Answer Key for 23EEE210 – Electrical Machines & Drives (Internal Assessment – III)

Part A (5 × 2 = 10 Marks)

1. How the ripple in armature current impacts torque in half-controlled rectifier-fed DC drives. (CO4, APP)

Answer: In half-controlled rectifier-fed DC drives, the armature current contains ripples due to the partial control of the rectifier (thyristors for positive cycle, diodes for negative cycle), leading to a pulsating DC output. These ripples cause fluctuations in the armature current, which directly affect the torque produced by the DC motor, as torque is proportional to armature current ($T \propto Ia$). The ripple results in torque pulsations, causing mechanical vibrations, increased wear, and reduced efficiency. In severe cases, it may lead to instability in speed control, especially at low speeds.

2. Outline the slip power recovery scheme. (CO4, UND)

Answer: The slip power recovery scheme is used for speed control of slip-ring induction motors. The rotor slip power, instead of being dissipated as heat in external resistors, is recovered and fed back to the AC supply or used to drive an auxiliary load. Two common methods are:

- **Static Kramer System**: Rotor AC is converted to DC, then inverted to AC and fed back to the supply.
- **Static Scherbius System**: Rotor AC is rectified, and a controlled inverter adjusts the power flow. This improves efficiency and enables sub-synchronous and super-synchronous speed control.

3. List the application of single-phase voltage regulator. (CO5, REM)

Answer:

- Voltage stabilization in domestic appliances (e.g., refrigerators, air conditioners).
- Power supply regulation in electronic equipment.
- Lighting control systems (e.g., dimmers).
- Industrial motor control for single-phase motors.
- Battery charging systems.

4. Compare the static Kramer and Scherbius system. (CO5, UND)

Answer:

Feature	Static Kramer System	Static Scherbius System
Operation	Converts rotor slip power to DC, then inverts to AC	Converts rotor slip power to DC, uses controlled inverter
Speed Range	Sub-synchronous speeds only	Sub-synchronous and super-synchronous speeds
Complexity	Simpler, fewer components	More complex, additional control circuitry
Efficiency	Moderate, limited by conversion losses	Higher, due to bidirectional power flow
Applications	Constant torque loads (e.g., fans, pumps)	Variable torque/speed applications (e.g., cranes)

5. Write a short note on v/f control. (CO5, UND)

Answer: Voltage/frequency (v/f) control is a method used for speed control of induction motors. It maintains a constant ratio of stator voltage (V) to frequency (f) to keep the air-gap flux constant, ensuring stable torque production. By varying the frequency, the motor's speed is controlled, while adjusting the voltage prevents magnetic saturation. It is widely used in variable frequency drives (VFDs) for applications like fans, pumps, and conveyors due to its simplicity and efficiency.

Part B (2 × 13 = 26 Marks, 1 × 14 = 14 Marks)

6(a). Illustrate the operation of single-phase fully controlled converter speed control of DC shunt motor drive with neat diagram. (CO4, UND, 13 Marks)

Answer:
Operation:
A single-phase fully controlled converter uses a bridge of four thyristors to convert AC input to controlled DC output for the armature of a DC shunt motor. The thyristors are triggered at specific firing angles (α) to control the output DC voltage, which adjusts the motor's armature voltage and thus its speed. The field winding is separately excited with a constant DC supply to maintain constant field flux. The output voltage is given by:

$$V_o = \frac{2V_m}{\pi} \cos(\alpha)$$

where (V_m) is the peak AC voltage, and (α) is the firing angle. Increasing (α) reduces (V_o), lowering the speed, and vice versa. The system allows precise speed control but introduces ripple in the output, requiring filters for smooth operation.

Diagram Description:

- A single-phase AC supply is connected to a fully controlled bridge rectifier (four thyristors in a bridge configuration).
- The bridge output is connected to the armature of the DC shunt motor.
- A separate DC supply or rectifier powers the field winding.
- A freewheeling diode is connected across the armature to ensure continuous current flow during thyristor off periods.
- A control circuit adjusts the firing angle (\alpha) of the thyristors.

Note: If you confirm, I can generate a diagram using a tool like TikZ in LaTeX or describe it further for clarity.

6(b). Analyze digital control DC motor drive with real-time example. (CO4, UND, 13 Marks)

Answer:
Digital Control of DC Motor Drive:
Digital control of DC motor drives involves using microcontrollers or digital signal processors (DSPs) to regulate motor parameters like speed, torque, and position. The system includes:

- **Sensors**: Measure speed (tachometer), current, or position.
- **Microcontroller/DSP**: Processes feedback and generates PWM signals to control the power converter (e.g., chopper or rectifier).
- **Power Converter**: Adjusts armature voltage/current to control motor speed.
- **Control Algorithm**: Implements PID control for precise regulation.

Real-Time Example:
In **electric vehicles (EVs)**, digital control is used for DC motor drives in auxiliary systems (e.g., cooling fans). A microcontroller (e.g., Arduino or STM32) receives speed feedback from an encoder, compares it with the desired speed, and adjusts the PWM duty cycle to a chopper circuit. This controls the armature voltage, ensuring the fan operates at optimal speed for battery cooling, improving efficiency and responsiveness compared to analog systems.

Advantages:

- Precise control with minimal steady-state error.
- Flexibility to implement complex algorithms (e.g., adaptive control).
- Real-time monitoring and fault detection.

Challenges:

- Requires accurate sensors and fast