

# EENG 577 M5 Assignment 1: PM Generator

E. Hildenbrandt

D. Davis

J. Brownlee

11 February 2025

## Permanent Magnet Generator

### Part 1)

The machine cross-section consists of 6 permanent magnets making up the poles. The machine is radial, meaning that the magnets are arranged radially around the rotor. The schematic shows the a, b, and c phases of the Y-connected armature. The damping bars are illustrated as the shorted windings kd and kq. The shorted windings sd and sq represent the shorted collar which also acts as a damping circuit. In Figure 1a, for simplicity, the stator windings are drawn as one coil, but in the actual machine they would be many coils arranged sinusoidally with peaks at the location drawn [1]. Here we assume a 2-pole rotor for the schematic in Figure 1b.

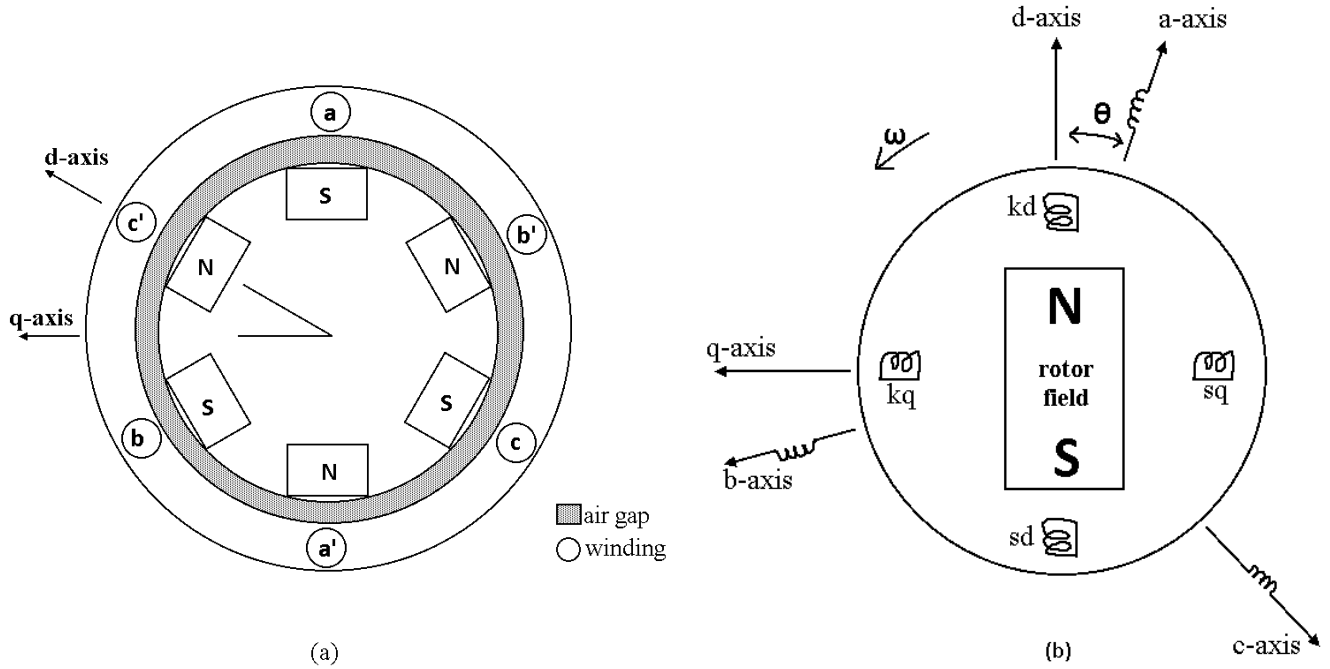


Figure 1: a) Machine Cross-Section. b) Machine Axes Schematic Diagram [2]

The state space model for a 6 pole 3 phase permanent magnet type synchronous machine is given below in the general form  $\dot{X} = AX + BU$ . The model neglects the effects from the damper bars, and the permanent magnetic is replaced with an equivalent field winding coil around the rotor with constant field current. This introduces a no-load phase to neutral back electromotive force vector on the armature phase winding with components  $e_a, e_b$ , and  $e_c$  [3]. The field winding current is constant and thus not considered as one of the state variables in Equation (1) [4]. We can calculate the values for A and B in given the resistance, self, and mutual inductance of the stator windings which results in values shown below.

$$\begin{bmatrix} \dot{i}_a \\ \dot{i}_b \\ \dot{i}_c \end{bmatrix} = - \begin{bmatrix} L_{sa} & L_{ma} & L_{ma} \\ L_{ma} & L_{sa} & L_{ma} \\ L_{ma} & L_{ma} & L_{sa} \end{bmatrix}^{-1} \cdot \begin{bmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{bmatrix} \cdot \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} L_{sa} & L_{ma} & L_{ma} \\ L_{ma} & L_{sa} & L_{ma} \\ L_{ma} & L_{ma} & L_{sa} \end{bmatrix}^{-1} \cdot \begin{bmatrix} v_a - E_m \cos(\theta - 0.46) \\ v_b - E_m \cos(\theta - 0.46 - 2\pi/3) \\ v_c - E_m \cos(\theta - 0.46 - 4\pi/3) \end{bmatrix} \quad (1)$$

$$A = -L^{-1} \cdot R$$

$$B = L^{-1}$$

$$A = \begin{bmatrix} -63.827 & 5.8025 & 5.8025 \\ 5.8025 & -63.827 & 5.8025 \\ 5.8025 & 5.8025 & -63.827 \end{bmatrix} \quad B = \begin{bmatrix} 6.7901 & -0.6172840 & -0.6172840 \\ -0.6172840 & 6.7901 & -0.6172840 \\ -0.6172840 & -0.6172840 & 6.7901 \end{bmatrix} \times 10^3 \quad (2)$$

## References

- [1] Stephen J. Chapman. (2005). Electric Machinery Fundamentals. McGraw-Hill.
- [2] A.A. Arkadan, and N.A. Demerdash, "Modeling of Transients in Permanent Magnet Generators with Multiple Damping Circuits Using the Natural abc Frame of Reference," IEEE Trans. On Energy Conversion, Vol. 3, No. 3, pp. 722-731, September 1988.
- [3] A.A. Arkadan EENG577 Class Notes, Colorado School of Mines.
- [4] A.A. Arkadan, N.A. Demerdash, J.G. Vaidya, and M.J. Shah, "Impact of Load on Winding Inductances of Permanent Magnet Generators with Multiple Damping Circuits Using Energy Perturbation," IEEE Trans. On Energy Conversion, Vol. 3, No. 4, pp. 880-889, December 1988.

## Appendix: Matlab

Calculate A and B Matrices

```
% M5 Assignment 1: PM Generator
Lsa = 150e-6;           %self inductance
Lma = 15e-6;            %mutual inductance
L = [Lsa, Lma, Lma;
     Lma, Lsa, Lma;
     Lma, Lma, Lsa];

rs = 9.4e-3;            %phase resistance
R = diag([rs rs rs]);

A = -inv(L)*R
B = inv(L)
```