Design of Magnetic Shielding for 600 MWh SMES

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Abstract

Superconductor Magnetic Energy Storage (SMES) systems are superconductor based inductor coils, which are capable of storing high energy. These coils carry large current which generates strong magnetic field. This generated magnetic field can cause interference with the devices around and also risk human safety. This paper discusses the preliminary design of superconductor based magnetic shielding to confine the magnetic lines of forces and reduce the leakage flux below the safety and interference limits. A magnetostatic analysis was carried out to understand the magnetic field variation with and without magnetic shielding. These studies help designing the suitable magnetic shields for SMES systems.

Introduction

Superconducting Magnetic Energy Storage (SMES) has high energy density storage capacity in comparison to conductor based energy storage systems and batteries. SMES are available in different geometries like solenoid and toroidal. Construction of solenoidal structure are easy but shielding is complex. On other hand, toroidal construction is complex but has low stray field. The stray magnetic field from SMES can cause electromagnetic interference and affect heart pacemakers. In this paper magnetic shielding for two solenoidal coils are discussed. These coils differ in dimension and thus, different shielding geometries are used. The coils with higher diameter to height ratio greater than are shielded with hemispherical dome whereas, conical shapes are used for ratio lower than 1. The flux density in solenodial coils is high at inside the coil and at the ends along the length. Accordingly, shielding geometry is selected. This paper primarily focuses on magnetostatic simulation with and without magnetic shield of SMES.

SMES specification

The two solenoidal coils of different dimensions are used for simulation is listed in Table 1. Two solenoidal coils are used for simulation. One is cylindrical solenoidal coil as shown in Fig 1 (a) and other is torus solenoidal coil as shown in Fig 1 (b).

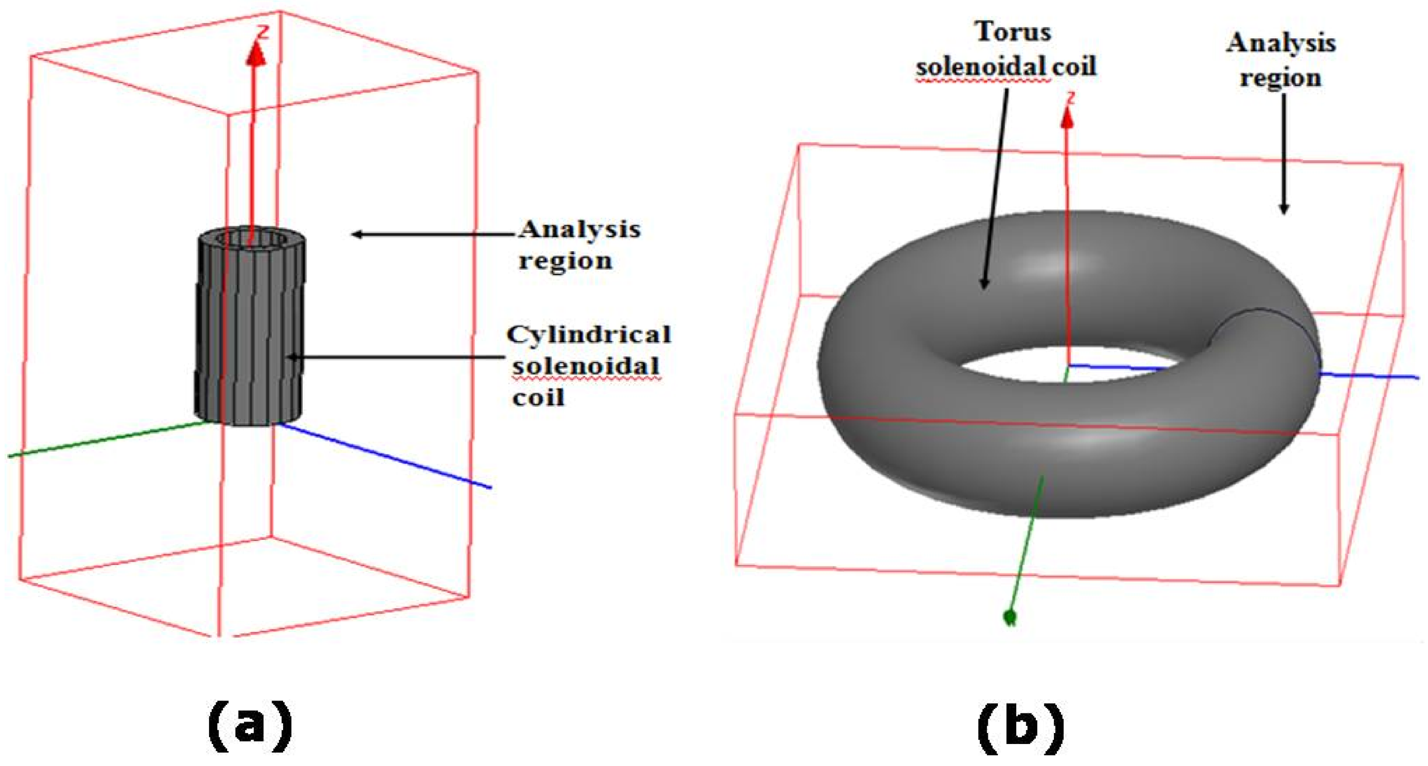

Figure 1: (a) A cylindrical coil (b) A torus coil

SMES FEM Analysis

Each of these coils have 6000 kAT (10 kA and 600 turns). The maximum flux density for cylindrical coil is 7.1 T and for torus coil is 7.9 T without any magnetic shielding. Fig. 2 (a) and (b) shows FEM based magnetostatic analysis for flux density distribution without magnetic shielding in 3-D space for cylindrical and torus solenoidal coils.

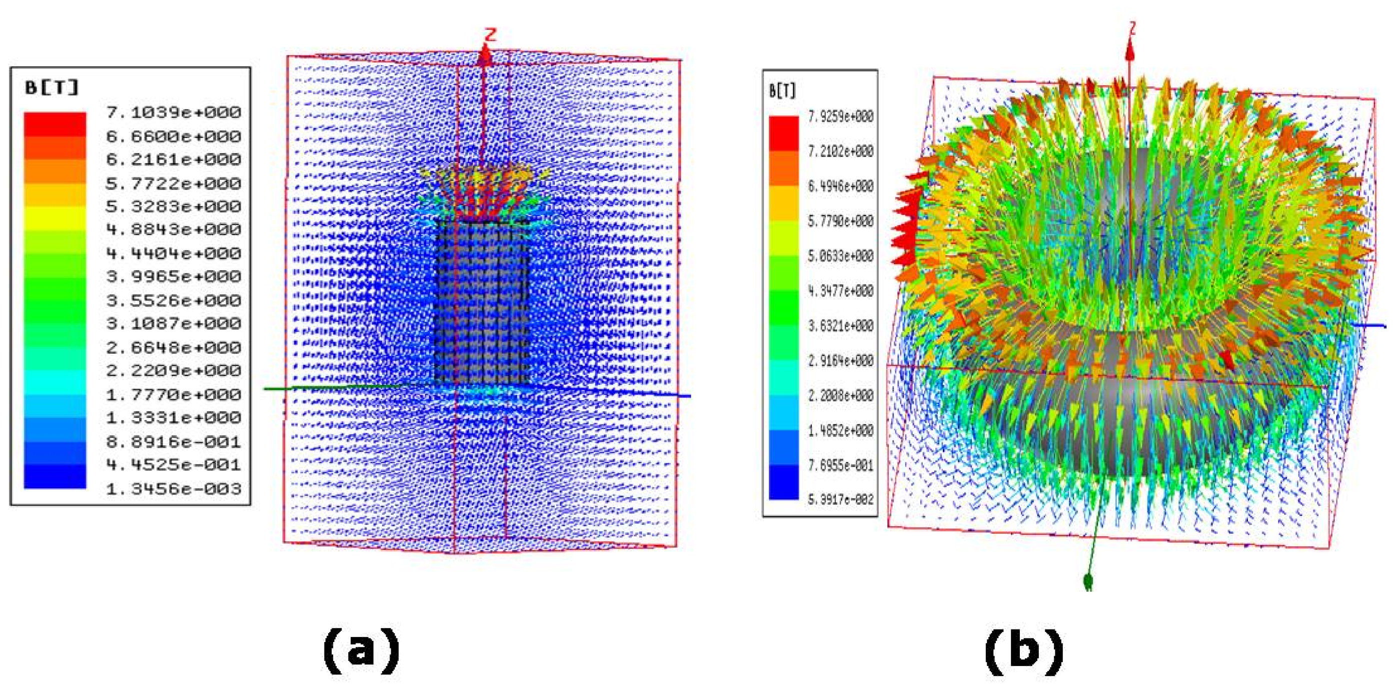

Figure 2: Magnetostatic analysis without magnetic shielding for (a) cylindrical coil (b) torus coil

FEM Analysis for Shielded SMES

Superconductor behaves like a perfect diamagnetic material in superconducting state. Due to virtue of this property, superconductor materials can be used for magnetic shielding. In general there are three different ways of magnetic shielding:

1. Passive shielding: It provides least reluctance path for completing the magnetic path, by using high permeability material like iron and mu metal.
2. Active shielding: An external coil is wounded on the energy storage coil and is excited externally, which opposes the field generated by energy storage device.
3. Superconductor shielding: Superconductor material behaves like a perfect diamagnetic material in superconducting state without any excitation. Thus, this property is widely considered for shielding SMES coil.

Fig. 3 (a) and (b) shows the schematic of cylindrical and torus solenoidal coil having magnetic shielding of conical and hemispherical shape respectively. The shape selection was done based on diameter to height ratio of SMES. The conical and hemispherical top and bottom magnetic shielding domes of superconductor material will reflect the magnetic flux lines. The adopted shapes will concentrate the magnetic fields in the confined region. Thus, the stray fields are limited to the boundary. This increases the flux density in the shielded area.

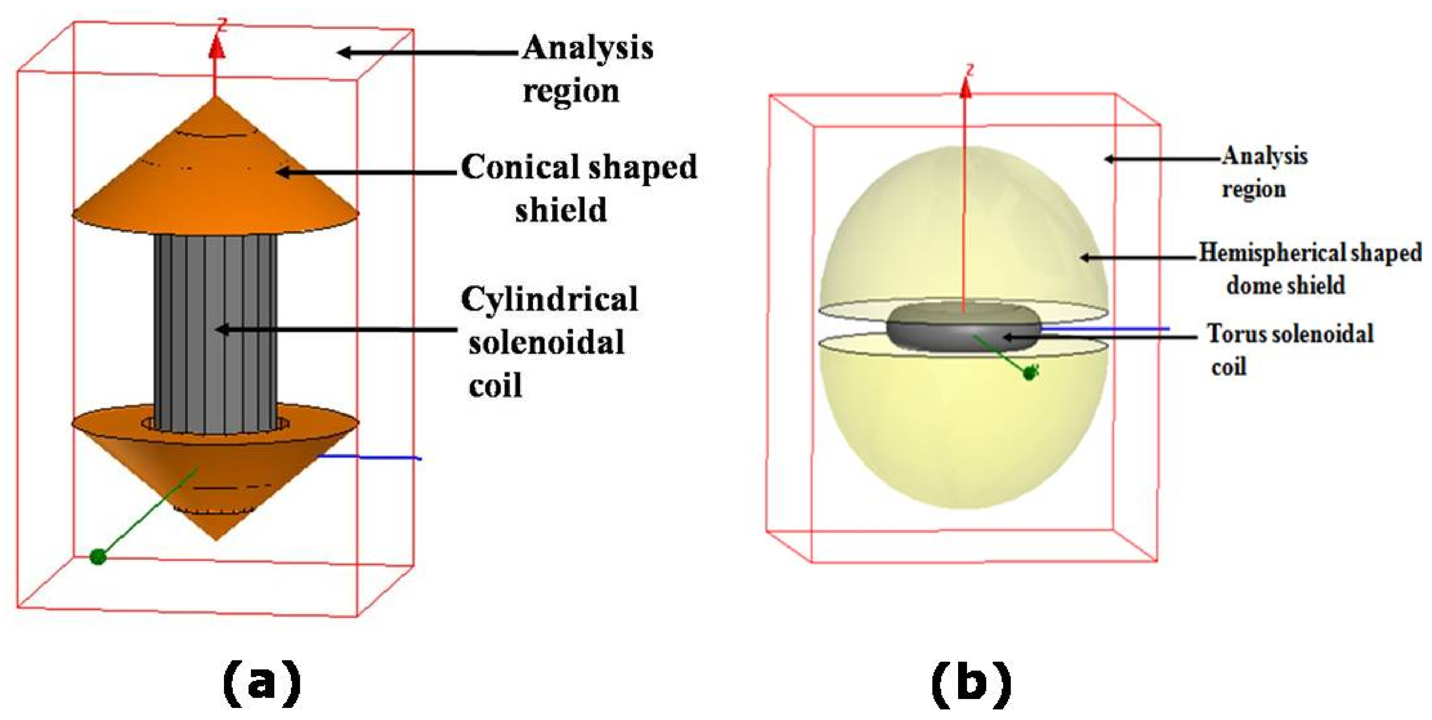

Figure 3: (a) A cylindrical coil with conical shaped shield (b) A torus coil with hemispherical shaped dome

Results and Discussions

Fig. 4 (a) and (b) shows FEM based magnetostatic analysis for flux density distribution with magnetic shielding in 3-D space for cylindrical and torus solenoidal coil. Due to conical magnetic shielding at the ends of cylindrical solenoidal coils, the maximum flux density reduced rom 7.1 T to 7.01 T. For hemispherical dome magnetic shield for Torus solenoidal coil as increased magnetic flux density from 7.9 T to 9.3 T. This indicates the hemispherical dome increases the flux density much higher in compared to conical domes because of reduce spacing between the domes. This increases flux density and also increases the electromagnetic forces. It also enhances the risk of quenching superconductor because of increase in magnetic flux density.

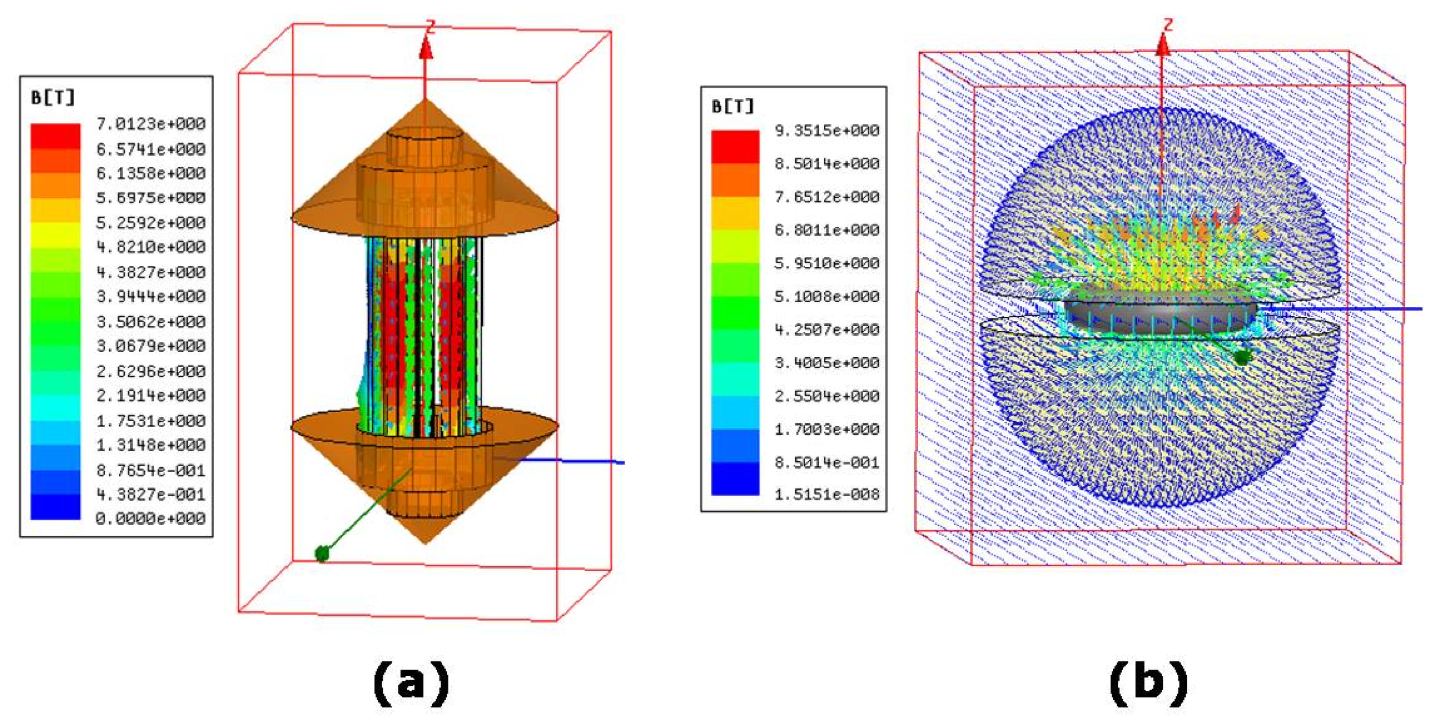

Figure 4: Magnetostatic analysis for (a) cylindrical coil with conical shaped magnetic shield (b) torus coil with hemispherical shaped magnetic shield

Conclusions

The preliminary magnetostatic studies for magnetic shielding of cylindrical and torus solenoidal coils were carried out. The simulation results indicate that the shape of magnetic shield affects the net flux density of SMES. The conical shape of shield was considered for cylindrical coil which had diameter to height ratio less than 1. The hemispherical dome was considered for diameter to height ratio greater than 1. Magnetostatic simulation for the later shielding shows the increased magnetic flux density from 7.9 T to 9.3 T. This increase in magnetic flux density can lead to quenching of superconductor also.

References

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