Experiment 3
V-I Characteristics of DC Generators

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1 Aim

To obtain V-I characteristics of a DC Generators

2 Circuit Diagram

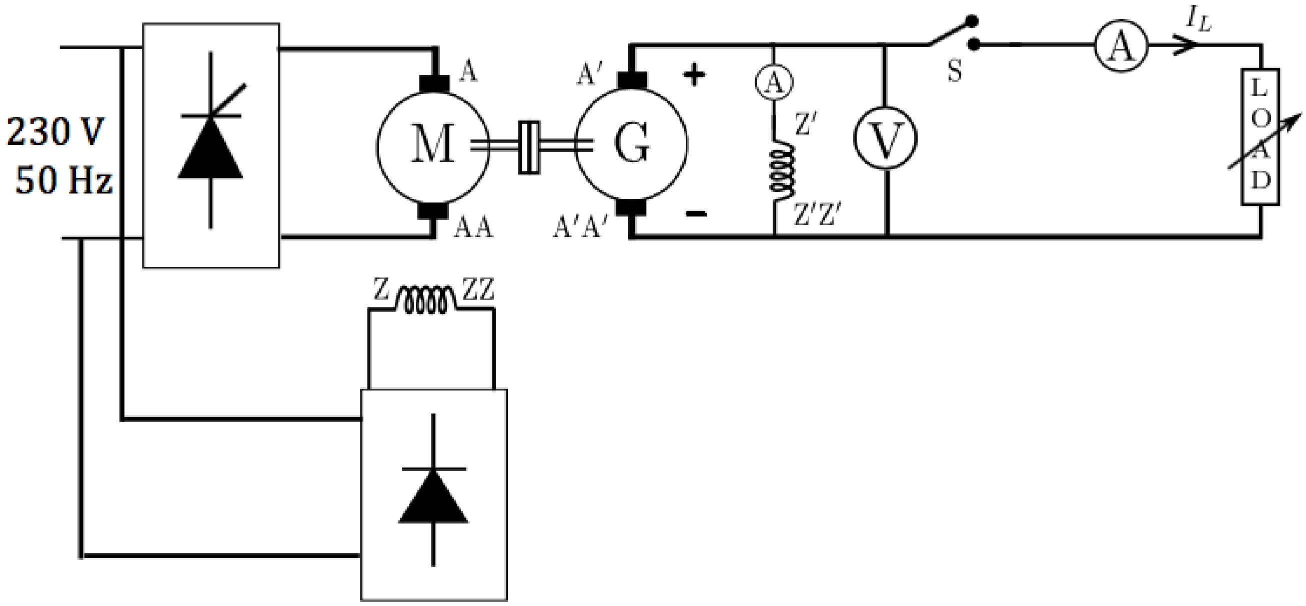


Figure 1: Circuit Diagram for self excited DC Generator

3 Observations

Field Current(A)	Open Circuit Voltage(V)
0	73.6
0.11	84.7
0.21	114.7
0.27	126.8
0.32	132.7
0.35	135.4
0.38	138.8

Table 1: Open Circuit Characteristics of DC Generator at 1300rpm

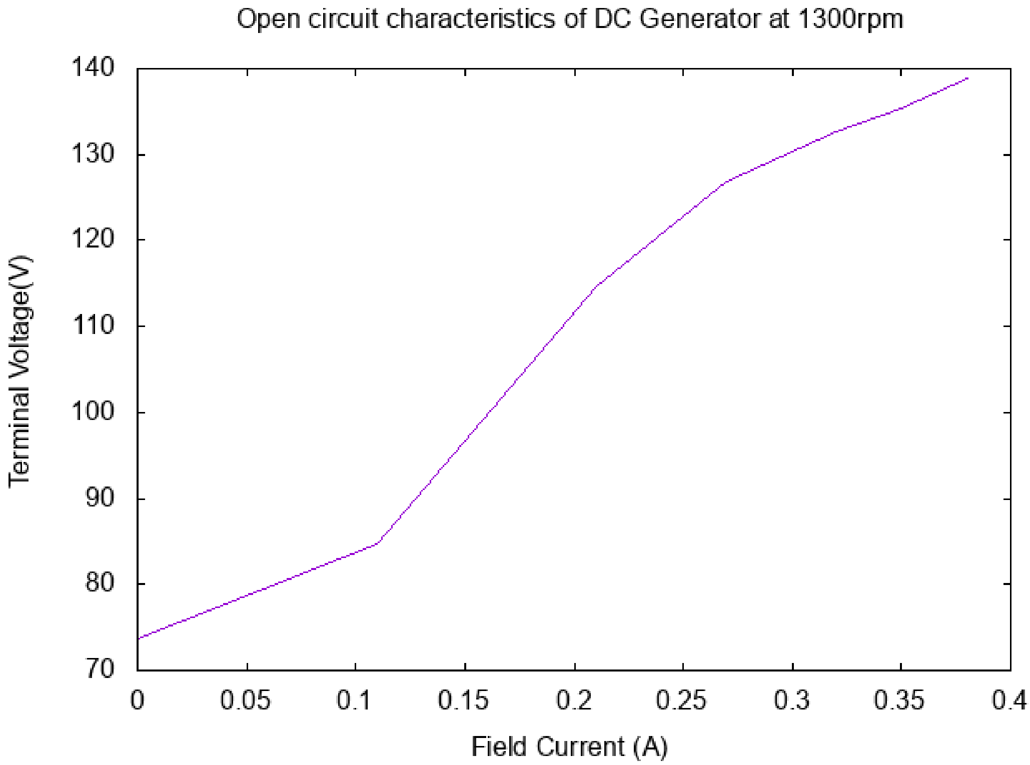
No. of Lamps(Load)	Terminal Voltage(V)
0	138.8
2	135.2
4	134.8
6	132.2
8	131.3
10	130
12	128.4

Table 2: Variation of Terminal Voltage with increasing resistive load of separately excited DC Generator at 1300rpm

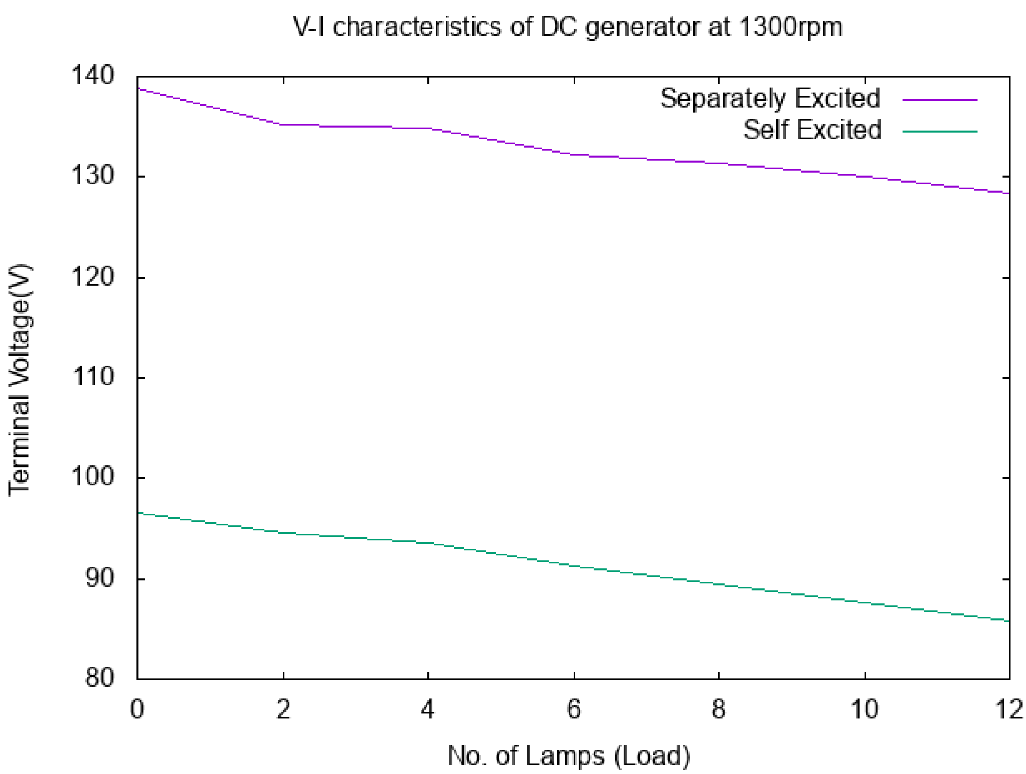
No. of Lamps(Load)	Terminal Voltage(V)
0	96.6
2	94.6
4	93.6
6	91.3
8	89.5
10	87.7
12	85.8

Table 3: Variation of Terminal Voltage with increasing resistive load of self excited DC Generator at 1300rpm

4 Graphs



Open circuit characteristics of DC Generator at 1300rpm
Terminal Voltage(V)
140
130
120
110
100
90
80
70
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Field Current (A)



V-I characteristics of DC generator at 1300rpm
Separately Excited
Self Excited
Terminal Voltage(V)
140
130
120
110
100
90
80
0
2
4
6
8
10
12
No. of Lamps (Load)

5 Conclusion

- The graph of open circuit characteristics looks similar to the B-H curve of the iron core. This is because H depends on the field current and the terminal voltage is proportional to the magnetic field B. Also the graph has a non zero y-intercept which means that the core had some residual flux initially.
- The V-I characteristics of DC generator shows that the terminal voltage of the generator reduces with increase in load. Comparing the slopes of separately excited DC generator with self excited DC generator, we observe that the slope in the second case is larger. This is because in case of self excited generator, the generator also has to supply the field current. This increases the armature current which in turn increases the drop due to armature resistance and the armature reaction.

6 Question and Answer

1. **Of the two machines which one did you choose to operate as motor?Justify your answer.**
   Answer: The DC Machine with the following nameplate ratings: 1.5 kW, Ra = 2.04 , RF = 415 is operated as a motor.At rated operation, the generator (the 1.1KW DC Machine) requires slightly more than 1.1kW as shaft power (difference due to windage loss). This power has to be supplied by the motor coupled to it. The 1.5kW DC Machine can supply upto 1.5kW shaft power. A portion of it is lost due to windage loss but it still can supply the required input power to the generator. If the machine order was reversed, there is no way that a 1.1kW DC machine can drive the 1.5kW DC generator to its rated condition.

2. **Assume that a given machine has the following name plate ratings: 220 V, 1.5 kW, 1500 rpm dc generator.What do these numbers imply?**
   Answer: 1500 rpm is the rated speed of rotation of the rotor at full load, 220 V is the rated load voltage while 1.5kW is the rated power supply.

3. **There are motors without any rotor winding (e.g. stepper motor). Explain how the torque is produced in these machines.**
   Answer:-In these motors permanent magnets are present instead of coils. Thus, we can change the polarity of the field voltage to change the direction of the magnetic field causing the permanent armature magnet to rotate. The torque is produced by the attraction of these permanent magnets to the field coils.

4. **How is the voltage induced in the armature (coil is rotating in a magnetic field) which is ac, converted to dc?**
   Answer: The conversion of ac to dc is done by the commutator which consists of a split ring and brushes. We can observe that as the shaft rotates, the commutator reverses the flow of current in a winding. For a single armature winding, when the shaft has made one-half complete turn, the winding is now connected so that current flows through it in the opposite of the initial direction. Hence we get an average DC with ripples. These ripples can be reduced by higher number of cores or a capacitor in parallel.Due to this functionality, the commutator is referred to as a mechanical rectifier.

5. **What is the effect of armature reaction?**
   Answer:-Armature reaction is the flux generated in armature due to current flowing in it which adds and subtracts to the flux due to the field coils. As the core of the armature is operating at knee point, the increase in flux is less than the decrease which leads to overall reduction in flux. This phenomenon is called armature reaction.

6. **'Saturation of the magnetic material is a blessing in the case of self excited generator' Is this statement true? Justify your answer. (Hint: comment on the following: (a) during voltage build up which is cumulative in nature. (b) if the generator is operated in the linear region of the magnetization curve)**
   Answer:

   (a) When a self-excited DC generator is started, due to residual magnetic field, an induced emf is created, and so there is some initial current flow. This current flows through the field coil to produce MMF (aiding the residual flux, else flip the coil). This in turn increases the total airgap flux and so more voltage is induced, resulting in a greater current flow. This effect is cumulative in nature. Saturation of the core allows the potential difference and current flow to steady, else this would continue to build up until the machine burns up (due to ohmic heat generation).

(b) Core saturation is also essential for the generator to operate. Otherwise the terminal voltage under load can drop down to zero. This is explained as follows: Suppose the DC shunt generator was operating in the linear region. Let us assume that there is a 10 % drop in terminal voltage when the load draws current. This results in a 10 % drop in field current (and so flux). A decrease in flux will reduce the induced emf to further decrease the terminal voltage. This effect will be cyclic and 'build down' the terminal voltage until is is almost zero (and so is negligible).

7. **In separately excited dc machine, the field winding carries a constant current. Hence, it dissipates power. Suggest a method to eliminate this power loss.**
Answer: -We can use permanent magnets in a separately excited DC machine but in doing so we save the power which would have been dissipated in generating the field flux. However, the tradeoff is that we lose control over field flux completely and also the magnet may lose its magnetic properties due to external damage.

8. **What may happen if load terminals are short circuited in (a) separately excited generator (b) self excited generator**
Answer:

(a) The flux in a separately excited DC generator depends only on the field current and so is constant in this scenario. This results in a constant induced voltage ($E_b \propto \ \Phi\omega$). At steady state, the current in the armature would be E_b/R_a where E is the induced emf in the armature due to the prime mover and R_a is the armature resistance.Thus, there will be huge inrush of current limited only by armature resistance. This might damage the generator if kept in this state for long time.

(b) Field current or armature voltage becomes zero thus not causing damage to the generator.) Hence only the residual flux would lead to an induced emf and the current in the armature would be E_{res}/R_a. This value is very small in general and the chances of machine damage are lower. Thus, they are self protective to short circuit faults.

9. **You have been given the plot of Efficiency Vs input power of the prime mover. Explain how will you obtain the plot of efficiency Vs output power of the generator. How will you obtain this plot incase the plot of Efficiency Vs input power of the prime mover is not available?**
Answer: Assuming that the output of the prime mover is exactly the same as the input power to the rotor winding. We also know that accounting for the copper losses, we get an output power reduced by a factor of $\frac{R_L}{R_a+R_L}$ where R_L is the load resistance and R_a is the resistance in the rotor coil. So for a given input to prime mover, from the efficiency, we get the output of prime mover and the output of the complete generator after accounting for the copper loss. The new efficiency at this operating point is obtained by multiplying by the same factor of $\frac{R_L}{R_a+R_L}$.

7 Summary of Demo Experiment

In this lab's demo experiment, we were shown the construction and working of a DC generator. The explanation was aided by a video and a deconstructed DC generator.A 3D model was also shown on the computer.
The DC Generator consists of field winding which is wound over an iron core. This produces a magnetic field which is static in nature. The armature is rotated in this static magnetic field due to which an EMF is induced in the armature. This EMF is alternating in nature which is converted to DC by a mechanical rectifier made using a combination of split ring and brushes. The output at the brushes is the DC voltage generated by the generator. We also came to know about the magnetic neutral plane and compensation winding.