IIT PALAKKAD

Indian Institute of Technology Palakkad
भारतीय प्रौद्योगिकी संस्थान पालक्काड
Nurturing Minds For a Better World

Power Systems Lab

Electrical Engineering

IIT Palakkad

(Hardware Experiment 1)

Open Circuit Characteristics of a Stand-Alone Induction Generator

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Department : Electrical Engineering

Experiment number : 05 (Hardware Experiment 1)

Open Circuit Characteristics of Induction Generator

Aim

1. To plot the open circuit characteristics of a stand-alone induction generator at rated speed and to find the critical capacitance.

2. To plot the voltage regulation characteristics of a given induction machine at rated speed.

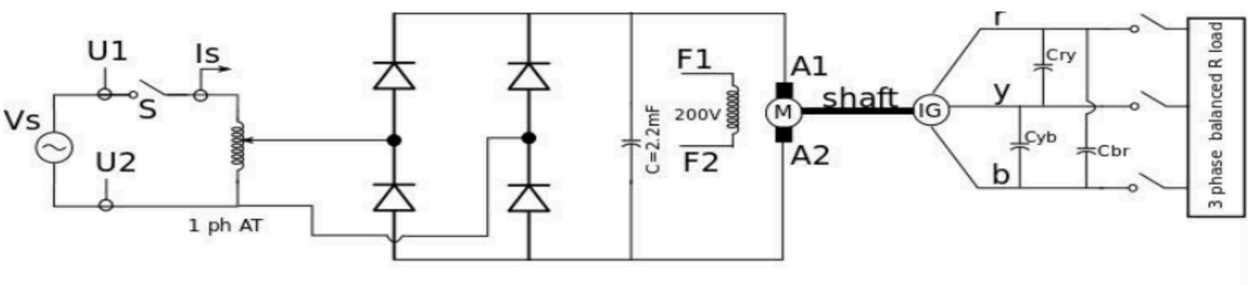
3. To estimate the capacitance requirement of the given induction machine for a given operating power factor.

Nameplate rating of machine(s):

1. Three-phase squirrel-cage induction motor: 4 poles (1500rpm), 24V Y-connected. 2.

Separately-excited DC machine: 2 pole.

Open circuit characteristics connection diagram



Procedure for Conducting the Test:

1. Make the connections as per the circuit diagram with all the breakers in the open position and all the variable sources in the minimum position

2. Operate the DC machine as a separately excited motor by connecting its field winding as per the circuit diagram.

3. Connect the armature winding to a variable voltage source as shown in the connection diagram.

4. Connect the capacitance in a delta fashion to the induction machine terminals and keep the load side breaker in the open position.

5. Now turn on the power supplies with the autotransformer in the minimum position.

6. Slowly vary the auto-transformer and note down the induction machine terminal voltage, speed of the machine, and machine phase current using the voltmeter and ammeter of the panel. **Caution: slowly vary the auto-transformer and make sure that the line voltage of the induction machine never exceeds the capacitor voltage rating.**

7. After the voltage builds up near the rated voltage (say 380V), load the induction machine by closing the breaker and find the regulation characteristics (load slightly, and the machine should not stall while loading).

8. After finishing the experiments, move the auto-transformer to the minimum position, open all the breakers, switch off the power supply, and remove the connections. Before touching the IG terminals, make sure that all the phase terminal voltages read zero.

OBSERVATIONS :

Open Circuit Test

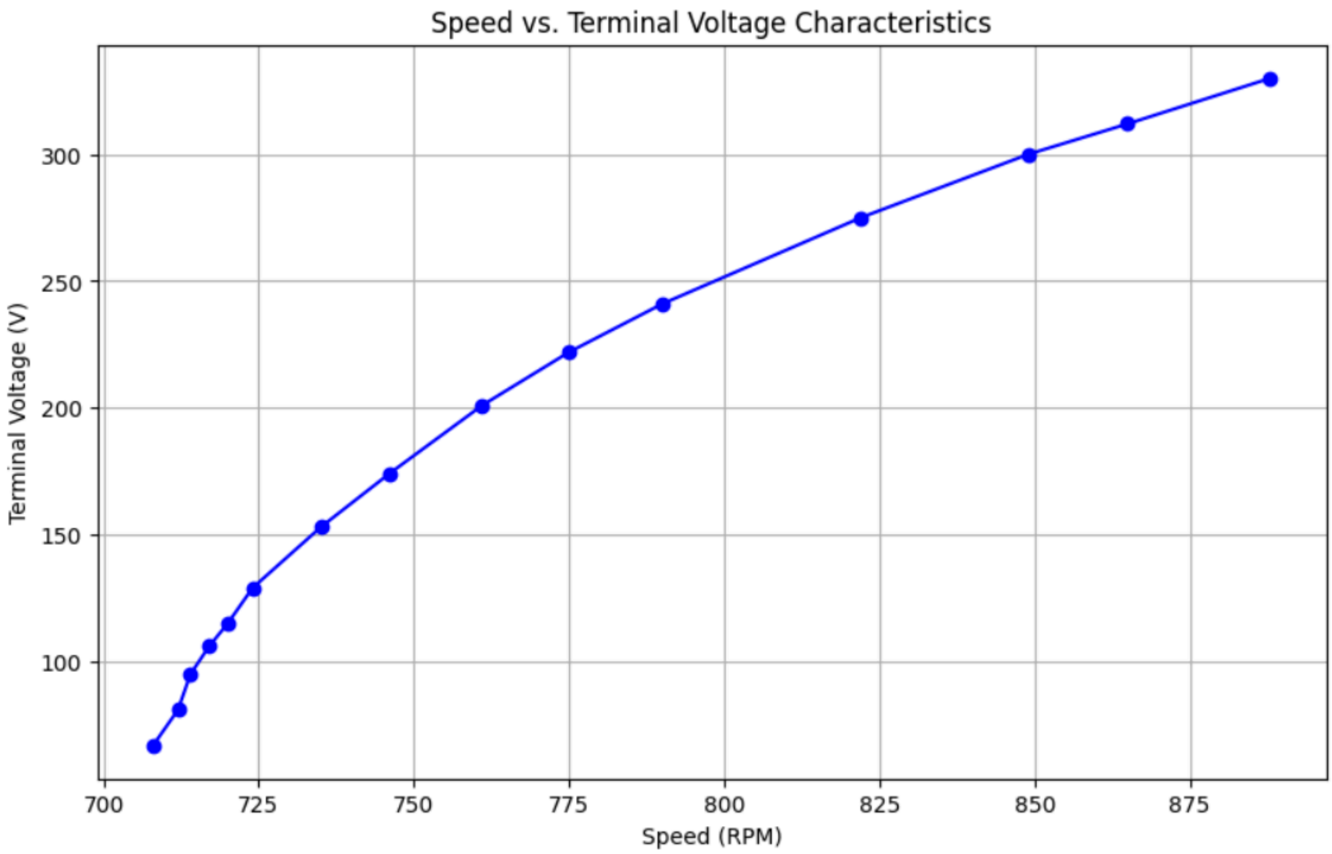
S. No	Rated speed	Speed	E_{LL} (V)	If (mA)
1	1500	708	67	234
2	1500	712	81	400.2
3	1500	714	95	510
4	1500	717	106	582
5	1500	720	115	701
6	1500	724	129	811
7	1500	735	153	930.8
8	1500	746	174	1000
9	1500	761	201	1080
10	1500	775	222	1190
11	1500	790	241	1300
12	1500	822	275	1380
13	1500	849	300	1490
14	1500	865	312	1580
15	1500	888	330	1690

Induction motor voltage regulation

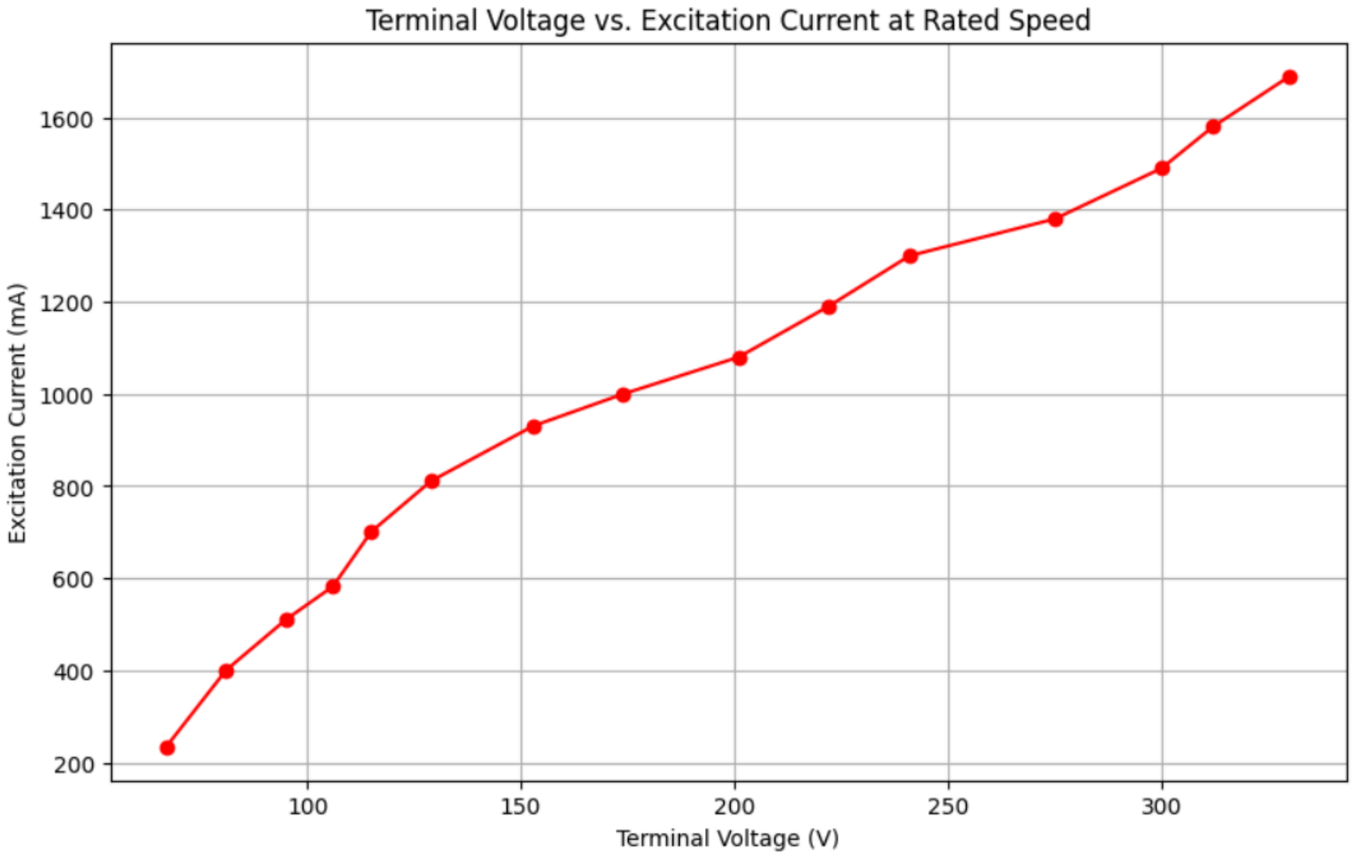
S.no.	Load current (mA)	Terminal voltage (V)
1	0 (no load)	252
2	0.2	238
3	0.37	215
4	0.5	189
5	0.58	161
6	0.51	115

Results

1. Plot speed Vs terminal voltage characteristics.



2. Plot Terminal voltage Vs excitation current at rated speed.



3. Estimate the critical capacitance at the rated speed.

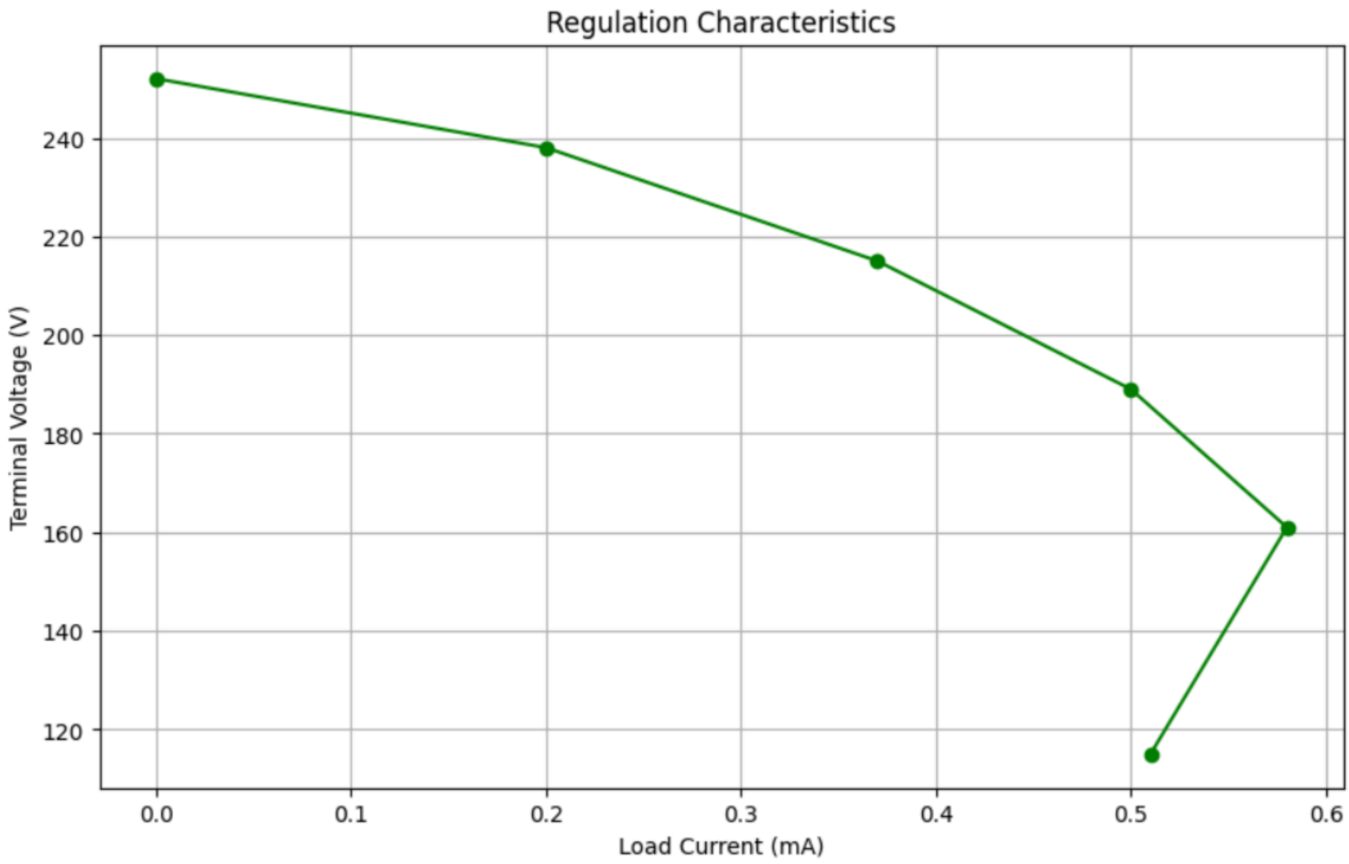
The critical capacitance C_{crit} is the minimum capacitance needed to excite the generator at no load at rated speed. The formula is typically derived from the magnetizing reactance X_m and frequency f as:

$$C_{crit} = \frac{1}{2\pi f X_m}$$

We'll assume a typical frequency of 50 Hz and a reasonable value for X_m (e.g., 100 Ω) for calculations.

=> Critical Capacitance at rated speed: 0.0318 mF.

4. Plot the regulation characteristics.



5. Estimate the capacitance requirement for various operating power factors for the given induction machine

For an induction generator, the capacitance requirement for a given power factor is given by the following relationship:

$$C = \frac{Q}{V^2 . 2\pi f}$$

Capacitance required at power factor 0.8: 0.008 mF

Capacitance required at power factor 0.9: 0.004 mF

Capacitance required at power factor 1.0: 0.000 mF

Inferences

1. In an induction generator, the open-circuit and voltage regulation tests are essential for understanding its voltage behavior under no-load and load conditions.
2. During the open-circuit test, an increase in excitation current results in a corresponding rise in terminal voltage. This is typical in no-load conditions, where the voltage build-up is influenced by the reactance and the excitation level provided by the capacitors. In other words, as the excitation current increases, it enhances the magnetic field within the generator, allowing the terminal voltage to build up.
3. In the voltage regulation test, it is observed that the terminal voltage drops as the load current increases. This characteristic reflects the inability of the induction generator to regulate voltage independently under load. To counter this drop in voltage with increased load, additional capacitance or a higher excitation current is required. This is because, unlike synchronous generators, induction generators do not have an inherent mechanism for external voltage regulation. Therefore, increased load demands a proportional increase in excitation to maintain stable terminal voltage.
4. The critical capacitance is the minimum capacitance required to initiate and sustain self-excitation at the generator's maximum operating speed in open-circuit conditions. If this capacitance level is not met, the generator cannot sustain voltage generation when there is no load. While this critical capacitance enables threshold excitation at no-load, it may need adjustment when the generator is loaded to ensure stable voltage levels.

Viva Questions

1) **How does an induction motor act as an induction generator?**
An induction motor acts as an induction generator when it is driven above its synchronous speed. At this speed, the rotor creates a magnetic field that lags behind the stator field. This lag induces a reverse current flow in the stator windings, effectively converting the motor into a generator that supplies power back to the source.

2) **Why are capacitors necessary for stand-alone operation of induction generators?**
In stand-alone operation, capacitors are essential for an induction generator because they provide the reactive power required to establish and maintain the magnetic field within the generator. Without this external reactive power source, the generator would be unable to initiate and sustain voltage output in isolated conditions.

3) Compare the stand-alone and grid-connected operation of an induction generator.
- In grid-connected operation, the induction generator draws reactive power directly from the grid, making capacitors unnecessary. The grid also helps stabilize frequency and voltage, simplifying overall voltage control.

- In stand-alone operation, the generator relies on capacitors to supply reactive power, which is essential for excitation. Voltage control becomes more challenging since terminal voltage varies with load changes, as there is no external source to stabilize it.

4) List a few applications of induction generators.

- Small-scale hydroelectric power plants
- Wind energy systems
- Backup power in isolated or remote areas

5) **What is critical capacitance?**

Critical capacitance is the minimum amount of capacitance required for an induction generator to achieve self-excitation at a specified speed. This level of capacitance enables the generator to independently initiate and maintain voltage output, especially important in stand-alone operation.