EE234 Experiment 2: Open Circuit and Short Circuit Tests on a Single Phase Transformer

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1 Overview of the experiment

The aim of the experiment was to obtain and comment on the:

- Open circuit and External characteristics of a separately excited DC generator
- External characteristics of a shunt DC generator

The experiment is based on the following equivalent circuits for the DC generators and on the magnetic properties of the material used:

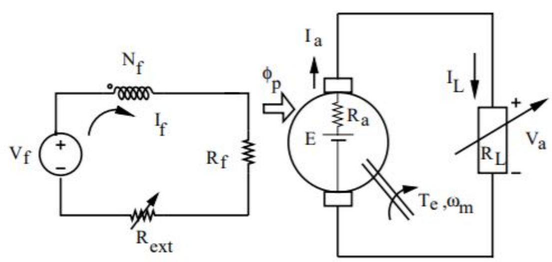


Figure 1: Equivalent circuit for the Separately Excited DC Generator

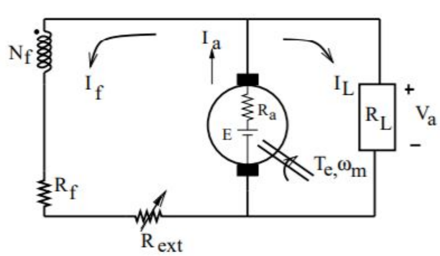


Figure 2: Equivalent circuit for the Self Excited DC Generator

2 Procedure

The following two DC machines were available:

- 1.5 kW DC machine: $R_a = 2.04\Omega$, $R_F = 415\Omega$, Friction and windage loss at 1500 rpm = 53 W
- 1.1 kW DC machine: $R_a = 2.10\Omega$, $R_F = 415\Omega$, Friction and windage loss at 1500 rpm = 53 W.

The former was used as the generator and the latter as the motor due to reasons as mentioned later in **Answers Q1**.

2.1 Part 1: Separately Excited DC Generator

The connections are made as depicted in the figure. With no load condition, voltage is increased slowly and readings are taken at regular intervals. Readings are also taken at rated voltage and when the voltage is 110% times the rated voltage.
Furthermore, loads are added in the form of lamps while voltage is at the rated value and readings were taken.

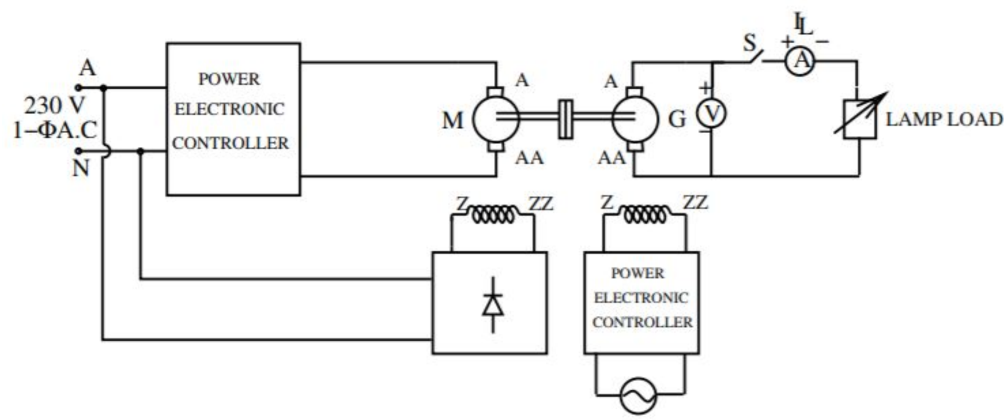


Figure 3: Connections for the circuit of the Separately Excited DC Generator

2.2 Part 2: Self Excited DC Generator

The connections are made as depicted in the figure. With no load condition, voltage is increased slowly and readings are taken at regular intervals. Above a certain speed the voltmeter reading starts increasing. By controlling the input to the prime mover, the speed is adjusted to the rated speed of the machine.
Furthermore, loads are added in the form of lamps keeping the speed constant

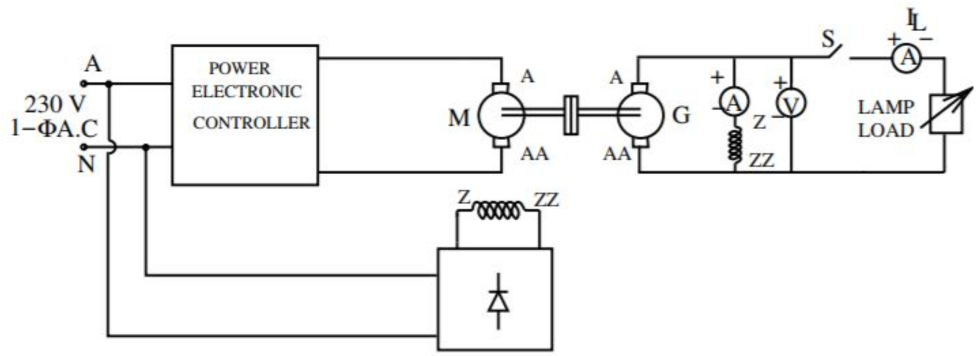


Figure 4: Connections for the circuit of the Shunt DC Generator

and readings were taken.
The experiment expects that the variation of open circuit voltage with field current and the variation of terminal voltage with load current for separately excited and self excited generators are plotted.

3 Observations and Calculations

DC Motor Specifications:

Rated Armature Voltage(V_a)	180V
Rated Armature Current(I_a)	10.5A
Rated Power	1.5KW
Rated speed(ω_m)	1500rpm
Rated Field Voltage(V_f)	220V
Rated Field Current(I_f)	0.42A

DC Generator Specifications:

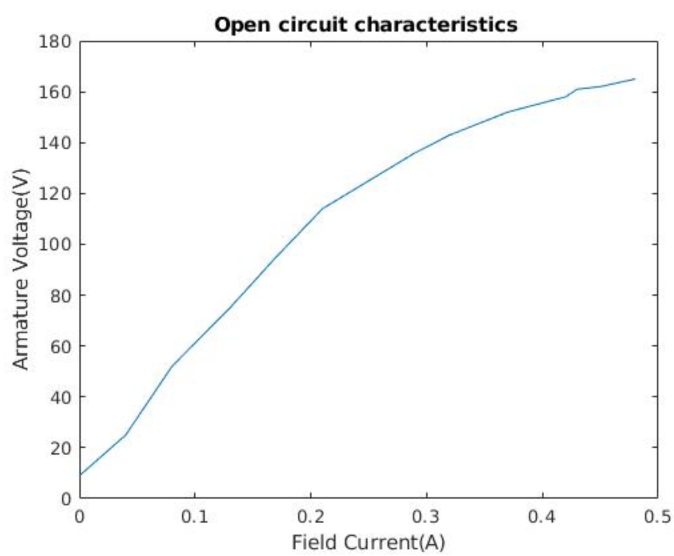
Rated Armature Voltage(V_a)	180V
Rated Armature Current(I_a)	7.5A
Rated Power	1.1KW
Rated speed(ω_m)	1500rpm
Rated Field Voltage(V_f)	220V
Rated Field Current(I_f)	0.46A

3.1 Separately excited DC generator observations

The Open circuit characteristics were measured by keeping the speed of the prime mover at its rated speed. In the process we measured Open Circuit Voltage, Field Voltage and Field Current. The below table summarizes the observations:

Armature Voltage(V)	Field Voltage(V)	Field Current(A)
9	0	0
25	18	0.04
52	37	0.08
75	54	0.13
95	71	0.17
114	89	0.21
136	120	0.29
143	134	0.32
152	101	0.37
158	180	0.42
161	189	0.43
162	195	0.45
165	219	0.48

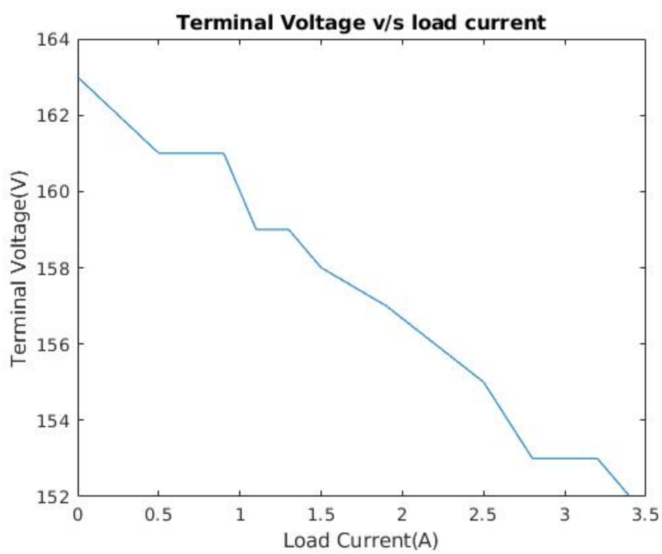
From the above table we see that the armature voltage due to residual magnetism is 9V. The below plot displays the open circuit characteristics of separately excited DC machine. From the below plot we can see that the slope eventually decreases for higher field current and it justifies the presence of residual magnetic field.



The below data shows the effect of loading at constant speed. We may use the subscript 'g' and 'm' to denote values pertaining to generator and motor respectively.

Load	w_m(rpm)	V_{ag}(V)	I_{ag}(A)	V_{fg}(V)	I_{fg}(A)	V_{am}(V)	I_{am}(A)	V_{fm}(V)	I_{fm}(A)
0	1491	163	0	218	0.47	165	1.5	207	0.42
1	1488	161	0.5	218	0.46	165	1.9	208	0.41
2	1492	161	0.9	220	0.46	167	2.3	209	0.42
3	1489	159	1.1	220	0.46	167	2.5	208	0.42
4	1487	159	1.3	220	0.46	167	2.7	208	0.42
5	1488	158	1.5	220	0.46	167	2.9	208	0.42
6	1491	157	1.9	219	0.46	168	3.3	208	0.41
7	1487	156	2.2	219	0.46	168	3.6	208	0.41
8	1488	155	2.5	219	0.46	168	4.0	207	0.41
9	1487	153	2.8	218	0.45	168	4.3	206	0.41
10	1491	153	3.2	218	0.45	168	4.7	206	0.41
11	1492	152	3.4	218	0.45	168	5.0	206	0.41

The plot of terminal Voltage v/s load current is shown below:

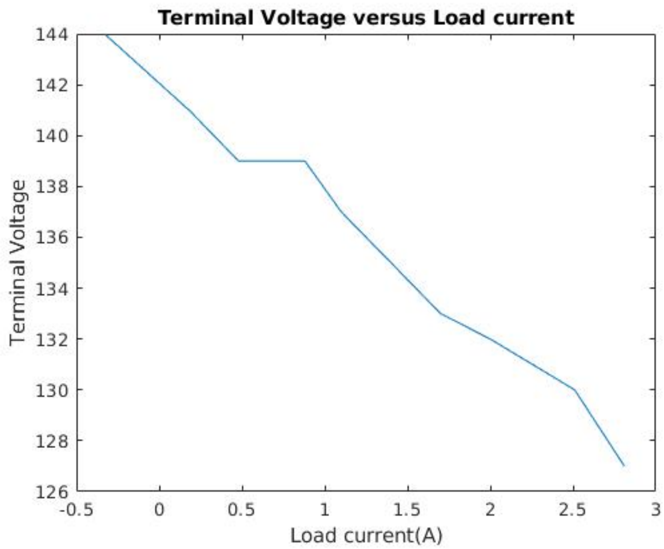


3.2 Self Excited DC generator

We first tabulate the no load characteristics as shown below:

w_m(rpm)	V_{ag}(V)	I_{ag}(A)	V_{fg}(V)	I_{fg}(A)	V_{am}(V)	I_{am}(A)	V_{fm}(V)	I_{fm}(A)
1163	74	0	74	0.17	129	0.9	207	0.42
1436	132	0	132	0.3	158	1.3	207	0.42
1500	144	0	144	0.33	165	1.4	208	0.42

The variation of terminal voltage and load current with load is shown below:



Load	w_m(rpm)	V_{ag}(V)	I_{ag}(A)	V_{fg}(V)	I_{fg}(A)	V_{am}(V)	I_{am}(A)	V_{fm}(V)	I_{fm}(A)	I_L(A)
0	1496	144	0	144	0.33	166	1.6	208	0.42	-0.33
1	1498	141	0.5	141	0.32	166	1.6	208	0.42	0.18
2	1496	139	0.8	139	0.32	166	2.2	207	0.41	0.48
3	1496	139	1.0	139	0.32	168	2.6	208	0.41	0.58
4	1493	139	1.2	139	0.32	168	2.6	208	0.41	0.88
5	1499	137	1.4	137	0.30	167	2.7	207	0.41	1.1
6	1498	135	1.7	135	0.3	168	3.2	207	0.41	1.4
7	1498	133	2.0	133	0.3	167	3.0	207	0.41	1.7
8	1500	132	2.3	132	0.30	168	3.5	207	0.41	2
9	1496	130	2.8	130	0.29	168	3.7	207	0.41	2.51
10	4195	129	2.9	129	0.29	105	4.0	207	0.41	2.61
11	1495	127	3.1	128	0.29	168	4.1	207	0.41	2.81

The below figure summarizes the data obtained.

4 Answers

1. The power rating of the prime mover should be greater than that of generator. Therefore we chose the machine with 1.5KW power rating as prime mover and the 1.1KW DC machine as the generator. Therefore machine with power rating of 1.5KW should be used as a prime mover.

2. 220 V signifies the voltage rating, 1.5KW is the power rating and 1500rpm is the rated speed of the DC generator. This implies that when fed with

power rating of 1.5KW at DC voltage of 220V, its shaft rotates at 1500rpm.

3. Principle behind working of motor without rotor coils is that magnetic flux flows through the path offering least reluctance. So, rotating stator magnetic field forces gear to move accordingly in order to offer minimum opposition to the flux.
4. The mechanical brush contacts reverse when the armature rotates, therefore when voltage becomes negative due to the reversal of polarity observed voltage remains positive. Hence the induced ac voltage is converted into dc voltage.
5. Weakening of stator field caused due to the rotor current is known as armature reaction.
6. Yes the given statement is indeed true. As if saturation didn't happen machine will fail to reach an equilibrium state. This is because in case of seperately excited machine stator field builds up from the residual magnetic field.
7. A possible alternative to avoid power loss can be using permanent magnets instead of field winding. But caveat associated with permanent magnets is that they demagnetize over time and you don't have control over the field unlike the case of field winding.
8. In case of seperately excited machine shorting of load terminals will result into high current which will damage the machine. For self excited dc machine armature voltage will drop across field and armature winding. Field winding being highly inductive and resistance of circuit being reduced current won't exceed its rated value immediately but may after some time.
9. Using the fact that efficiency=(output power/input power)*100, corresponding output power can be calculated and thus the plot of efficiency vs outputpower. In the other case we will have to experimentally calculate efficiency corresponding to known input powers.