EE228 Laboratory #13
Synchronous Machine Torque and Terminal Characteristics

Purpose: Today we will investigate a synchronous machine operating as a synchronous motor and determine the effect on the terminal characteristics of varying the DC field winding current.

Data Collection

1. Identify on the face-plate of the synchronous machine the rated phase voltage, phase current, and speed (assume that the machine will be Y-connected

   $V_{as,rat}$ =_____ $I_{as,rat}$ =_____ N_m =_____

   Given the machine is rated for 60Hz, how many poles are there? _____

2. Connect the circuit shown below in Figure 1.
   a. Couple the synchronous machine to the dynamometer with the timing belt.
   b. Use the hand-held Fluke meter to implement ammeter 3 connected to the field circuit. Set it to measure DC current.
   c. Ensure that the polarity of the power analyzer voltmeters is correct.
   d. Set the synchronous machine field rheostat at its full CCW position (for maximum resistance).
   e. Set the power supply voltage control knob for 0V (zero field current)
   f. Close the switch located on the synchronous machine faceplate to complete the field circuit.
   g. Have the instructor verify your setup: _____

3. Turn on the power supply (the motor should be turning). Measure the speed with the dynamometer.

   $$N_{no-field} = _____$$

4. Gradually increase the DC voltage applied to the rotor and increase the field current from 0A to 400mA. Measure the speed with the dynamometer.

   $$N_{field} = _____$$

5. We are configured to measure the total three-phase real power using the two-wattmeter method. The sum of the two real power measurements gives us the total three-phase real power (this value is also available via the wattmeter). The power factor angle is determined by the following:

$$\tan\phi_{PF} = \sqrt{3}\frac{[W_2 - W_1]}{[W_1 + W_2]}$$

6. For load torque values of $T_L = 0, 0.2, 0.4, 0.6, 0.8$ N-m, complete the following table (*note we will collect the no-belt data at the conclusion of the lab*). For this level of excitation, the machine is **underexcited** and will appear inductive (the voltage leading the current). Compute the power factor angle ϕ_{PF} for each data point.

T_L (N-m)	V_1 (Vrms)	I_1 (Arms)	W_1 (W)	W_2 (W)	$P_{3\phi}$ (W)	ϕ_{PF} (deg)
No Belt						

7. Reduce the load torque to zero. Adjust the field winding resistance to produce a field current of 700mA. In a similar manner, complete the following table for $T_L = 0, 0.2, 0.4, 0.6, 0.8, 1.0$. If W_2 is smaller than W_1, this indicates that the machine is overexcited and appears capacitive (current leads the voltage). Again, the no-belt data will be collected later.

T_L (N-m)	V_1 (Vrms)	I_1 (Arms)	W_1 (W)	W_2 (W)	$P_{3\phi}$ (W)	ϕ_{PF} (deg)
No Belt						

8. Reduce the load torque to zero. Decrease the field voltage to zero. De-energize the power supply. Carefully (have the instructor) reach behind the faceplate and remove the timing belt. Close the faceplate.

9. Re-energize the power supply. Adjust the field voltage to produce a field current of 700mA. Measure and record the data in the table above.

10. Adjust the field resistance to provide a field current of 400mA. Measure and record the data in the first table. Obviously, the difference between the $T_L = 0\,N-m$ measurements and the no-belt measurements represent the friction losses of the belt drive (which are appreciable in this setup). Calculate them here

    $P_{belt,0.4A}$ =_____ $P_{belt,0.7A}$ =_____

11. Next, we will examine how the magnitude of the stator current and the power factor vary with field excitation at no-load. Reduce the voltage control knob to zero. De-energize the power supply. Adjust the field resistance full CW for its minimum value.

12. Re-energize the power supply. Adjust the variable voltage control knob to provide field currents of approximately 100mA, 200mA, 300mA, 400mA, 500mA, 600mA, 700mA, and 800mA (if the current meter acts whacky, reduce the voltage down and bring it up again). Record the data in the following table.

13. If possible, hone in on the value of I_F that minimizes the stator current magnitude and provides unity power factor. This is termed normal excitation. Record the value here:

    $I_{F,norm}$ = _____

14. Reduce the voltage control knob to zero. De-energize the power supply. Disconnect the cabling and return it to the appropriate rack. Proceed to the questions at the end of the lab.

I_F (ADC)	I_1 (Arms)	W_1 (W)	W_2 (W)	$P_{3\phi}$ (W)	ϕ_{PF} (deg)

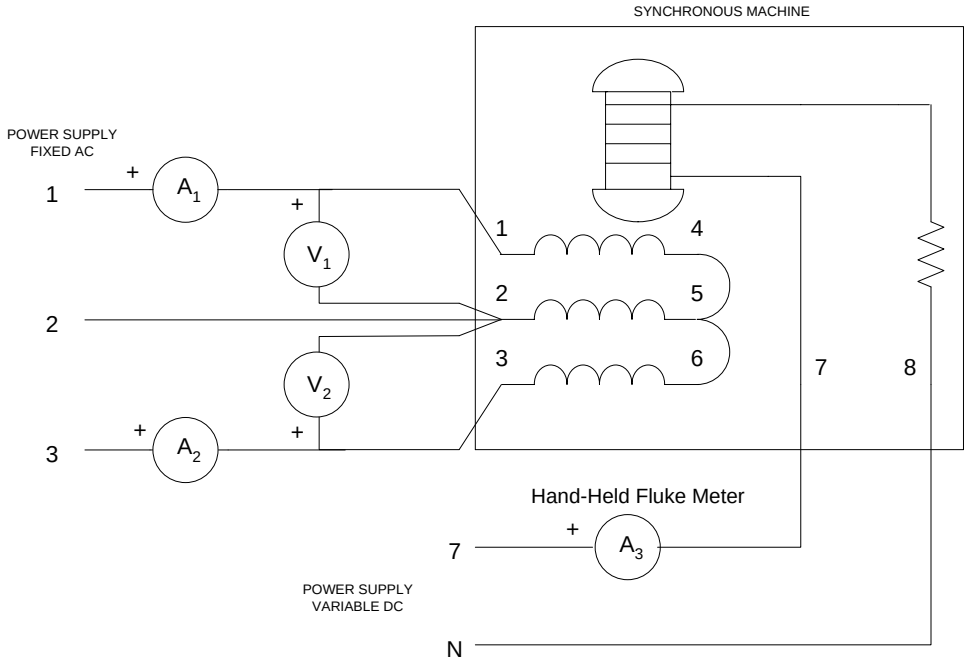

Figure1. Two Wattmeter Configuration

Questions

1. Calculate the efficiency of the motor at 0.8N-m for the two field current settings. Re-calculate the efficiency by first subtracting the losses produced by the belt drive (Note, the mechanical power out is found by multiplying torque in N-m times speed in *rad/s)*

2. For the data points at 0.8N-m and assuming the terminal voltage is the reference phasor (at zero degrees), find the phasor value for the phase current $\tilde{I}_{as}$. Also, determine the line-to-neutral voltage $\tilde{V}_{as}$.

3. Given that $r_S = 12.6\Omega$ and $X_S = 120\Omega$, for the 0.8N-m data sets, calculate the excitation voltage $\tilde{E}_a$ (both magnitude and angle).

4. Since $\left|\tilde{E}_a\right| = \dfrac{L_{sf} I_F \omega_e}{\sqrt{2}}$, use your data from step #3 to derive two estimates for the parameter L_{sf}.

5. Sketch, in the same figure below, the variation of I_1 (magnitude of line current) with I_F and the variation of the power factor (value, not angle) with I_F.

6. Have a great day!