EXPERIMENT NO. 4

CHARACTERISTICS OF A SEPARATELY-EXCITED SHUNT GENERATOR

PURPOSE:

The objective of the experiment is to study the dynamic characteristics of a separately-excited shunt generator.

DISCUSSION:

As with any piece of electrical equipment, it is desirable to determine how a particular generator will perform under load conditions and to see why and how certain things happen. Since the armature circuit (armature with the interpole compensating winding) has some ohmic resistance, there will be a voltage drop in this circuit when current flows. There will also be an additional drop due to armature reaction. Knowing the external characteristic (load current versus terminal voltage) and the resistance of the armature circuit it is possible to predict the internal or total characteristic.

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
  - Automatic DC Starter
  - Dynamometer Field Rheostat (250Ω)
  - Universal Machine Field Rheostat (173Ω + 11Ω)
  - Resistive Load Bank
- 1 0-150 volt DC Voltmeter
- 1 0-15 amp DC Ammeter
- 1 0-10 amp DC Ammeter

PROCEDURE:

1. Connect the Dynamometer to operate as a shunt motor as shown in Figure 3. Adjust the Dynamometer Field Rheostat to its minimum resistance (fully counter-clockwise) position, and the auxiliary resistance switch to "out".

2. Connect the ULM to operate as a shunt generator as shown in Figure 3. Adjust the Universal Machine Field Rheostat to its maximum resistance (fully clockwise) position.

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

4. Start the Dynamometer 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 to 2400 RPM. Increase the Universal Machine's field current to 6 amps by means of the field rheostat.

5. The output voltage will now be approximately 130 volts. Load the generator from zero to 12 amps. The Dynamometer speed should be adjusted after each load step to maintain 2400 RPM. For each load step, measure the load current and terminal voltage and record your readings in Table 3.

   Note: Finer load steps (than 300 watts) are obtained by using two of the three 3Ø load jacks instead of the 1Ø load jacks. See Figure 3.

6. Repeat Step 5 with the ULM Field Rheostat in the fully ccw position. Record your readings in Table 4.

7. While the generator is still warm, measure the resistance of the armature circuit (including interpole).

REPORT:

Prepare a formal report following the suggested procedure for writing laboratory reports. Plot the terminal volts as ordinates versus the load current as abcissa for the rated field current in Table 3. This curve represents the external characteristics of the generator. On the same set of axes, plot the internal generated volts as ordinate versus the armature current as abcissa. This curve represents the internal characteristics of the generator. On a separate sheet, plot the external and internal characteristics of the generator when operated at full shunt field current using the data in Table 4. Discuss the internal and external characteristics of the generator for both values of shunt field current.

QUESTIONS:

1. Referring to the curves you plotted, explain why one curve is the external characteristic and the other is the internal.

2. What additional factors beside armature resistance causes the terminal voltage to drop under load?

3. Is the voltage regulation of the shunt generator better for high or low values of field current? Why?

4. Would the voltage regulation be better for speeds above or below the normal if the voltage was kept at the rated value?

5. How would you calculate the percent regulation?

TABLE 3: RATED FIELD CURRENT

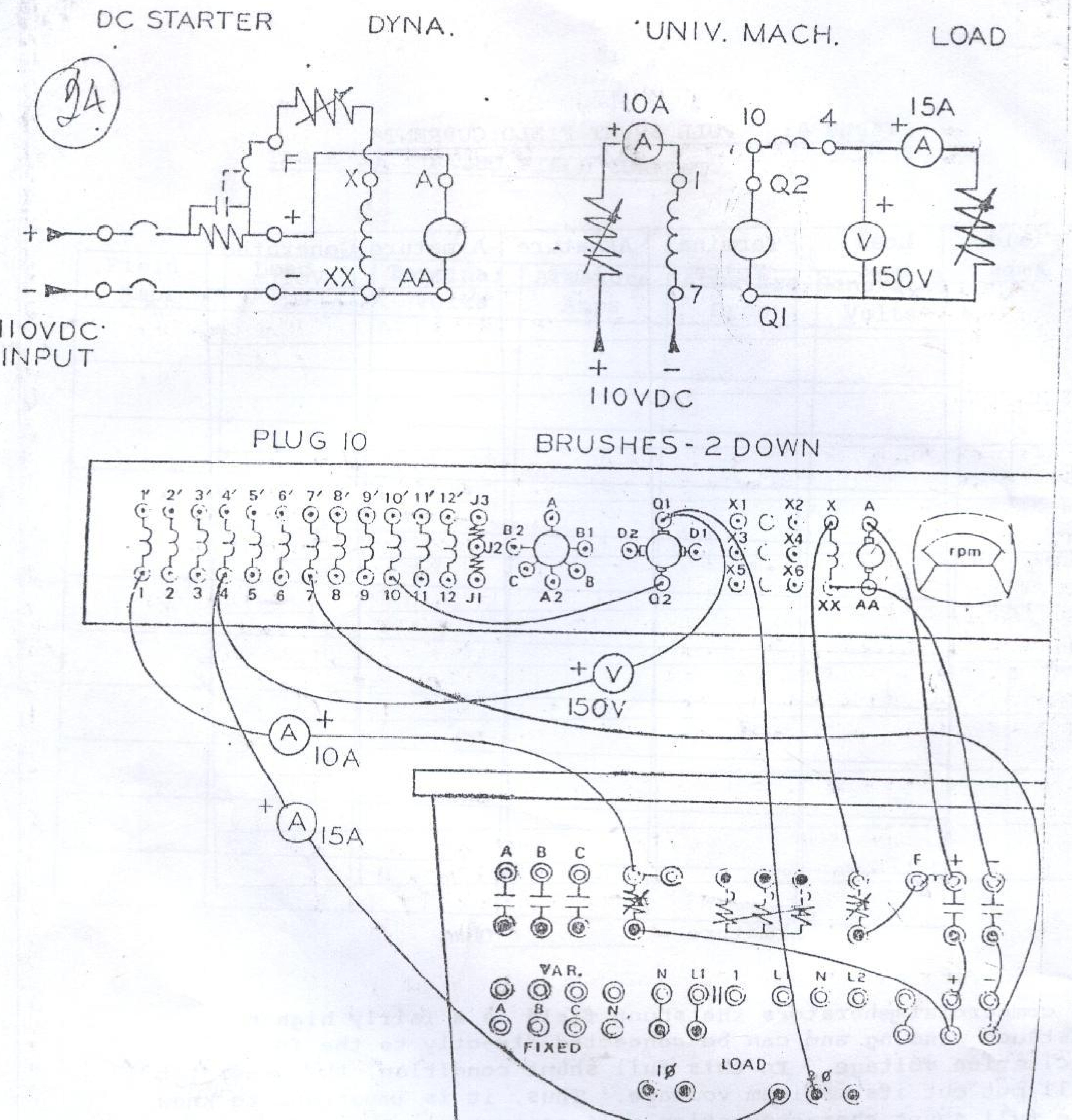
Field Amps	Load Amps	Terminal Volts	Armature Amps	Armature Drop	Generated Volts

TABLE 4: FULL SHUNT FIELD CURRENT*

Field Amps	Load Amps	Terminal Volts	Armature Amps	Armature Drop	Generated Volts

$R_{Armature}$ = ____________ Ohms

*In commercial generators the shunt field is a fairly high re-
sistance winding and can be connected directly to the full
excitation voltage. In this full shunt condition, the generator
will put out its maximum voltage. Thus, it is important to know
the full shunt characteristics of a generator. The ULM has a
very low resistance shunt field (because it is designed to operate
on AC and DC) and cannot be connected directly to the full ex-
citation voltage. With the ULM Field Rheostat in its minimum
resistance, full ccw position, the swamp resistor limits the field
current to a value which is equivalent to this full shunt condition.



STATOR CONNECTIONS:
Use Plug 10 or make the connections below.

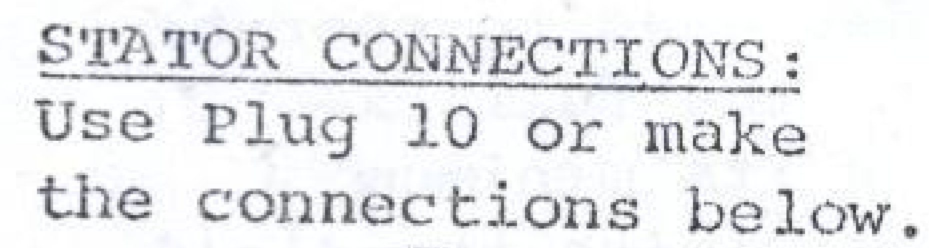


FIGURE 3: SEPARATELY EXCITED SHUNT GENERATOR

EXPERIMENT NO. 5

CHARACTERISTICS OF A SERIES GENERATOR

PURPOSE:

The objectives of the experiment are to gain familiarity with the operation of a series generator and to obtain its voltage regulation curve.

DISCUSSION:

The series generator is self-excited. When not loaded, a small voltage is generated due to the residual magnetism in the poles. When the generator is connected to a load, a small current will flow through the series field winding. If the flux produced by this current aids the residual magnetism, the generated voltage will rise. Additional decreases in load resistance will continue the "build-up" of generator's voltage until a certain point is reached. Increasing the current output beyond this point will decrease the generated voltage. The point where the voltage stops rising depends upon the shape of the magnetization curve, the armature reaction and the total resistance.

The drop in voltage is due to the following:

1. Demagnetizing effect of the back ampere-turns in the armature which tends to offset any increase in the magnetic field caused by the increased current in the series field.

2. The IR drop in the armature and series field increases with increases in current output.

Commutating poles (also called interpoles or compensating windings) are used in DC motors and generators to set up a flux to "buck" down the cross field flux produced by the heavy currents in the armature. This cross flux distorts the main field flux by shifting it to one side in the air gap under the main pole face resulting in less effective flux from one main pole to the other and poor commutating under the brushes.

The commutating poles are needed more in series motors and generators than in shunt and compound machines. In the series motor or generator, the main field flux varies with the load current, thus amplifying the distortion in flux in the air gap. This results in a weaker field and poor commutation.

The commutating poles allow DC motors of all types to operate at wider ranges of speed and weaker fields and allows DC generators to maintain better regulation at heavier loads.

APPARATUS REQUIRED:

1 ULM Set
1 ULM Set Instruction Manual - Bulletin 120CI
1 ULM Console Instruction Booklet - Bulletin 120CI
1 ULM Console containing,
  110 volt DC Power Supply
  Automatic DC Starter
  Dynamometer Field Rheostat (250Ω)
  Resistive Load Bank
1 0-150 volt DC Voltmeter
1 0-15 amp DC Ammeter

PROCEDURE:

1. Connect the Dynamometer to operate as a shunt motor as shown in Figure 4. Adjust the Dynamometer Field Rheostat to its minimum resistance (fully counter-clockwise) position and the auxiliary resistance switch to "out".

2. Connect the ULM to operate as a series generator as shown in Figure 4.

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

4. Start the Dynamometer by switching the main AC, DC supply, and DC starter circuit breakers and pushing the start button of the DC starter. Adjust the speed to 2400 RPM. Load the output of the generator until all ten load steps are in. The Dynamometer speed should be adjusted after each load step is added to maintain 2400 RPM. For each load step, measure the load current and terminal voltage, and record your readings in Table 5.

5. Disconnect the commutating winding by removing the connection between Q2 and 10 and add a connection between Q2 and 1. Repeat Step 4 and record the reading in Table 6.

REPORT:

Prepare a formal report. Using the data in Table 5, plot the voltage regulation curve of the series generator. Using the data in Table 6, plot, on the same set of axes, the voltage regulation of the generator without commutating poles. Discuss and compare the shapes of the two curves.

QUESTIONS:

1. If the poles lose their residual magnetism, how can it be restored?

2. How could you change the output voltage for any one value of load current?

3. Did the removal of the commutating field have any visual effect on the commutation at the brushes?

TABLE 5: LOAD TEST
WITH COMMUTATING POLES

Terminal Volts	Load Amps

TABLE 6: LOAD TEST
WITHOUT COMMUTATING POLES

Terminal Volts	Load Amps

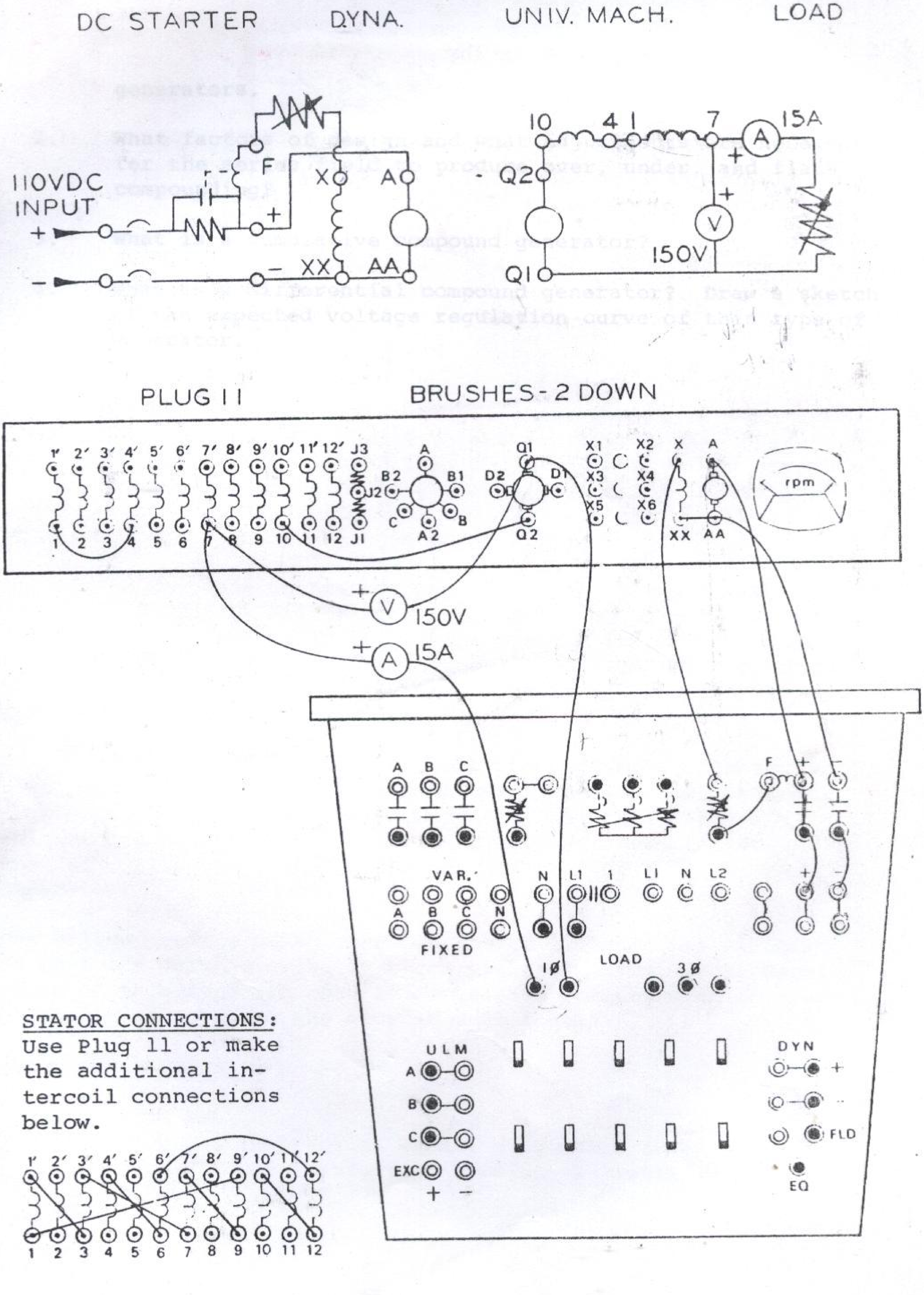


FIGURE 4: SERIES GENERATOR

generators.

2. What factors of design and what adjustments are necessary for the series field to produce over, under, and flat-compounding?

3. What is a cumulative compound generator?

4. What is a differential compound generator? Draw a sketch of the expected voltage regulation curve of this type of generator.

TABLE 7: LOAD TEST WITH SERIES CONNECTED COMPOUNDING

Terminal Volts	Load Amps

TABLE 8: LOAD TEST WITH PARALLEL CONNECTED COMPOUNDING

Terminal Volts	Load Amps

EXPERIMENT NO. 6

CHARACTERISTICS OF A COMPOUND GENERATOR

PURPOSE:

The objectives of the experiment are to gain familiarity with the operation of a compound generator and to study the effects of various degrees of compounding.

DISCUSSION:

A compound generator is essentially a shunt generator with a few turns of heavy wire in series with the armature. When the shunt field is directly across the line, it is called a "LONG SHUNT" compound generator as shown in Figure 5. When the shunt field is connected directly across the armature circuit, it is a "SHORT SHUNT" compound generator as shown in Figure 6.

Cumulative compound generators may be under-, flat-, or over-compounded. The generator may be designed so that when current flows to the series field it strengthens the field just enough to compensate for the drop in voltage due to the armature circuit resistance. In this case, the generator is flat-compounded and maintains a constant voltage from no-load to full-load.

If the generator is designed so that the current in the series field does not completely compensate for the armature voltage drop, the generator is under-compounded. In this case, the voltage regulation characteristics would be somewhere between that of a flat-compounded generator and that of a plain shunt generator.

The series winding of an over-compounded generator is designed so that the voltage actually rises with increased load. Generators of this type are used to compensate for the drop in speed of the prime mover as the generator is loaded.

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
Automatic DC Starter
Dynamometer Field Rheostat (250Ω)
Universal Machine Field Rheostat (173Ω + 11Ω)
Resistive Load Bank
1 0-150 volt DC Voltmeter
1 0-10 amp DC Ammeter
1 0-15 amp DC Ammeter

PROCEDURE:

1. Connect the Dynamometer to operate as a shunt motor as shown in Figure 7. Adjust the Dynamometer Field Rheostat to its minimum resistance (fully counter-clockwise) position and the auxiliary resistance switch to "out".

2. Connect the ULM to operate as a compound generator as shown in Figure 7. Adjust the Universal Machine Field Rheostat to its maximum resistance (fully clockwise) position.

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

4. Start the Dynamometer 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 to 2400 RPM. Increase the generator's field current to 4 amps.

5. The output voltage will now be approximately 110 volts. Load the generator from zero to 10 amps. The Dynamometer speed should be adjusted after each load step is added to maintain 2400 RPM. For each load step, measure the load current and terminal voltage and record your readings in Table 7.

6. Remove the connection between 2' and 8'. Connect 2' to 8 and 8' to 2. Repeat Step 5, recording your readings in Table 8.

REPORT:

Prepare a formal report. Plot and compare the regulation curves of the generator for the two different degrees of compounding.

QUESTIONS:

1. Explain the uses of the over-compounded and flat-compounded

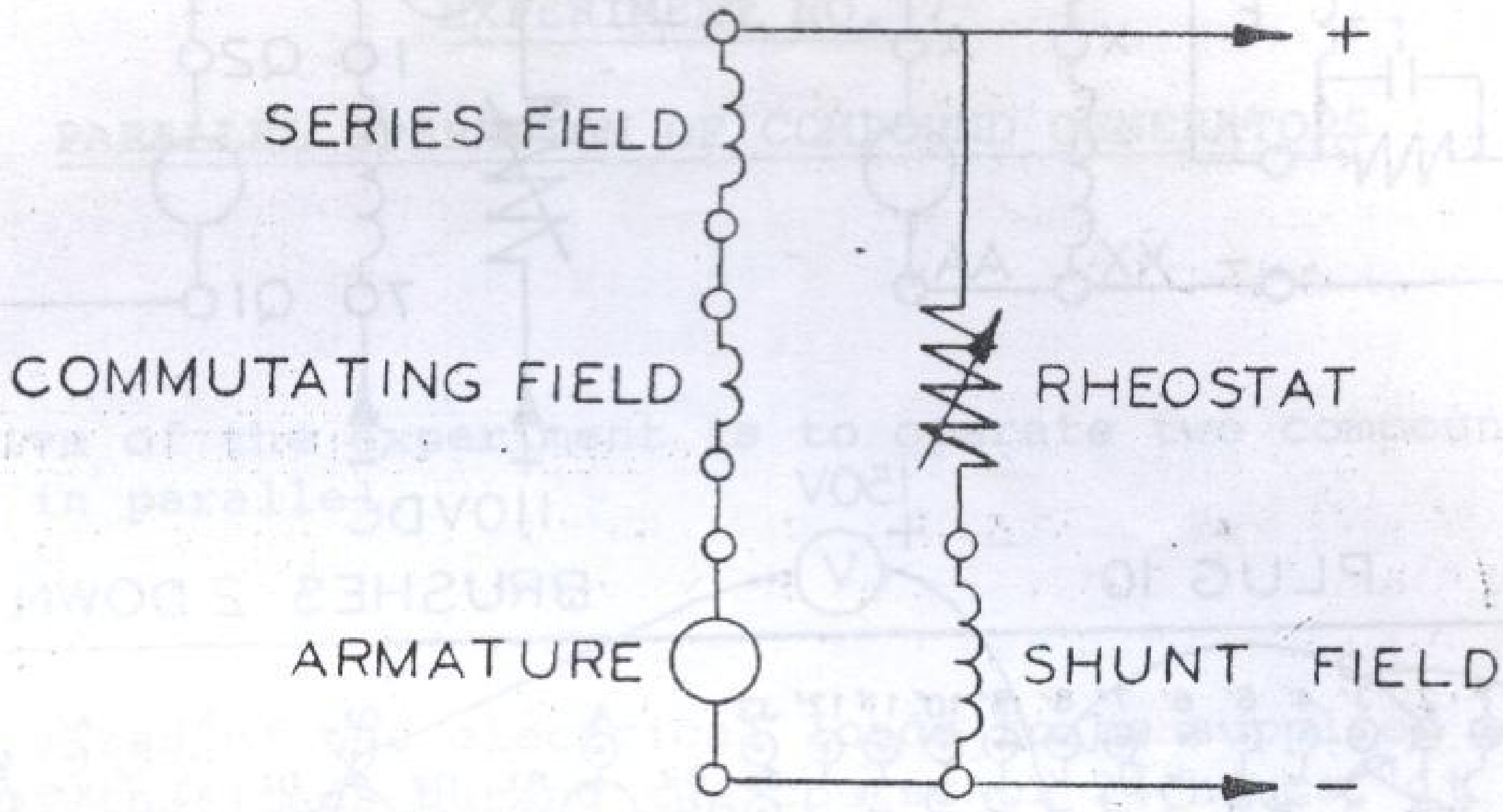


FIGURE 5: LONG SHUNT CONNECTIONS

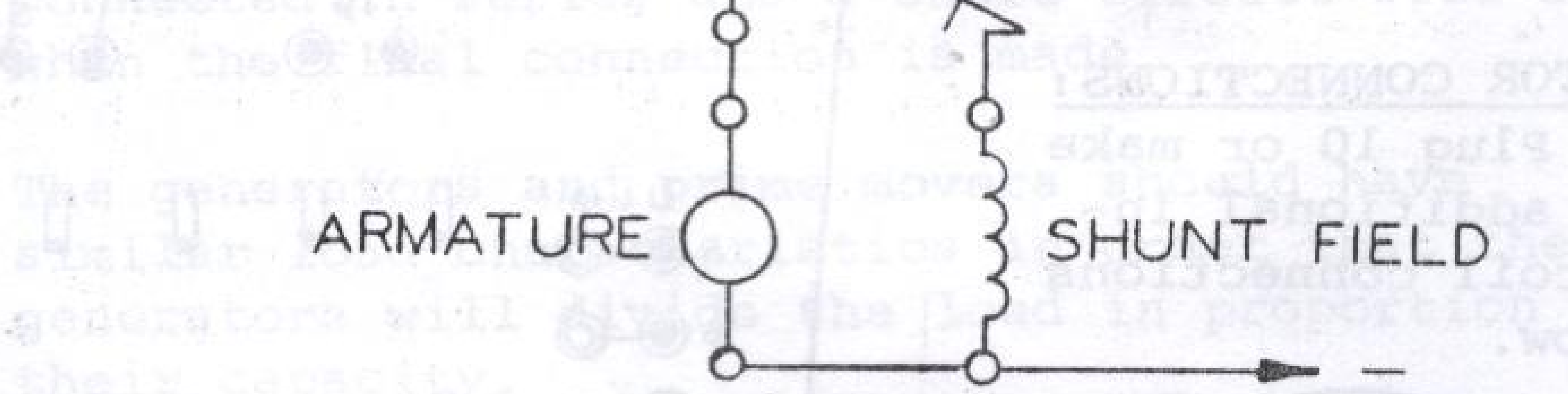


FIGURE 6: SHORT SHUNT CONNECTIONS

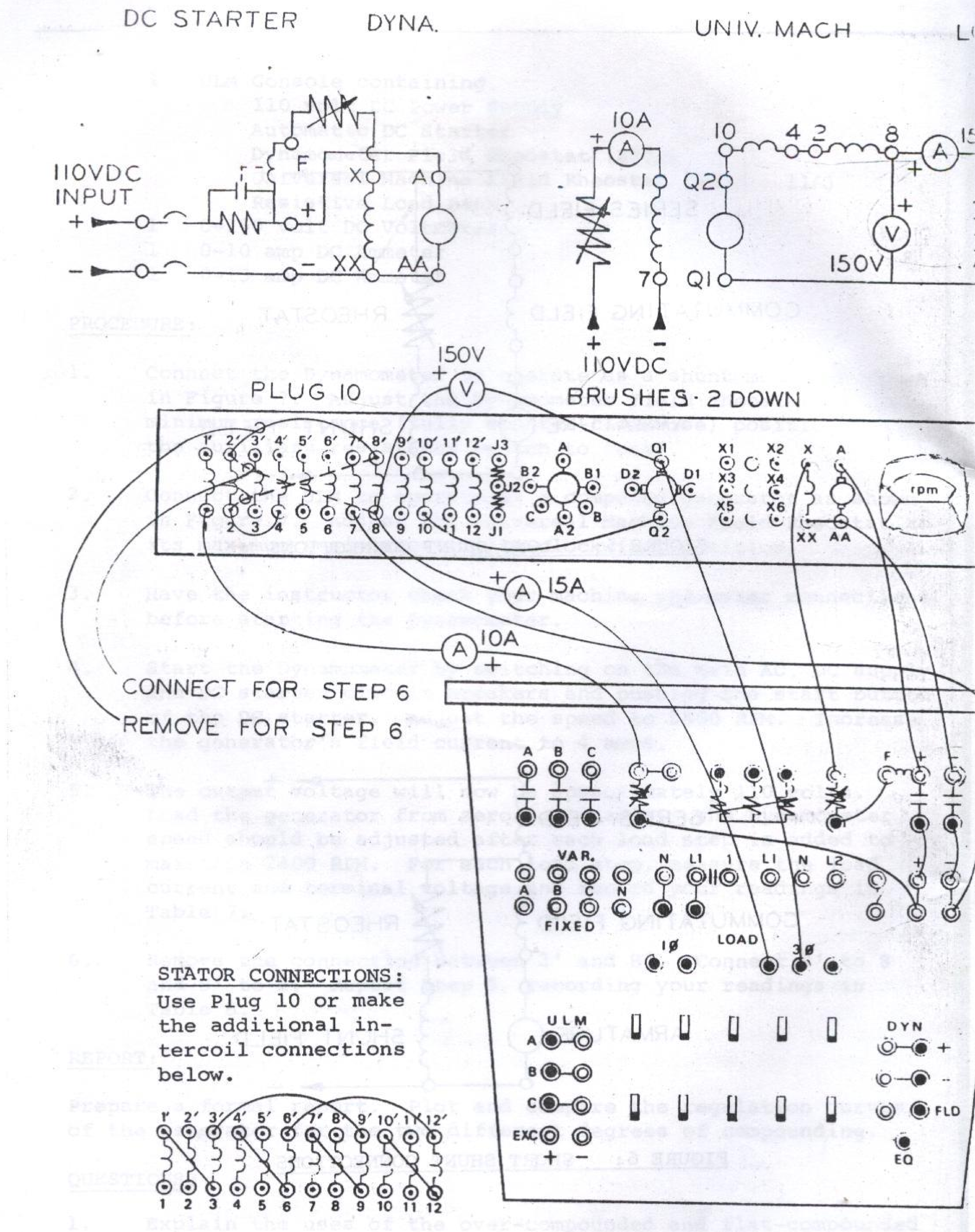


FIGURE 7: COMPOUND GENERATOR

EXPERIMENT NO. 7

PARALLEL OPERATION OF COMPOUND GENERATORS

PURPOSE:

The objective of the experiment is to operate two compound generators in parallel.

DISCUSSION:

Due to the sizes of the electrical loads to be supplied and the variation of the loads during the course of 24 hours, it is often more economical to use several small generators instead of one large generator to supply the electrical energy. This permits the shutting down of most of the excess generating capacity during the hours of light load. During the periods of greater loads, it is necessary to use more than one generator to supply the power; and these generators must be connected in parallel in order that their combined output may be fed into the outgoing lines.

In order that these machines shall operate satisfactorily, several conditions must be fulfilled:

1. The machines must be adjusted to the same voltage before paralleling, otherwise there will be an interchange of current between the two generators.

2. Only terminals of the same polarity shall be connected together, otherwise the generators will be connected in series and a short circuit will result when the final connection is made.

3. The generators and prime movers should have similar load characteristics in order that the generators will divide the load in proportion to their capacity.

4. When compound generators are paralleled, an additional line called an equalizing bus must be provided to prevent any one of the generators taking more than its fair share of the load. Unless

this is done, the generator with the greater amount of over-compounding will tend to take more than its proportional share of the load. This will cause more current to pass through its series field which will tend again to raise the generated voltage resulting in the generator delivering even more of the load current. This is a cumulative process, and if not stopped, will result in one generator trying to supply the entire load. The equalizer keeps an equal voltage drop across all the series fields and, hence, prevents any gross inequalities in the current distribution. Because of the low resistance of the series fields, the equalizer connection must also be of low resistance.

APPARATUS REQUIRED:

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

PROCEDURE:

1. Connect the Dynamometers to operate as shunt motors as show in Figure 8. Adjust the Dynamometer Field Rheostats to thei minimum resistance (fully counter-clockwise) position and th auxiliary resistance switch to "out".

2. Connect the ULMs to operate as compound generators as shown in Figure 8. Adjust the Universal Machine Field Rheostats their maximum resistance (fully clockwise) position.

3. Connect the outputs of the compound generators to the DC control section of the switchboard as shown in Figure 9. Connect the resistive load bank on the loading section to one of the generator's output on the DC control section.

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

5. Start the Dynamometers by switching on the Main AC, DC supply, DC supply, and DC starter circuit breakers and pushing the start button of the DC starters.

6. Bring the voltage of both generators up to 110 volts. When the voltages are equal, close the paralleling switch. If the voltages were exactly the same, the ammeters will read zero. If they do not read zero, adjust the field rheostats until there is no current flow between the generators.

7. Apply the load to the paralleled generators. Record in Table 9 the voltage of the generators, the current of each generator, and total current for values of load from no-load to 10 amps on each generator.

8. Reduce the total load to less then 10 amps and then reduce the voltage of generator No. 2 until the load is practically zero and disconnect it from the line by opening the paralleling switch.

9. Bring generator No. 2 back on the line by raising its voltage slightly above that of generator No. 1, closing the paralleling switch and adjusting its rheostat until it has taken its share of the load.

10. Shut off the Dynamometer of generator No. 2 and note the results.

REPORT:

Prepare a formal report. Plot the terminal voltage, kilowatt of generator No. 1 and kilowatt of generator No. 2 as ordinates versus the total kilowatt as abcissa on one set of axes. Analyze your curves and also discuss the conditions necessary for paralleling, manner of shifting load, stability, need for the equalizer bus, and other pertinent facts. What was the effect of shutting down the Dynamometer of generator No. 2?