

## ECE 410L

# Electrical Machines and Energy Conversion Laboratory Manual



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**An Electrical Machines and Energy  
Conversion Laboratory Manual**  
Second Edition

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*by*

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## Preface

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This manual is meant for students at the junior and/or senior level enrolled in an electrical engineering program. Students should have had calculus and ordinary differential equations courses. Ideally the students should have taken an electromagnetic course, if not, then, the second college physics should suffice. This textbook manual became an idea after several years of teaching, researching, consulting and studying the area of electrical machines.

Our student population has changed dramatically. The classic methods of learning and teaching have changed as well. The main reason for all this, in my judgment, is the introduction of computers in our everyday life and professional life as well. We have reached the point that if it cannot be simulated, then it is not possible to have a correct answer. Partially, faculty has created this situation with the encouragement in the use of simulation packages since the very first courses in the electrical engineering program. This is not all bad. With the right direction we can use those simulations as corroboration of the experimental results obtained by pure "brain power."

In technical areas such as electrical machines, the material has become classic. Only recently we have experienced the revival of this area due to the expansion of power electronics and motor control, adjustable speed drives, space exploration and industrial control

The intent of this manual is to bridge the gap between lecture, homework, design projects and simulation. We bring a unique way to teach this material and that is that in each lab we have a "hands on" experiment that must be done from beginning to end in a way that industry would have it done. Also, we are attempting to create each experiment as a "stand alone" lab in a way that practicing engineers and students alike can self-study the material.

Finally, our ultimate goal is to have the students realize that there is a level of thinking required to learn this material. Once they reached this level, the material becomes fun and easy.

## Acknowledgements

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This manual is an updated version of the previous Lab Manual prepared by Professor Bruno Osorno. Author would like to thank Professor Osorno who wrote the first edition of this manual at 2005. This manual is prepared based on the new equipment in the lab and feedback from generations of students that took those courses and went through the pain to learn the material without a manual and had to rely in my handwritten notes.

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**LABORATORY SAFETY**

The students' acceptance of safety and health as part of every project will be enhanced if an atmosphere is created in which they feel free to correct each other and to point out deficiencies on the part of the faculty and staff directly to them. It must be absolutely clear that students have the right and the responsibility to identify unsafe actions, procedures or conditions without jeopardizing their grade in the laboratory or any other course.

**Recommended General Safety Rules:**

The following safety rules are recommended for general use. The Laboratory Director may modify this list to meet specific requirements. Electrical shocks can kill or maim an individual instantaneously. Therefore, extreme care must be taken when working with electrical equipment and circuits.

1. "Horseplay" is hazardous and will not be tolerated.
2. No student may work alone in the laboratory at any time so that in case of an emergency there will be someone to be able to call for help as well as disconnect the power supply to the bench.
3. All students should be familiar with the locations of all power supply switches.
4. An electrical circuit should never be energized before it has been completely wired and rechecked. The power supply should be disconnected before any changes are made to a circuit.
5. When taking meter readings of an energized circuit, use only one hand. This eliminates an arm-chest-arm path for current to flow. Current levels of a few milliamperes flowing through the heart can be lethal.
6. Shoes must be worn in the laboratory. Preferably, the shoes should be rubber soled or with electrically insulated soles.
7. All students should make certain that their hands and work areas are dry before beginning any laboratory exercise.
8. Do not work on a wet floor.
9. Shirts or blouses are required in the laboratory.
10. Each student must know the use and location of all first aid and emergency equipment (including fire extinguishers) in and near the laboratory room(s).
11. Be certain of the conditions of the equipment and the dangers present before working with a piece of equipment.
12. Worn or frayed extension cords or those with broken connections or exposed wiring must not be used. All electrical devices must be grounded before they are turned on.
13. Never rely on safety devices such as fuses, relays, interlock mechanisms, grounding wires to protect you.
14. Never remove a grounding prong of a three wire input plug.
15. Do not work on a cluttered bench. Place bookbags and coats/jackets on safe locations away from the circuits and equipment.
16. No portion of a student's body, hair, or clothing should come in contact with any part of an energized circuit.
17. You must concentrate on the tasks at hand, and irrelevant conversations are discouraged.
18. No deviation from approved equipment operating procedures is permitted.
19. All laboratory aisles and exits must remain clear and unblocked.
20. The instructions on all warning signs must be read and obeyed.

21. Good housekeeping must be practiced in the laboratories, shops, and storage areas. Eating, drinking, use of all tobacco products, gum chewing, and application of makeup are prohibited in the laboratories, shops, and storage areas.
22. Glass breakage and malfunctioning instruments or equipment should be reported to the Teaching Assistant or Laboratory Director immediately.
23. All injuries, accidents, and "near misses" must be reported to the Laboratory Director.
24. No tools, supplies, or any other items may be tossed from one person to another.
25. Casual visitors to the laboratory are to be discouraged and must have permission from the Teaching Assistant or Laboratory Director to enter. All visitors and invited guests must adhere to all laboratory safety rules. Adherence is the responsibility of the person visited.

## LAB #1 "FARADAY'S LAW"

### INTRODUCTION

The objective of this experiment is to demonstrate Faraday's law. We will observe in the oscilloscope the voltage induced in a coil by a magnetic flux. This voltage is the result of the movement of a magnet next to a coil.

### PROCEDURE A

- (1) Connect the diagram shown below
- (2) Set your oscilloscope to observe the alternating signal.  
Hint: Use the X-Y mode, First press trigger source and the press x-y plot button.
- (3) Move the permanent magnet back and forth in front of the coil.
- (4) Take a snapshot from the scope screen and include it in your report.

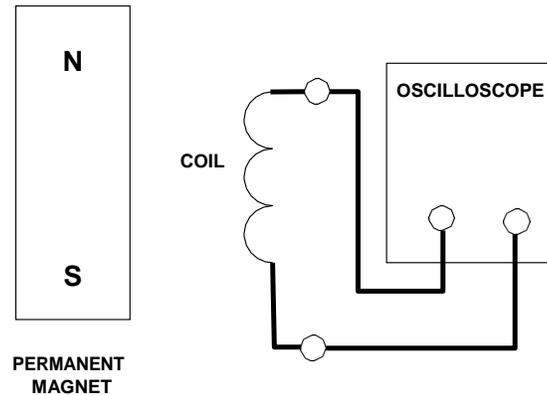


Figure 1.1

### PROCEDURE B

- (1) Connect the diagram shown below.
- (2) Apply approximately  $v(t) = 20\cos(377t + \phi)$  [volts] to coil number 1. (Use the single-phase AC output in power supply. First measure the output voltage and then apply to the coil.)
- (3) Using the oscilloscope measure the voltage induced in the coil. Find the frequency of the signal.
- (4) Insert the iron core (plunge) and observe what happens to the voltage.

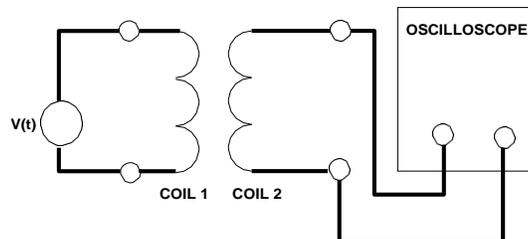


Figure 1.2

**REPORT**

- (1) Copy and paste your snapshot photos taken from signals generated in your oscilloscopes screen. Indicate what they are.
- (2) In part A. What happens to the voltage induced and its corresponding frequency when you move the magnet faster and closer to the coil? Is the frequency a function of the rate of change of flux (speed)?
- (3) In part B. What happens to the voltage induced when you separate the coils even more? Is the frequency affected by the separation?

What happened to voltage and frequency when you put the coils closer together than before? Why?

What happens to the voltage and frequency when you insert the plunge? Why?  
Elaborate on your conclusion using the relevant electromagnetic equations.

- (4) Explain the use of Faraday's Law in part A and in part B of this experiment. Be explicit.

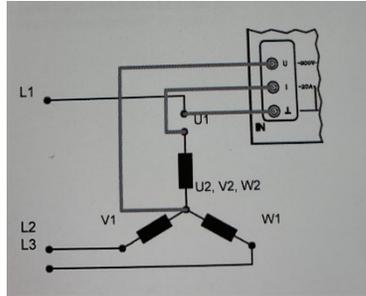
**LAB #2**  
**“THREE PHASE POWER AND POWER FACTOR MEASUREMENT”**

**INTRODUCTION**

The objective of this experiment is to measure and calculate active power, reactive power and power factors for three phase resistive, inductive and capacitive load banks.

**PROCEDURE PART A**

- (1) Connect the circuit shown in the diagram below. Connection to Lucas\_Nuelle Wattmeter is shown in the gray box for the Y balanced load.



- (2) Apply about 10 to 15 volts rms, then measure line-line voltage, line current, power factor and three phase active/reactive power for three different load cases as below in Y connection

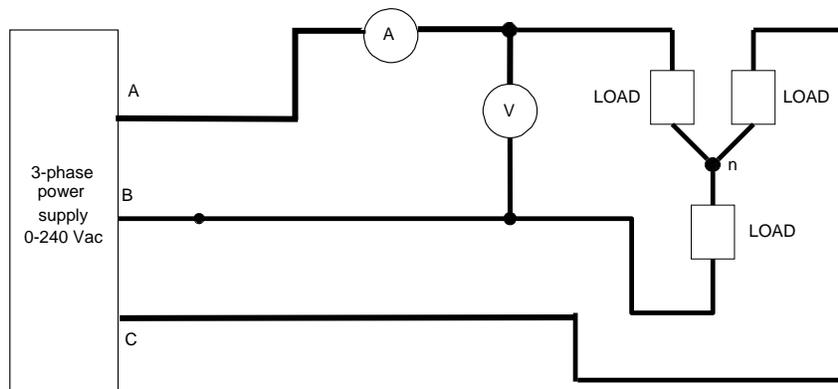
Run your experiment for three different load cases:

- (a) Mainly Resistive.
- (b) Mainly Capacitive.
- (c) Mainly Inductive

- (3) Repeat experiment number (2) for delta connection.

**REPORT (for each load)**

1. Create a table with two major columns for Experimental vs calculated results.
2. Include all calculations based on the resistor, capacitor and inductor power factors
3. Calculate and compare the power factor in two different ways.
4. Calculate and compare the  $Q_{3\phi}$  two different ways.
5. Calculate and compare the  $P_{3\phi}$  two different ways.



### LAB #3 “AIR-CORE AND FERROMAGNETIC HYSTERESIS LOOP”

#### INTRODUCTION

The objective of this experiment is to demonstrate the physical existence of “hysteresis loops” in air and iron cores. We will use a single phase transformer to obtain the iron core hysteresis loop, and a pair of coils to obtain the air core hysteresis loop.

#### PROCEDURE PART A: (air core)

- (1) Connect the diagram shown in Figure 3.1 with air core.
- (2) Apply AC voltage (approx. 20 volts)
- (3) Put second coil together with the first one.
- (4) Adjust oscilloscope until the flux and current curves appear.
- (5) Use X-Y channel to obtain the hysteresis loop.

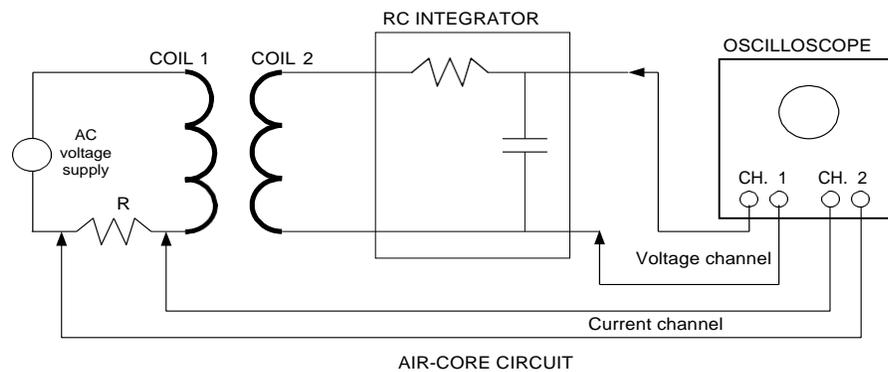


Figure 3.1

#### PROCEDURE PART B: (iron core)

- (1) Connect the diagram shown Figure 3.2 with iron core.
- (2) Apply approximately 100 volts.
- (3) Repeat steps 4 and 5.

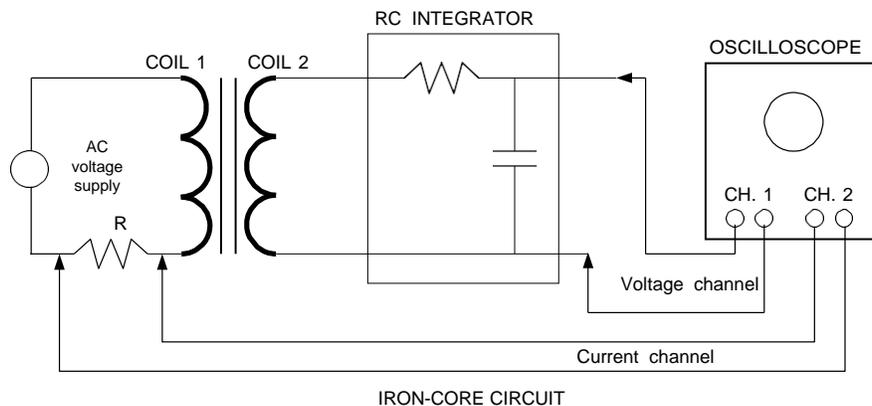


Figure 3.2

## REPORT

- (1) Draw, approximately, the signals generated in your oscilloscope. Indicate what they are. Be thorough.
- (2) In part A. Why is the hysteresis loop linear? What does the slope mean?
- (3) In part B. Why is the hysteresis loop nonlinear?
- (4) What is the main harmonic content (other than the fundamental) in the current signal?
- (5) What is its frequency?
- (6) Identify, approximately, the voltage at which saturation of the iron occurred.

**LAB #4**  
**“OPEN CIRCUIT AND SHORT CIRCUIT TESTS IN TRANSFORMERS”**

**INTRODUCTION**

In this lab experiment we are going to obtain the values of the parameters of the approximate equivalent diagrams of transformers.

**PROCEDURE PART A:** (open circuit test)

- (1) Connect diagram in Figure 4.1.
- (2) Start applying voltage from 0 to approximately 120 volts.
- (3) Obtain readings for;  $P_{oc}$ ,  $I_{oc}$ ,  $V_{oc}$  and then turn off the voltage supply.

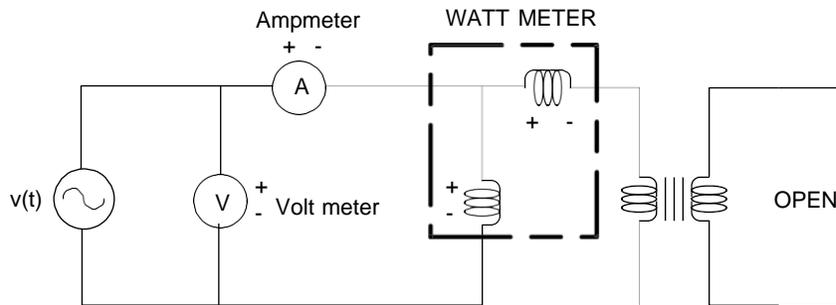


Figure 4.1

**PROCEDURE PART B:** (short circuit test)

- (1) Connect the diagram in Figure 4.2.
- (2) Start applying voltage from 0 to approximately 10% of the rated voltage.
- (3) Obtain readings for  $P_{sc}$ ,  $I_{sc}$ ,  $V_{sc}$  and then turn off the voltage supply

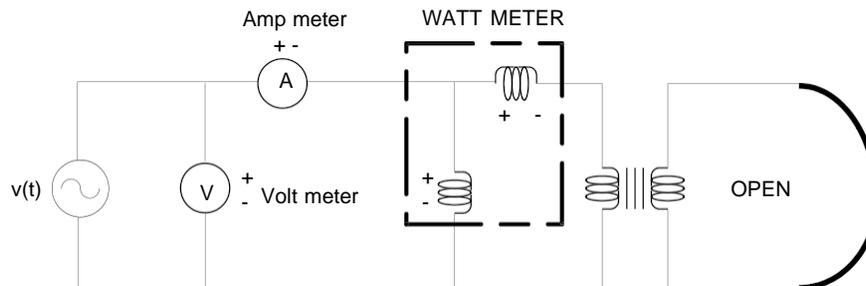


Figure 4.2

## REPORT

In your report, be sure to include all the calculation details as well as the followings (**in table form**):  
(Show all calculations step by step)

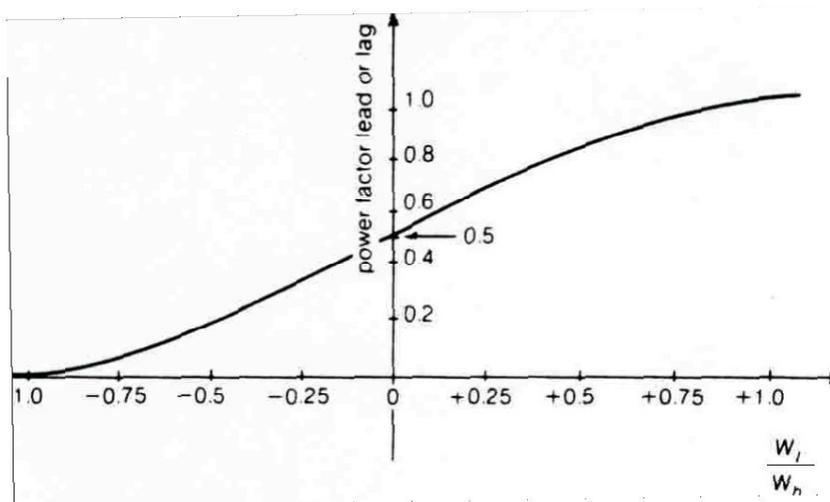
- Open circuit power factor.
- Excitation current.
- Magnetizing current.
- Open circuit admittance.
- Magnetizing reactance.
- Resistance of the core.
- Equivalent impedance.
- Equivalent reactance.
- Short circuit power factor.
- Draw two approximate equivalent diagrams with as much information as you can. One referred to the primary, and the other referred to the secondary.

**TABLE 1 (OPEN CIRCUIT TEST)**

$P_{oc} [W]$	$I_{oc} [A]$	$V_{oc} [V]$	$R_c [\Omega]$	$X_m [\Omega]$	$I_\phi [A]$	$I_c [A]$	$I_m [A]$	$\cos \Phi_{oc}$ (Leading or Lagging)

**TABLE 2 (SHORT CIRCUIT TEST)**

$P_{sc} [W]$	$I_{sc} [A]$	$V_{sc} [V]$	$R_1 [\Omega]$	$X_1 [\Omega]$	$R_2 [\Omega]$	$X_2 [\Omega]$	$\cos \Phi_{sc}$ (Leading or Lagging)



**LAB #5**  
**“EQUIVALENT DIAGRAMS, %VR, and  $\eta$  OF TRANSFORMERS”**

**INTRODUCTION**

In this experiment calculate the full load Voltage Regulation (VR) and efficiency for both equivalent diagrams. (i.e. %VR and  $\eta$  for the equivalent diagrams, referred to the primary and for the one referred to the secondary).

**CALCULATE USING MATLAB:**

- (a) The values of EP and ES induced by the equivalent mutual flux. (0.8 pf lagging)
- (b) The primary current at 0.8 power factor lagging.
- (c) The primary voltage when the transformer delivers rated load at rated secondary voltage.
- (d) Draw the equivalent diagrams with as much information as you can. (Include currents and voltages).
- (e) Efficiency of the transformer at full load and 0.8 pf lagging, 1.0 pf, 0.8 pf leading.
- (f) %VR at full load at 0.8 pf lagging 1.0 pf and 0.8 pf leading.

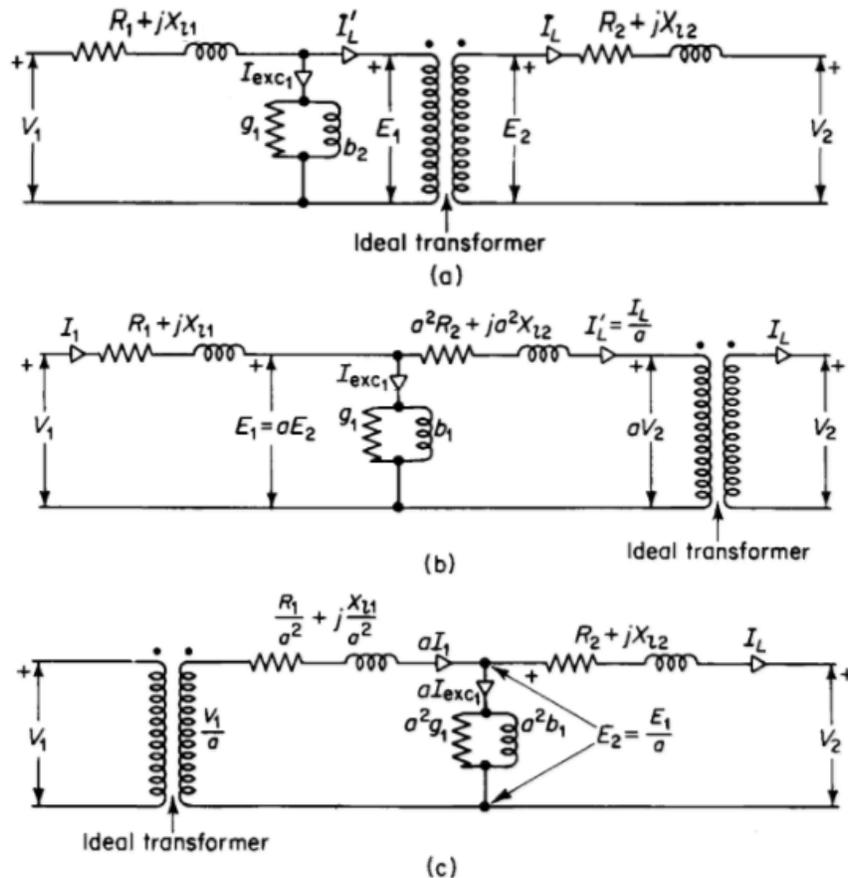


Figure 5.1. Exact equivalent circuits of a transformer: (a) Actual transformer equivalent circuit (b) Equivalent circuit referred to the primary (c) Equivalent circuit referred to the secondary

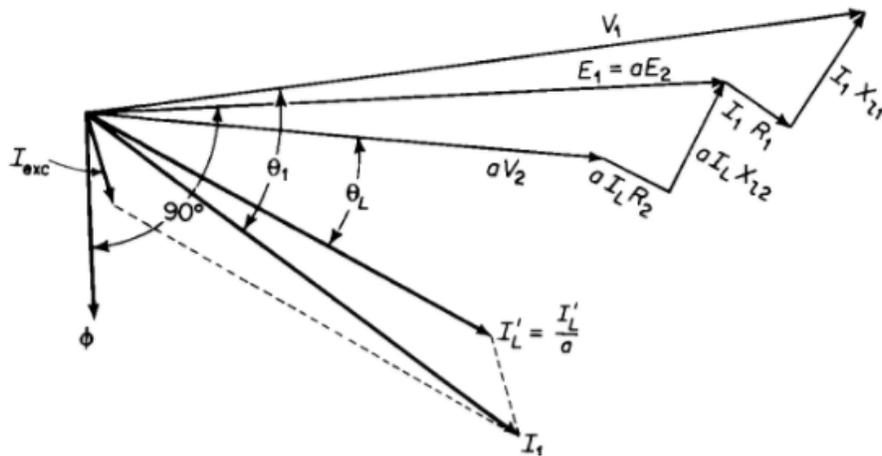


Figure 5.2. Phasor diagram for the exact equivalent circuit referred to the primary (Figure 1 (b))

The constants of a 150-kva, 2400V/240V, 60 Hz transformer are as follows:

- Resistance of the 2400V winding  $R_1 = 0.216 \Omega$
- Resistance of the 240V winding  $R_2 = 0.00210 \Omega$
- Leakage reactance of the 2400V winding  $X_{11} = 0.463 \Omega$
- Leakage reactance of the 240V winding  $X_{12} = 0.00454 \Omega$
- Exciting admittance on the 240V side  $Y_{exc} = 0.0101 - j0.069 \text{ mho}$

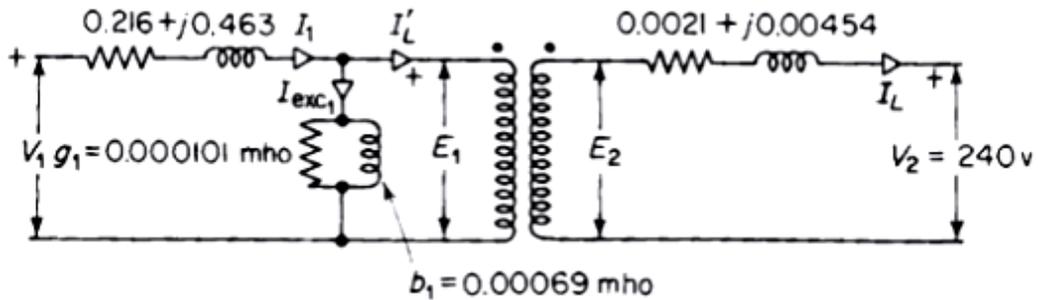


Figure 5.3. Equivalent circuit for transformer of example.

**LAB #6**  
**“PROGRAM TO DETERMINE TRANSFORMER EFFICIENCY”**

**INTRODUCTION**

Using the data obtained in the previous experiment, you are being asked to write a program to calculate the efficiency and the maximum efficiency for your transformer.

**EXPERIMENT**

Write a program in *Matlab* to calculate the efficiency of the transformer used in the laboratory. Next page shows the flowchart for this program.

**INPUT**

Used the flowing data to run your program, and check that it runs properly.

$$S_{\text{Transf}} = 10\text{Kva} \qquad \frac{2200\text{ V}}{220\text{ V}} \qquad f=60\text{Hz} \qquad P_{\text{SC}} = 204\text{W}$$

$$P_{\text{OC}}=133\text{W} \qquad V_{\text{SC}} = 95\text{V} \qquad I_{\text{SC}} = 4.54\text{A}$$

***Constant power factor 0.85 lagging***

**OUTPUT**

The output of the program must have the following columns and format:

LOAD (kW)	P <sub>CU</sub> (kW)	P <sub>C</sub> (kW)	P <sub>Losses</sub> (W)	P <sub>in</sub> (kW)	η

The entry LOAD [kW] must decrease from 120% to 0% in steps of 5%. Determine (using Matlab) the value of maximum efficiency and its corresponding load value.

**REPORT**

- (1) For your report, plot “η vs. LOAD”
- (2) Plot P<sub>CU</sub>[W] vs. LOAD [kW], and in the same graph P<sub>C</sub> [W] vs. LOAD.
- (3) Finally, repeat the whole experiment using the data from your laboratory’s transformer and 0.85 pf lagging.

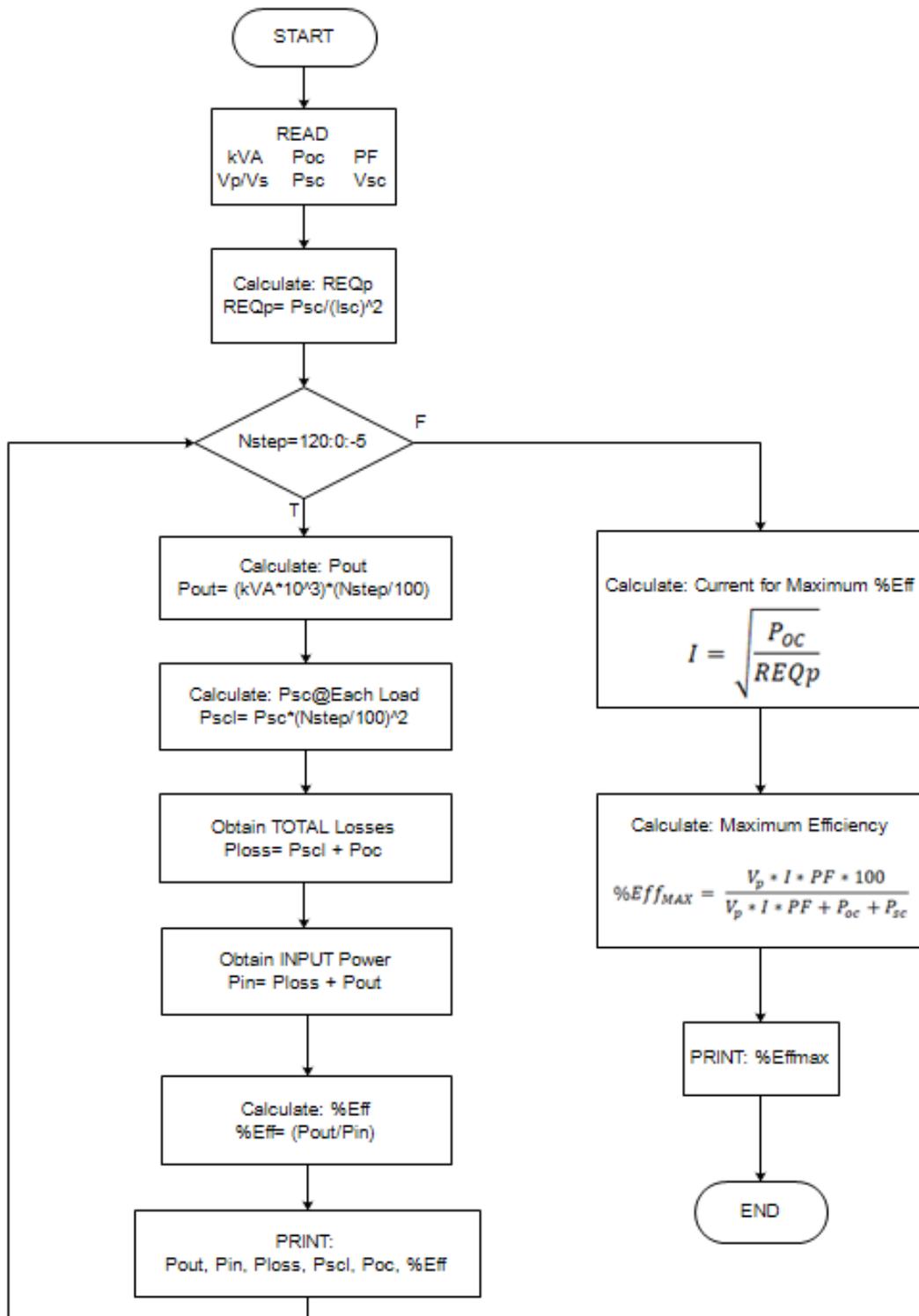


Figure 6.1

## LAB #7 "THREE PHASE TRANSFORMERS"

### INTRODUCTION

In this experiment you are being asked to use the three phase connections studied in class.

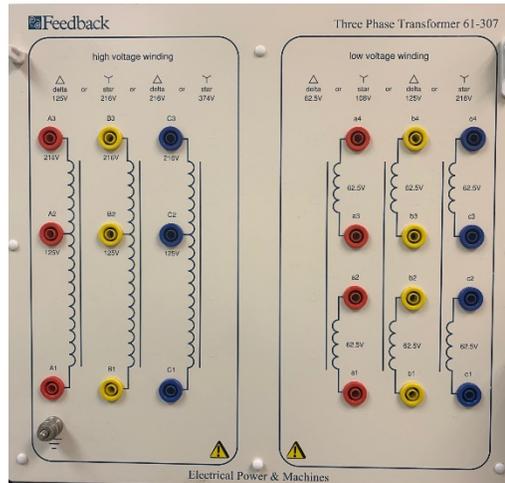


Figure 7.1. Three Phase Transformer

### EXPERIMENT

In the lab perform the following connections for three phase transformer in Figure 7.1:

- (1) Y-Y
- (2) Y- $\Delta$
- (3)  $\Delta$ -Y
- (4) V-V

For each connection, measure:

$$\overline{V}_{PLL} \text{ (Primary Line-Line)}$$

$$\overline{V}_{PLN}$$

$$\overline{V}_{SLL} \text{ (Secondary Line-Line)}$$

$$V_{SLN}$$

### REPORT

1. Build a table for each connection case and include your measurements.
2. In your report calculate the turn's ratio for each connection.
3. Furthermore, for the V-V connection prove that  $P_V / P_{3\phi} = 0.577$   
(hint: Use the textbook relevant section for the proof)

## LAB #8 “SYNCHRONOUS IMPEDANCE”

### INTRODUCTION

In this experiment we will perform the OPEN CIRCUIT and SHORT CIRCUIT tests in a synchronous machine, to calculate the synchronous impedance and the synchronous reactance. Also, we need to obtain the resistance of the armature.

### PROCEDURE

1. For the **OPEN CIRCUIT** test, connect mechanically the DC machine to the synchronous machine.
2. The DC machine should be connected as a DC shunt motor (be sure the field rheostat is set at minimum resistance).
3. Connect the field of the synchronous machine to the DC power supply (insert a meter to measure  $I_f$ ).
4. Start the DC machine applying voltage gradually until you reach 125 volts ( $V_t$ ). Set the speed to 1800 RPM.
5. Turn on the field (turn on the DC switch) of the synchronous machine and apply field current ( $I_f$  of the synchronous generator) as follows:

- $I_f$
- 0
  - 0.1
  - 0.2
  - 0.3
  - 0.4
  - 0.5
  - 0.6
  - 0.7
  - 0.8

At each step measure the terminal voltage of the synchronous machine. Maintain the speed constant at 1800 RPM throughout the experiment.

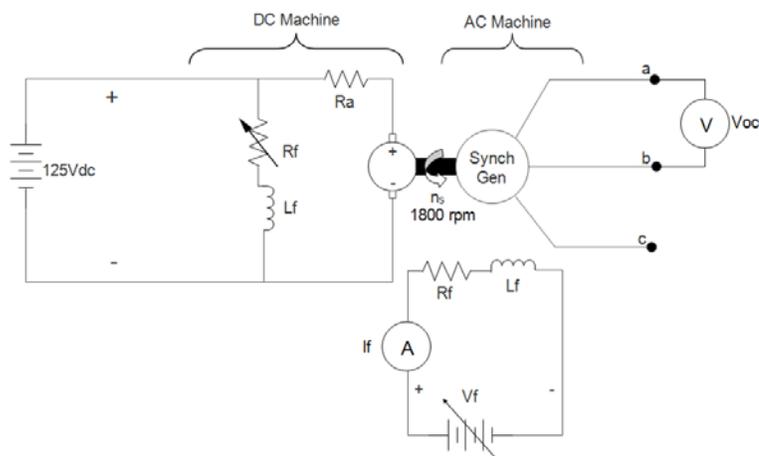


Figure 8.1. Three phase synchronous machine connection diagram (Open Circuit Test)

For the **SHORT CIRCUIT** test, keep the same connection as before.

Short the stator of your synchronous machine, and **carefully** apply voltage to the **field** of the synchronous machine, so that you can measure the short circuit current ( $I_{SC}$ ), and the field current ( $I_f$ ). Let  $I_{SC}$  be:

- $I_{SC}$
- 0
- 0.1
- 0.2
- 0.3
- 0.4

Keep speed constant all of the time.

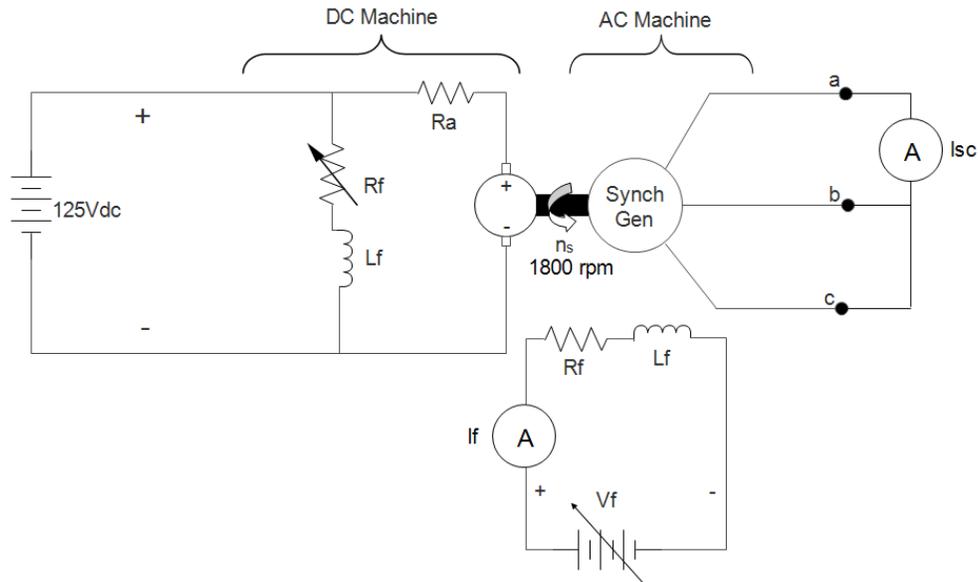


Figure 8.2. Three phase synchronous machine connection diagram (Short Circuit Test)

### ARMATURE RESISTANCE

To find the value of the armature resistance " $R_a$ ", use the DC voltage-current test. Apply  $\frac{3}{4}$  of the **rated current** to one of the stator's windings. ( $R_a = 1.5R_{DC}$ ). Apply the same procedure to measure  $R_f$  (you might need this value later).

### REPORT

1. Give your data and results in table form.
2. Plot  $V_{OC}$  vs  $I_f$ , and  $I_{SC}$  vs  $I_f$  on the same graph.
3. From your graph obtain the necessary data to calculate  $Z_s$  and  $X_s$  for the following values of  $I_f$ : 0.15, 0.25, 0.35, 0.45, 0.55, 0.65.

4. Plot  $X_s$  on the graph where you have  $V_{OC}$  vs.  $I_f$  and  $I_{SC}$  vs.  $I_f$ .
5. How many poles does the machine have?

**HINTS:**

$$Z_s = R_{AC} + jX_s$$

$$Z_s = \frac{V_{OC}}{I_{SC} \times \sqrt{3}}$$

**TABLE 1 OPEN CIRCUIT TEST DATA**

FIELD CURRENT ( $I_f$ )	LINE TO LINE TERMINAL VOLTAGE ( $V_t$ )

**TABLE 2 SHORT CIRCUIT TEST DATA**

FIELD CURRENT ( $I_f$ )	SHORT CIRCUIT CURRENT ( $I_{sc}$ )

**TABLE 3 CALCULATED VALUES**

FIELD CURRENT ( $I_f$ )	SHORT CIRCUIT CURRENT ( $I_{sc}$ )	LINE TO LINE TERMINAL VOLTAGE ( $V_t$ )	CALCULATED IMPEDANCE ( $Z$ )	CALCULATED WINDING RESISTANCE ( $R_{AC}$ )	CALCULATED WINDING REACTANCE ( $X_s$ )

## LAB #9

### “SYNCHRONIZING WITH THE SYSTEM, AND LOADING THE SYNCHRONOUS GENERATOR (%VR)”

#### INTRODUCTION

In this laboratory experiment, we are going to synchronize the synchronous generator to the system (DWP) and observe its behavior.

Also, we are going to load the synchronous generator with three different types of loads (i.e. Inductive, resistive, and capacitive), and obtain the percentage of voltage regulation (**%VR**) for each load.

#### PROCEDURE

Part A:

- Connect mechanically the DC motor (shunt connection) to the synchronous generator, and run it at 1800 RPM.
- Between the three-phase power supply and the generator connect a three-phase switch with light bulbs as shown in Figure 9.1.

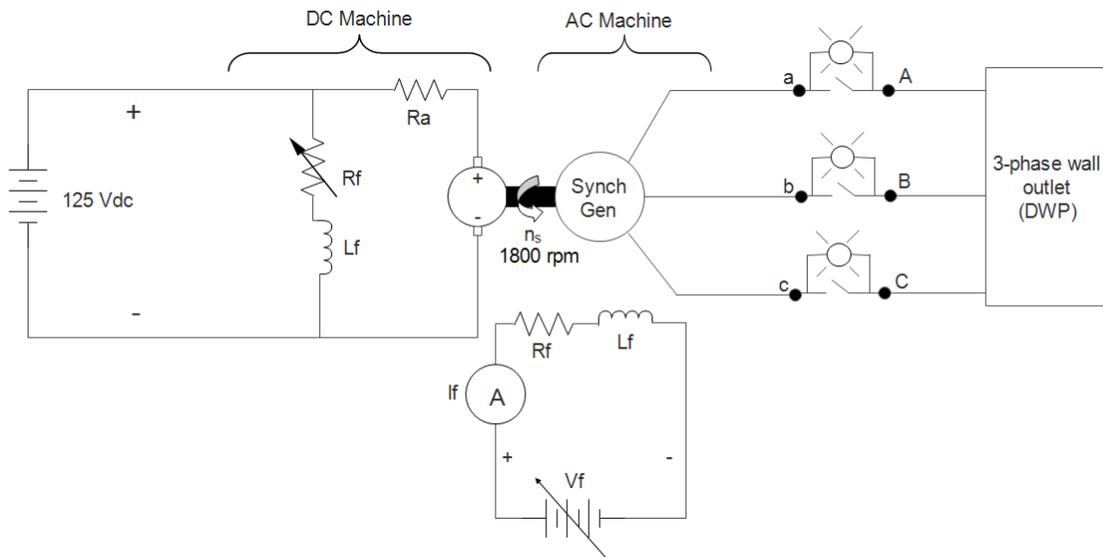


Figure 9.1. Synchronizing with the system.

When all lights go off **AT THE SAME TIME**, close the switches and your machine becomes synchronized with the system. Observe its behavior under different conditions (i.e. change the field current and see what happens to the voltage terminal “ $V_t$ ”) Change the prime mover’s field rheostat (DC machine’s rheostat) and check the speed.

Part B:

- Connect the generator to a resistive load (connected in WYE). See figure 9.2
- Vary the field current to obtain 208 V at the terminals of the generator.

- Maintaining the field current and speed (1800 RPM) constant, vary the load (turn on the switches) and measure  $V_t$ ,  $I_a$  and RPM.
- Repeat the same process for an inductive load.
- Repeat the same process for a capacitive load.

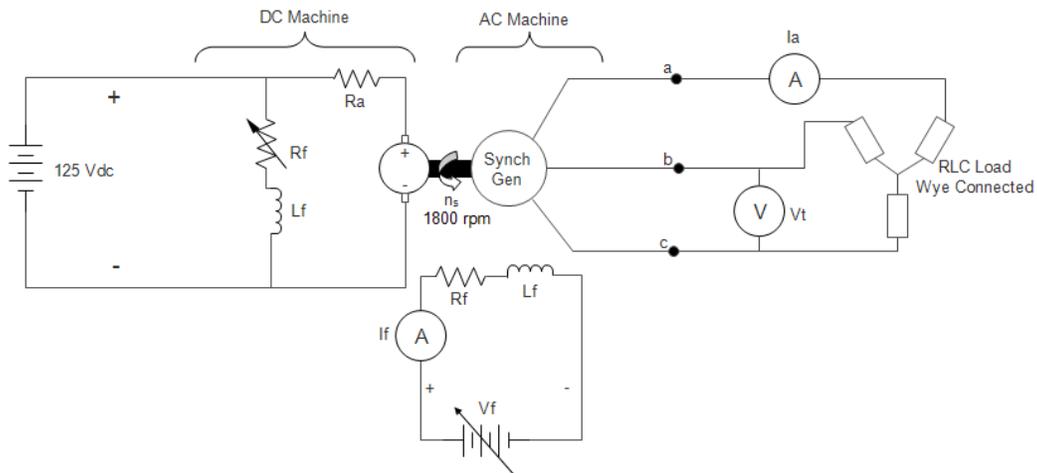


Figure 9.2. Loading the synchronous generator.

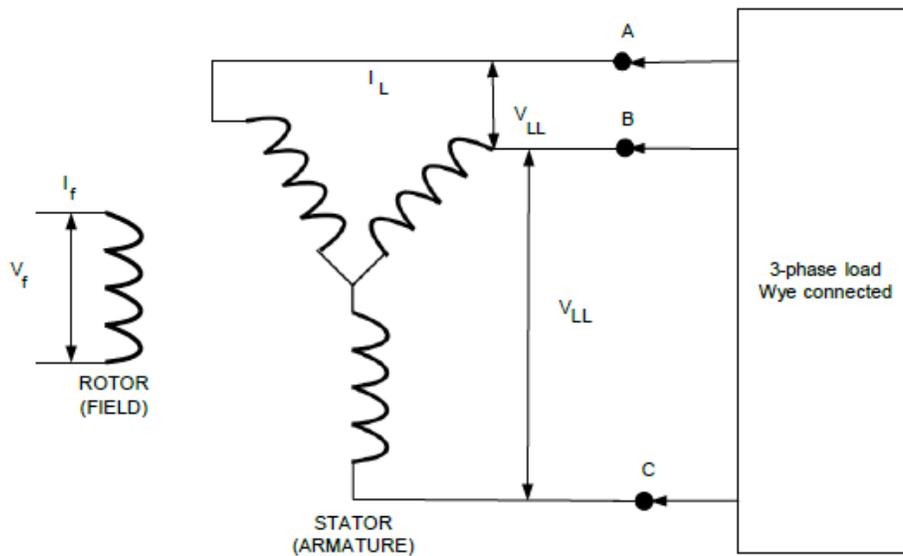


Figure 9.3. Loading the synchronous generator. Electric diagram.

## REPORT

For the synchronous generator:

- Report** the behavior of the machine when synchronized to the system.
- Explain the conditions necessary to accomplish such synchronization.

For the synchronous generator *OPERATION UNDER RLC LOAD*:

- Calculate the voltage regulation **for each load. (resistive, inductive and capacitive)**
- Draw the corresponding phasor diagram for each power factor.

# LAB #10

## PROGRAM TO DETERMINE THE CHARACTERISTICS OF SYNCHRONOUS MACHINES

### INTRODUCTION

In this program you are being asked to calculate the parameters indicated below for a synchronous generator operating at full load, for two different cases:

- (a) Power Factor **Leading**
- (b) Power Factor **Lagging**

Parameters:

- (1) %VR.
- (2) Real power output (P)
- (3) Reactive power (Q)
- (4) Synchronous speed ( $\omega_s$ )
- (5) Overexcited or underexcited.
- (6) Efficiency ( $\eta$ )

### PROCEDURE

The following is the input data that you must have for your program:

- (1) Synchronous reactance ( $X_s$ ).
- (2) Resistance ( $R_{ac}$ ).
- (3)  $KVA_{rated}$
- (4)  $KV_{rated}$
- (5) Power Factor
- (6) Type of Power Factor (leading or lagging).
- (7) Frequency (Hz).
- (8) Number of poles (N)
- (9)  $I_f$
- (10)  $R_f$
- (11) Core losses
- (12) Mechanical losses

### DATA

The data for this program is:

10 KVA  
230 V  
60 Hz  
4 poles  
WYE connected generator:  
 $R_a = 0.3 \Omega$ ,  $X_s = 5.6 \Omega$ ,  $R_f = 4.5 \Omega$ ,  $I_f = 10$  A for all leading and lagging pf  
 $P_c = 300$  W,  $P_{mech} = 200$  W

### REPORT (output)

Let the power factor angle change from -90 to 90 in steps of 10.

- (1) %VR
- (2)  $P_{out}$
- (3)  $Q_{out}$

- (4) Synchronous Speed ( $\omega_s$ )
- (5) Overexcited or Underexcited
- (6) Plot part 1, 2, 3, and 7 on the same graph
- (7) Efficiency at full load ( $\eta$ )

### HINTS

$$P_{rot} = P_c + P_{mech}$$

$$P_{in} = P_{out} + P_{loss}$$

$$\eta = \frac{P_{out}}{P_{in}}$$

$$I_{rated} = \frac{KVA * 1000}{\sqrt{3} V_t}$$

$$P_{fcu} = I^2 R_f$$

$$P_{scu} = 3 I_{rated}^2 R_a$$

$$P_{loss} = P_{rot} + P_{cu} + P_{scu}$$

$$E = \frac{V_t}{\sqrt{3}} + I_{rated} * Z$$

$$\%VR = \frac{\left( |E| - \frac{V_t}{\sqrt{3}} \right)}{\frac{V_t}{\sqrt{3}}}$$

$$P_{out} = KVA * \cos(\phi)$$

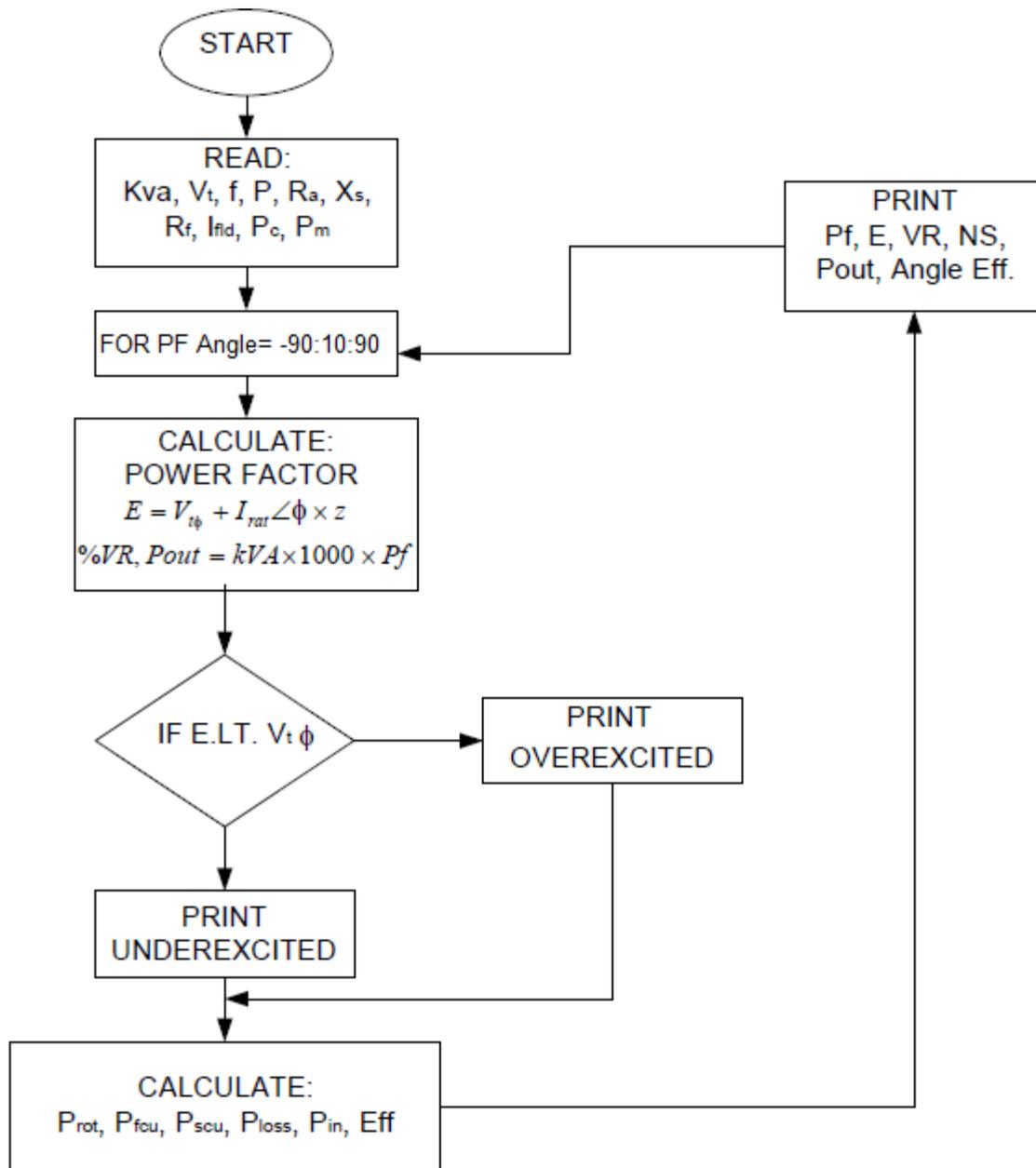


Figure10.1 Flow Diagram for synchronous generator computer program.

## GENERAL INSTRUCTIONS

### ELECTRIC MACHINES EXPERIMENTS USING LUCAS\_NUELLE TRAINING BENCHES

1. FOR EXPERIMENTS 11 -14, CLICK ON “LABSOFT” APP ON THE PC NEXT TO THE BENCH
2. Choose English as the selected language
3. Enter your name (No password is required)
4. Choose Electrical Machines and Drives 300 W U.S



**LAB #11**  
**SYNCHRONOUS GENERATOR (THREE PHASE MULTIFUNCTION MACHINE)**

**INTRODUCTION**

The purpose of this experiment is:

- Set up the multifunction machine to operate as a synchronous generator
- Measure the generator voltage at constant speed and variable exciter current
- Measure the generator voltage at constant excitation and variable speed

**PROCEDURE:**

**Follow up the labsoft instructions step by step for the following tasks:**

**A. Connection and Starting**

1. Assume the circuit according the circuit schematic illustrated in labsoft synchronous generator experiment.
2. Putting the machine into "Speed Control" Mode
3. Measure the generator voltage at varying excitation with constant speed
4. Measure the generator voltage at varying speed and constant excitation

**B. Load Characteristics**

1. Assume the circuit according the circuit schematic illustrated in labsoft synchronous generator experiment.
2. Record the load characteristics at constant excitation and speed
3. Run the experiment and fill up the load characteristic table
4. Plot the results
5. Check your answers

**REPORT**

Generate a report file from labsoft.

**ANSWER THE FOLLOWING QUESTIONS AND INCLUDE IN YOUR REPORT:**

1. Why did the rotational losses remain the same at different loads?
2. Which losses are variable, and which losses are considered fixed?
3. Draw the corresponding phasor diagram for each type of load?

**LAB #12**  
**THREE PHASE INDUCTION MOTORS EEM 41.3 60 HZ VERSION**

**INTRODUCTION**

We are going to connect (to the power supply) the three-phase induction motor and operate the motor in star and delta configurations.

- Identify the differences between star and delta.
- Put the motor into operation with the brake
- Subject the motor to the load

**PROCEDURE**

1. Assume the circuit according the circuit schematic illustrated in labsoft Asynchronous generator experiment.
2. Use the ActiveServo and set the machine into "Torque Mode"
3. Measure and plot the Speed, Current and Torque of the motor at the star connection
4. Measure and plot the Speed, Current and Torque of the motor at the delta connection

**REPORT:**

**Generate a report from the experiment and check the answer for related questions. Include a detail justification for each answer in the report.**

**PART II: LOAD CHARACTERISTICS**

**PROCEDURE**

1. Assume the circuit according the circuit schematic illustrated in labsoft Asynchronous generator load characteristics experiment.
2. Record the load characteristic of the motor
3. Determine the nominal Torque.
4. Determine the highest degree of efficiency.
5. Plot and measure how the motor responds to loads.

Do all the experiments for the star connection!!!

Check your answers based on your observations. Save the report and submit it on canvas.

**LAB #13**  
**DC Shunt motors**  
**Set up-Connections, Rotation reversal, Speed Control, Load Characteristic**

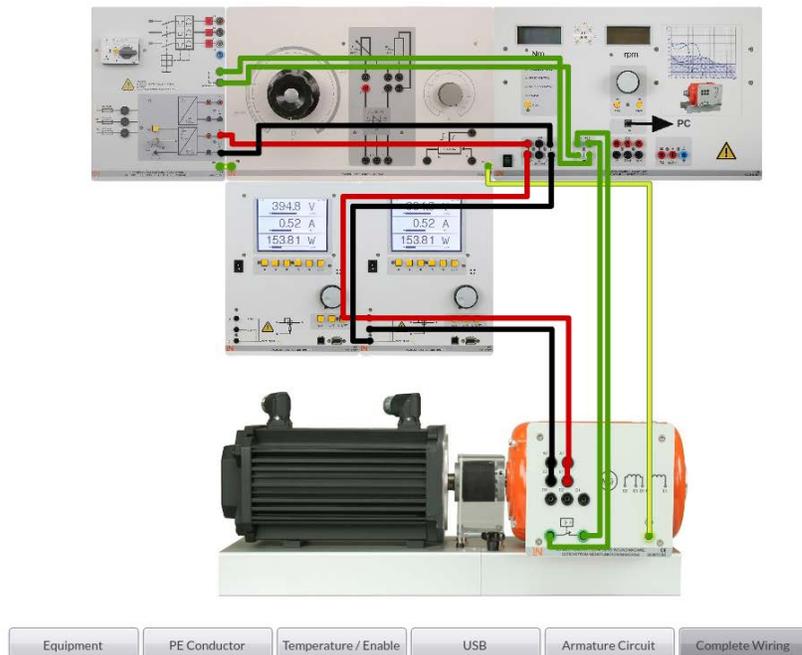
**INTRODUCTION**

Over the next few pages you will perform the following exercises pertaining to "DC shunt-wound motors":

- Connection and starting
- Reversing rotation direction
- Speed control
- Load characteristics

**PROCEDURE PART A (*constants*)**

1. Click on Labsoft App, login and choose DC shunt wound motor300W experiment.
  2. Follow instructions step by step on your screen to satisfy the following training contents.
  3. Answer the questions properly and check your answers at each step.
- Identify the terminal connections of the motor and operate the motor as a shunt-wound motor
  - Read the nominal data of the motor based on the rating plate
  - Connect the motor to the starter
  - Become familiar with how the starter works
  - Operate the motor with the servo machine test system
  - Subject the motor to a load
  - Measure armature voltage and current



*Figure 13.1.* Set-up for DC shunt-wound motor  
"Load characteristic"

**LAB #14**  
**A SEPERATELY EXCITED DC GENERATOR**  
**LOAD CHARACTERISTICS, VOLTAGE CONTROL AND POLARITY**

**INTRODUCTION**

In this experiment, you will be conducting the following exercises on a "separately excited DC shunt-wound generator":

- Voltage control (field regulating range)
- Voltage polarity
- Load characteristics

**PROCEDURE**

1. Click on Labsoft App, login and choose DC shunt wound motor300W experiment.
  2. Follow instructions step by step on your screen to satisfy the following training contents.
  3. Answer the questions properly and check your answers at each step.
- Connect up the machine as a separately excited DC shunt-wound generator
  - Recognize which variables affect the output voltage of the generator
  - Determine the output voltage as a function of the speed
  - Understand the purpose of the field regulator and how it works

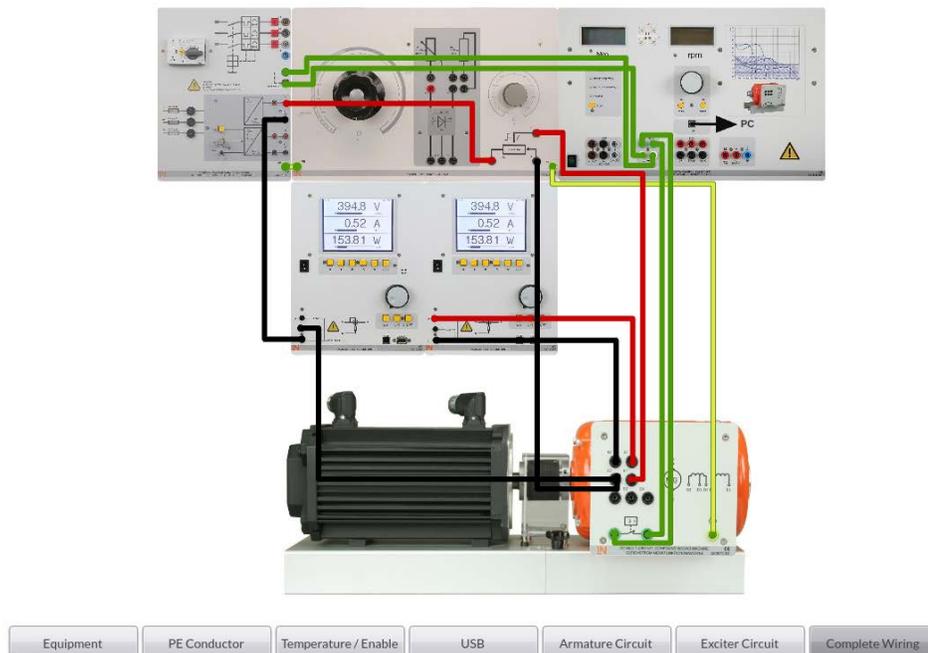


Figure 14.1. Set-up for DC shunt-wound generator, separately excited "Voltage control"

# **APPENDIX 1**

## Matlab Tutorials

```
%Energy tutorial 1
%angles are always input in radians
x=45*pi/180
y=cosx
v=sinx
```

```
%Energy tutorial 2
%angles are always input in radians
%creating a complex number
x=80*pi/180
y=cos(x)
v=sin(x)
```

```
1 Z=10*y+i*10*v
```

```
%Energy tutorial 3
%angles are always input in radians
%using a list
t=0:10:360;
x=t*pi/180;
y=cos(x);
v=sin(x);
Z=10*y+i*10*v
```

```
%Energy tutorial 4
%angles are always input in radians
%for-end
for j=1:36
    x=(j*10)*pi/180;
    y=cos(x);
    v=sin(x);
    Z=10*x+i*10*v
end
```

```
%Energy tutorial 5
%angles are always input in radians
%for-end and vector format
for j=1:180
    x(j)=j*pi/180;
    y(j)=cos(x(j));
    v(j)=sin(x(j));
    Z(j)=10*x(j)+i*10*v(j)
end
```

```

%Energy tutorial 6
%angles are always input in radians
%for-end, vector form and output format
clc
clear
for j=1:16
    x(j)=(j*10)*pi/180;
    y(j)=cos(x(j));
    v(j)=sin(x(j));
    z(j)=10*x(j)+i*10*v(j);
end
%to format the output in matrix form , %we need to initiate a zero
matrix with %the same size as the one we want .
%
v=[0,0,0,0;0,0,0,0;0,0,0,0];
%
k=0;
for n=1:4;
    for m=1:4;
        v(n,m)=z(k+m);
    end
end
k=4;
end
v

```

```

%Energy tutorial 7
%Angles are always input in radians
%For-end loop. Formatting the output
%Plotting
for j=1:16
    x(j)=(j*10)*pi/180;
    y(j)=cos(x(j));
    v(j)=sin(x(j));
    z(j)=10*x(j)+i*10*v(j);
end
%to format the output in matrix for, we %need to initiate a zero matrix
with the %same size as the one we want .
%
v=[0,0,0,0;0,0,0,0;0,0,0,0];
%
k=0;
for n=1:4;
    for m=1:4;
        v(n,m)=z(k+m);
    end
k=4;
end
v
plot(real(z), imag(z))

```

```
%Energy tutorial 8
%Creating a vector
clc
clear
for k=1:25;
    Poc(k)=133;    %this equality works only with a “ real value”
                  %on the rhs (not a variable)
end
disp(poc')        %Displays the vector
```

```

%Energy tutorial 9
%Table form (formatted output)
%CAUTION: "fprintf" works only with real numbers
clc
clear
for k=1:25;
    Poc(k)=133;          %this equality works only with a "value"
on the                 %rhs (not a variable)
end
out=[ Poc'];          %this is a vector used to create a
                    %formatted output
for m=1:25;
    fprintf (' %8.4f\n',out); %formatted output use "fprintf"
end

```

```

%Energy tutorial 10
%Table form (formatted output)
%CAUTION: "fprintf" works only with real numbers
%making it look better
clc
clear
for k=1:25;
    Poc(k)=133;          %this equality works only with a "value"
on the                  %rhs (not a variable)
end
%
%title of the table
%
fprintf ('table of Poc\n\n');
%
%Column Headings
fprintf('Open circuit losses\n');
fprintf('+++++\n');
%
out=[ Poc'];          %this is a vector used to create a formatted output
fprintf (' %8.4f\n',out); %formatted output use "fprintf"

```

```

%Energy tutorial 11
%Table form (formatted output)
%Multiple plots on same axis
clc
clear
for k=1:25;
    Poc(k)=133;          %this equality works only with a "value"
                        %rhs (not a variable)
end
%
%title of the table
%
fprintf ('table of Poc\n\n');
%
%Column Headings
fprintf('Open circuit losses\n');
fprintf('+++++\n');
%
out=[ Poc'];          %this is a vector used to create a formatted output
fprintf (' %8.4f\n',out); %formatted output use "fprintf"
for j=1:25;
    y(j)=2*j;
    x(j)=j;
end
plot(x, y,'b-');
hold on;
plot (x, Poc,'-ko');
hold off;
legend ('2 to the 25th power','Open circuit losses')

```

```

%Energy tutorial 12
%Table form (formatted output)
%Multiple plots on same axis
%One way to input power factor
clc
clear
for k=1:25;
    Poc(k)=133;          %this equality works only with a "value"
                        % on the rhs (not a variable)

end
kv=215
pf1=input('if pf is leading enter +1, if it is lagging enter-1:');
pf2=input('please enter pf:');

for kva=1:1000:100
    current=kva*cos(pf1*pf2)/kv + (kva*sin(pf1*pf2)/kv)*i
end
%
%title of the table
%
fprintf ('table of Poc\n\n');
%
%Column Headings
fprintf('Open circuit losses\n');
fprintf('+++++\n');
%
out=[ Poc'];          %this is a vector used to create a formatted output
fprintf (' %8.4f\n',out); %formatted output use "fprintf"
for j=1:25;
    y(j)=2*j;
    x(j)=j;
end
plot(x, y,'b-');
hold on;
plot (x, Poc,'-ko');
hold off;
legend ('2 to the 25th power','Open circuit losses')

```