

ELECTRIC VEHICLE

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EE/EEE

JHARKHAND UNIVERSITY OF TECHNOLOGY (JUT)

UNIT IV: CONVERTERS AND EV CHARGERS

4.1 Power Electronics in Electric Vehicles

Definition

Power electronics in EVs are electronic circuits and devices responsible for converting and controlling electrical energy between the battery, motor, and charging units. Key converters include DC-DC converters that adjust battery voltage for low-voltage systems, DC-AC converters (inverters) that provide variable frequency AC power to drive motors, and AC-DC converters (rectifiers) which convert grid AC power into DC for battery charging. Filters smooth voltage and current to reduce electrical noise and improve system performance. These components enable efficient motor control, regenerative braking, and safe battery charging.

Explanation

1. DC-DC converters step down high-voltage DC to low-voltage DC for auxiliary electronics.
2. DC-AC converters (inverters) produce variable frequency AC power to control motor speed.
3. AC-DC converters (rectifiers) convert grid AC to DC for battery charging.
4. Filters reduce harmonic distortion and electromagnetic interference.
5. Power electronics facilitate energy recovery via regenerative braking.
6. Advanced materials like SiC and GaN enhance efficiency and thermal performance.
7. Controllers protect against electrical faults and optimize power flow.
8. Vehicle control unit coordinates the operation of power electronics for performance.

Real-Life Example

Tesla Model 3 uses SiC MOSFET based inverters for efficient motor control and DC-DC converters for stable auxiliary power supply.

Working (Flow)

Battery (DC) → DC-DC converter (auxiliary power) → DC-AC inverter → Electric motor → Wheels

Grid (AC) → AC-DC rectifier + filters → Battery (DC charging)

Applications

- Motor speed and torque control
- Auxiliary electronics power supply
- Battery charging from grid
- Regenerative braking energy recovery
- Improving EV efficiency

Advantages

- Precise control of electric motors
- Efficient energy conversion
- Enhanced battery protection
- Supports energy regeneration
- Reduced electrical noise

Disadvantages

- System complexity and cost
- Thermal management necessary
- Sensitive power electronics require protection

Flowchart + Diagram (2D)

text

[Battery] --DC-DC--> [Auxiliary Loads]

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--DC-AC Inverter--> [Motor] --> [Wheels]

[Grid AC] --AC-DC + Filters--> [Battery]

4.2 Charging Methods

Definition

Charging methods define how electricity is supplied to EV batteries, ranging from slow home AC charging to rapid public DC fast charging. Trickle charging maintains battery charge at low current, household AC charging offers faster charging at 240V, and public DC fast chargers provide high current for rapid battery top-ups. Charging type influences charge time, battery health, and user convenience.

Explanation

1. Home charging typically uses Level 1 (110-120V) or Level 2 (240V) AC.
2. Trickle charging slowly replenishes battery capacity over long periods.
3. Household AC charging uses dedicated circuits for faster home charging.
4. Public DC fast chargers can deliver up to several hundred kW power.
5. Charging speed depends on battery size and charger power.
6. Safety features prevent overcharge and overheating.
7. Infrastructure development affects charging access.
8. Charging methods impact battery longevity.

Real-Life Example

Tesla's Supercharger network provides DC fast charging, enabling 80% charge in 30 minutes.

Working (Flow)

Grid AC → Charger or outlet → AC-DC conversion → Controlled DC → Battery pack

Applications

- Overnight home charging
- Maintaining charge via trickle
- Rapid public charging for long drives
- Fleet vehicle charging
- Emergency charge

Advantages

- Convenience of charging locations

- Fast charging speeds publicly
- Supports sustainable EV use
- Safety protocols in place
- Range extension opportunities

Disadvantages

- Varying charge times
- Possible battery stress with frequent fast charging
- Infrastructure limitations

Flowchart + Diagram (2D)

text

Grid (AC) -> Charger -> EV Battery

4.3 Charging Systems and Smart Charging

Definition

Charging systems include wireless (inductive), onboard (vehicle-integrated), and offboard chargers (external). Smart charging uses communication to manage charging timing (V1G) and bidirectional energy flow (V2H, V2G, V2X), optimizing grid load, cost, and renewables integration.

Explanation

1. Wireless charging transfers power via magnetic fields.
2. Onboard chargers convert AC to DC inside the EV.
3. Offboard chargers supply DC power externally enabling faster charging.
4. V1G schedules unidirectional smart charging to manage peaks.
5. V2H/B allows vehicles to power homes/buildings.
6. V2X expands bidirectional flow to other loads.
7. V2G supports grid demand through energy discharge.
8. Smart charging reduces cost and emissions.

Real-Life Example

Nissan Leaf uses V2H for emergency home backup power.

Working (Flow)

EV and grid communicate → Charging/ discharging optimized → Grid stability and user savings achieved

Applications ●

- Grid load balancing
- Renewable energy utilization
- Backup power
- Cost-efficient charging

Advantages

- Efficient energy use
- Grid stability support
- Emergency power solutions
- Cost savings for users
- Encourages renewable use

Disadvantages

- Requires complex communication
- Infrastructure investment
- Security/personal data concerns

Flowchart + Diagram (2D)

text

Grid <--> Smart Charger <--> EV Battery

4.4 Charging Stations

Definition ❤

Charging stations provide electrical power to EVs in home, public, and commercial settings. They are classified by power levels and include battery swapping stations for rapid turnaround. Proper selection/sizing depends on user demand and grid capacity. Components include transformers, converters, communication and safety devices. Charging time depends on battery capacity and charge current. Battery swapping replaces discharged batteries quickly but requires battery standardization and infrastructure.

Explanation

1. Charging stations vary from low power residential to high power public.
2. Sizing based on vehicle throughput and power availability.
3. Equipped with transformers, rectifiers, power converters.
4. Communication handles user management and billing.
5. Safety devices protect from faults.
6. Single line diagrams show power flow for design.
7. Charging time is battery capacity divided by charging current.
8. Battery swapping reduces inactive time but needs standards.

Real-Life Example

Tesla Superchargers operate high-power stations, while Nio offers battery swap stations in China.

Working (Flow)

Grid → Transformer → Rectifier → DC-DC converter → Charging outlet → EV battery

Applications

- Residential and public EV charging
- Fleet depots
- Battery swapping hubs
- Emergency/fast charging

Advantages

- Supports EV adoption and convenience
- Reduces charging wait times
- Scalable infrastructure
- Supports grid management

Disadvantages

- Capital intensive
- May require grid upgrades
- Battery swapping limited by compatibility

Flowchart + Diagram (2D)

text

Grid -> Transformer -> Rectifier -> DC-DC Converter -> Charging Station -> EV Battery

Charging Time Formula

$$\text{Charging Time} = \frac{\text{Battery Capacity (Ah)}}{\text{Charging Current (A)}}$$

Summary (Hinglish)

Charging stations EV ki charging ke liye zaroori hain. Proper sizing aur safety ka dhyan rakhna chahiye. Battery swapping se time bach sakta hai, magar infrastructure ki zaroorat hai.

Keywords

Converters, Inverters, DC-DC, Rectifiers, Charging Methods, V2G, Battery Swapping

Suggested Diagrams:

1. Block Diagram of Typical EV Power Electronics:

- Shows battery, DC-DC converter, DC-AC inverter, AC-DC rectifier, filters, motor, and auxiliary loads.
- Helps understand power flow and conversion inside an EV.

2. Single Line Diagram of EV Charging Station:

- Displays power flow from grid to transformer, rectifier, converter, charging point, and EV battery.
- Useful for understanding station components and power management.

3. Working Schematic of DC-DC Converter:

- Illustrates voltage step-up/step-down operation for supplying auxiliary systems.

4. Inverter (DC-AC Converter) Operation Diagram:

- Shows DC input converted into variable frequency AC output controlling motor speed.

5. Rectifier (AC-DC Converter) Circuit Diagram:

- Converts grid AC power to DC for battery charging.

6. Charging Methods Flowchart:

- Summarizes home charging, household AC charging, trickle charging, and public DC fast charging.

7. Smart Charging Communication Model:

- Depicts communication links between EV, charger, grid, and building in V1G, V2H, V2G, and V2X systems.

8. Charging Time Calculation Chart:

- Visualizes relationship between battery capacity, charging current, and charging time.

9. Battery Swapping Station Layout:

- Outline of battery replacement process and infrastructure required.



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