Experiment-6: Characteristics of a Self-excited DC Shunt Generator

Group Members:

1. *V. L. Narasimha Reddy (EE18BTECH11046)*
2. *D. Krishna Srikar (EE18BTECH11014)*

Aim:-

The aim of this experiment is to study the following characteristics of a DC shunt Generator through Matlab Simulink.

- *Open Circuit Characteristics (O.C.C) through the no-load test to determine the critical field resistance and critical speed.*
- *External Characteristics through load test.*

Theory:-

For a self-excited DC shunt generator, the field excitation is provided by the generator output voltage itself. The armature e.m.f starts building with the help of the residual magnetism in the ferromagnetic core. Generally, it is seen that when the load on the generator increases from no-load to full load, the terminal voltage will decrease due to armature reaction and voltage drop-in armature, which is practically absent under no-load conditions. Hence it is necessary to study the performance characteristics under these two conditions.

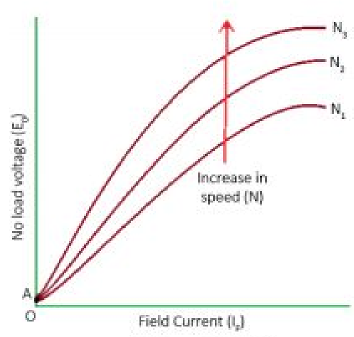


Fig.a: O.C.C.

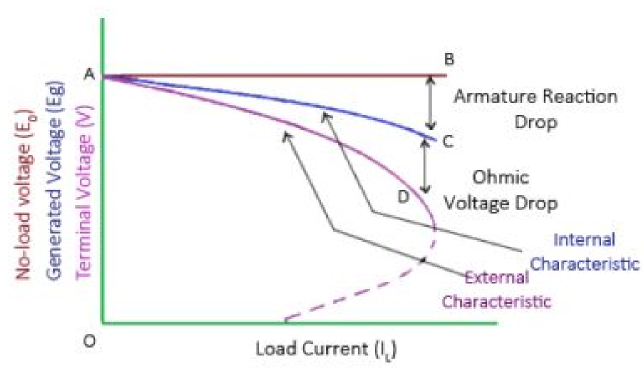


Fig.b: Internal and External characteristics

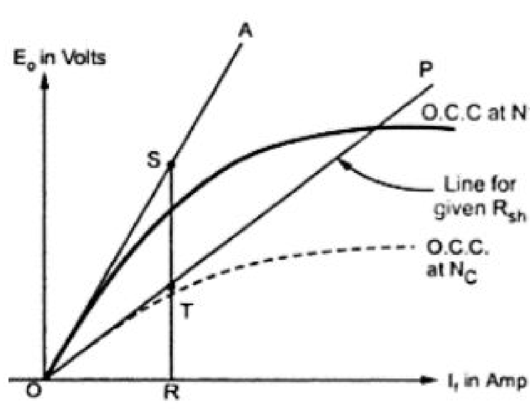


Fig.c: Calculation of critical resistance and speed

Open Circuit Characteristic (O.C.C.) (E0/If):-

Open circuit characteristic is also known as a magnetic characteristic or no-load saturation characteristic. This characteristic shows the relation between generated emf at no load (E0) and the field current (If) at the given fixed speed. The O.C.C. curve is just the magnetization curve and it is practically similar for all types of generators. The data for the O.C.C. curve is obtained by operating the generator at no load and keeping the speed constant. Field current is varied and the corresponding terminal voltage is recorded.

Internal or Total Characteristic (E/Ia):-

The internal characteristic curve shows the relation between the on-load generated emf (Eg) and the armature current (Ia). The on-load generated emf Eg is always less than E0 due to armature reaction. Eg can be determined by subtracting the drop due to the demagnetizing effect of armature reaction from no-load voltage E0. Therefore, the internal characteristic curve lies below the O.C.C. curve.

External Characteristic (V/IL):-

The external characteristic curve shows the relation between the terminal voltage (V) and load current (IL). The terminal voltage V is less than generated emf Eg due to voltage drop in the armature circuit. Therefore, the external characteristic curve lies below the internal characteristic curve. External characteristics are very important to determine the suitability of a generator for a given purpose. When load resistance is decreased in DC shunt generator, the load current increases. But, load resistance can be decreased up to a certain limit, beyond this limit any further decrease in load resistance results in decreasing load current and terminal voltage. Consequently, the external characteristic curve turns back.

<u>Critical Resistance and Critical Speed:-</u>

The critical field resistance is defined as the maximum field circuit resistance (for a given speed) with which the shunt generator would excite. The shunt generator will build up voltage only if field circuit resistance is less than critical field resistance. For a given speed of rotation, the output voltage of the generator fails to reach the desired level in the case the resistance of the field circuit exceeds an upper limit. The respective upper limit defines the critical resistance of the field circuit of the generator. In the same way, for a particular field resistance, the generator fails to excite when the generator speed falls below a lower limit. The respective lower limit defines the critical speed of the generator. It is to be noted that the critical resistance varies with the generator speed as
shown in the above figure (O.C.C.) and the critical speed varies with the generator field resistance.

CRITICAL RESISTANCE (RC):

Draw the tangent (shown by OA in above Fig.c), to the initial part of this O.C.C. then the slope of this line is the critical resistance for that particular speed.
Note: If speed changes, then the O.C.C. changes hence the value of RC will also change.

CRITICAL SPEED (NC):

It is known that as speed changes, the open circuit characteristics also change, similarly for different shunt field resistances, the corresponding lines are also different. For the calculation of critical speed follow the below procedure.
1) Take a particular value of R_{sh} (E0/If) and draw a line from origin connecting to that point (shown by OP in Fig.c).
2) Select any field current to say point R.
3) Draw a vertical line from R to intersect OA at S and OP at T.
4) Then the critical speed NC is,

$$Nc = N_{nominal}(RT/RS)$$

Circuit Arrangement:-

The circuit arrangements are shown in the following Figures. Here, A and AA are the terminals of the armature winding; F and FF are the terminals of the field winding. Resistance R_f, ex is the external resistances connected in series with the field winding. Care should be taken for the connection for armature and field terminals. A wrong connection will cause demagnetization of the residual magnetism making the DC generator fail to excite. The DC generator is mechanically coupled with the synchronous motor which acts as a prime mover.

Test Procedure:-

Open Circuit Characteristic (O.C.C.) (E0/If):

1) The rheostat in the field circuit should first be set at the maximum position.
2) Bring the synchronous motor speed to the nominal value by adjusting the 3-Ph variable AC supply and variable DC field supply. The speed of the motor can be measured by using a tachometer.
3) Now, the resistance of the rheostat is to be gradually reduced while continuously monitoring the voltage reading across the terminals of the DC generator. It can be observed that the output voltage of the DC generator is initially very small, but will suddenly start building as the resistance of the rheostat is gradually reduced. (If this does not happen to reduce the prime-mover input and switch off the supply. Interchange the field terminals of the generator and repeat the same procedure).
4) Tabulate the readings of E0 and If for different rheostat positions (at least 10 positions).
5) Plot the graph between E0 and If which gives the O.C.C.
6) Calculate critical field resistance and critical speed from the plot.

IN SIMULINK:

1) *Make connections as shown in the figure below using the Simscape->Electrical library.*
2) *Since self-excitation is not possible in Simulink, we excited the field winding externally using DC voltage.*
3) *Take 'w' as input for DC machine and input it with rated its speed.*
4) *Adjust the DC voltage given to Field winding to get it's rated field voltage.*
5) *Change DC voltage and observe the readings E_0 and I_f and plot them on graph for different values.*

6) *Calculate critical field resistance and critical speed from the plot.*

External Characteristics (V/IL):

1) The rheostat in the field circuit should first be set at the maximum position.
2) Bring the synchronous motor speed to the nominal value by adjusting the 3-Ph variable AC supply and variable DC field supply. The speed of the motor can be measured by using a tachometer.
3) Now, the resistance of the rheostat is to be gradually reduced while continuously monitoring the voltage reading across the terminals of the DC generator. It can be observed that the output voltage of the DC generator is initially very small, but will suddenly start building as the resistance of the rheostat is gradually reduced. (If this does not happen to reduce the prime-mover input and switch off the supply. Interchange the field terminals of the generator and repeat the same procedure).
4) Once, the generator output reaches the nominal value, take the readings of terminal voltage by increasing the load current, while keeping the field current constant.
5) Plot the graph between V and I_{load} which gives the external characteristics.

IN SIMULINK:

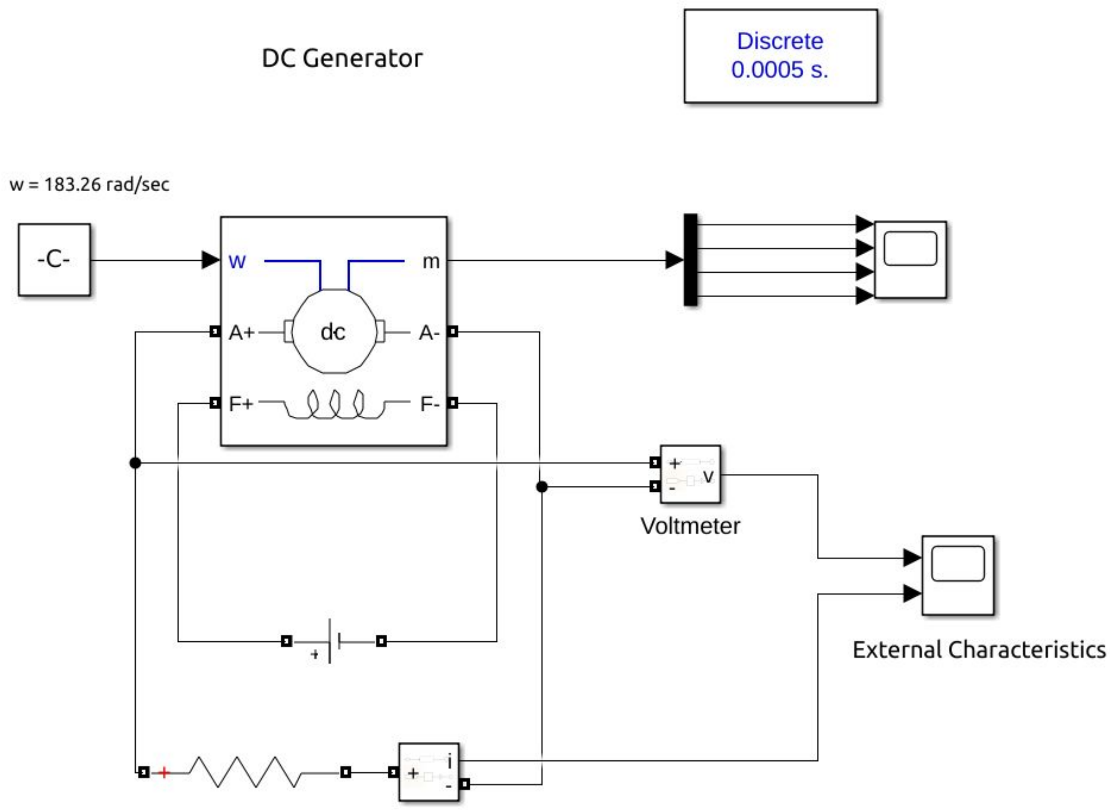
1) *Make connections as shown in the figure below using the Simscape->Electrical library.*
2) *Since self-excitation is not possible in Simulink, we excited the field winding externally using DC voltage.*
3) *Take 'w' as input for DC machine and input it with rated its speed.*
4) *Adjust the DC voltage given to Field winding to get it's rated field voltage.*
5) *Change Load resistance and take readings for I_{load} and $V_{terminal}$l for each load*
6) *Plot the graph between V and I_{load} which gives the external characteristics.*

Circuit Diagrams:

Circuit for External Characteristics:

Circuit for OC Characteristics:

DC Generator



O.C.C:

Speed = 183.26 rad/sec

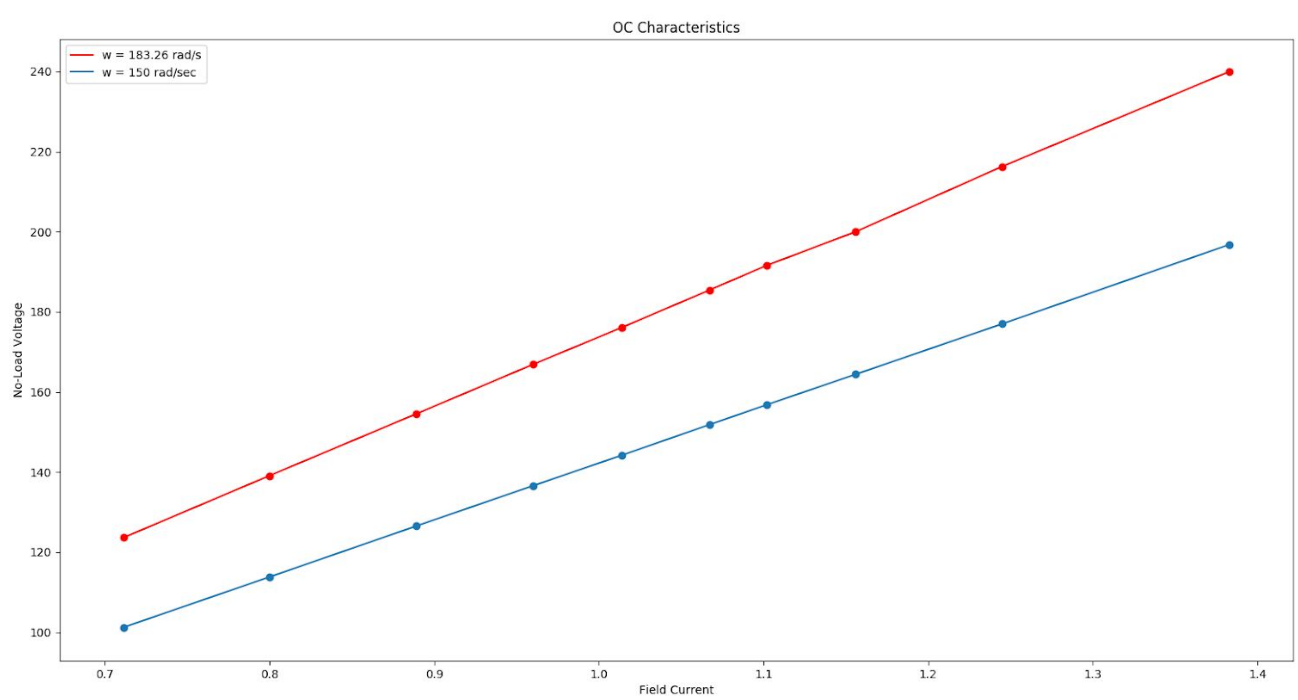
S.no	***No-Load Voltage(in Volts)***	***Field Current(in Amps)***	***Field Voltage(in Volts)***
1.	*240*	*1.383*	*389*
2.	*216.3*	*1.245*	*350*
3.	*200*	*1.156*	*325*
4.	*191.6*	*1.102*	*310*
5.	*185.4*	*1.067*	*300*
6.	*176.1*	*1.014*	*285*
7.	*166.9*	*0.9602*	*270*
8.	*154.5*	*0.889*	*250*
9.	*139.1*	*0.8*	*225*

10.	*123.6*	*0.7112*	*200*

Speed = 150 rad/sec

S.no	***No-Load Voltage(in Volts)***	***Field Current(in Amps)***	***Field Voltage(in Volts)***
1.	*196.8*	*1.383*	*389*
2.	*177*	*1.245*	*350*
3.	*164.4*	*1.156*	*325*
4.	*156.8*	*1.102*	*310*
5.	*151.8*	*1.067*	*300*
6.	*144.2*	*1.014*	*285*
7.	*136.6*	*0.9602*	*270*
8.	*126.5*	*0.889*	*250*
9.	*113.8*	*0.8*	*225*
10.	*101.2*	*0.7112*	*200*

Plot of OC Characteristics:



Calculations:

Critical Resistance:

For w = 183.26 rad/sec

(139.1-123.6)/(0.8-0.7112) = 174.5 Ω

Critical Resistance = 174.5 Ω

For w = 150 rad/sec

(113.8-101.2)/(0.8-0.7112) = 141.89 Ω

Critical Resistance = 141.89 Ω

Critical Speed:

*Critical Speed = Nominal Speed * (RT/RS)*

*Critical Speed = 183.26 * (126.5/154.5) = 150 rad/sec*

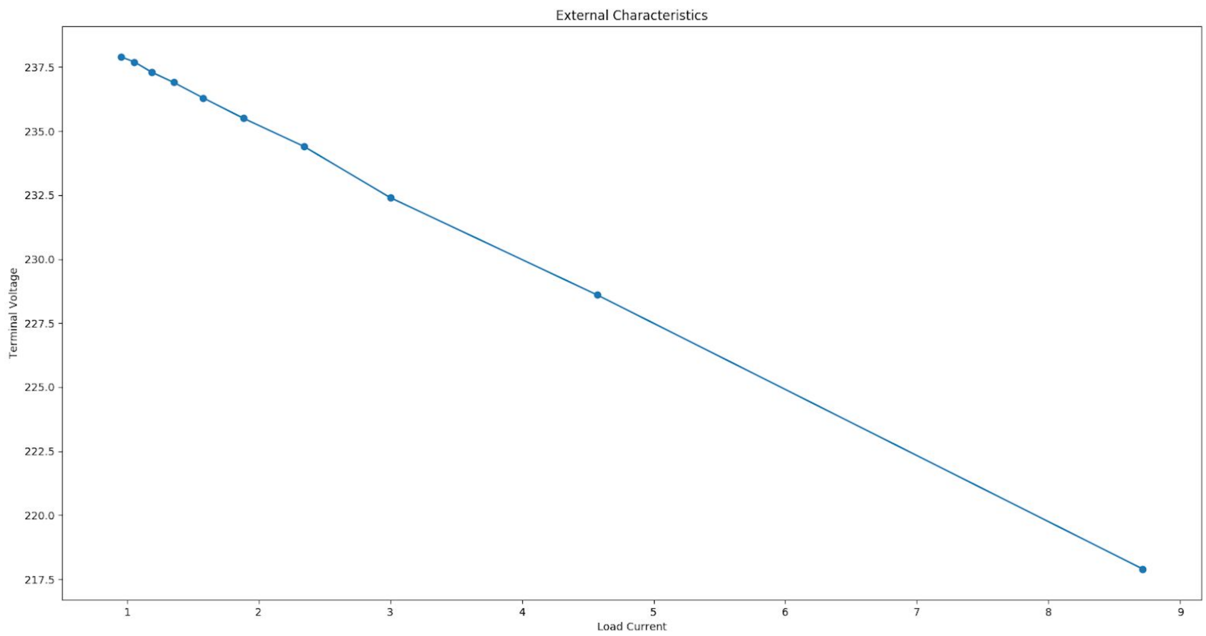
Hence, Critical Speed = 150 rad/sec

<u>External Characteristics:</u>

Field Voltage = 389 Volts

S.no	Load Current(in Amps)	Terminal Voltage(in Volts)	Load Resistance(in Ohm)
1.	8.716	217.9	25
2.	4.572	228.6	50
3.	3	232.4	75
4.	2.344	234.4	100
5.	1.884	235.5	125
6.	1.576	236.3	150
7.	1.354	236.9	175
8.	1.187	237.3	200
9.	1.056	237.7	225
10.	0.9518	237.9	250

Plot of External Characteristics:



Conclusions:-

1) *From the O.C.C and External characteristics*

   Nominal Speed = 183.26 rad/sec

   Critical Speed = 150 rad/sec

   Critical Resistance = 174.5 Ω(at nominal speed)

2) *Residual Magnetism is the small magnetic field left in the iron cores in the shunt fields when the generator is at rest. Without it, the fields would have to be flashed with a DC current in order to start the generator generating.*

3) *Since we used Simulink for the experiment, there is no Residual voltage or Residual magnetism.*