initial values	PHASE POS	PHASE POS				
🖃 🕒 Transientmagnet *							
🖃 🔘 Sub types	Coil conductor re	Coil conductor re	Coil conductor re	Coil conductor reg	Coil conductor re	Coil conductor reg	Coil conductor re
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🕒 material							
G conductor *							
🕒 Component		CO_COIL_7P	CO_COIL_8P	CO_COIL_9P	CO_COIL_10P	CO_COIL_11P	CO_COIL_12P
Turn number *	7	7	7	7	7	7	7
Fill factor (0 < Cf < 1)	false	false	false	false	false	false	false
🖃 🕒 Series or parallel *							
🖃 🔘 Sub types	All the symmetric	All the symmetric	All the symmetric	All the symmetrica	All the symmetric	All the symmetrica	All the symmetric
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Positive orientation for	t	Positive orientatio	Positive orientat				
🕒 Color	Initial values	COIL_POS_7	COIL_POS_8	COIL_POS_9	COIL_POS_10	COIL_POS_11	COIL_POS_12
Visibility *	Initial values	VISIBLE	VISIBLE	VISIBLE	VISIBLE	VISIBLE	VISIBLE
Mechanical set	ROTOR	ROTOR	ROTOR	ROTOR	ROTOR	ROTOR	ROTOR


- Flux 2D project: define physics
  - Modify I/O parameter



Data Tree	Graphic
General data	- 🤹 🔍 🖸
🗄 🗁 Geometry	
🗄 🗀 Mesh	
庄 🗠 🗀 Physics	
🚊 🦢 Parameter/Quantity	
🖻 🖓 💼 Parameter I/O	
·····CO_BAR_PER	
CO_DCVOLTAGE_VAL	
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Modify tabulated I/O parameter by impo	ortation of a 2D table
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Dit Physical parameter[CO_TETAINI]	×
Name of the Physical parameter *	
CO_TETAINI	
Comment	
( Definition ∖ Property ∖	
Type of Physical parameter	
Parameter controlled via a scenario	
Reference value *	
0.0	
Geometric parameter	
OK Apply Cancel 🔞	



- Flux 2D project: define physics
  - Create solving scenario

Step	Action
1	Click on [Solving] – [Solving scenario] – [New]
2	Create the following scenario "BRUSH_ANGLE"

Project Application Geometry Mesh Physics Parameter/Quantity	Solving Display View Select Tools Extensions Help			
🕘 🖻 👶 📑 🍠 🖪 💁 💁 🔛 🐁 🍇 🍇	Solving scenario	•	Mew New	
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	😰 Generate component for Altair Flux e-Machine Toolbox coupling			

me of the solving scenario	* BRUSH_ANGLE		Comment		
			Parametric distribu	ition	
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Control type of transien	solving process				
Control by time					
Control by position of r	echanical set ROTOR				
Parameter control List	of resulting values \				
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- Flux 2D project: define physics
  - Save project





- Flux 2D project: solving
  - Solve scenario











Display flux lines



- By modifying the parameter Co\_TETAINI, one can rotate the initial flux line distribution
- If Co\_TETAINI is set to 0°, then the flux line will be perpendicular to magnets flux lines



• On theoretical point of view , the coils should be fed to create a rotor magnetic field in quadrature with stator field



- The computation with no magnet allows to check that point
- It will lead to a positive torque in that case (for positive speed)
- Modifying the SHIFT\_ANGLE parameter will allow to adjust this angle



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# **III. BACK EMF ANALYSIS**



- Flux 2D project: define physics
  - Delete project results





- Flux 2D project: define physics
  - Save project

	. ,	New	CIMEN		ا العند ا	
tep	Action	<ul> <li>Open project</li> <li>Close</li> </ul>	Ctrl-O		Graphic	
1	Click on [Project] – [Save as]	Recent projects	► Ctrl-S		♥ @ ₹	
2	Define the project name "DC_Motor_3_Back_EMF"	Command file		1)	역함 Choose the new name of the project Save In: C Flux	×
3	Click on [Save]	() Overlay	•		DC_Motor_1_GeoMesh.FLU     DC_Motor_2_BrushAngle.FLU     DC_Motor_2_BrushAngle.Solved.FLU     DC_Motor_2_BrushAngle_Solved.FLU	
		Import Export Import Print	Alt-F4			
					File Name: DC_Motor_3_Back_EMF	Save Cancel

Project Application Geometry Mesh Physics Display View Select Tools Extensions Help



- What do we need to do ?
  - Replace air or vacuum region by magnet and stator
  - Replace linear region of rotor by M800-50A
  - Set the resistance of supply to CO\_RESIST\_VAL = 10000  $\Omega$  (back EMF will be taken on the resistance)
  - Set the speed to 10000 rpm



- Flux 2D project: define physics
  - Import materials

Step 1	Action Click on [Physics] – [Material] – [Import material .DAT]	Project Application Geometry Mesh Data Tree Geometri data Geometry Geometry Mesh Physics Descret advantive Construction Descret advantive Construction Descret advantive Descret advantive Des	Physics Parameter/Quantity Solving Display on Infinite box mit Periodicity g Symmetry Doman options Miterial J Point region ∠ Line region AB Face region	View	Select Tools Extensions Help Image: Select Tools     Extensions     Help       Image: Select Tools     Image: Select Tools     Image: Select Tools     Image: Select Tools       Image: Select Tools     Image: Select Tools     Image: Select Tools     Image: Select Tools       Image: Select Tools     Image: Select Tools     Image: Select Tools     Image: Select Tools       Image: Select Tools     Image: Select Tools     Image: Select Tools     Image: Select Tools       Image: Select Tools     Image: Select Tools     Image: Select Tools     Image: Select Tools
2	Select the two materials: FLU_1010_XC106RO FLU_M800_50A	⊕ a Tools ⊕ a Extensions	Mechanical set     Electrical components     Electrical components     Crouit     Assign regions to geometric entities     Assign solid conductors components to regions     Assign solid conductors components to regions     Display arrows on magnet		Force delete Maj-Supprimer     Import from material manager     Incort material DAT     Orat material IOAT     Orat material for face region     New B(H) 2D curve (Material)
3	Click on [Import]		값 Delete Arrows 큰 Load and run physics macro	•	
			Check physics A     A     エ     E     Check circuit A	lt-P lt-⊂	



- Flux 2D project: define physics
  - Modify face regions

Step	Action
1	Modify the following face regions

😓 Edit Face region[ROTOR,SHAFT,STATOR]				×
Entities	Modify all	ROTOR	SHAFT	STATOR
E Face region				
B Name *		ROTOR	SHAFT	STATOR
Comment	Initial values	ROTOR	SHAFT	STATOR
Fransientmagnet *				
🖃 🚫 Sub types	Initial values	Magnetic non conducti	Magnetic non conductin	Magnetic non conducti
B Magnetic non conducting region		Magnetic non conducti	Magnetic non conductin	Magnetic non conducti
Material *		FLU_M800_50A	FLU_1010_XC10+RO	FLU_1010_XC10+RO
Color	Initial values	Blue	Yellow	Blue
Visibility *	Initial values	VISIBLE	VISIBLE	VISIBLE
🕞 Mechanical set	Initial values	ROTOR	ROTOR	STATOR
OK Apply Cancel	0			



- Flux 2D project: define physics
  - Modify face regions

Step	Action
1	Modify the following face regions

Image: Book State					
Entities	Modify all	MAGNET_1	MAGNET_2	MAGNET_3	MAGNET_4
🖃 📵 Face region					
Name *		MAGNET_1	MAGNET_2	MAGNET_3	MAGNET_4
Comment	Initial values	MAGNET POLE1	MAGNET POLE2	MAGNET POLE3	MAGNET POLE4
Transientmagnet *					
🖃 💿 Sub types	Magnetic non conducting				
Magnetic non conducting region		Magnetic non conducting	Magnetic non conducting	Magnetic non conducting	Magnetic non conducting
Material *	MAGNET	MAGNET	MAGNET	MAGNET	MAGNET
Color	Initial values	Red	Green	Red	Green
Visibility *	Initial values	VISIBLE	VISIBLE	VISIBLE	VISIBLE
G Mechanical set	Initial values	STATOR	STATOR	STATOR	STATOR
OK     Apply     Cancel					



- Flux 2D project: define physics
  - Orient materials

Step	Action
1	Click on [Physics] – [Material] – [Orient material for face region]
2	Define the orientation angle for the four magnets
3	Click on [OK]



lorient material for face region					×
Orient region's materials	Oriented type	Coordinate sys	Angle	X coordinate	Y coordinate
□ ISOTROPE					
A ROTOR					
A SHAFT					
⊿ STATOR					
UNIDIRECTIONALMAGNETIZATION					
A MAGNET_1	Direction	XY1	45		
AGNET_2	Direction	XY1	45+90+180		
AGNET_3	Direction	XY1	45+180		
△ MAGNET_4	Direction	XY1	45+270+180		
OK Cancel 🔘					



- Flux 2D project: define physics
  - Modify electric circuit







- Flux 2D project: define physics
  - Modify electric circuit





• Flux 2D project: define physics

• Modify electric circuit

		7 View Celer? Tools Main						
Sten	Action	· · · · · · · · · · · · · · · · · · ·	백 책 책 책 이 🖉					
Otep	Action	Data Tree	Graphic	I bi bi be be be bi bi bi bi bi	ы			_ 0
1	Click on the icon 🔀 to close the circuit editor context	B C Components     Components     B C Components     B C Company Components     B C Company Components     B C Company Components     B C Company Components     B C C C C C C C C C C C C C C C C      B C C C C	-150 -100 -50 - 0 - 50 - 7 -600 -600	00	50, 400, 450, 500, 550,	590 550 770 750	, 800 . , 950 . , 1000 . , 1050 . , 1120	1150 120 -500 -450 -400
			-389 -389 -289 -289 -789 -199 -199 -90 -90 -90					350 250 250 150 50 50 50
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- Flux 2D project: define physics
  - Modify mechanical set

Step	Action
1	Modify the velocity value for the mechanical set "ROTOR"

TOTOR		
omment		
vne of mechanical set		
Rotation around one axis	-	-
Axis (Kinematics)		_
Rotation Axis		
Rotation around one axis parallel to Oz	•	
Coordinate system *		
XY1	-	
Pivot point	Formula or Value	
First coordinate	0 <u>f()</u>	
Second coordinate	0 <u>f()</u>	

lit Mechanical set[ROTOR]	×
Mechanical set name *	
ROTOR	
Comment	
Type of mechanical set	
Rotation around one axis	•
Axis / Kinematics \	
Type of Kinematics	_
Imposed Speed	
General \ Internal characteristics \ External characteristics \ Mechanical stops \	
Velocity (rpm) *	f()
0	fO
lechanical set sub-system	
MECHANICAL_SYSTEM_1	~
Cancel	



- Flux 2D project: solving
  - Create scenario

Step	Action
1	Click on [Solving] – [Solving scenario] – [New]
2	Create the following scenario "BACK_EMF"



e of the solving scen			Comm	ent ametric distribut	tion		
ontrol of transient sta	ate Control of parameters Result	storage Hype	View export				
ontrol type of trans	ient solving process						
Control by time							
Control by position	of mechanical set ROTOR						
Parameter control 🕅	List of resulting values \						
Interval definition -			Intervals table	e			
Lower limit	360.0		Lower limit	Higher limit	Method	Values	_
Higher limit			0.0	360.0	Step Value	1.0	
Variation method	Step value	-					
Step value							
		>>					
					Clear last interval		



- Flux 2D project: solving
  - Save project

Sten	Action	Project	Application	Geometry	y Mesh	Physics	Parameter/C	Quantity	Solving	Display	View	Select	Tools	Extension	s Help
otep	Action	New New		Ctrl-N	2	<u>۳</u>	盟 ‰ %	a 👫 🕅	****	жв  ж н∮   Ж	*/	火 🐉	1 K.	4 4	@ <u>*</u> @ <u>/}</u>
1	Click on [Project] – [Save]	Der Oper	n project e ent projects	Ctrl-O						Grap	ohic @	ā,   Ľ.×	XP X	) 🖻 í	ê Ę
		Save Save Com Macr Sver Ver Sver Sver Sver Sver Sver Sver Sver Sv	e e as mand file ro rlay ort ort :	Ctrl-5	1										



- Flux 2D project: solving
  - Solve project











- Flux 2D project: post-processing
- Solvina Data exchange Support Graphic Curve Computation Advanced Display View Help Project Application Display of Back EMF • 😹 📓 🖉 🎋 🎘 🖄 🕺 🏭 🥕 🎍 🗑 📐 2D curve (Path) 2 🔁 🖽 🏠 🔊 5 🗳 2D curve (I/O parameter) New 2D curve (I/O parameter) ъI Data Tree 🔁 2D curve (Material Curve) 🕨 🤽 Edit Ctrl-E -General data 🍄 Delete Supprimer + Geometry 😹 3D curve (2D grid) + 🗀 Mesh 3D curve (2 I/O parameters) Þ. 餐 Display + Physics Click on [Curve] - [2D 3D curve (Path + I/O Parameter) 🕨 👯 Hide 🗄 🗀 Parameter/Quantity 🔨 Integral of 2D curve + Solver so curve (dedicated to rotating machine) curve (I/O parameter)] + Post processing Derivative of 2D curve 1 🕂 🗀 Tools - [New 2D curve (I/O 🗽 Spectrum analysis (FFT) Extensions Superimpose 2D curves (I/O parameter) parameter)] 1 Import a 2D curve - Flux file (txt) Not the second s Create the curve NTXT export 2 "BACK EMF" Not Excel export Scomputation on circuit New 2D curve (I/O parameter) X Х Name of 2D curve (I/O parameter) \* Type of electrical component BACK\_EMF Resistor Comment I/O parameters on the abscissa Formula CO RESISTOR Voltage [V] Add U(CO\_RESISTOR) f() X choice Parameter name Current value Limit min Limit max Current [A] f() Power - Active [W] 0.0 ✓ 360.0 -ANGPOS\_ROTOR Add all Resistance [Ω] Joule losses [W] Formula on ordinate Region Circuit Mechanical set U(CO RESISTOR) Delete all f() f() 58 Clear 6 Ok Cancel OK Cancel

- Flux 2D project: post-processing
  - Display of voltage on R1 and of position





- Flux 2D project: post-processing
  - Display of voltage on Coil\_1

Step	Action
1	Click on [Curve] – [2D curve (I/O parameter)] – [New 2D curve (I/O parameter)]
2	Create the curve for the voltage on Coil_1

	Project Application Solving	Data exchange	Support Grap	hic Curve Com	outation Advanced	Display V	iew Help	
sina	📄 🔌 😓 📕 🍠	2 🕨 💌	1 🗄 🧏 🐐	🖉 📐 2D curve (	Path)	•	🔜 📓 🌌 % 🤾 も や 🖁	
Jing	Data Tree			2D curve (	I/O parameter)	•	New 2D curve (I/O parameter)	(1)
	🖃 🛛 General data			2D curve (	Material Curve)	+	K Edit	Ctrl-E
1	🗄 🧰 Geometry			🗽 3D curve (	2D grid)	•	No Delete	Supprimer
•	Mesh			🕍 3D curve (	2 I/O parameters)	•	No. 19 19 19 19 19 19 19 19 19 19 19 19 19	
	Privsics     Privsics     Parameter/Ouantity			🕍 3D curve (	Path + I/O Parameter)	• •	14 Hide	
	🕀 🗀 Solver			SD curve (	dedicated to rotating p	achine) 🕨	🟒 Integral of 2D curve	
	🕀 🖆 Post processing			SD curve (	dedicated to rotating in	nachine) 🖡	Derivative of 2D curve	
	Tools						In Spectrum analysis (FFT)	
	± Extensions							
							5 Superimpose 2D curves (1)O parameter	0
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1					7		Import a 2D curve - formatted file (txt)	)
Nev	w 2D curve (I/O parameter)	1		×			聲 TXT export	
Name	of 2D curve (I/O parente	r) *					😫 Excel export	
VOLTA	GE COIL 1 (2)	.,						
Comm	ant C							
Comm	ent							
I/O par	rameters on the abscissa							
X cho	oice Parameter name	Current value	Limit min	Limit max				
	ANGPOS_ROTOR		✓ 0.0	✓ 360.0				
Eorm	ula on ordinato							
Form								
	Region	Circuit	Mechanical s	set				
		1N)		f()				
		1180		f()				
	r							
		Clear						
							<b>•</b>	
	OK Cancel						$\Delta$	ALIAI

- Flux 2D project: post-processing
  - Display of voltage on Coil\_1







- Flux 2D project: post-processing
  - Isovalue magnetic flux density

2 NO VACUUM

Vector [T]

Cancel

Quantity \*

B

Current density Energy (volume density) Lorentz force (volume density) Magnetic field Magnetic filux density Permeability Power (volume density)

OK

Step	Action
1	Click on [Graphic] – [Isovalues] – [New]
2	Create the isovalue for the magnetic flux density



f()



- Flux 2D project: post-processing
  - Isovalue magnetic flux density





- Flux 2D project: post-processing
  - Save project





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# **IV. CONSTANT SPEED ANALYSIS**



- Next computation is to set the speed at 10000 rpm
- Goal : look at current ripple and torque ripple
- Delete all the results of the previous project BACKEMF.FLU.
- Save as CONSTANT\_SPEED.FLU



- Flux 2D project: define physics
  - Delete project results





- Flux 2D project: define physics
  - Save project

Step	Action
1	Click on [Project] – [Save as]
2	Define the project name "DC_Motor_4_CST_Speed"
3	Click on [Save]





Cancel

Save

- Flux 2D project: define physics
  - Modify electric circuit



Project	Application Geometry Mesh	Physics	Parameter/Quantity	Solving	Display	View	Select	Tools	Extensions	Help
•	🔶 🔒 🍠 🕵 🔽	👓 Infin	ite box			•	🖄 🏂	٤.	4 4	•%
Data Tre	e	nt Perio	odicity							
Gener	al data	siz Sym	metry	- 32		🚓 🚓 🗠	• [			
÷(2	Geometry	🔮 Dom	ain options	•× =	•		- T   P			
÷- 🗀	Mesh	<sup>8</sup> Mate	əriəl			•				
÷ ն	Physics	CuFe Place	t region							
÷	Parameter/Quantity	2								
±	Solver		region	•						
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- Flux 2D project: define physics
  - Modify electric circuit

Step	Action
1	Modify the voltage source value





- Flux 2D project: define physics
  - Modify electric circuit

71

ер	Action									
1	Modify the resistance value									
	*** Edit Resistor[CO_RESISTOR]         Resistor name *         CO_RESISTOR         Comment         Model \Terminals \Appearance \Evaluated info         Resistance (Ohm) *         1E-4	armation \	] , , ,	, pp			) (			
	Cancel	© 9								

- Flux 2D project: define physics
  - Modify electric circuit

Step	Action	a X 5 또 오 가 좀 비 책 부 작 책 세 이 이 이 Data Tree	색 책 책 책 시 ▷ ⑦ Graphic				_ 0
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				1207 I		×2	


- Flux 2D project: solving
  - Create solving scenario

Step	Action
1	Click on [Solving] – [Solving scenario] – [New]
2	Create the following scenario "LOAD_10000RPM"

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Post processing	🐇 Multi p	hysic solving sessio	n (existing scenario)					
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- Flux 2D project: solving
  - Save project

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600 650

CO\_RESIST\_VAL

ANGPOS\_ROTOR (deg)

ANGPOS ROTOR (deg)

CO\_NSLOT

600

800

200

200

1.5E-8-

16-6

## **CONSTANT SPEED ANALYSIS**

Data Tree

----

- Flux 2D project: solving
  - Solve scenario

Step	Action
1	Click on [Solving] – [Solve]
2	Select the solving scenario "LOAD_10000RPM"
3	Save the solved project as a new project "DC_Motor_4_CST_Speed_ Solved"





ANGPOS ROTOR (deg)

CO\_DCVOLTAGE\_VAL

ANGPOS\_ROTOR (deg)

ANGPOS ROTOR (deg) Step number 3/721 (Estimated remaining time: 48 minutes

CO\_RCOIL

200

200 400

0.01

0.01

50 100

200

200 400 600

9.50

2.5E-8

2E-8 1.5E-8

10

ELTORO\_ROTOR (N.m)

ANGPOS ROTOR (dea)

ANGPOS ROTOR (deg)

CO\_INDUCT\_VAL

150 200 250 300 350 400 450 500 550

600



- Flux 2D project: postprocessing
  - Torque and current

Step	Action
1	Click on [Curve] – [2D curve (I/O parameter)] – [New 2D curve (I/O parameter)]
2	Create the curve "TORQUE_AND_CURRENT"

Project Application Solving Data exchange Support Graphic	Curve Computation Advanced Display	y View Help	
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E Carateler/Quartery		. K Integral of 2D curve	
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- Flux 2D project: postprocessing
  - Torque and current



TORQUE\_AND\_CURRENT

#### Circuit / Current [CO\_VSOURCE]





- Flux 2D project: postprocessing
  - Power

Step	Action
1	Click on [Curve] – [2D curve (I/O parameter)] – [New 2D curve (I/O parameter)]
2	Create the curve for absorbed power and mechanical power

Project Application Solving Data exchange Support Graphic	Curve Computation Advanced Display	View Help	
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- Flux 2D project: postprocessing
  - Power



### ABSORBED\_POWER\_AND\_MECHANICAL\_POWER

- Flux 2D project: postprocessing
  - Coil currents

Step	Action
1	Click on [Curve] – [2D curve (I/O parameter)] – [New 2D curve (I/O parameter)]
2	Create the curve for the coil currents

Project Application Solving Data exchange Support Graphic	Curve Computation Advanced Displ	ay View Help
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	<u>fO</u>	
Clear		2



- Flux 2D project: postprocessing
  - Coil current





- Flux 2D project: solving
  - Save project

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## **V. CONCLUSION**



### CONCLUSION

- In this tutorial, the DC motor model is created by Flux Overlay.
- Three different analysis have been created to analyze the motor performance.



# **THANK YOU**

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