SNS COLLEGE OF TECHNOLOGY

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DEPARTMENT OF AUTOMOBILE ENGINEERING

COURSE NAME : 23AUB201 – AUTOMOTIVE ELECTRICAL DRIVES AND CONTROLS

II YEAR / III SEMESTER

Unit 5 – Electric Motor Drives

Topic : Permanent Magnet Synchronous Motor and control and Switched Reluctance Motors and control

PERMANENT MAGNET SYNCHRONOUS MOTOR

- A Permanent Magnet Synchronous Motor (PMSM) is a high-performance motor where permanent magnets are embedded in the rotor to generate a constant magnetic field.
- The stator windings produce a rotating magnetic field when AC power is applied, and the rotor synchronizes with this field, resulting in high efficiency and precise speed control.

COMPONENTS

❖ **Stator**

- **Core**: Made of laminated silicon steel to minimize eddy current losses. Contains slots for holding stator windings.
- **Windings**: Three-phase windings are arranged in the slots to produce a rotating magnetic field when AC is supplied. Distributed or concentrated winding configurations can be used.

❖ **Rotor**

- Made of high-strength materials like neodymium-iron-boron (NdFeB) or samarium-cobalt.
- Provide a constant magnetic field without requiring an external power source.

COMPONENTS

❖ **Air Gap**

➢ The gap between the stator and rotor allows the magnetic field to interact with the rotor.

❖ **Shaft**

➢ Transfers mechanical power from the rotor to the load.

❖ **Cooling System**

➢ May include fins, fans, or liquid cooling systems to dissipate heat generated during operation.

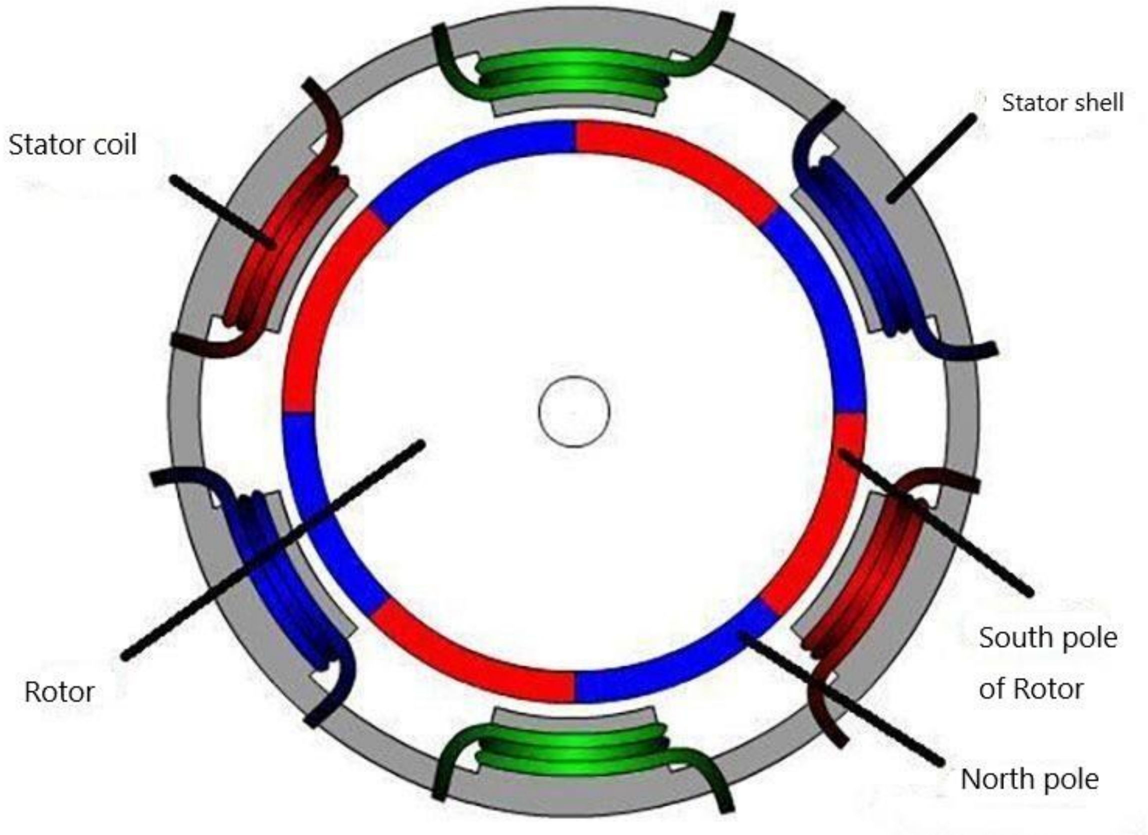
WORKING

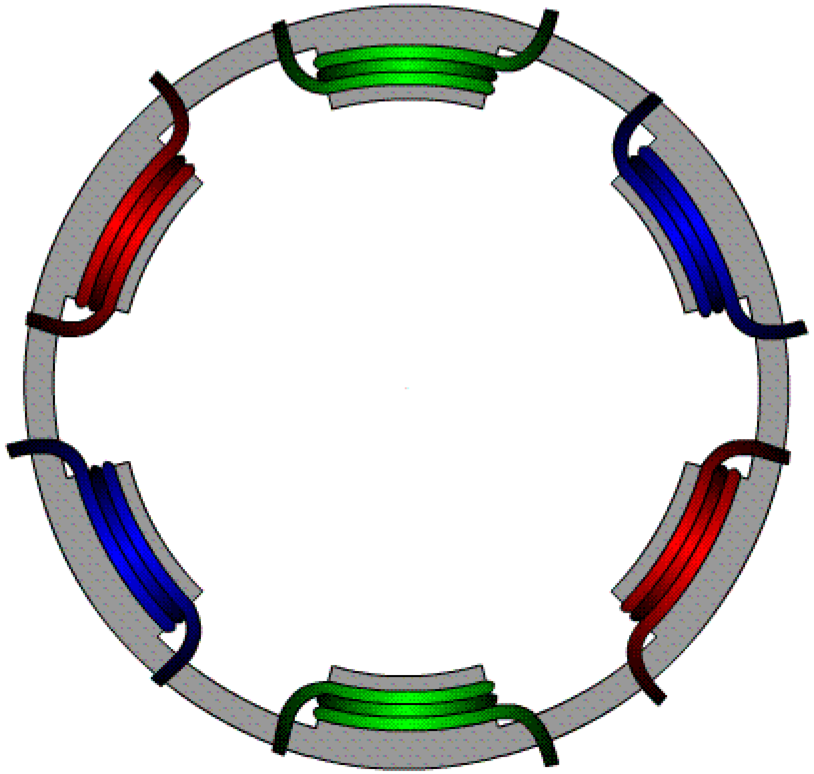
- PMSM works on the principle of **synchronous speed**, where the rotor rotates at the same speed as the magnetic field generated by the stator.
- A three-phase AC voltage is supplied to the stator windings.
- This generates a rotating magnetic field (RMF) within the stator.
- The magnetic field of the stator interacts with the magnetic field of the rotor.
- The rotor aligns itself with the stator's rotating magnetic field to maintain synchronization.
- The rotor rotates at a speed directly proportional to the supply frequency

WORKING

- ❖ Torque is produced due to the magnetic attraction between the stator's RMF and the rotor's permanent magnets.
- ❖ The torque is smooth and ripple-free, ensuring efficient operation.
- ❖ Speed is adjusted by changing the supply frequency using an inverter.
- ❖ Torque is controlled by varying the current in the stator windings.

WORKING


Stator coil
Stator shell
Rotor
South pole
of Rotor
North pole



ADVANTAGES

- **Efficient Rotor Design**: No external power source is needed for the rotor, reducing losses.
- **Compact and Lightweight**: Permanent magnets allow a smaller and lighter rotor compared to induction motors.
- **High Performance**: High torque and efficiency due to direct interaction between the rotor and stator fields.

APPLICATION

- **Electric Vehicles (EVs)**: Compact size and high torque are ideal for drivetrain systems.
- **Industrial Machines**: Used in CNC machines and robotics for precision control.
- **Renewable Energy**: Drives for wind turbines and generators.

CONTROL METHOD

- **Field-Oriented Control (FOC)**:
  - Decouples torque and flux control, enabling independent control of these components.
  - Improves efficiency and dynamic response.
- **Direct Torque Control (DTC)**:
  - Directly controls torque and flux without complex calculations.
  - Provides fast dynamic response but may result in higher torque ripple.

CONTROL METHOD - PULSE WIDTH MODULATION

- **Position and Speed Sensors**: Encoders or resolvers detect rotor position and speed, enabling accurate control.
- **Inverter**: Converts DC power to variable frequency AC power, controlling motor speed and torque.
- Uses Pulse Width Modulation (PWM) for efficient power delivery.

SWITCHED RELUCTANCE SYNCHRONOUS MOTOR

- The Switched Reluctance Motor (SRM) is a type of synchronous motor that operates based on the principle of variable reluctance.
- It does not use permanent magnets or induced currents in the rotor, making it robust, simple, and cost-effective.
- Torque is produced through the alignment of the rotor poles with the energized stator poles.

COMPONENTS

❖ **Stator:**

- **Core**: Made of laminated ferromagnetic material to minimize eddy current losses.
- **Windings**: Each stator pole has concentrated windings, which are separately energized by a power electronic drive.
- **Number of Poles**: Typically higher than the rotor poles, enabling precise control and reducing torque ripple.

COMPONENTS

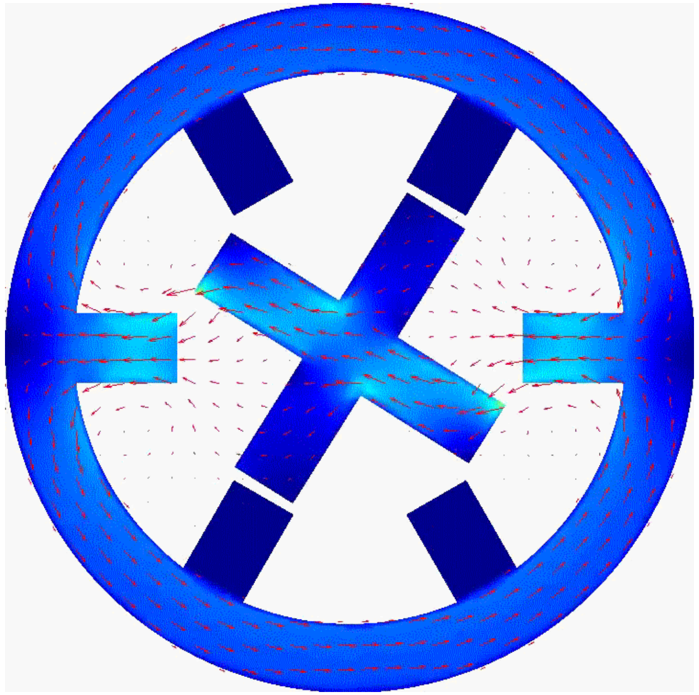
- **Rotor:**
  - **Construction**: A salient-pole design made of laminated ferromagnetic material.
  - **No Windings or Magnets**: The rotor is a simple structure without windings or permanent magnets, reducing cost and maintenance.
- **Air Gap:**
  - The gap between the rotor and stator, kept small to improve magnetic efficiency.
- **Power Converter:**
  - A specialized electronic drive system is used to sequentially energize the stator windings.

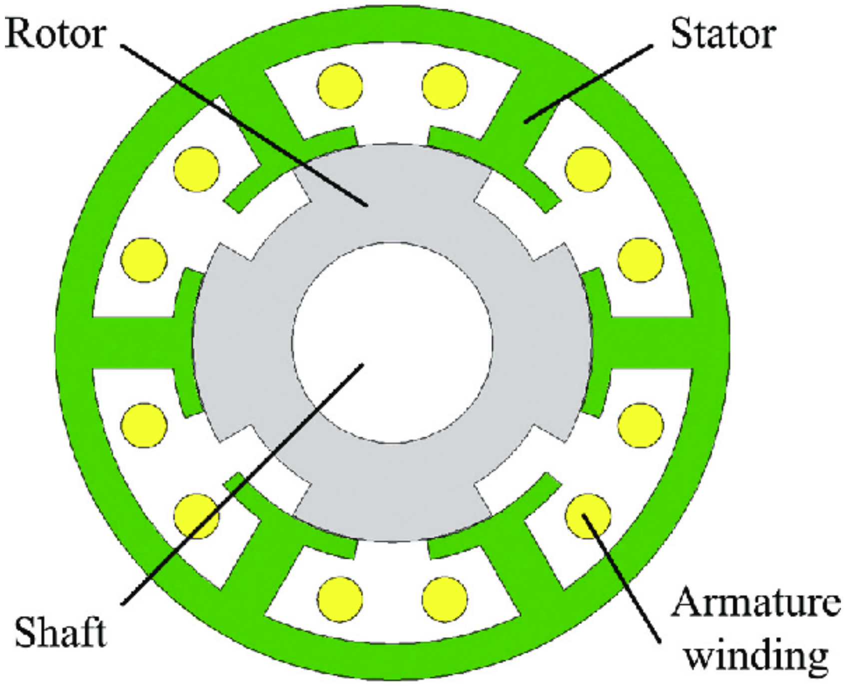
WORKING

- A specific phase of the stator winding is energized, creating a magnetic field.
- The rotor aligns itself with the energized stator pole to minimize reluctance.
- The stator poles are energized sequentially in a particular order using a power electronic drive.
- This creates a rotating magnetic field, causing the rotor to follow and produce continuous rotation.
- The rotor speed synchronizes with the switching frequency of the stator phases.
- Torque is generated by the tendency of the rotor to align with the energized stator poles.

WORKING

❖ The amount of torque depends on the inductance difference between aligned and unaligned positions.





ADVANTAGES

- High reliability due to the absence of magnets and rotor windings.
- Cost-effective design with simple manufacturing.
- Excellent performance in harsh environments.
- High torque at low speeds.

APPLICATION

- **Electric Vehicles (EVs)**: Suitable for heavy-duty EVs due to its ruggedness.
- **Industrial Drives**: Widely used in conveyors, compressors, and pumps.
- **Wind Energy**: Acts as a generator in wind turbines.
- **Household Appliances**: Used in washing machines and vacuum cleaners for efficient operation

CONTROL METHOD

- **Control Algorithms**:
  - **Field-Oriented Control (FOC)**: Used for precise torque and speed control.
  - **Direct Torque Control (DTC)**: Offers fast dynamic response without position sensors.
- **Feedback Sensors**:
  - Encoders or resolvers for rotor position.
  - Hall sensors for speed and direction.

CONTROL METHOD

- **Power Electronics**:
  - Inverters convert DC to AC for motor operation.
  - High-frequency switching ensures smooth performance.
- **Thermal Management**:
  - Advanced cooling techniques are essential due to the motor's high power density.
- **Fault Detection**:
  - Built-in systems monitor parameters like current, voltage, and temperature to detect and mitigate faults

THANK YOU !!!