Design and Development of a Smart Solar Parking Lot

B.Sc. ELECTRICAL ENGINEERING

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Design and Development of a Smart Solar Parking Lot

A thesis submitted in partial fulfillment of the requirements for the
Degree of Bachelor of Science in
Electrical Engineering

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DECLARATION

This thesis is a presentation of my original research work. Every attempt is taken to explicitly state where other people's contributions are involved, with appropriate citations to the literature and acknowledgment of teamwork in research and discussions. Additionally, I certify that this work is original to the extent that it is not plagiarized and that all references are included.

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The undersigned hereby certify that they have read and recommend the thesis entitled "Design and Development of a Smart Solar Parking Lot" by Mohammad Hassam Nasir and Bilal Lateef for the degree of Bachelors of Science in Electrical Engineering.

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Thank you,

Mohammad Hassam Nasir

Bilal Lateef

DEDICATION

We want to dedicate this thesis to my cherished friends, family, and teachers.

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ABSTRACT

Due to emissions from the burning of fossil fuels in power plants and combustion engines, which result in environmental pollution and the production of greenhouse gases (GHG), solar parking lots are crucial for the survival of our planet and can also contribute to the main grid. To save our planet, world is moving towards renewable energy resources such as the use of photovoltaic (PV) panels and shifting from combustion engine cars to electric vehicles (EVs) so that the burning of fossil fuels can be minimized. In this proposal, latest technologies will incorporate the with solar parking lots so that the maximum quantity of solar energy can be withdrawn out of PVs. Wide bandgap (WBG) materials will be used in the DC-DC converters in this study because they will result in an improvement in efficiency, switching speed, and dependability. Using WBG will also decrease the power loss in the converters. It is also proposed that solar parking lots can also contribute to the main grid after EVs get fully charged. This phenomenon can be done by using an intelligent control center that will analyze the battery percentage of EVs and will intelligently decide rather charge the EVs or supply power to the main grid. In this project, simulations will be performing on MATLAB and Proteus to get accurate and optimized results. After getting desired results, a prototype of project will be developed using suitable hardware to get results near the simulations.

CHAPTER 1
INTRODUCTION

The burning of fossil fuels by combustion engines causes a lot of pollution. This pollution is causing degradation of environment, So the world is shifting towards alternate solutions so that this pollution can be minimized. Solar energy and Electric vehicle are best alternates to the fossil fuels.

1.1 Background

The world is gradually shifting towards renewable energy resources as it becomes increasingly clear that the planet cannot sustain its current rate of fossil fuel consumption. Climate change and its severe consequences are driving nations to look for alternative sources of energy that are clean, sustainable and renewable. Solar, wind, hydro, geothermal, and bioenergy are the main types of renewable energy. These sources are renewable, meaning they are replenished over time, and do not emit harmful pollutants into the atmosphere.

World energy consumption is shifting toward electricity because of the excessive burning of fossil fuels which are polluting our environment and are the cause of greenhouse gases (GHG). As electricity production is mainly dependent on fossil fuels which are about 68% [1] so renewable energy is a need as the solution for coping with both increasing electricity demand and environmental sustainability. The promotion of photovoltaic (PV) or solar panels as a part of the answer to decarbonize the energy sector is a result of the dropping cost of these technologies.

There is a lot of area in the world currently used as the parking area for cars. Most of it is covered with sheds to protect the cars from sunlight, rain, and other factors. To produce clean electricity, sheds should be replaced with PVs in this way the energy which is being wasted currently, can be used to produce clean electricity without burning any fossil fuels. According to research, about 121800 TW [1] of solar energy is absorbed by the earth's surface in just one hour.

Solar energy, in particular, is growing rapidly and becoming more affordable. Wind energy is also rapidly expanding, especially in countries with strong wind currents. Hydro power is being harnessed to produce electricity in countries with abundant water resources. Geothermal energy, which comes from heat generated within the earth, is being used to power homes and businesses in countries with volcanic and geothermal activity. Bioenergy, which is produced from organic matter, is being used to create heat, electricity, and biofuels.

Governments around the world are supporting the transition to renewable energy by providing incentives and subsidies for renewable energy projects and by setting targets for the amount of renewable energy to be generated in the future. Private companies are also investing heavily in renewable energy, recognizing the economic benefits of investing in clean energy. The trend towards renewable energy is also driven by consumers who are demanding clean energy options.

In conclusion, the switch to renewable energy sources is essential for halting climate change and ensuring the planet's sustainability. There are many advantages to using renewable energy, including less reliance on limited fossil fuels, decreased emissions, and increased energy security. Renewable energy is becoming more and more popular, and this trend is only anticipated to increase in the years to come.

1.1.1 Solar Parking

Solar parking lots are a type of parking facility that harnesses the power of the sun to generate electricity. They are made up of a sizable number of solar panels set up on a parking lot's roof or on buildings with unique designs placed above the places for parking. The panels convert the sun's energy into electricity, which can be used on-site or fed into the grid for others to use. Solar parking lots offer many benefits, both for the environment and for businesses and communities. Firstly, they reduce the amount of carbon emissions that are produced by traditional power generation methods. Secondly, they can help to lower energy costs for businesses and communities by reducing their reliance on expensive grid-generated electricity. Furthermore, solar parking lots are low maintenance and have a long lifespan, making them a cost-effective investment over time. Additionally, they can also provide shade for vehicles and reduce the amount of heat that is absorbed by parked vehicles, making them more comfortable for drivers. Overall, solar parking lots are an innovative and sustainable solution for communities and businesses looking to reduce their carbon footprint and improve energy efficiency.

Figure 1.1:Solar Parking Lots

Solar parking lots, as depicted in Figure 1.1, can boost the local economy by adding jobs necessary for the building and upkeep of the structure. Additionally, the growing usage of solar energy may contribute to the expansion of the renewable energy sector, resulting in fresh developments and improvements in the sector. Solar parking lots can also be used to inform the public about the advantages of renewable energy and encourage others to use comparable solutions. Furthermore, by reducing their reliance on traditional sources of electricity, solar parking lots can improve energy security and reduce the risk of power outages caused by natural disasters or other disruptions to the power grid. Solar parking lots can also be designed to be aesthetically pleasing, blending in with their surroundings and enhancing the overall appearance of the area. They can also provide benefits to the wildlife, such as creating habitats for birds and insects. In conclusion, solar parking lots are a flexible and sustainable solution that may benefit communities and companies in a variety of ways while helping to create a future where energy is cleaner and more sustainable.

The vast areas currently being used as parking lots for cars provide a significant opportunity for the generation of clean electricity. Instead of using fossil fuels to generate power, the energy absorbed by the earth's surface can be captured by installing solar panels in place of conventional carport sheds. Given that the earth's surface absorbs over 121800 TW of solar energy in a one hour, there is a tremendous potential for solar energy generation. The transformation of these parking lots into solar parks will aid in lessening global reliance on fossil fuels and advance the development of cleaner, more sustainable energy sources. Additionally, the use of solar parking lots would lessen carbon emissions and assist to temper the consequences of climate change. This change would have a positive impact on both the environment and public health, making it an important step towards a more sustainable future. The deployment of solar panels in these areas can also create job opportunities and stimulate the growth of the renewable energy industry, leading to further advancements in the field. In conclusion, converting parking lots into solar parks is a smart and sustainable solution that would benefit the environment, economy, and society as a whole.

1.1.2 Effect of EVs

The most promising strategy for accomplishing this is to switch to electric cars (EVs) from conventional automobiles. EVs are very energy efficient and clean, if and only if charged by electricity generated by renewable energy resources. In the last decades, researchers have put their efforts into electric vehicles to replace cars with combustion engines. As shown in the diagram, the internals of a basic electric car are shown. According to figure 3, it is made up of a large battery pack for a long driving range, a strong, durable, and effective motor for a suitable speed, and a power electronics controller for the car's electronics. A cooling system to avoid the components from overheating. A DC-DC converter supplies pure DC to the motor. A charging port to charge the battery. It also includes many other sensors and equipment to increase reliability.

The internal structure of electric vehicles (EVs) consists of several key components that work together to power the vehicle. The battery, motor, controller, and charging system make up an EV's primary parts.

The battery is the most important component of an EV as it stores the energy used to power the vehicle. Lithium-ion batteries, which are used in contemporary EVs and offer a high energy density, a long cycle life, and a low self-discharge rate. A high-voltage battery pack is often made up of numerous separate cells that are connected in series.

The motor is responsible for converting the stored energy in the battery into motion. EVs use electric motors, which are more efficient and produce less emissions than internal combustion engines. The motor is typically connected to the wheels of the vehicle via a drivetrain, and it is controlled by the vehicle's controller.

The controller acts as the brain of the EV, managing the flow of energy between the battery and the motor. The controller regulates the power output of the motor to ensure optimal performance and efficiency.

Finally, the charging system is responsible for recharging the battery when it is depleted. Most EVs can be charged from a standard electrical outlet, but faster charging options are also available for those who need to recharge quickly. The charging system typically includes a charger, power cord, and charging port.

These components work together to power the vehicle and provide a smooth and efficient driving experience for the driver. The internal structure of EVs is designed to be lightweight, compact, and highly efficient, making them an attractive option for those looking for a sustainable transportation solution.

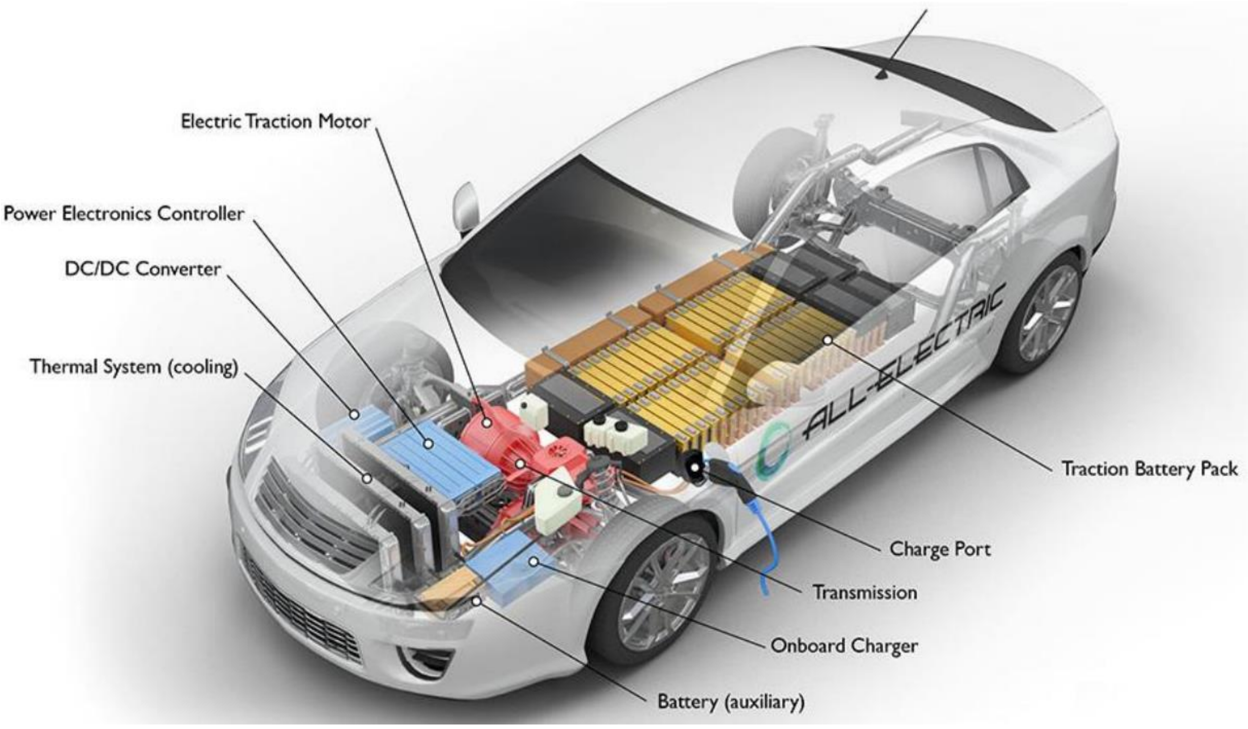

Figure 1.2: Internal Components of EVs

The first functional electric automobiles were developed in the 19th century, beginning the history of electric vehicles. The creation of these vehicles was driven by the need to reduce air pollution and noise pollution caused by internal combustion engines. In the early 20th century, electric vehicles were popular and widely used, however, they lost popularity with the introduction of gasoline-powered cars which were more convenient to refuel and had longer ranges.

Due to increased worries about climate change and a rise in the desire for environmentally friendly transportation options, there has been a renaissance in interest in electric vehicles in recent years. The development of battery technology and the infrastructure for charging electric vehicles has made them more useful for daily use. Many major automakers have invested heavily in the development of electric vehicles, and today there is a growing range of electric cars available to consumers, from compact city cars to family-sized vehicles and even luxury sports cars. Governments all across the globe have contributed significantly to the development of electric vehicles by promoting their adoption with incentives like tax credits and subsidies. In addition, there has been a push to install charging infrastructure, making it easier for drivers to recharge their vehicles on long trips.

1.1.3 DC-DC Converters

In solar parking lots, DC-DC converters are crucial because they transform high-voltage solar panel direct current (DC) into the low-voltage DC required to charge electric cars (EVs). Because it directly impacts the quantity of energy that can be transmitted from the solar panels to the EVs, the efficiency of these converters is essential for the overall effectiveness of the solar parking lot.

Resistance, inductance, and switching losses are the main causes of losses in DC-DC converters in solar parking lots. Resistance losses, which are proportional to the current flowing through the converter, happen as a result of the resistance of the converter's components. The magnetic energy that is stored in the inductors causes inductance losses, which are inversely proportional to the switching frequency. Switching losses, which happen while the converter's power switches are on and off, are inversely correlated with the frequency of switching and the capacitance of the switches.

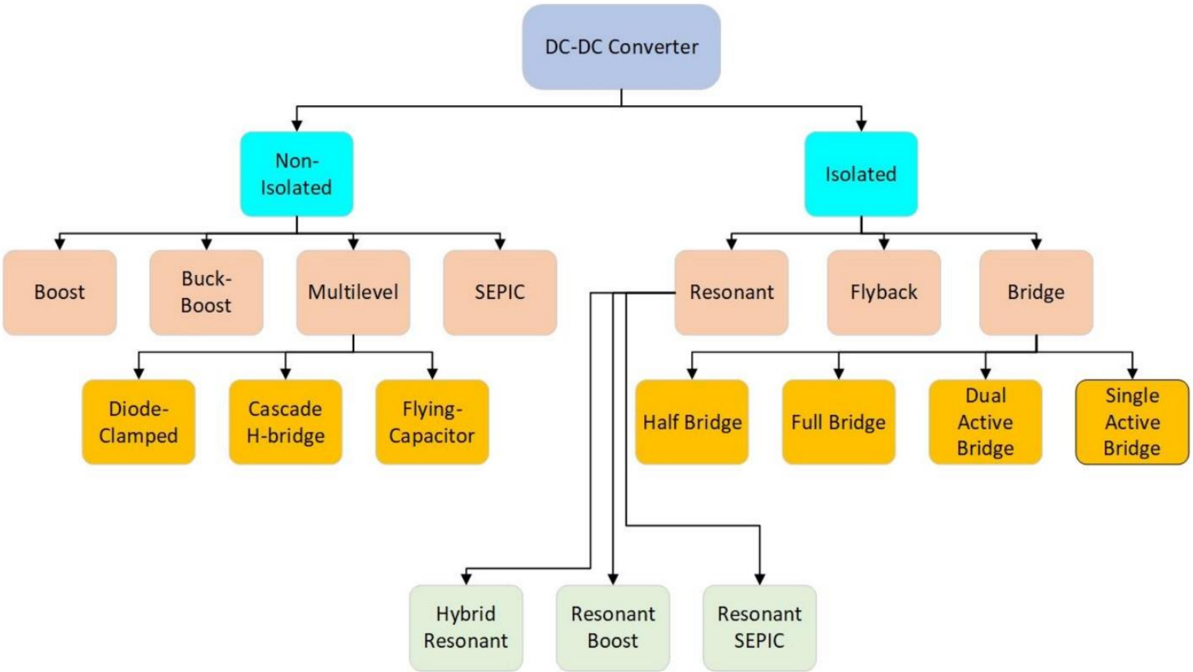

Figure 1.3:Types of DC-DC Converters

Minimising these losses is crucial to raising the DC-DC converters in solar parking lots' efficiency. High-frequency inductors and capacitors, as well as other components of high quality and low resistance, can be used to accomplish this. In addition, it is important to use power switches with low capacitance, and to switch the converter at high frequencies to minimize switching losses. Furthermore, by enhancing the current and voltage waveforms throughout the conversion process, sophisticated control techniques can be applied to lower the losses.

In conclusion, as they are utilised to transform the high-voltage DC from the solar panels into the low-voltage DC required to charge EVs, DC-DC converters are a crucial part of solar parking lots. The efficiency of these converters is important for the overall performance of the solar parking lot, as it directly affects the amount of energy that can be transferred to the EVs. More energy may be transported from the solar panels to the EVs by increasing the efficiency of the DC-DC converters and reducing resistance, inductance, and switching losses.

1.1.4 Evolution of DC-DC Converters

Due to the demand for greater efficiency, dependability, and power density in power conversion applications, Wide Band Gap (WBG) semiconductors have replaced traditional semiconductors in DC-DC converters. Conventional semiconductors, like silicon, perform poorly at high switching frequencies and temperatures, which reduces efficiency and raises the need for thermal management.

1.1.5 Wide Bandgap Semiconductors

Wider bandgap (WBG) semiconductors, such silicon carbide (SiC) and gallium nitride (GaN), have a greater operating temperature and switching frequency than silicon, which increases efficiency and lowers the need for thermal management. Furthermore, WBG semiconductors have a lower ON-state resistance than conventional semiconductors, allowing for better power densities and faster switching rates, which reduce switching losses.

Table 1.1: Properties of Semiconductor materials [28]

Material	E_g (eV)	ε_r	μ (cm^2/Vs)	υ_s (cm/s)	E (MV/cm)	κ (W/cm.K)	T_{max} (˚C)
Si	1.12	11.7	1400	1×10^7	0.3	1.5	300
GaAs	1.4	12.8	8500	1×10^7	0.4	0.5	300
GaN	3.39	9.00	900	2.5×10^7	3.3	1.3	600
4H-SiC	3.26	9.66	1000	2.2×10^7	2.0	4.9	700

Although the usage of WBG semiconductors in DC-DC converters is still in its infancy, it is anticipated that as the technology develops and WBG devices become more affordable, their application will spread. The use of WBG semiconductors in DC-DC converters will make it possible to create high-performance power conversion systems for a variety of applications, such as high-power electronics, electric cars, and renewable energy systems.

The goal of research on isolated DC-DC converters in recent years has been to increase gain, increase conversion efficiency, and decrease loss. For powering loads including motor drives, uninterruptible power supplies, renewable energy sources, and battery chargers, the majority of power converters are unidirectional. On the other side, some applications demand bidirectional power converters. Renewable energy and battery storage applications are one illustration of this. The simple circuits of the boost converter and buck converter are depicted in the schematics below.

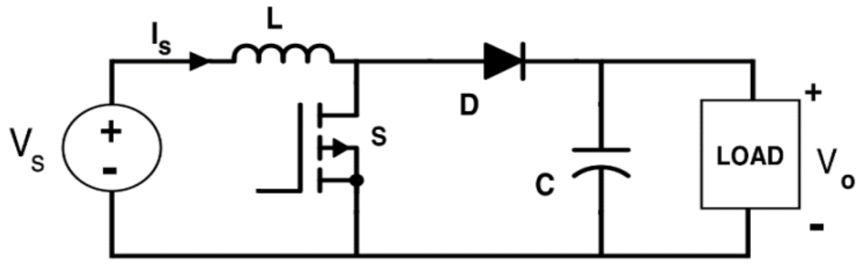

Figure 1.4:Boost Converter

A step-down DC-DC converter called a "buck converter" lowers the output voltage from the input voltage. In order to control how long the input voltage is supplied to the output, a switch is used. Energy is stored in an inductor when the switch is on, and it is transmitted to the output through a diode when the switch is turned off. The ratio of the on and off times determines the output voltage.

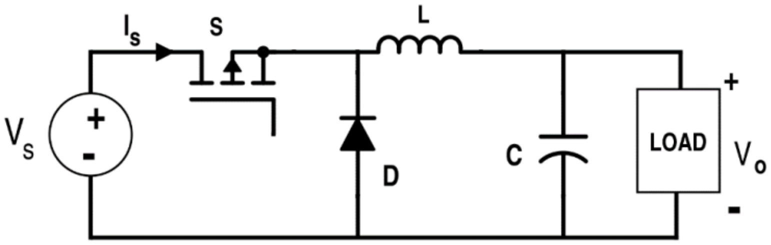

Figure 1.5:Buck Converter

A DC-DC converter known as a "buck-boost converter" has the ability to step up or step down the input voltage in order to produce an output voltage. Similar to a boost converter, it operates by utilising a switch to regulate how long the input voltage is supplied to an inductor. The direction of the current flow via the inductor, however, controls the output voltage. The output voltage will be greater than the input voltage if the current flows in one direction, and lower than the input voltage if the current flows in the opposite way. As a result, a variety of applications that call for both step-up and step-down voltage conversion can use the buck-boost converter.

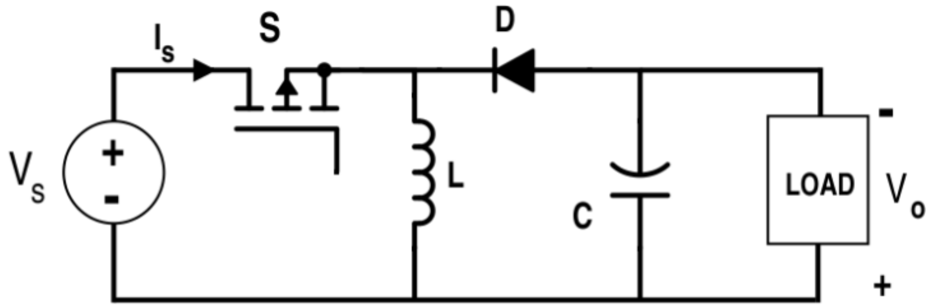

Figure 1.6:Buck-Boost Converter

1.1.6 Evolution of Semiconductors

Silicon (Si) MOSFET-based semiconductors, also called 1st generation semiconductor technology, have made quite a progress in the power semiconductor industry. WBG semiconductor materials like silicon carbide (SiC) and gallium nitride (GaN), which have entered the power semiconductor market due to their superior qualities to first-generation semiconductors such as high frequency, high voltage control, and less heat, are the focus of current research. WBG devices are employed because they perform better than Si devices in terms of power conversion and reliability, such as Si-carbide (SiC) and gallium-nitride (GaN) devices. Well-known SiC power devices have been the subject of extensive research. The investigations on GaN devices for high-power (HP) applications are, nevertheless, scarce. The traits of WBG are shown in the following table.It is required to first present a summary of traditional 1st generation semiconductors, such as Si-based 5 power devices and their uses in the previous ten years, in order for the latest research and development and potential implementations of WBG power DC-DC converter topologies to be clearly understood. The basic operation of first-generation semiconductors, which can be N-P-N or P-N-P, is depicted in the following diagram.

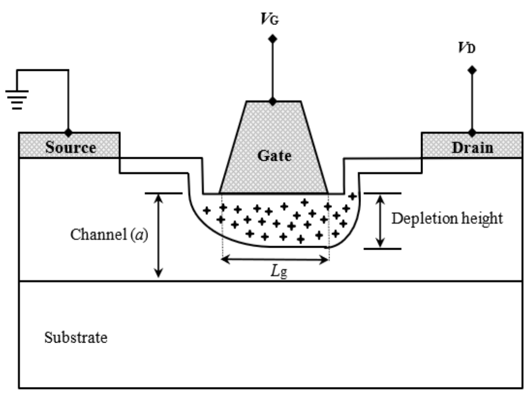

Figure 1.7: A Cross-sectional view of an operating MESFET

The demand for greater performance and efficiency in electronic devices has propelled the evolution of semiconductors from silicon through Silicon Carbide (SiC) and Gallium Nitride (GaN).

Silicon has been the dominant semiconductor material for many decades, and it has been widely used in a variety of electronic devices, such as microprocessors, memory chips, and power devices. However, silicon has limitations when it comes to high-temperature operation and high-frequency switching, leading to decreased efficiency and increased thermal management requirements.

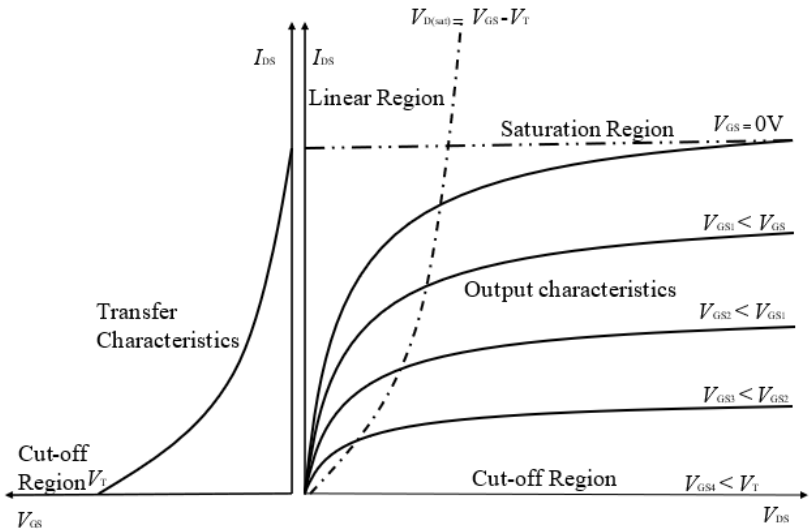

Figure 1.8: I-V Characteristics of an n-channel Transistor

SiC and GaN are Wide Band Gap (WBG) semiconductors that have emerged as alternative materials to silicon. SiC and GaN have wider bandgaps compared to silicon, which allows for higher temperature operation and higher frequency switching, leading to increased efficiency and reduced thermal management requirements. Additionally, SiC and GaN have lower ON-state resistance compared to silicon, enabling higher power density and higher switching speeds, leading to reduced switching losses.

The usage of SiC and GaN in electronic devices is still in its infancy, but as the technology develops and the price of WBG devices falls, it is anticipated that utilisation will rise in the upcoming years. SiC and GaN semiconductors will make it possible to create high-performance power electronics, including fast-switching power transistors, high-frequency power converters, and high-power amplifiers.

1.2 Objectives

This thesis has the following four objectives:

- Decarbonization: To create environment-friendly power sources and decarbonization.
- Less dependency on fossil fuels.
- Shifting to EVs: To maximize the use of EVs around the world.
- Less Load: Minimizing the load of the main grid.
- Charging the EVs on Renewable energy resources.
- Maximizing the efficiency of DC-DC converters and Ev's chargers so that Evs can be recharged instantly.
- High Efficiency: The use of GaN in solar power conversion systems can result in higher efficiency and reduced losses, maximizing the amount of energy generated by the solar panels and improving overall system performance.
- Increased Reliability: GaN has a higher temperature tolerance compared to traditional semiconductors, such as silicon, leading to improved reliability and longer lifespan of the power conversion systems in a solar parking lot.
- Power Density: GaN's lower ON-state resistance and higher switching speeds result in reduced switching losses and higher power density, enabling the use of smaller and more compact power conversion systems in a solar parking lot.
- Enhanced User Experience: With improved efficiency, reliability, and power density, a solar parking lot equipped with GaN-based power conversion systems can provide a more seamless user experience for charging electric vehicles and powering lighting and other systems in the parking lot.
- Cost Savings: The increased efficiency and reliability of GaN-based power conversion systems can result in reduced maintenance and replacement costs over the lifespan of the solar parking lot, leading to cost savings for the owner.

Overall, the objectives of a solar parking lot incorporating GaN semiconductors should be focused on maximizing energy generation, improving system performance and reliability, and reducing costs

1.3 Conclusion

This chapter describes the shifting of world towards the renewable energy resources such as towards Solar Energy. It also describes how can we use the parking lots to generate electricity and utilize it to charge the Electric vehicles or if there are no EVs, this electricity can result in the lowering of the load on the main grid. It also tells about the types of DC-DC converters and the generation of semi-conductions that are being used in these electronics.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Numerous suggestions for improving solar parking lots have been made. The following are some research publications.

Table 2.1: Electrical parameters of SiC & GaN [28]

Properties	4H-SiC	6H-SiC	3C-SiC	GaN
Band-gap (eV)	3.2	3.0	2.3	3.4
Hole mobility (cm^2/Vs)	115	90	40	30
Donor ionization energy (MeV)	45	85	40	28.5
Electron mobility (cm^2/Vs)	800	400	750	900

Mahsa Z. Farahmand et al have proposed the use of electric rice vehicles and photovoltaic (PV) panels to reduce carbon emissions and create solar parking lots. there has been a growing concern about the negative impact of transportation on the environment, particularly with regard to air pollution and fuel consumption. These solar parking lots are designed to generate clean energy through the use of PV panels. To make this technology feasible, there are a number of issues that need to be resolved. One of the main challenges is cost, as the installation of PV panels can be expensive. Additionally, the quality of the PV panels must be carefully considered, as the efficiency and durability of the panels can greatly impact their long-term performance and energy production. Despite these challenges, researchers have continued to investigate the potential of PV technology for use in solar parking lots. They have performed studies to assess how different PV technologies affect energy output and to find strategies to boost the effectiveness and dependability of these systems. [2]

A strategy proposed by Rishabh Ghotge involves using renewable energy sources, such as photovoltaics (PVs), to facilitate the scheduled charging of electric vehicles (EVs). This strategy aims to improve the overall supply of electricity from the grid, leading to a more flexible and efficient system. By utilizing renewable energy sources, the proposed strategy can help reduce the reliance on non-renewable resources for generating electricity. Moreover, the use of PVs in charging EVs can help in better prediction of the load on the main grid. This is so that the entire load on the grid can be better planned and managed. PVs can create energy when there is enough sunshine, and the amount of electricity generated can be precisely calculated in advance. The suggested approach can increase system flexibility in addition to increasing the supply of electricity. This is because EVs can be charged during off-peak hours when there is excess electricity available, and this excess electricity can be used to power the grid during peak hours. This reduces the need for additional capacity, which can result in significant cost savings.[3]

Y. Elhenawy et al suggests the design of an automated multistory parking lot that can charge electric vehicles (EVs) and also contribute to the main grid. The simulations conducted by the researchers indicate that this model has the potential to significantly reduce carbon emissions, with an estimated reduction of 77,842 kg per year. The suggested concept can encourage the wider use of EVs while also enhancing the overall sustainability of the electric grid by including charging infrastructure into parking lots. [4]

Gerardo J. Osorio proposed method involves integrating electric vehicles (EVs) and solar parking lots into the power system. The solar parking lots in this scenario would act as a backup power source to control the level of charge in EVs. Use of solar parking lots as a backup power source can ensure that the EVs remain charged even during periods of high demand or when the main grid experiences power outages. This combination of solar parking lots and electric vehicles can encourage the use of renewable energy sources and lessen dependency on fossil fuels. [5]

Xiaoli Sun et al proposed a review of the latest and upcoming technologies related to electric vehicles (EVs), including batteries, charging technologies, electric motors, control systems, and charging infrastructure. The review aimed to highlight the technical challenges related to these technologies, such as efficiency, reliability, and safety.The use of advanced batteries is crucial for the long-term success of EVs. The review covers the latest developments in battery technology, including advancements in lithium-ion batteries and solid-state batteries. The charging technologies of EVs are also an important area of consideration. The review discusses advancements in both wired and wireless charging methods and their potential benefits.Electric motors and control systems are also key components of EVs. The review examines advancements in motor and control technology, including the development of more efficient and powerful motors and more sophisticated control systems. The analysis also discusses the difficulties involved in creating and deploying a charging infrastructure for electric vehicles. [6]

Digital twin technology, which was proposed by Ghanishtha Bhatti and colleagues, has the potential to revolutionise the design and production of electric vehicle technologies. Digital twins can shed light on the behaviour and efficiency of electric car parts such battery management systems, intelligent charging, driver assistance systems, and power drive systems by simulating a virtual version of a physical system. By enabling early issue detection and mitigation in the design process, lowering the requirement for physical testing, and increasing the accuracy of simulations, this can result in cost-effective and efficient development. Overall, the adoption of digital twin technology in the automobile sector could hasten the shift to more environmentally friendly modes of transportation. [7]

Julio A. Sanguesa also suggested that for electric transportation to reach its full potential, advancements in EV technology are essential. They identified a number of areas, such as battery technological trends, charging techniques, power control, and battery energy management, where considerable advancements have been made. Significant advancements in battery technology over the past few years have led to improvements in energy density, range, and charging speed. Improvements in charging infrastructure, such as the development of high-power fast-charging stations, have also contributed to the increased adoption of EVs. Additionally, power control systems have become more sophisticated, enabling efficient energy transfer between the battery and the motor. However, there are still challenges that need to be addressed. One major challenge is the limited range of EVs, which is still a concern for many potential buyers. Battery degradation over time and high costs are also issues that need to be overcome to make EVs more attractive to consumers. [8]

Haixiong Ye et al proposed that by using converter techniques and multiplier cells we can decrease the voltage across the power semi-conductors that cause low-rating semi-conductors. we can increase overall efficiency by using MOSFETs with lower resistance and lower ranges for power diodes.[9]

A maximum power point tracking method (MPPT) is required to get the most output possible out of the PVs, according to a proposal made by Kummara Venkat Guru Raghavendra et al. In order to aid in the design of the following generation of converters, they also suggested integrating MPPT with the DC-DC converter. [10]

Hanqing WANG and colleagues have proposed integrating Electrochemical Impedance Spectroscopy (EIS) with DC-DC converters to monitor the real-time health of fuel cells powered by hydrogen energy. EIS is a non-destructive technique that can provide important information on the electrochemical behavior and performance of fuel cells. By integrating EIS with DC-DC converters, it is possible to obtain high-resolution data on the impedance spectra of fuel cells and gain insight into their real-time health. This can facilitate timely detection of performance degradation or failure and aid in the development of effective maintenance strategies for hydrogen fuel cells. The proposed integration of EIS with DC-DC converters is a promising approach for enhancing the performance and reliability of fuel cells in hydrogen-powered systems.[11]

Wide Band Gap (WBG) materials perform, offer advantages, and are more reliable than simple Si-based power devices, according to Xiaoyang Cheng et al., who proposed the recent advancements made in the field of wide bandgap semiconductors. These substances include SiC and GaN. [12]

Due to the fact that the majority of these materials are transparent conductive oxides, such as tin-doped indium oxide (ITO) and amorphous In-Ga-Zn-O (IGZO), Rachel Woods-Robinson et al proposed to produce transparent WBG semiconductors. Additionally, the production of solar cells and screens uses these materials. [13]

Wide bandgap (WBG) semiconductors have been recommended for usage in power electronics and gadgets made for smart grid applications by Javier Ballestn-Fuertes and colleagues. Compared to conventional silicon-based devices, WBG semiconductors like silicon carbide (SiC) and gallium nitride (GaN) provide benefits in terms of efficiency, switching speed, and power dissipation. Such smart features make WBG devices well-suited for use in smart grids, where they can help increase energy efficiency, improve grid stability, and reduce overall energy consumption. The adoption of WBG technology in power electronics and devices is a promising avenue for advancing the smart grid concept and achieving a more sustainable energy future[14].

2.2 Wide Bandgap MESFETs

Here is some literature review mainly focused on WBG materials

Table 2.1:Research and Development History of WBG MESFETs

Author	Year	Development	Ref.
Muench et al.	1977	First wide bandgap MESFET fabricated using SiC.	[16]
Scott et al.	1984	Wide band MESFET's model using dual gate.	[17]
Aksun et al.	1986	Quater micron MESFETs with G_M = 360 mS/mm, f_T = 55 GHz and NF = 2.8 dB.	[18]
Kelner et al.	1987	SiC MESFETs structure using *p*-type Si substrate with G_M = 2.3 mS/mm	[19]
Asif et al.	1993	GaN MESFETs having L_g = 4 μm and W = 100 μm with G_M = 23 mS/mm, V_B = 120 V and $\upsilon_s = 5\times10^6$ cm/s.	[20]
Allen et al.	1997	SiC MESFETs having L_g = 0.45 μm for high power Sband applications with f_T = 22 GHz and f_{max} = 50 GHz.	[21]
Clarke et al.	2002	Development of 4H-SiC MESFETs for S-band applications with PD = 5.6 W/mm and PAE = 36%.	[22]
Henry et al.	2004	SiC power MESFETs for S-band operations with 20 W output power, PD = 4.4 W/mm, and PAE = 60%.	[23]
Rorsman et al.	2004	Effects of L_g on f_T, f_{max} and PD.	[24]
Gang et al.	2010	MESFETs fabrication using home-grown epi structures with PD = 7.8 W/mm and PAE = 40%.	[25]

Chuan et al.	2013	MESFETs with a multi-recessed gate and a dual p-buffer layer.	[26]
Jia et al.	2015	MESFET fabrication using multi-recessed source/drain drift regions.	[27]

2.3 Conclusion

This chapter describes the shifting of world towards the renewable energy resources such as towards Solar Energy. It also describes how can we use the parking lots to generate electricity and utilize it to charge the Electric vehicles or if there are no EVs, this electricity can result in the lowering of the load on the main grid. It also tells about the types of DC-DC converters and the generation of semi-conductions that are being used in these electronics. It also describes the generations of semiconductors such as Silicon semiconductors are considered as 1^{st} generation of semiconductors while the materials like Gallium Nitride and Silicon Carbide are the latest generation of semiconductors.

CHAPTER 3
DATA COLLECTION AND METHODOLOGY

All the data collected from previous researches is being utilized in order to simulate the whole scenario in the software. All the simulations were done on the software called MATLAB.

3.1 Designed Circuit on Simulink

The circuit I designed was on Simulink was of a boost DC-DC converter. It consisted of diode, inductor, capacitor, load, MOSFET and pulse generator. The circuit configuration was of boost converter. The circuit diagram is following figure 3.1:

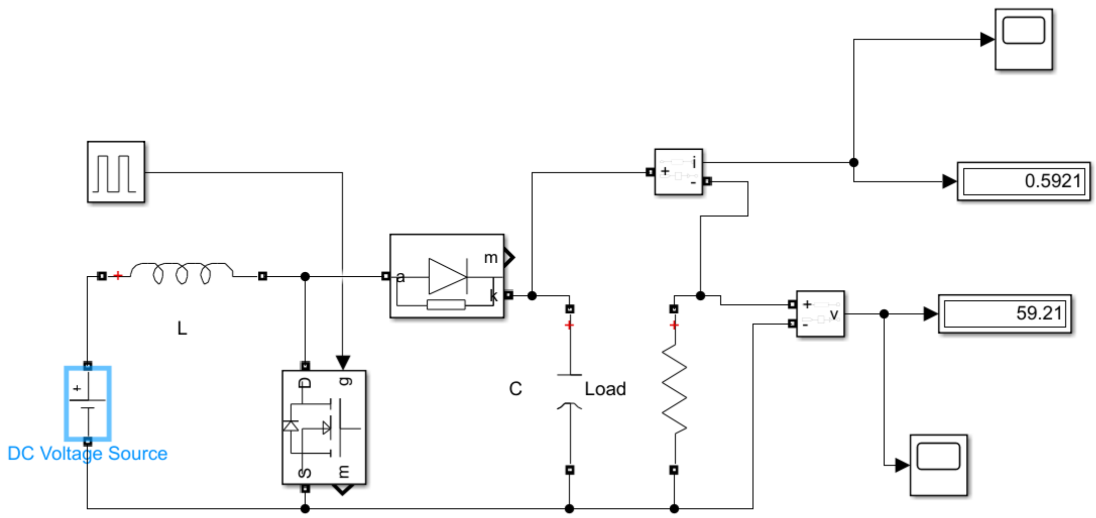

Figure 3.1:Simulink Circuit

The input voltages were 5V as we are assuming the power supply as a renewable energy resource. We are taking the ideal conditions in order to get maximum efficiency. Also, the load is assumed as an electric vehicle, which is going to charge by the energy supplied by the converter. A voltage measurement device and an oscilloscope are connected in order to measure the voltage across the load and observe the waveform behaviour, respectively.

3.2 Internal Structure of WBG based FET

The internal components of the FET employed in the simulations are depicted in the following diagram. The values of the following parameters are kept as low as possible: CGS (Gate to Source Capacitance), CGD (Gate to Drain Capacitance), RDS (Drain to Source Resistance), CDS (Drain to Source), and RI. Their values are 10^{-6} or below. Because these are the intrinsic devices of the FET. The output efficiency of the transistor is dependent on these properties. I_M is the current source and it has high frequency which results in high switching frequency of transistor. The internal circuit of transistors is shown in Figure 3.2, together with intrinsic and extrinsic device elements.

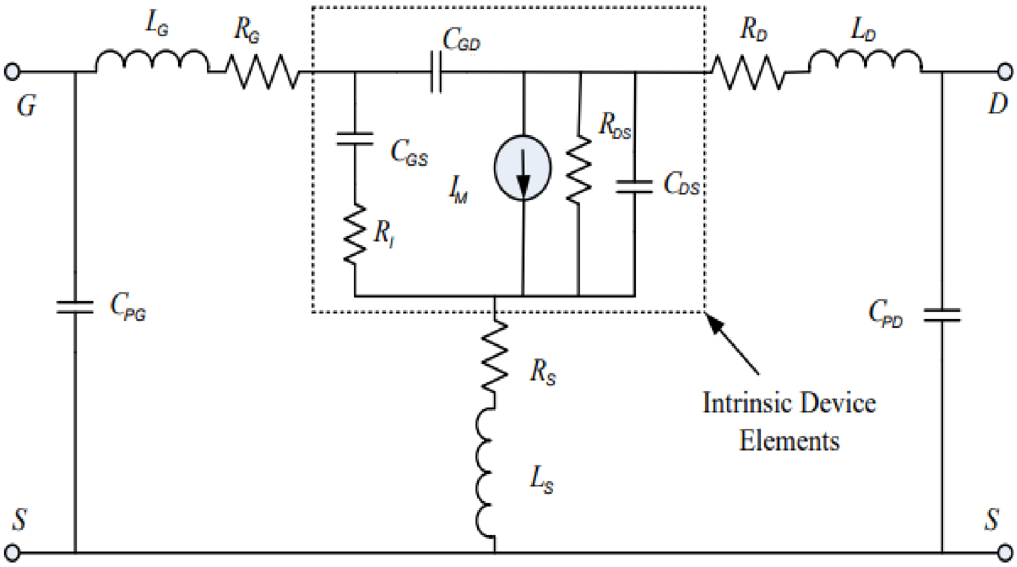

Figure 3.2:Internal Elements of Transistor

Here are some performance parameters comparison in the following table

Table 3.1: Performance Parameters Comparison [30]

Parameter	**MESFET**	**HEMT**
Threshold voltage, V_T	Low	High (Approx. >0 V)
Transconductance, G_M	Low	High
Breakdown voltage, V_{Br}	Low	High
Capacitances	Monotonically varies	Decrease rapidly
Operating voltage	High (Approx. 50 V)	Very high
Power handling capacity	High due to high operating voltage	Very high
PD	High due to high operating voltage	Very high
Power added efficiency	High	Very high

Operating temperature	As large as 500 ˚C	As large as 700 ˚C (ultimate limit is ceramic packaging)
Drain-to-source resistance, R_{DS}	High	Low

3.3 Behavior of Output Waveforms and Results

The simulation took 0.08 seconds to complete. According to figure 3.3, the voltages were raised from 12V to about 60V. The values of the voltages are displayed on the y-axis and the total run time is on the x-axis. At almost 0.03s, the wave form has stabilized.

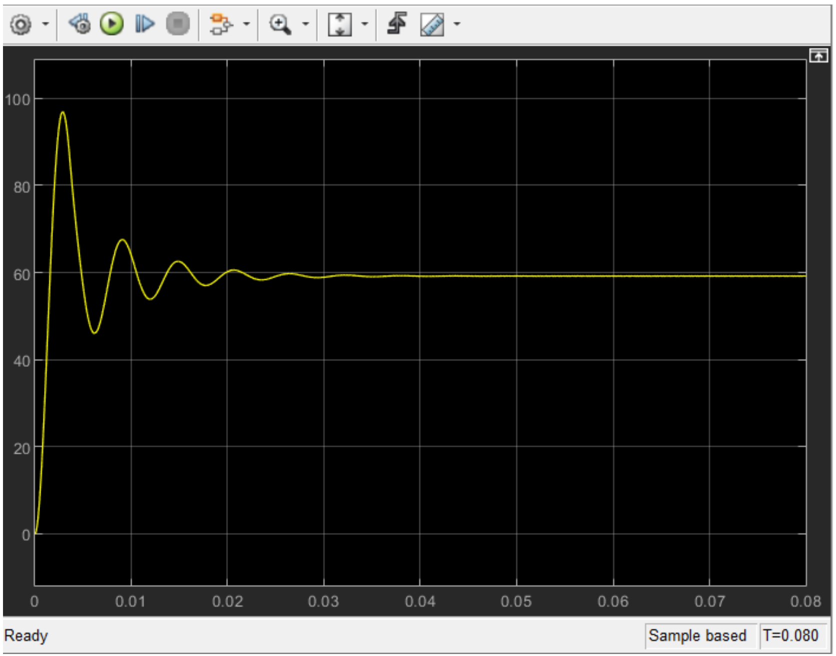

Figure 3.3: Voltage Behavior of DC-DC Converter

Additionally, the behaviour of the current was observed since, as shown in figure 3.4, the current I, which is on the y-axis of the graph while the current in is on the x-axis:

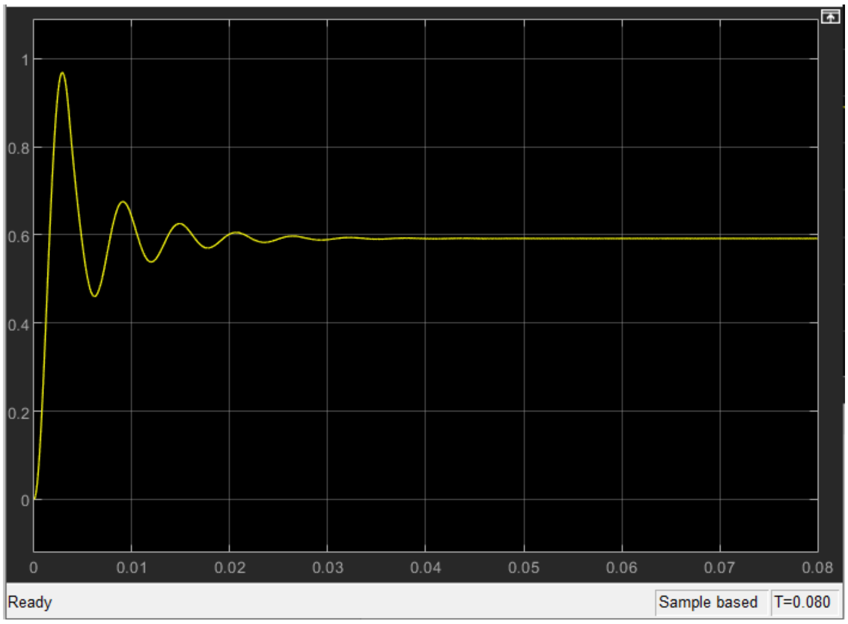

Figure 3.4: Current Behavior of DC-DC Converter

3.6 Characteristics of Transistors

The specific transistor which is being used have following characteristics as shown in the Table 3.2:

Table 3.2: Specifications of Transistor [29]

Key Specifications	
V_{DS} (V) min	600
V_{TDS} (V) max	750
$R_{DS(on)}$ (mΩ) max*	180
Q_{rr} (nC) typ	54
Q_g (nC) typ	6

Where Q_{rr} (nC) typ is a parameter that describes the reverse recovery charge of a diode. Q_{rr} stands for "reverse recovery charge" and is typically measured in nanoCoulombs (nC). A MOSFET's gate charge is described by a parameter called Qg (nC) typ, which stands for Metal-Oxide-Semiconductor Field-Effect Transistor. The term "gate charge" (Qg) is used and is normally expressed in nanoCoulombs (nC).

3.7 C++ Code for Arduino

Arduino is being used for smart controlling. It is programmed in C++ language. The code is following

```
#include <LiquidCrystal.h>// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(2, 3, 4, 5, 6, 7);

float Voltage1 = A0;        //Defining and initializing the voltage
float Voltage2 = A1;        //Defining and initializing the voltage
float Voltage3 = A2;        //Defining and initializing the voltage
float Voltage4 = A3;        //Defining and initializing the voltage

float V1=0, V2=0, V3=0, V4=0;
int adc_value;
int percent_value;
int stop=0, timer=5;
#define relay1 8
#define relay2 9
#define relay3 10
void setup() {
Serial.begin(9600);
pinMode(Voltage1,INPUT);       //Set voltage as input pin
pinMode(Voltage2,INPUT);       //Set voltage as input pin
pinMode(Voltage3,INPUT);       //Set voltage as input pin
pinMode(Voltage4,INPUT);       //Set voltage as input pin

pinMode(relay1,OUTPUT);
pinMode(relay2,OUTPUT);
pinMode(relay3,OUTPUT);

lcd.begin(20, 4);
lcd.clear();
```

lcd.setCursor(3,1);
lcd.print("WELCOME To");
lcd.setCursor(5,2);
lcd.print("");
delay(4000);
lcd.clear();
}
void loop(){
V1= ((analogRead(Voltage1)*(4.5/1023)*10));
V2= ((analogRead(Voltage2)*(4.5/1023)*10));
V3= ((analogRead(Voltage3)*(4.5/1023)*10));
V4= ((analogRead(Voltage4)*(4.5/1023)*10));
lcd.setCursor(0,0);
lcd.print("Solar:");
lcd.print(V2,1);
lcd.print(" ");
lcd.setCursor(0,1);
lcd.print("MPPT Out:");
lcd.print(V3,1);
lcd.print(" ");
lcd.setCursor(0,2);
lcd.print("UPS Battery:");
lcd.print(V4,1);
lcd.print(" ");
lcd.setCursor(0,3);
lcd.print("Battery:");
lcd.print(V1,1);

```
lcd.print("  ");
lcd.setCursor(13,3);
lcd.print("C:");
if(V1>10){ lcd.print("Off  ");
stop=0; digitalWrite(relay1, LOW);
}
if(V1<6){stop=1;}
if(stop==1){
if(V2>12){lcd.print("S  ");
digitalWrite(relay1, HIGH); //s
}else{digitalWrite(relay1, LOW); lcd.print("  ");}
if(V2<11 && V4>10){lcd.print("UPS ");
digitalWrite(relay2, HIGH);//w
}else{digitalWrite(relay2, LOW); lcd.print("  ");}

}else{
    if(V4<10)digitalWrite(relay3, HIGH);
else if(V4>13)digitalWrite(relay3, LOW);
}

delay(200);
}
```

3.8 Cascode Device Structure

Here is the internal structure of the transistor in which Gate, Source and Drain are mentioned:

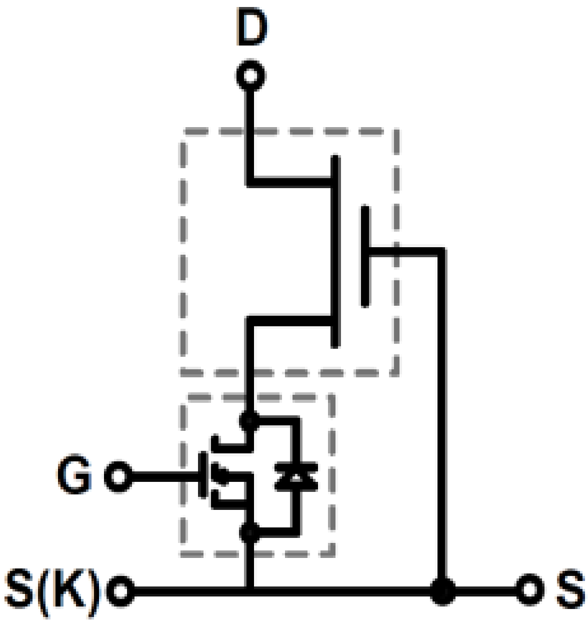

Figure 3.5: Cascode Device Structure [29]

Table 3.3: Electrical Parameters (TC=25°C unless otherwise stated) [29]

<table>
<tr><th>Symbol</th><th colspan="2">Parameter</th><th>Limit Value</th><th>Unit</th></tr>
<tr><td>$I_{D25^\circ C}$</td><td colspan="2">Continuous drain current @T_C=25°C</td><td>17</td><td>A</td></tr>
<tr><td>$I_{D100^\circ C}$</td><td colspan="2">Continuous drain current @T_C=100°C</td><td>12</td><td>A</td></tr>
<tr><td>I_{DM}</td><td colspan="2">Pulsed drain current (pulse width: 100µs)</td><td>60</td><td>A</td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td></tr>
<tr><td>V_{DSS}</td><td colspan="2">Drain to source voltage</td><td>600</td><td>V</td></tr>
<tr><td>V_{TDS}</td><td colspan="2">Transient drain to source voltage [b]</td><td>750</td><td>V</td></tr>
<tr><td>V_{GSS}</td><td colspan="2">Gate to source voltage</td><td>±18</td><td>V</td></tr>
<tr><td>$P_{D25^\circ C}$</td><td colspan="2">Maximum power dissipation</td><td>96</td><td>W</td></tr>
<tr><td>T_C</td><td rowspan="2">Operating temperature</td><td>Case</td><td>-55 to +150</td><td>°C</td></tr>
<tr><td>T_J</td><td>Junction</td><td>-55 to +175</td><td>°C</td></tr>
<tr><td>T_S</td><td colspan="2">Storage temperature</td><td>-55 to +150</td><td>°C</td></tr>
<tr><td>T_{CSOLD}</td><td colspan="2">Soldering peak temperature [c]</td><td>260</td><td>°C</td></tr>
</table>

Table 3.4: Detailed Parameters of FET [29]

Symbol	Parameter	Min	Typ	Max	Unit	Test Conditions
Forward Device Characteristics						
$V_{DSS-MAX}$	Maximum drain-source voltage	600	—	—	V	V_{GS}=0V
$V_{GS(th)}$	Gate threshold voltage	1.65	2.1	2.6	V	V_{DS}=V_{GS}, I_D=500μA
$R_{DS(on)}$	Drain-source on-resistance (T_J=25°C) [a]	—	150	180	mΩ	V_{GS}=8V, I_D=11A, T_J=25°C
	Drain-source on-resistance (T_J=175°C) [a]	—	340	—		V_{GS}=8V, I_D=11A, T_J=175°C
I_{DSS}	Drain-to-source leakage current (T_J=25°C)	—	2.5	30	μA	V_{DS}=600V, V_{GS}=0V, T_J=25°C
	Drain-to-source leakage current (T_J=150°C)	—	8	—		V_{DS}=600V, V_{GS}=0V, T_J=150°C
I_{GSS}	Gate-to-source forward leakage current	—	—	100	nA	V_{GS}=18V
	Gate-to-source reverse leakage current	—	—	-100		V_{GS}=-18V
C_{ISS}	Input capacitance	—	760	—	pF	V_{GS}=0V, V_{DS}=480V, f=1MHz
C_{OSS}	Output capacitance	—	44	—		
C_{RSS}	Reverse transfer capacitance	—	5	—		
$C_{O(er)}$	Output capacitance, energy related [b]	—	64	—	pF	V_{GS}=0V, V_{DS}=0V to 480V
$C_{O(tr)}$	Output capacitance, time related [c]	—	105	—		
Q_g	Total gate charge [d]	—	6.2	9.3	nC	V_{DS}=100V, V_{GS}=0V to 4.5V, I_D=11A
Q_{gs}	Gate-source charge	—	2.1	—		

Q_{gd}	Gate-drain charge	—	2.2	—		
$t_{d(on)}$	Turn-on delay	—	6	—	ns	V_{DS}=480V, V_{GS}=0V to 10V, I_D=11A, R_G=2Ω
t_r	Rise time	—	4.5	—		
$T_{d(off)}$	Turn-off delay	—	9.7	—		
t_f	Fall time	—	4	—		
Reverse Device Characteristics						
I_S	Reverse current	—	—	12	A	V_{GS}=0V, T_C=100°C, ≤50% Duty Cycle
V_{SD}	Reverse voltage [a]	—	2.6	—	V	V_{GS}=0V, I_S=12A, T_J=25°C
		—	4.6	—		V_{GS}=0V, I_S=12A, T_J=175°C
		—	1.8	—		V_{GS}=0V, I_S=6A, T_J=25°C
t_{rr}	Reverse recovery time	—	17	—	ns	I_S=11A, V_{DD}=400V, di/dt=2000A/µs, T_J=25°C
Q_{rr}	Reverse recovery charge	—	54	—	nC	

CHAPTER 4
HARDWARE IMPLEMENTATION

4.1 Introduction

The prototype is basically working as an OFF-Grid system as it has a backup battery, DC-DC converter for stable voltage supply, a Solar panel, a controller for smart operations, and relays for switching.

4.2 Block Diagram

To design and develop the down-scaled model of a smart solar parking lot, here is the proposed block diagram.

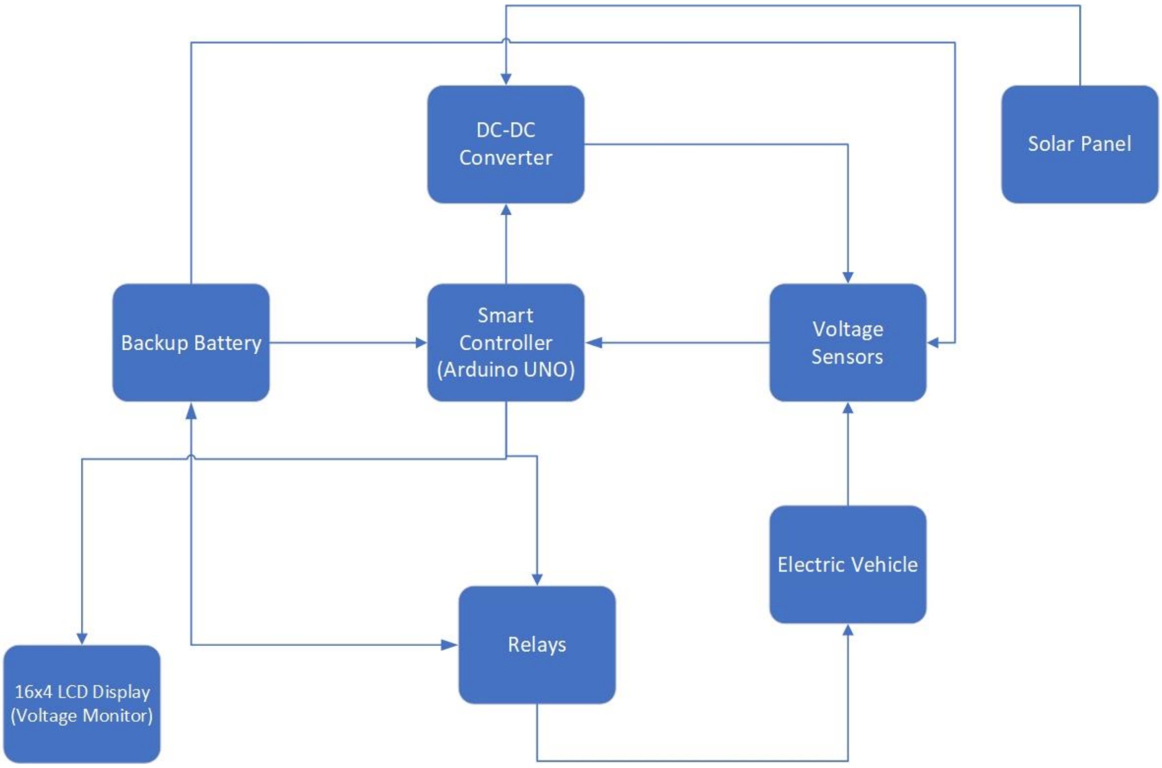

Figure 4.1: Block Diagram of Prototype

The block diagram in Figure 4.1 illustrates the fundamental concept of connection between the prototype's parts. All the smart control operations are being done by controller (Arduino Uno). Relays are being used to direct the supply according to the given conditions. Voltage sensors monitor voltages and communicate with the controller in real time. LCD sows the real time voltages of Solar Panel, MPPT (Maximum Power Point Tracking), backup battery, and electric vehicle.

4.3 List of Components

Following equipment are being used in the prototype

Table 4.1: List of Hardware Components

Sr. No.	Equipment	Quantity
1.	Solar Panel (20Watt)	1
2.	Controller (Arduino Uno)	1
3.	DC-DC Converter (Buck-Boost)	1
4.	Transistors used in Converter()	2
5.	Voltage Sensing Panel	1
6.	16x4 LCD	1
7.	5V Regulator (Transistor 7805)	1
8.	Backup Battery (12V, 4AH)	1
9.	Relays (JQC-3F(T73) 3VDC, 10A)	3
10.	Optocoupler Relay Driver PC817	3
11.	Connection wires	As per Demand
12.	Diodes	7
13.	Electric Vehicle	1

4.3.1 Solar Panel

Photovoltaic (PV) panels, usually referred to as solar panels, are machines that transform sunlight into electricity. They are constructed of several solar cells that cooperate to collect solar energy and transform it into useful electricity.

- **Power Output:** The 20-watt rating indicates the maximum power output of the solar panel when exposed to specific conditions, typically defined as 1000 watts per square meter of solar irradiance, at a temperature of 25°C (77°F), and with sunlight falling perpendicularly to the panel surface. The actual power output can vary depending on environmental factors such as temperature, shading, and orientation.

- **Physical Dimensions:** The physical dimensions of a 20-watt solar panel can vary, but a common size is around 510 mm x 355 mm (20 in x 14 in) for a rectangular-shaped panel. The dimensions may differ depending on the specific manufacturer and model.

- **Solar Cells:** A 20-watt solar panel is composed of individual solar cells, typically made of silicon, which convert sunlight into electricity. The number and arrangement of solar cells determine the panel's voltage and current characteristics.

- **Voltage and Current:** The current and voltage generation from a 20-watt solar panel might differ based on elements like the quantity and arrangement of solar cells. The open-circuit voltage (Voc) and current in the short circuit (Isc) of a common 20-watt solar panel may be in the range of 18 to 22 volts and 1 to 1.2 amps, respectively.

- **Construction and Encapsulation:** Solar panels are constructed with protective materials such as tempered glass on the front surface and a weather-resistant back sheet to ensure durability and protection against environmental conditions. The cells are encapsulated within a protective material, such as ethylene-vinyl acetate (EVA), and supported by a sturdy frame.

- **Application:** A 20-watt solar array is regarded as a tiny panel and is frequently used for a variety of tasks, including recharging batteries, running solar lighting systems, minor off-grid installations, powering educational initiatives, and setting up portable solar systems..

- **Installation and Connectivity:** Solar panels can be installed either standalone or as part of a larger solar system. For connectivity, they typically have positive and negative leads or connectors to facilitate wiring with other components such as charge controllers, batteries, or inverters.

It's crucial to remember that the aforementioned parameters are approximations and may change based on the individual 20-watt solar panel model and manufacturer. When selecting a solar panel, it's essential to consider your specific power requirements, available sunlight, and other factors to ensure it meets your needs.

Figure 4.2: Solar Panel (20Watts)

Here are some Mathematical Terms

- **Power (P):** The amount of voltage (V) & current (I) generated by a solar panel are multiplied to determine its power output. It has the following mathematical expression:

$$P = V \times I \text{ ………………………………(4.1)}$$

where P is the watts (W) of output power, V is the voltage at which it operates (V), and the value I is the amperes (A) of current.

- **Efficiency (η):** The efficiency of a solar panel represents the ratio of the actual power output to the amount of solar energy it receives. It is expressed as a percentage. The efficiency can be calculated using the following equation:

$$\eta = (\frac{P}{Pin})\ x\ 100 \text{ ………………………………(4.2)}$$

where η is the efficiency, P is the power output of the panel, and P_{in} is the solar energy incident on the panel.

- **Energy (E):** The energy generated by a solar panel over a specific period of time can be calculated by multiplying the power output (P) by the duration (t). It can be expressed as:

$$E = P \times t \text{ ………………………………(4.3)}$$

where t is the amount of time in hours (h), P is the output power in watts (W), and E is the amount of energy used in watt-hours (Wh).

- **Current-Voltage (I-V) Curve:** The I-V curve of a solar panel can be used to show the current-voltage relationship. It demonstrates that the current output changes as the voltage changes. The I-V curve helps understand the panel's performance under different operating conditions and can be used for analysis and system design.

4.3.2 Arduino-UNO

Popular microcontroller boards like the Arduino Uno are frequently utilised for electronic design and prototyping. It is built on the ATmega328P microprocessor and provides a straightforward and user-friendly platform for both new and seasoned manufacturers. The Arduino Uno's specifications are as follows:

- **Microcontroller:** This ATmega328P microcontroller, which runs at a clock rate of 16 MHz, supplies electricity to the Arduino Uno. The programme can be stored in 32KB of flash memory, variables can be stored in 2KB of SRAM, and non-volatile data can be stored in 1KB of EEPROM.

- **Digital I/O Pins:** There are fourteen pins for digital input and output on the board, numbered 0 through 13. Numerous actuators, sensors, and various other electronic components can be connected using these pins, which can be set up as inputs or outputs.
- **Analog Inputs:** The six analogue input pins on an Arduino Uno are numbered A0 to A5. These pins are helpful for interacting with analogue sensors including sensors for temperature, sensors for light, and potentiometers and can read analogue voltages from 0 to 5 volts.
- **PWM Outputs:** Among the digital pins, 6 pins (marked with "~" symbol) support Pulse Width Modulation (PWM) output. PWM allows you to simulate analog output by controlling the width of the pulse. This feature is handy for tasks such as controlling motor speed or LED brightness.
- **Power Supply:** There are various ways to power the Arduino Uno. A USB (Universal Serial Bus) link to the a computer system, a direct current (DC) connector that has a suggested voltage range of 7–12V, or a separate power source linked via the 5V line or Vin pin can all be used to power the device.
- **Communication Interfaces:** A integrated USB interface on the Arduino Uno enables it to be linked to an operating system for communication and programming. During in-circuit programming and debugging, it also contains a special ICSP header. Additionally, it enables serial connection using software serial libraries and equipment UART (Universal Asynchronous Receiver-Transmitter).
- **Programming:** The Arduino Development Software (IDE), which offers an easy-to-use interface for creating, developing, and publishing code to the board, can be used to programming the Arduino Uno. A simplified form of C++ that includes Arduino-specific libraries and functions is the programming language utilised.
- **Shields and Expansion:** Arduino Uno is compatible with a wide range of expansion boards called "shields" that provide additional features and functionalities. Shields can be easily stacked on top of the Arduino Uno board to extend its capabilities, such as adding Wi-Fi connectivity, motor control, or LCD displays.

Figure 4.3: Arduino UNO

Figure 4.3 depicts the Arduino UNO's physical layout. Due to its simplicity and adaptability, Arduino Uno is a preferred choice among professionals, students, and hobbyists. It is simple to locate tools, instructions, & project concepts to get begun with creating individual electronic projects because to its big community and comprehensive documentation.

4.3.3 C++ Code for Arduino UNO

Arduino is being used for smart controlling. It is programmed in C++ language. The code is following

#include <LiquidCrystal.h>// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(2, 3, 4, 5, 6, 7);
float Voltage1 = A0;   //Defining and initializing the voltage
float Voltage2 = A1;   //Defining and initializing the voltage
float Voltage3 = A2;   //Defining and initializing the voltage
float Voltage4 = A3;   //Defining and initializing the voltage
float V1=0, V2=0, V3=0, V4=0;
int adc_value;
int percent_value;
int stop=0, timer=5;

```
#define relay1 8
#define relay2 9
#define relay3 10

void setup() {
Serial.begin(9600);

pinMode(Voltage1,INPUT);        //Set voltage as input pin
pinMode(Voltage2,INPUT);        //Set voltage as input pin
pinMode(Voltage3,INPUT);        //Set voltage as input pin
pinMode(Voltage4,INPUT);        //Set voltage as input pin

pinMode(relay1,OUTPUT);
pinMode(relay2,OUTPUT);
pinMode(relay3,OUTPUT);

lcd.begin(20, 4);
lcd.clear();
lcd.setCursor(3,1);
lcd.print("WELCOME To");
lcd.setCursor(5,2);
lcd.print("");
delay(4000);
lcd.clear();
}

void loop(){
```

V1= ((analogRead(Voltage1)*(4.5/1023)*10));
V2= ((analogRead(Voltage2)*(4.5/1023)*10));
V3= ((analogRead(Voltage3)*(4.5/1023)*10));
V4= ((analogRead(Voltage4)*(4.5/1023)*10));
lcd.setCursor(0,0);
lcd.print("Solar:");
lcd.print(V2,1);
lcd.print(" ");
lcd.setCursor(0,1);
lcd.print("MPPT Out:");
lcd.print(V3,1);
lcd.print(" ");
lcd.setCursor(0,2);
lcd.print("UPS Battery:");
lcd.print(V4,1);
lcd.print(" ");
lcd.setCursor(0,3);
lcd.print("Battery:");
lcd.print(V1,1);
lcd.print(" ");
lcd.setCursor(13,3);
lcd.print("C:");

if(V1>10){ lcd.print("Off ");
stop=0; digitalWrite(relay1, LOW);
}
if(V1<6){stop=1;}
if(stop==1){
if(V2>12){lcd.print("S ");
digitalWrite(relay1, HIGH); //s
}else{digitalWrite(relay1, LOW); lcd.print(" ");}
if(V2<11 && V4>10){lcd.print("UPS ");
digitalWrite(relay2, HIGH);//w
}else{digitalWrite(relay2, LOW); lcd.print(" ");}
}else{
if(V4<10)digitalWrite(relay3, HIGH);
else if(V4>13)digitalWrite(relay3, LOW);
}
delay(200);
}

4.3.4 DC-DC Converter

An electrical circuit known as a DC-DC converter, more precisely a Buck-Boost converter, transforms a DC (direct current) voltage that is supplied into a distinct DC output voltage level that could be greater or lesser than the input voltage. The Buck-Boost converter is a kind of switching power supply that effectively controls the output voltage using a mix of switches that are needed, inductors, capacitors, and diodes.

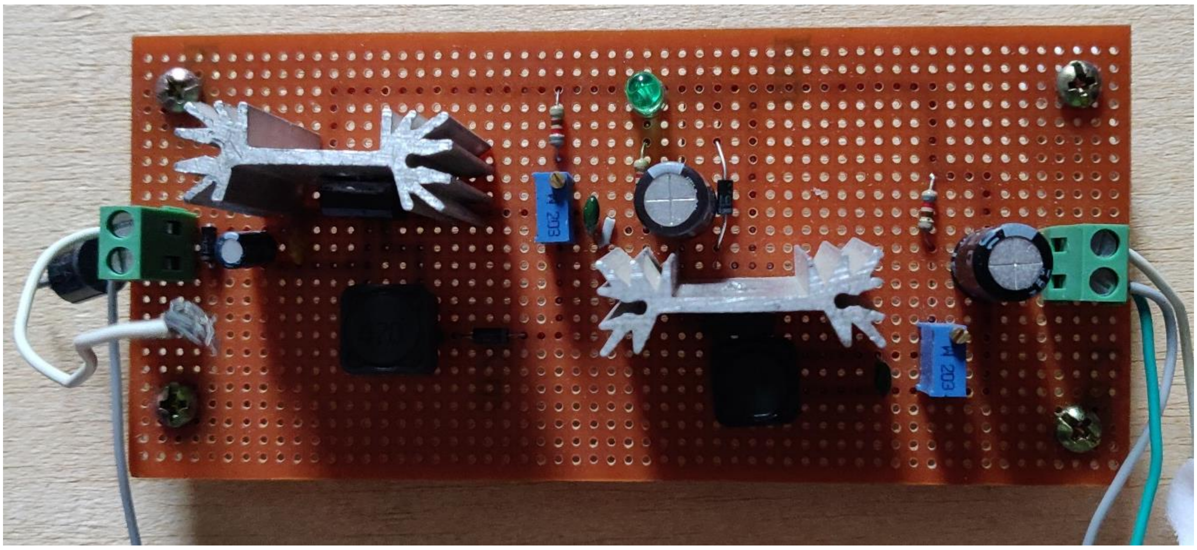

Figure 4.4: DC-DC Converter (Buck-Boost)

Following are some specifics regarding the Buck-Boost converter:

- **Working Principle:** The pulse-width modulated (PWM) signal controls a switch (usually a transistor) that switches the source voltages either on or off at a high rate in the Buck-Boost converter's operation. An inductor stores energy when the switch that controls it is turned on, and the stored power is transmitted to the output when the switching is turned off. The switch's duty cycle can be adjusted to modify the switch's average output voltage.
- **Step-Up and Step-Down Operation:** A Buck-Boost conversion may step up the voltage at the input to produce an output voltage that's greater or step down the input voltage to produce a lower output voltage. Due to its adaptability, it may be used in a range of applications where varying voltage levels or variable input voltage are necessary.
- **Efficiency:** Buck-Boost converters are known for their high efficiency. The switching action allows for efficient power transfer with minimal power loss compared to linear regulators. However, the efficiency can vary depending on factors such as input/output voltage differential, switching frequency, and component quality.
- **Voltage Regulation:** The output voltage of the Buck-Boost converter is controlled through feedback. The output voltage is compared to a reference voltage using a voltage feedback loop, and the amount of duty period of the switch is changed as necessary. Even when there are changes in the load or input voltage fluctuations, this feedback mechanism aids in maintaining a consistent output voltage..

- **Applications:** Buck-Boost converters find applications in various electronic devices and systems. Some common uses include battery-powered devices, portable electronics, solar power systems, electric vehicles, LED lighting, and telecommunications equipment. They are particularly useful in situations where the input voltage may be unpredictable or when a regulated output voltage is required regardless of the input voltage level.
- **Design Considerations:** Input/output voltages spectrum, current load specifications, effectiveness, switch the frequency, components selection, and protective features should all be considered while developing or operating a Buck-Boost converter. Due to power consumption in the switching components, temperature considerations are also significant.

So Here are some common equations for a basic Buck converter, Boost converter, and Buck-Boost converter:

- **Buck Converter:**

Output Voltage $(Vout) = Duty\ Cycle\ (D) \times Input\ Voltage\ (Vin)$ ……..(4.3.4.1)

Efficiency $(\eta) = (Vout \times Iout) / (Vin \times Iin)$ ………..………..…(4.3.4.2)

where Vin is the source electricity, Vout is the resultant voltage, Iin is the current at the input, and I out is the current at the output, and D is the average duty cycles (the proportion of the switch-on duration to the overall switching period).

- **Boost Converter:**

Output Voltage $(Vout) = (Vin / (1 - D))$ ……………………………………(4.3.4.3)

Efficiency $(\eta) = (Vout \times Iout) / (Vin \times Iin)$ ………………………………(4.3.4.4)

where Iin is the source of current, Iout is the resultant current, D is the percentage of a duty cycle, and Vin and Vout are the input and output voltages, respectively.

- **Buck-Boost Converter:**

Output Voltage $(Vout) = (D \times Vin) / (1 - D)$ ………………………………(4.3.4.5)

Efficiency $(\eta) = (Vout \times Iout) / (Vin \times Iin)$ ………………….……………(4.3.4.6)

where Iin is the source of current, Iout is the resultant current, D is the percentage of a duty period, and Vin and Vout are the input and output voltages, respectively.

It's important to remember that DC-DC converters come in a variety of forms, including step-down Buck converters, step-up Boost converters, and step-up/step-down Buck-Boost converters. Every type operates on the idea of efficiently converting DC power, albeit each has unique properties and uses.

4.3.5 Transistor Used in Converter (XL6609E1)

This particular transistor is used in the Buck-Boost converter. It has following Features:

- Wide input voltage range of 5 to 32 volts
- Output voltage, whether positive or negative
- Using just one feedback pin for programming.
- Reference adjustable version at 1.25V
- Constant switching frequency of 400 kHz
- Maximum 4A switching current
- Built-in Over Voltage Protection for SW PIN
- Superb load and line regulation
- Enable EN PIN TTL shutdown
- High performance of up to 94%
- Built-in frequency adjustment
- Built-in frequency adjustment
- Internal current limit feature

4.3.4 Voltage Sensor

Voltage sensors are electronic gadgets or systems that measure the potential level of an electrical signal or power source. They are also referred to as voltage sensors or voltage monitors. They frequently track and identify voltages for security, control, or measurements in a variety of applications.

As there are any techniques which are used to monitor voltages but here we are using Voltage Divider A simple and common method to sense voltage is by using voltage dividers. This involves connecting a series of resistors in a specific ratio to the voltage being measured. The voltage across a specific resistor in the divider can then be measured using an analog-to-digital converter (ADC) or an instrumentation amplifier.

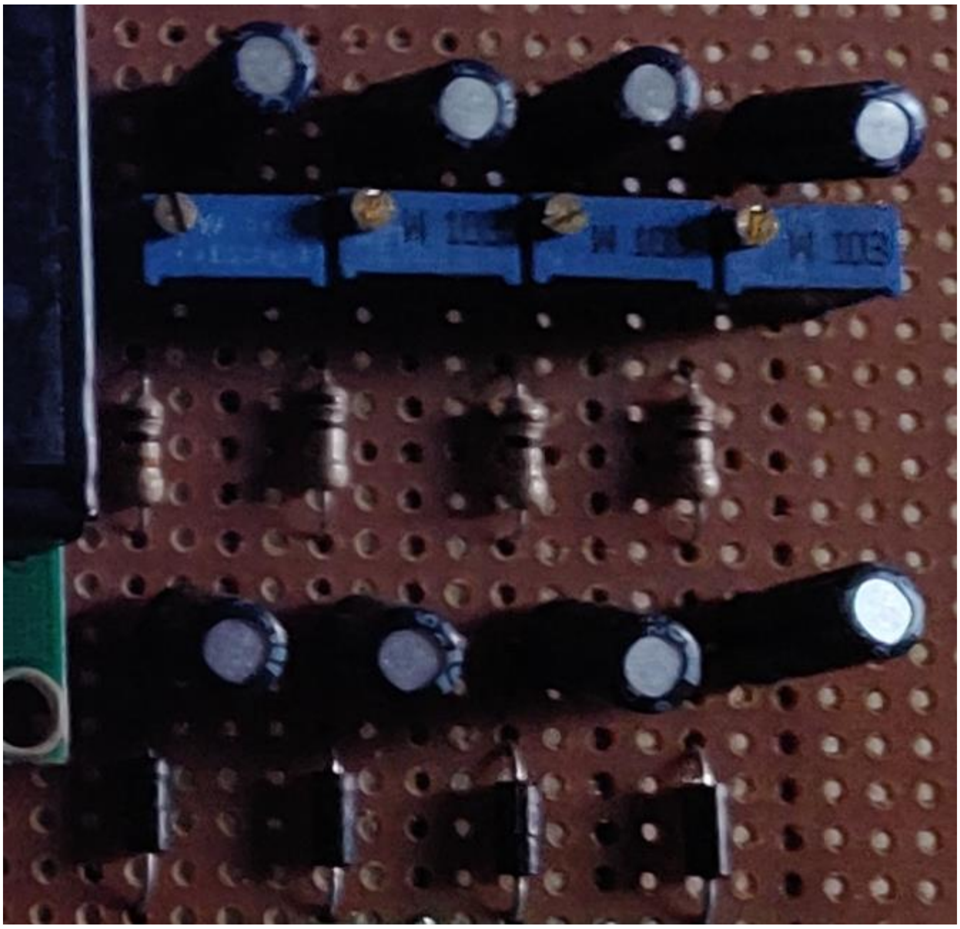

Figure 4.5: Voltage Divider Circuit

Voltage sensors are essential for a variety of applications, including as voltage regulation, safety systems, motor control, battery management, and power supply monitoring. Voltage range, precision, speed of response, consumption of electricity, and interface compliance to the remaining components of the system's components are some of the criteria used to choose a voltage sensor.

4.3.5 LCD (16x4)

A 16x4 LCD (Liquid Crystal Display) refers to a type of alphanumeric display module that can display 16 characters per line and has 4 lines. It is commonly used in various electronic devices and microcontroller-based projects for displaying text and basic graphical information. Here are some details about a typical 16x4 LCD:

- **Display Format:** The 16x4 LCD has a total of 16 characters (letters, numbers, symbols) that can be displayed per line and 4 lines in total. This provides a total of 64 character spaces for displaying information.

- **Character Size:** The character size on a 16x4 LCD is typically 5x8 pixels. Each character occupies a rectangular area of 5 pixels wide and 8 pixels high.
- **Communication Interface:** 16x4 LCD modules are commonly compatible with the Hitachi HD44780 LCD controller, which supports a parallel interface. It requires a minimum of 6 data lines (DB0-DB7) and several control lines (such as RS, RW, and E) for communication with a microcontroller or other control circuitry.
- **Backlight:** Many 16x4 LCD modules come with a built-in LED backlight for better visibility in low-light conditions. The backlight can be controlled separately from the character display.
- **Power Supply:** The typical operating voltage for a 16x4 LCD is 5V, although some modules may support a wider voltage range. It requires a power supply for both the logic circuitry and the backlight (if applicable).
- **Command Set:** The 16x4 LCD module uses a specific set of commands to control its operation, such as writing characters to the display, positioning the cursor, clearing the display, and controlling the backlight. These commands are sent over the communication interface to the LCD controller.
- **Library Support:** To simplify the usage of 16x4 LCD modules, there are various libraries available for popular microcontroller platforms like Arduino. These libraries provide functions and abstractions to easily interface with the LCD module and display text or custom characters.
- **Application:** 16x4 LCDs are commonly used in devices where more text needs to be displayed compared to a standard 16x2 LCD. They can be found in applications such as digital signage, industrial control panels, measurement instruments, and data loggers.

When using a 16x4 LCD, it's essential to refer to the datasheet or documentation specific to the module you are working with, as pin assignments and command sets may vary slightly among different manufacturers.

4.3.6 5V Regulator (7805)

To provide constant 5V to the LCD and Arduino Uno we are using a regulator so that the required voltages can be acquired.

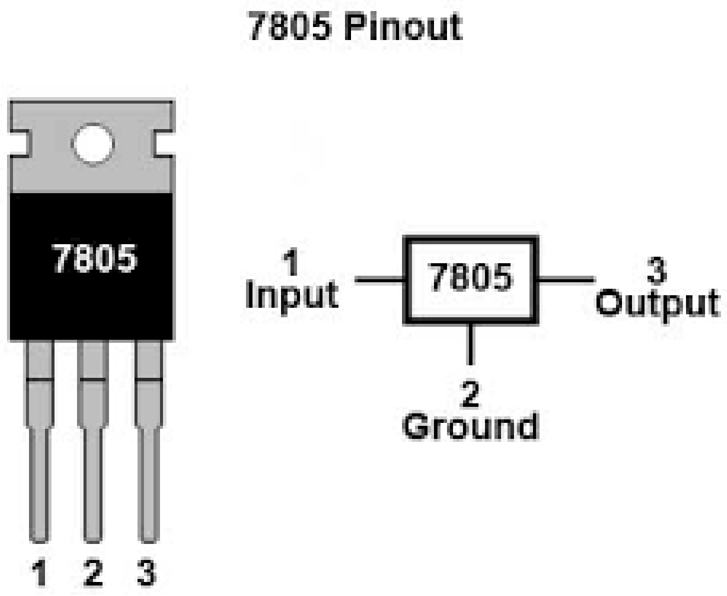

Figure 4.6: 7805 Regulator Transistor

The inside of the equivalent circuit of Figure 4.7 is illustrated below.

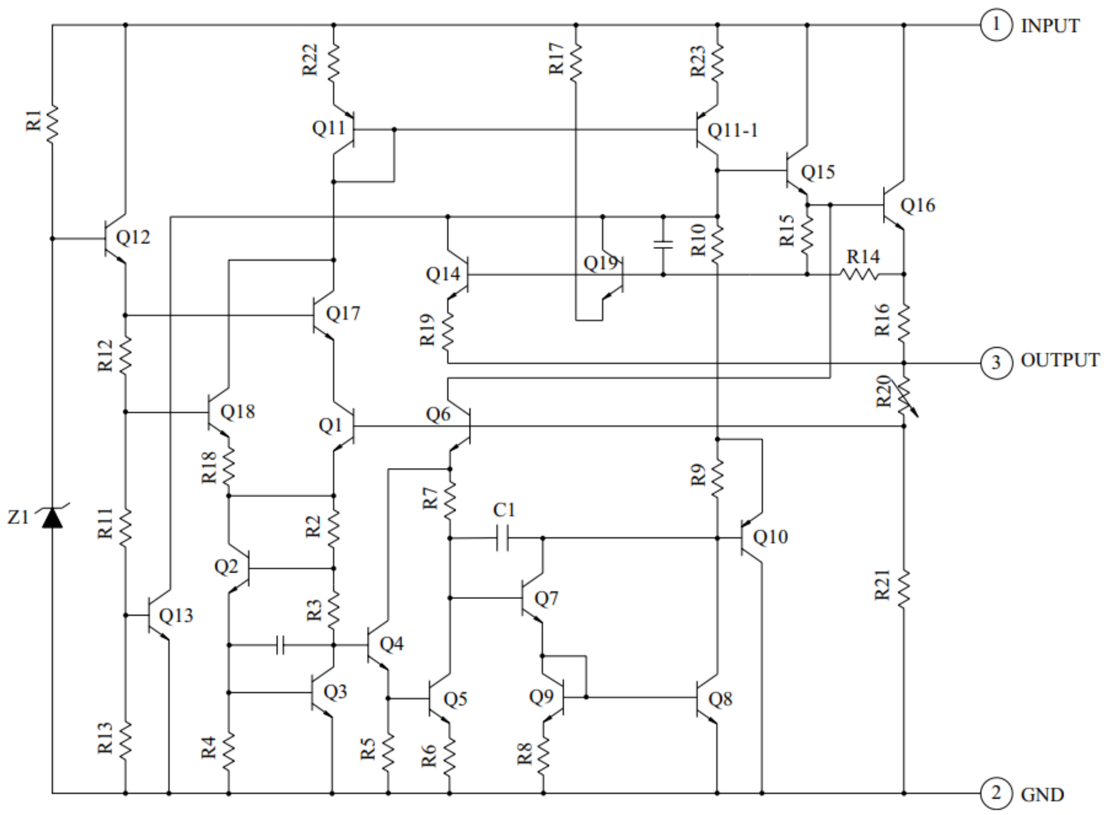

Figure 4.7: Internal Circuit of 7805

4.3.7 Backup Battery (12V, 3AH)

We are using OSAKA battery as a backup battery in order to run the whole circuit and it will be charged through the solar panel. Its type is Lead Acid and it can also be used in motorcycles. Let's break down these specifications:

1. **Voltage (12V):** This indicates the electrical potential or voltage that the battery can provide. In this case, it is 12 volts, which is a common voltage level for many electronic devices and systems.

2. **Capacity (4AH):** The quantity of charge a battery can store and provide over time is measured by its capacity. Usually, it is expressed in ampere-hours (AH). In this case, the battery has a capacity of 4 ampere-hours, which means it can deliver a current of 1 ampere for 4 hours, 2 amperes for 2 hours, or any combination that adds up to 4 ampere-hours.

The backup battery you mentioned can be used to provide a 12-volt power source in situations where a primary power source fails or is unavailable. It is commonly used in applications such as uninterruptible power supplies (UPS), emergency lighting systems, security systems, telecommunications equipment, and other devices that require backup power.

It's worth noting that the actual runtime provided by the battery will depend on the power consumption of the connected devices. Higher power consumption will result in shorter backup times, while lower power consumption will allow for longer backup durations.

Figure 4.8: Lead Acid Battery

4.3.8 Relays (JQC-3F(T73) 3VDC, 10A)

The JQC-3F(T73) relay is an electromagnetic relay that is commonly used in various electronic and electrical applications. Here are some details about this specific relay:

- **Type:** The JQC-3F(T73) relay is a power relay, capable of switching relatively high currents and voltages. There is a single-pole, double-throw (SPDT) relays, which means that it contains a common terminal as well as three other terminals: one typically open (NO), one normally closed (NC), and one that is not.
- **Coil Voltage:** The coil voltage of the JQC-3F(T73) relay is 3V DC, which means it requires a 3-volt direct current to energize the coil and activate the switching mechanism.
- **Contact Rating:** This relay has a contact rating of 10A, which means it is capable of switching currents up to 10 amps. The contacts are designed to handle both AC (alternating current) and DC (direct current) loads.
- **Mounting:** The JQC-3F(T73) relay is typically mounted on a PCB (printed circuit board) using through-hole soldering. It has standard pin configurations for easy integration into circuit designs.
- **Operation:** The JQC-3F(T73) relay operates using an electromagnetic coil that, when energized, generates a magnetic field. The contacts change from the normally closed (NC) state to their ordinarily open (NO) position when the relay armature is drawn to this field. The contacts go back to being closed once the coil is de-energized.
- **Applications:** Relays like the JQC-3F(T73) are commonly used in a wide range of applications where electrical isolation, high-current switching, or signal amplification is required. They are often used in control circuits, automation systems, power distribution, home appliances, automotive electronics, and industrial machinery.

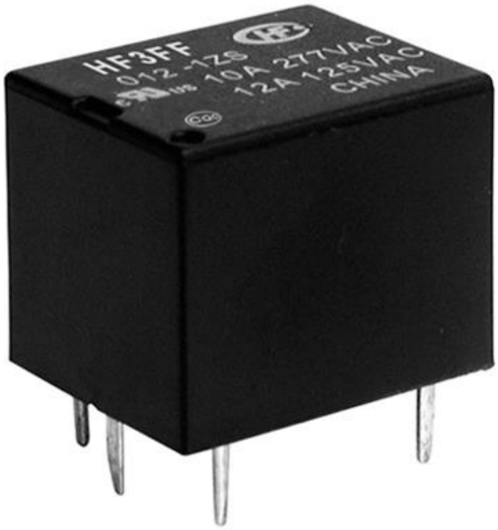

Figure 4.9: Relay JQC-3F(T73)

It's important to note that the JQC-3F(T73) relay is just one specific model as shown in the figure 4.9, and there are various other relay types and models available with different specifications, coil voltages, contact ratings, and pin configurations. When using a relay in a specific application, it's essential to refer to the manufacturer's datasheet and specifications to ensure proper selection and understanding of its characteristics and limitations.

4.3.9 Optocoupler Relay Driver PC817

The PC817 is an optocoupler device commonly used as a relay driver. It is made up of a phototransistor and an infrared LED combined into one package. PC817 optocoupler provides electrical isolation between the input and output, allowing for safe interfacing between different voltage levels or electrical systems. Here are some details about the PC817 optocoupler relay driver:

- **Pin Configuration:** The PC817 optocoupler typically has a 4-pin DIP (Dual In-line Package) configuration. The pins are numbered as follows:

    i. **Pin 1:** Anode of the infrared LED (Positive terminal)

    ii. **Pin 2:** Cathode of the infrared LED (Negative terminal)

    iii. **Pin 3:** Collector of the phototransistor

    iv. **Pin 4:** Emitter of the phototransistor

Figure 4.10: PC817 Optocoupler

- **Input-Output Isolation:** The optocoupler offers an electrical barrier between the LED on the input side and the phototransistor on the output side. This separation helps protect sensitive components or circuits from voltage spikes, noise, or potential ground loops.

- **Operation:** When a forward current is applied to the infrared LED (pins 1 and 2), it emits infrared light. This light is detected by the phototransistor (pins 3 and 4), causing the transistor to conduct current between its collector and emitter.

- **Relay Driving:** The PC817 optocoupler is commonly used to drive relays or other high-power loads. The phototransistor's output can be linked to a relay's coil to supply the correct amount of current to energize the coil and turn on the relay switch.

- **Current Transfer Ratio (CTR):** The connection among the source LED current and the resultant phototransistor current is described by the PC817 optocoupler's specified current transfer ratio. It establishes the ratio of input to output signal amplification.

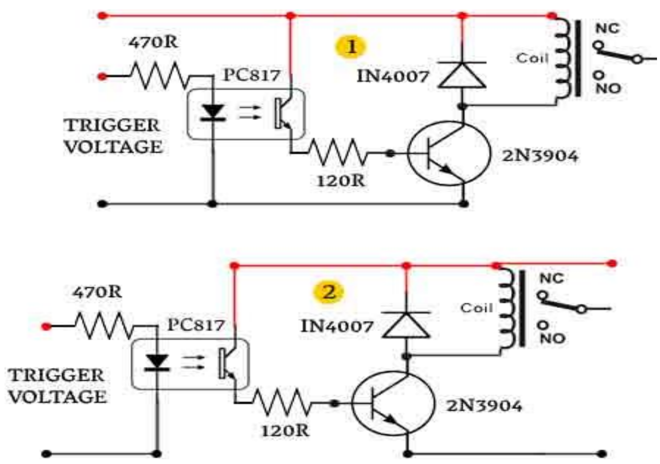

Figure 4.11: Internal Circuit of PC817

- **Voltage and Current Ratings:** The PC817 optocoupler has specific voltage and current ratings, including maximum forward current for the LED, maximum collector-emitter voltage for the phototransistor, and power dissipation limits. These ratings must be considered to ensure proper operation and reliability.
- **Application:** The PC817 optocoupler relay driver is widely used in various applications, including industrial control systems, digital logic circuits, motor control, power supply control, and communication systems. It provides a convenient and safe means of interfacing low-voltage control signals with higher-voltage or high-power loads.

As shown in figure 4.11 there is no physical connection in the PC817. When using the PC817 optocoupler, it's important to consult the manufacturer's datasheet and specifications for precise information on operating conditions, electrical characteristics, and recommended circuit configurations.

4.3.10 Diodes for Protection

Electronic components called diodes carry electricity in one of the directions while limiting it in the other. They are essential components in electronic circuits and are employed in correction, signal modification, voltage regulation, and switching, among other processes.

The so-called semiconductor diode, which is often constructed using components like silicon or germanium, is the most prevalent kind of diode. A high number of carriers of positive charge (p-type) are present on one side of the p-n junction seen in semiconductor diodes, while a greater number of carriers of negative charge (n-type) are present on the other side. This junction produces a depletion area that prevents current from flowing in one direction.

Figure 4.12: Diodes used for Protection

The depletion region narrows and current can flow through the diode when a forward voltage is placed across it in the right position (anode positive, cathode negative for a conventional diode). The diode displays an acceptable resistance to current flow in this forward biased state. On the other hand, if an anode negative, cathode positive voltage is supplied, the depletion region spreads and a large resistance to the current flow results. This state is called reverse bias, and the diode effectively blocks the current.

4.3.11 Electric Vehicle

A down scaled model of electric vehicle is being used in the hardware. It has a battery, two motors for movement and a 12mm barrel jack for recharging purpose. The following figure shows the structure of model EV.

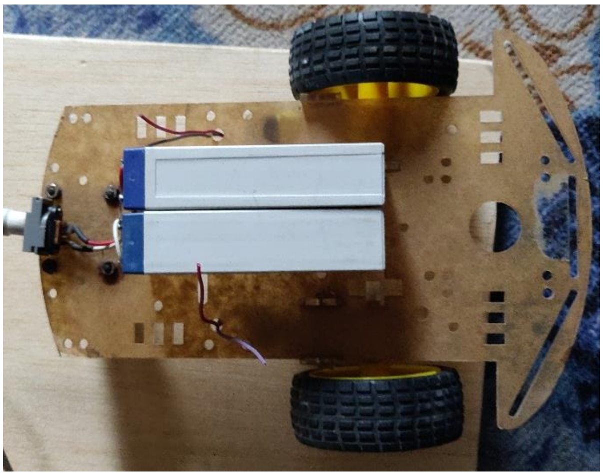

Figure 4.13: Electric Vehicle

CHAPTER 5
BUISNESS DESCRIPTION

5.1 Form of Business

Our company will be organised as a sole proprietorship.

5.1.1 Team/Organizational Structure

Every firm begins on a small size and eventually begins to expand. Similar to this, we will launch our company on a modest scale by creating a distinctive product and attempting to market it globally. Our company will eventually start to expand and unquestionably turn a profit. The positions of power that will be given to the company's members are as follows:

The company will be owned by and directed by Muhammad Hassam Nasir.

Bilal Latif will oversee the marketing division of the business.

5.1.2 Vision

Our goal is to spread awareness of the smart solar parking lot culture. Our core vision values are:

1. Sustainable Energy Generation:
   - Harnessing abundant sunlight using state-of-the-art solar panels.
   - Transforming parking lots into mini solar farms.
   - Generating clean and renewable energy to reduce dependence on fossil fuels.
2. Smart Energy Management:
   - Implementing advanced energy management systems.
   - Real-time monitoring of energy production, consumption, and storage.
   - Optimizing power flow and maximizing energy efficiency.
   - Remote monitoring and maintenance for smooth operation and issue resolution.
3. Environmental Sustainability:
   - Significantly reducing carbon emissions through renewable energy generation.
   - Promoting sustainable practices and reducing reliance on non-renewable resources.
   - Contributing to local and global efforts in mitigating climate change.
4. Community Impact:
   - Providing a sustainable and eco-friendly solution to parking needs.
   - Raising awareness about renewable energy and its benefits.
   - Promoting a cleaner and healthier environment for the community.

5.1.3 Mission

Our Mission is:

- Promote renewable energy adoption.
- Reduce carbon emissions.
- And enhance community engagement through the integration of solar energy in parking lots.

5.1.4 Goal and Objective

The goal of our company is:

1. **Renewable Energy Adoption:**
    - Increase the adoption of solar energy in parking lots.
    - Promote the use of clean and renewable energy sources.
2. **Carbon Footprint Reduction:**
    - Reduce carbon emissions associated with parking lot operations.
    - Minimize the environmental impact of traditional parking infrastructure.
3. **Energy Efficiency:**
    - Optimize energy management systems to maximize energy efficiency.
    - Minimize energy waste and improve overall system performance.
4. **Sustainable Transportation:**
    - Support the growth of electric vehicles by providing charging infrastructure.
    - Encourage the transition to clean and sustainable transportation options.
5. **Community Engagement:**
    - Educate and engage local communities about the benefits of solar energy.
    - Foster awareness and participation in sustainable practices.
6. **Technological Innovation:**
    - Drive advancements in solar panel technology and energy management systems.
    - Foster research and development to improve the efficiency and effectiveness of solar parking lots.
7. **Scalability and Accessibility:**
    - Develop scalable solutions that can be implemented in various parking lot sizes and configurations.
    - Ensure affordability and accessibility to enable widespread adoption.
8. **Collaboration and Partnerships:**

- Collaborate with industry stakeholders, government entities, and energy providers to accelerate solar parking lot implementation.
- Establish partnerships to expand the reach and impact of sustainable parking solutions.

5.2 Industry and Marketing Analysis

5.2.1 Industry Analysis

After the industrial visit, we came to know about the demand for our product and also the companies. As this app is not very much in Pakistan so we took help from different sites from where we got information about our product we found many industries which are working on that product but they didn’t get success in their business so we came to know that how to improve our product and what changes are required in our product and also which type of features we can add in our product to make it better. Here is some information about the different companies in different countries. The following are some aspects that are investigated by the companies’ reports about our app we have found:

- **Collection of Suitable Hardware:** The system is totally based on the collection of suitable Hardware.

- **Others:** There are other issues like security, monitoring handling and dealing with the emergency situation, etc. These are the critical flaws that we have to work hard to achieve our goals.

5.2.2 Competitive Analysis

As we have discussed that there are many companies that are working on different products for solar parking lots. The Japanese and American industries are very much in this market but we use the scamper technique to complete this product so we are at the top of the list. This experiment is not much done by our industries so we should avail of this opportunity and have to fulfill the requirements of the market. With continued growth, to serve the people and Industries, the company will provide easy and cost-effective services to different companies in Pakistan and all others which are existing around the globe.

5.2.3 Purpose

Our purpose is to develop an app that addresses the following problems:

- To utilize WBG-based semiconductors to increase the efficiency of DC-DC converters.
- Decarbonization
- Shifting to EVs

5.3 SWOT Analysis

5.3.1 Strengths

- It is very beneficial for the IT and Power Industry development of a country.
- It takes less time for giving accurate output.
- More efficient than any other app.

5.3.2 Weaknesses

- The communication errors can occur with the passage of time.
- Constantly required the Wi-Fi Connection.

5.3.3 Opportunities

- Introduction of wide bandgap materials-based DC-DC converters will attract the industries.
- The primary concern is to introduce modern ways in the field of the power sector.

5.3.4 Threats

- People will have data breaching concerns.
- It is difficult to influence the conventional mindset.

5.3.5 Marketing Objectives Follow

- Social media is a very much effective, powerful, and economical source of advertisement nowadays.
- Electronic media (News Channel) is also a very much attractive and convincing source to advertise our product.
- We will target Power Sector Industries for our project promotion.
- Letting the government know about its need and how it can fulfil its power sector requirements.

5.4 Marketing Communication

In the next aspects of the public communications spectrum, the inherent strengths and shortcomings are taken into consideration and what they are incorporated, and how they are applied in this situation. By using social and electronic media which are nowadays considered as the most powerful and effective source of promotion and advertisement.

5.4.1 Advertising

It is an informal and sponsored means of educating the consumers through, radio, news media, online portals, etc. about their goods and services. Advertising is one of the most commonly used marketing tactics in which the information about the goods and services of the business can be effectively conveyed to the vast target audience.

5.4.2 Personal Selling

Marketing involves the selling of our project through videos and portals. Telling our customers how our system can fulfil their needs and how this bus can help them in making their work more easy, convenient, and more economical.

5.4.3 Direct Marketing

The efficacy of direct marketing can be directly calculated. Through inventing the technology, businesses use emails, faxes, and cell phones to connect with potential clients directly without including someone else.

5.5 Financial Plan

5.5.1 Resources Required

The following resources are required:

- All the basic resources are required to start a business (i.e. Machinery, electronic equipment, a proper place, etc.)
- Accessories.
- Human resources.
- Electricity (etc.)

Table 5.1: Initial budget Expenses

Sr. No	Capital Nature Expenses	Amount (PKR)
1	Laptops (250,000 x 1)	250,000/-
2	Equipment (17,000 x 1)	170,000/-
	Revenue Nature Expenses	
3	Internet (4000 x 12)	48000/-
4	Misc. Expenses (1,500 x 12)	18,000/-
5	Electricity (10,000 x 12)	100,000/-
	Total: Initial Expenses (Budgeted)	533,000/-

Table 5.2**:** Statement of comprehensive income (budget)

Sr. No		1st Year	2nd Year	3rd Year	4th Year	5th Year
1	**Revenue**	433,000/-	530,000/-	660,000/-	780,000/-	800,000/-
2	**Cost of Production**	(80,000)	(100,000)	(130,000)	(170,000)	(200,000)
3	**Other Operating Expenses**	(100,000)	(100,000)	(105,000)	(111,000)	(135,000)
4	**Depreciation**	(5,000)	(5,000)	(5,000)	(5,000)	(5,000)
5	**Misc.**	(4000)	4000	4000	4000	4000
6	**Marketing Expenses**	(8000)	(16000)	(16000)	(20000)	(20000)
7	**Profit before Commission**	30,000/-	40,000/-	60,200/-	89,800/-	110,400/-

8	**Commission**	(13,000)	(18,000)	(25,000)	(35,000)	(46000)
9	**Profit After Commission**	**20,000/-**	**23,000/-**	**38,000/-**	**53,000/-**	**69,000/-**

5.6 Notes

5.6.1 Note-1

All expenses & revenue are estimated.

5.6.2 Note-2

On all non-current assets, depreciation is provided using the straight-line approach at a rate of 10%.

5.6.3 Note-3

The commission will be granted at a rate of 10% of the annual profit.

5.6.4 Note-4

As the income is below the minimum prescribed level as per the "Income Tax Ordinance, 2001" in all years. Consequently, no tax provision is calculated.

5.6.5 Note-5

Sensors like Arduino, Relay, Wi-Fi controllers, and other necessary electrical equipment are included in raw material.

5.6.6 Note-6

Electricity is a variable overhead cost that varies with production based on factors like the number of units generated annually.

5.6.7 Note-7

All calculations are based on assumptions. So, there is a chance of imparity in these calculations.

5.7 Conclusion

In this chapter, the total business strategy is portrayed exhaustively alongside the five-year monetary arrangement. The undertaking's qualities and different highlights are additionally portrayed exhaustively. The design is to make it simple for the peruse to comprehend the financial worth and social remaining of this venture.

CHAPTER 6
CONCLUSION AND FUTURE WORK

6.1 Conclusion

A scaled-down model of a smart solar parking lot was given in this thesis. As there is an exponential increase in the pollution of the world due to the excessive burning of fossil fuels. One of the major reasons of burning of fossil fuels are combustion engines. So, in order to reduce the emissions from the vehicles, world is shifting towards EVs and to charge the them solar panels should be used. As solar panels take a lot of space so there was a need of sufficient space in order to install them. So, the space of parking will be utilized for this purpose.

This thesis also discusses the value of DC-DC converters and the application of next-generation semiconductors like silicon carbide (SiC) and gallium nitride (GaN). As they are more efficient than conventional material based semi-conductors. By using latest semi-conductors based MESFETs or HEMT, the efficiency of DC-DC converter can be greatly improved. Because they have high switching frequency, resistant to harsh conditions and wide range of voltage and current.

As 1st generation of semi-conductors are not that efficient as compared to WBG (Wide bandgap) based semiconductors so there are losses during the switching. Heat is also produced so a lot of energy is also lost due to the fast switching, rise in temperature also shortens the reliability of transistor and its performance.

6.2 Future Work

Now a days, research is being done on the ultrawide bandgap materials and 2D materials which are way more efficient and reliable than 1st generation semiconductors and also better than wide band gap (WBG) materials.

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