Module 5: DC Machines

30 Important Questions and Answers

1. DC Machine

Q1. What is a DC machine? What is the difference between a DC generator and a DC motor?

Ans: A DC machine is an electromechanical energy converter that works on direct current. A DC generator converts mechanical energy into electrical energy; a DC motor converts electrical energy into mechanical energy. The same machine can work as either (reversibility).

Q2. Name the main parts of a DC machine.

Ans: Yoke (frame), pole cores with pole shoes, field winding, armature core and armature winding, commutator, brushes with brush holders, shaft, bearings and end covers.

Q3. What is the function of the commutator?

Ans: In a generator it converts the alternating EMF induced in the armature conductors into unidirectional (DC) output. In a motor it reverses the current in the armature conductors so that torque stays in one direction. It is made of hard-drawn copper segments insulated from each other by mica.

Q4. Why is the armature core laminated and made of silicon steel?

Ans: Thin insulated laminations reduce eddy current loss, and silicon steel has low hysteresis loss and high permeability, so the core heats less and efficiency improves.

Q5. What is the difference between lap winding and wave winding?

Ans: Lap winding: number of parallel paths A = P (number of poles); used for high-current, low-voltage machines. Wave winding: A = 2 for any number of poles; used for low-current, high-voltage machines.

2. DC Generators and EMF Equation

Q6. State the working principle of a DC generator.

Ans: Based on Faraday's law of electromagnetic induction: when a conductor moves in a magnetic field cutting the flux, an EMF is induced in it. Its direction is found by Fleming's right-hand rule.

Q7. How are DC generators classified?

Ans: By excitation. Separately excited: the field is supplied from an outside source. Self-excited: the field is supplied by the generator itself, and this is of three types: series, shunt and compound.

Q8. Write the EMF equation of a DC generator.

Ans: E = (phi x Z x N x P) / (60 x A) volts, where phi is flux per pole (Wb), Z total armature conductors, N speed in rpm, P number of poles and A number of parallel paths (A = P for lap, A = 2 for wave).

Q9. A 4-pole lap-wound generator has 400 conductors, 0.02 Wb flux per pole and runs at 1000 rpm. Find the generated EMF.

Ans: For lap winding A = P = 4. E = (0.02 x 400 x 1000 x 4) / (60 x 4) = 133.3 V.

Q10. What is self-excitation? What conditions are needed for a shunt generator to build up voltage?

Ans: A self-excited generator supplies its own field current. It needs (1) residual magnetism in the poles, (2) correct connection of the field winding so that its flux aids the residual flux, and (3) field resistance less than the critical resistance. The speed must be right.

3. Series, Shunt and Compound Generators

Q11. Describe a series generator.

Ans: The field winding (few turns of thick wire) is in series with the armature and the load, so $I_{se} = I_a = I_L$. It builds voltage only when the load is connected, and its terminal voltage rises with load current. Use: boosters, arc lamps.

Q12. Describe a shunt generator.

Ans: The field winding (many turns of thin wire) is connected in parallel with the armature, so $I_{sh} = V / R_{sh}$. Terminal voltage falls slightly as load increases. Use: lighting, battery charging and general supply.

Q13. Describe a compound generator and its types.

Ans: It has both a series and a shunt field winding. Cumulative compound: the two fluxes aid each other (over, flat or under compound). Differential compound: the fluxes oppose each other and the voltage drops sharply with load.

Q14. What is the difference between long-shunt and short-shunt compound generators?

Ans: Long shunt: the shunt field is connected across the series combination of armature and series field (across the load terminals). Short shunt: the shunt field is connected across the armature only, and the series field is in the load line.

Q15. State the applications of series, shunt and compound generators.

Ans: Series: boosters, arc lighting. Shunt: lighting, battery charging, general power supply. Cumulative compound: lighting and power supply where voltage must stay steady, and to compensate line drop. Differential compound: arc welding.

4. DC Motors and Types

Q16. State the working principle of a DC motor.

Ans: When a current-carrying conductor is placed in a magnetic field, a force acts on it ($F = B \times I \times l$). The direction is given by Fleming's left-hand rule. The forces on armature conductors produce torque and the armature rotates.

Q17. What is back EMF? State its significance.

Ans: When the armature rotates in the field, an EMF is induced in it that opposes the supply voltage. $E_b = V - I_a R_a$. It limits the armature current, regulates the speed and gives the motor its self-governing property.

Q18. A DC motor on 220 V supply draws an armature current of 20 A. If armature resistance is 0.5 ohm, find the back EMF.

Ans: $E_b = V - I_a R_a = 220 - (20 \times 0.5) = 210$ V.

Q19. How are DC motors classified?

Ans: Shunt motor (field in parallel with armature), series motor (field in series with armature), and compound motor (both fields), which may be cumulative or differential. Also separately excited motor.

Q20. Give the characteristics and applications of a DC series motor. What precaution is needed?

Ans: It has very high starting torque, and its speed falls sharply with load. Uses: electric traction, cranes, hoists, elevators. It must never be started or run without load, because speed becomes dangerously high (runaway); it should be directly coupled, never belt-driven.

Q21. Give the characteristics and applications of shunt and compound motors.

Ans: Shunt motor: nearly constant speed with moderate starting torque; used for lathes, drilling machines, fans, blowers and pumps. Cumulative compound motor: high starting torque with fairly steady speed; used for rolling mills, presses, shears and lifts.

5. Starters (3-Point and 4-Point)

Q22. Why is a starter required for a DC motor?

Ans: At start the speed is zero, so back EMF is zero and armature current $I_{st} = V / R_a$ is very large (e.g. 220 / 0.5 = 440 A), which can burn the armature and damage the supply. A starter adds resistance in series with the armature to limit this current, and is cut out step by step as speed rises.

Q23. Name the parts of a 3-point starter.

Ans: Terminals L (line), A (armature) and F (field); a starting resistance with studs; a handle (arm) with a spring; a no-volt release (hold-on) coil; an overload release coil; and a soft iron piece.

Q24. Explain the working of a 3-point starter.

Ans: The handle is moved slowly from OFF to the ON position so the starting resistance is cut out step by step. At the end the no-volt coil holds the handle. If supply fails, the coil loses its magnetism and a spring returns the handle to OFF. On overload, the overload coil lifts its iron piece, short-circuits the no-volt coil, and the handle is released.

Q25. What is a 4-point starter and why is it used?

Ans: It has a fourth terminal N, and the no-volt coil is connected across the supply in a separate branch, not in series with the shunt field. So when the field current is reduced by the field rheostat for speed control, the holding coil current does not change and the handle does not drop out.

Q26. State the difference between 3-point and 4-point starters.

Ans: 3-point: terminals L, A, F; the no-volt coil is in series with the shunt field, so weakening the field may release the handle; suited to normal speed. 4-point: terminals L, A, F, N; the no-volt coil is independent of the field circuit; suited to wide speed control by field weakening.

6. Speed Control of DC Motors

Q27. On what factors does the speed of a DC motor depend?

Ans: N is proportional to E_b / phi, that is N = K x (V - $I_a R_a$) / phi. So speed can be changed by varying the flux, the armature circuit resistance or the applied voltage.

Q28. What are the methods of speed control of a shunt motor?

Ans: Flux control: a rheostat in series with the shunt field raises speed above normal, and is simple and efficient. Armature (rheostat) control: resistance in series with the armature lowers the speed below normal, but wastes power. Voltage control: varying the armature voltage (multiple voltage or Ward-Leonard).

Q29. What are the methods of speed control of a series motor?

Ans: Field diverter (a resistance in parallel with the series field), tapped field control, armature diverter, resistance in series with the armature, and series-parallel control, which is used in traction.

Q30. What is the Ward-Leonard method of speed control?

Ans: A motor-generator set in which a generator feeds the armature of the DC motor, and the generator field is varied to change the voltage applied to the motor. It gives smooth, wide-range speed control in both directions but is costly, and is used in rolling mills, lifts and paper machines.