Electrical Machines Lab (EE19BTECH11041)

Experiment 7:

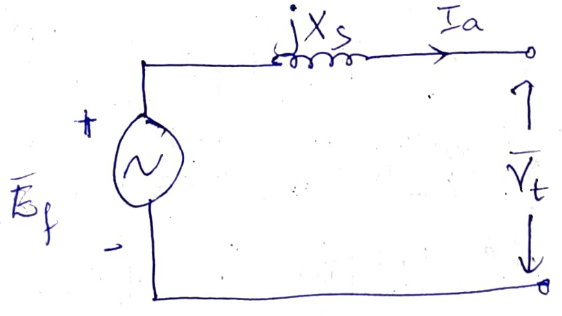
Determination of Voltage Regulation of a Synchronous Generator Using EMF Method

Aim:

The aim of the experiment is to get value of X_s and R_a for a given synchronous generator and to find the voltage regulation of it using EMF method.

Synchronous Reactance:

The Single-phase equivalent circuit of an alternator for a balanced operation is shown as follows.

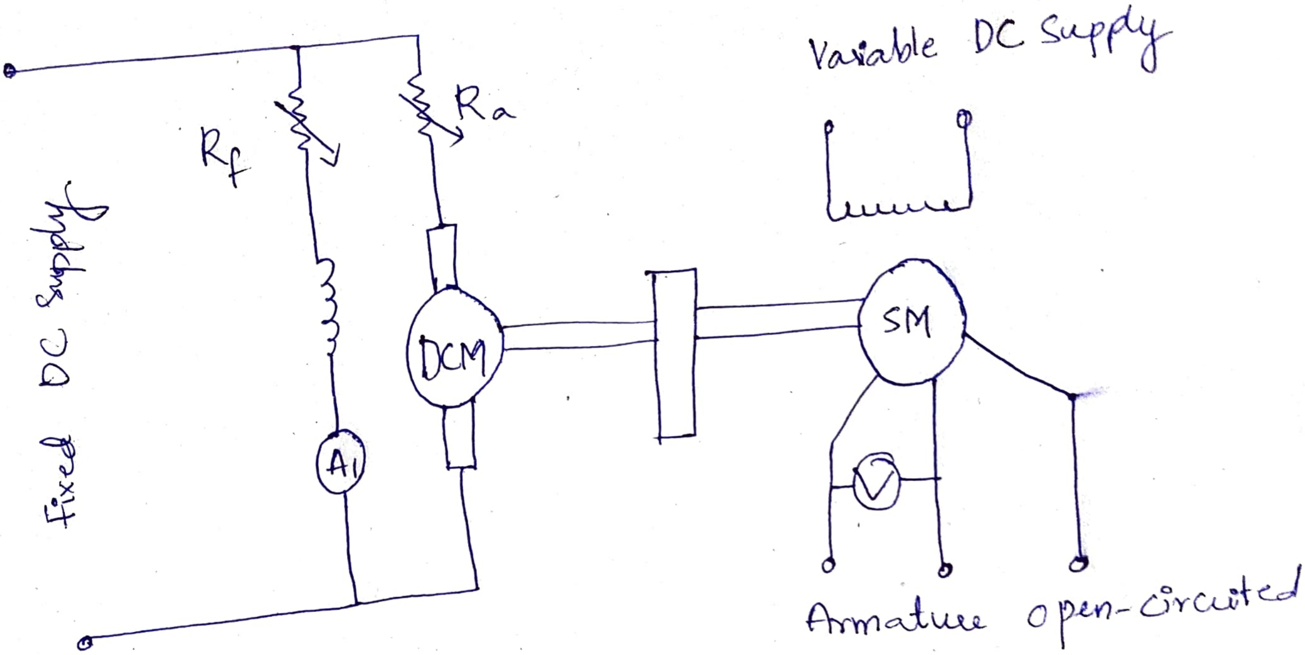


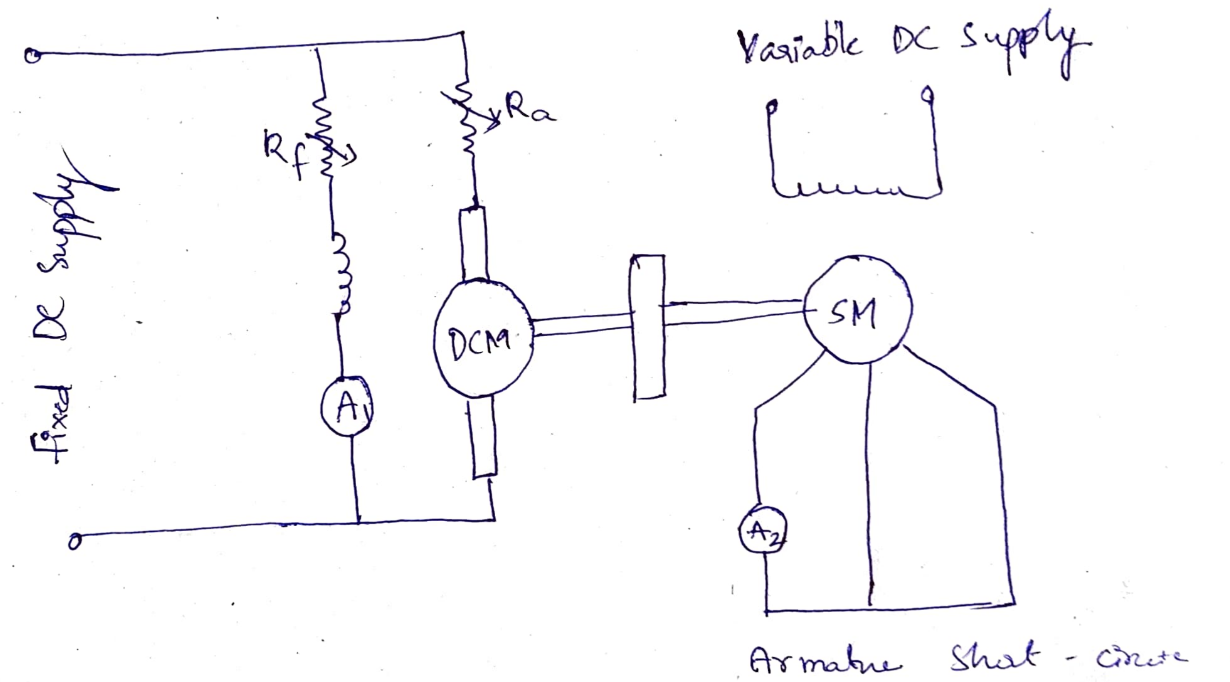
Here, $\bar{E}_f$ is the voltage that is induced in the armature winding by the field excitation and hence, is called as the excitation voltage. Apart from the excitation voltage, there will be a voltage drop in the armature circuit because of the armature current $\bar{I}_a$ ~~itself~~.

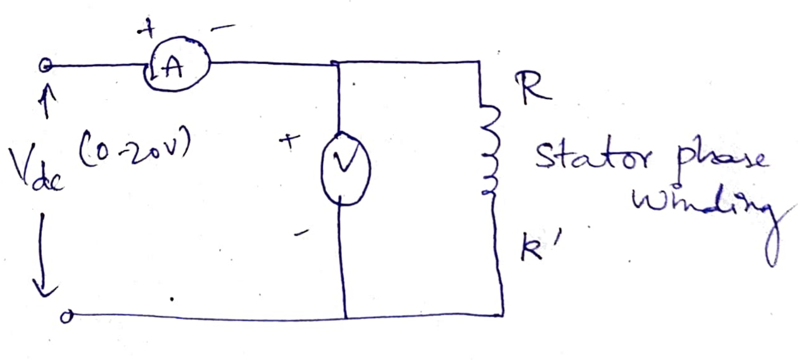
By assuming a ~~voltage~~ linear magnetization and by ignoring the armature resistance, it can be shown that the respective voltage drop is proportional to the armature current with a phase lead of 90°. Thus, the voltage drop caused by the armature current can in effect be modelled through an inductive reactance X_s, which is finally called as the synchronous reactance.

Circuit Arrangement:

The circuit arrangement to conduct the experiment is shown in figures 2, 3, 4. Here, three different tests are to be performed. The first test is called as the open circuit test and is to be conducted by employing the circuit configuration shown in Figure 2. Subsequently a short circuit test and voltmeter ammeter method. is used to calculate the per phase resistance of the stator by employing the circuit configuration.


Variable DC supply
Ra
Rf
Fixed DC supply
DCM
SM
A1
V
Armature open-circuited


Variable DC supply
Ra
Rf
Fixed DC supply
DCM
SM
A1
A2
Armature Short-circuit


+
-
A
Vdc
(0-20V)
+
V
-
R
Stator phase winding
R'

Procedure :

① To perform a test, the speed of the DC shunt motor should initially be set close to 1500 r.p.m by adjusting it's armature and field resistances.

② For the open circuit test, the current in the alternator field is to be gradually increased (by adjusting the variable DC voltage) and the corresponding armature voltages are to be noted down.

③ Similarly, for the short circuit test, the armature current are to be noted down for different values of field currents. Although the open circuit test should be continued upto a voltage higher than the rated voltage, exceeding the armature rated current is strictly prohibited in the short circuit test.

Based on the observations from open circuit and short circuit tests, the synchronous reactance of the alternator can be calculated as follows,

$$X_s = \frac{V_{oc}}{\sqrt{3}\, I_{sc}}$$

Here V_{oc} and I_{sc} are the open circuit line to line voltage and short circuit line current, respectively for the same value of field current.

The value of X_s should be calculated for all the different values of the alternator field current:

(4) Per phase resistance of the synchronous machine is calculated using voltmeter and ammeter method. but the value obtained here is a DC resistance of the machine winding. AC resistance should be calculated by multiplying the DC resistance with factor of 1.1 (to account for skin effect)

$$R_{ac} = 1.1 * R_{dc}$$

Now the voltage regulation of the machine is calculated, using the values of X_s and R_a as given the following formula.

$$\% \text{ voltage regulation} = \left(\frac{V_{nl} - V_{fl}}{V_{fl}}\right) \times 100$$

where V_{nl} (no load) voltage is

$$V_{nl} = \sqrt{(V_{fl} * \cos\theta + I * R_s)^2 + (V_{fl} * \sin\theta + I * X_s)^2}$$

V_{nl} is full load voltage.

and θ is the power factor angle.

Results:

I. Open Circuit and Short Circuit Test's Observations:

S.No	Open Circuit Test		Short Circuit Test		Synchronous reactance (X_s)
	Field Current (I_f)	Open circuit Voltage (V_{oc})	Field current (I_f)	Short circuit Current (I_{sc})	
1	0.1A	103 V	0.05	0.79	
2	0.12A	119 V	0.07	0.9A	
3	0.13A	125V	0.1A	1.12A	
4	0.18A	175V	0.11A	1.29A	
5	0.2A	200V	0.16	1.75A	
6	0.25A	230V	0.18	2A	
7	0.3A	272V	0.24	2.5	
8	0.35A	298V	0.28	3A	
9	0.42A	332V	0.34	3.5A	
10	0.45A	342V	0.38	4.0A	
11	0.5A	360 V	0.41	4.2A	
12	0.55A	380 V			
13	0.6A	392V			
14	0.65	401 V			
15	0.7	415 V			
16					

Results:

Common I_f values

X_s avg = 50.797

I_f	V_{oc}	I_{sc}	Synchronous reactance X_s
0.1A.	103V	1.12A	53.095
0.12A	119V	1.29A	53.2594
0.18 A	175V	2A	50.5181
0.25 A	230V	2.5A	53.116
0.35 A	298V	3.5A	49.157
0. 42A	332V	4.2A	45.6381

II Voltmeter ammeter method for stator resistance measurement

S.No	Voltage ~~(current(amps)~~	Current ~~Voltage(volts)~~	DC resistance $R_{dc} = V/I$	Per phase stator resistance $R'_s = 1.1 * R_{dc}$
1	1V	0.5A	2 Ω	2.2 Ω
2	3V	1.1A	2.7272 Ω	2.999 Ω
3	4V	1.5A	2.667 Ω	2.933 Ω
4	7V	2.5A	2.8 Ω	3.08 Ω
5	9V	3.1A	2.9 Ω	3.19 Ω
6	10V	3.6A	2.7778	3.055 Ω

$\boxed{R_s(avg) = 2.9095 \Omega}$

(6) Conclusions:

$$\% \text{ Voltage reg} = \frac{V_{nl} - V_{fl}}{V_{fl}} \times 100$$

$$V_{nl} = \sqrt{(V_{fl} * \cos\theta + I_a R_s)^2 + (V_{fl} \cdot \sin\theta + I_a X_s)^2}$$

From O.CC and SCC

. we need to find V at rated and I_{sc} at that I_f.
4.2A

By extrapolation I_{sc} at $V_{oc} = 415V$, $I_{sc} =$ [illegible] A

$V_{fl} = 239.6$

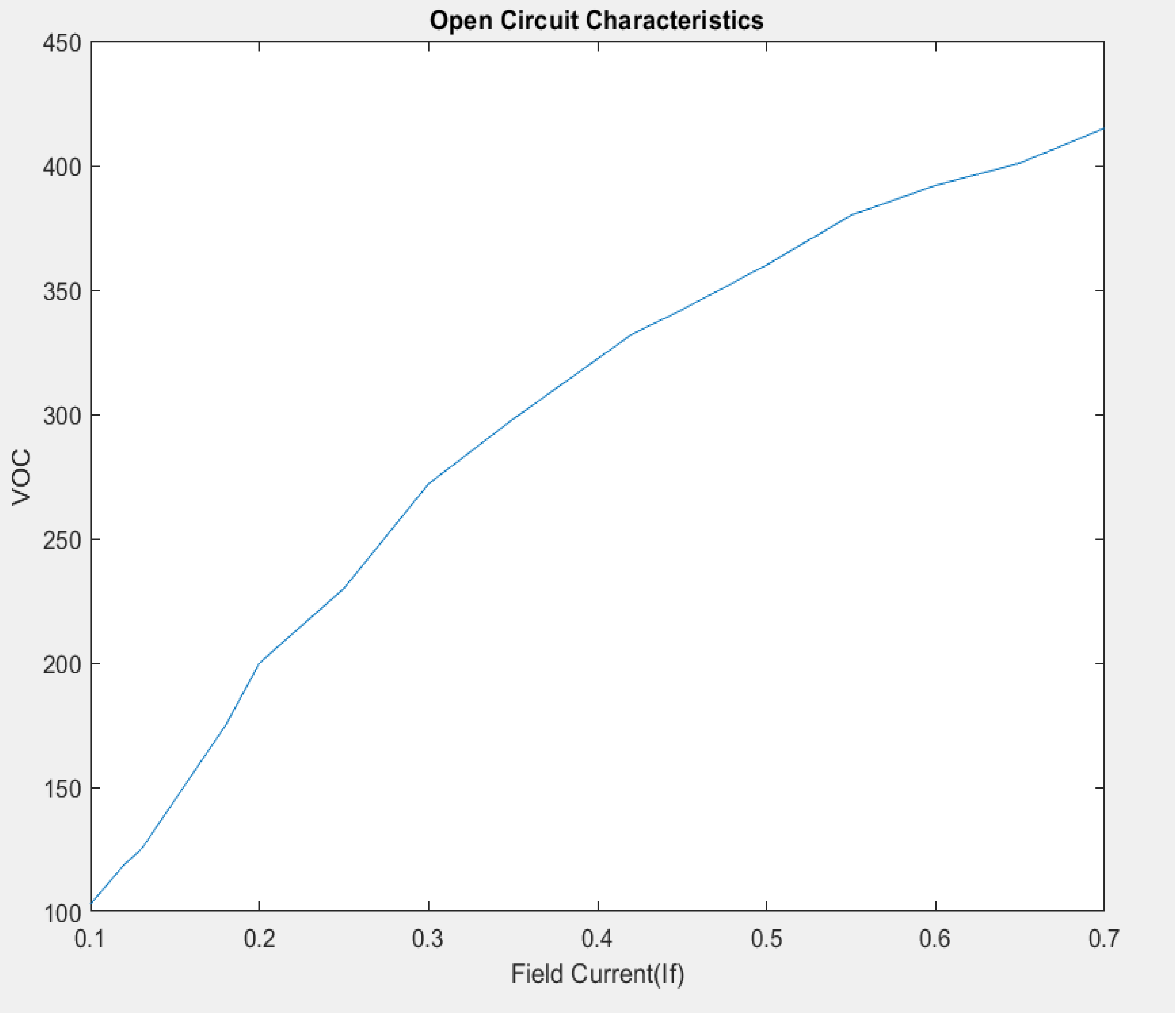
$$V_{nl} = \sqrt{(239.6 \cos\theta + 4.2 \times 2.9)^2 + 239.6 \sin\theta + (4.2 \times 50.77)^2}$$

Let's use $\cos\phi = 1$

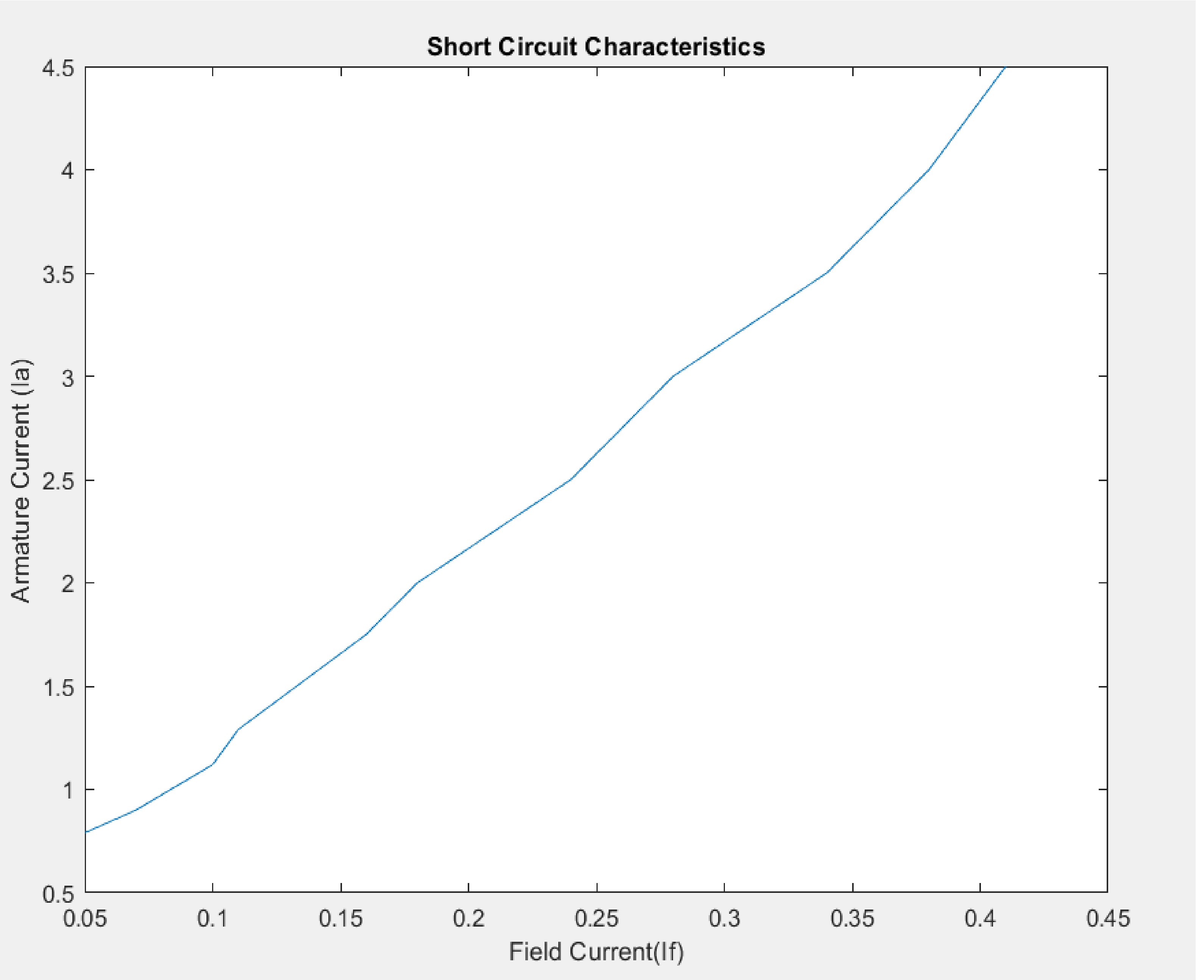
$$V_{nl} = \sqrt{(251.8)^2 + (213.1)^2} = 330.03V$$

$$\boxed{\% \text{ Voltage reg} = 37.74\%}$$

O.C.C :


Open Circuit Characteristics
450
400
350
300
250
200
150
100
VOC
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Field Current(If)

S.C.C:



Short Circuit Characteristics
Armature Current (Ia)
Field Current(If)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45