

**U23EEV35 - DESIGN OF ELECTRIC VEHICLE CHARGING
SYSTEM-LEARNING MATERIAL**

UNIT I

PART A

1. What are the components of a charger that facilitates charging?

- i. On-board charger,
- ii. Home charger,
- iii. Fast chargers and
- iv. Connectors with communication protocols and
- v. Charging stations

2. What are the charging methods?

- i. Conductive Charging
- ii. Battery Swapping
- iii. Wireless Charging

3. List the classification of EV Chargers.

- EV chargers can be classified as:
 - i. On board Chargers and
 - ii. Off board chargers
- Based on the Power Flow, they are classified as:
 - i. Unidirectional Chargers and
 - ii. Bidirectional chargers.

4. Compare the different modes of charging?

Charge Mode	Phase	Voltage	Power	Current	Specific Connector
Mode 1	AC- 1 Phase	230-250 V	3.8 kW	16A	No
	AC- 3 Phase	480 V	7.6 kW		
Mode 2	AC- 1 Phase	230-250 V	7.6 kW	32A	No
	AC- 3 Phase	480 V	15.3 kW		
Mode 3	AC- 1 Phase	230-250 V	60 kW	32 -250A	Yes
	AC- 3 Phase	480 V	120 kW		
Mode 4	DC	60-1000V	>150 kW	250-400A	Yes

5. What is the need of standard for chargers?

- i. ensure reliable and safe EV integration with Grid
- ii. To provide accurate functionality, protection, interoperability, and integration with various parameters and conditions.

6. List the various bodies contribute for regulating charging and grid integration.

- i. The Society of Automotive Engineers (SAE)
- ii. Institute of Electrical and Electronics Engineers (IEEE)

- iii. International Electro technical Commission (IEC)
- iv. International Organization for Standardization (ISO),
- v. Japan Electric Vehicle Association (JEVA),
- vi. Underwriters Laboratories (UL),
- vii. National Electrical Manufacturers Association (NEMA),
- viii. Standardization Administration of China (SAC),
- ix. American National Standards Institute (ANSI),
- x. National Fire Protection Association (NFPA), and

7. List some of the EV charger standards and their description.

Standards	Description
International Electro technical Commission (IEC)	
IEC 61851	General charging requirements
IEC 61980	Wireless power transfer (WPT) for EVs
IEC 62196	Plugs, sockets, and connectors for EV conductive charging technique
IEC61000	Compactibility level of low frequency conductance, Harmonic Emission, EMC, Flciker Limits.
The Society of Automotive Engineers (SAE)	
J2293	EV and off-board EV supply equipment requirements for charging from utility grid
J1772	Standard for conductive charging
J1773	Standards for inductively coupled charging systems
J2954	WPT for EVs
J2894	Power quality requirements and testing procedures for EVs
J1766, J2344	Safety requirements for charging
J2847	Communication Requirement between EV charging system interfaces
Institute of Electrical and Electronics Engineers (IEEE)	
P2100.1	WPT and charging system standards
P2030	Standard for addressing the interoperability of smart grid
P2030.1	Draft for electrified transportation infrastructure
519	IEEE recommended practices and Requirements for Harmonic control in Electrical power system
1159	Monitoring Electrical Power Quality

8. Define inductive charging.

It does not use wired connection between the supply and the Power Electronic Interface (PEI) for charging.

9. What are the different types of Inductive power transfer?

- i. Lumped or Concentrated
- ii. Distributed

10. What are the advantages of static charging?

Static WEVCS can be installed in parking areas, car parks, homes, commercial buildings, shopping centers, and park 'n' ride facilities.

- Static WEVCS can easily replace the plug-in charger with minimal driver participation,
- Solves associated safety issues such as trip hazards and electric shock.

11. List the advantages of bidirectional power flow in charging.

- The design enables surplus energy to be transferred to the PEVs to reduce stress or receive energy to rectify peak demand energy in static or dynamic modes.
- Acts as a buffer or a back-up for mobile energy storage in the dynamic V2G operation.

12. Define EV charging infrastructure.

The network of chargers, stations, and communication protocols for EV charging.

13. Mention the international standards for WPT.

SAE J2954, IEC 61980, ISO 19363.

14. What is dynamic charging?

Charging EV while in motion using embedded road infrastructure.

15. List advantages of conductive charging.

Efficient, simple, low cost, widely used.

16. Mention disadvantages of inductive charging.

Lower efficiency, high cost, alignment issues.

17. Define bidirectional EV chargers.

Chargers allowing power flow both to and from the EV battery.

18. What is Mode 3 charging?

AC charging with special connector; supports up to 60 kW.

19. What is the difference between on-board and off-board chargers?

On-board chargers are integrated with EV; off-board are external fast chargers.

20. List the benefits of international charging standards.

Safety, interoperability, reliability, global EV adoption

PART B

1. Explain Battery Electric Vehicle with a block diagram.
2. List and explain the various EV Charging technologies in brief.
3. Illustrate conductive charging with required block diagrams.
4. Analyze the various charging levels and compare each.
5. Explain the various modes of charging.
6. Explain inductive charging in detail and analyses its advantages and disadvantages.
7. Explain Static and Dynamic Charging.
8. Describe bidirectional power flow and its role in V2G
9. Illustrate EV charging infrastructure with types of chargers.
10. Analyze the need for standards and regulations in EV charging systems.

UNIT II

1. Classify the architecture of EV charging stations.

The architecture of EV charging stations can be classified as

- i. AC bus,
- ii. DC bus, and
- iii. a combination of AC and DC bus structures.

2. Mention the advantages and disadvantages of AC Bus systems.

• **Advantages:**

- i. Matured AC technology and
- ii. Availability of standard charging components in the market.\
- iii. Complexity of the device is low.

• **Disadvantages:**

- i. Increase in cost, Complexity, power conversion stages, and reduced efficiency of the charging system due to the power converters.
- ii. Difficult to achieve high power quality and stability.

3. Mention the advantages and disadvantages of DC Bus systems.

• **Advantages:**

- i. More efficient,
- ii. Cost-effective,
- iii. Small, and more flexible structures with greater dynamic performance
- iv. Simple Control strategy

• **Disadvantages:**

- i. Low operating PF of common DC bus charging stations generate undesirable harmonic impacts on the utility grid.
- ii. Requires protection devices to withstand unexpected changes.

4. Mention the advantages of combined AC and DC Bus systems.

• **Advantages:**

- i. Very Reliable
- ii. Flexible
- iii. More efficient

5. Mention the configurations of the converters used in the Battery Charging System.

- i. AC-DC Converter
- ii. DC-DC Converter
- iii. AC-AC Converter

6. What are the various Boost converter based PFC topologies used in Battery Charging?

The boost converter-based PFC topologies include AC-DC converter with boost PFC circuit, interleaved boost converter, bridgeless interleaved boost converter.

7. Write the need of DC–DC converter in an EV charging system.

DC–DC converter in an EV charging system regulates voltage and current as per battery requirement.

8. Mention the advantages of Buck Converter.

○ Advantages:

- Low cost
- Simple in structure and operation.

○ Disadvantages:

- Large input current ripple
- Sluggish transient response

9. Mention the advantages of Zeta Converter.

- i. Produces output voltage of same polarity to that of input voltage.
- ii. Produces low output voltage ripple when compared to SEPIC converter

10. Mention the various DC-DC converters used in the Battery Charging System.

The various DC-DC Converters used in the Battery Charging System are: Buck Converter, Boost Converter, Buck Boost Converter, Cuk Converter, Sepic Converter and Zeta Converter.

11. What are boost converter-based PFC topologies?

AC-DC converter with boost PFC, interleaved boost, bridgeless interleaved boost.

12. Mention few Disadvantages of Buck Converter.

- Sluggish transient response.
- Large input current ripple

13. State the Advantages of Zeta Converter.

- Low output voltage ripple.
- Same polarity output

14. Give Disadvantages of Zeta Converter.

- moderate efficiency compared to simpler converters.
- Slightly complex

15. What is an interleaved boost converter?

A boost converter using multiple phases to reduce ripple and improve efficiency.

16. Mention the Purpose of isolated Half-bridge bidirectional converter.

It allows energy flow in both directions with isolation.

17. Give the role of AC-DC converter with boost PFC.

It Converts AC to DC while improving input power factor.

18. Why is PFC required in AC-DC converters?

To reduce harmonic distortion and align input current with voltage.

19. Give advantages of interleaved boost converter.

Lower ripple, improved efficiency, reduced stress on components.

20. Give disadvantages of half-bridge bidirectional converters.

More complex control, higher cost, needs isolation.

PART B

1. Classify and explain the layouts of EV Battery Charging Systems.
2. Explain AC–DC converter with boost PFC circuit with circuit diagram.
3. Explain in brief the various DC-DC converters used in electric Vehicles.
4. Explain the operation and working of an isolated Half-bridge bidirectional converter with the circuit diagram.
5. Illustrate the operation of Isolated Half-bridge bidirectional converter.
6. Compare AC bus, DC bus, and combined bus systems.
7. Analyze need and working of power factor correction in EV chargers.
8. Illustrate AC-AC converter and its applications in EV charging.
9. Explain non-isolated DC-DC bidirectional converter topologies.
10. Evaluate advantages and limitations of various converter topologies in EV chargers.

UNIT III

PART A

1. What are the considerations while choosing a converter topology?

A low-cost converter which is efficient, has high power density, high safety margin, less harmonic distortion at supply, and is of smaller size, is always desired for all applications. A converter with fewer components (active and passive) and high operating frequency (reduction in passive components size) suffers from low power density, EMI, low controllability, high component stress (require large size/rating components), and lower safety margins. The converter with sophisticated topologies suffers in terms of more PWM pulses with a complex control, efficiency, size, and cost. An optimum trade-off is generally made in the selection of converter topology, which extensively depends on the complex applications.

2. What are the factors which influence Charging topology?

- i. Application
- ii. Number of stages of conversion
- iii. Level of charging
- iv. Type of input power supply
- v. Voltage level
- vi. Type of battery pack and rating

3. Mention the AC-DC converter used in Battery Charger of Three phase off board Charring?

Two stage DAB based matrix converter Full bridge multi-level isolated converter

4. Mention the AC-DC converter used in Battery Charger of on board Charring?

Single phase single stage DAB Converter Bi-directional matrix converter

5. Mention the DC-DC converter used in Battery Charger of on board Charring?

Full Bridge DC-DC Converter
Two Stage Full Bridge isolated dc-dc converter

6. Classify the EV Charging Strategies.

- Uncoordinated Strategies
- Coordinated Strategies

7. What is Uncoordinated Charging?

The charging occurs once they are connected to the Power Grid until they attain the maximum SoC is called as Uncoordinated Charging.

8. What is Coordinated Charging?

The charging occurs once they are connected to the Power Grid until they attain the maximum SoC but the charging and discharging is optimized and controlled, is called as Coordinated Charging.

9. List the advantages of integrating EV Charging with Home Solar PV System.

- i. Helps to mitigate the effects of the high penetration of EVs
- ii. Increase the HSP system implementation.
- iii. Helps the grid become stable as of balancing the generation and power consumption from the grid

10. What is the Objective of EVC-HSP System?

- i. To utilize the HSP system to efficiently charge the EVB
- ii. To support the loads at home or grid when the EV is traveling.

11. Analyze the needs pf fast-charging infrastructure (FCI) integration with an Energy Buffer Unit (EBU) and a PV system.

- i. To mitigate the effects of the EV fast-charging
- ii. Reduce the dependence of the EV fast-charging on the grid
- iii. Helps to build a micro-grid

12. What are the Converters / components of the Fast Charging Infrastructure?

- i. Grid Converter (GC Converter)
- ii. PV Converter
- iii. Energy Buffer Unit Converter (EBU Converter)
- iv. Electric Vehicle Battery Converter (EVB Converter)

14. State the advantages of using renewable energy in EV charging.

- Sustainable energy use
- Reduced cost of operation
- Reduced grid dependency,

15 Give the Disadvantages of renewable-based charging.

- Higher initial setup cost
- Intermittency of generation
- Requires storage

16. Why is battery storage needed in renewable EV charging?

To balance supply-demand mismatch and enable fast charging.

17. What are the advantages of coordinated charging strategy?

- Improves grid stability
- Extends battery life.
- Reduces peak load

18. What is a DAB converter?

Dual- active bridge converter; bidirectional DC-DC converter with high efficiency.

19. Give the types of EV charger topologies for renewable integration.

Single-stage, two-stage, multilevel and DAB-based converters.

20. Mention the advantages of energy buffer unit (EBU) in fast charging.

- reduces grid stress
- Smooth power demand
- Supports intermittent renewable supply

PART B

1. List the factors which influence the topology of the EV chargers.
2. Enumerate the Choice of Converter topology and Suitable selection of converters.
3. Illustrate various topologies of power converters used in EV charging.
4. Explain the various EV charging/discharging strategies in detail.
5. Illustrate the integration of EV charging- home solar PV systems.
6. Explain the various Operation modes of EVC-HSP (Electric Vehicle Charging – Home Solar PV) System.
7. Explain the Control strategy of EVCHSP system based on operating modes.
8. Analyze the power flow in Fast-charging infrastructure with solar PV and energy storage with various operating modes.
9. Compare AC-DC and DC-DC converter topologies for renewable EV charging.
10. Evaluate advantages and limitations of renewable-based EV charging systems.

UNIT IV

PART A

1. What do you mean by Wireless Power Transfer?

Wireless Power Transfer (WPT) is the technology by which electromagnetic wave is generated by using one or multiple transmitters and the waves are processed by one or several receivers without using any conductor as the medium to transfer the power.

2. Mention the Features of Wireless Power Transfer.

- a. Direct Contact with separation
- b. Unidirectional and bidirectional power flow
- c. Air-gap underwater or underground
- d. Variable power
- e. Number of receivers
- f. Number of Transmitters

3. What are the classifications of WPT?

Based on the Power:

- Low power (up to 1 kW),
- Medium power (1–100 kW)
- High power (more than 100 kW) Based

on the Direction of Power flow:

- Unidirectional -
- Bidirectional – Load provides energy to the source.

4. List the various technologies of WPT.

Operation	Technology
Near Field operation	Inductive power transfer Capacitive power transfer Resonant power transfer
Mid-Range Operation	Strongly coupled Magnetic Resonant
Far-field Operation	Microwave and Radiofrequency optical

5. What are the advantages of WPT?

- a. Capacitive WPT is able to transfer even with metallic objects
- b. The electrical field is restricted to the region separating the two plates.

6. List the various type of batteries used in EVs.

- a. Lead Acid Battery
- b. Lithium Ion Battery
- c. Nickel Metal Hydride Battery
- d. ZEBRA

7. What are the types of Li-ion Batteries used in EVs?

- a. Lithium-Cobalt Oxide (LCO),
- b. Lithium-nickel-manganese-cobalt (NMC),
- c. Lithium-nickel-cobalt-aluminium (NCA) and
- d. Lithium-Iron phosphate (LFP).

8. What are the disadvantages of Nickel-metal hydride batteries?

- a. Low efficiency
- b. High cost,
- c. High self-discharge rate,
- d. Heat generation
- e.

9. What are the functions of **BMS**?

- a. BMS monitors various parameters of the battery, namely voltage, temperature, State of Charge (SoC), State of Health (SoH), input current and output current.
- b. BMS activate the protection circuits when over-currents, over-voltages, over- heating or abrupt discharge occurs.

10. Differentiate passive cell balancing and active cell balancing.

Passive Cell Balancing	Active Cell Balancing
Excess of voltage of the cell is discharged with a dissipative element.	The energy is distributed among the cells in order to balance the energy that they store.

11. What are the four methods of charging?

- a. Constant-Current (CC) charging\
- b. Constant-Voltage (CV) charging
- c. Constant-Current–Constant-Voltage (CC–CV) charging
- d. Multi-stage constant-current (MCC) charging

12. List the advantages of WPT.

- a. Very convenient, Safe and Reliable power transfer technology due to the elimination of direct electrical contacts
- b. The power transfer is n not affected due to hostile environments such as snow, water, dirt, wind, and chemicals.
- c. Provides galvanic isolation (i.e.) has a separation that prevents the flow of current between the functional elements of the system.

13. Mention the operation modes of WPT.

- i. Static,
- ii. Stationary or Quasi-dynamic
- iii. Dynamic mode

14. Give the principle of magnetic resonance Wireless Power Transfer.

Magnetic resonance WPT transfers power using resonating transmitter and receiver coils, enabling efficient power transfer over mid-range distances.

15 Give the working principle of inductive Wireless Power Transfer.

Inductive WPT transfers power through magnetic coupling between closely spaced primary and secondary coils.

16. Give the principle of capacitive Wireless Power Transfer.

Capacitive WPT transfers power using an electric field established between conductive plates separated by a dielectric medium.

17. List the international standards for wireless charging of electric vehicles.

SAE J2954, IEC 61980, and ISO 19363.

18. Differentiate inductive WPT and capacitive WPT.

Inductive WPT uses magnetic fields between coils, whereas capacitive WPT uses electric fields between conductive plates.

19. State any two limitations of wireless power transfer for EV charging.

Lower efficiency compared to conductive charging and higher system cost.

20. What is the role of resonant frequency in magnetic resonance WPT?

Resonant frequency enables maximum power transfer and improves efficiency over mid-range distances.

PART B

1. Explain magnetic resonance WPT with working principles.
2. Explain capacitive WPT and applications.
3. Illustrate WPT system with EV integration.
4. Explain various battery technologies in EVs.
5. Describe functions of BMS and cell balancing methods.
6. Illustrate CC, CV, and CC-CV charging with standards.

7. Analyze static, stationary, and dynamic WPT modes.
8. Evaluate advantages, limitations, and standards of WPT in EVs.
9. Classify WPT systems and explain each.
10. Explain inductive power transfer technology with diagrams.

UNIT V
PART A

1. **What is the need for Power Factor Correction (PFC)?**
It makes the input current of the power supply to be in phase with the mains voltage, so that the real power drawn from the mains can be maximized.
2. **Why Boost Converter is considered for Power Factor Correction?**
 - i. The line voltage of the system is from zero to a peak value, therefore the Boost Converter is used to step up to a specified output DC bus voltage.
 - ii. The boost converter has the filter inductor on the input side, which provides a smooth continuous input current waveform
3. **What are the modes of Operation of PF?**
The boost converter operates in three modes:
 - i. Continuous Conduction Mode
 - ii. Discontinuous Conduction Mode
 - iii. Critical Conduction Mode
4. **What is continuous Conduction Mode?**
In this mode the MOSFET of the boost converter does not switch ON when the boost inductor current is zero during the switching cycle.
5. **List the advantages of Continuous Condition Mode.**
 - i. Peak current is lower, and the RMS current factor with a trapezoidal waveform is reduced compared to a triangular waveform, reducing device conduction losses.
 - ii. Turn-off losses are lower due to switch off at much lower maximum current.
 - iii. The HF ripple current to be smoothed by the EMI filter is much lower in amplitude.
6. **List the disadvantages of Continuous Condition Mode.**
Requires large filters
7. **What is discontinuous Conduction Mode?**
In this mode the MOSFET of the boost converter is turned ON, when the inductor current reaches zero.
8. **What are the disadvantages of discontinuous Conduction Mode?:**
 - i. High peak current
 - ii. Uses larger cores due to which high I^2R losses and skin effect losses.
 - iii. Due to the input swings large filters are required.
9. **What are the advantages of Critical Conduction Mode**
 - i. Power saving
 - ii. Improved power density
10. **Define Power Factor Correction (PFC).**
Power Factor Correction is the process of improving the power factor of an electrical system. It minimizes distortion in the input current waveform.
PFC ensures that the input current is in phase with the supply voltage.
11. **Give the Purpose of PFC in EV chargers.**
Reduce harmonics, improve efficiency and meet standards.
12. **Write the equation for sizing boost inductor.**
$$L = \frac{V_{in} \times D}{f_s \times \Delta I_L}$$
13. **Write the equation of Average current calculation in rectifier.**
Average current calculation in rectifier.

$$I_{avg} = \frac{1}{T} \int_0^T i(t) dt$$

14. Write the equation of Power loss in boost converter.

$$P_{loss} = I^2_{RESR} + V_{DS} I_{switch}$$

15. Give the importance of PF in grid integration.

Reduces reactive power, improves voltage stability.

16. List the advantage of Boost Converter for PFC.

Smooths current waveform and maintains output voltage.

17. List the Disadvantage of boost PFC.

Requires precise control, filter sizing, and increases cost.

18. Differentiate between Continuous vs discontinuous mode comparison.

CCM: smoother current, less losses; DCM: higher peak, more stress.

19. What is the role of EMI filter in PFC.

Suppresses high-frequency harmonics, protects grid.

20. Mention the Standards for PFC circuits in EV chargers.

IEC 61000 series, IEEE 519.

1. Illustrate sizing of boost inductor with example calculations.
2. Explain average current calculation and power loss in rectifier.
3. Compare continuous, discontinuous, and critical conduction modes.
4. Illustrate power factor correction in EV chargers with diagrams.
5. Explain design considerations for boost PFC in EV chargers.
6. Discuss advantages and disadvantages of boost PFC.
7. Analyze impact of PFC on grid and harmonics.
8. Evaluate different PFC topologies for EV charging systems.
9. Design a boost converter for given EV charging specifications.
10. Explain the modes of operation of boost converter in PFC circuits.