# Electrical Machine Lab
## db-tech, DB-609

# User Manual

# RLC Circuits

# I. INTRODUCTION

## OBJECTIVES:

- Study the phasor relationship between Voltage and Current in a single phase AC Circuit.
- Study the concept of real power (P), reactive power (Q), apparent power(S) and power factor (cosΦ).
- Identify a method to improve the line side power factor with the help of a capacitor bank.

## BACKGROUND SUMMARY:

AC circuit elements consist of resistors (R), inductors (L) and capacitors(C) which can be fed from either a 3 phase or 1 phase 50 Hz, 220V source. Resistor and inductor combination connected to a single phase AC source results in a lagging current with respect to voltage. If R & L are connected in series, the phasor sum of the voltages across L and R equals the source voltage. In contrast if they are connected in parallel the phasor sum of the currents drawn by R & L equals the source current. Power factor of any load (source) is defined as the cosine of the angle between the load(-source) current and corresponding load(source) voltage. By connecting a capacitor bank in parallel with such a RL circuit can improve the power factor which in turn reduces the current drawn from the source for a given power drawn by the resistor.
Power relations in a single phase system
Real power =Vrms *Irms cosΦ in watts (where Φ is angle between V and I)
Reactive power = Vrms *Irms * sin(Φ) in VARs
Apparent power = Vrms *Irms in VA

## INSTRUMENTS and COMPONENTS:

- Power Supply Module
- Resistance Module
- Inductance Module
- Capacitance Module
- AC Voltmeter Meter
- AC Amp/Current Meter

## RLC Series Circuit

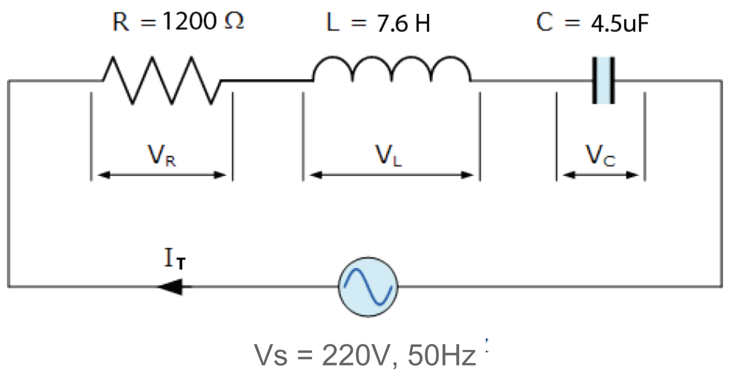



Figure: 01 RLC Series Circuit

## RLC Parallel Circuit

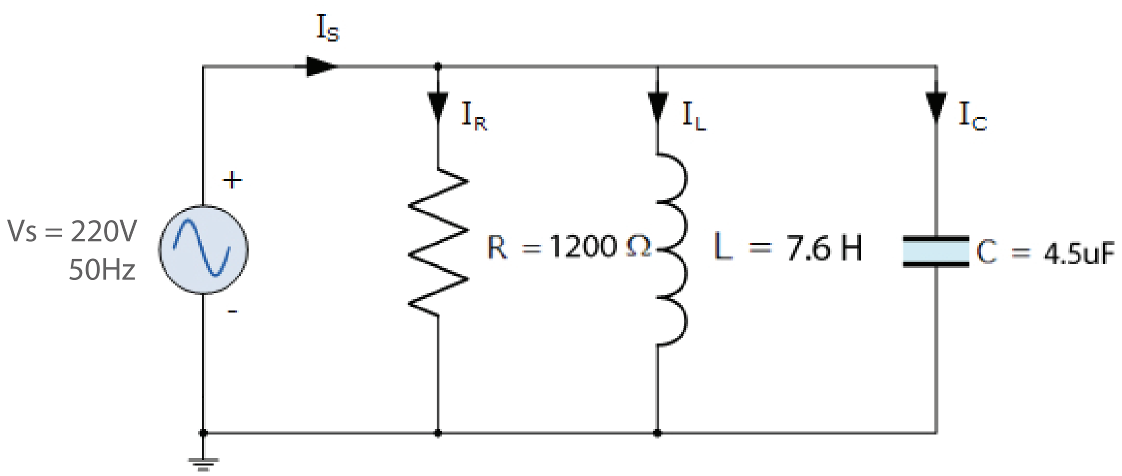



Figure: 02 RLC Parallel Circuit

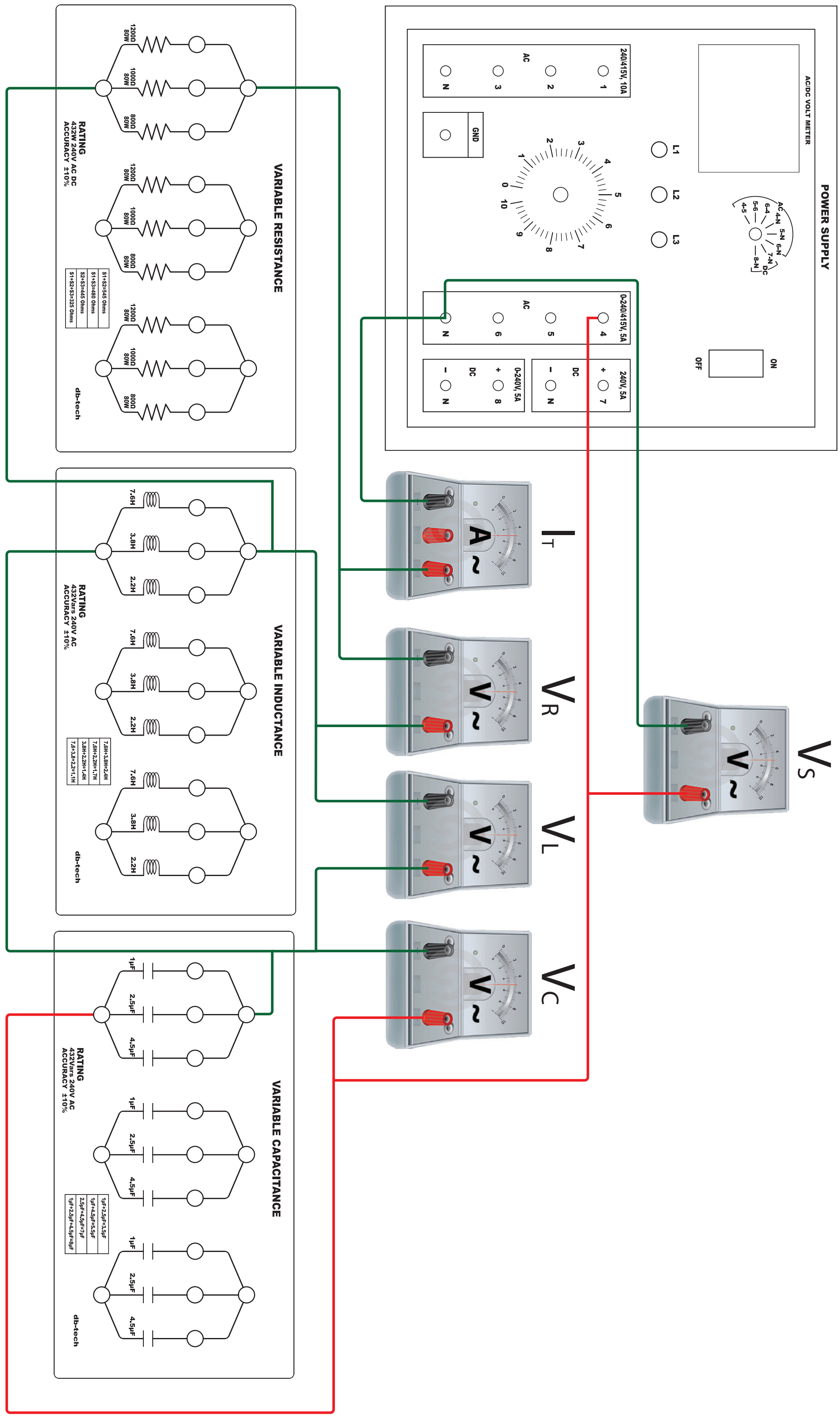



Figure: 03 Connection Diagram of RLC Series Circuit

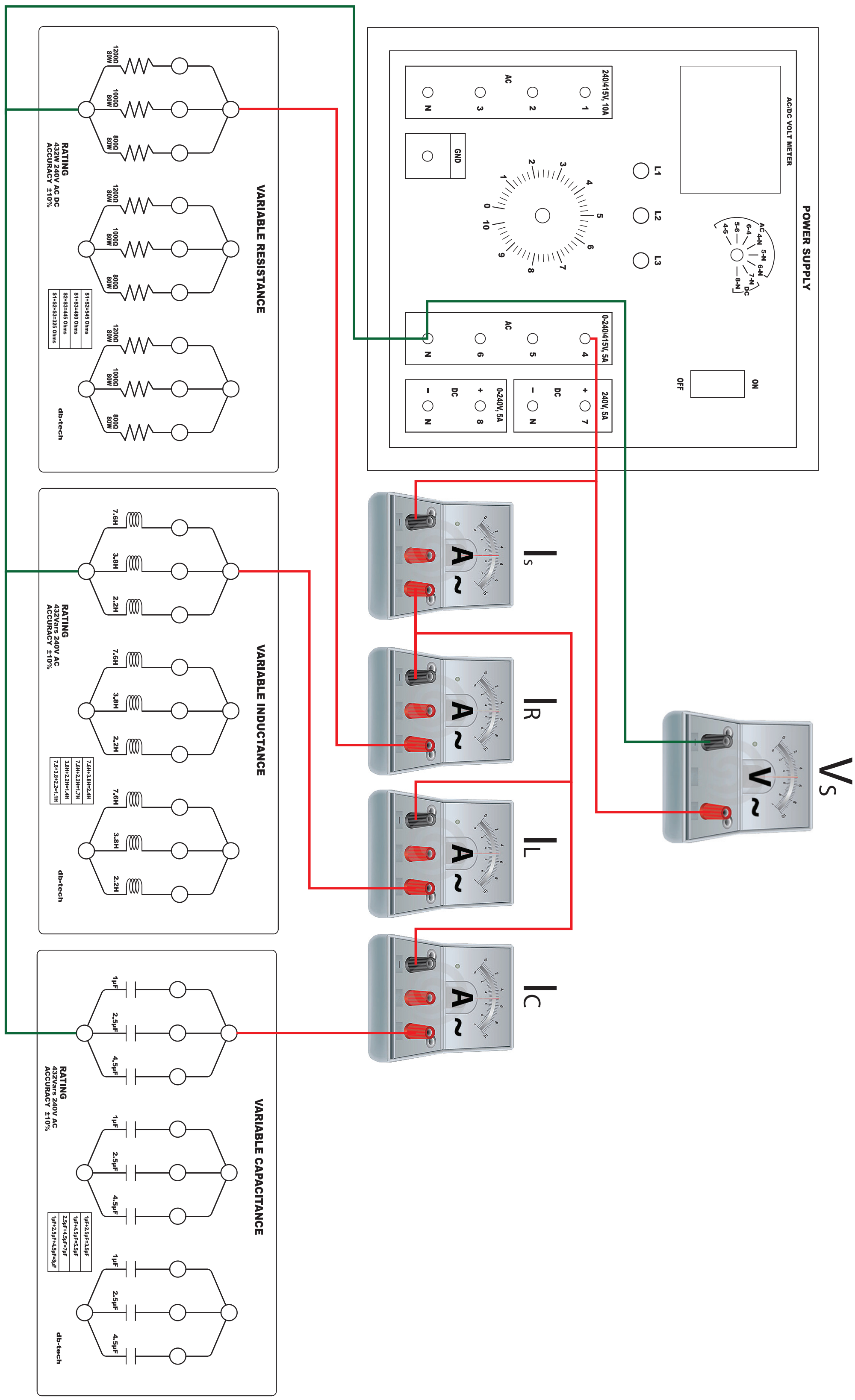



Figure: 04 Connection diagram of RLC parallel circuit

# Single PhaseTransformer

# I. INTRODUCTION

OBJECTIVES:

1. To learn how real world transformers operate under ideal conditions.
2. To learn what happens to the output voltage when the transformer is loaded.

INSTRUMENTS AND COMPONENTS

Power Supply Module
AC Voltmeter 500V
AC Ammeter 0.5~8 Amp
AC Wattmeter
Transformer Module
Load Resistor

# II. LABORATORY EXPERIMENTS

**CAUTION:** HIGH VOLTAGES ARE PRESENT IN THIS LABORATORY EXPERIMENT! DO NOT MAKE ANY CONNECTIONS WITH THE POWER ON! THE POWER SHOULD BE TURNED OFF BEFORE THE CIRCUIT IS MODIFIED!

1. To perform an open circuit test, the high voltage (primary) side of the transformer is energized by connecting it to the variable voltage supply terminals as shown in the circuit of Figure 1. In order to obtain open circuit test data, adjust the variable AC voltage supply to its zero voltage position before turning on the AC power switch. Next turn on the AC power switch and adjust the variable AC voltage supply until the voltmeter $V_1$ reads 100 volts. Record the measurements of $I_1$, $V_2$, $W_1$, and $V_1$.

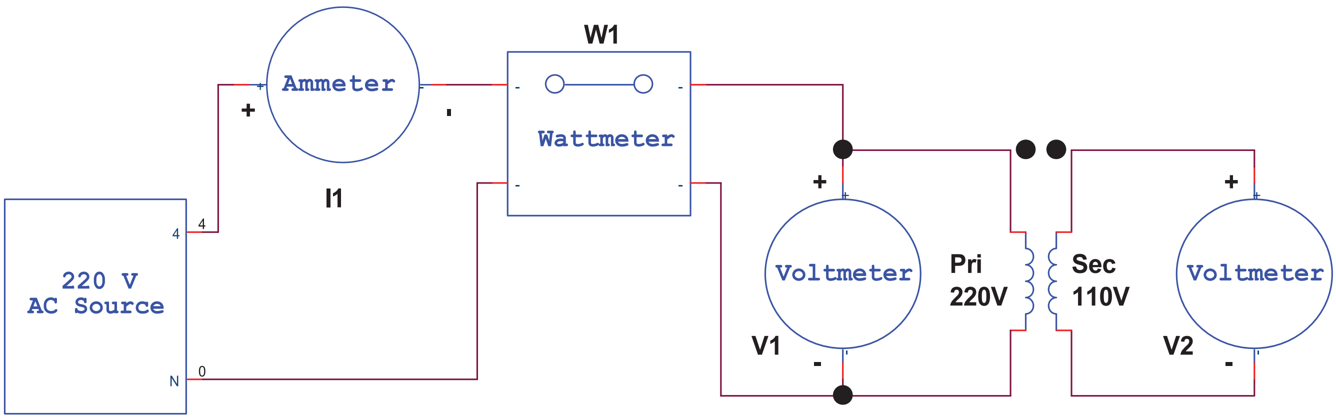



Figure 1: Open Circuit Test Setup

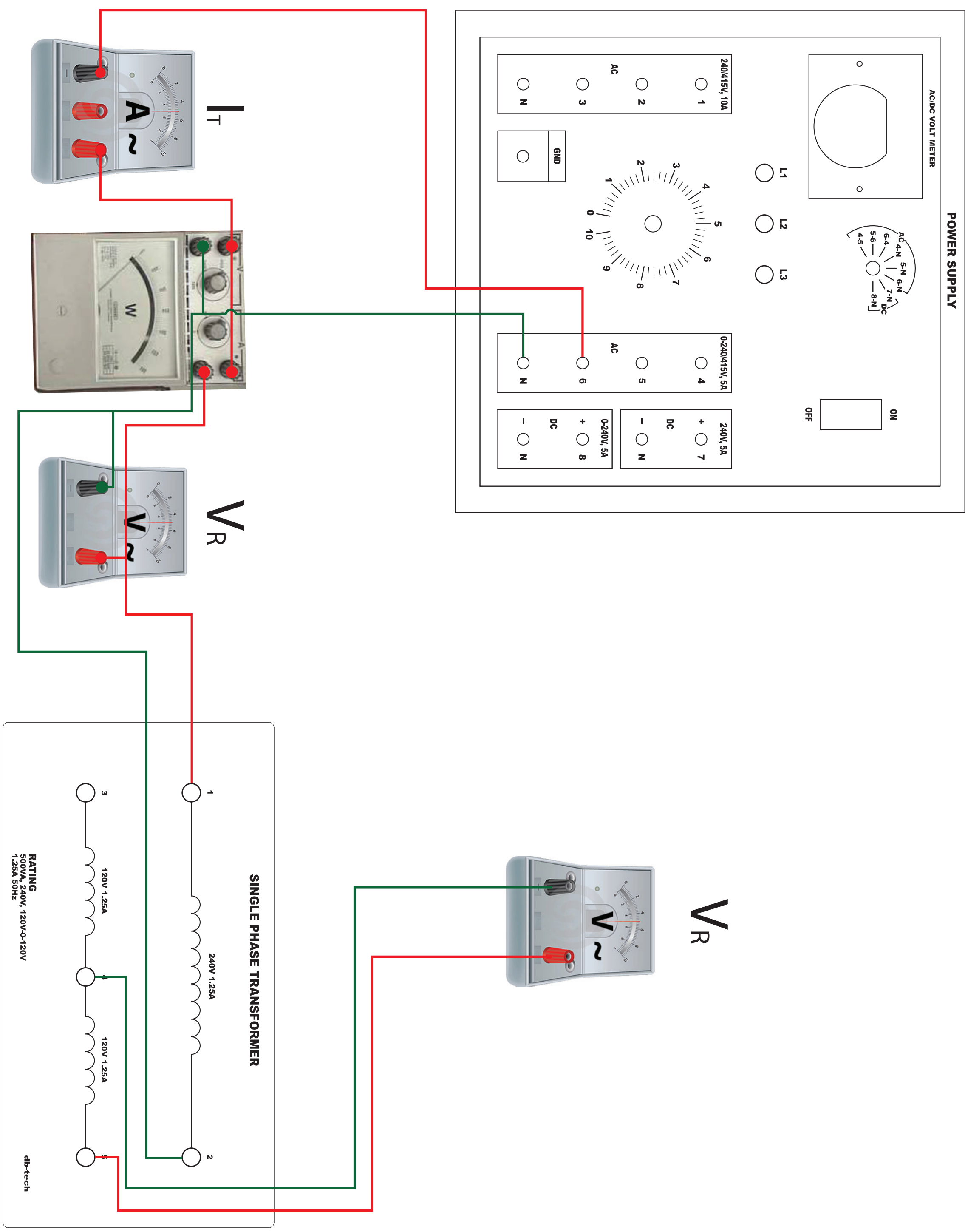



Figure: 02 Connection diagram of open circuit test

The wattmeter reading is actually the power lost due to the core resistances and primary winding resistance.

## III. PRELAB EXERCISES

**All voltages given in Figures 3-5 have phase angles of 0 degrees.**

1) Consider the following ideal transformer circuit in Figure 1.

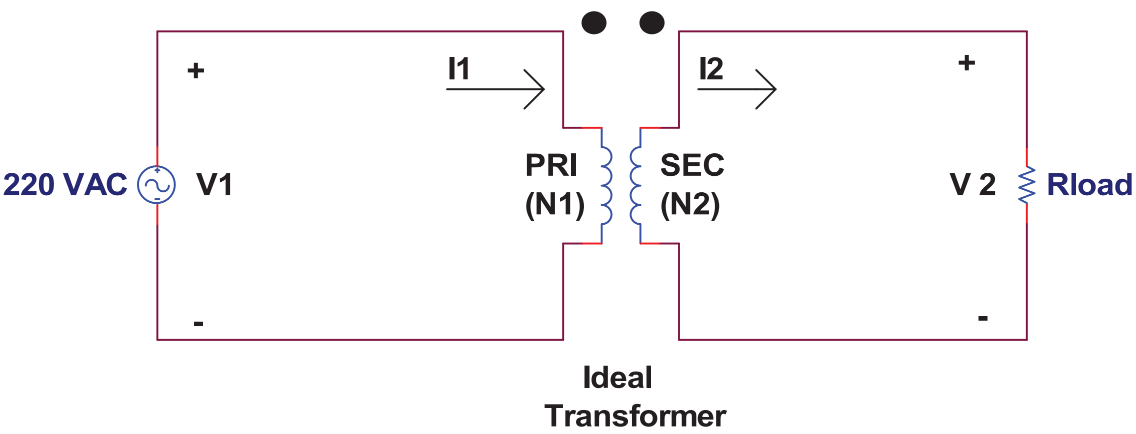



Figure 3: Ideal Transformer Circuit

a. Compute the voltage across $V_2$, $I_1$, and $I_2$.
b. Compute the power input and power output.
c. Compute the reflected impedance seen on the primary side (Hint, you know $V_1$ and $I_1$).

2) Consider the following circuit (Figure 4) that models a real transformer.

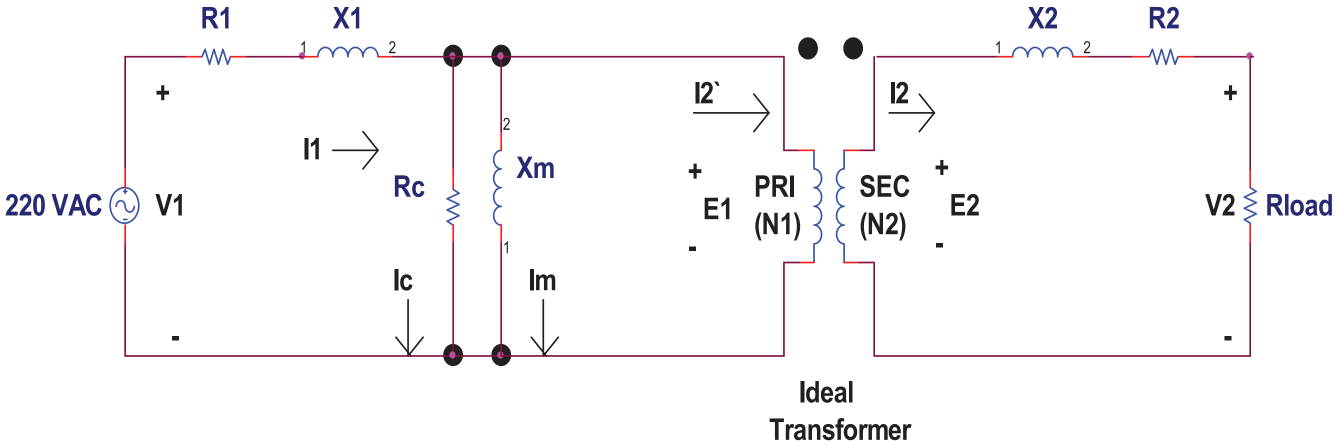



Figure 4: Real Transformer Circuit

Transformer Experiment

a. Explain how the following equivalent circuit (Figure 3) was obtained. This circuit is functionally identical to the circuit above it (Figure 2).

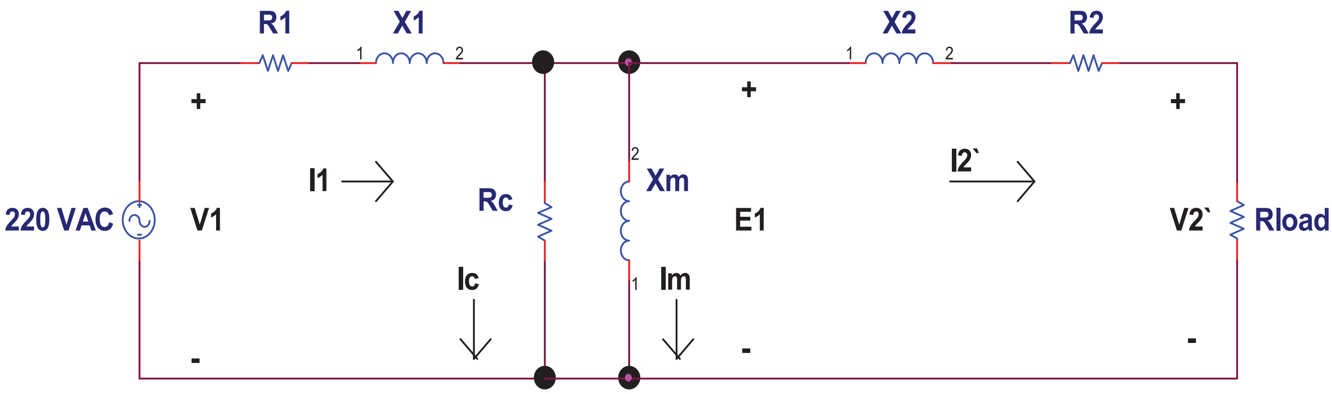



Figure 5 : Real Transformer Equivalent Circuit

b. What is the output voltage $V_2$?
c. Calculate the voltage $V_{2'}$ for the following loads. (Remember, you are reflecting these resistances to the primary side of the transformer.)
   i. 800 Ohms
   ii. 1000 Ohms
   iii. 1200 Ohms

Transformer Experiment

d. Calculate the real power on the input side of the circuit $V_1$ and the real power on the output side with each of the three load resistances.
e. How do these powers compare to those that you calculated in problem 1?
f. Calculate the efficiencies of both the real and ideal transformer.
$efficiency = \frac{Power\_output}{Total\_input\_power}(100\%)$ (Remember, these quantities are in terms of real power.)

2. A short circuit test can be performed by connecting a voltage source to the primary (high voltage) side of the transformer with the secondary (low voltage) side shorted. In this situation it is **VERY IMPORTANT TO ADJUST THE VARIABLE AC VOLTAGE SUPPLY TO ZERO BEFORE TURNING ON THE AC POWER SWITCH**. Use the 8 amp range on the ammeter to short the secondary winding as shown in Figure 6. Then increase the supply voltage slowly until the $I_2$ ammeter reads 4.0 amps. A typical value is for $I_1$ is about 0.40 amps. Record the measurements for $V_1$, $I_1$, and $I_2$.

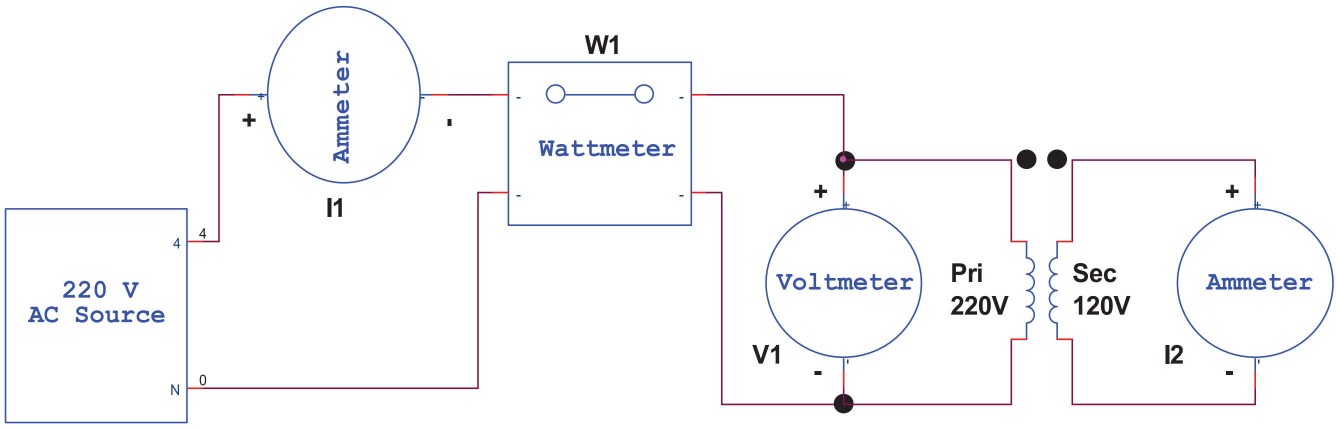



Figure 6: Short Circuit Test Setup

Theoretically what would happen to the output current $I_2$ if the input voltage was increased to 100V? (Do not actually increase the voltage to 100V, just predict what will happen.)

3. Set up the circuit shown in Fig. 7 with the 1.25 ohm resistor. This circuit can be used to measure voltage regulation and power efficiency. Make sure the variable AC voltage supply is in the lowest position and turn the power on. Slowly increase the voltage until $V_1$ equals 100 volts and wait for the resistor to stabilize thermally (about 2 minutes). Record $V_1$, $I_1$, $V_2$, $W_1$, and $I_2$.

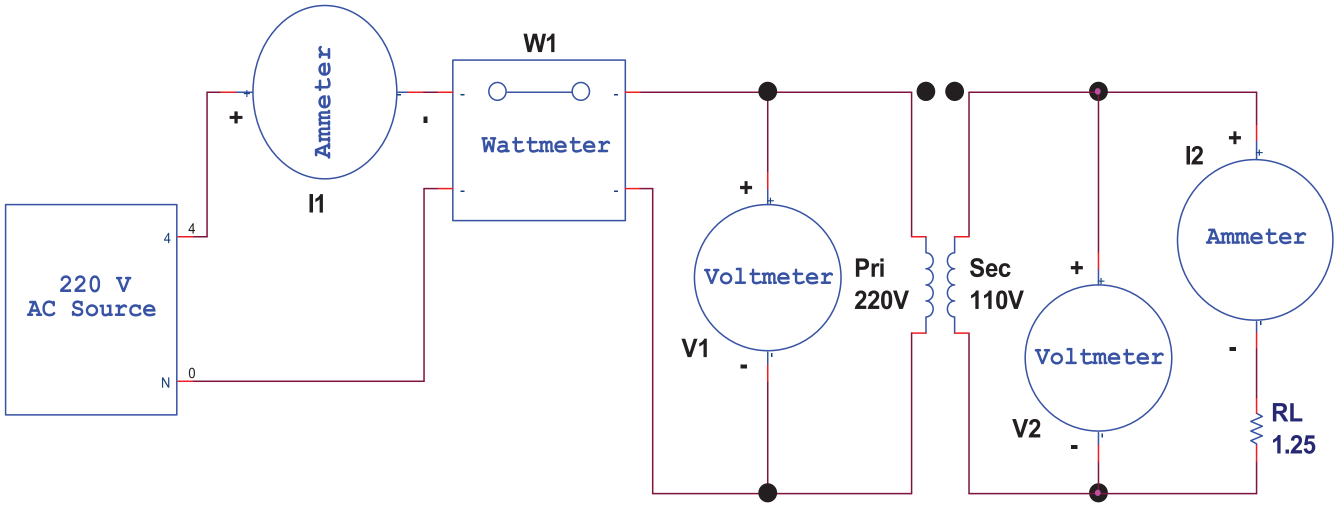



Figure 7: Loaded Circuit Test Setup

Use the voltages from Part 3 to calculate the voltage ratio and compare with the winding ratio.

How do the ratios in Part 3 compare to the ratios from Part 1?

Calculate percent regulation. (Hint: Vnoload comes from Part 1 of the Procedure.)

$$regulation = \frac{Vnoload - Vload}{Vload}(100\%)$$

Calculate the output power $W_2$ in the load resistor. Why is $W_2$ different from the input power $W_1$?

What is the efficiency of the transformer?

$$efficiency = \frac{Power\_output}{Total\_input\_power}(100\%)$$

# Three PhaseTransformer

## Experiment II - Three-Phase Transformers

Two or three-winding transformers that are used in power systems are 'voltage' transformers as their applied primary voltage is normally constant. Three single-phase transformers can be used but since the sum of symmetrical, three-phase currents and flux is zero, there is no need for a common 'return' limb in the magnetic circuit and a 3-limb, core type transformers is normally used. The primary and secondary windings for each phase are wound with the HV winding around the voltage winding, as shown in

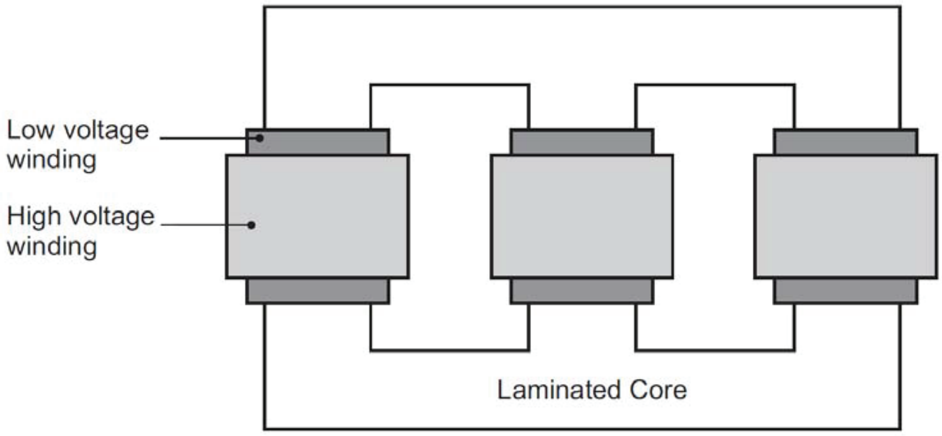



Figure 1: Three-limb, core type transformer

The T-equivalent circuit for a two-winding transformer is shown in Figure 2. The relative values of the total series impedance and the magnetising reactance ($X_m$) are of the order of 10% to 2000% respectively. They rarely have to be considered together and in most load and fault calculations the transformer may be represented by only the series impedance.

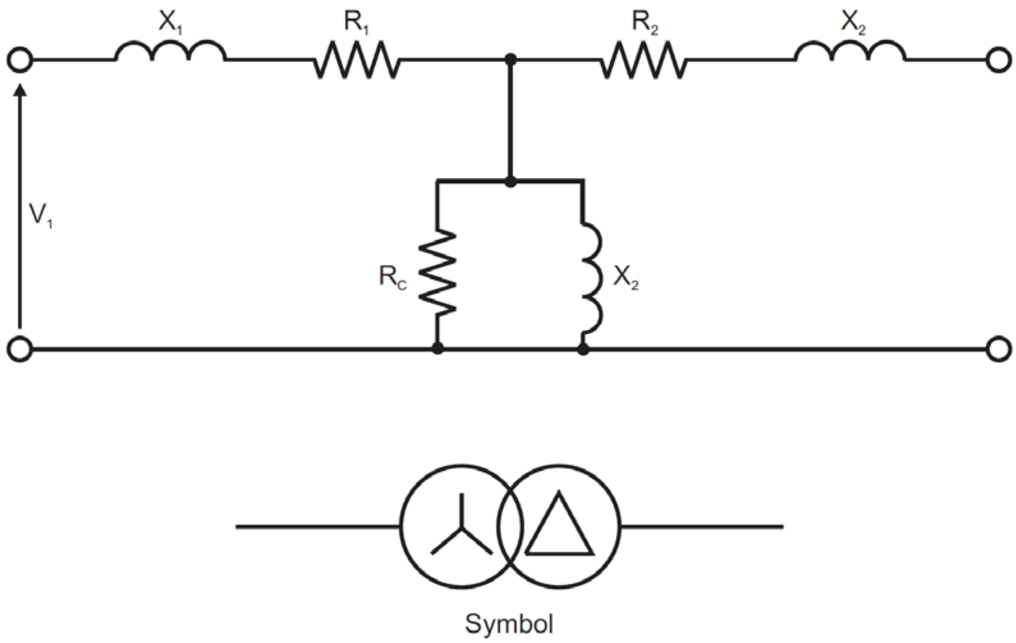
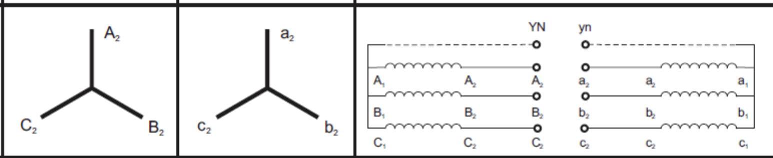
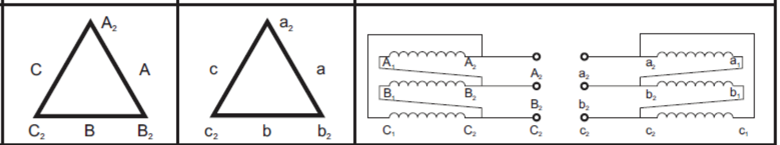
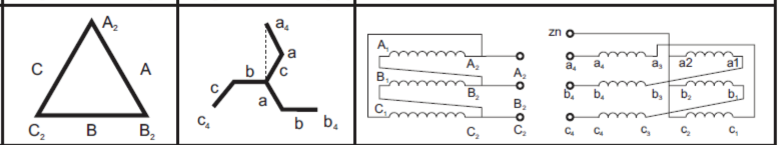
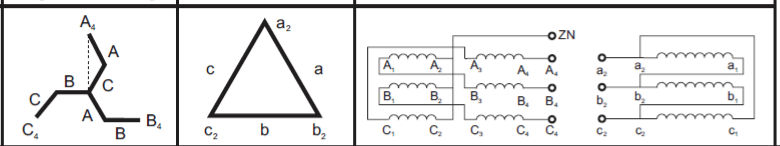
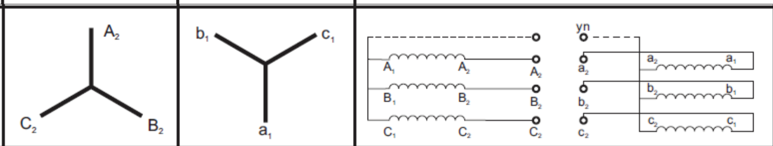
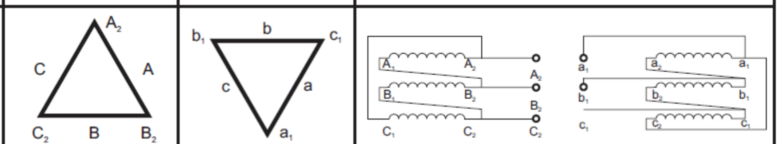
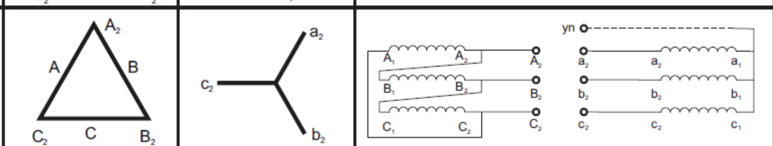
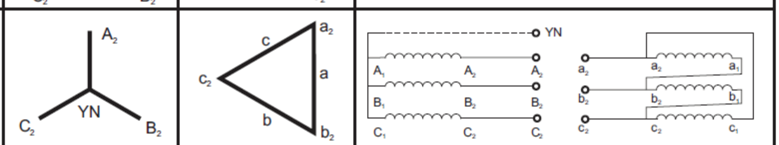
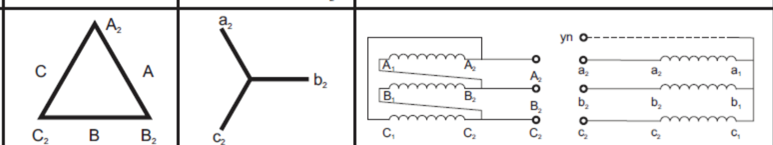
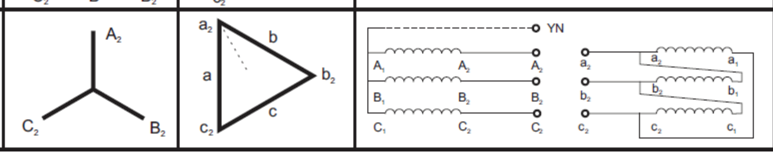



Figure 2: T-equivalent circuit for a two-winding transformer

Windings of three-phase transformers may be connected in star or delta. Depending on the primary and secondary connections, phase shifts of 0°, +30° and 180° can be produced between the primary and secondary phase-to-neutral voltages. It is therefore necessary to have standardization of nomenclature and connection procedures as shown in Table 1.

**Table 1: Time-phasor diagrams for three-phase transformers**

| Vector Symbols | Line terminal markings and vector diagram of induced voltage (HV Windings / LV Windings) and Winding Connections | Phase Displacement | Main Group Number |
|---|---|---|---|
| Y y 0 |  | 0° | 1 |
| D d 0 |  | | |
| D z 0 |  | | |
| Z d 0 |  | | |
| Y y 6 |  | 180° | 2 |
| D d 6 |  | | |
| D y I |  | -30° | 3 |
| Y d I |  | | |
| D y II |  | +30° | 4 |
| Y d II |  | | |

The distribution transformers in the Power System Simulator are phase connected Yd1. This means that the secondary phase voltage lags the primary phase voltage by 30°.

The winding connections to produce this phase shift are shown in Table 1. In this diagram the winding between A2 and YN of the star is wound on the same limb of the transformer as the winding 'a' of the delta. Hence, these voltages are in phase, as shown, so causing the -30° phase shift between primary and secondary phase voltages.

## Tap changing

If the taps of the two parallel connected transformers are unequal, $\bar{E}_A \neq \bar{E}_B$, a circulating current will be produced as shown in Figure 3. $I_s$ is mainly reactive.

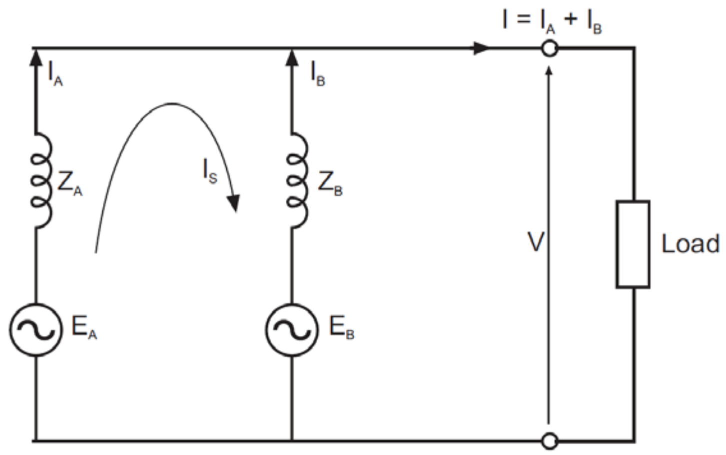



**Figure 3: Circulating current produced by unequal taps of two parallel transformers**

## Pre-lab Work

1. Use a phasor diagram to demonstrate the phase shift for generator transformer Dy11 and distribution transformer Yd1 is +30° and -30° respectively (assume HV side is a reference).
2. What are the conditions for satisfactory operation of two transformers in parallel? Explain briefly why.
3. Two identical transformers operated in parallel have different tap settings. Transformer 1 is set as +2.5% and transformer 2 is set as 0%. Theoretically analyse which transformer output more current/power.
4. Two identical transformers operated in parallel have different impedances (Transformer 1 has an extra 0.15pu impedance inserted in the secondary side). Theoretically analyse which transformer will be overloaded.

## Experiment Setup

The connection diagram for this experiment is shown in Figure 4.

### Task 1: Primary to secondary phase changes in three phase transformers

Use Distribution Transformer 1 (left hand side) or Distribution Transformer 2 (right hand side) and Generator transformer for this experiment.

To measure a phase shift for a distribution transformer: Connect TP17 (or TP18) to phase angle meter connection V2. Connect TP19 (or TP21) to phase angle meter connection V1.

To measure a phase shift for the generator transformer: Connect TP3 to phase angle meter connection V2. Connect TP4 to phase angle meter connection V1.

The angle shown on the phase angle meter is the phase shift between V1 and V2 and with V1 as a reference.

Use an oscilloscope and the phase angle meter to confirm that the phase angle between the primary and secondary line voltages of a distribution transformer is -30°. Similarly look at the primary and secondary winding voltages of the generator transformer. The phase difference in this case is +30°, since the transformer is phase connected Dy11.

### Task 2: Unequal taps

Unequal ratios in parallel-connected transformers are equivalent to a small voltage generator circulating current only around the transformer 'loop'. Investigate the effect of unequal ratios by setting unequal taps on the two distribution transformers. The smallest difference in percentage taps should be considered initially and the transformers should not be supplying a load. Currents, power and reactive power should be measured by the M230 meters in each transformer primary and secondary. Compare measured and calculated values of current for the distribution transformer (using the parameters of distribution transformer shown in the Appendix I) . Why do the two primary currents have different measured values?

### Task 3: Unequal impedances

Two transformers will not share a total load to their ratings if the per unit impedances of the two transformers are not identical, and one transformer will become overloaded before the total output reaches the sum of their individual ratings. Set up the distribution system to supply a total load of say, 50% resistive and 50% inductive (see Appendix I). Insert a 0.1 pu transmission line in the secondary of one of the transformers and investigate the effect its inclusion has on the division of load between the two transformers. Repeat, if possible, with transmission lines of different values (i.e. 0.15 pu and 0.2 pu).

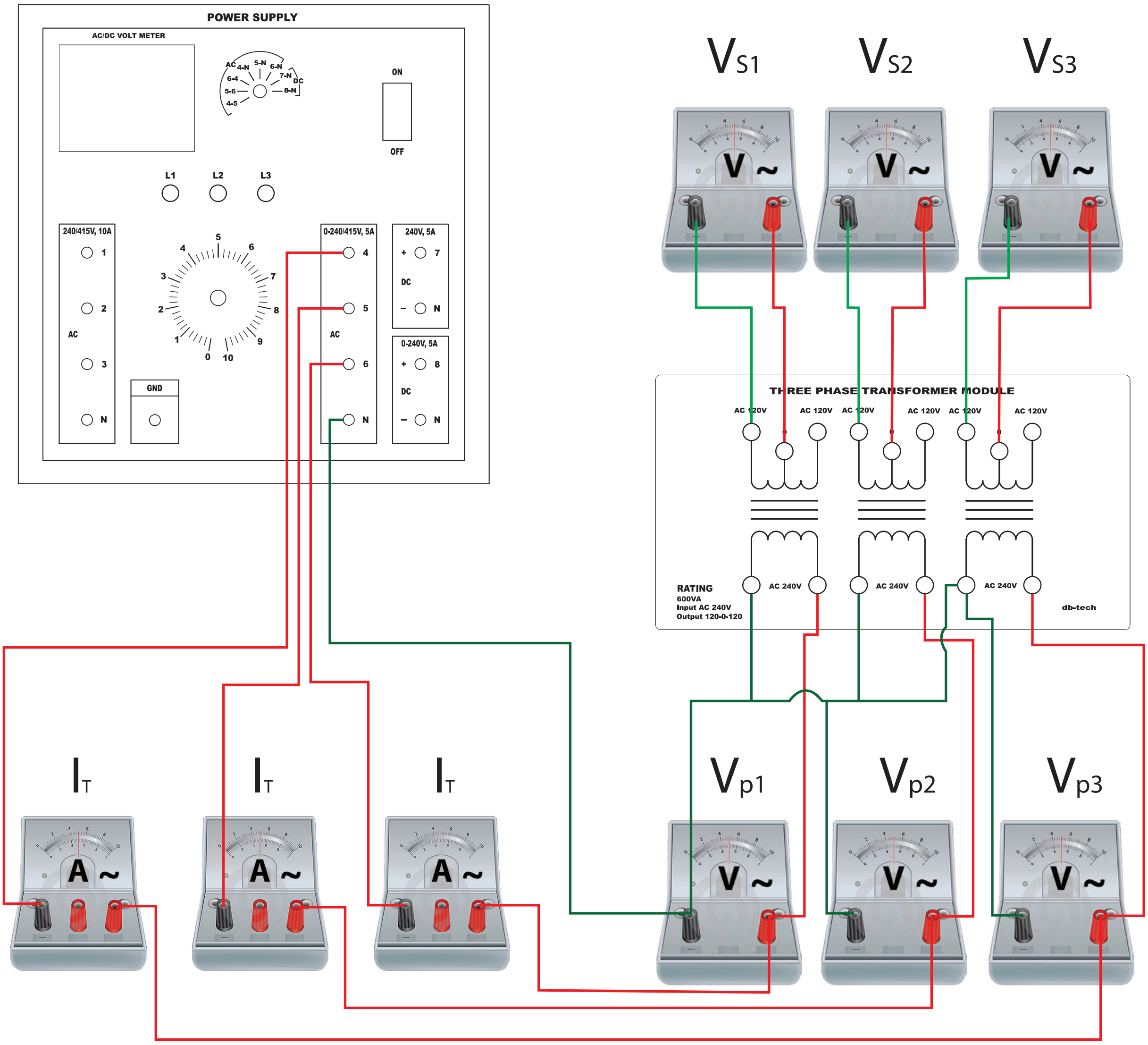



Figure: 01 Connection diagram of 3 phase open circuit test

# DC Motor/Generator

## I. INTRODUCTION

The purpose of this experiment is to examine the construction of a DC motor/generator, to learn the basic motor wiring connections, and to study the performance characteristics of a shunt and series dc motor. **INSTRUMENTS AND COMPONENTS:**

Power Supply Module (220Vac, 0-220Vdc)
DC Metering Module (220V, 5A)
DC Motor/Generator Module
Connections Leads
Timing Belt
Electrodynamometer Module
Strobotac

## II. BACKGROUND

Direct current motors are unsurpassed for adjustable-speed applications, and for applications with severe torque requirements. Millions of fractional horsepower DC motors are used by the transportation industries in automobiles, trains and aircraft where they drive fans and blowers for air conditioners, heaters and defrosters; they operate windshield wipers and raise and lower seats and windows. One of their most useful functions is for the starting of gasoline and Diesel engines in autos, trucks, buses, tractors and boats.

The DC motor contains a stator and a rotor, the latter being more commonly called an armature. The stator contains one or more windings per pole, all of which are designed to carry direct current, thereby setting up a magnetic field.

The armature and its windings are located in the path of this magnetic field, and when the winding also carries a current, a torque is developed causing the motor to turn.

A commutator associated with the armature winding is actually a mechanical device, to assure that the armature current under any given stator pole will always circulate in the same direction irrespective of position. If a commutator were not used, the motor could not make more than a fraction of a turn, before coming to a halt.

In order for a DC motor to run, current must flow in the armature winding and the stator must develop a magnetic field (flux), either by means of a shunt winding or a series winding (or both).

The torque developed by a DC motor is directly proportional to the armature current and the stator flux. On the other hand, motor speed increases when the voltage applied to the armature increases. Motor speed will also increase when the stator flux is reduced. As a matter of fact, the speed can attain dangerous levels if, accidentally, there is a complete loss of the stator field. DC motors have been known to fly apart under these over speed conditions. However, your DC motor has been carefully designed to withstand possible over speed conditions.

In a shunt motor, the field winding, as well as the armature winding, is connected in parallel (shunt) directly to the dc supply lines. If the dc line voltage is constant, then the armature voltage and the field strength will be constant. It is, therefore, apparent that the shunt motor should run at a reasonably constant speed.
The speed does tend to drop with an increasing load on the motor. This drop in speed is mainly due to the resistance of the armature winding. Shunt motors with low armature winding resistance run at nearly constant speeds through a broad range of loads.

Just like most energy conversion devices, the dc shunt motor is not 100% efficient. In other words, all of the electric power which is supplied to the motor is not converted into mechanical power. The power difference between the input and output is dissipated in the form of heat, and constitutes what are known as the "losses" of the machine. These losses increase with load, with the result that the motor gets hot as it delivers more mechanical power.

The series motor behaves quite differently. In this motor, the magnetic field is produced by the current which flows through the armature winding; with the result that the magnetic field is weak when the motor load is light (the armature winding draws minimum current). The magnetic field is strong when the load is heavy (the armature winding draws maximum current). The armature voltage is nearly equal to the supply line voltage (just as in the shunt wound motor if we neglect the small drop in the series field). Consequently, the speed of the series wound motor is entirely determined by the load current. The speed is low at heavy loads, and very high at no load. In fact, many series motors will, if operated at no load, run so fast that they destroy themselves. The high forces, associated with high speeds, cause the rotor to fly apart, often with disastrous results to people and property nearby.

The torque of any dc motor depends upon the product of the armature current and the magnetic field. For the series wound motor this relationship implies that the torque will be very large for high armature currents, such as occur during start-up. The series wound motor is, therefore, well adapted to start large heavy-inertia loads, and is particularly useful as a drive motor in electric buses, trains and heavy duty traction applications.

## III. PRELAB EXERCISES

In the lab you will be measuring the quantities: source voltage, field current, armature current, speed, and load torque. Suppose these measurements are 120V, 0.25A, 2.6A, 1675rpm, and 9 lbf.in.

- Compute the speed and load torque in SI units (rad/sec and Nm respectively)

- Assuming shunt connected DC motor, compute back emf, field resistance, armature resistance, field loss, armature loss, power efficiency, starting torque, and no-load speed. Assuming stator flux to be linear function of field current, determine the constant $KK_F$.
- Suppose the connection is switched to series mode while maintaining the same voltage and load torque = 0.25 lbf.in. Assuming stator flux to be linear function of field current, determine the new speed, armature/filed current, back emf, field loss, armature loss, power efficiency, and starting torque.

## IV. LABORATORY EXPERIMENTS

**CAUTION!** HIGH VOLTAGES ARE PRESENT IN THIS LABORATORY EXPERIMENT! DO NOT MAKE ANY CONNECTIONS WITH THE POWER ON! THE POWER SHOULD BE TURNED OFF AFTER COMPLETING EACH INDIVIDUAL MEASUREMENT!

A. Connect the circuit shown in Figure 1. Note that the armature is connected to the variable 0-120Vdc output (terminals 7 and N) while the shunt field is connected to the fixed 120Vdc output (terminals 8 and N).

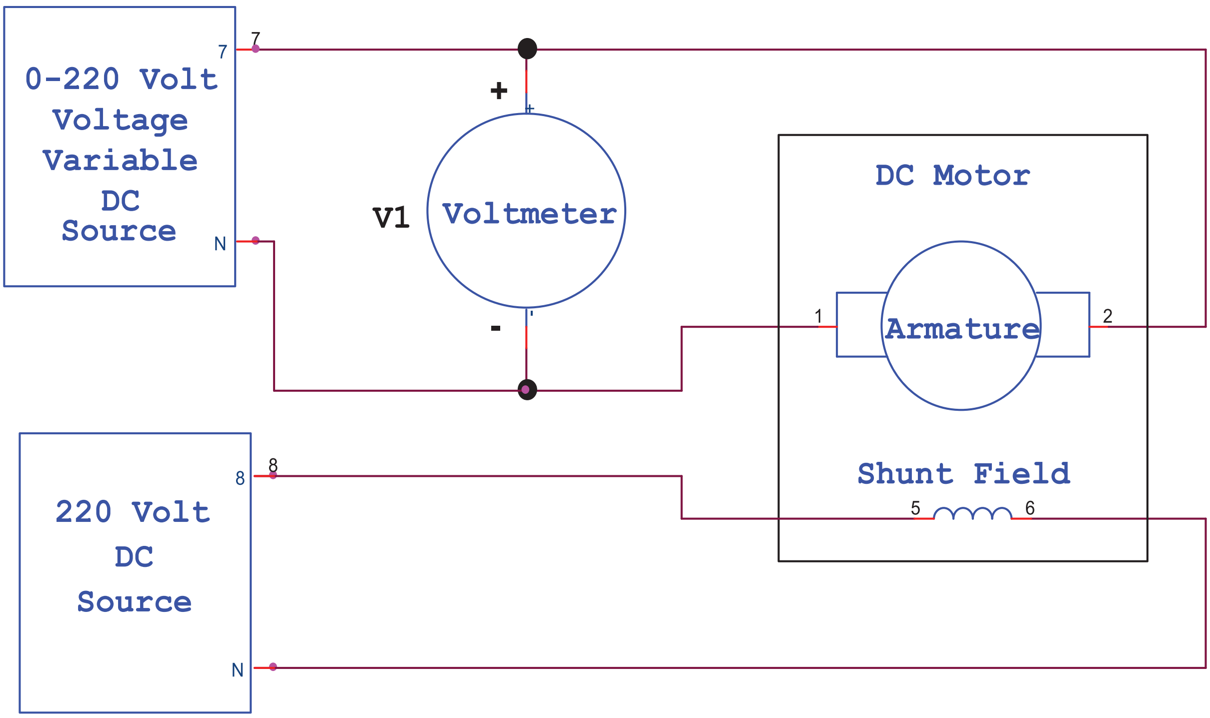



**Figure 1: Separately Excited Connection Diagram**

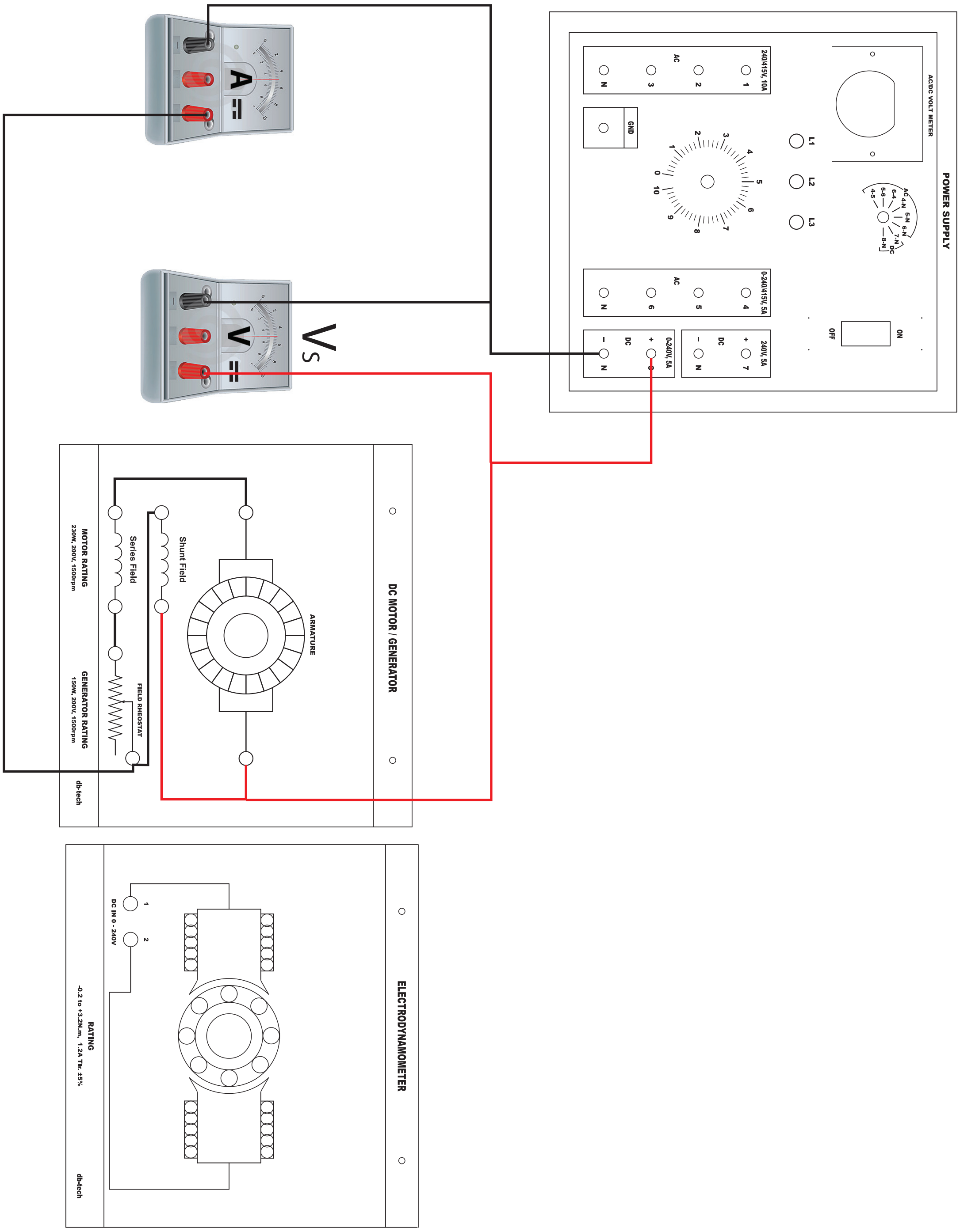



Figure: 02 Connection Diagram of DC Motor with Dynamometer.

- Turn on the power supply. Adjust the armature voltage to values shown in Table 1. Use your strobotac and measure the motor speed. Record your speed measurement in Table . (Wait un til the motor speed stabilizes before you take your measurement). Plot each of the points from Table 1 (i.e. Plot speed versus armature voltage). Draw a smooth curve through your plotted points.

B. Using your EMS Power Supply, DC Motor/Generator, DC Metering and Electrodynamometer Modules, connect the circuit shown in Figure 2. **DO NOT APPLY POWER AT THIS TIME!** Notice that the motor is wired for shunt field operation and is connected to the variable dc output of the power supply (terminals 7 and N). The electrodynamometer is connected to the fixed 120V ac output of the power supply (terminals 1 and N). Do not couple the dynamometer to the dc motor/generator with the timing belt at this time.

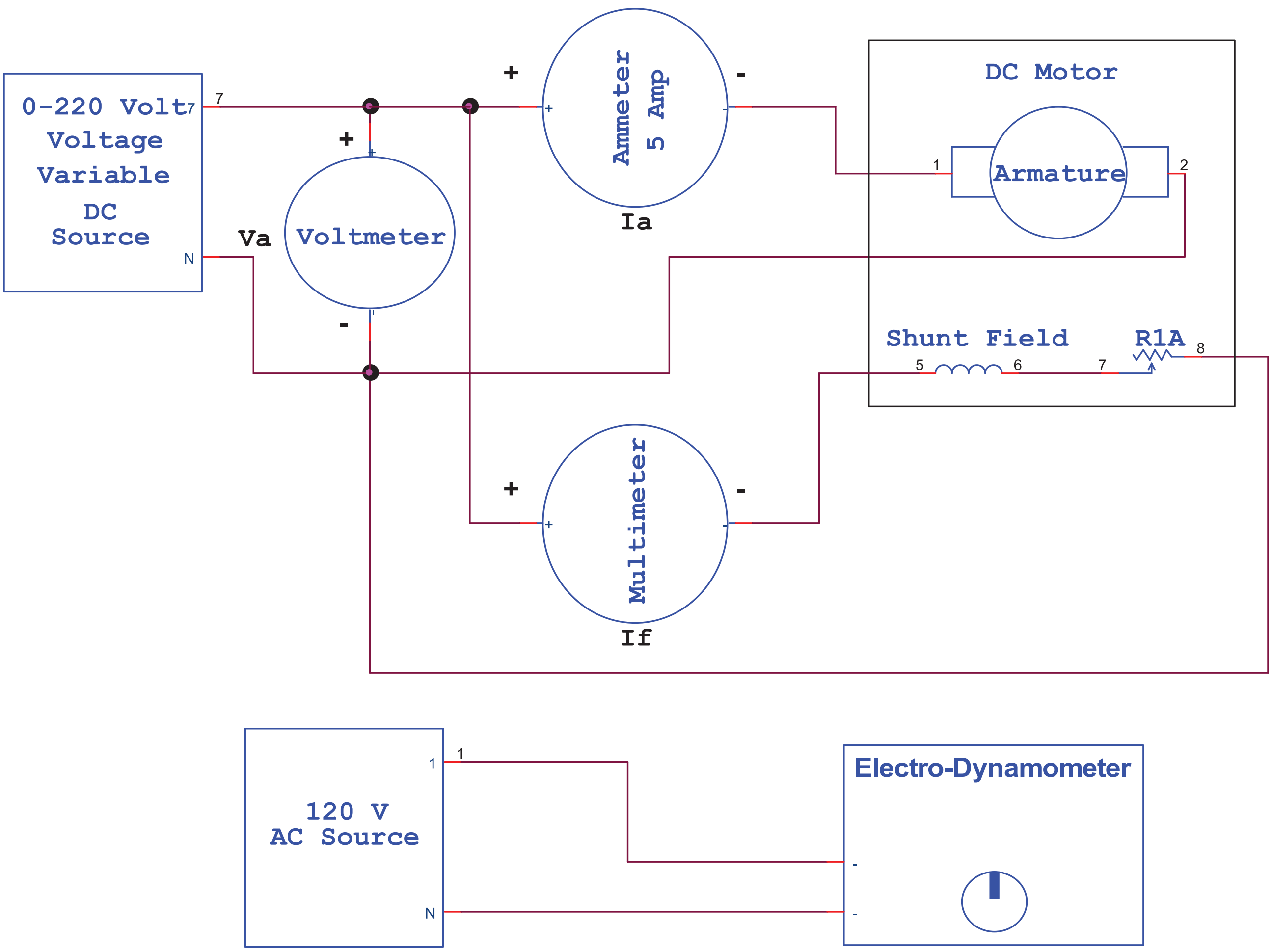



**Figure 2: Shunt Connection Diagram**

- Set the shunt field rheostat control knob at its full CW position (for maximum shunt field excitation). Turn on the power supply. Adjust the variable output voltage to 120Vdc as indicated by the meter. Adjust the shunt field rheostat for a no-load motor speed of 1800 r.p.m. as indicated on your strobotac. (Make sure that the volt-meter, connected across the input of your circuit, indicates exactly 120Vdc). Measure the armature and field currents as indicated by the ammeters, for a motor speed of 1800 r.p.m. Record these values in Table 2.
- Return the voltage to zero and turn off the power supply. Couple the dynamometer to the dc motor/generator with the timing belt. Set the dynamometer control knob at its full CCW position. Turn on the power supply and adjust the variable output voltage to 120Vdc. Readjust the field current using the field rheostat to the value obtained in previous step if necessary. Apply a load to your dc motor by varying the dynamometer control knob until the scale marked on the dynamometer housing indicates 3 lbf.in. (Readjust the power supply, if necessary, to maintain exactly 120Vdc). Measure the armature and field currents and motor speed. Record these values in Table 2. Repeat for each of the torque values listed in Table , while maintaining a constant 120Vdc input. Return the voltage to zero and turn off the power supply.

- Plot the recorded motor speed values from Table 2 (i. e. Plot speed versus torque). Draw a smooth curve through your plotted points. The completed graph represents the speed vs torque characteristics of a typical dc shunt-wound motor.
- Calculate the speed regulation for the shunt connected motor (full load = 9 lbf.in) using the equation:

$$Speedregulation = \frac{speed(no\_load) - speed(full\_load)}{speed(full\_load)} = \_\_\_\_\_\_\_\_\_\_\%$$

- Set the dynamometer control knob at its full CW position (to provide the maximum starting load for the shunt-wound motor). Turn on the power supply and gradually increase the dc voltage until the motor is drawing 3 amperes of armature current. The motor should turn slowly or not at all. Measure and record the dc voltage and the torque developed.

  V = ____________ Volts torque = ____________ lbf.in

- Return the voltage to zero and turn off the power supply. The armature current in the previous step is limited only by the equivalent dc resistance of the shunt-wound motor. Calculate the value of the starting armature current if the full line voltage (120Vdc) were applied to the shunt-wound dc motor.

  Starting current = ____________ A

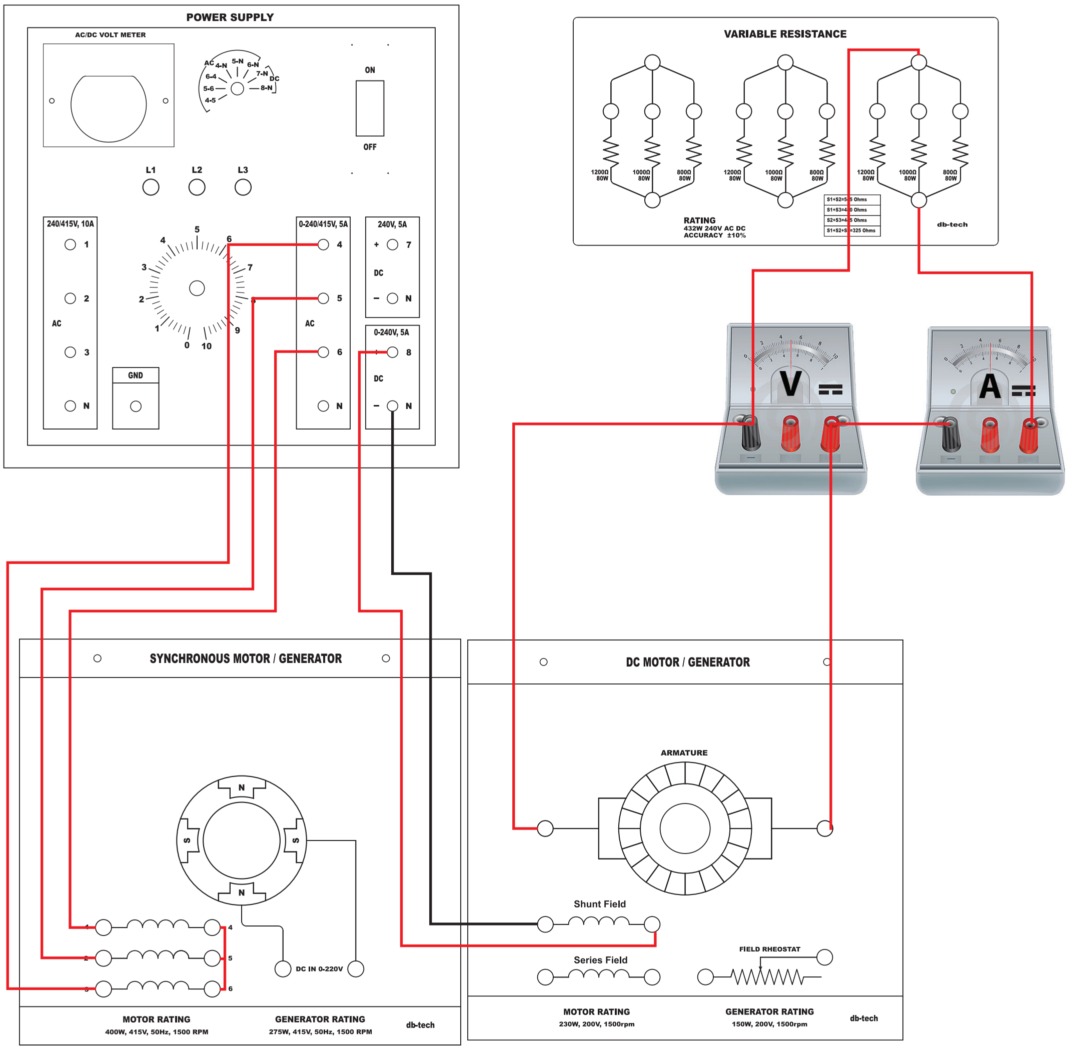



Figure: 04 Connection diagram of DC Generator

# Split Phase/Capacitor Start Motor Electro Dynamometer

## I. INTRODUCTION

The objectives of the experiment are: To examine the construction of the capacitor- run and the capacitor -start motors; To determine their starting and running characteristics; To compare their starting and running performance with each other. **INSTRUMENTS AND COMPONENTS:**

Split-Phase/Capacitor Start Motor Module
Power Supply Module (220Vac, 0-220 Vac)
Electrodynamometer Module
Timing Belt

AC Volt Meter(250 V)
AC Amp Meter (2.5/8/25A)
Techometer

## II. BACKGROUND

Single-phase motors are all rather noisy because they vibrate at 100 Hz when operated on- a 50 Hz power line. Various attempts to reduce this noise, such as resilient rubber mounting, are never totally effective in eliminating this vibration, particularly when the motor is directly coupled to a large resonant-prone fan.

The capacitor run motor is very useful in this type of application because the motor can be designed to have low vibration under full-load. The capacitor serves to shift the phase on one of the windings so that the current through the winding is 90 degree phase shifted from the current through the other winding, thus making the capacitor run motor a truly two-phase machine at its rated load. Because the capacitor remains in the circuit at all times no centrifugal switch is required.

When running at no-load, the motor is always noisier than at full-load because only under full-load does it run as a true two-phase machine. If the proper value of capacitance is chosen, the power factor can be close to 100% under full load conditions. However, the starting torque is quite low and the capacitor run motor is not recommended for severe starting conditions.

In a split-phase motor, the phase difference between start and run winding currents falls far short of 90 degrees. The starting torque developed in a motor that uses a split-phase stator also falls far short of the maximum that can be attained at an ideal 90 degree phase difference.

A phase shift closer to the ideal 90 degrees is possible through the capacitor-start system for creating a rotating stator field. This system, a modification of the split-phase system, uses a low reactance capacitor placed in series with the start winding of the stator to provide a phase shift of approximately 90 degrees for the start current resulting in greatly improved starting torque over the standard split-phase system. Capacitor start motors have the same running characteristics as their split-phase counterparts.

The capacitor and the start winding are disconnected by a centrifugal switch, just as in the case of the standard split-phase motor. Reversing the direction of rotation of a capacitor start motor is the same as in the case of the split-phase motor, that is, reverse the connections to the start or to the running winding leads to the supply/source.

Electro dynamometer and AC Metering Modules, connect the circuit shown in Fig. 1.

a. Couple the electrodynamometer to the capacitor run motor with the timing belt. (Leave the belt off for the zero torque setting in part 3.)

b. Connect the input terminals of the electrodynamometer to the fixed 120 Vac output of the power supply, terminals 1 and N.

c. Set the dynamometer control knob at its full ccw position (to provide a minimum starting load for the capacitor run motor).

3. a. Turn on the power supply and adjust for 1 20 Vac.

b. Measure and record in Table 1 the line current, the power and motor speed for each torque listed in Table 1.

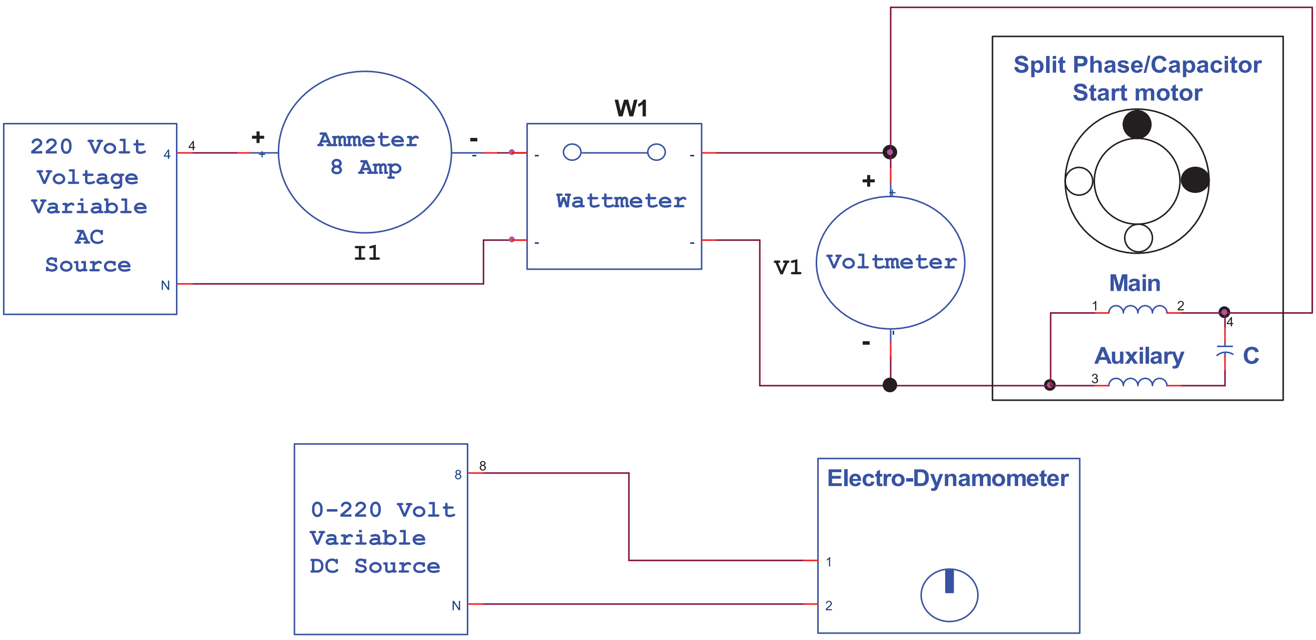



Figure: 1 Capacitor run motor connection diagram

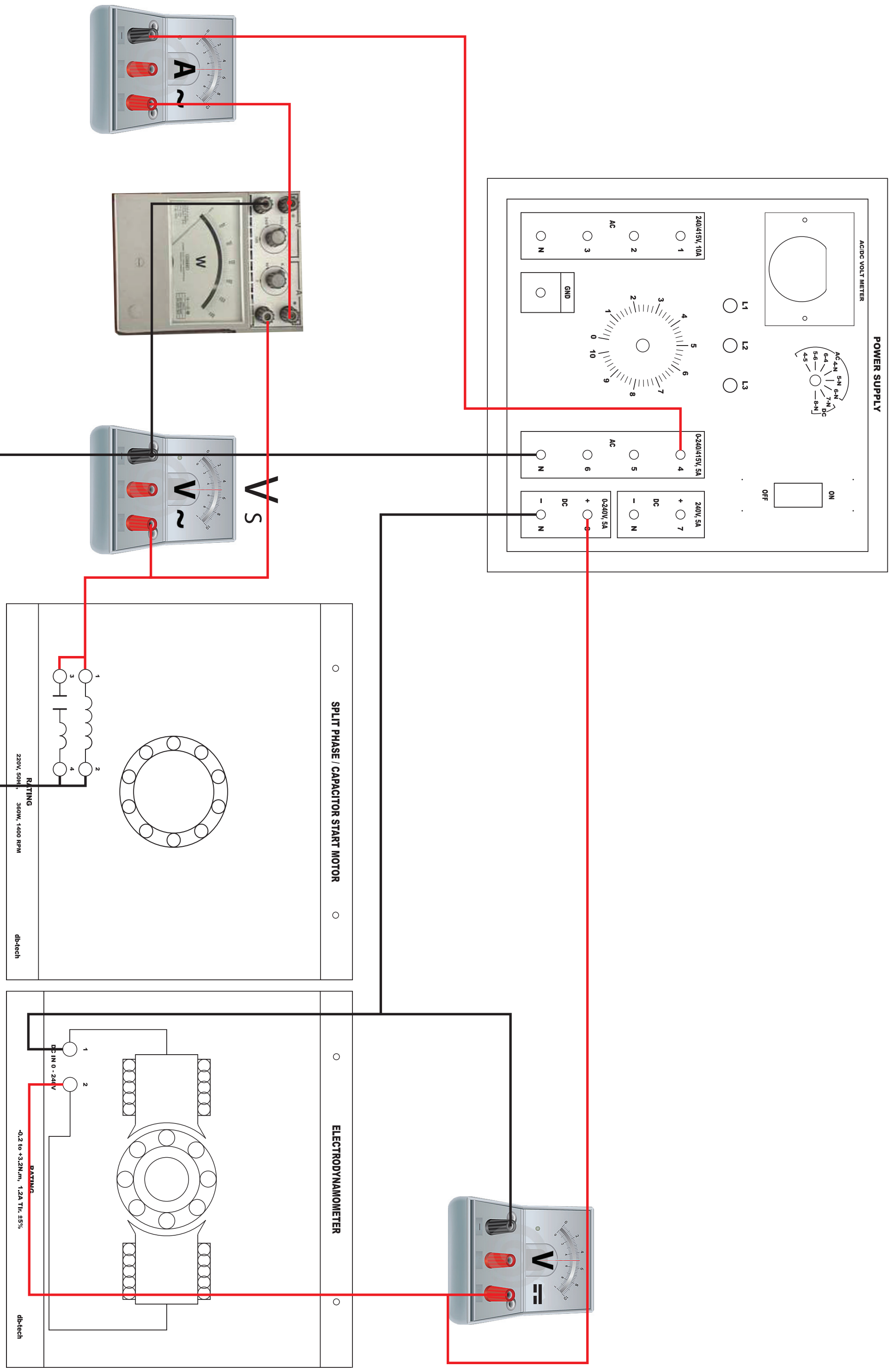



Figure: 02 Connection diagram of capacitor start motor

# Three Phase Induction Motor

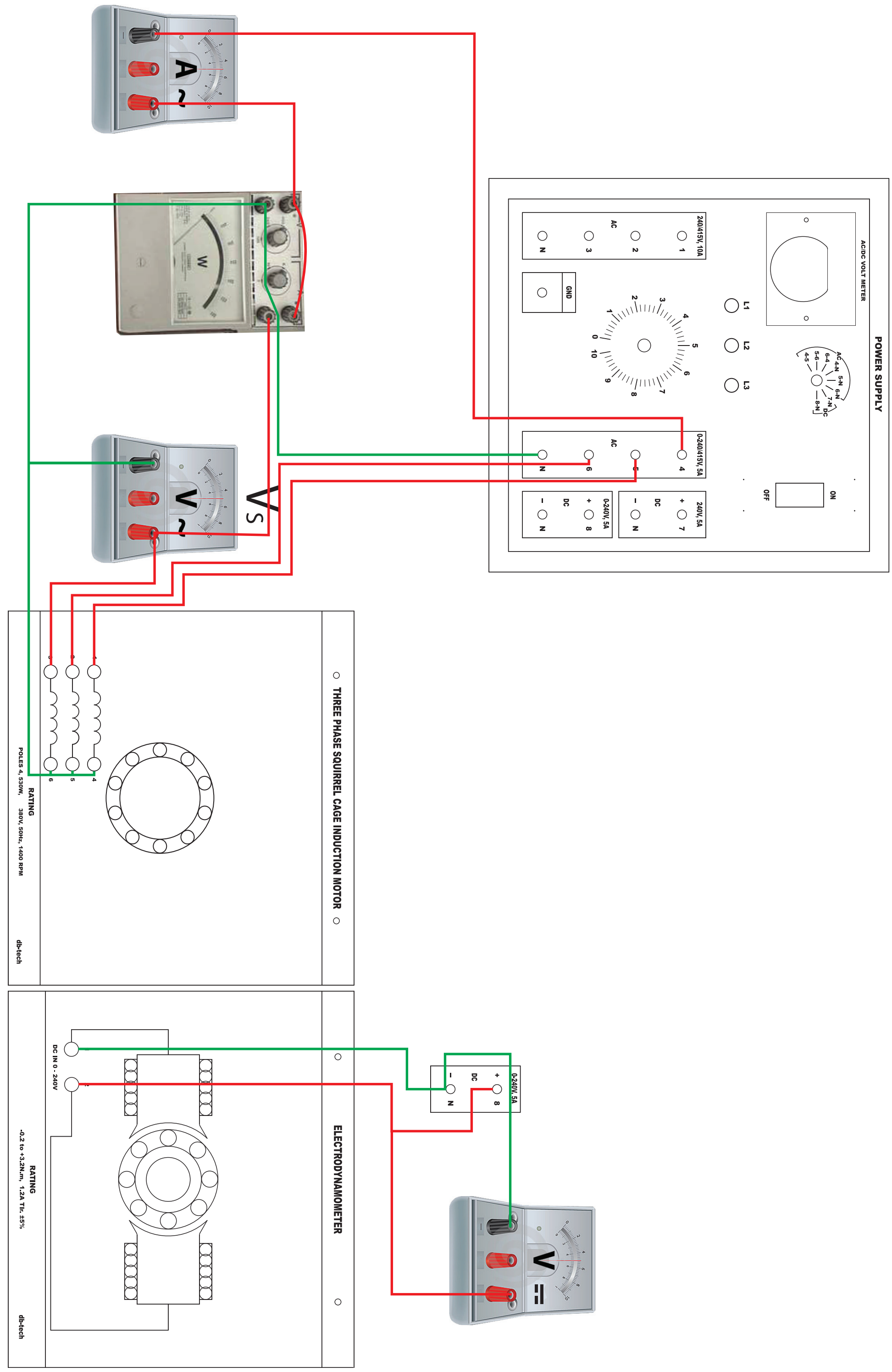

POWER SUPPLY
AC/DC VOLT METER
THREE PHASE SQUIRREL CAGE INDUCTION MOTOR
ELECTRODYNAMOMETER
Vs

Figure: 01

# Synchronous Motor/Generator

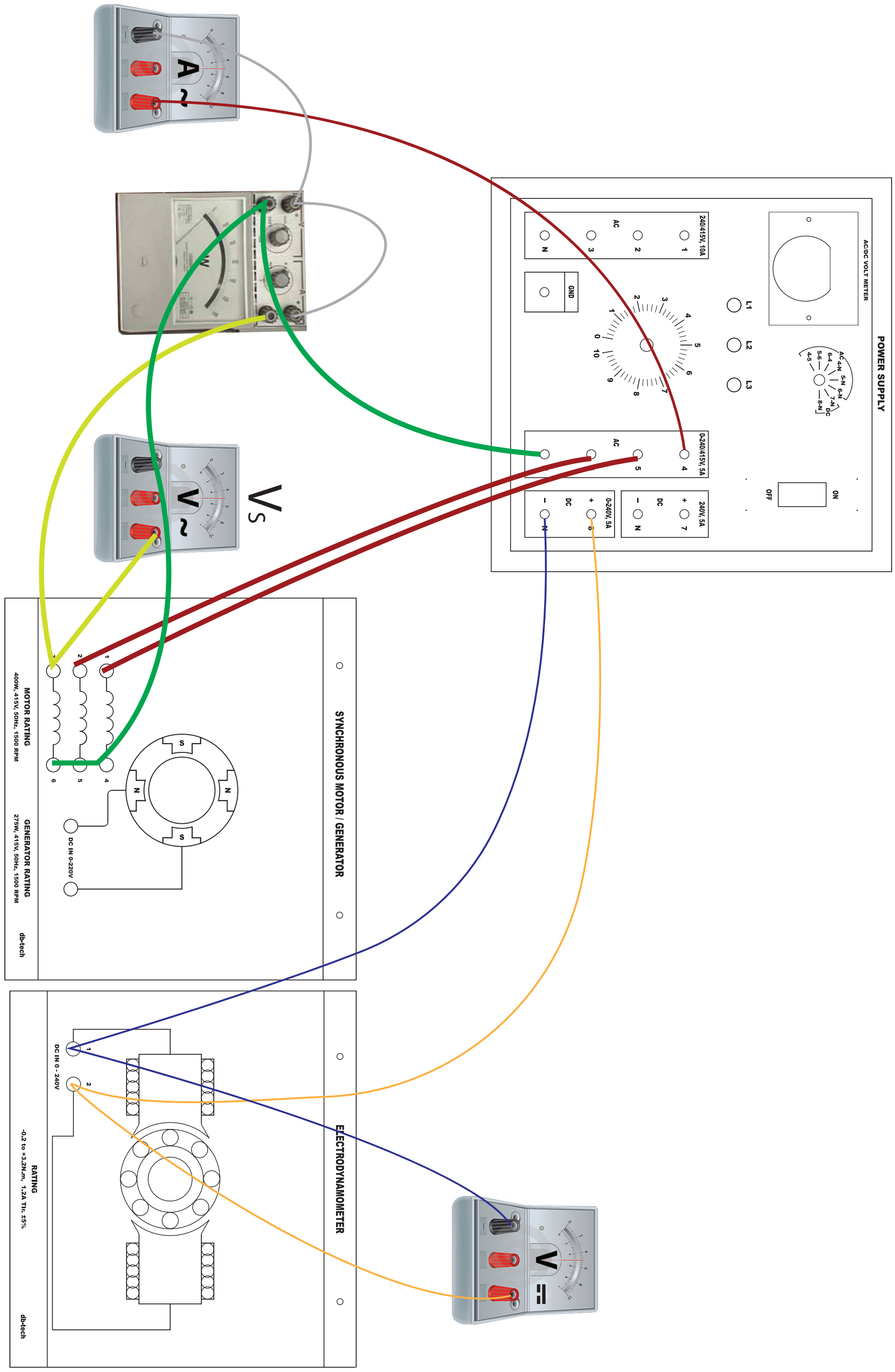



Figure: 01 Connection diagram of synchronous motor with dynamometer

# Synchronization of synchronous machine with grid

**Theory:**

Synchronous machine can be connected to the grid (represented by an equivalent generator) only when each of the voltages between the terminals $R_g\ R_s, Y_g\ Y_s$ and $B_g\ B_s$ is zero at any instant of time. This condition is fulfilled when the line voltages on the generator side are equal, at all instants of time, to the corresponding voltages on the bus bar side. This is possible only if the following conditions are fulfilled:

- The voltages $V_{grid}$ and $V_{synchronousMachine}$ are equal in magnitude and are in phase.
- Both the Grid and synchronous generator must have same frequency of supply voltage.
- The generator and grid voltages should have the same phase sequence.

When these conditions are fulfilled, the synchronizing switch between the generator and the grid can be switched on. Fulfillment of these conditions is checked by the following methods:

A. *Synchronization by three dark lamp method*:

Connect the D.C. motor - synchronous generator as shown in figure 6.2. Start the D.C. motor and bring its speed to the synchronous speed of the generator (1500-rpm). Adjust the field excitation of the synchronous machine so that about rated voltage (400V, L-L) is obtained. Assume that the grid has 400V, L-L. Let the phase sequence of the generator terminals RYB be the same as that of the respective terminals of the grid, RYB. The voltage phasors for this condition are shown in figure 6.3.If the generator frequency is slightly more than that of the bus, then the phasors $R_g$, $Y_g$ and $B_g$ move anti-clockwise relative to $R_s$, $Y_s$, and $B_s$. The voltages across the lamps $L_R, L_Y$ and $L_B$ (which are indicated by the phasors $R_g\ R_s, Y_g\ Y_s$ and $B_g\ B_s$) will increase & decrease simultaneously and therefore, the three lamps will brighten up and darken at the same time.

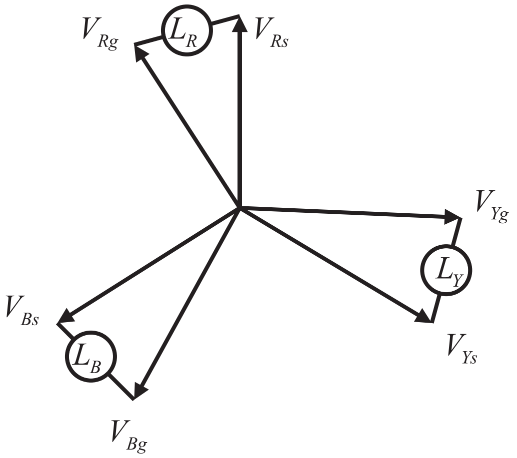



Figure 6.3 Voltage Phasors and Lamp connection for dark lamp method.

If the phase sequences are $R_g \; Y_g \; B_g$ and $R_s \; B_s \; Y_s$, for this condition the voltages across lamps given by phasors $R_g \; R_s$, $Y_g \; Y_s$ and $B_g \; B_s$ are not equal to each other at any instant. Therefore the lamps go through their zero voltage one after the other. The phase sequences are thus different and can be corrected by interchanging any two terminals either on the generator side or on the bus side. When such a change is made *both the three-phase main switch S2 and the D.C. main switch S1 should be switched off.*

With the phase sequence corrected, if there is a large difference between the frequency of the generator and that of the bus, the lamps will brighten & darken in quick succession. By adjusting the speed of the generator, this rapidity can be reduced, which indicates that the frequencies are coming closer and the lamps will brighten up & darken slowly.

The correct moment of synchronization in this method is when all the lamps are completely dark, at which time all the voltages of bus are exactly in phase with the corresponding voltages of the generator. At this moment the synchronizing switch S3 is closed and the generator is synchronized with the mains.

B. *Bright lamp method:*

C. *Method of using synchroscope:*

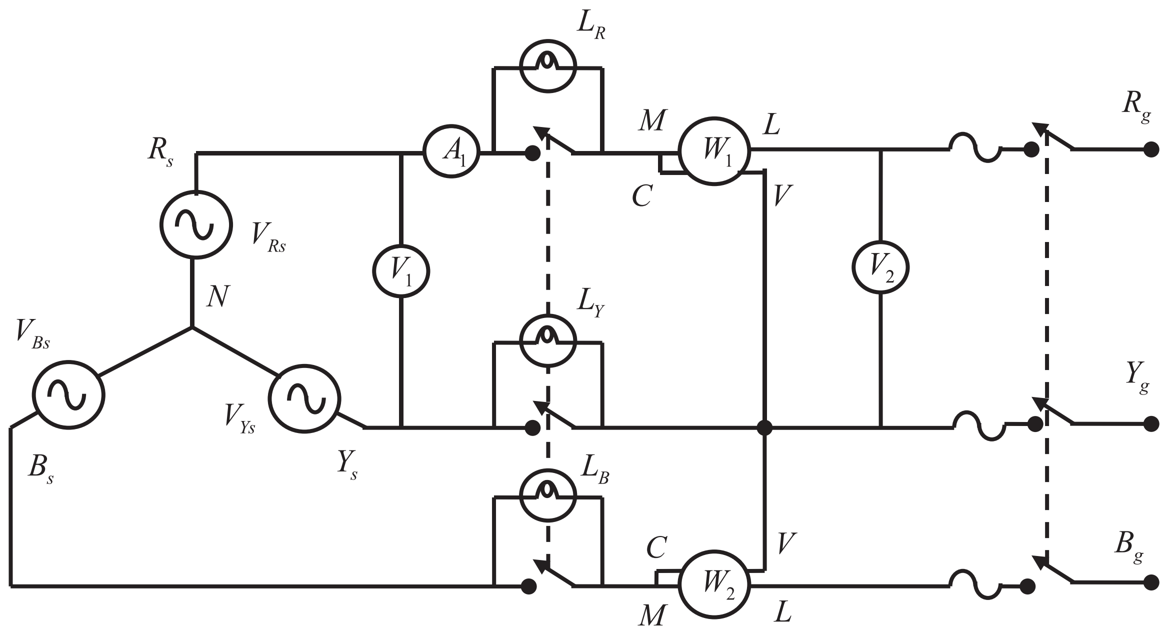



Fig. 6.3 Synchronization with grid using lamp method

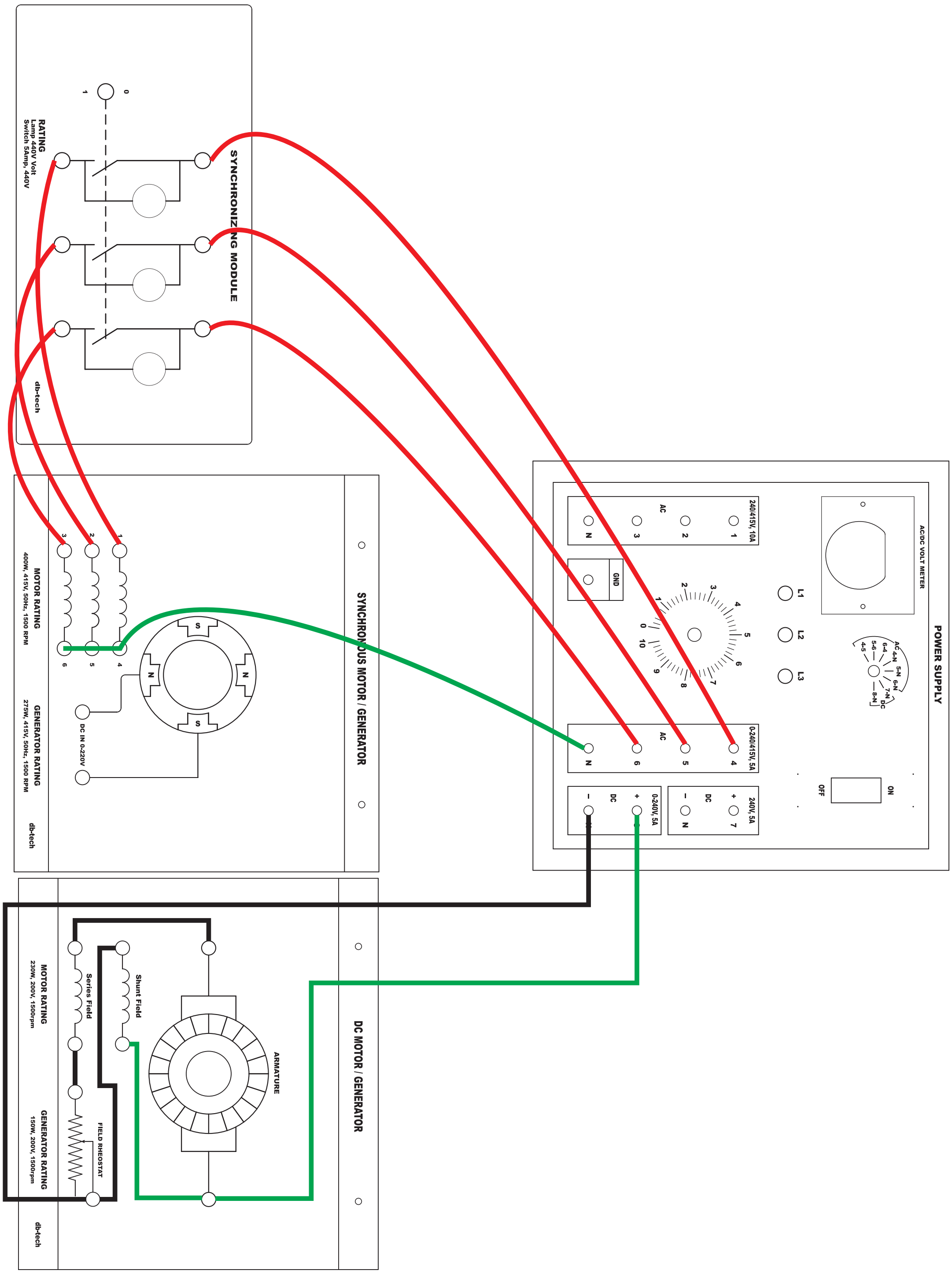

SYNCHRONIZING MODULE
RATING
Lamp 440V Volt
Switch 5Amp, 440V
db-tech
SYNCHRONOUS MOTOR / GENERATOR
MOTOR RATING
400W, 415V, 50Hz, 1500 RPM
GENERATOR RATING
275W, 415V, 50Hz, 1500 RPM
DC IN 0-220V
POWER SUPPLY
AC/DC VOLT METER
240/415V, 10A
0-240/415V, 5A
0-240V, 5A
240V, 5A
GND
ON
OFF
DC MOTOR / GENERATOR
MOTOR RATING
230W, 200V, 1500rpm
GENERATOR RATING
150W, 200V, 1500rpm
Series Field
Shunt Field
ARMATURE
FIELD RHEOSTAT

Figure: 02

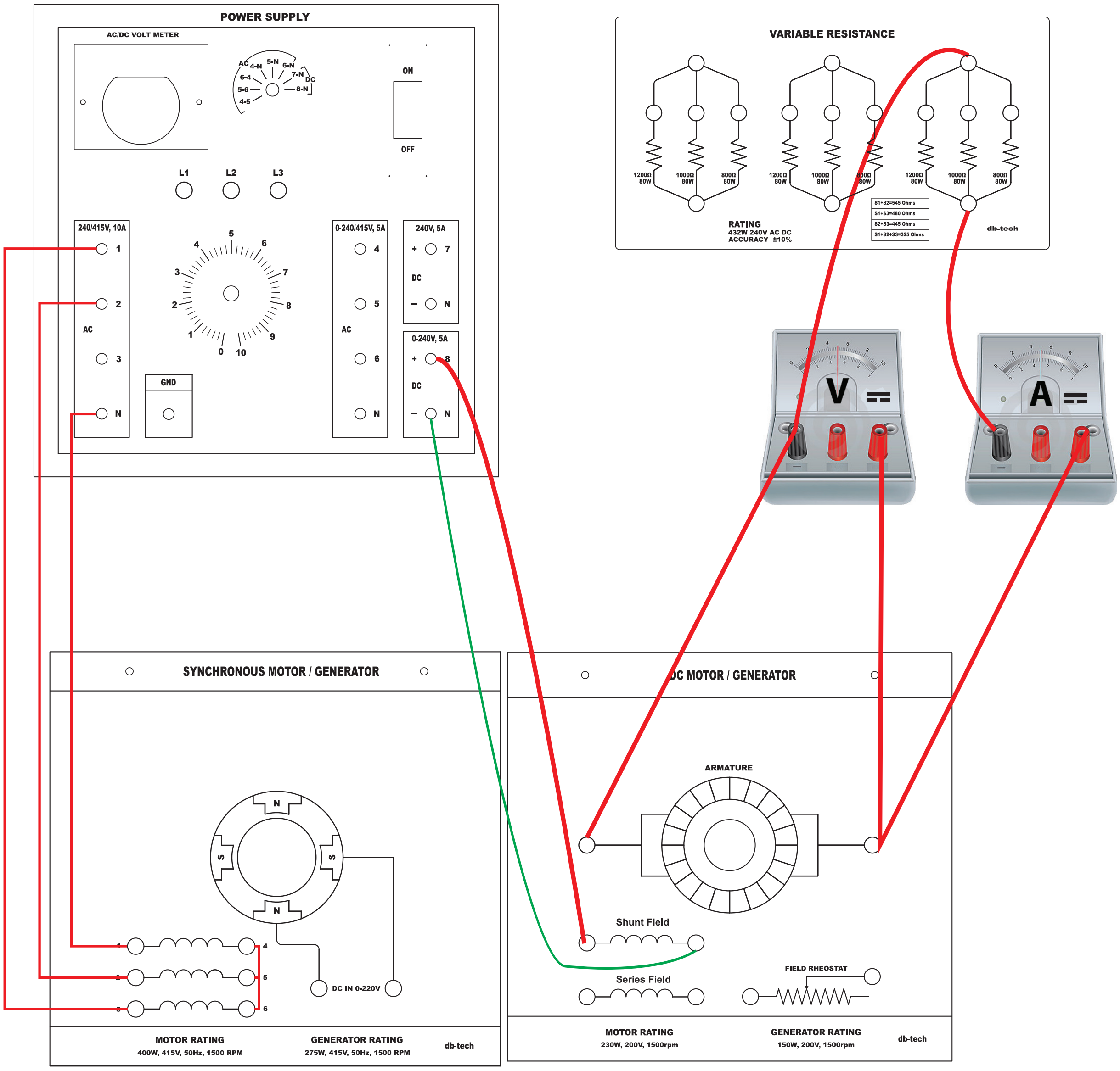

POWER SUPPLY
AC/DC VOLT METER
ON
OFF
L1
L2
L3
240/415V, 10A
AC
GND
0-240/415V, 5A
240V, 5A
DC
0-240V, 5A
VARIABLE RESISTANCE
1200Ω 80W
1000Ω 80W
800Ω 80W
RATING
432W 240V AC DC
ACCURACY ±10%
S1+S2=545 Ohms
S1+S3=480 Ohms
S2+S3=445 Ohms
S1+S2+S3=325 Ohms
db-tech
V
A
SYNCHRONOUS MOTOR / GENERATOR
DC IN 0-220V
MOTOR RATING
400W, 415V, 50Hz, 1500 RPM
GENERATOR RATING
275W, 415V, 50Hz, 1500 RPM
db-tech
DC MOTOR / GENERATOR
ARMATURE
Shunt Field
Series Field
FIELD RHEOSTAT
MOTOR RATING
230W, 200V, 1500rpm
GENERATOR RATING
150W, 200V, 1500rpm
db-tech

Figure: 03