Chapter 1

Introduction

The integration of electric vehicles (EVs) into the grid marks a transformative shift in the landscape of transportation and energy systems. As the global demand for sustainable and efficient mobility solutions rises, the intersection of electric vehicles and power grids becomes increasingly critical. This thesis, entitled "Reliability Aspect and Performance Enhancement of Grid-Integrated Electric Vehicles," delves into the intricate dynamics of this symbiotic relationship between EVs and the power grid. Research estimates in [1], The Global EV market was estimated at 170 billion in 2022 and is expected to reach over 1103.17 billion by 2030, and poised to grow at a CAGR of 23.1 % during the forecast period 2023 to 2030' as shown in Fig.1.1. Which represents a graphical global sales data after 10 years, one would assume that EVs would have been the mainstream and part of everyday life in the country. The demand for EVs is growing substantially worldwide. EVs have been developed in several nations, but the USA, UK, Germany, and China comprise most of the global EV market. In the Indian context, it was discovered that one out of every 125 cars is electric, with two- Wheelers and three-wheelers make up the bulk. The factors affecting EV performance over the past 20 years seem to have stayed the same. Lack of product innovation cost concerns and insufficient charging infrastructure density are the main factors limiting EV adoption in India. While EVs contribute significantly to reducing carbon emissions and dependence on traditional fossil fuels, their successful integration into the grid demands an in-depth understanding of reliability and potential performance enhancements. This research embarks on a comprehensive journey to unravel the complexities associated with the seamless integration of electric vehicles into the existing grid infrastructure.

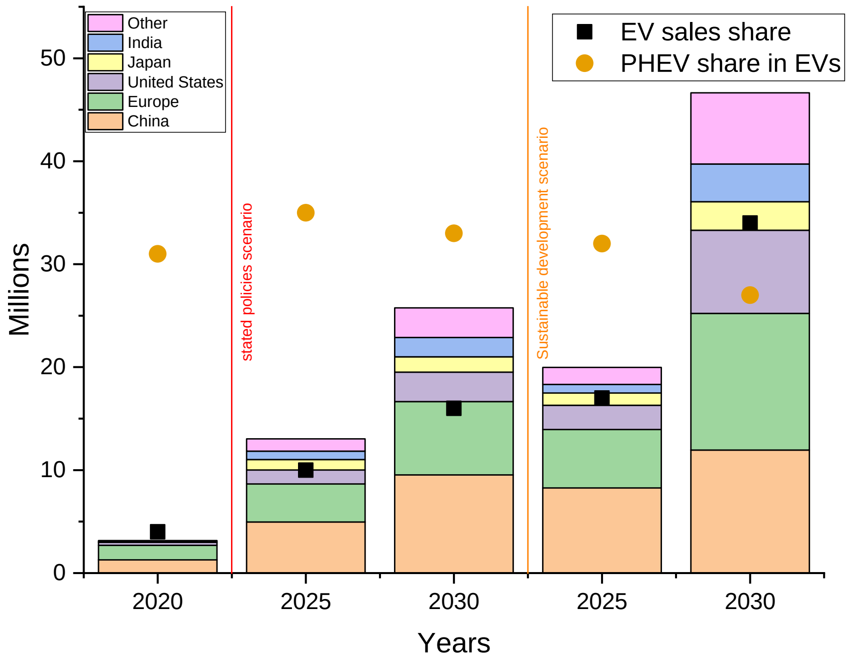

Figure 1.1: EV sales and forecasting data for the year (2020–2030).

The reliability aspect, a cornerstone of this investigation, scrutinizes the dependability and stability of grid operations when coupled with electric vehicles' charging and discharging patterns. This entails an examination of the potential impacts on grid resilience, Converter topologies, and the development of robust charging infrastructure capable of accommodating the increasing demand imposed by EVs. As electric vehicles become an integral part of our daily lives, ensuring the grid's reliability under these evolving circumstances is paramount.

Furthermore, this thesis delves into strategies and technologies to enhance the overall performance of grid-integrated electric vehicles. From advanced energy management systems to innovative charging infrastructure, exploring performance enhancement avenues is vital for maximizing the benefits of electric mobility. This research aims to contribute novel insights and solutions that not only address the existing challenges but also propel the efficiency and effectiveness of grid-integrated electric vehicles to new heights.

In the subsequent chapters, we will delve into the existing literature, analyze the current state of grid-integrated electric vehicles, identify challenges, propose converter topologies for reliability improvement, and explore avenues for performance enhancement. Through this research, we aspire to contribute to the evolving field of electric mobility and pave the way for a sustainable and resilient energy future.

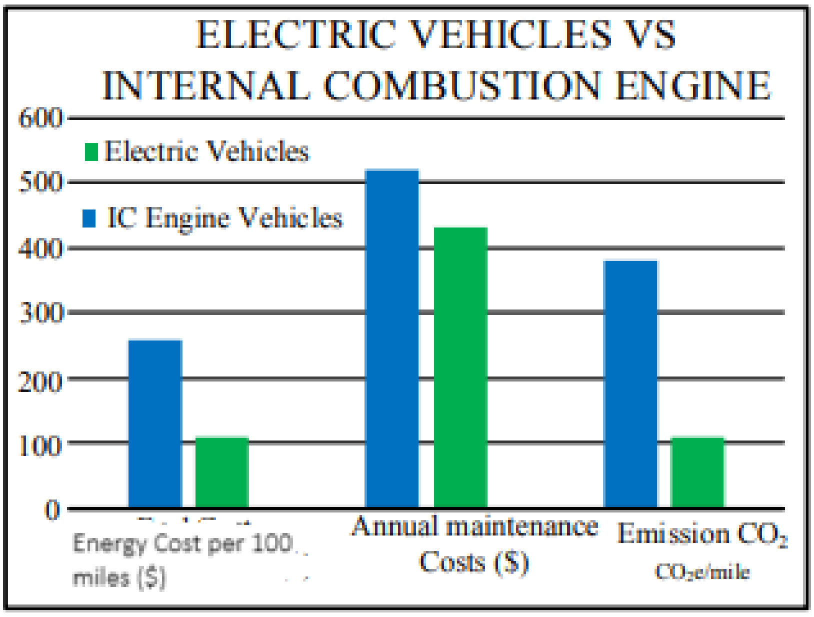

Figure 1.2: Comparison between EV and IC engines.

1.1 Background and Motivation

- Electric Vehicle (EV) technologies must overcome a lot of obstacles, including delayed charging, isolation, power loss caused by converter structure, the reliability of power electronic components, and the temperature of EV batteries.
- The reliability of power electronic components associated with EV converter topologies ensure the reliable performance of the entire system.
- The switching technique and appropriate control algorithm depend on the hardware setups involved in battery charger architecture.
- A proper control method for the DC/DC converter is essential to maintain a fixed and regulated output voltage, ensuring an efficient and safe EV grid integrated system.

With growing environmental concerns and increased emissions, the world is moving toward electrification in every industrial sector. The automotive industry has observed rapid growth, with internal combustion (IC) engines being replaced by electric motors. Electric motors are a viable option because of their higher efficiency and robustness. Fig. 1.2 shows a comparison between the classical IC engine vehicle and EVs [2]. It is observed that EVs are a realistic solution to offer reduced maintenance cost, better fuel economy, and limits CO2 emissions as compared to the classical IC engines. The electrification of not only private vehicles but also local transport vehicles has seen a significant boom recently. One of the significant parts of local transport is an inverter supplied from a battery pack to propel the electric motor and the vehicle. EVs can be classified into three major categories: two-wheelers, three-wheelers, and four-wheelers. Two-wheelers are used mostly in personal transportation and currently for delivery service. In contrast, three-wheelers are used for short-range local mobility, along with four-wheelers that are mainly used as personal and passenger vehicles for higher range. Three-wheeler vehicles have become popular in the Asian market because of their low price and high robustness. In Thailand and India, these three-wheelers are known as tuk-tuk or e-rickshaws and have evolved from IC engine vehicles to full-electric vehicles. Small four-wheelers such as golf carts and all-terrain vehicles (ATVs) have also gone full electric to reduce the size and increase efficiency. These vehicles are comparatively cheaper as they are hauled by 850 W motors are powered by low voltage battery packs of 48 V, 120 Ah lead-acid batteries. As the depth-of-discharge for these lead-acid battery packs is only 20 % battery packs require to be charged often [3]. Thus a charger becomes a fundamental component for these vehicles. Charging these battery packs without compromising with the IEEE standards of low total harmonic distortion (THD) is an essential requirement.

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1.2 Overview of EVs

The demand for EVs is growing substantially worldwide. EVs have been developed in several nations, but the USA, UK, Germany, and China comprise most of the global EV market. An EV is a vehicle that uses energy from recharge batteries to be entirely or partially powered by electric motors. In the 1880s, the first usable EVs were designed. In 20^{th} centuries, EVs have become the common alternative for combustion fuel vehicles.

Due to innovation, increased development in ICE, and the mass production of lower-priced gasoline-powered vehicles, the use of EVs has decreased.

Challenges and issues in EV technology:

The technology of EVs is more energy-efficient and environmentally safe compared to conventional internal combustion vehicles (ICE) because they do not emit CO_2. The adoption of electric vehicles provides various possibilities, including advances in the tracking of renewable energy sources (RES) and V2G technologies. The difficulties with EV charger reliability have hindered EV adoption and possibly prompted a condition called charging anxiety. Energy storage technology is crucial to solving the issues of charging time and range anxiety. In [3], the author has addressed details of ESS categorization, comparative performance of the various Energy storage systems(ESSs) charging infrastructure, ESS for EVs, Battery management systems(BMS) for EV applications, Thermal management system of EVs, failure and future aspects EVs battery, Alternative energy sources. The electrical grid can benefit economically and environmentally by integrating RES and V2G technology. Before EVs can be effectively used in the marketplace, several complex problems and restrictions still need to be resolved. The key aspects and technical challenges associated with the anticipated upcoming developments of EVs are detailed in [4,5], which are as follows:

(i) Due to the high initial cost of EV batteries, it is still quite expensive to purchase an EV than a typical ICE vehicle.

(ii) The present charging solutions are still in adolescence despite the substantial developments in battery technology. Limited life cycle and low energy density are the key issues with Li-ion batteries. Due to the relatively short life duration, frequent maintenance is needed yearly or in two years; the size and weight of the batteries make up about one-third of the vehicle. Few battery technologies can give superior performance, but they are still experimental and have not yet reached their best extent.

(iii) To get the best performance out of batteries, reliable battery management systems are required. Improving the designing techniques used to size the battery subsystems is necessary. The optimal battery subsystem configuration provides excellent performance, several ranges, and longer battery life.

(iv) The V2G technology is an alternative solution to many important problems in the power network. It might accelerate RES integration. However, the V2G concept demands the active participation of EV owners.

(v) EV customers should be encouraged to actively participate in the inflation of V2G installation by new management policies that are implemented simultaneously with certain compensation packages. Otherwise, implementing the V2G technology in action becomes challenging [6].

(vi) Extensive investment is required to update the existing electrical infrastructures to effectively implement the V2G technology. A fully updated charging station (CS) with the appropriate installed EVs is also needed to successfully execute the V2G structure. Energy and conversion losses may also rise due to batteries being cycled too frequently [7].

(vii) The implementation of such a complex infrastructure and reward-based schemes require the use of effective planning strategies and cutting-edge research techniques.

1.2.1 Classification of Electric Vehicles

EVs can be classified into several technical categories: plug-in hybrid electric vehicles (PHEVs), hybrid electric vehicles (HEVs), fuel cell electric vehicles (FCEVs), and battery electric vehicles (BEVs). This classification is based on the combined utilization of fuel and electricity to power the vehicles. Fig. 1.3 presents the system architecture of different EV types, along with a summary of charging infrastructure, aspects of grid integration, and reliability assessment within grid-integrated distribution systems incorporating EVs.

(a) Hybrid Electric Vehicles (HEVs)

HEVs represent a specific type of hybrid vehicle that integrates an electric drive system and an ICE. These vehicles leverage the engine and energy generated during braking and acceleration to recharge their batteries. Series HEVs often feature large battery packs, powerful motors, and compact internal combustion engines. Common examples of HEVs seen on roads include the Cadillac Escalade Hybrid, Honda CR-Z, Honda Civic Hybrid, Acura ILX Hybrid, BMW Active Hybrid 3, and BMW Active Hybrid 5 [8]. Hybrid Electric Vehicles (HEVs) offer several advantages over both Battery Electric Vehicles (BEVs) and Internal Combustion Engine (ICE)-based vehicles:

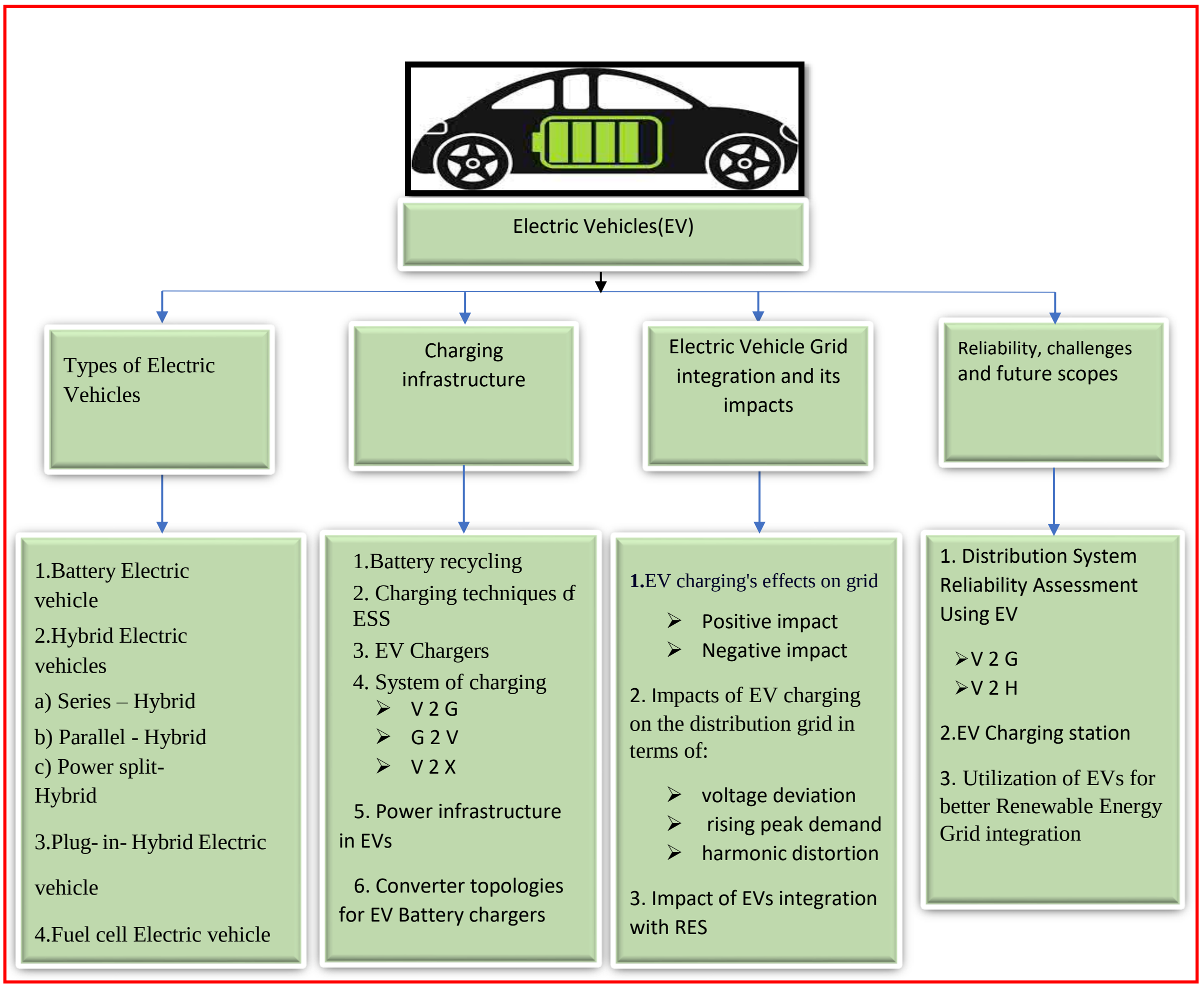


Figure 1.3: Literature review Framework including EVs types, charging infrastructure, reliability, and future Perspectives.

HEVs have the following advantages:

(i) A larger range of travel than BEVs.

(ii) Emissions are extremely low compared to ICE-based vehicles.

HEVs have a few drawbacks, including:

(i) *Battery Degradation:* Reduced efficiency and performance over time.

(ii) *Complex Dual Systems:* More potential points of failure.

(iii) *Specialized Maintenance:* Limited availability of trained mechanics.

(iv) *Electronic System Issues:* Prone to glitches and failures.

(v) *Cooling System Concerns:* Additional cooling requirements can lead to reliability issues.

(vi) *Limited Service Centers:* Difficult to find HEV-specific service centers.

(vii) *Start-Stop System Wear:*Increased wear on engine components.

They are more expensive to operate than BEVs, but ICE-based cars are less expensive.

(b) Plug-in hybrid electric vehicles (PHEVs)

These vehicles can recharge their batteries through regenerative braking, the ICE, and EV chargers connected to the distribution system [9,10]. In a Plug-in Hybrid Electric Vehicle (PHEV), the Internal Combustion Engine (ICE) and electric motor work together, supported by a battery storage system (BSS). There are various operating modes for the PHEV:(i) charge depletion (CD) mode, (ii) charge sustaining mode (iii) charge blended (CB) mode. In CD mode, the PHEV's ICE remains off, and the vehicle uses the energy stored in the battery until the battery is discharged to a predetermined charge level. The percentage charge level of a battery can be represented by the state of charge (SOC). The operating mode of the PHEV is changed to a charge-sustaining mode after reaching the minimum SOC level. In CS mode, the ICE and regenerative electric energy maintain the SOC at the minimum level. Charge blended (CB) mode is used for higher fuel efficiency [11]. In CB mode, an ICE and an electric motor (EM) operate together dynamically to run for extended periods of time. This most efficient configuration substantially reduces the carbon emissions [12]. The Toyota Prius Plug-In, BMW i3, GM Chevy Volt, Cadillac ELR, BMW i8, Porsche SE, Ford Fusion Energies, Ford Cmax Energy and are popular PHEVs.

The following benefits of PHEVs are given below:

(i) Long-distance traveling is possible.

(ii) Less dependency on fuel than conventional ICE-powered vehicles.

(iii) Low environmental pollution emissions.

Drawbacks:

(i) Pollution of the environment is not eliminated.

(ii) Costs are more to operate than BEVs.

(c) Battery electric vehicles (BEVs)

The BEVs does not require the support of a conventional ICE because it is just driven by an EM and an energy storage system (ESS). When they run out of ESS, they are plugged into an electrical outlet to recharge them, and BEVs's regenerative braking system allows them to recharge their batteries rapidly. It recovers energy frequently used, and brake energy is transformed into heat energy by the brakes and uses the vehicle's EM to slow down the vehicle [13]. BMW i3, Tesla Model S, Mitsubishi iMiEV, Nissan Leaf, Ford Focus Electric, and others are examples of commercially available BEVs. BEVs primary benefits are:

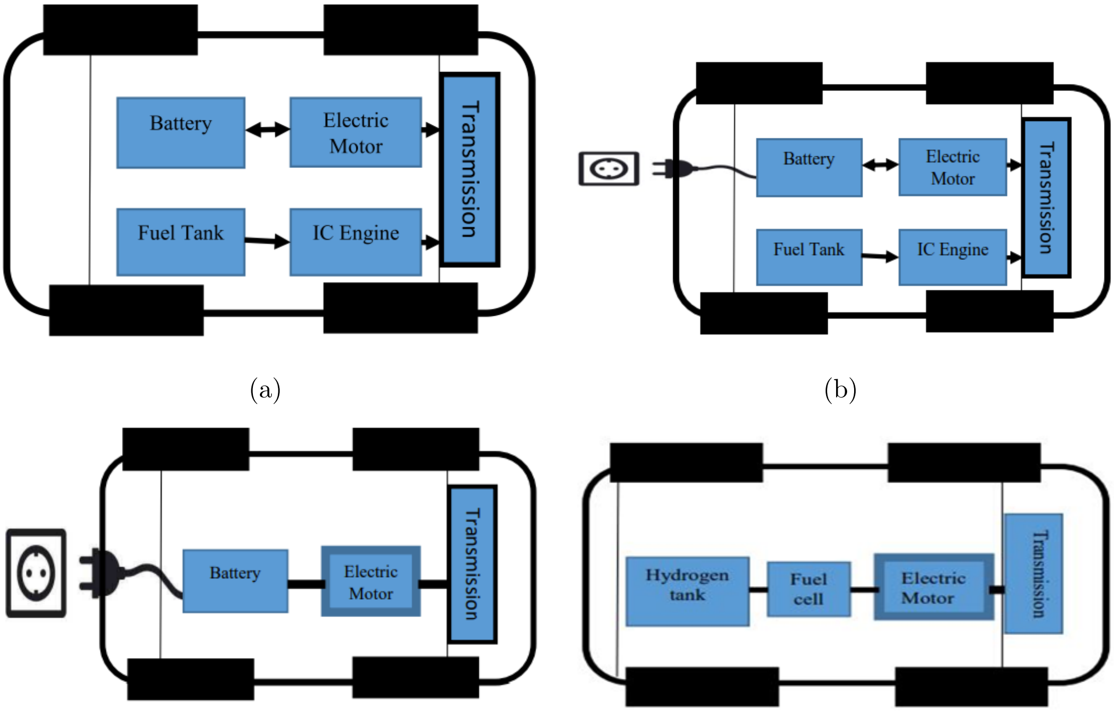
(i) No emissions from tailpipes.
(ii) No need to refuel with oil or gas.
(iii) Simple at-home charging.
(iv) Low overall cost of operating and quick and smooth acceleration.

In addition to the benefits, BEVs have some drawbacks as follows:

(i) A shorter drive range than ICE-based vehicles.
(ii) More expensive compared to ICE-based vehicles, yet only takes 1-2 years to pay for fuel savings.

(d) Fuel cell electric vehicles (FCEV)

Although the FCEVs are driven by electric motors similar to BEVs, FCEVs use fuel cells rather than batteries. Chemical energy is converted into electrical energy in FCEVs. Hydrogen gas is used as a fuel in this type of vehicle, and converted electric energy is used to drive the EM as discussed [14]. Hydrogen can be produced from fossil sources such as water electrolysis and natural gas. Like ICEVs, FCEVs have a quick refueling time [10, 13]. Super-capacitors and batteries can also be used together to power them. FCEVs don't have batteries. Therefore, they won't affect the power system as they don't need electrical input from the distribution system to charge the battery. Toyota Mirai, Hyundai Nexo, Honda Clarity Fuel Cell, Hyundai Tucson FCEV, River Simple Rasa, and others are examples of commercially available FCEVs. Li-ion BEVs are now the most popular kind of autonomous electric vehicle. The developed world's governments are very supportive of BEVs technology. Currently, the following obstacles are still preventing the widespread adoption of BEVs. BEVs are more expensive and less autonomous than ICE



(a) (b)

(c) (d)

Figure 1.4: Schematic diagram of different types of EVs; (a) HEV, (b) PHEV, (c) BEVs, and (d) FCEV

automobiles. The following benefits of FCEVs are given below.

(i) *Zero emissions:* Produces only water vapor and heat.

(ii) *Efficiency:* Higher efficiency compared to internal combustion engines.

(iii) *Quiet operation:* It can reduced noise pollution. (iv)*Long range:* It Can achieve similar ranges to conventional vehicles.

(iv)*Fast refueling:* It takes minutes to refuel compared to hours for electric batteries.

Drawbacks:

Cost: Initial cost is higher due to expensive technology.

Infrastructure: Limited hydrogen refueling stations globally.

Hydrogen production: Often derived from fossil fuels, impacting emissions.

Durability: Lifespan and reliability of fuel cells compared to engines.

Safety concerns: Hydrogen storage and handling require strict safety measures.

1.2.2 Power Electronics in EVs

Power Electronics is the major and essential technology enabling EVs. Power electronics play a crucial role in EVs by facilitating the conversion, control, and distribution of electrical power. They are responsible for managing the flow of electricity between the battery, motor, and various vehicle systems.

(i) Motor Control: Power electronics control the speed and torque of the electric motor by adjusting the voltage and current supplied to it. This allows efficient and precise control of the vehicle's acceleration, deceleration, and overall performance.

(ii) Battery Charging and Discharging: Power electronics regulate the charging and discharging of the battery pack in the EV. They ensure the battery is charged safely and efficiently from various power sources such as AC mains, DC fast chargers, or regenerative braking.

(iii) DC/DC Conversion: Electric vehicles typically operate on different voltage levels for systems such as the traction motor, auxiliary systems, and onboard electronics. Power electronics convert voltage levels between the battery pack and these subsystems to ensure compatibility and efficiency.

(iv) Regenerative Braking: Power electronics facilitate regenerative braking by converting kinetic energy during braking into electrical energy, which is then stored back in

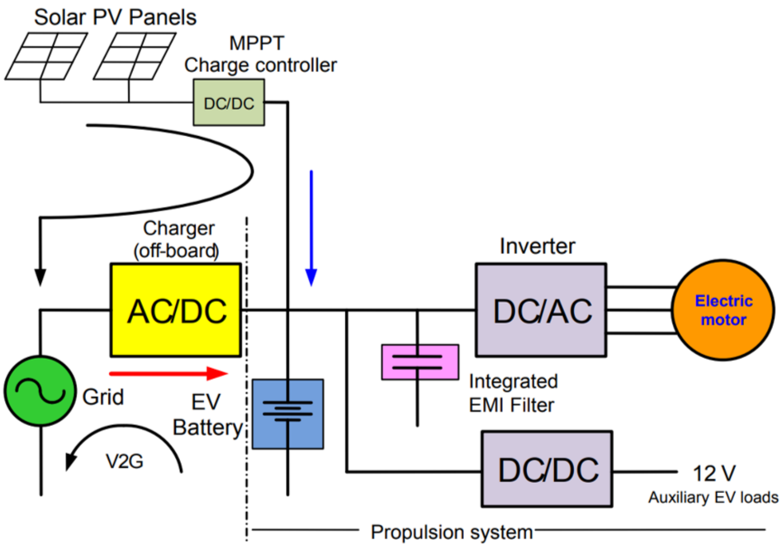


Figure 1.5: Grid-Connected Solar-Powered Electric Vehicle Charging System Overview.

the battery. This improves overall energy efficiency and extends the driving range of the vehicle.

(v) Inverter Operation: Inverters are a type of power electronic device that converts DC power from the battery into AC power for the electric motor. They play a critical role in controlling the motor's speed and direction of rotation.

(vi) Thermal Management: Power electronics generate heat during operation, and efficient thermal management is essential to maintain performance and reliability. Cooling systems, such as liquid or air-cooling, dissipate heat and keep the power electronics within safe operating temperatures.

(vii) Efficiency Optimization: Power electronics help optimize the overall efficiency of the electric drive-train by minimizing energy losses during the conversion and transmission of electrical power. This improves the vehicle's energy utilization and extends its driving range.

(viii) Vehicle-to-Grid (V2G) Integration: Advanced power electronics enable bidirectional power flow between the EV's battery and the electrical grid, allowing vehicles to serve as mobile energy storage units. This capability, known as vehicle-to-grid (V2G) integration, enables EVs to provide grid services such as peak shaving, load balancing, and emergency backup power.

Some key roles of power electronics in Grid-Connected Solar-Powered Electric Vehicle Charging Systems are illustrated in Fig.1.5.

- DC/DC converter (battery voltage to 12 V for auxiliary supplies)
- DC-AC Inverter (traction inverter)
- AC-DC converter or rectifier (alternator output to DC for charging the batteries)
- AC-DC converter or rectifier (Charger)
- DC/DC Converter with MPPT for Sun to Vehicle (S2V) Charger

1.2.3 Reliability in Power Electronics

The reliability of power electronic components associated with EV converter topologies ensures the reliability of the entire system.

That includes:

(1) Circuit topology

(2) Switching technique (modulation strategy)

(3) Control algorithm and system

The Control system regulates the load voltage and controls the power flow smoothly while the circuit and modulation maintain high performance during steady-state operation.

Reliability Parameters of Power Electronics in EV chargers can vary depending on the design and components used. some common reliability parameters are considered:

- Mean Time Between Failures (MTBF)
- Failure Rate, Component Selection and Quality
- Mean Time to Repair (MTTR)
- Availability and Operating Temperature Range
- State of Health (SoH)
- Failure mode and effect analysis (FMEA)

1.2.4 Reliability Issues in EVs:

- Battery Degradation: Lithium-ion batteries degrade over time due to charge/discharge cycles, temperature variations, and deep discharges, impacting range and efficiency. Factors such as thermal management, depth of discharge (DoD), and charging speed significantly affect battery lifespan.

- Power Electronics Failures:

  Converter topologies and switching devices (MOSFETs, IGBTs, SiC-based components) are critical for efficient power conversion but are prone to failures due to thermal stress, electromagnetic interference (EMI), and switching losses. Reliability considerations include Mean Time Between Failures (MTBF), Failure Rate, and Component Quality.

- Charging Infrastructure Reliability:

  Grid disturbances, power outages, and fluctuations impact EV charging station reliability. Bidirectional chargers (G2V & V2G) introduce additional reliability concerns, such as voltage fluctuations and grid stability issues.

- Thermal Management System Challenges:

  Effective cooling mechanisms (liquid or air-cooled systems) are required to prevent overheating of batteries, inverters, and power converters. Poor thermal management reduces efficiency, safety, and component longevity.

- Electric Motor and Drivetrain Reliability:

  Permanent magnet motors in EVs face issues like demagnetization, mechanical wear, and insulation failures. Powertrain vibrations and resonance effects can impact the durability of mechanical components.

- Software and Control System Failures:

  EVs rely heavily on embedded control algorithms for battery management, motor control, and energy optimization. Software glitches, cyber threats, and communication failures (CAN bus, V2X systems) can compromise vehicle reliability.

1.3 Key Challenges and Constraints

(i) A faster response for bidirectional chargers in G2V and V2G modes can be achieved by using PI and SMC (Sliding Mode Control) controllers.
(ii) Designing a converter for coordinated management of the distribution system integrated with a large number of EVs with V2G capability.
(iii) Developing small signal and steady-state mathematical models of EV charging systems for two-way smooth, safer, and reliable power transfer control.
(iv) Achieving high performance of bidirectional converter during abnormal conditions (faults, failures, malfunctioning, etc).

1.4 Research Objectives and Scopes

EV innovative charging features must be more extensive in the environment, comprising various charging powers, CS, battery swapping stations, retail and wholesale trading, and ancillary parts of the system, to more correctly and honestly mimic the practical implementation. Continuous research should be done to determine the best trade-off between computational load and performance [15]. EV technologies must overcome many obstacles, including delayed charging, isolation, power loss caused by converter structure, the reliability of power electronic components, and the temperature of EV batteries. So, the reliability of electronic components associated with EV converter technology ensure the reliable performance of the entire system as discussed in [15, 16].

The direction of the next research studies is as follows:

- Analyze and propose simple and effective control techniques for the converter topologies and report complete dynamic modeling and closed-loop control.
- To get a faster response of grid-integrated EV during motoring and braking mode, charging-discharging (V2G, G2V, S2V, and V2V) mode in the future because synchronization reliability plays a vital role.
- To study and develop a novel Power Electronics converter for use in EV charger, in MATLAB/Simulink software, which is validated with a laboratory-based experimental setup.

- Develop a reliable mathematical model for the reliability, availability, and maintainability analysis of an EV system in the future.
- Develop prototypes for all the proposed EV charger Converter topologies to verify mathematical analysis and simulations with experimental results.

1.5 Methodology

As illustrated in Fig. 1.6, the following research methodology has been adopted to achieve the objectives within the given time limit.

1.6 Organization of the Thesis

The thesis is structured into eight chapters, organized according to the progression of contributions. Fig. 1.7 illustrates the structure of the thesis. The thesis contents are summarised as discussed in Fig. 1.7 named as the thesis outline. The significant research contributions of this thesis are as follows.

Chapter 1: This chapter describes the research background, motivation, literature review based on the classification of EVs, challenges and issues in EV technology, classification of converter topology, objectives and scope, and thesis structure.
chapter 2: Integrating EVs with the power grid is a critical step toward sustainable transportation. This chapter includes the study of EV converter topologies for grid integration, merits and demerits of various battery charging technologies, advanced off-board and on-board EV chargers, charging infrastructures, and standards. Bi-directional converters enhance efficiency and prolong battery life. In this chapter, Vehicle-to-grid (V2G) and grid-to-vehicle (G2V) approaches are explored to assess travel behavior, reliability parameters, and battery capacity; positive and negative impacts of grid integration; and Issues related to EV converters are discussed.
chapter 3: This chapter introduces an event-triggered control approach for a boost converter's LPV (linear parameter-varying framework), integrating and establishing a suitable triggering condition. The controller design, dependent on the duty ratio, enhances voltage regulation performance. Stability is verified for the closed-loop system comprising

Report a comprehensive study of existing EVs and power converter topologies, charging infrastructure, and reliability Aspects for Grid integrated EVs, and identify merits and demerits

Considering the fact that an extensive literature survey of EV charging infrastructure and converter topologies has already been carried out, and the reliability aspects of rid-integrated electric vehicles are very limited attention, perform a comparative study the possible control algorithm in EV Power converters for robustness.

Based on the merits and demerits and the reliability aspects of grid-integrated EVs, propose a new converter topologies, modulation, and control techniques to make it more acceptable for practical use

Perform preliminary simulation on a suitable platform to find the suitability of the proposed system

Analyze comprehensively to find out all justification of successes or failures in achieving desired results

Modify converter topology or modulation and control schemes to achieve the desired results

Verify the results with the help of mathematical expressions and also through simulation results

If the mathematical model and simulation results have an acceptable agreement, build a scale-down lab prototype and verify analytical and simulation results with experimental result

Figure 1.6: Research Methodology.

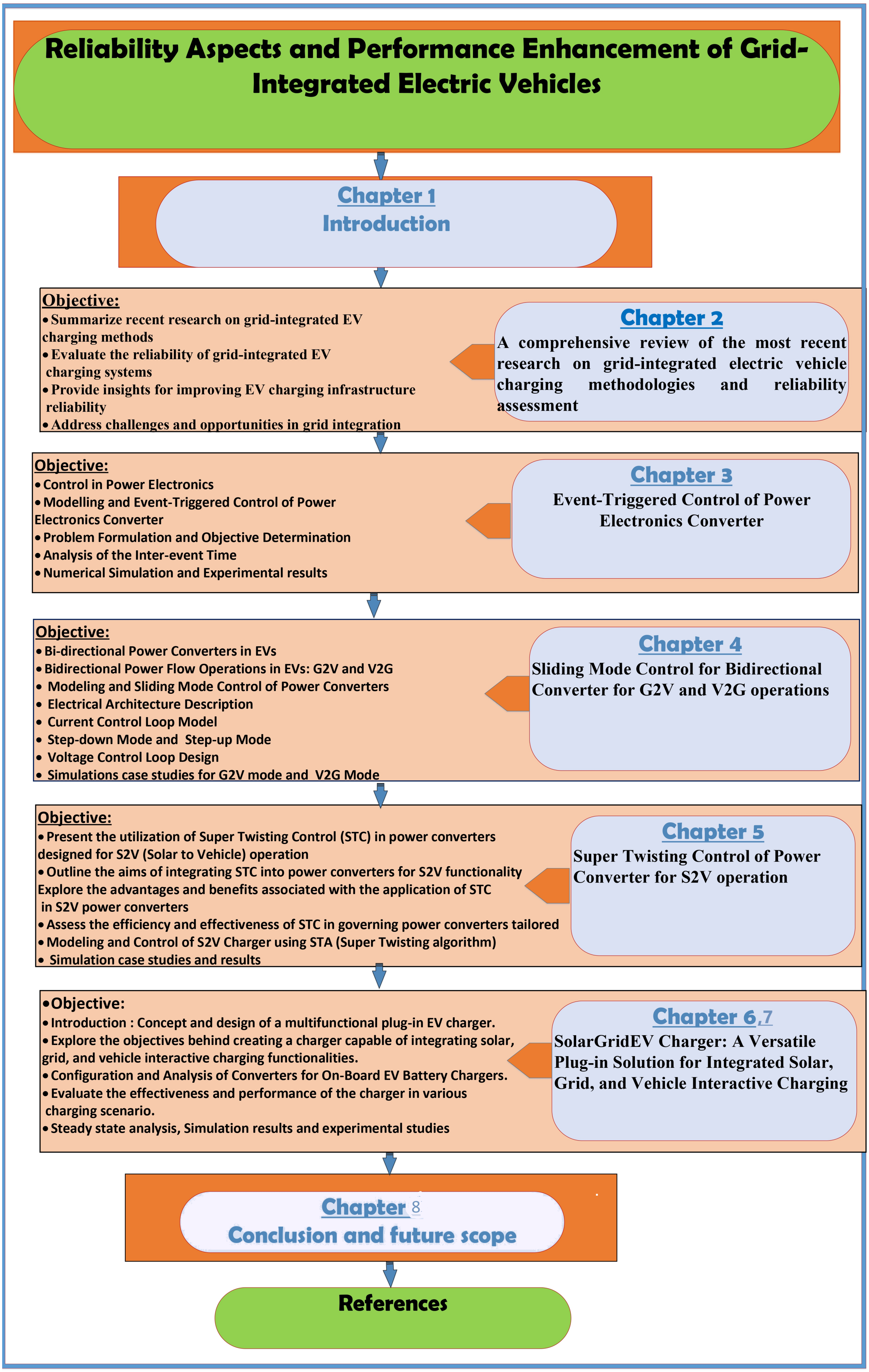


Figure 1.7: Outline of the thesis.

the boost converter and the parameter-dependent controller. Simulation and experimental results are presented for two cases: (i) variations in input voltage and (ii) changes in load currents. In both scenarios, the proposed controller demonstrates favorable performance, notably reducing the necessity for control updates and thus minimizing computational and communication resource usage. Furthermore, a lower bound on the inter-event time is proposed to eliminate Zeno behavior.

chapter 4: This chapter contributes to the field of battery electric vehicle (BEVs) chargers by investigating the application of a sliding mode controller for both Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) operations. Implementing the sliding mode control ensures unconditional stability during both step-up and step-down modes without the converter needing to determine its operating mode. Additionally, the proposed controller effectively mitigates the chattering effect, a significant issue in power converters. To address the slower dynamics of the output voltage, the stability of the converter is first established for the current control loop, followed by the construction of the voltage control loop in a cascaded manner. Simulation results validate the effectiveness of the proposed controller in achieving the desired control objectives.

chapter 5: This chapter explores Super Twisting Control (STC) as a viable control strategy for power converters operating in S2V (Solar-to-Vehicle) mode. The implementation of STC offers a robust and adaptive solution to the challenges encountered during the conversion of solar energy to electric vehicle power. By leveraging the inherent advantages of STC, such as its ability to mitigate disturbances and uncertainties, this study aims to enhance the efficiency and reliability of S2V systems. Simulation experiments are conducted to validate the effectiveness of the proposed STC-based control scheme in achieving precise and stable power conversion performance, thus contributing to the advancement of sustainable energy utilization in transportation.

chapter 6: This chapter proposes a novel interleaved buck-boost topology with reduced switches designed for AC-DC and DC/DC conversion systems. The proposed AC-DC buck-boost converter offers effective Power Factor Correction (PFC) operation across a wide input voltage range. It employs a single-sensor controller, which is advantageous for battery charging technologies. A tabular comparison evaluating the proposed converter is presented and discussed alongside simulation results. The chapter also provides a comprehensive evaluation of design considerations for inductors in Discontinuous Conduction

Mode (DCM) and the selection of filter capacitors. Furthermore, critical conduction parameters essential for DCM operation are determined through simulation. Rated at 1 kW, the proposed converter achieves an efficiency of 94 percent and a power factor of 0.9992, rendering it suitable for EV battery charging. Moreover, the compact size and reduced cost of the proposed on-board charger position it as a versatile converter for Vehicle-to-Vehicle (V2V) and Solar-to-Vehicle (S2V) applications, extending beyond traditional Grid-to-Vehicle (G2V) scenarios. **chapter 7:** A single-stage S2V power converter necessitates the implementation of maximum power point tracking (MPPT) for solar PV. Traditionally, this is achieved using boost or boost-derived converters. However, the interleaved boost converter is preferred, as discussed in Chapter 7, due to its advantages. **chapter 8:** This chapter concludes the works accomplished in this thesis, enumerates the benefits of the methods, and proposes future scopes of the work.