Analysis of Electromagnetic Behavior of Permanent Magnetized Electrical Machines in Fault Modes

M. U. Hassan[1], R. Nilssen[1], A. Røkke[2]
1.Department of Electrical Power Engineering, NTNU, Trondheim, Norway.
2.Rolls Royce Marine AS, Trondheim, Norway.

Introduction: Permanent Magnet Synchronous Machines (PMSM) as shaft generators is not new in marine vessels propulsion drive trains. Due to risk of fires in stator windings by internal faults, DNV GL requires PMSM to be electrically dead without losing propulsion for too long. This necessitates a novel design for on shaft PM generator with flux weakening capability. Using COMSOL Multiphysics®, a 3D model of Dual Rotor PMSM was modeled. The DR-PMSM has two rotors instead of one, with identical surface mounted magnets on both rotors. One of these rotors has the capacity to rotate with respect to the other, to reduce the flux by re-alignment of rotors.

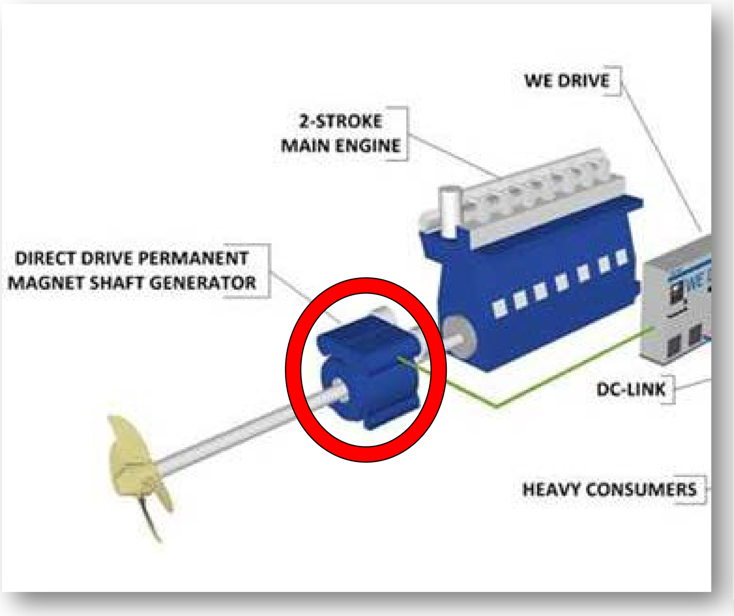

Figure 1.On shaft generator

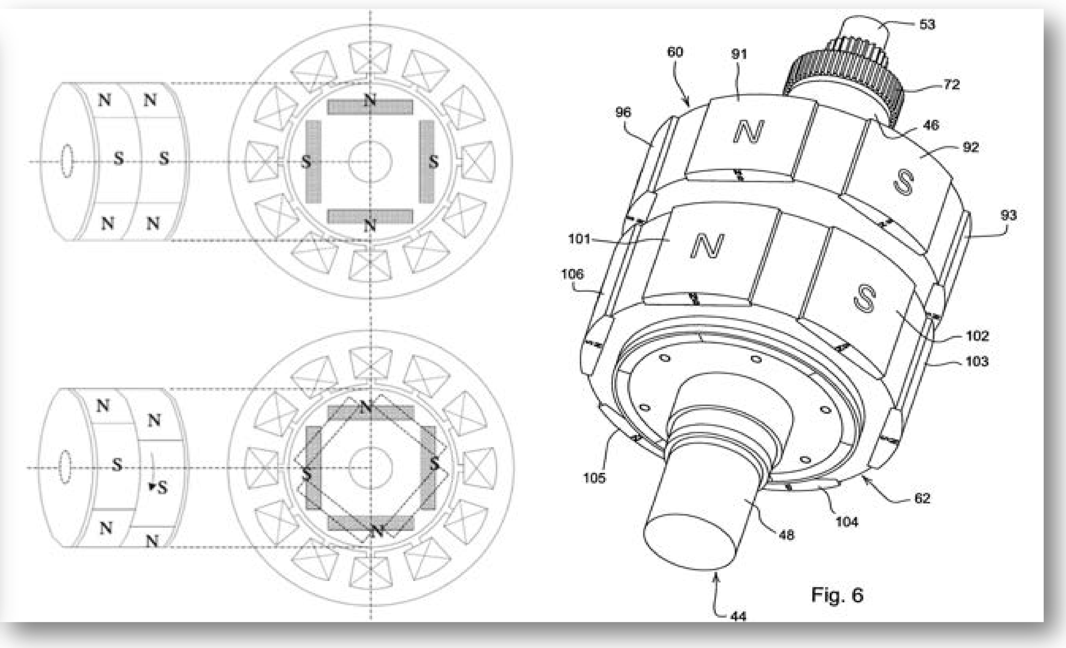

Figure 2.DR-PMSM construction

Computational methods: Various simulation were performed in order to study the DR-PMSM. The lamination were modeled using anisotropy of permittivity and conductivity in the stator core. A 2D model was also made to check the validity of the DR-PMSM machine. Following properties were checked in the 3D machine model of DR-PMSM:

1.Validity of the machine
2.Induced voltages in the coils
3.Forces acting on the rotor
4.Flux in the stator iron.

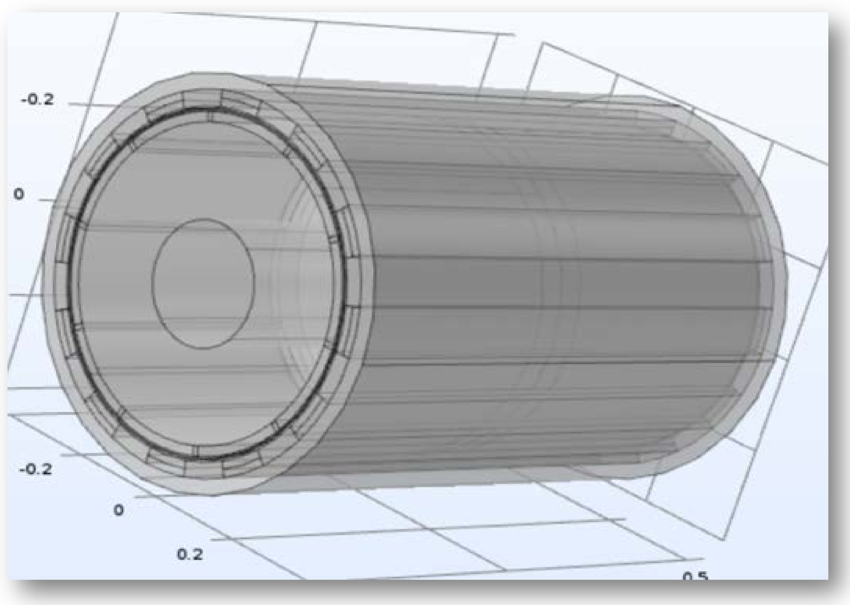

Figure 3. DR-PMSM 3D model

Results:

1. Validity of the machine: To confirm the 3D machine model validity, a 2D model of a conventional PMSM was also modeled. The power balance ($T_e\omega = V_aI_a + V_bI_b + V_bI_b$) for both the machine models were concluded to be similar.

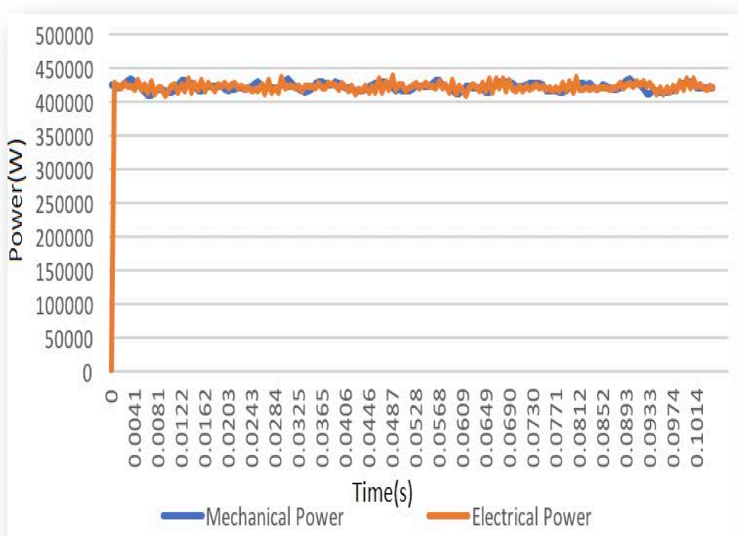

Figure 4. Power balance for DR-PMSM

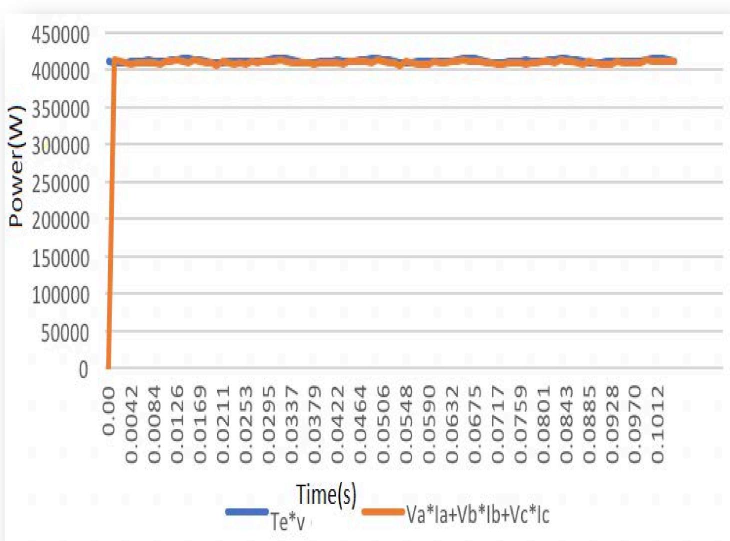

Figure 5. Power balance for conventional PMSM

2. Induced voltages in the machine: The back emf for different rotor position was calculated to check the flux weakening control.

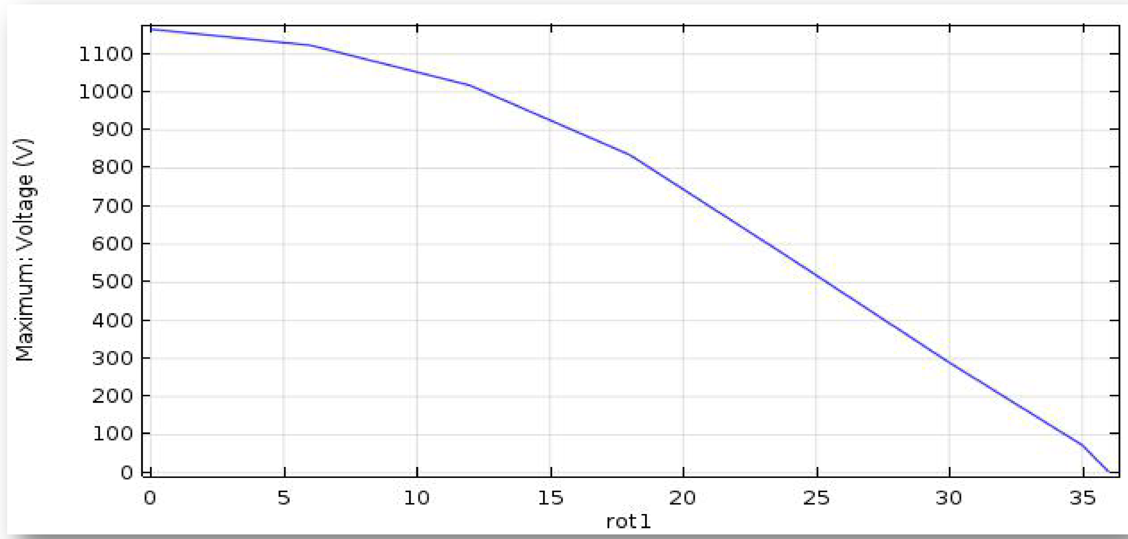

Figure 6. Voltages in Phase at various rotor positions

3. Forces: Due to the shifting mechanism, there are significant forces on the rotor. For this, axial torques on individual rotors and the stator are calculated in stationary conditions.

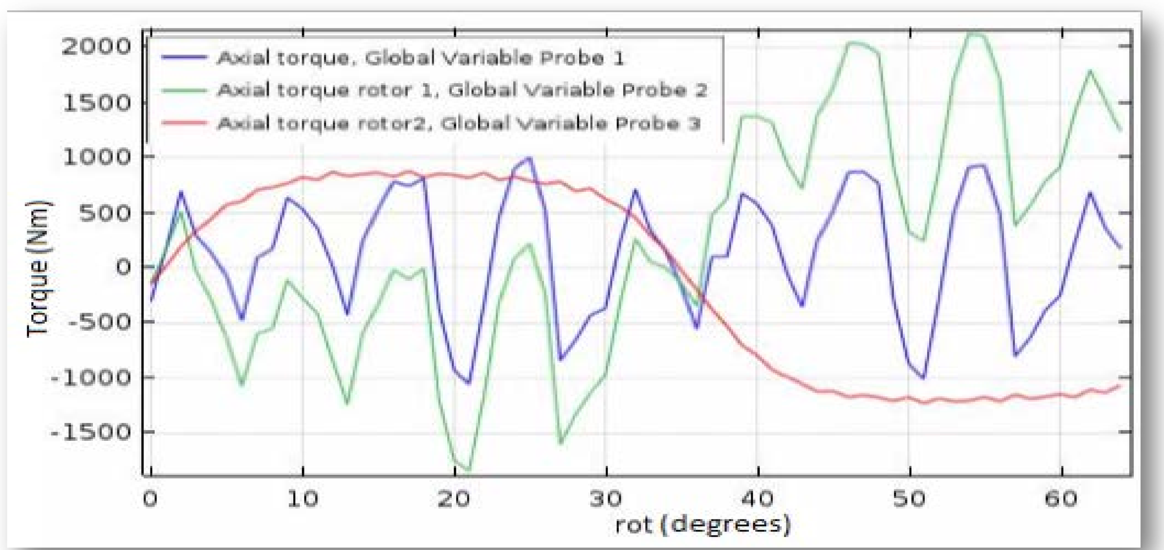

Figure 7. Axial torques on the rotor and the stator

4. Flux in the stator: The middle part of the stator has axial flux components which induce eddy currents when the machine is re-aligned. To mitigate this effect, the stator with a gap can be made for DR-PMSM.

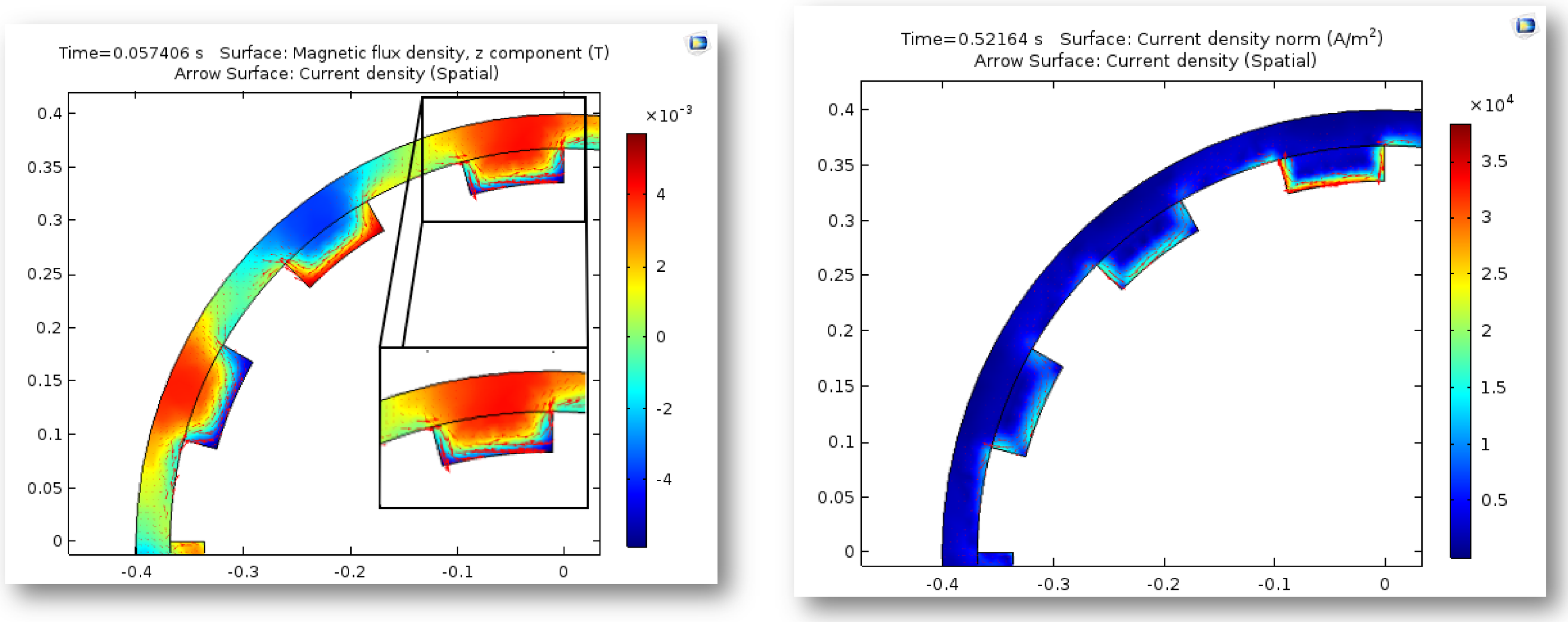

Figure 8. Eddy currents in the middle part of the stator

Conclusions:

1.The efficiency of DR-PMSM is similar to a conventional PMSM.

2.Induced voltages can be reduced to zero by the flux weakening mechanism in DR-PMSM.

3.The forces on the rotors due to the shifting mechanism can be minimized by reducing cogging in the machine.

4.Axial flux components in the machine induce certain hot spots in the middle part of the stator (between the gap of the two rotors), which should be further studied.