KUVAM BHUTANI (230002037)
TANISHKA NAINIWAL (230002073)

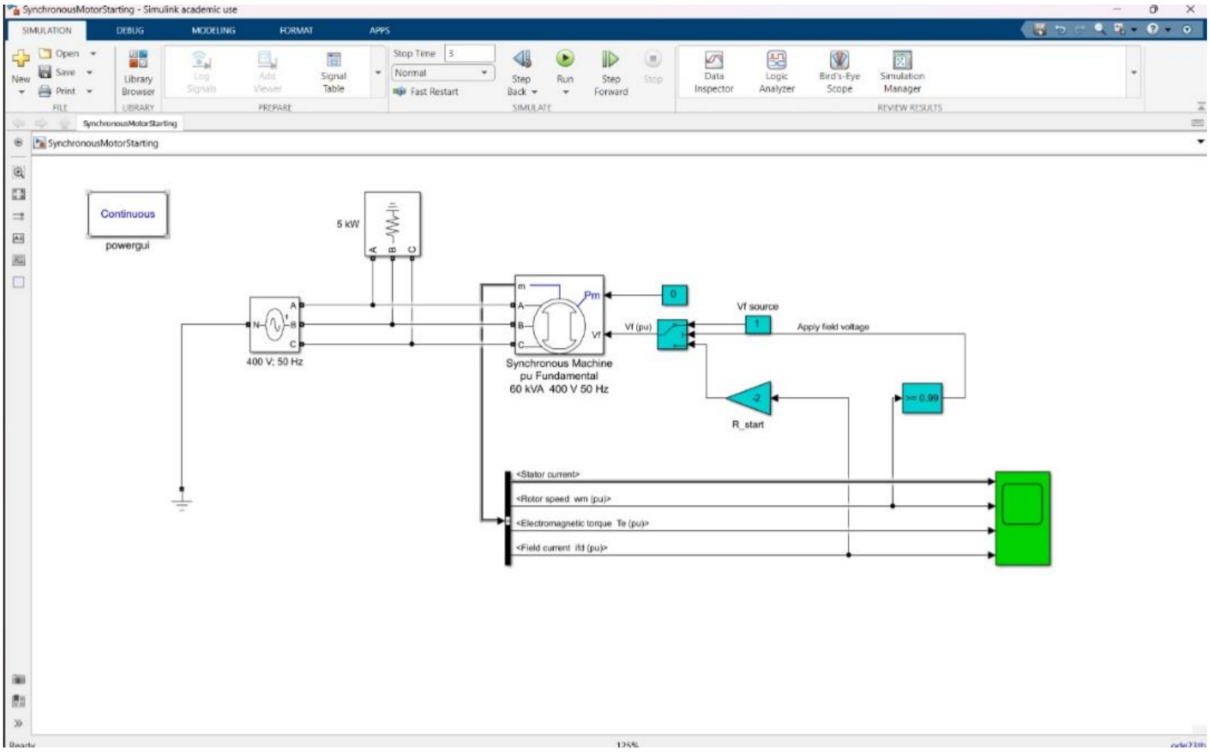
SIMULATION OF SYNCHRONOUS MOTOR

Overview of the Synchronous Motor Starting Process :-

1) Three-Phase AC Voltage Source (400 V, 50 Hz) : It represents the supply of a balanced three-phase AC voltage (400V, 50 Hz). This voltage is supplied to the synchronous motor to start it. It consists of three lines (phases A, B, and C), each delivering 400 V at a frequency of 50 Hz.

2) 5 kW Load : This represents the initial electrical load connected to the system. It could simulate the losses or resistive part of the circuit, which is common in motor-starting simulations.

3) Synchronous Machine Block (60 kVA, 400 V, 50 Hz) : This block represents the synchronous machine (motor) itself, with a power rating of 60 kVA, operating at 400 V and 50 Hz. The mechanical port (Pm) accepts the mechanical load. The excitation voltage or field voltage (Vf) is applied here, which is important for controlling the motor's synchronous speed.There are monitoring signals for rotor speed, stator current, electromagnetic torque, and field current .



4) Field Voltage (Vf source = 1 pu) : This is the field excitation voltage source. The value of 1 pu (per unit) means that the excitation voltage is set to its nominal value. Field excitation is crucial in a synchronous motor to control the magnetic field and achieve synchronization with the stator's rotating magnetic field.

5) Starting Resistance (R start) : In synchronous motors, a starting resistor (R start) may be included to reduce the inrush current during startup . The block in model represents this resistor. Once the motor reaches a certain speed, this resistor can be removed from the

circuit by the switch. This transition happens when the rotor speed reaches synchronous speed (≥ 0.99pu).

6) Rotor Speed Control and Synchronization Logic : This measures the rotor speed in per unit (pu). The rotor of a synchronous motor must reach synchronous speed to operate properly .The logic block (comparison block) checks if the rotor speed is ≥ 0.99 pu (close to synchronous speed). If true, this block sends a signal to a switch (S), which represents a synchronization switch allowing the motor to enter steady-state operation once it achieves synchronous speed.

7) Switch (S) : There is a switch block connected to the signal comparing the rotor speed with 0.99 pu . The switch controls when the motor can transition into steady-state operation When the rotor speed is less than 0.99 pu, the switch remains open (meaning the motor hasn't reached synchronous speed yet). During this period, the motor is in its acceleration phase, and the starting resistor (R_start) is still in the circuit to limit inrush current. Once the rotor speed reaches or exceeds 0.99 pu (detected by the speed comparison block), the switch closes, signaling that the rotor has nearly reached synchronous speed. This action likely causes the starting resistor to be bypassed, allowing the motor to run in normal operation mode without additional resistance.

10) Powergui Block: This block is required to run any Simulink model with power systems elements. It is essential for simulations that include electrical components in time or frequency domain. It allows to set the simulation parameters, such as the simulation type (continuous or discrete) .

Steps in Motor Starting Process :-

1. Initial Voltage Application: The three-phase 400 V, 50 Hz supply is applied to the stator of the synchronous motor.

2. Field Excitation: The field voltage source (Vf = 1 pu) energizes the rotor winding, producing the necessary magnetic field.

3. Speed Build-up: The rotor begins to accelerate under the effect of the applied torque and mechanical load.

4. Synchronous Speed Detection: As the rotor speed (wm) approaches synchronous speed (≥ 0.99 pu), a comparison block detects this condition.

5. Removing Starting Resistance: Once the motor reaches close to synchronous speed, the starting resistor (R_start) is bypassed, and the motor can operate efficiently at synchronous speed.

6. Steady-State Operation: After synchronization, the motor operates in steady state, with its rotor running at the same speed as the stator's magnetic field.

Performance Analysis of Synchronous Motor Start-Up

Stator current: This graph shows the current going through the stator windings of the motor over time. At the beginning, the current is very high with lots of fluctuations. This is because when the motor first starts, it needs a lot of current to get moving. As the motor picks up speed, the current gradually decreases and becomes steady. High current at startup is normal, but we don't want it to stay high because it can damage the motor. The starting resistor helps reduce this initial surge of current. Once the motor reaches its stable operating speed, the current stays steady, indicating that the motor is running smoothly.

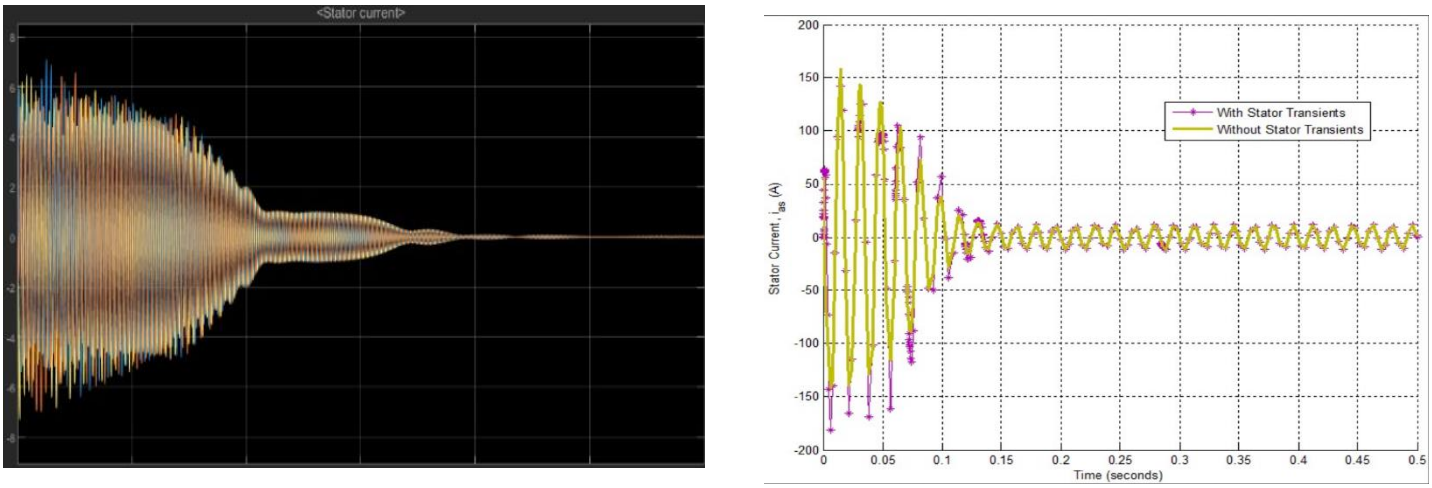


Figure 1 STATOR CURRENT

Electromagnetic Torque: This graph shows the torque, or the rotational force, generated by the motor. At first, there are large swings in the torque, with both positive and negative values. This happens because the motor is trying to find its rhythm to reach synchronous speed, which causes some instability. Over time, the torque stabilizes as the motor synchronizes with the power supply. Large torque swings can cause vibrations or stress on the motor. When the torque stabilizes, it means the motor is running smoothly and efficiently, which is what we want for reliable operation .

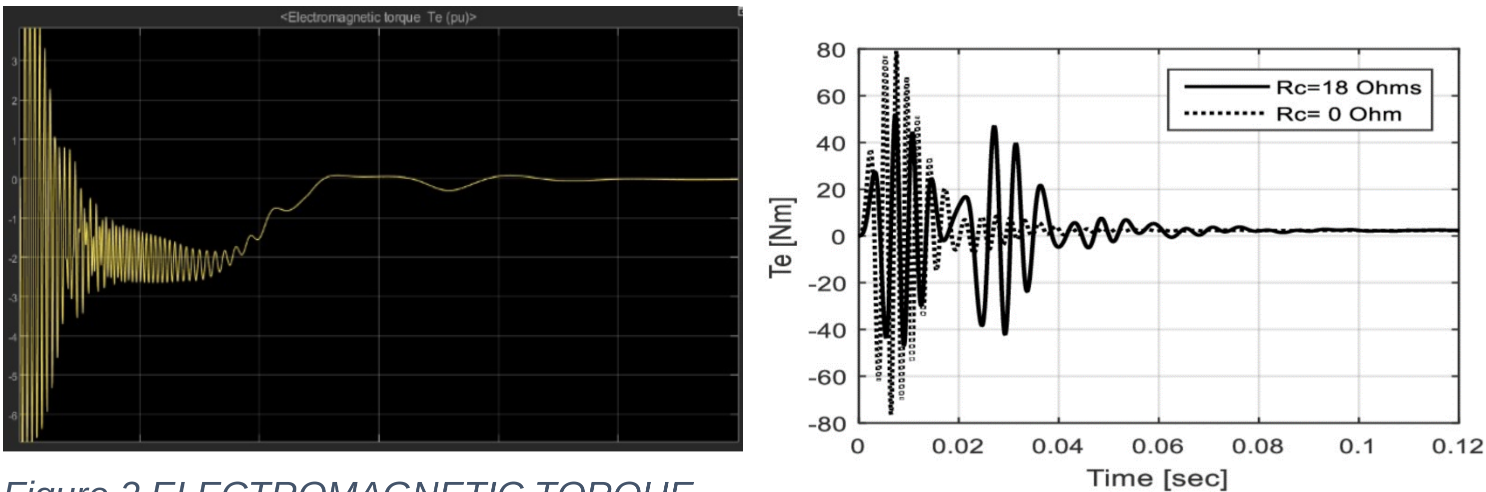
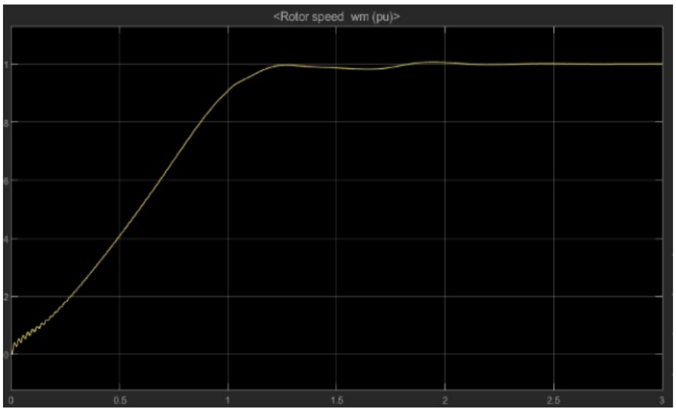


Figure 2 ELECTROMAGNETIC TORQUE

Rotor Speed (wm) : This graph shows the speed of the motor's rotor in per-unit (pu), where 1 pu means the motor has reached synchronous speed.The rotor starts from rest and gradually speeds up. It approaches 1 pu (or synchronous speed) and then levels off, meaning the rotor has matched the speed of the rotating magnetic field in the stator.
The smooth increase to synchronous speed shows that the motor is starting up correctly without any jerky movements. Reaching and maintaining synchronous speed is essential because it means the motor is properly synchronized with the power supply and can run continuously and efficiently.



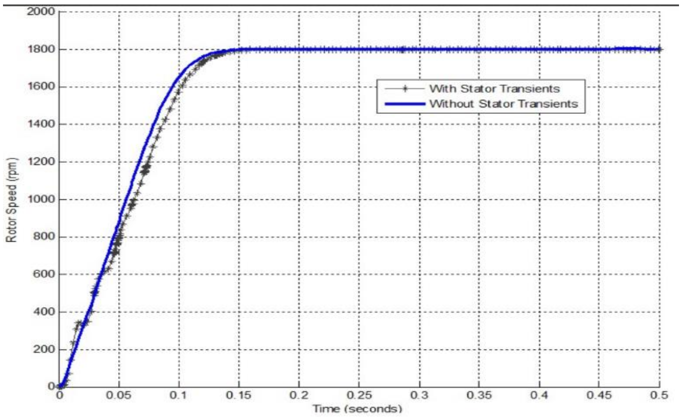


Figure 3 ROTOR SPEED

Field Current : This graph shows the current in the motor's field winding, which is responsible for producing the magnetic field in the rotor. At first, the field current has some oscillations, as the motor's magnetic field is adjusting to sync with the stator's rotating magnetic field. Eventually, the field current also settles into a steady value as the motor reaches synchronous speed. A stable field current means the motor's magnetic field is properly aligned and steady, allowing for efficient torque production. When this current becomes stable, it indicates the motor is running smoothly without any fluctuations in its magnetic field.

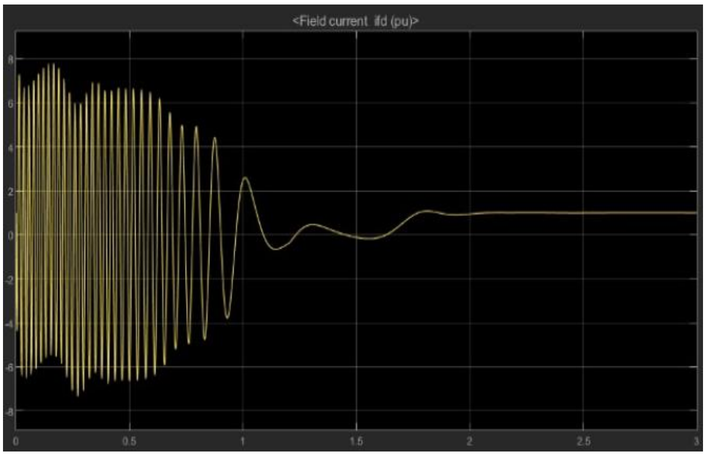


Figure 4 FIELD CURRENT