

Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.685 Electric Machines

Problem Set 4

Issued September 23, 2013
Due October 2, 2013

Problem 1: Generate and plot a vee curve diagram for the turbogenerator you analyzed in Problem Set 3. This is a plot of armature current magnitude $|I_a|$ vs. field current I_f for *real* values of output power of 0, 200, 400, 600, 800 and 1000 MW.

Problem 2: This problem concerns a salient pole synchronous generator with the following parameters:

| | | |
|---|------|-----------------------|
| VA Rating | 150 | MVA |
| Voltage Rating | 13.8 | kV (line-line, RMS) |
| | 7967 | V (line-neutral, RMS) |
| D-Axis Synchronous Reactance | 2.5 | Ω |
| Q-Axis Synchronous Inductance | 1.5 | Ω |
| Stator Winding Phase Resistance | .009 | Ω |
| Field Winding Resistance | 1.0 | Ω |
| Magnetic Core Loss at Rated Voltage | 1.0 | MW |
| Field Current for Rated Voltage, Open Circuited (I_{fnl}) | 600 | A |
| Number of pole pairs (p) | 7 | |
| Stator Connection | | Wye |

1. To start, note that this machine will have a stability limit for operation at low field excitation (corresponding to high absorbed reactive power). For a round rotor machine this limit is reached at a torque angle of 90° , but this machine has saliency so you must determine the value of angle for which stability is reached. Compute and plot the angle and corresponding value of field current at the stability threshold for this machine, against real power. *Hint:* The stability limit is reached when the derivative of torque with respect to angle is zero. Since torque is proportional to real power, you can use the derivative of power with angle. For this part of the problem, ignore resistances and core loss.
2. Find the value of reactive power at the underexcited stability limit and plot $Q(P)$.
3. Find required field current for operation at rated power at unity power factor, and plot a torque/angle curve for operation at rated terminal voltage and that field current.
4. Now, considering the loss elements: armature resistance loss, core loss and field winding loss, calculate and plot machine efficiency over the range of $50MW < P < 150MW$ at unity power factor.

Problem 3: A particular salient-pole generator has inductances of:

$$L_d = 6\text{mH}$$

$$L_q = 4\text{mH}$$

$$L_0 = 1\text{mH}$$

Find the elements of the phase inductance matrix:

$$\begin{bmatrix} L_a & L_{ab} & L_{ac} \\ L_{ab} & L_b & L_{bc} \\ L_{ac} & L_{bc} & L_c \end{bmatrix}$$

as functions of rotor position ϕ . You may find it convenient to use the periodicity of the machine to reduce the number of calculations you need to do.

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