Created in COMSOL Multiphysics 5.5

Generator in 3D

Introduction

This example is a static 3D simulation of a generator comprising a rotor with permanent magnets. The center of the rotor consists of annealed medium carbon steel, which is a nonlinear ferromagnetic material which saturates at high magnetic flux density. The center is surrounded with several blocks of a permanent magnet made of samarium and cobalt, creating a strong magnetic field. The stator is made of the same nonlinear material as the center of the rotor, confining the field in closed loops through the winding. The winding (not included in the model) is wound around the stator poles. Figure 1 shows the generator with part of the stator sliced in order to show the winding and the rotor.

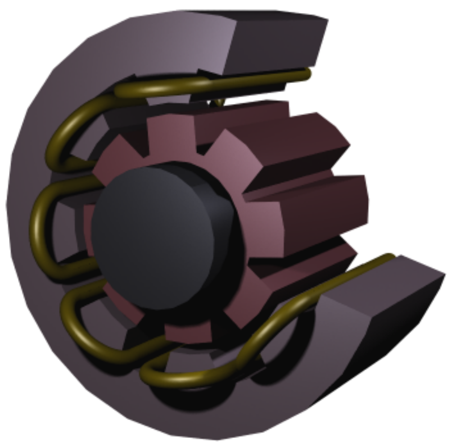


Figure 1: Drawing of a generator showing how the rotor, stator, and stator winding are constructed.

Model Definition

This model solves for the magnetic scalar potential, V_m, based on the assumption that currents can be neglected, which holds true when the generator terminals are open. The equation for V_m becomes

$$-\nabla \cdot (\mu \nabla V_m - \mathbf{B}_r) = 0$$

The stator and center of the rotor are made of annealed medium-carbon steel (soft iron), which is implemented in COMSOL Multiphysics as an interpolation function of the B-H curve of the material; see Figure 2.

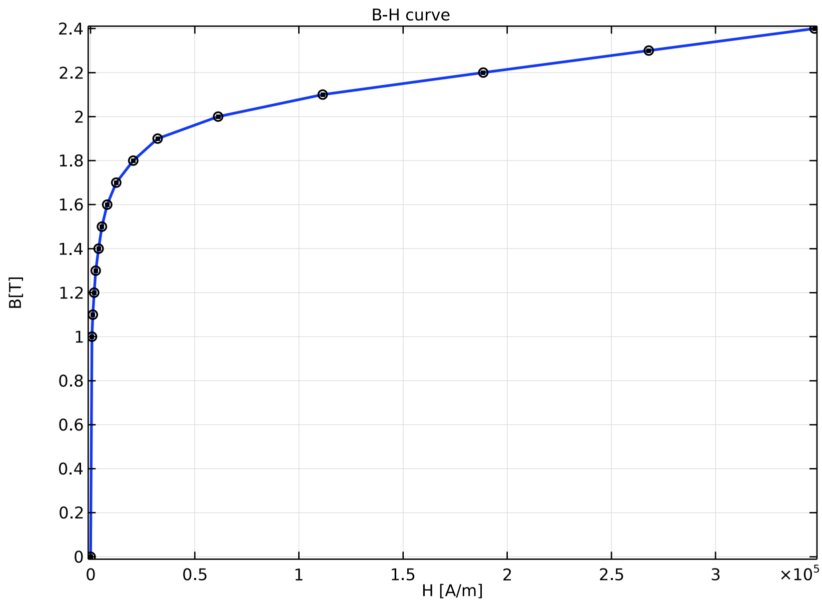


Figure 2: The norm of the magnetic flux, $|\mathbf{B}|$*, versus the norm of the magnetic field,* $|\mathbf{H}|$*, for the rotor and stator materials.*

Results and Discussion

Figure 3 shows the norm of the magnetic flux for a slice through a centered cross section of the generator. The plot also shows the streamlines of the magnetic flux. The starting points of the streamlines have been carefully selected to show the closed loops between neighboring stator and rotor poles. A few streamlines are also plotted at the edge of the generator to illustrate the field there.

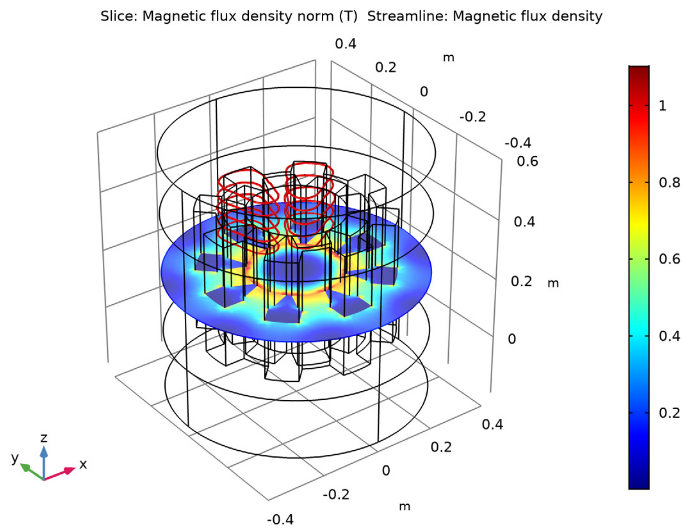


Figure 3: A combined slice and streamline plot of the magnetic flux density.

Application Library path: `ACDC_Module/Motors_and_Actuators/generator_3d`

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click **Model Wizard**.

MODEL WIZARD

1 In the **Model Wizard** window, click **3D**.

2 In the **Select Physics** tree, select **AC/DC>Magnetic Fields, No Currents>Magnetic Fields, No Currents (mfnc)**.

3 Click **Add**.

4 Click **Study**.

5 In the **Select Study** tree, select **General Studies>Stationary**.

6 Click **Done**.

GEOMETRY 1

Import 1 (imp1)

The geometry for this application is provided as a CAD file.

1 In the **Home** toolbar, click **Import**.

2 In the **Settings** window for **Import**, locate the **Import** section.

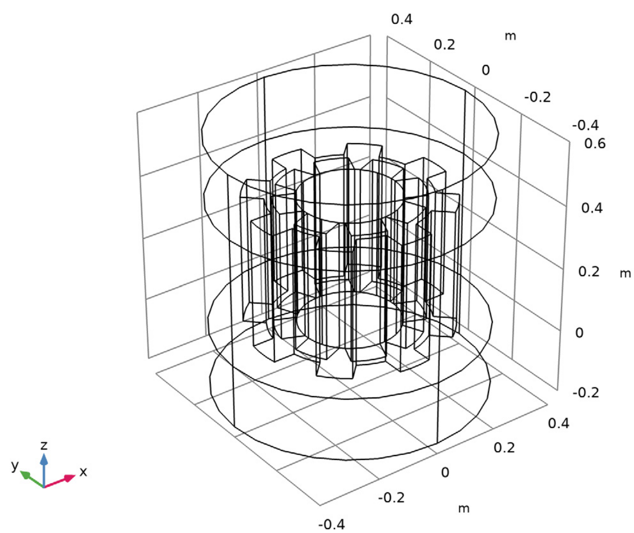
3 Click **Browse**.

4 Browse to the model's Application Libraries folder and double-click the file `generator_3d.mphbin`.

5 Click **Import**.

6 Click the **Wireframe Rendering** button in the **Graphics** toolbar.

7 Click the **Zoom Extents** button in the **Graphics** toolbar.



DEFINITIONS

Cylindrical System 2 (sys2)

In the **Definitions** toolbar, click **Coordinate Systems** and choose **Cylindrical System**.

ADD MATERIAL

1 In the **Home** toolbar, click **Add Material** to open the **Add Material** window.

2 Go to the **Add Material** window.

3 In the tree, select **Built-in>Air**.

4 Click **Add to Component** in the window toolbar.

5 In the tree, select **AC/DC>Soft Iron (Without Losses)**.

6 Click **Add to Component** in the window toolbar.

7 In the tree, select **AC/DC>Hard Magnetic Materials> Sintered NdFeB Grades (Chinese Standard)>N50 (Sintered NdFeB)**.

8 Click **Add to Component** in the window toolbar.

9 In the **Home** toolbar, click **Add Material** to close the **Add Material** window.

MATERIALS

Soft Iron (Without Losses) (mat2)

1 In the **Model Builder** window, under **Component 1 (comp1)>Materials** click **Soft Iron (Without Losses) (mat2)**.

2 Select Domains 2 and 7 only.

N50 (Sintered NdFeB) (mat3)

1 In the **Model Builder** window, click **N50 (Sintered NdFeB) (mat3)**.

2 Select Domains 5, 6, and 8–13 only.

3 In the **Settings** window for **Material**, locate the **Material Contents** section.

4 In the table, enter the following settings:

Property	**Variable**	**Value**	**Unit**	**Property group**
Recoil permeability	murec_iso ; murecii = murec_iso, murecij = 0	1	1	Remanent flux density
Electrical conductivity	sigma_iso ; sigmaii = sigma_iso, sigmaij = 0	0	S/m	Basic
Relative permittivity	epsilonr_iso ; epsilonrii = epsilonr_iso, epsilonrij = 0	1	1	Basic
Remanent flux density norm	normBr	`0.84[T]`	T	Remanent flux density

5 In the **Label** text field, type `Generic SmCo Magnet`.

MAGNETIC FIELDS, NO CURRENTS (MFNC)

Magnetic Flux Conservation 2

1 In the **Model Builder** window, under **Component 1 (comp1)** right-click **Magnetic Fields, No Currents (mfnc)** and choose **Magnetic Flux Conservation**.

2 Select Domains 2 and 7 only.

3 In the **Settings** window for **Magnetic Flux Conservation**, locate the **Constitutive Relation B-H** section.

4 From the **Magnetization model** list, choose **B-H curve**.

Magnetic Flux Conservation 3

1 In the **Physics** toolbar, click **Domains** and choose **Magnetic Flux Conservation**.

2 Select Domains 5, 9, 10, and 13 only.

3 In the **Settings** window for **Magnetic Flux Conservation**, locate the **Coordinate System Selection** section.

4 From the **Coordinate system** list, choose **Cylindrical System 2 (sys2)**.

5 Locate the **Constitutive Relation B-H** section. From the **Magnetization model** list, choose **Remanent flux density**.

6 Specify the **e** vector as

-1	r
0	phi
0	a

Magnetic Flux Conservation 4

1 In the **Physics** toolbar, click **Domains** and choose **Magnetic Flux Conservation**.

2 Select Domains 6, 8, 11, and 12 only.

3 In the **Settings** window for **Magnetic Flux Conservation**, locate the **Coordinate System Selection** section.

4 From the **Coordinate system** list, choose **Cylindrical System 2 (sys2)**.

5 Locate the **Constitutive Relation B-H** section. From the **Magnetization model** list, choose **Remanent flux density**.

Specify a reference level for the scalar magnetic potential by constraining the value at one point.

Zero Magnetic Scalar Potential 1

1 In the **Physics** toolbar, click **Points** and choose **Zero Magnetic Scalar Potential**.

2 Select Point 1 only.

The default **Magnetic Insulation** boundary condition applies in this case.

MESH 1

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Mesh 1**.

2 In the **Settings** window for **Mesh**, locate the **Physics-Controlled Mesh** section.

3 From the **Element size** list, choose **Finer**.

Free Tetrahedral 1

1 Right-click **Component 1 (comp1)>Mesh 1** and choose **Free Tetrahedral**.

2 Click **Build All**.

STUDY 1

1 In the **Model Builder** window, click **Study 1**.

2 In the **Settings** window for **Study**, locate the **Study Settings** section.

3 Clear the **Generate default plots** check box.

4 In the **Home** toolbar, click **Compute**.

RESULTS

3D Plot Group 1

In the **Home** toolbar, click **Add Plot Group** and choose **3D Plot Group**.

Slice 1

1. Right-click **3D Plot Group 1** and choose **Slice**.
2. In the **Settings** window for **Slice**, locate the **Plane Data** section.
3. From the **Plane** list, choose **XY-planes**.
4. In the **Planes** text field, type 1.
5. Click **Replace Expression** in the upper-right corner of the **Expression** section. From the menu, choose **Component 1>Magnetic Fields, No Currents>Magnetic>mfnc.normB - Magnetic flux density norm - T**.

Streamline 1

1. In the **Model Builder** window, right-click **3D Plot Group 1** and choose **Streamline**.
2. Select Boundary 78 only.
3. In the **Settings** window for **Streamline**, locate the **Coloring and Style** section.
4. Find the **Line style** subsection. From the **Type** list, choose **Tube**.
5. In the **3D Plot Group 1** toolbar, click **Plot**.
6. Click the **Zoom Extents** button in the **Graphics** toolbar.