EXPERIMENT NO. 15

PARALLEL OPERATION OF POLYPHASE ALTERNATORS

PURPOSE:

The objectives of the experiment are to parallel two polyphase alternators and to demonstrate the effects of various loads on their paralleled output.

DISCUSSION:

The following steps are necessary in placing a polyphase alternator in parallel with other alternators across a bus.

1. The alternator is brought up to rated speed, and its effective line voltages are adjusted to the bus voltage by means of a voltmeter.

2. The phase sequence is checked by means of a phase-sequence indicator or synchronizing lamps.

3. The frequency of the incoming alternator is compared to the bus frequency by means of a synchroscope or a lamp method. If the incoming machine frequency is low, the prime-mover speed is increased; if high, the speed is decreased.

4. The paralleling switch is closed at the instant the lamps or synchroscope indicate that the voltages are synchronized. The incoming alternator is now floating on the line.

5. The alternator is made to take on load by increasing the speed of its prime mover.

6. The power factor at which the alternator carries reactive power is adjusted by means of its field rheostat.

7. The bus voltage is adjusted by adjusting all field rheostats simultaneously.

APPARATUS REQUIRED:

2 ULM Sets
1 ULM Set Instruction Manual - Bulletin 120MI

1 ULM Console Instruction Booklet - Bulletin 120CI
2 ULM Consoles each containing,
 110 volt DC Power Supply
 Automatic DC Starter
 Dynamometer Field Rheostat (250Ω)
 Universal Machine Field Rheostat (173Ω + 11Ω)
1 AC Control Section of a Hampden Switchboard
1 Loading Section of a Hampden Switchboard

PROCEDURE:

1. Connect each of the Dynamometers to operate as shunt motors as shown in Figure 22. Adjust their field rheostats to the minimum resistance position and the auxiliary resistance switch to "out".

2. Connect each of the Universal Machines to operate as alternators as shown in Figure 22.

3. Make the switchboard connections as shown in Figure 23. Prepare the switchboard as follows:

 A. Put all instrument switches to the off position.

 B. Put the paralleling and field switches to the off position.

 C. The Universal Machine field vernier to its mid-resistance position.

4. Have the instructor check your machine and switchboard connections.

5. Start one of the Dynamometers by switching on the main AC, DC supply and DC Starter circuit breakers and pushing the start button of the DC starter. Adjust the speed up to 3600 RPM. Close the field switch on the switchboard of the running alternator (henceforth, referred to as alternator #1). The field current will now be indicated on the DC ammeter. This field current can be varied by means of the Universal Machine Field Rheostat on the console and the Universal Machine Field Vernier on the switchboard.

 Adjust the output voltage to 115 volts. Switch on the output circuit breaker and add a 1000 watt resistive load to the alternator. Maintain the 115 volt-60 cycle output by adjustment of the field current and speed. Record the volts, amps, watts, power factor, and frequency in Table 24. Only one wattmeter and power factor meter are provided. These instruments are each provided with two switches and one removable (off position only) handle. The meters will indicate for either alternator depending which one of its two switches is being operated.

6. Start the second Dynamometer and bring the speed up to 3600 RPM. Close the field switch of alternator #2 and adjust the output to 115 volts.

   Place the phasing lamp switch in the dark position. The phasing lamps should now be flashing. If the lamps flash off and on alternately, the phase sequence of alternator #2 is incorrect. If the lamps flash off and on together, the phase sequence is correct.

   Adjust the speed of alternator #2 to decrease the speed of the flashes. When the flashing has been caused to stop so that the lamps are dark, the alternators are synchronized; that is, their voltages are equal and in phase.

   A more accurate way of determining the exact point of synchronism is the synchroscope. The synchroscope is controlled by two instrument switches and two removable keyed handles. Both handles fit either switch and each handle enables the operation of the switch to only one of its two operative positions. Turn the synchroscope switch of alternator #1 to the R (running) position. Turn the synchroscope switch of alternator #2 to the I (incoming) position. The resulting pointer rotation of the synchroscope indicates the difference in frequency of the two alternators. If the rotation is in the "FAST" (clockwise) direction, the incoming frequency (alternator #2) is too high. If the rotation is in the "SLOW" (counter-clockwise) direction, the incoming frequency is too low. The rate at which the pointer rotates indicates the magnitude of the frequency differential.

   Close the parallel switch when the pointer is caused to stop at the index position. Alternator #2 is now floating on the line.

7. Adjust alternator #2 so that it shares the load with alternator #1. As you increase the load on alternator #2, maintain unity power factor by adjusting the field current. Note

that at light loads, the reading on the power factor meter will drift and should be ignored.

8. Decrease the load to 500 watts and vary it in several steps to 2000 watts. Record the volts, amps, watts, power factor, and frequency for each machine in Table 25.

9. Decrease the load to 1000 watts and open the parallel switch. Alternator #2 is now disconnected from the line. Open its field switch and shut off its shunt motor.

10. If time permits, synchronize the two alternators again using the electronic switch and oscilloscope. Make the connections as shown in Figure 24. The connections should enable a dual trace of both alternator wave forms to be displayed on the CRT. Externally synchronize the oscilloscope sweep to one of the "SYN" outputs of the electronic switch. This will cause one of the waveforms to become stationary. The other alternator's waveform will roll to the right or left depending on its frequency relative to the alternator. When this waveform is caused (by adjustment of the speed of alternator #2) to stop so that the waveforms are exactly in phase, they may be paralleled.

11. If time permits, vary the power factor of the load on the paralleled alternators and note the results.

REPORT:

Prepare a formal report. Discuss in detail the methods used to synchronize the alternators. Discuss your experience in dividing the load between the two alternators. Plot the volts, amps, watts, power factor, and frequency for each alternator as ordinates versus the total output power as abcissa on one set of axes. How did the varying load affect the alternators?

QUESTIONS:

1. With the alternators paralleled, what would happen if one of the prime movers were shut off?

2. Can a synchroscope be used to check phase sequence?

3. What other methods can be used to check phase sequence?

4. What causes hunting or oscillation of alternators?

TABLE 24: ALTERNATOR #1

	L1-L2 Volts	L2-L3 Volts	L3-L1 Volts	L1 Amps	L2 Amps	L3 Amps	Watts	Power Factor	Freq
Alt. #1									

TABLE 25: PARALLELED ALTERNATORS

	L1-L2 Volts	L2-L3 Volts	L3-L1 Volts	L1 Amps	L2 Amps	L3 Amps	Watts	Power Factor	Freq
Alt. #1									
Alt. #2									

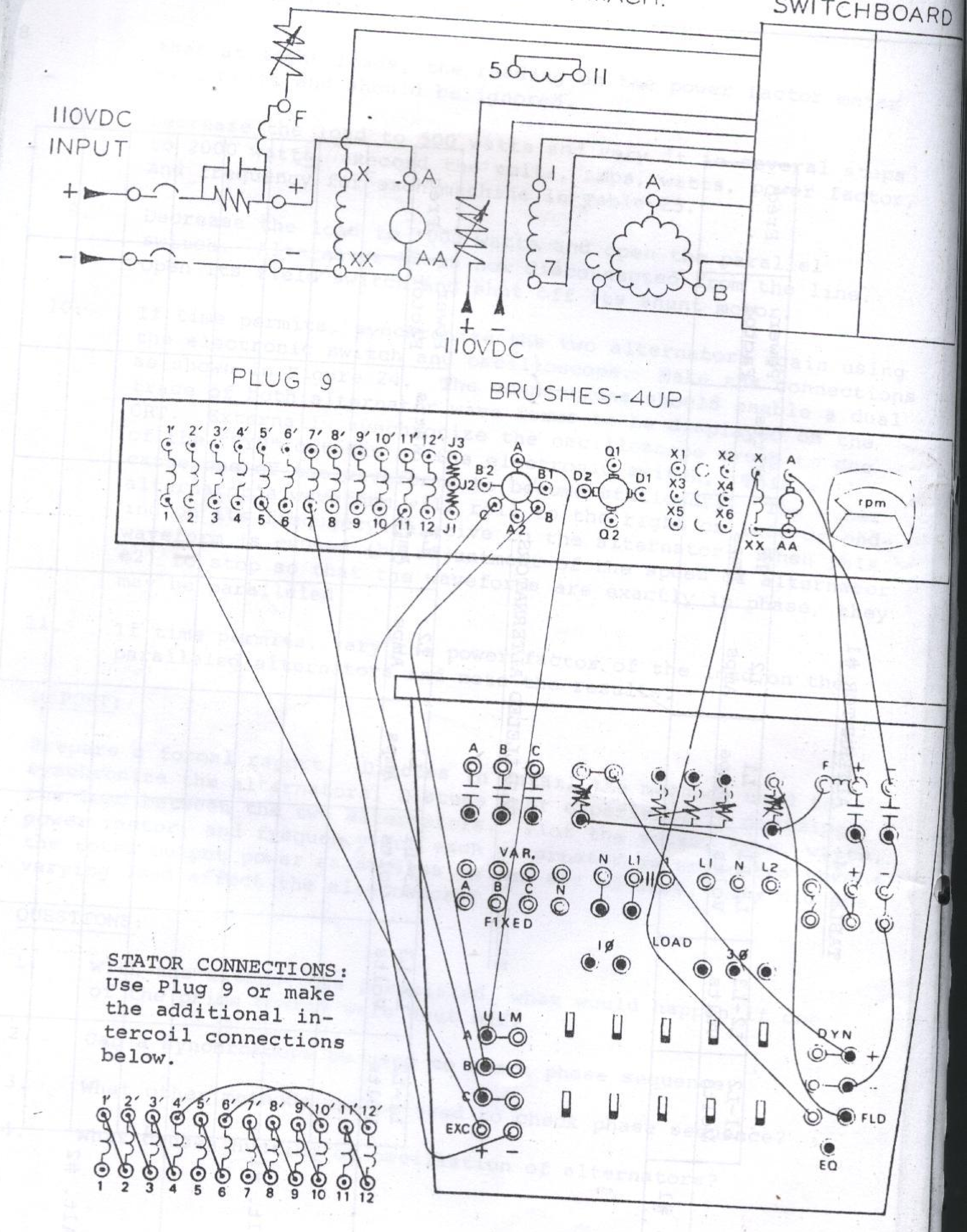


FIGURE 22: INDIVIDUAL MACHINE CONNECTIONS.

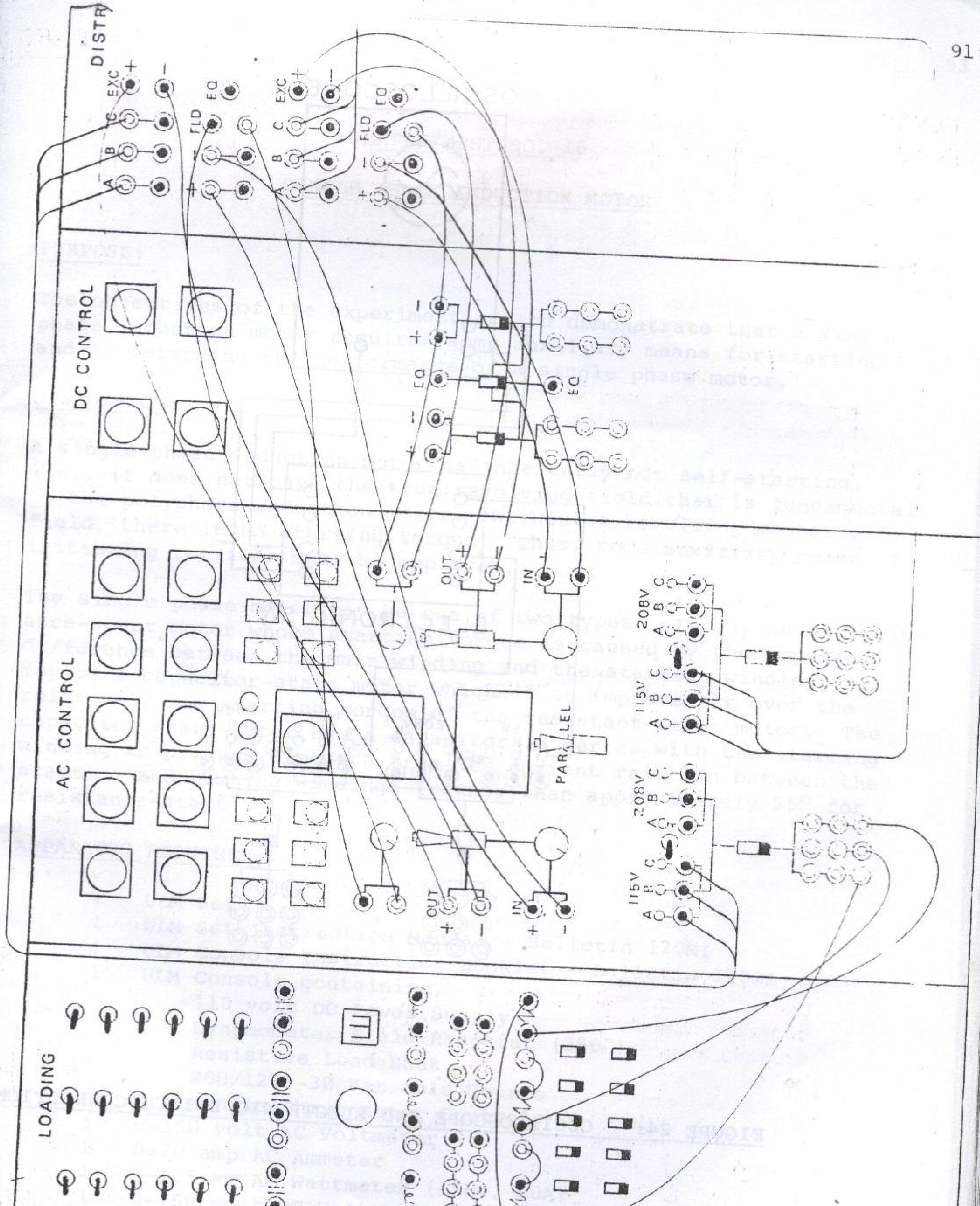


FIGURE 23: SWITCHBOARD CONNECTIONS FOR PARALLE

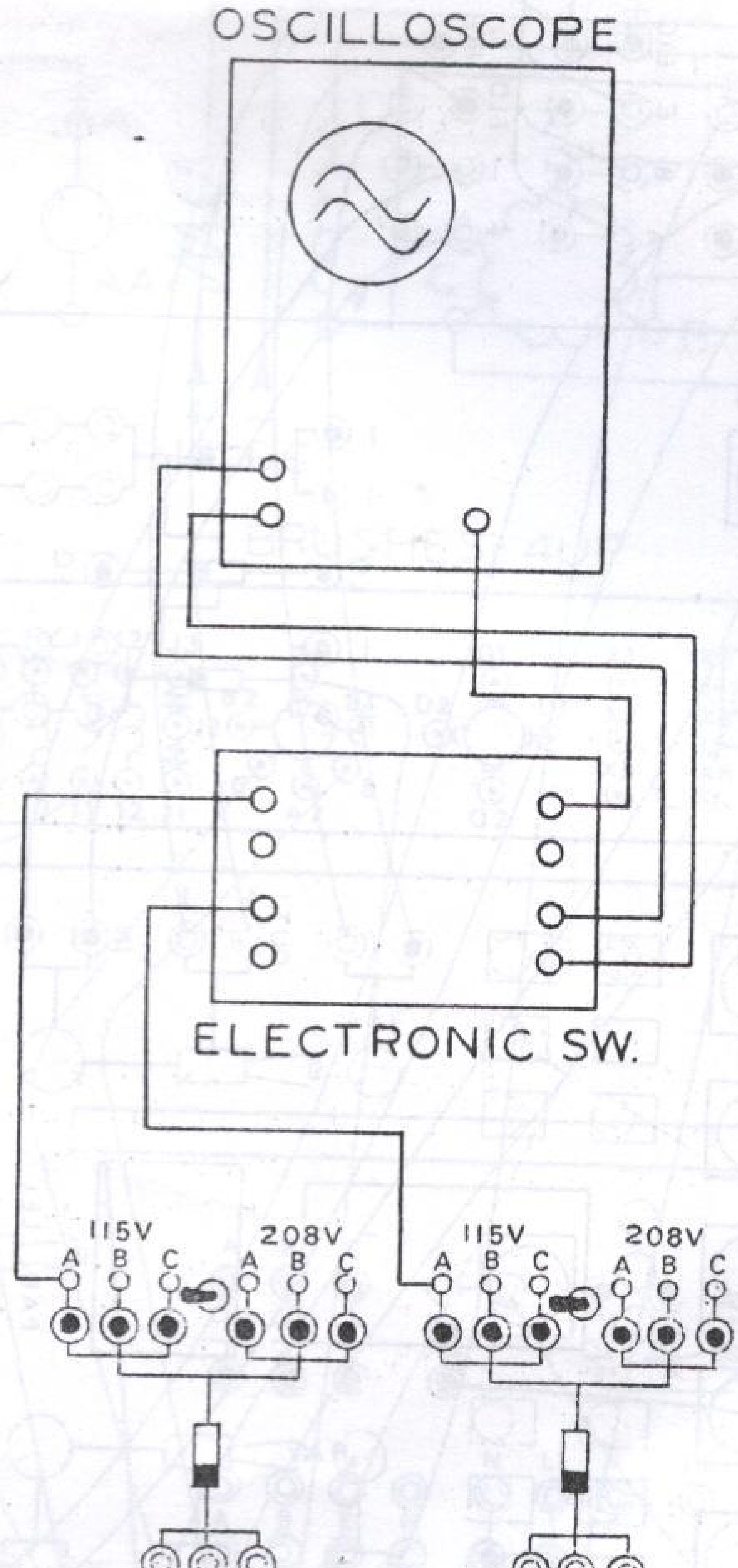


FIGURE 24: OSCILLOSCOPE AND ELECTRONIC SWITCH CONNECTIONS

EXPERIMENT NO. 16

SINGLE PHASE INDUCTION MOTOR

PURPOSE:

The objectives of the experiment are to demonstrate that a single phase induction motor requires some auxiliary means for starting and to determine the performance of a single phase motor.

DISCUSSION:

A single phase induction motor is inherently not self-starting, i.e., it does not have the true revolving field that is fundamental to the polyphase induction motor. Without a revolving magnetic field, there is no starting torque. Thus, some auxiliary means of initiating rotation must be employed.

The single phase motor may be one of two types. It may be a resistance-start motor whose starting torque is caused by the impedance difference between the main winding and the starting winding. It may be a capacitor-start motor which is an improvement over the relatively low starting torque of the resistant-start motor. The capacitor start-motor has a capacitor in series with the starting winding to produce almost a true 90° current relation between the starting and running windings (rather than approximately 25° for resistance-start).

APPARATUS REQUIRED:

- 1 ULM Set
- 1 ULM Set Instruction Manual - Bulletin 120MI
- 1 ULM Console Instruction Booklet - Bulletin 120CI
- 1 ULM Console containing,
  - 110 volt DC Power Supply
  - Dynamometer Field Rheostat (250Ω)
  - Resistive Load Bank
  - 208/120v-3Ø Variable Source
  - Single Phase Motor Controls
- 1 0-150 volt AC Voltmeter
- 1 0-20 amp AC Ammeter
- 1 0-1.5 kw AC Wattmeter (150v, 20A)
- 1 0-150 volt DC Voltmeter

PROCEDURE:

1. Connect the Universal Machine to operate as a single-phase motor as shown in Figure 25. The current coils of the meters MUST be shorted when starting.

2. Connect the Dynamometer to operate as a shunt generator as shown in Figure 25. Adjust its field rheostat to the maximum resistance (fully clockwise) position.

3. Have the instructor check your machine and meter connections before starting the motor.

4. With the switches in the "CAP. START ON" and CAP. RUN" positions, start the motor by switching on the MAIN AC circuit breaker. As soon as the motor comes up to speed, change the switches to the "CAP. START OFF" and "IND. RUN" positions. It is very important that the starting capacitor be switched off as soon as possible. This capacitor is not capable of continuous duty. It should not be on the line for more than three seconds. It is also important that both the starting and running capacitors be used for starting. Their combined capacitance gives the best starting performance.

5. Adjust the output of the Dynamometer to 110 volts DC and perform a load test on the motor from no-load to 2.0 ft-lbs load on the Dynamometer. Record the data in Table 26.

REPORT:

Prepare a formal report. Using the data in Table 26, plot the amps watts, RPM, and power factor versus the output torque as abcissa on one set of axes. Include sample calculations of how you determined power factor. Analyze your curves, comparing them to the results that one would expect considering the theory involved. Explain any sources of error in your results.

QUESTIONS:

1. Would the motor start without a starting winding? Would it have started if the rotor was spun manually? Explain.

2. If the start winding were reversed, would the machine start in the opposite direction?

3. In a resistance-start motor, would resistance added in series

with the starting winding increase or decrease the starting torque?

4. Describe the operation, characteristics and applications of the following motors:

   Split-phase (Resistance-Start) Motor
   Split-phase (Capacitor-Start) Motor
   Single-Value Capacitor Motor
   Two-Value Capacitor Motor
   Shaded Pole Motor

TABLE 26: LOAD TEST

Volts										
Amps										
Watts										
RPM										
Power Factor										
Torque										

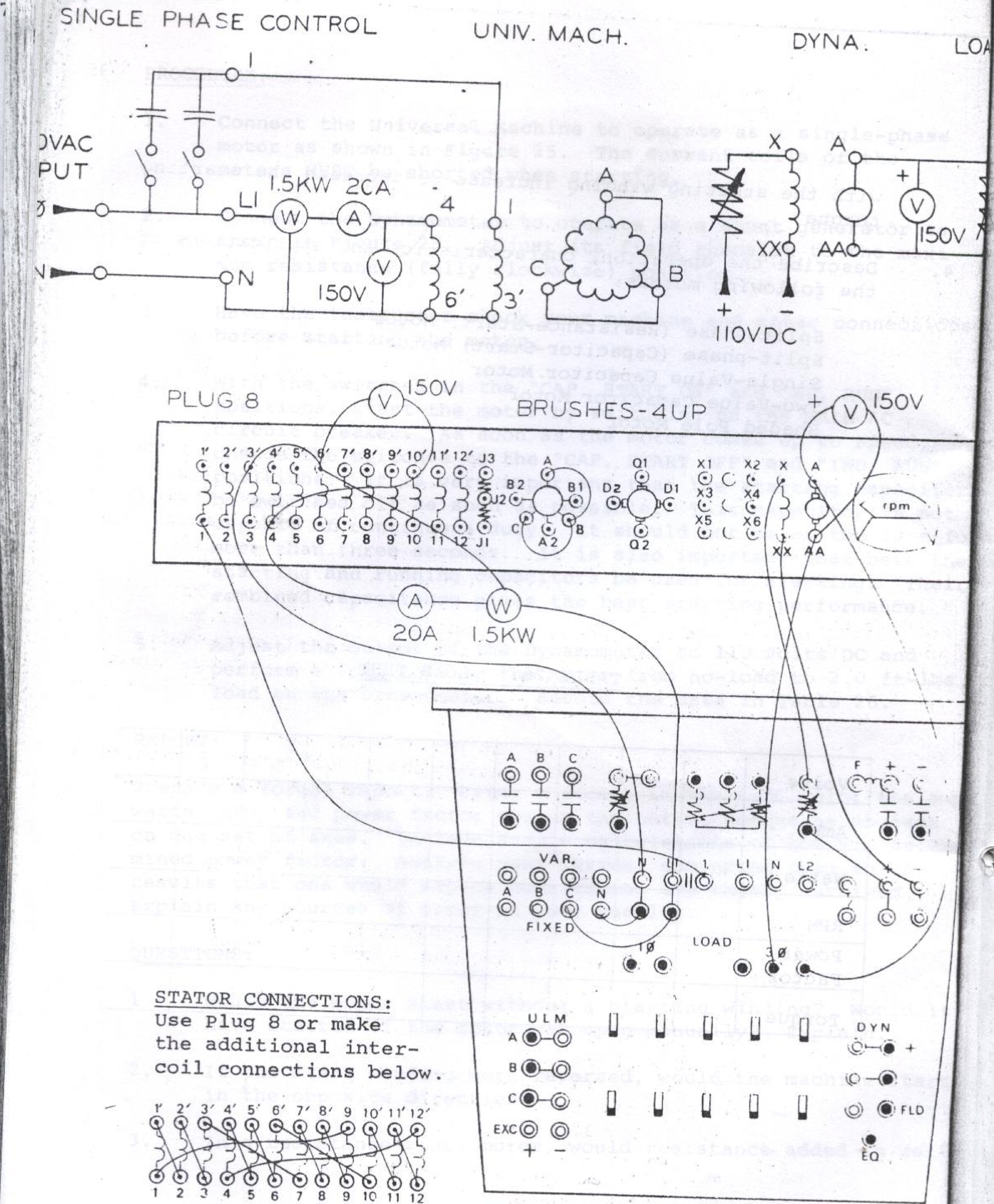


FIGURE 25: SINGLE-PHASE INDUCTION MOTOR

EXPERIMENT NO. 17

SINGLE PHASE CAPACITOR MOTOR

PURPOSE:

The objective of the experiment is to demonstrate the characteristics of a two-value capacitor motor.

DISCUSSION:

Because it runs continuously as a permanent split-phase motor, the single-value capacitor motor requires no starting switch. The motor starts and runs by virtue of the quadrature phase-splitting produced by the two windings. As a result, it does not possess the high running torque produced by either of the two types of split-phase induction motors studied in the previous experiment. Furthermore, the capacitor used in the single-value capacitor motor is designed for continuous duty and is of an oil-filled type. The value of the capacitor is based on its optimum running characteristic rather than its starting characteristic. The result is that this motor has a very poor starting torque.

The two-value capacitor motor, on the other hand, uses a high capacity electrolytic starting capacitor and lower capacity running capacitor to provide high starting torques as well as optimum running conditions.

APPARATUS REQUIRED:

1 ULM Set
1 ULM Set Instruction Manual - Bulletin 120MI
1 ULM Console Instruction Booklet - Bulletin 120CI
1 ULM Console containing,
  110 volt DC Power Supply
  Dynamometer Field Rheostat (250Ω)
  Resistive Load Bank
  208/120v-3Ø Variable Source
  Single Phase Motor Controls
2 0-150 volt AC Voltmeters
2 0-20 amp Ammeters
2 0-1.5 kw AC Wattmeters (150v, 20A)
1 0-150 volt DC Voltmeter

PROCEDURE:

1. Connect the Universal Machine to operate as a two-value capacitor motor as shown in Figure 26. The current coils of the meters MUST be shorted when starting.

2. Connect the Dynamometer to operate as a shunt generator as shown in Figure 26. Adjust its field rheostat to the maximum resistance (fully clockwise) position.

3. Have the instructor check your machine and meter connections before starting the motor.

4. With the switches in the "CAP. START ON" and "CAP. RUN" positions, start the motor by switching on the MAIN AC circuit breaker. As soon as the motor comes up to speed, change the switch to the "CAP. START OFF" position.

5. Adjust the output of the Dynamometer to 110 volts DC and perform a load test on the motor from no-load to 2.5 ft-lbs. load on the Dynamometer. Record the data in Table 27.

REPORT:

Prepare a formal report. Using the data in Table 27, plot the amps, watts, RPM, and power factor versus the output torque as abcissa on one set of axes. Include sample calculations of how you determined power factor. Analyze your curves comparing them to the results obtained in Experiment No. 16.

QUESTIONS:

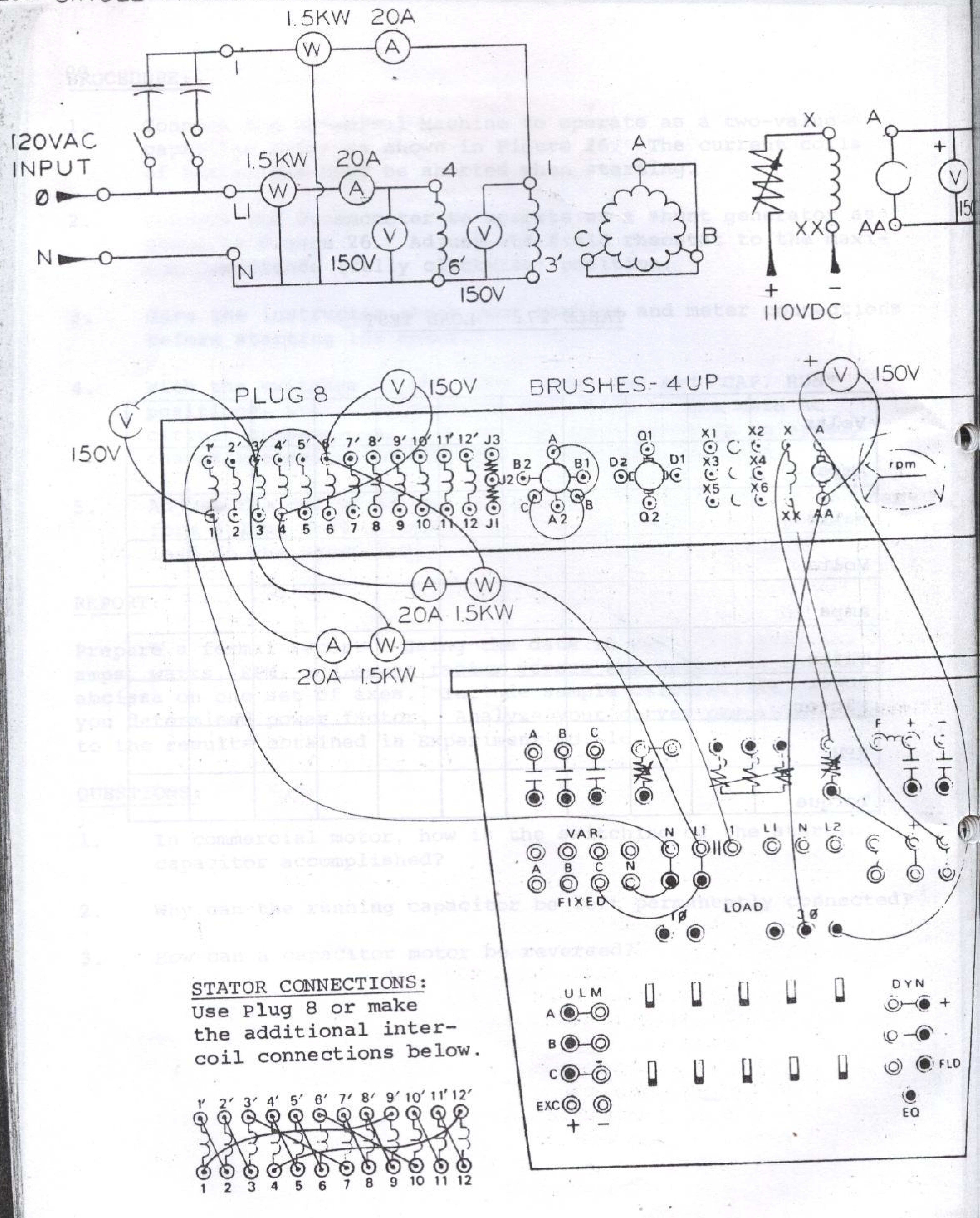
1. In commercial motor, how is the switching of the starting capacitor accomplished?

2. Why can the running capacitor be left permanently connected?

3. How can a capacitor motor be reversed?

TABLE 27: LOAD TEST

Volts										
Amps										
Watts										
Volts										
Amps										
Watts										
Power Factor										
RPM										
Torque										



STATOR CONNECTIONS:
Use Plug 8 or make the additional inter-coil connections below.

FIGURE 26: SINGLE-PHASE CAPACITOR MOTOR

EXPERIMENT NO. 18

LOAD CHARACTERISTICS OF A SQUIRREL CAGE MOTOR

PURPOSE:

The objectives of the experiment are to study the load characteristics of a squirrel-cage motor.

DISCUSSION:

There are two general types of induction motor rotors, (1) the wound rotor and (2) the squirrel-cage rotor. The wound rotor usually has a 3Ø winding which is brought out to terminals by means of three slip rings and brushes. These terminals are usually connected to a 3Ø rheostat so that the resistance of the rotor circuit may be adjusted for the purpose of changing the speed-torque-current characteristics of the motor. In the squirrel-cage rotor, the rotor conductors are short-circuited at each end by continuous end rings; hence, the name "squirrel-cage".

Although the experimental machine is a wound rotor machine, for this experiment the rotor slip rings have been short-circuited converting the rotor to the equivalent of a squirrel-cage rotor.

APPARATUS REQUIRED:

- 1 ULM Set
- 1 ULM Set Instruction Manual - Bulletin 120MI
- 1 ULM Console Instruction Booklet - Bulletin 120 CI
- 1 ULM Console containing,
  - 110 volt DC Power Supply
  - Dynamometer Field Rheostat (250Ω)
  - Resistive Load Bank
  - 208/120v-3Ø Source
  - AC Starter
- 1 0-300 volt AC Voltmeter
- 2 0-10 amp AC Ammeters
- 2 0-1.5 kw AC Wattmeters
- 1 0-150 volt DC Voltmeter

PROCEDURE:

1. Connect the Universal Machine to operate as a squirrel-cage

motor as shown in Figure 27. The meters should be connected into the circuit as shown with provisions for shorting their current coils when starting.

2. Connect the Dynamometer to operate as a shunt generator as shown in Figure 27. Adjust its field rheostat to the maximum resistance (fully clockwise) position.

3. Have the instructor check your machine and meter connections before starting the ULM.

4. Start the motor by switching on the main AC circuit breaker and pushing the start button on the AC starter. Observe the direction of rotation. Stop the motor and swap any two of the stator leads (1,5,9). Restart the motor again and observe the direction of rotation.

5. Adjust the output of the Dynamometer to 110 volt DC. Perform a load test on the motor from no-load to seven resistance load steps. Record the volts, amps, watts, and speed of the ULM and the torque of the Dynamometer in Table 28. Calculate the power factor for each load point.

   When using only two wattmeters on a three-phase system as shown in Figure 27, the total wattage is the sum of the readings on the two meters. If one of the meters goes down the scale below zero, reverse the current coil connections of the meter and record the reading as negative. Subtract the negative reading from the positive reading on the other wattmeter to obtain total wattage. As the motor is loaded, the negative reading will go positive. It will be necessary to again reverse the connections to obtain the positive reading.

REPORT:

Prepare a formal report following the suggested procedure for writing laboratory reports. Using the data in Table 28, plot the amps, RPM, and power factor as ordinates versus the output torque as abcissa on one set of axes. Analyze your curves, comparing them to the results that one would expect considering the theory involved. Your analysis should reveal your comprehension of the theory of operation of a polyphase induction motor.

QUESTIONS:

1. Why does a polyphase motor start without special starting 'indings?

2. What would be the result of one phase open-circuiting while the motor was running?

3. Why is a polyphase motor more desirable than a single-phase motor?

TABLE 28: LOAD TEST

Volts										
Amps										
Amps										
Watts										
Watts										
Total Watts										
Power Factor										
RPM										
Torque										