ECE 470 POWER SYSTEMS I

Lab # 2 Per-unit Representation of Power System Elements

The objective of this lab is to model a synchronous machine, a Y-Δ transformer, and a load in pu calculations and to use this model to predict load and voltage levels.

PRE-LAB

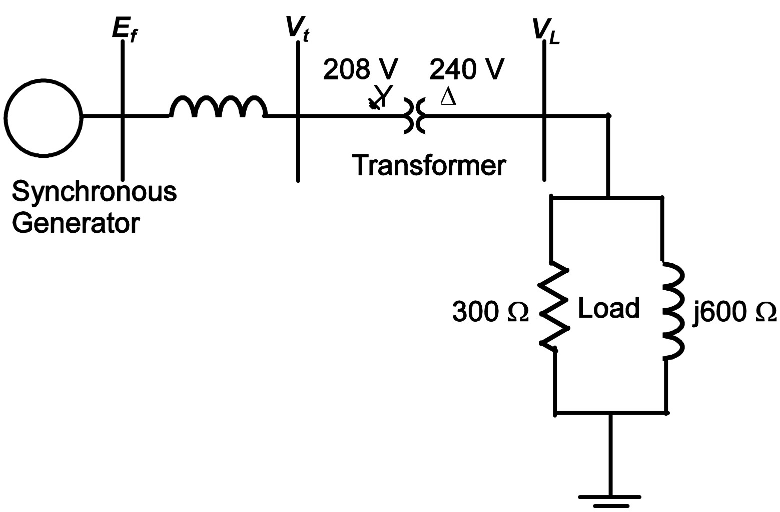
Complete this before starting the lab

Review the lab and lecture material from Machines & Power (ECE370) which specifies how to measure the series impedance of transformers. Also review the material in chapter 7 of Yamayee & Bala that deals with the measurement of the synchronous reactance of generators, this involves dividing the rated open-circuit voltage by the rated short-circuit current. Complete the drill exercise on the back of this page and confirm you have the correct answer.

For the circuit shown below, devise circuit diagrams that will measure the following:

a) Line voltage and line current at the load and the generator terminals.

b) The real and reactive power drawn by the load. Use the Yokagowa power meter and oscilloscope for this.



LAB PROCEDURE

Get your circuit approved before starting

The lab bench should be arranged with two synchronous machines mounted on the bedplate. One machine will be run as a motor, driving the other machine as a generator. Use the variable 3ϕ supply to run the motor.

Measure the synchronous reactance of the generator; do this by measuring the OCC and SCC, then divide the rated open-circuit voltage by the corresponding short-circuit current. Its resistance can be neglected (you may want to confirm this with an ohmmeter).

Measure the winding resistance and leakage reactance of the transformer viewed from the X winding, when both sets of X and H windings are in series.

The output of the generator goes through the transformer, being stepped up to 240 V **line-to-line**. This means that the X windings need to be in series on the Y side, while the H windings will also be in series on the Δ side.

The load is a parallel Y-connected 300Ω resistance and 600Ω inductive reactance. This should draw approximately 215 VA @ 0.9 lag pf when the load voltage is 240 V.

Using base values of 200VA, 240V in the load circuit, determine the values of E_f (unsaturated and saturated), the corresponding values of I_f and V_t needed to supply the load @ 240 V.

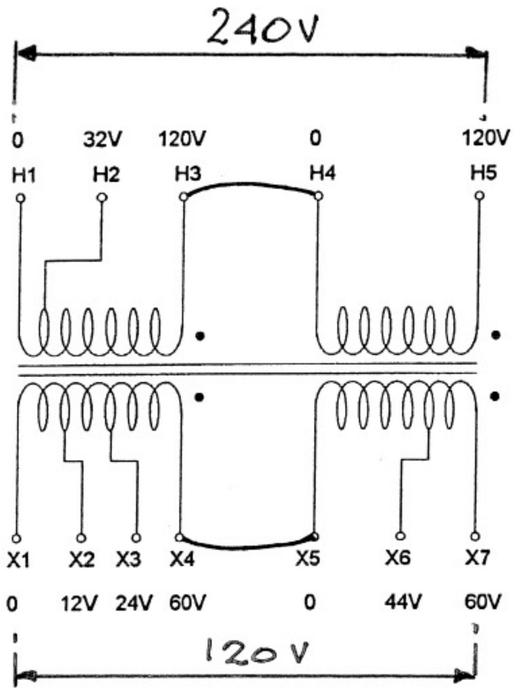
Set the generator excitation current so that the open-circuit voltage is equal to the saturated value of E_f. Re-connect the load, measure and compare V_t and V_L with the predicted values.

Drill Problem

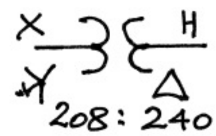
a) A 14kV/1.4kV transformer is comprised of three single-phase units connected Y-Δ. Each unit is rated 3 MVA 8kV/1.4kV and had the following Short-circuit data for tests performed on the hv side: 567.5 V, 375 A, 28.1 kW. Determine the winding resistance and leakage reactance.

b) A 14 kV, 9MVA synchronous generator has a synchronous reactance of 16.17 ohm. This generator and the transformer from part (a) are to be used to supply a load of 9 MVA @ 0.9 lag pf. at 1.4 kV. Work on a base of 9 MVA and 1.4 kV in the load circuit and determine the magnitudes of the excitation and terminal voltages (kV line) of the generator.

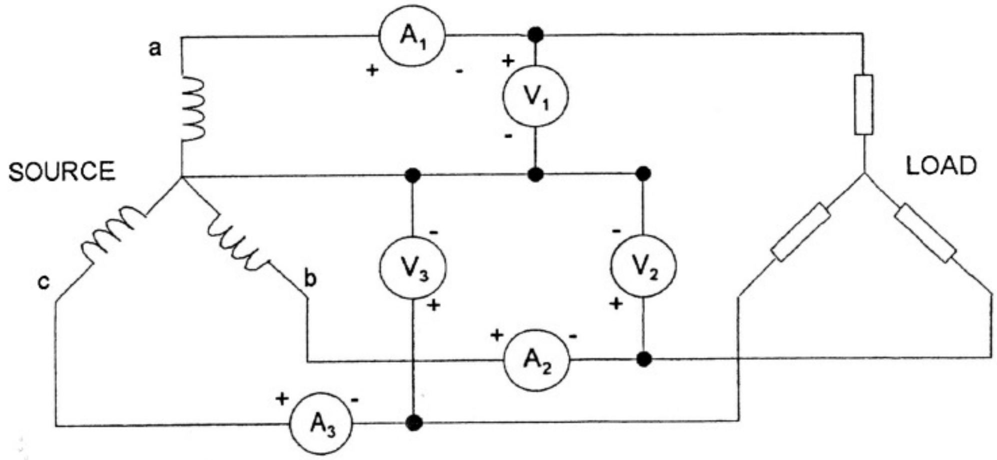
TRANSFORMER CONNECTIONS



WHEN THE 'X' WINDINGS ARE CONNECTED IN WYE AND THE 'H' WINDING ARE CONNECTED IN DELTA THE TRANSFORMATION IS 208V : 240V



THREE-PHASE WATTMETER CONNECTIONS



SERIES 100 OPERATING INSTRUCTIONS

MODEL SM-100-3 SYNCHRONOUS MACHINE

GENERAL:

The SM-100-3 is a three-phase, four-pole machine consisting of a wye/delta stator and a quadrature rotor having a DC field winding and a damper winding. A three-pole circuit breaker and a IND START-SYN C RUN switch are provided in the terminal box. Ratings follow:

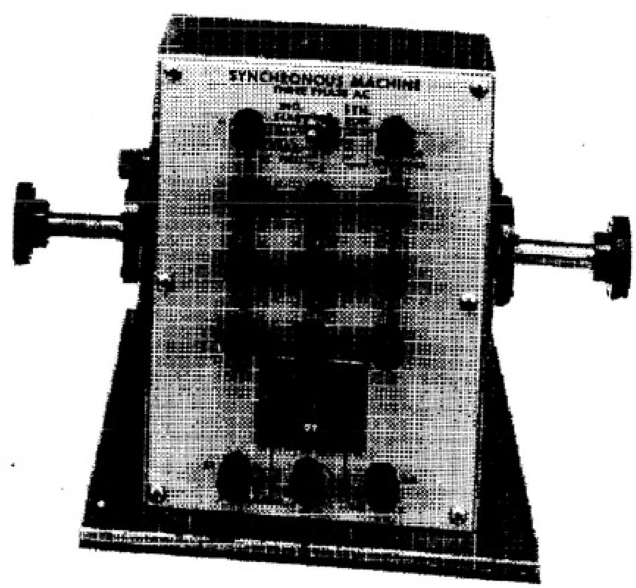
SPECIFICATIONS:

SM-100-3 MOTOR & ALTERNATOR:

Speed -	1800 RPM
Voltage -	208/120 V-3ϕ-4W
Temperature Rise - (from Ambient)	40 °C (104 °F)
Insulation -	Class B
Rating -	Continuous

CIRCUIT BREAKERS:

Type of Operator -	Rocker
No. of Poles -	Three
Overload Type -	Thermal
Trip Rating -	1.7 Amps
Reset Method -	"OFF" to Reset



ALTERNATOR:

Power -	120 Volt-Amp.
Load Current -	0.2 Amps
Field Excitation -	Separate 1.6 Amps

MOTOR:

Horsepower -	1/3 HP
Current -	1.7 Amps
Frequency -	60 Hz.

OPERATION (SYNCHRONOUS MOTOR):

The proper connections for operation of the SM-100-3 as a synchronous motor are shown in Figure 1. With the switch in the SYN RUN position, energize the variable DC supply and adjust the output voltage from zero up to the value which causes 1 amp to flow through the rotor. Return the switch to the IND START position and start the motor by pushing in the circuit breaker button. When the motor reaches no load speed, move the switch to the SYN RUN position. The rotor will then synchronize with the line and the motor will be running at exactly 1800 RPM. Used to demonstrate the various characteristics of synchronous motors.

OPERATION (ALTERNATOR):

The proper connections for operation of the SM-100-3 as an alternator are shown in Figure 2. With these connections made and the switch in the SYNC RUN position, drive the alternator at 1800 RPM with a suitable prime mover. Energize the DC voltage supply and increase the supply's output to increase the alternator's output voltage to the desired value. Push the circuit breaker's button in to connect the alternator's output to the load. Used to demonstrate the characteristics of a polyphase alternator of the stationary armature type. It may also be used as the loading device when testing the various motors.

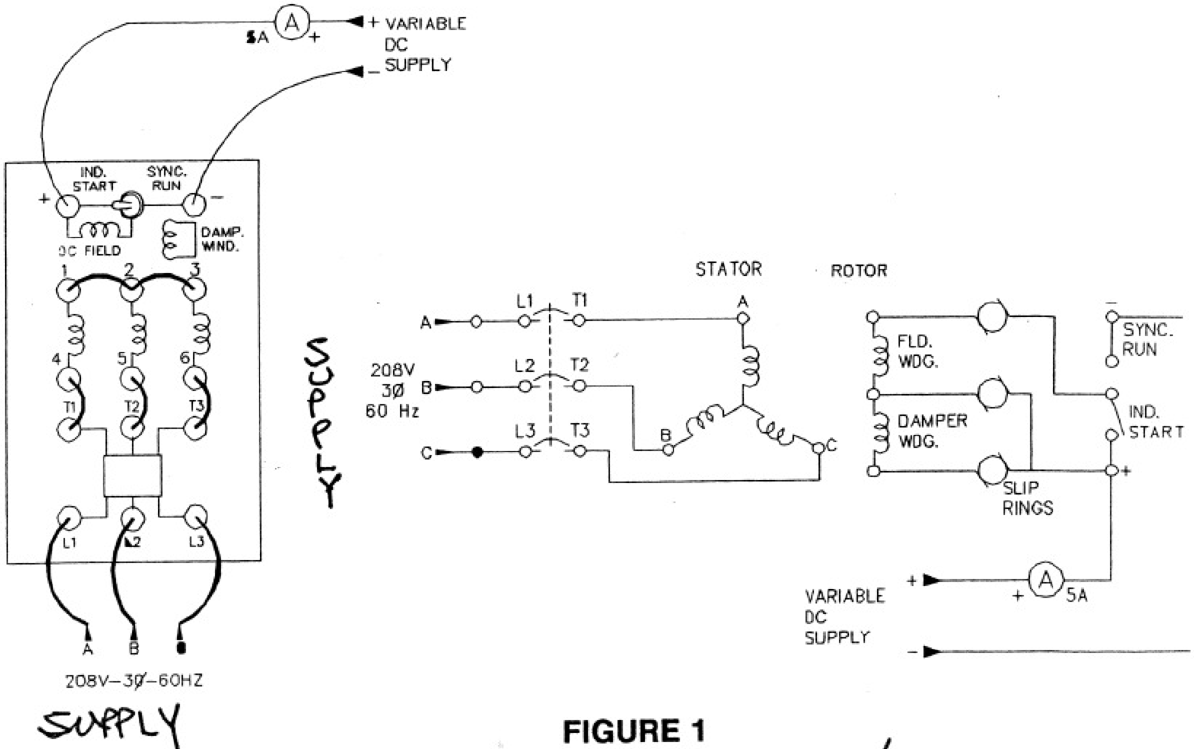


FIGURE 1

SYNCHRONOUS MACHINE (MOTOR)

Hampden ENGINEERING CORPORATION
MANUFACTURERS OF EQUIPMENT FOR EDUCATION AND INDUSTRY
P. O. BOX 563, EAST LONGMEADOW, MASSACHUSETTS 01028-0563

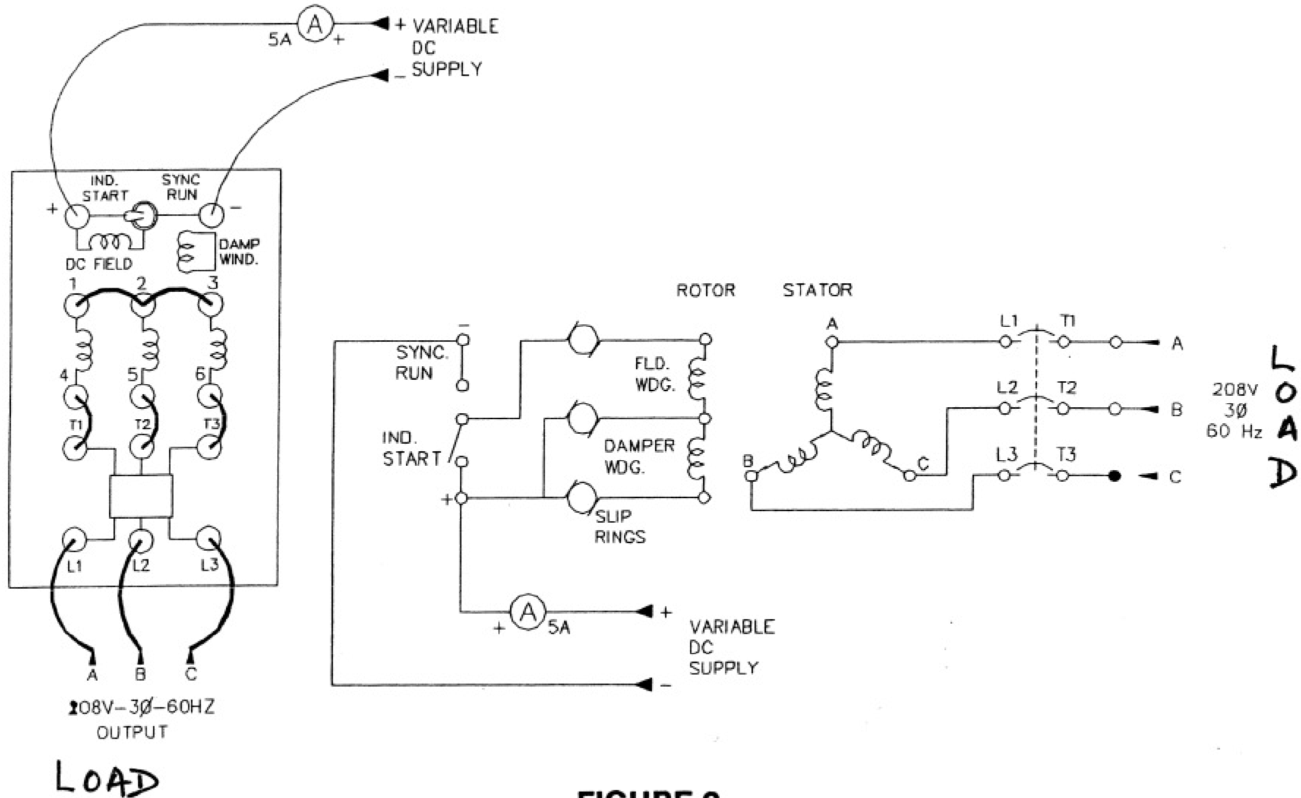


FIGURE 2

SYNCHRONOUS MACHINE (GENERATOR)