

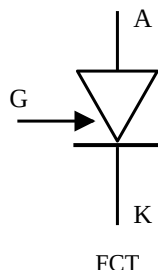
## Advance Power Electronics (315340)

Model Question Paper — Set C · Model Answers

### Q.1

#### a) Symbol and applications of FCT.

2 M



Circuit symbols: FCT (A: anode, K: cathode, G: gate, D: drain, S: source)

- Induction heating
- High-frequency inverters and choppers
- Switched mode power supplies / pulse power

(Symbol 1 M, any two applications 1 M)

#### b) $dv/dt$ and $di/dt$ rating of SCR.

2 M

- **$dv/dt$  rating:** the maximum rate of rise of forward anode voltage that an SCR can withstand in the OFF state without being falsely turned ON ( $V/\mu s$ ).
- **$di/dt$  rating:** the maximum rate of rise of anode current that an SCR can safely withstand during turn-ON without damage by local hot spots ( $A/\mu s$ ).

(1 M each)

#### c) Duty cycle and output voltage.

2 M

**Duty cycle (D):** ratio of ON time of the chopper to the total chopping period,  $D = T_{on}/T = T_{on}/(T_{on} + T_{off})$ .

$$V_o = D \cdot V_s = 0.75 \times 110 = 82.5 \text{ V}$$

(Definition 1 M, answer 1 M)

#### d) Converters used in SMPS.

2 M

- Buck (step-down) converter
- Boost (step-up) converter
- Buck-boost converter
- Flyback converter
- Forward converter
- Push-pull, half-bridge and full-bridge converters

(Any four,  $\frac{1}{2}$  M each)

**e) Modulation index and frequency modulation ratio.**

2 M

- **Modulation index ( $m_a$ ):** ratio of peak amplitude of reference (sine) wave to peak amplitude of carrier (triangular) wave,  $m_a = A_r/A_c$ . It controls output voltage.
- **Frequency modulation ratio ( $m_f$ ):** ratio of carrier frequency to reference frequency,  $m_f = f_c/f_r$ . It decides the number of pulses per cycle.

(1 M each)

**f) Types of AC voltage stabilizers.**

2 M

- Relay type (automatic tap-changing) stabilizer
- Servo controlled (motorised variac) stabilizer
- Static (solid-state) stabilizer
- Others: manual tap-changing, constant voltage transformer (CVT, ferro-resonant)

(Any four ½ M each)

**g) Needs of VFD in industry.**

2 M

- Smooth, stepless speed control of AC induction motors over a wide range.
- Energy saving in pumps and fans (power  $\propto$  speed<sup>3</sup>) instead of throttling valves/dampers.
- Soft start: low starting current and reduced mechanical stress.

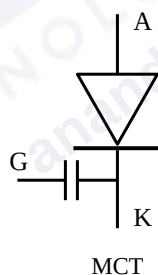
(Any two, 1 M each)

## Q.2

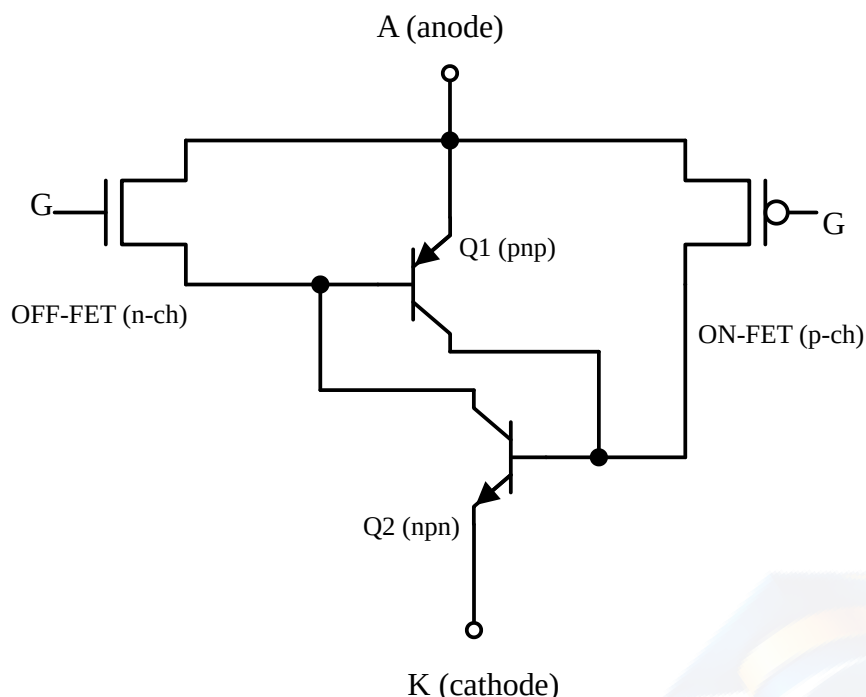
**a) Construction and working of MCT with equivalent circuit.**

4 M

**MCT (MOS-Controlled Thyristor)** is a thyristor (p-n-p-n) in which two MOSFETs are built into the gate structure: an **ON-FET** to turn it ON and an **OFF-FET** to turn it OFF. Both MOSFET gates are connected together to one gate terminal G.



Circuit symbols: MCT (A: anode, K: cathode, G: gate, D: drain, S: source)



*Equivalent circuit of MCT: thyristor (Q1-Q2) with ON-FET and OFF-FET (both gates tied to common gate G)*

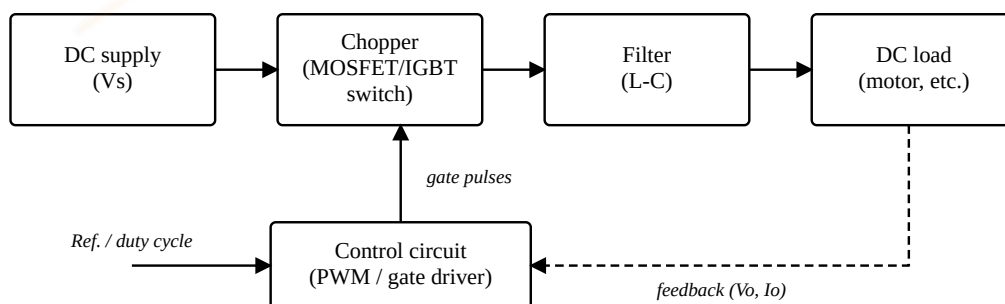
- **Turn ON (P-MCT):** a negative gate voltage (w.r.t. anode) turns ON the p-channel ON-FET. It injects current into the base of npn transistor Q2; regenerative action of Q1-Q2 latches the thyristor ON.
- **Turn OFF:** a positive gate voltage turns ON the n-channel OFF-FET, which short-circuits the emitter-base junction of pnp transistor Q1. Q1 stops conducting, the regenerative loop breaks and the MCT turns OFF.
- Thus the MCT combines the low conduction loss of a thyristor with the easy voltage control of a MOSFET.

*(Equivalent circuit 2 M, working 2 M)*

## b) Principle of DC chopper with block diagram.

4 M

A **chopper** is a static DC-to-DC converter which converts a fixed DC input voltage into a variable DC output voltage. It is a high-speed ON/OFF semiconductor switch (MOSFET, IGBT, GTO or thyristor) connected between source and load.



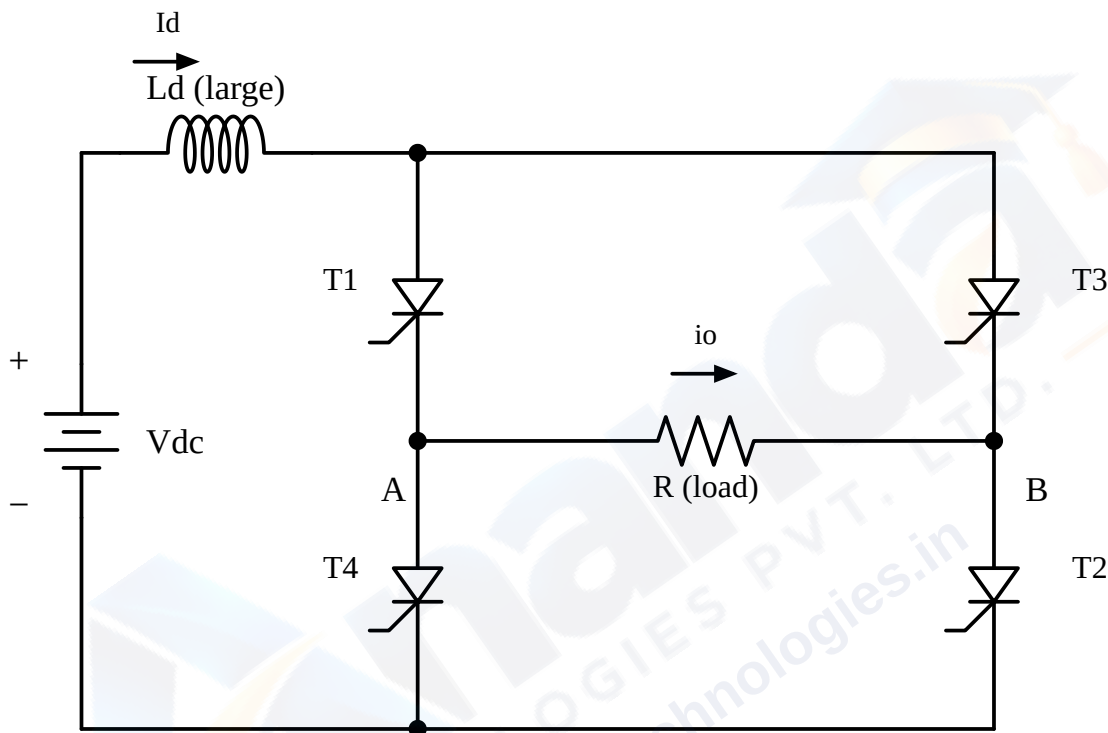
*Block diagram of DC chopper (DC-to-DC converter)*

- The chopper switch is turned ON for  $T_{on}$  and OFF for  $T_{off}$  repeatedly. During  $T_{on}$ ,  $v_o = V_s$ ; during  $T_{off}$ ,  $v_o = 0$ .
- The control circuit generates gate pulses of required duty cycle; feedback keeps the output at the desired value.
- **Derivation:** average output voltage  $V_o = (1/T) \int_0^{T_{on}} V_s dt = V_s \cdot T_{on}/T = D \cdot V_s$ , where  $D = T_{on}/T$ .
- $V_o$  is varied from 0 to  $V_s$  by varying  $D$  (TRC or CLC).

(Block diagram 2 M, principle 1 M, derivation 1 M)

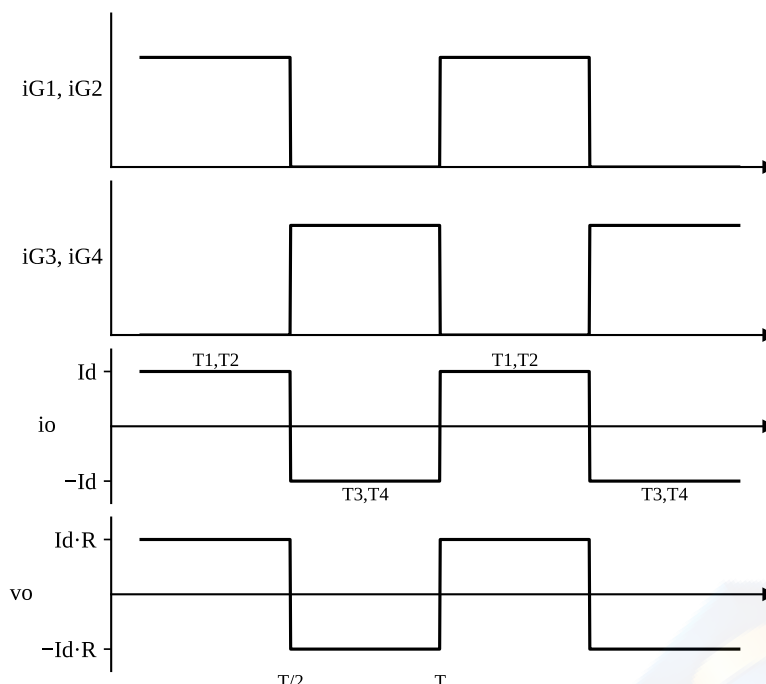
### c) Working principle of CSI; need of large inductor.

4 M



Single-phase current source inverter (CSI) with resistive load

- A DC voltage source with a **large inductor  $L_d$**  in series acts as a constant current source  $I_d$  (current cannot change quickly in a large inductor).
- $0 < t < T/2$ : thyristors T1 and T2 are triggered; current flows  $A \rightarrow B$  through the load,  $i_o = +I_d$ .
- $T/2 < t < T$ : T3 and T4 are triggered; T1, T2 turn OFF (with ideal switches) and current flows  $B \rightarrow A$ ,  $i_o = -I_d$ .
- The **load current is a square wave** of amplitude  $I_d$ , independent of the load. The output voltage depends on the load: with resistive load  $v_o = i_o \cdot R$ , also a square wave of amplitude  $I_d R$ .
- Output frequency  $f = 1/T$  is controlled by the triggering rate. In a practical thyristor CSI, a capacitor across the load provides commutation.



Single-phase CSI with  $R$  load: square-wave load current ( $\pm I_d$ ); load voltage  $v_o = i_o \cdot R$  has the same shape

**Why large inductor:** a large  $L_d$  in series makes the DC input current constant (ripple-free), so the source acts as a current source; it also limits the current during faults (inherent short-circuit protection).

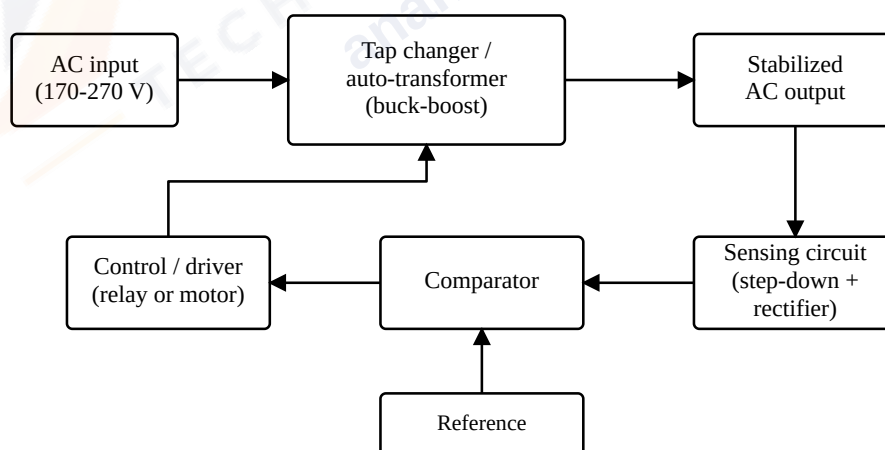
(Circuit 1 M, working 2 M, reason 1 M)

#### d) Necessity and block diagram of voltage stabilizer.

4 M

##### Necessity:

- Appliances are designed for rated voltage; **low voltage** makes motors/compressors draw more current, overheat and fail.
- High voltage** stresses insulation and can burn electronic equipment and lamps.
- Sensitive equipment (medical, CNC, computers) malfunctions on voltage fluctuation.



General block diagram of AC voltage stabilizer

- Tap changer / auto-transformer (buck-boost):** adds (boost) or subtracts (buck) voltage to the input to correct it.

- **Sensing circuit:** samples the output through a step-down transformer and rectifier to get a DC voltage proportional to output.
- **Comparator:** compares the sensed voltage with a fixed reference and produces an error signal.
- **Control / driver:** the error operates relays (relay type) or a servo motor (servo type) or IGBTs (static type) to correct the output.

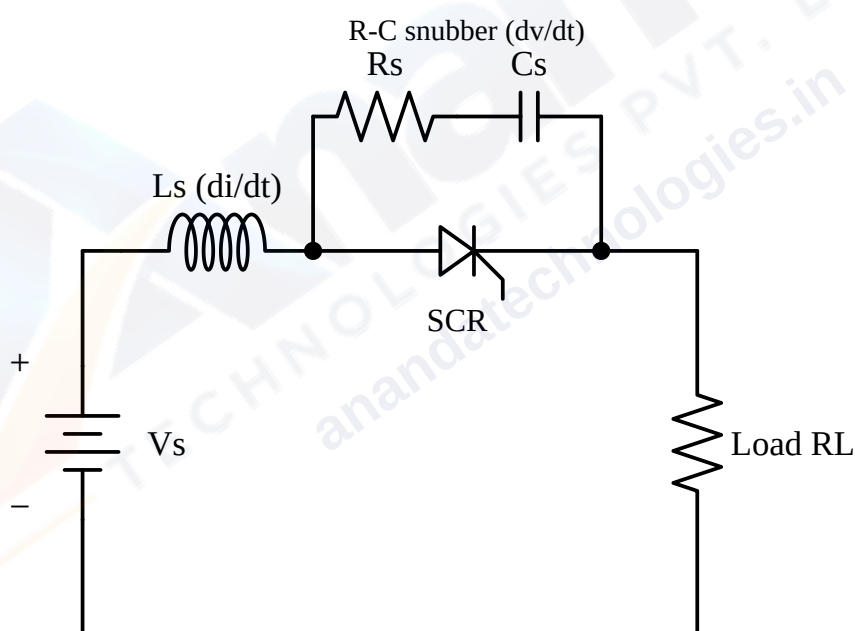
(Necessity 1 M, block diagram 2 M, explanation 1 M)

### Q.3

#### a) Compare di/dt and dv/dt protection.

4 M

| Point              | di/dt protection                                | dv/dt protection                                               |
|--------------------|-------------------------------------------------|----------------------------------------------------------------|
| Purpose            | Limits rate of rise of anode current at turn-ON | Limits rate of rise of forward voltage across SCR in OFF state |
| Protection element | Inductor $L_s$ in series with SCR               | R-C snubber ( $R_s, C_s$ ) in parallel with SCR                |
| Problem avoided    | Local hot spots near gate and junction damage   | False (unwanted) turn-ON by dv/dt triggering                   |
| Design relation    | $L_s \geq V_s / (di/dt)_{\text{rated}}$         | $dv/dt \approx R_s \cdot V_s / L_s$ kept below rated dv/dt     |
| Acts during        | Turn-ON of the SCR                              | Application of forward voltage (OFF state)                     |

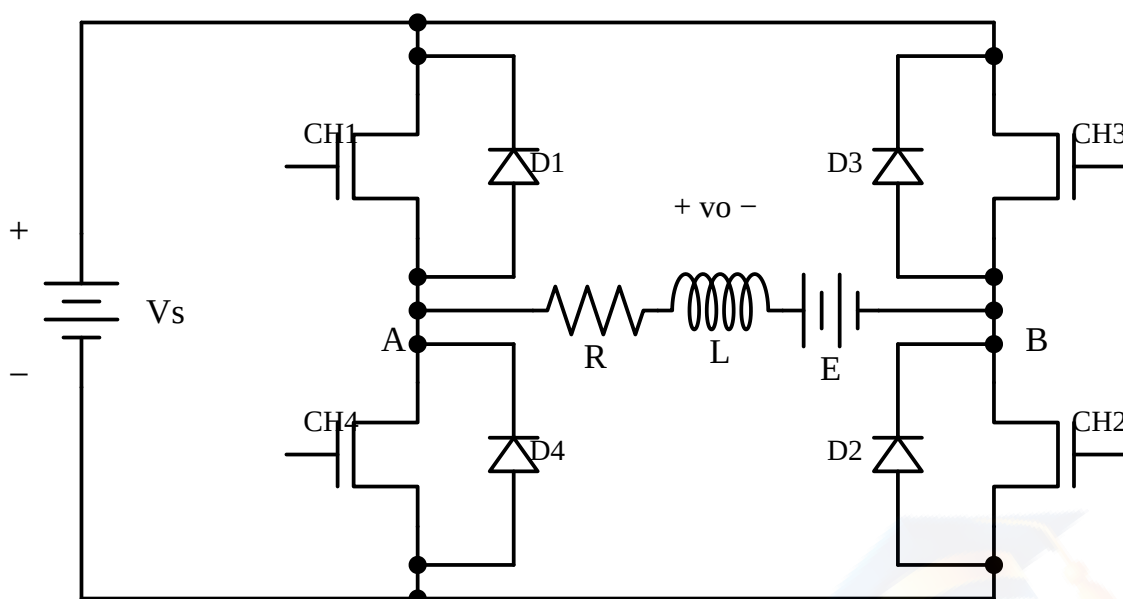


Protection of SCR: series inductor  $L_s$  (di/dt) and R-C snubber across SCR (dv/dt)

(Any four points, 1 M each)

**b) Type E (four-quadrant) chopper.**

4 M



Type E (four-quadrant) chopper

Type E chopper uses four switches CH1-CH4 with antiparallel diodes D1-D4 (H-bridge). Both  $V_o$  and  $I_o$  can be reversed, so it works in **all four quadrants**.

| Quadrant               | Switch operation         | Freewheeling / feedback path                  | $V_o, I_o$   |
|------------------------|--------------------------|-----------------------------------------------|--------------|
| I (forward motoring)   | CH2 kept ON, CH1 chopped | CH1 OFF: current via CH2 and D4 ( $v_o = 0$ ) | $+V_o, +I_o$ |
| II (forward braking)   | CH4 chopped, others OFF  | CH4 OFF: current via D1, D2 to source         | $+V_o, -I_o$ |
| III (reverse motoring) | CH4 kept ON, CH3 chopped | CH3 OFF: current via CH4 and D2 ( $v_o = 0$ ) | $-V_o, -I_o$ |
| IV (reverse braking)   | CH2 chopped, others OFF  | CH2 OFF: current via D3, D4 to source         | $-V_o, +I_o$ |

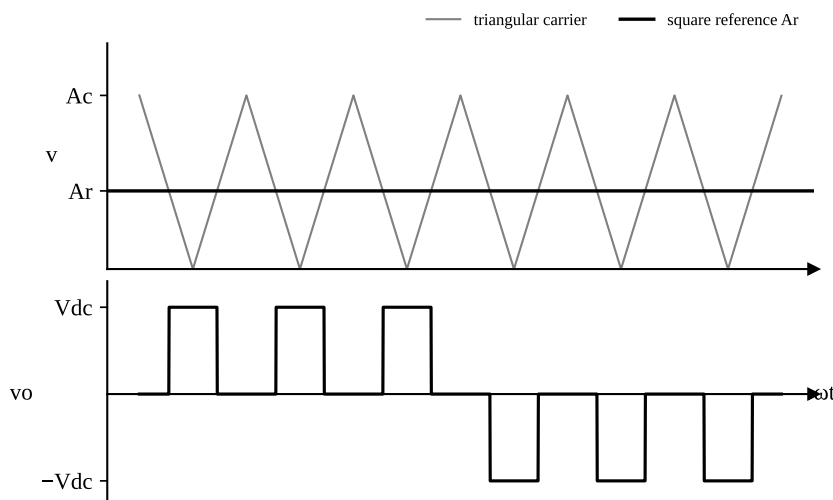
Application: reversible regenerative DC motor drives (forward/reverse motoring and braking).

(Circuit 2 M, four-quadrant operation 2 M)

**c) Multiple-pulse PWM.**

4 M

- A **square (rectangular) reference** signal of amplitude  $A_r$  at output frequency is compared with a **triangular carrier** of amplitude  $A_c$ .
- The carrier frequency decides the number of pulses  $N$  per half cycle ( $N = f_c/2f_r$ ). All pulses have **equal width**.
- Pulse width  $\delta = (A_r/A_c) \cdot (\pi/N)$ ; output voltage is controlled by varying  $A_r$ .
- Compared with single-pulse PWM, lower-order harmonics are reduced, but switching losses increase.

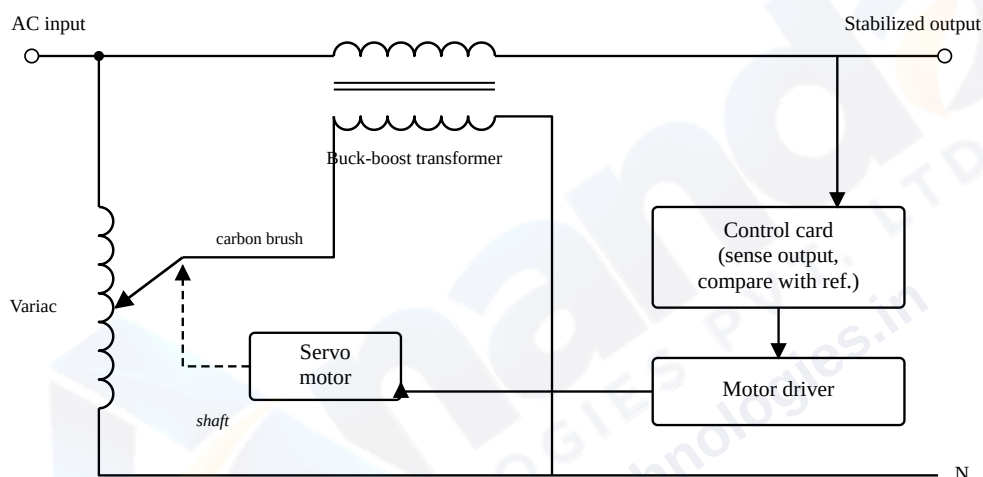


Multiple-pulse (uniform) PWM, 3 pulses per half cycle (computed): pulse width set by  $A_r/A_c$

(Principle 2 M, waveforms 2 M)

#### d) Servo type voltage stabilizer.

4 M



Servo controlled voltage stabilizer: motor-driven variac feeds the buck-boost transformer in series with the line

- Main parts: **buck-boost transformer** (secondary in series with the line), **variatic** (variable auto-transformer) feeding the buck-boost primary, **servo motor** that moves the variac carbon brush, and a **control card**.
- The control card continuously compares the output voltage with the set reference. If output is low, the error drives the servo motor in one direction; the variac applies an in-phase voltage to the buck-boost primary, and the secondary **adds** (boost) voltage.
- If output is high, the motor rotates in the opposite direction; the injected voltage is in anti-phase and is **subtracted** (buck). The motor stops when the error becomes zero.
- **Advantages:** high accuracy ( $\pm 1\%$ ), smooth stepless correction, high capacity (single/three-phase, up to hundreds of kVA), no waveform distortion. **Disadvantages:** slower response (moving parts), carbon brush wear needs maintenance, bulky and costly.
- **Applications:** industries, hospitals, CNC machines, laboratories, commercial buildings.

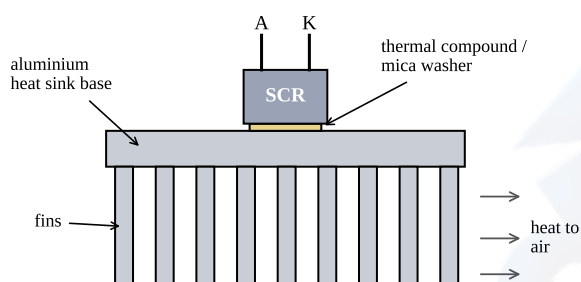
(Diagram 2 M, working 1 M, advantages/disadvantages 1 M)

## Q.4

### a) Role of heat sink; specifications.

4 M

- A heat sink is a metal (usually aluminium) block with fins on which the SCR is mounted. It provides a low thermal resistance path from case to ambient air.
- Fins give a large surface area, so heat is removed by convection and radiation; black anodised finish improves radiation.
- It reduces the sink-to-ambient thermal resistance  $\theta_{sa}$ , so for the same power loss the junction temperature stays below  $T_{jmax}$ .
- Thermal compound / mica washer between SCR and sink reduces  $\theta_{cs}$  (and gives electrical isolation).



SCR mounted on a finned heat sink (heat flows junction  $\rightarrow$  case  $\rightarrow$  sink  $\rightarrow$  ambient air)

### Specifications:

- Thermal resistance  $\theta_{sa}$  ( $^{\circ}\text{C}/\text{W}$ )
- Material and surface finish (aluminium, black anodised)
- Surface area / number and size of fins
- Mounting type (stud, flat base, press-pack) and cooling (natural / forced air)

(Role 2 M, any four specifications 2 M)

### b) Step-up chopper numerical and comparison.

4 M

Given:  $V_s = 48 \text{ V}$ ,  $D = 0.6$ ,  $f = 20 \text{ kHz}$

| Quantity       | Formula                                 | Result           |
|----------------|-----------------------------------------|------------------|
| Period T       | $1/f = 1/20\ 000$                       | $50 \mu\text{s}$ |
| Ton            | $D \cdot T = 0.6 \times 50 \mu\text{s}$ | $30 \mu\text{s}$ |
| Toff           | $T - T_{on}$                            | $20 \mu\text{s}$ |
| Output voltage | $V_o = V_s / (1 - D) = 48/0.4$          | <b>120 V</b>     |

| Point                | Step-down chopper                             | Step-up chopper                                           |
|----------------------|-----------------------------------------------|-----------------------------------------------------------|
| Output voltage       | $V_o = D \cdot V_s$ , less than $V_s$         | $V_o = V_s / (1 - D)$ , more than $V_s$                   |
| Effect of duty cycle | $V_o$ increases linearly with D (0 to $V_s$ ) | $V_o$ increases non-linearly with D ( $V_s$ to very high) |

(Vo 1 M, Ton & Toff 1 M, comparison 2 M)

### c) Compare 120° and 180° conduction modes.

4 M

| Point                              | 120° mode                                                                | 180° mode                                                                                            |
|------------------------------------|--------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|
| Conduction period of each switch   | 120°                                                                     | 180°                                                                                                 |
| Switches ON at a time              | Two                                                                      | Three                                                                                                |
| Phase voltage waveform             | Quasi-square: $\pm V_{dc}/2$ with 60° zero gaps                          | Six-step: $V_{dc}/3$ , $2V_{dc}/3$                                                                   |
| Line voltage waveform              | Six-step: $V_{dc}$ , $V_{dc}/2$                                          | Quasi-square, 120° pulses of $V_{dc}$                                                                |
| RMS phase voltage                  | 0.408 $V_{dc}$ (lower output)                                            | 0.471 $V_{dc}$ (higher output)                                                                       |
| Short-circuit (shoot-through) risk | 60° gap between turning OFF one switch and ON the other in a leg — safer | Upper and lower switch of a leg switch at the same instant — risk of short circuit, dead time needed |

(Any four points, 1 M each)

### d) Backup time and transfer time; backup numerical.

4 M

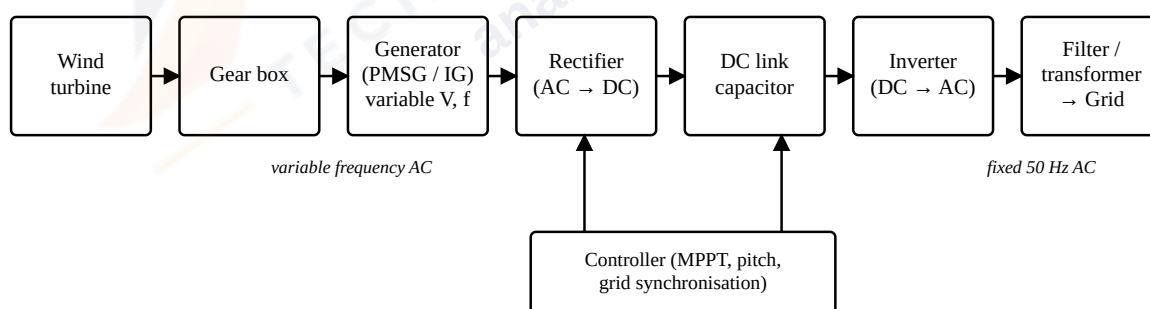
- **Backup time:** Time for which the battery can supply the rated load after mains failure: Backup (h)  $\approx V_{batt} \times Ah \times \eta_{inverter} / \text{Load (W)}$ .
- **Transfer time:** Time taken to transfer the load from mains to inverter (or back). Ideally zero for on-line UPS; a few ms for off-line UPS.

**Numerical:** Backup  $\approx V \times Ah \times \eta / \text{Load} = 24 \times 150 \times 0.85 / 600 = 5.1$  hours (ideal estimate; in practice it is lower because the battery is not discharged fully — e.g., at 80 % depth of discharge  $\approx 4.1$  h).

(Definitions 2 M, numerical 2 M)

### e) AC-to-AC converter with DC link in wind generation.

4 M



AC-to-AC conversion with DC link in a variable-speed wind energy system

- Wind speed keeps changing, so the turbine/generator speed and the generated **voltage and frequency vary**. The grid needs constant 50 Hz and voltage, so direct connection is not possible.
- **Rectifier (AC → DC):** converts the variable-frequency generator output to DC.
- **DC link capacitor:** smooths the DC and **decouples** generator frequency from grid frequency.

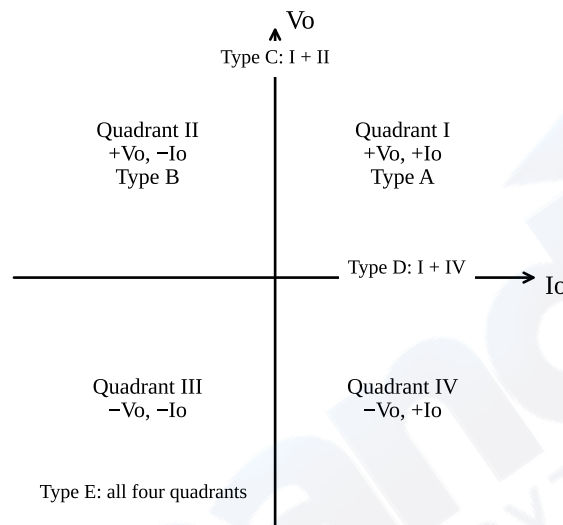
- **Inverter (DC → AC):** PWM inverter produces AC at fixed 50 Hz synchronised with the grid; filter and step-up transformer connect it to the grid.
- **Controller:** MPPT (optimum rotor speed for each wind speed), pitch control and grid synchronisation; also controls reactive power.
- **Advantages:** variable-speed operation captures more energy, less mechanical stress, good power quality and fault ride-through.

(Block diagram 2 M, explanation 2 M)

## Q.5

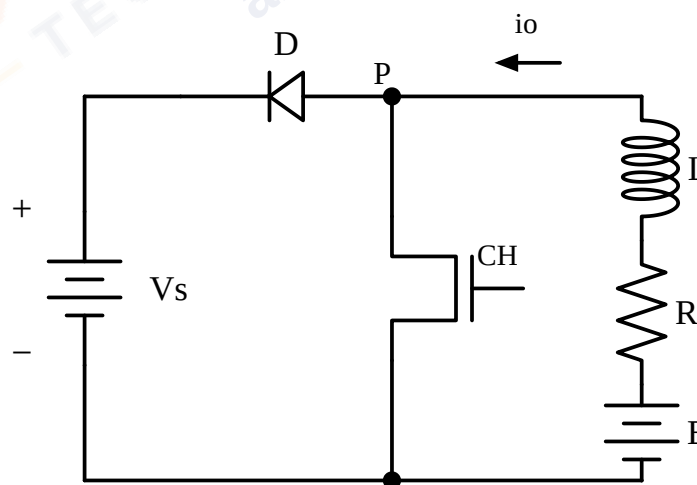
### a) Quadrant classification and Type B chopper.

6 M



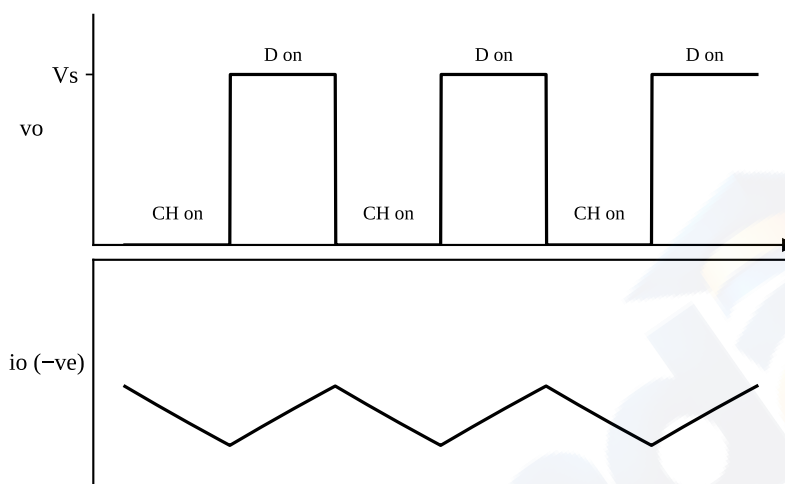
Classification of choppers according to quadrant of operation ( $V_o$ - $I_o$  plane)

- Type A — I quadrant
- Type B — II quadrant
- Type C — I and II
- Type D — I and IV
- Type E — all four quadrants



Type B (second quadrant) chopper

- Load must contain a DC source  $E$  (e.g., back emf of a DC motor during braking).  $V_o$  is positive but current flows from load to source, so  $I_o$  is negative — **second quadrant**.
- **CH ON:** load terminals are shorted through CH;  $E$  drives current through  $L$  and  $R$ ; energy is stored in  $L$ ;  $v_o = 0$ .
- **CH OFF:** the induced voltage of  $L$  adds to  $E$ , so  $(E + L \, di/dt) > V_s$ ; diode  $D$  conducts and the current is fed back to the source;  $v_o = V_s$ .
- Average voltage  $V_o = (1 - D) \cdot V_s$ . It works as a step-up chopper and is used for **regenerative braking** of DC motors.



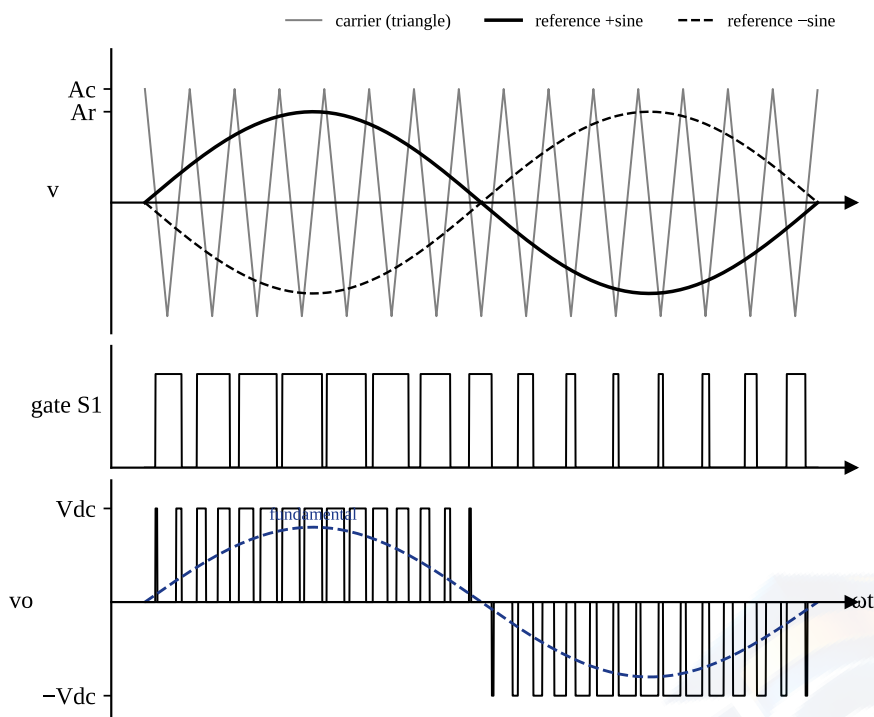
Type B chopper waveforms (computed): load voltage and load current (current flows from load to source, so  $i_o$  is negative)

(Classification 2 M, circuit 1 M, working 2 M, waveforms 1 M)

## b) SPWM with numerical.

6 M

- A **sine reference wave** of the desired output frequency  $f_r$  and amplitude  $A_r$  is compared with a **triangular carrier** of high frequency  $f_c$  and amplitude  $A_c$ .
- When the sine is greater than the carrier the comparator turns ON the switch ( $S_1$ ); otherwise it is OFF. For the other leg,  $-sine$  is compared (unipolar SPWM). The output therefore has many pulses whose **width is proportional to the instantaneous value of the sine wave**.
- **Modulation index**  $m_a = A_r/A_c$  controls the output voltage (fundamental peak =  $m_a \cdot V_{dc}$  for a full bridge,  $m_a \leq 1$ ). Reference frequency controls the output frequency.
- **Frequency modulation ratio**  $m_f = f_c/f_r$  decides the number of pulses; harmonics appear near  $m_f$  and its multiples and are easily filtered.



Sinusoidal PWM (computed,  $m_a = 0.8$ ,  $m_f = 15$ ): pulse width varies sinusoidally; output contains a strong fundamental

**Advantages:** low-order harmonics eliminated, near-sinusoidal current, small filter, smooth voltage control — used in VFDs, UPS and solar inverters.

**Numerical:**  $V_{dc} = 300 \text{ V}$ ,  $A_r = 4 \text{ V}$ ,  $A_c = 5 \text{ V}$ ,  $f_r = 50 \text{ Hz}$ ,  $f_c = 1 \text{ kHz}$

| Quantity                   | Formula                                                  | Result  |
|----------------------------|----------------------------------------------------------|---------|
| Modulation index           | $m_a = A_r/A_c = 4/5$                                    | 0.8     |
| Frequency modulation ratio | $m_f = f_c/f_r = 1000/50$                                | 20      |
| Peak fundamental voltage   | $V_{1m} = m_a \cdot V_{dc}$ (full bridge, $m_a \leq 1$ ) | 240 V   |
| RMS fundamental voltage    | $V_1 = V_{1m}/\sqrt{2}$                                  | 169.7 V |

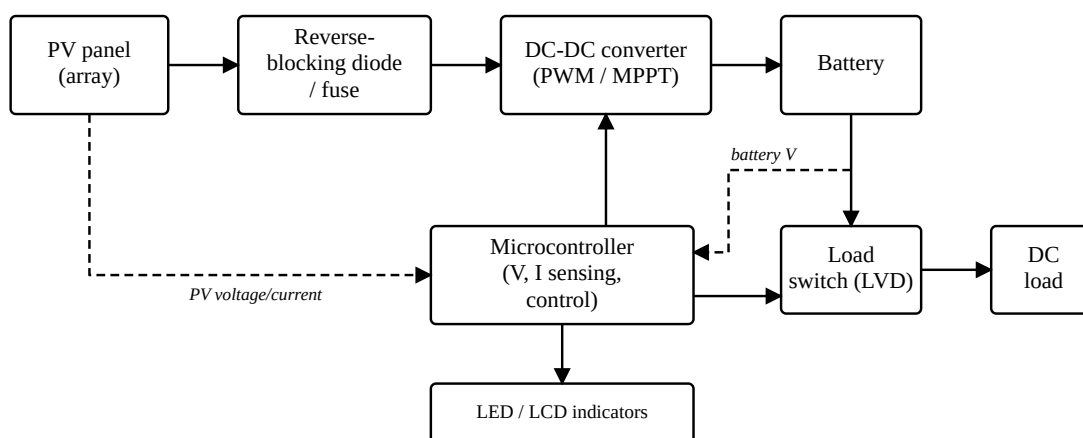
(Explanation 2 M, waveforms 2 M, numerical 2 M)

### c) Charge controller: function, block diagram, PWM vs MPPT.

6 M

#### Functions:

- Prevents **overcharging** of the battery by reducing/stopping charging current at full charge.
- Prevents **deep discharge** by disconnecting the load at low battery voltage (LVD).
- Prevents **reverse current** from battery to PV panel at night (blocking diode/MOSFET).
- Extracts maximum power from the panel (MPPT type) and gives status indication.



Block diagram of PV charge controller

- **PV panel** converts sunlight to DC; output varies with irradiance and temperature.
- **Blocking diode / fuse** prevents reverse flow and protects against faults.
- **DC-DC converter (PWM / MPPT stage):** regulates charging voltage and current; MPPT type operates the panel at its maximum power point.
- **Microcontroller:** senses PV and battery voltage/current, decides charging stage (bulk, absorption, float) and controls the converter and load switch.
- **Load switch (LVD):** disconnects load at low battery voltage. **Indicators** show charging status and battery level.

| Point               | PWM controller                                                                       | MPPT controller                                                                                        |
|---------------------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| Working             | Switches PV to battery with PWM pulses; panel voltage pulled down to battery voltage | DC-DC converter operates panel at its maximum power point ( $V_{mp}$ ) and converts to battery voltage |
| Efficiency / energy | Lower                                                                                | 15–30 % more energy harvested                                                                          |
| Panel voltage       | Must match battery voltage                                                           | Panel voltage can be higher than battery                                                               |
| Cost                | Cheap                                                                                | Costly                                                                                                 |
| Use                 | Small systems                                                                        | Medium and large systems                                                                               |

(Functions 1 M, block diagram 2 M, explanation 1 M, comparison 2 M)

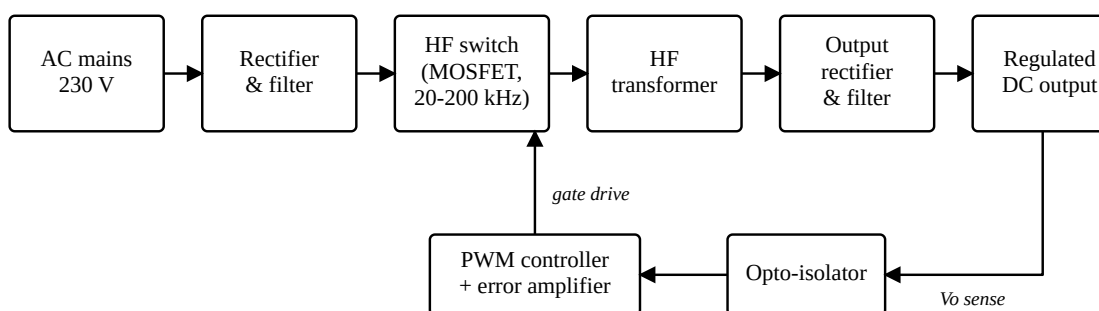
## Q.6

a) SMPS: types, block diagram, advantages.

6 M

Types of SMPS:

- **Non-isolated:** buck, boost, buck-boost (Cuk) converters.
- **Isolated (with HF transformer):** flyback, forward, push-pull, half-bridge and full-bridge converters.



Block diagram of switched mode power supply (SMPS)

- **Rectifier & filter:** converts 230 V AC mains into unregulated DC.
- **HF switch (chopper):** MOSFET switched at 20–200 kHz converts DC into high-frequency pulses; duty cycle decides output.
- **HF transformer:** steps the voltage up/down and gives isolation; being high frequency, it is very small.
- **Output rectifier & filter:** fast-recovery/Schottky diodes and L-C filter give smooth DC.
- **Feedback (error amplifier + PWM controller + opto-isolator):** output voltage is compared with reference; the PWM controller changes the duty cycle to keep  $V_o$  constant against input and load changes.

#### Advantages over linear power supply:

| Point            | SMPS                                                       | Linear supply                                     |
|------------------|------------------------------------------------------------|---------------------------------------------------|
| Efficiency       | High, 70–95 % (switch works ON/OFF)                        | Low, 30–60 % (series transistor in active region) |
| Size and weight  | Small and light (HF transformer, small L, C)               | Large and heavy (50 Hz transformer)               |
| Heat / heat sink | Less heat, small heat sink                                 | More heat, large heat sink                        |
| Input range      | Wide input voltage range                                   | Narrow input range                                |
| Output           | Step-up, step-down, inverted and multiple outputs possible | Only step-down                                    |
| Noise            | Produces EMI / ripple (needs filtering)                    | Very low noise and ripple                         |

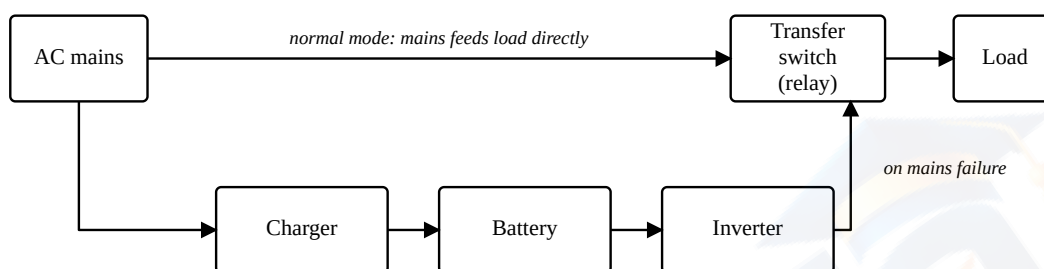
(Types 1 M, block diagram 2 M, explanation 1 M, advantages 2 M)

#### b) On-line vs off-line UPS; off-line UPS block diagram.

6 M

| Specification                   | On-line UPS                                                                        | Off-line UPS                                                                       |
|---------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| Input voltage range             | Wide ( $\approx 110\text{--}300\text{ V}$ ); rectifier accepts large variation     | Narrow ( $\approx 180\text{--}260\text{ V}$ ); outside this it switches to battery |
| Output frequency                | Fixed $50\text{ Hz} \pm 0.1\%$ (crystal-controlled inverter), independent of mains | Follows mains frequency in normal mode; fixed only in battery mode                 |
| Total harmonic distortion (THD) | Low, $< 3\%$ (pure sine-wave inverter)                                             | High in battery mode (quasi-square output); mains waveform passed as               |

|                           |                                                                                                                |                                                                                               |
|---------------------------|----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
|                           |                                                                                                                | it is                                                                                         |
| Load power factor         | Designed for 0.8–0.9 lagging; handles non-linear loads well                                                    | Typically rated for $\approx 0.6$ –0.7; not suited for large reactive loads                   |
| Protection circuit used   | Complete: input surge/spike filter, over/under voltage, overload, short circuit, battery low, automatic bypass | Basic: overload, short circuit, battery low cut-off; little isolation from mains disturbances |
| Nature of output waveform | Pure sine wave at all times                                                                                    | Mains (normal), square / modified sine (battery mode)                                         |



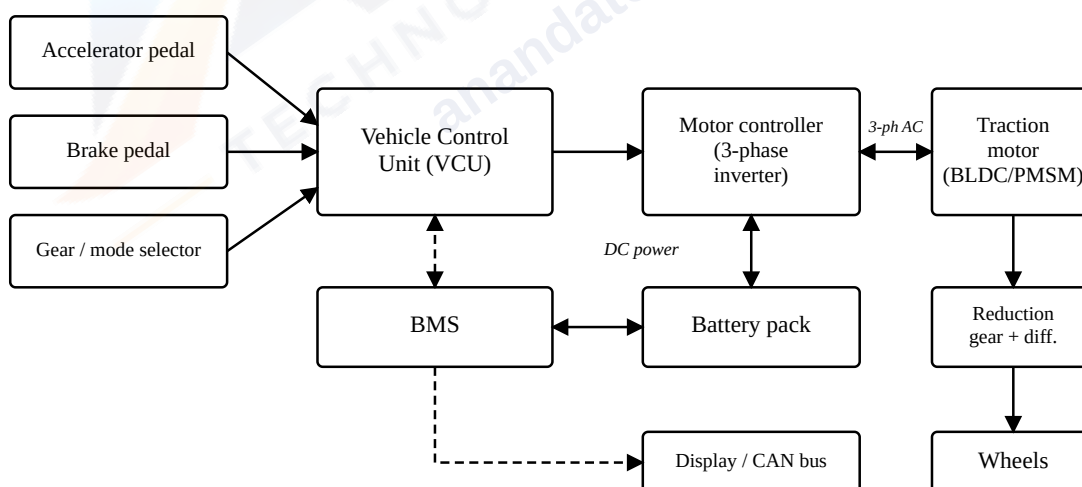
*Off-line (standby) UPS: inverter supplies load only after mains failure (transfer time 2–10 ms)*

- In normal mode the load is fed **directly from mains** through the transfer switch; the charger keeps the battery charged; inverter is OFF (standby).
- When mains fails (or goes out of range), the sensing circuit starts the inverter and the transfer relay connects the load to the inverter output after 2–10 ms.
- Simple, cheap and efficient, but provides no conditioning in normal mode; used for PCs and home loads.

*(Six points 3 M, block diagram 2 M, explanation 1 M)*

### c) EV control unit and drive mechanism.

6 M



*Control unit and drive mechanism of an electric vehicle*

- **Vehicle Control Unit (VCU):** the main controller (brain). It reads accelerator, brake and gear/mode inputs, calculates the required torque and sends commands to the motor controller over the CAN bus; manages regenerative braking and energy use.

- **Motor controller (inverter):** converts battery DC into 3-phase variable-frequency AC using PWM and controls motor torque and speed.
- **BMS:** monitors cell voltage, current, temperature and SOC; protects and balances the battery and informs the VCU of available power.
- **Drive mechanism:** traction motor (BLDC / PMSM / induction) → single-speed reduction gear → differential → axle → wheels. Two-wheelers often use hub motors directly in the wheel.
- During braking, the motor works as generator and the controller returns energy to the battery (regenerative braking).

*(Block diagram 3 M, explanation 3 M)*

**Note:** This is a **model question paper prepared by Ananda Technologies** only for practice and exam preparation, based on the pattern of previous MSBTE question papers and the K-scheme syllabus. It is **not an official MSBTE paper**, and it does **not** mean that these questions will come in the exam. Answers follow standard textbook points; marks shown are indicative. Free for students — [anandatechnologies.in](http://anandatechnologies.in)