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Thème

MODELISATION AND SIMULATION OF WIRELESS CHARGING SYSTEM FOR ELECTRIC VEHICLES

Soutenu publiquement, le 29 / 06 /2022 , devant le jury composé de :

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Dedication

"

*A special feeling of gratitude to my loving parents, **Djamel** and **SAHNINE Abbasia** whose words of encouragement and push for tenacity ring in my ears. My sisters **Abir**, **Souha** and **Kawthar** have never left my side and are very special.*

*I also dedicate this work to all my friends who have always supported me throughout the process, and all the family **MOUISSAT** and **SAHNINE** without exception.*

*Without forgetting my partner **RAKIK Mohamed Akram** with whom I have developed my end of study project.,*

Finally to all those who appreciate me at my true value. To all my loved ones, to all of you.

Thanks.

"

-MOUISSAT, Mohammed Issam Eddine

Dedication

"

I dedicate this precious work to the dearest people in the world, to whom I express my love and affection for their encouragement, understanding and patience, who understood me and pushed me to learn, I am talking about you, my dear parents ***Abdelkader*** *and* ***REGUIEG Nassima****. To my brother* ***Saber*** *and sisters* ***Sara*** *and* ***Anfel*** *and all the family:* ***"RAKIK"*** *without exception.*

To all my friends who have always supported me, and all my friends of the Electrotechnical Engineering Class of 2019.

Without forgetting my partner ***MOUISSAT Mohammed Issam Eddine*** *with whom I have developed my end of study project.*

Finally to all those who appreciate me at my true value.

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"

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May the members of the jury, **M. FEROUANI Abdel Karim**, **Mme. BOUSMAHA Imene** and **M. MHAMEDI Mohammed** find here an expression of our sincere thanks for the honour they have given us by taking the time to read and evaluate this work.

I would also like to thank the ESSAT pedagogical and administrative team for their efforts to provide excellent training. And especially to all the teachers of the Department of Electrical Engineering.

In closing, I would like to thank anyone who has contributed directly or indirectly to this work.

Abstract

This project presents a modelisation and simulation of wireless charging system for electric vehicles, the purpose of this project is to model a system that could charge electric vehicles without the need of charging cable just by using magnetic field using on the resonance coupling method to achieve highest power transfer.

The system contains two major parts. The first part is the power circuit that uses power converters like AC/DC converter ”rectifier” and DC/AC converters ”inverter” and coupling coils to connect the transmitting circuit that is the charging station to the receiving circuit inside the electric-vehicle.

The second is command and control circuit that is used to control the charging process, that part detect electric vehicle presence,measure state of charge of the battery,enable wireless communication between charging station and electric vehicles to exchange data.

Different software were used to simulate the wireless charging system,MATLAB-simulink was used to simulate power circuit, and ISIS Proteus was used to simulate command and control circuit.

obtained results shows that wireless charging system output power could attained 8,5 kW which is more than slow charging.

Keywords : Wireless charging, resonance coupling , Coupling coils, Power converter, Charging station, Electric vehicle.

Résumé

Ce projet présente la modélisation et la simulation d'un système de charge sans fil pour les véhicules électriques, le but de ce projet est de modéliser un système qui pourrait charger les véhicules électriques sans avoir besoin de câble de charge en utilisant simplement le champ magnétique en utilisant la méthode de couplage par résonance pour atteindre le plus haut transfert de puissance.

Le système comprend deux parties principales. La première partie est le circuit d'alimentation qui utilise des convertisseurs de puissance tels que le redresseur (convertisseur CA/CC) et l'inverseur (convertisseur CC/CA), ainsi que des bobines de couplage pour connecter le circuit d'émission, qui est la station de charge, au circuit de réception à l'intérieur du véhicule électrique.

Le deuxième est le circuit de commande et de contrôle qui est utilisé pour contrôler le processus de charge, cette partie détecte la présence du véhicule électrique, mesure l'état de charge de la batterie, permet la communication sans fil entre la station de charge et les véhicules électriques pour échanger des données.

Différents logiciels ont été utilisés pour simuler le système de charge sans fil, Matlab-simulink a été utilisé pour simuler le circuit de puissance, et ISIS proteus a été utilisé pour simuler le circuit de commande et de contrôle.

Les résultats obtenus montrent que la puissance de sortie du système de charge sans fil peut atteindre 8,5 kW, ce qui est supérieur à la charge lente.

Mots clés : Chargement sans fil, couplage par résonance , Bobines de couplage, Convertisseur de puissance, Station de charge, véhicule électrique.

ملخص

يقدم هذا المشروع نمذجة ومحاكاة نظام الشحن اللاسلكي للسيارات الكهربائية ، والغرض من هذا المشروع هو نمذجة نظام يمكنه شحن السيارات الكهربائية دون الحاجة إلى كابل شحن فقط باستخدام المجال المغناطيسي باستخدام طريقة اقتران الرنين لتحقيق أعلى نقل للطاقة.

يحتوي النظام على جزئين رئيسيين. الجزء الأول هو دارة الطاقة التي تستخدم محولات الطاقة مثل محول التيار المتردد / التيار المستمر " المعدل "ومحولات التيار المستمر/التيار المتردد" العاكس " و لفائف التوصيل لتوصيل دارة الإرسال التي هي محطة الشحن بدارة الاستقبال داخل السيارة الكهربائية.

او الجزء الثاني هو دارة القيادة والتحكم التي تستخدم للتحكم و معاينة عملية الشحن ، وهذا الجزء يكشف وجود السيارة الكهربائية ، و يقوم بقياس حالة شحن البطارية ، و يوفر الاتصال اللاسلكي بين محطة الشحن و السيارة الكهربائية لتبادل البيانات.

تم استخدام برامج مختلفة لمحاكاة نظام الشحن اللاسلكي ، وتم استخدام ماتلاب - سيمولينك لمحاكاة دارة الطاقة ، وتم استخدام إيزيس بروتيوس لمحاكاة دارة القيادة والتحكم.

تظهر النتائج التي تم الحصول عليها أن طاقة التي يخرجها نظام الشحن اللاسلكي يمكن أن تصل إلى 8.5 كيلو واط ، وهو أعلى من الشحن البطيء.

كلمات مفتاحية :

الشحن اللاسلكي ، اقتران الرنين ، لفائف اقتران ، محول الطاقة ، محطة الشحن ، السيارة الكهربائية.

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List of Acronyms

EV	*Electric Vehicle*
BEV	*Battery Electric Vehicle*
HEV	*Hybrid Electric Vehicle*
PHEV	*Plug-in Hybrid Electric Vehicle*
FCEV	*Fuel Cell Electric Vehicle*
WCS	*Wireless Charging System*
WPT	*Wireless Power Transfer*
ICC	*Integrated Circuit Cards*
IC	*Internal Combustion*
HC	*Combustion of Hydrocarbon*
R/P	*Reserves-to-Production Ratio*
AC	*Alternative Current*
DC	*Direct Current*
MOSFET	*Metal-Oxide-Semiconductor Field-Effect Transistor*
IGBT	*Insulated-Gate Bipolar Transistor*
PWM	*Pulse-Width Modulation*
MSPWM	*Modified Sinusoidal Pulse Width Modulation*

SOC *State Of Charge*

PDM *Pulse Duration Modulation*

General introduction

Nowadays, the world is considering the environment as one of the most essential aspects to respect due to the effect that are happening now and the effect that the scientists predicts in the future that could seriously affect the world, so the industry is heading to produce product that are eco-friendly and products that doesn't have negative effects on the environments. The electric vehicles is one the technologies that aim to take the place of traditional vehicles (Internal combustion engine vehicles) because of their performances and especially because of no gazes emission. Since electric vehicles store electric energy using batteries, charging those batteries represent engineering challenge which is to develop charging method that is efficient, save to the user and autonomous. In our project “modelisation and simulation of wireless charging system for electric vehicle ” we interested in the wireless charging technology or no contact charging method.

In electric vehicles, the challenging aspect is energy storing and the method used to store that energy, to store electric energy, it needs to be transferred from source ”grid” to the battery, the problematic how to transferred electric energy from grid to electric vehicle in efficient, safe and autonomous way.

The objectives of our project is to design a wireless power transfer system that is capable of charging electric vehicles battery without the need of human physical interaction like in case of plug in charging method by designing power system that is capable of charging electric vehicle battery with power Superior to 3kW, also designing control system that allows the user to control charging process.

This project is organized into three chapters:

The first chapter **General aspects about electric vehicles** is chapter in which we talk about the history of electric vehicles and its structure and environmental impacts, we also talk about batteries specially lithium-ion batteries used in electric vehicles, and finishing the chapter by seeing different charging technologies used in electric vehicles.

In the second chapter **Modelisation of wireless charging system** we see in details the structure of the wireless charging system including power converters, command part components and the theoretical calculus of the coupling circuit.

In the third chapter **Simulation of the wireless charging system** we implemented the theoretical calculus used in chapter two into scripts to calculate power circuit parameters using Matlab, and by using simulink we simulated power circuit and obtained results, we've simulated also control circuit using ISIS.

Chapter 1

Generalities about electric vehicles

1.1 Introduction

The electric car has often been considered as a technology with a bright future and hopes to put an end to the alarming pollution of the atmosphere caused by the road transport sector, which is capable of taking an important share of the market, but which did not succeed. The main reason for this failure is the competition, which has a well-established technology: the internal combustion engine, which has taken advantage of economies of scale, low fuel costs and subsidies.
The objective of this first chapter is to present a brief history, some generalities on electric vehicles, and to study its functioning as well as its different architectures and the elements constituting

1.2 Basics

As the effects of global warming are increasingly felt, many people are looking for ways to reduce their carbon footprint. Electric vehicles are one way to do this, and in some parts of the world, they're becoming more popular with everyday consumers.
Generally, an electric vehicle (EV) is a motor vehicle that uses electricity to power its wheels. EV's can be powered by battery packs; an off-board source of electricity (i.e., a powerhouse).
Specifically, EV's is an automobile powered by one or many electric motors for propulsion (traction motors). It can be powered by a collector system, with electricity from extravehicular sources, or it can be powered autonomously by a battery which requires recharging. Although prototype electric vehicles (EVs) were invented in the 1800s and various models were built in the 1900s, the EV industry only began in earnest after the turn of the 21st century.

There are 4 (four) types of electric cars, with the following outline:

- Battery Electric Vehicle (BEV)
- Hybrid:
  - Hybrid Electric Vehicle (HEV)
  - Plug-in Hybrid Electric Vehicle (PHEV)
- Fuel Cell Electric Vehicle (FCEV)

1.3 Historical background

1.3.1 History of EV's [1]

1828-1835: First small-scale electric car: Horses and carriages are the primary means of transportation, but innovators in Hungary, the Netherlands and the United States are thinking ahead and developing the first small electric cars.
1832: First crude electric vehicle is developed: Around 1832, Robert Anderson developed the first simple electric cars, but these did not become practical until the 1870s or later. The picture here is of an electric car built by a British inverter in 1884.
1889-1891: First Electric Vehicle debuts in the U.S: William Morrison of Des Moines built the first successful electric car in the United States. His car was nothing more than an electric car, but it sparked interest in electric vehicles.
1899: Electric cars gain popularity: Compared to the gasoline and steam-powered cars of the day, electric cars were fairly easy to drive and didn't emit any odorous pollutants - which quickly became popular with city dwellers, especially women.
1900-1912: Electric cars reach their heyday: By the turn of the century, electric vehicles were all the rage in the United States, making up about a third of all vehicles on the road.
1901: Edison takes on Ev's batteries: Many innovators are noticing high demand for electric vehicles and are looking for ways to improve the technology. Thomas Edison, for example, believed that electric cars were a superior mode of transportation and worked to make better batteries.
1901: World's first hybrid electric car is invented: Ferdinand Porsche, founder of the sports car of the same name, created the Lohner-Porsche Mixte, the world's first hybrid electric car. The vehicle is powered by electricity stored in a battery and gas engine.
1908-1912: Model T deals a blow to electric vehicles: The introduction of electric starters helped to further increase sales of gas-powered vehicles. Pictured above is Henry Ford's first Model T, the 1,000,000th in the U.S., which made gasoline easy for rural America and led to the growing popularity of gasoline-powered cars.

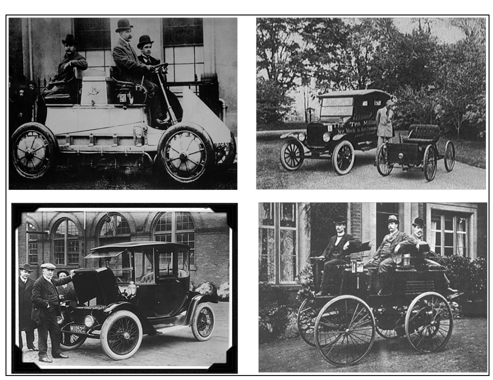

Figure 1.1: Ancient models of EV's

1920-1935: Decline in electric vehicles: better roads and the discovery of cheap Texas crude are leading to a decline in electric vehicles. In 1935 they all disappeared. Pictured here is one of the gas stations popping up across the U.S., supplying rural America with gasoline and leading to the growing popularity of gasoline-powered vehicles.
1968-1973: Gas prices soar: Over the next 30 years or so, cheap, abundant gasoline and continued improvements in the internal combustion engine left little need for alternative fuels in cars. But in the 1960s and 1970s, soaring gasoline prices reignited interest in electric vehicles.
1971: Over the moon with EV's: Around the same time, the first manned spacecraft landed on the moon. NASA's lunar rover runs on electricity and is helping to raise the profile of electric vehicles.
1973: The next generation of EV's: Many automakers large and small are beginning to explore alternative fuel vehicle options. General Motors, for example, is developing a prototype of an electric city car, which it showed at the first Low Emissions Energy System Development Symposium in 1973.

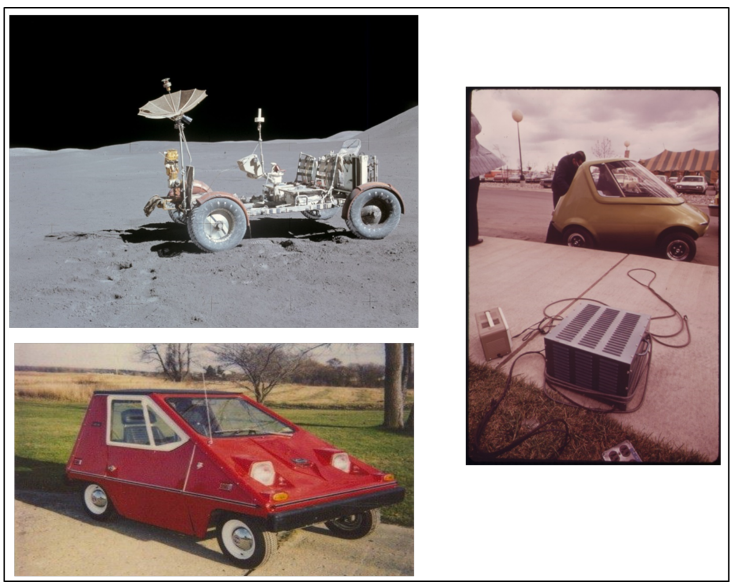

Figure 1.2: New utilisations for EV's

1975-1977: Leader in EV's vehicle sales: The current successful EV is Sebring-Vanguard's Citi Car. The company makes more than 2,000 Citi Cars - wedge-shaped compact cars with a range of 50 to 60 miles. By 1975, its popularity made Sebring-Vanguard the sixth-largest U.S. automaker.
1979: Interest in Ev's fades: Electric vehicles currently have disadvantages such as limited power and range compared to gasoline-powered vehicles, which has led to a renewed waning of interest in electric vehicles.
1990-1992: New regulations renew Ev's interest: New federal and state regulations are reviving interest in electric vehicles. As a result, automakers are starting to convert popular models to electric vehicles, bringing their speed and performance closer

to gasoline-powered vehicles.
1996: EV1 gains a cult following: General Motors has unveiled the EV1, an electric vehicle designed and built from the ground up. The EV1 quickly gained cult status.
1997: First mass-produced hybrid: With the Prius, Toyota introduced its first production hybrid. In 2000, Toyota launched the Prius around the world, and it became an instant celebrity, boosting its popularity (and electric vehicle popularity).
1999: Building a better electric car: Scientists and engineers are working behind the scenes to improve electric vehicles and their batteries. Seen here is a researcher at the Department of Energy's National Renewable Energy Laboratory testing an electric vehicle battery.
2006: Silicon Valley startup takes on electric cars: Silicon Valley startup Tesla Motors has announced it will build a luxury electric sports car with a range of more than 200 miles. Other automakers are taking notice and are accelerating work on their own electric vehicles.
2009-2013: Developing a nation-wide charging infrastructure: To help consumers charge their vehicles on the go, the Department of Energy is investing in a nationwide charging infrastructure, installing 18,000 residential, commercial and public chargers. Including chargers installed by automakers and other private companies, there are 8,000 public charging stations in the U.S. today.
2010: First commercially available plug-in hybrid for sale: General Motors introduces the Chevrolet Volt, making it the first commercial plug-in hybrid. The Volt uses battery technology developed by the power sector.
2010: Nissan launches the LEAF: In December 2010, Nissan will launch the LEAF, a pure electric vehicle with zero tailpipe emissions. In January 2013, thanks to a loan from the Department of Energy, Nissan began assembling the LEAF in Tennessee for the North American market.

Figure 1.3: New generation of EV's

2013: EV's battery costs drop: The battery is the most expensive component in an electric vehicle. Thanks to an investment from the U.S. Department of Energy, battery costs will drop by 50 percent in just four years, helping make electric vehicles more affordable for consumers.

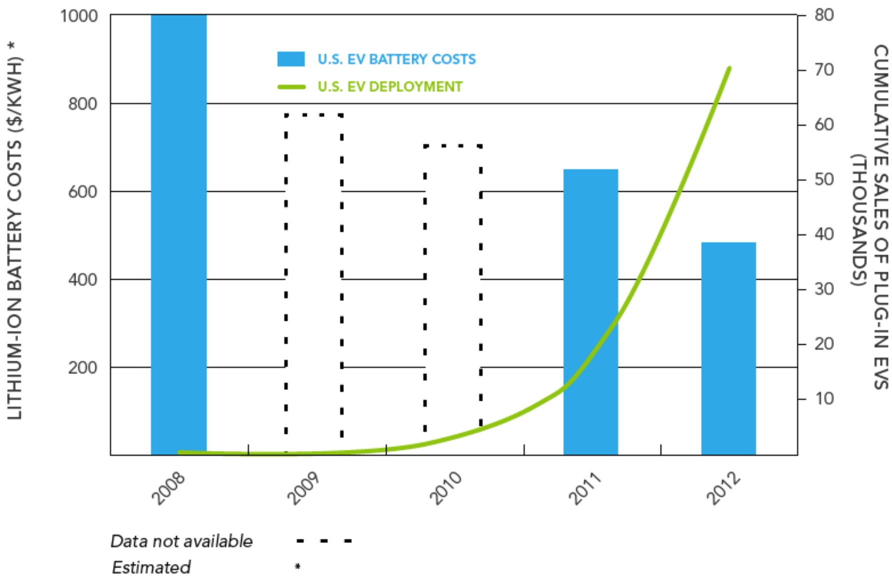

Figure 1.4: Deployment and cost for EV's and batteries between 2008-2012

2014: EV's and multitude of choice: Consumers now have a variety of options when shopping for electric vehicles, including hybrids, plug-in hybrids, and fully electric vehicles. Today, there are currently 23 plug-in electric vehicles and 36 hybrid models to choose from.

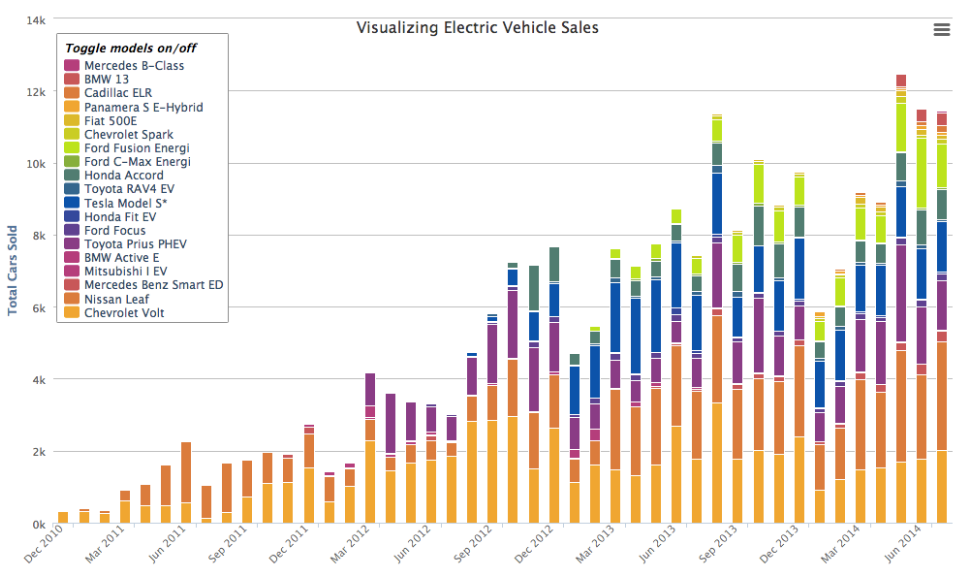

Figure 1.5: Variety of choice for Ev's nowdays

2015: The future of electric cars: Electric vehicles have enormous potential to help the world create a more sustainable future. If the world switched all light commercial vehicles to hybrid or plug-in electric vehicles, we could reduce the carbon footprint of the transportation sector by up to 20%.

Figure 1.6: Appearance of new charging systems for EV's

1.3.2 History of WCS

Nikola Tesla dreamed of a "wireless powered world" in the late 19th century (figure 1.7). He sometimes tried to transmit energy wirelessly, believing that he could use resonance phenomena to send energy anywhere on Earth. Unfortunately, his dream did not come true. Still, he is considered a pioneer in wireless power transfer (WPT). Around the same time, in 1894, M. Hutin and M. LeBlanc proposed an apparatus and method for inductively powering an electric vehicle (EV) using an alternating current (AC) generator with a frequency of about 3 kHz (Figure 1.8). Electric vehicles were developed shortly after the advent of the steam engine about 100 years ago. However, with the development of the internal combustion engine, electric vehicles gradually fell out of favor. So, after Hutin and LeBlanc, WPT inductively coupled chargers for electric cars were forgotten, and so was Tesla's WPT dream after him. In order to realize Tesla's dream of wireless transmission of power, people have been working tirelessly. In 1926, H. Yagi and S. Uda, inventors of the Yagi-Uda antenna, conducted an interesting WPT experiment in Japan. They placed unfed parasitic elements between the transmit and receive antennas at a frequency of 68 MHz to transmit wireless power (Figure 1.9). The device, called a "wave channel," is similar to a Yagi-Uda antenna. This is a WPT experiment on radio waves. However, it can be considered a coupled WPT because wireless power is transmitted through the coupled antenna/director acting as a resonator. They managed to get around 200 mW by transmitting 2-3 W of power. Meanwhile, in the United States, H.V. Noble demonstrated WPT on 100 MHz radio waves at the 3rd Chicago World's Fair in 1933 (Figure 1.10). The distance between the transmitting and receiving antennas is 5-12 m, and the transmitted radio power is about 15 kW. For example, the dream of wireless power was adopted after World War II by W.C. Brown in the United States in the 1960s with microwaves,

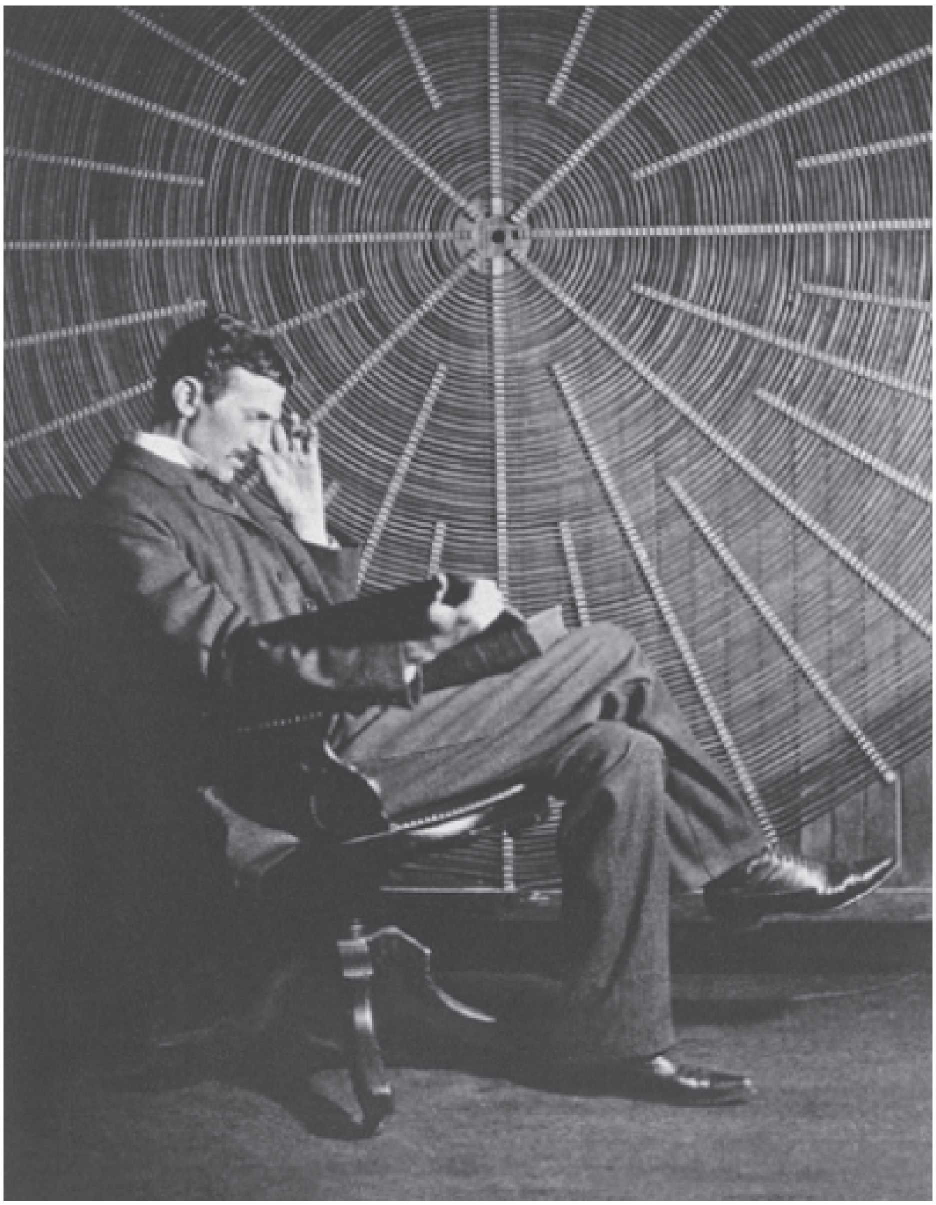

Figure 1.7: Nikola Tesla sitting in front of a spiral coil used in his wireless

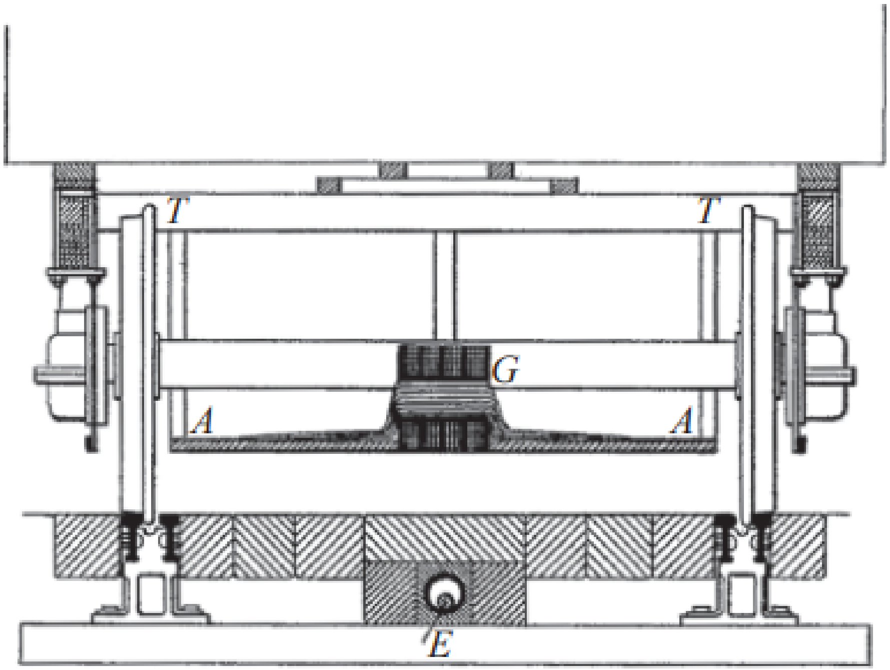

Figure 1.8: Diagram from the patent for M. Hutin and M.LeBlanc's first wireless charger for electric vehicles

in New Zealand in the 1970s with induction very low frequency (VLF) by D. Otto and many researchers. Figure 1.11 shows W.C. Brown's first experiments with WPT-assisted flying drones on microwaves in the 1960s. But in addition to some commercial wireless phones, inductive wireless chargers for electric toothbrushes, and razors, WPT technol-

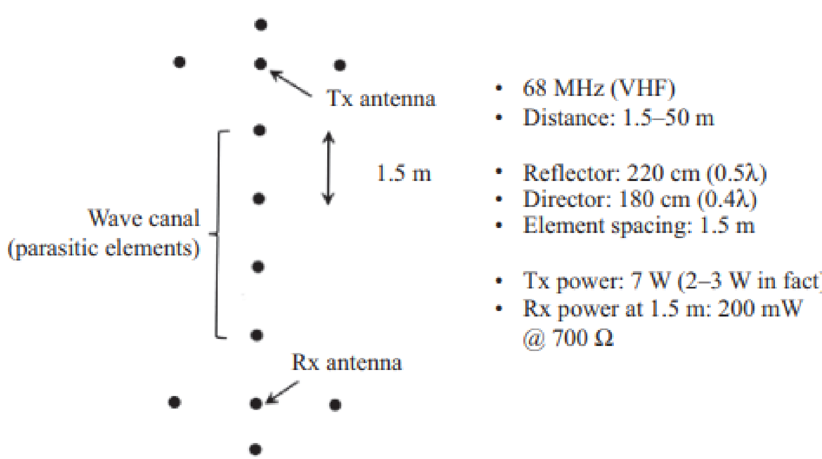

Figure 1.9: Wave canal by H. Yagi and S. Uda in Japan in 1926

ogy became a lost technology.
In integrated circuit cards (ICC), the inductive WPT is assumed to be 13.58 MHz. But it

Figure 1.10: Demonstration of WPT via radio waves by Harrell Noble at the Chicago World fair III in 1993

is considered a near field communication system, not WPT. We had to wait for the 21st century when the WPT dream resurfaced. A century after Tesla, Hutin, and LeBlanc, we now have the same WPT dream. Over the past hundred years, there have been many research, development, and commercial products based on the aforementioned WPT technology. Its functional principle can be divided into ”electromagnetic clutch WPT” and ”electromagnetic clutch WPT”. ”Uncoupled WPT” or ”Radiated WPT”. Electromagnetically coupled WPT is called near-field WPT and uses a high frequency magnetic or electric field.

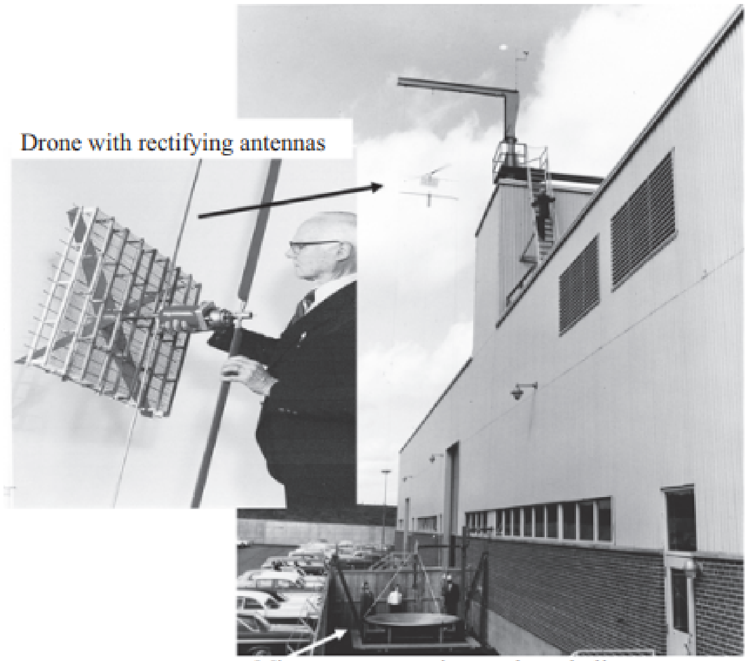

Figure 1.11: First WPT-aided flying drone experiment via microwave by W.C.Brown in the 1960s

When a high frequency magnetic field is used, it is also known as inductively coupled WPT. WPT with inductive coupling is explained by Ampere's law and Faraday's law. Radiated WPT, known as far-field WPT, is a type of WPT that occurs on radio waves. WPT on radio waves is explained by Maxwell's equations. Recently, resonantly coupled WPTs have been developed as improved inductively coupled WPTs. A resonantly coupled WPT system was proposed in 2007 by a research group at MIT. WPT with resonant coupling is based on WPT with inductive coupling. Thanks to the resonance phenomenon, the distance between the transmitter and receiver can be increased more than the conventional inductively coupled WPT. Figure 1.12 shows the relationship between Ampere's law, Faraday's law, Maxwell's equations, inductively coupled WPT, resonant coupled WPT, and radio wave WPT.[8]

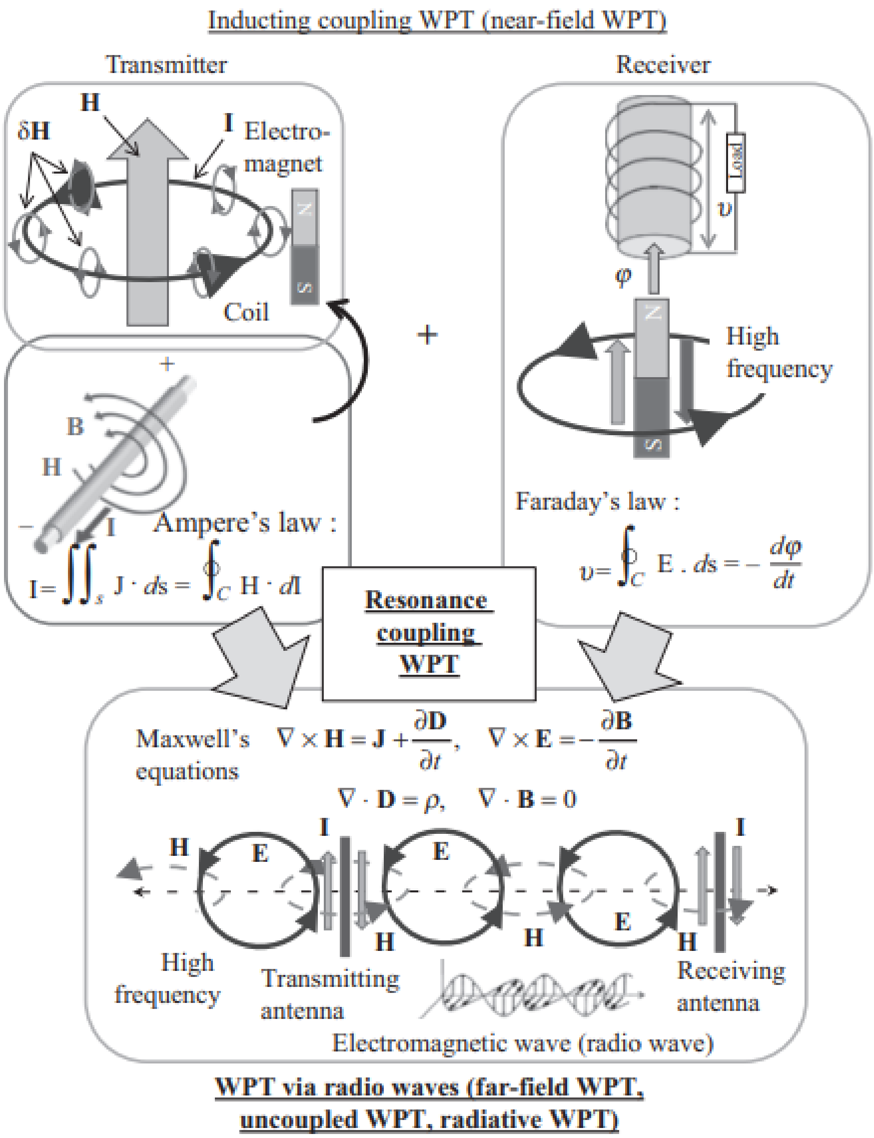

Figure 1.12: Relationship between Ampere's law, Faraday's law, Maxwell's equations, inductive-coupling WPT, resonance-coupling WPT, and WPT via radio waves

1.4 Fundamentals of Electric vehicles [2]

In Electric vehicles internal combustion engine and fuel tank are replaced with and electric motor and a battery pack, a modern electric train is illustrated as follow:
The drive train consists of three major subsystems: electric motor propulsion, energy source, and auxiliary. The electric propulsion subsystem comprises the vehicle controller, power electronic converter, electric motor, mechanical transmission, and driving wheels. The energy source subsystem involves the energy source, the energy management unit, and the energy-refueling unit. The auxiliary subsystem consists of the power steering unit, the hotel climate control unit, and the auxiliary supply unit.

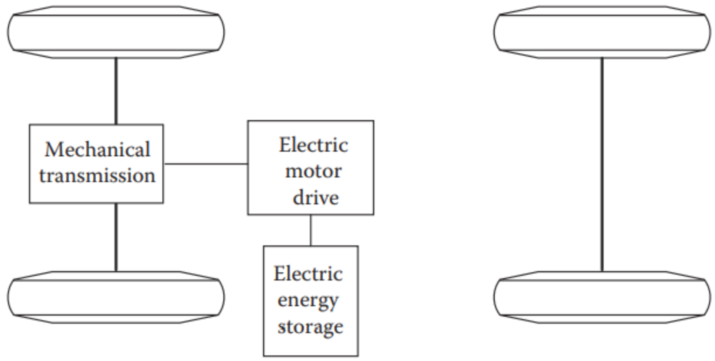

Figure 1.13: Primary electric vehicle power train

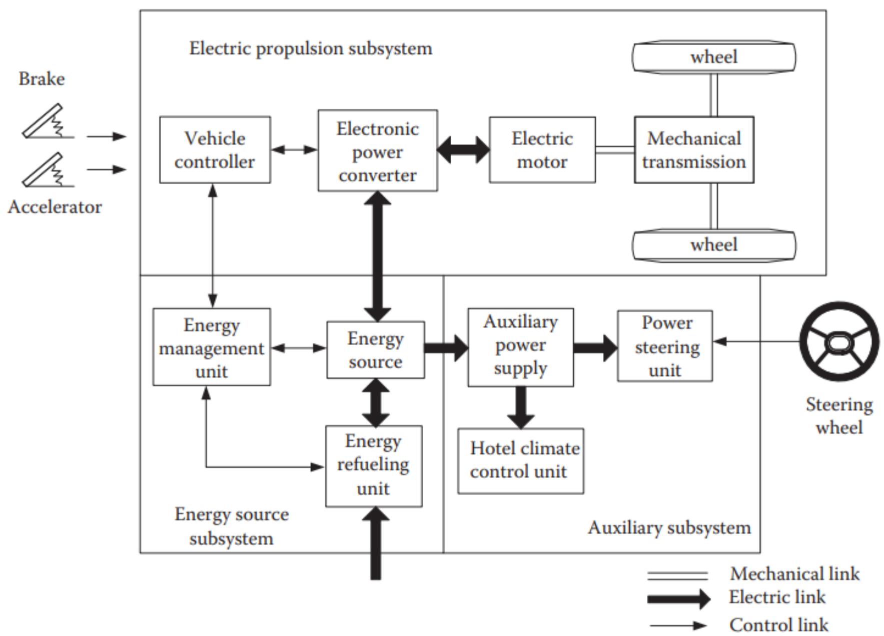

Figure 1.14: Conceptual illustration of general EV configuration

Based on control inputs from the accelerator and brake pedals, the vehicle controller appropriate control signals are provided to an electronic power converter for regulating the flow of power between the electric motor and the energy source. Regenerative braking of electric vehicles produces lagging power electric current, and this recovered energy can be recovered Enter energy, provided the energy is acceptable. The same goes for most EV batteries super capacitors and flywheels easily have the ability to absorb regenerative energy. This the energy management unit controls the regenerative energy together with the vehicle controller braking and its energy recovery. It can also be controlled together with the power supply unit Refueling device and for monitoring energy availability. Auxiliary power provides the necessary power for all electric vehicle auxiliary equipment, especially hotel air conditioning and power steering, with different voltage levels.

EV configuration very due to the variation in electric propulsion characteristics and energy source as shown:

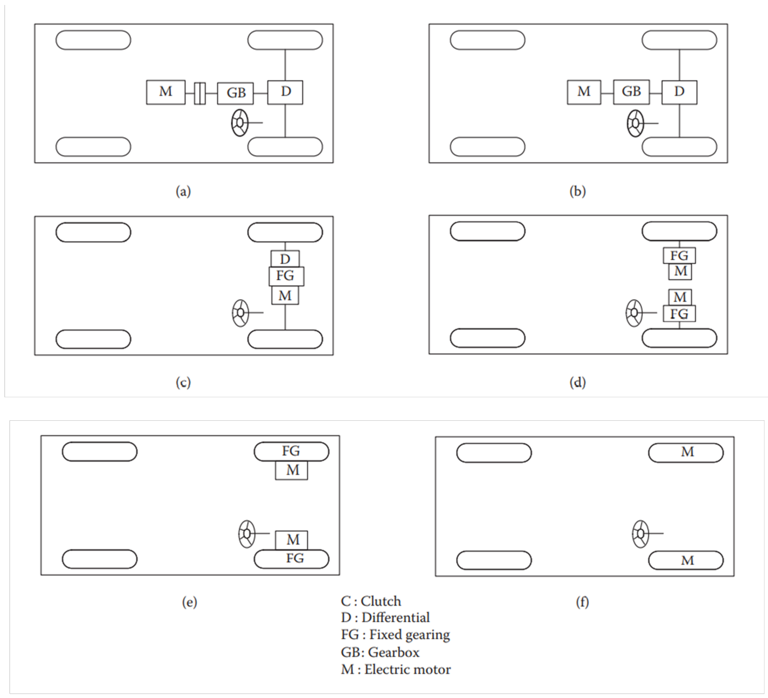

Figure 1.15: Possible EV configurations

a. In this configuration, an electric propulsion replaces the internal combustion engine of a conventional vehicle train. It consists of an electric motor, a clutch, a gearbox and a differential. The clutch is used to connect and disconnect the power coming from the electric motor, the gearbox provides a set of gear ratios to change the speed-power profile to match the load requirement, the differential will enable the wheels of both sides to be driven at different speeds when the vehicles run along a curved path.
b. Using an electric motor that has constant power in long speed range, a multispeed gearbox can be used to reduce the need for a clutch. This configuration not only reduce the weight of the mechanical transmission system, it also simplifies the drive control because gear shifting is not needed.
c. The electric motor, the fixed gearing and the differential can be further integrated into one single assembly bock, the whole driven train is further simplified and assembled and compacted.
d. The mechanical differential is replaced by using two traction motors, when the vehicle is running along curved path, each one of the motors will drive at different speed.
e. The traction motor can be placed inside a wheel. This arrangement is called in-wheel drive, a thin planetary gear set may be employed to reduce the motor speed and torque, the ting planetary gears set offers the advantage of high-speed reduction ratio.

f. By fully abandoning any mechanical gearing between the electric motor and the driven wheels, the out rotor of the electric motor is directly connected to the driving wheels. This arrangement requires the electric motor to have a higher torque, to start and accelerate the vehicle.

1.5 Environmental Impact

1.5.1 Environmental Impact of Modern Transportation

The development of internal combustion (IC) engine vehicles, and especially automobiles, is one of the greatest achievements of modern technology. Automobiles have made great contributions to the growth of modern society by satisfying many of the needs for mobility in everyday life. The rapid development of the automotive industry, unlike that of any other industry, has prompted the progress of human beings from a primitive security to a highly developed industrial one. The automobile industry and the other industries that serve it constitute the backbone of the world's economy and employ the greatest share of the working population. However, the large number of automobiles in use around the world has caused and continues to cause serious problems for environment and human life. Air pollution, global warming, and the rapid depletion of the Earth's petroleum resources are now problems of paramount concern. In recent decades, the research and development activities related to transportation have emphasized the development of high-efficiency, clean, and safe transportation. Electric vehicles (EVs), hybrid electric vehicles (HEVs), and fuel cell vehicles have been typically proposed to replace conventional vehicles in the near future. This chapter reviews the problems of air pollution, gas emissions causing global warming, and petroleum resource depletion. It also gives a brief review of the history of EVs, HEVs, and fuel cell technology.

Air Pollution

At present, all vehicles rely on the combustion of hydrocarbon (HC) fuels to derive the energy necessary for their propulsion. Combustion is a reaction between the fuel and the air that releases heat and combustion products. The heat is converted to mechanical power by an engine and the combustion products are released to the atmosphere. An HC is a chemical compound with molecules made up of carbon and hydrogen atoms. Ideally, the combustion of an HC yields only carbon dioxide and water, which do not harm the environment. Indeed, green plants "digest" carbon dioxide by photosynthesis. Carbon dioxide is a necessary ingredient in vegetal life. Animals do not suffer from breathing carbon dioxide unless its concentration in air is such that oxygen is almost absent.
Actually, the combustion of HC fuel in combustion engines is never ideal. Besides carbon dioxide and water, the combustion products contain a certain amount of nitrogen oxides (NOx), carbon monoxides (CO), and unburned HCs, all of which are toxic to human

health.

Nitrogen Oxides:

Nitrogen oxides (NOx) result from the reaction between nitrogen in the air and oxygen. Theoretically, nitrogen is an inert gas. However, the high temperatures and pressures in engines create favorable conditions for the formation of nitrogen oxides. Temperature is by far the most important parameter in nitrogen oxide formation. The most commonly found nitrogen oxide is nitric oxide (NO), although small amounts of nitric dioxide (NO2) and traces of nitrous oxide (N2O) are present. Once released into the atmosphere, NO reacts with the oxygen to form NO2. This is later decomposed by the Sun's ultraviolet radiation back to NO and highly reactive oxygen atoms that attack the membranes of living cells. Nitrogen dioxide is partly responsible for smog; its brownish color makes smog visible. It also reacts with atmospheric water to form nitric acid (HNO3), which dilutes in rain. This phenomenon is referred to as "acid rain" and is responsible for the destruction of forests in industrialized countries. Acid rain also contributes to the degradation of historical monuments made of marble.

Carbon Monoxide:

Carbon monoxide results from the incomplete combustion of HCs due to a lack of oxygen. It is a poison to human beings and animals who inhale/breathe it. Once carbon monoxide reaches the blood cells, it fixes to the hemoglobin in place of oxygen, thus diminishing the quantity of oxygen that reaches the organs and reducing the physical and mental abilities of affected living beings. Dizziness is the first symptom of carbon monoxide poisoning, which can rapidly lead to death. Carbon monoxide binds more strongly to hemoglobin than oxygen. The bonds are so strong that normal body functions cannot break them. People intoxicated by carbon monoxide must be treated in pressurized chambers, where the pressure makes it easier to break the carbon monoxide–hemoglobin bonds.

Unburned HCs:

Unburned HCs are a result of the incomplete combustion of HCs. Depending on their nature, unburned HCs may be harmful to living beings. Some of these unburned HCs may be direct poisons or carcinogenic chemicals such as particulates, benzene, or others. Unburned HCs are also responsible for smog: the Sun's ultraviolet radiations interact with the unburned HCs and NO in the atmosphere to form ozone and other products. Ozone is a molecule formed of three oxygen atoms. It is colorless but very dangerous, and is poisonous because as it attacks the membranes of living cells, causing them to age prematurely or die. Toddlers, older people, and asthmatics suffer greatly from exposure to high ozone concentrations. Annually, deaths from high ozone peaks in polluted cities have been reported.

Other Pollutants:

Impurities in fuels result in the emission of pollutants. The major impurity is sulfur: mostly found in diesel and jet fuel, but also in gasoline and natural gas. The combustion of sulfur (or sulfur compounds such as hydrogen sulfide) with oxygen releases sulfur oxides (SOx). Sulfur dioxide (SO2) is the major product of this combustion. On contact with air, it forms sulfur trioxide, which later reacts with water to form sulfuric acid, a major component of acid rain. It should be noted that sulfur oxide emissions originate from transportation sources but also largely from the combustion of coal in power plants and steel factories. In addition, there is debate over the exact contribution of natural sources such as volcanoes. Petroleum companies add chemical compounds to their fuels in order to improve the performance or lifetime of engines. Tetraethyl lead, often referred to simply as "lead," was used to improve the knock resistance of gasoline and therefore allow better engine performance. However, the combustion of this chemical releases lead metal, which is responsible for a neurological disease called "saturnism." Its use is now forbidden in most developed countries and it has been replaced by other chemicals.

Global Warming

Global warming is a result of the "greenhouse effect" induced by the presence of carbon dioxide and other gases, such as methane, in the atmosphere. These gases trap the Sun's infrared radiation reflected by the ground, thus retaining the energy in the atmosphere and increasing the temperature. An increased Earth temperature results in major ecological damages to its ecosystems and in many natural disasters that affect human populations Considering the ecological damages induced by global warming, the disappearance of some endangered species is a concern because this destabilizes the natural resources that feed some populations. There are also concerns about the migration of some species from warm seas to previously colder northern seas, where they can potentially destroy indigenous species and the economies that live off those species. This may be happening in the Mediterranean Sea, where barracudas from the Red Sea have been observed. Natural disasters command our attention more than ecological disasters because of the amplitude of the damages they cause. Global warming is believed to have induced meteorological phenomena such as "El Niño," which disturbs the South Pacific region and regularly causes tornadoes, inundations, and dryness. The melting of the polar icecaps, another major result of global warming, raises the sea level and can cause the permanent inundation of coastal regions and sometimes of entire countries. Carbon dioxide is the result of the combustion of HCs and coal. Transportation accounts for a large share (32% from 1980 to 1999) of carbon dioxide emissions. The distribution of carbon dioxide emissions is shown in Figure 1.16. Figure 1.17 shows the trend in carbon dioxide emissions. The transportation sector is clearly now the major contributor to carbon dioxide emissions. It should be noted that developing countries are rapidly increasing their transportation sector, and these countries represent a very large share of the world population. Further discussion is provided in the next subsection. The large amounts of carbon dioxide released into the atmosphere by human activities are believed to be largely responsible for the increase in the global Earth temperature observed during the last decades (Figure 1.18). It is important to note that carbon dioxide is indeed digested by plants and sequestrated by oceans in the form of carbonates. However, these natural assimilation processes are limited and cannot assimilate all of the emitted carbon dioxide, resulting in an accumulation of carbon dioxide in the atmosphere.

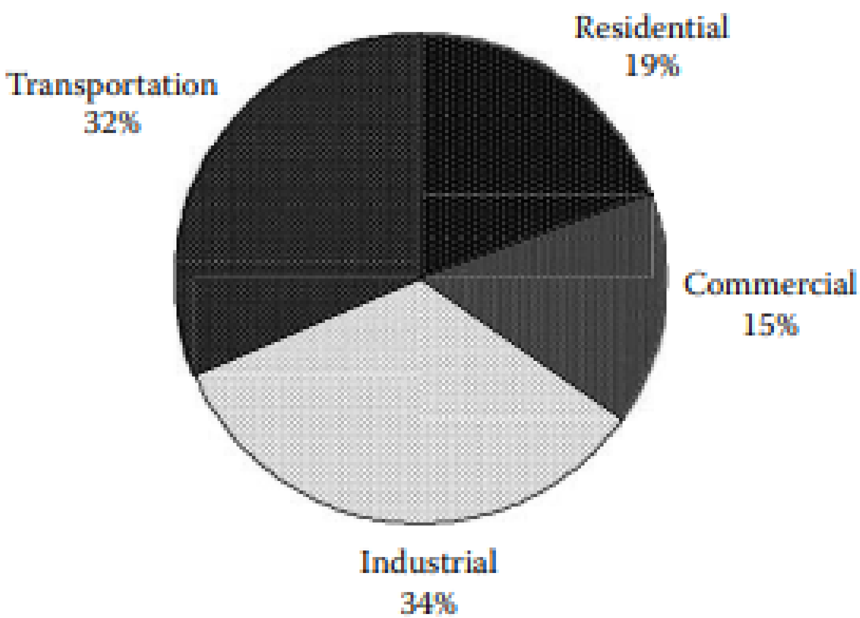

Figure 1.16: Carbon dioxide emission from 1980 to 1999

Petroleum Resources

The vast majority of fuels for transportation are liquid fuels originating from petroleum. Petroleum is a fossil fuel, resulting from the decomposition of living matters that were imprisoned millions of years ago (Ordovician, 600–400 million years ago) in geologically stable layers. The process is roughly the following: living matters (mostly plants) die and are slowly covered by sediments. Over time, these accumulating sediments form thick layers and transform to rock. The living matters are trapped in a closed space, where they encounter high pressures and temperatures and slowly transform into either HCs or coal, depending on their nature. This process takes millions of years to accomplish. This is what makes the Earth's resources in fossil fuels finite. The oil extracted nowadays is the easily extractable oil that lies close to the surface, in regions where the climate does not pose major problems. It is believed that far more oil lies underneath the Earth's crust in regions such as Siberia, or the American and Canadian Arctic. In these regions, the climate and ecological concerns are major obstacles to extracting or prospecting for oil. The estimation of the total Earth's reserves is a difficult task for political and technical

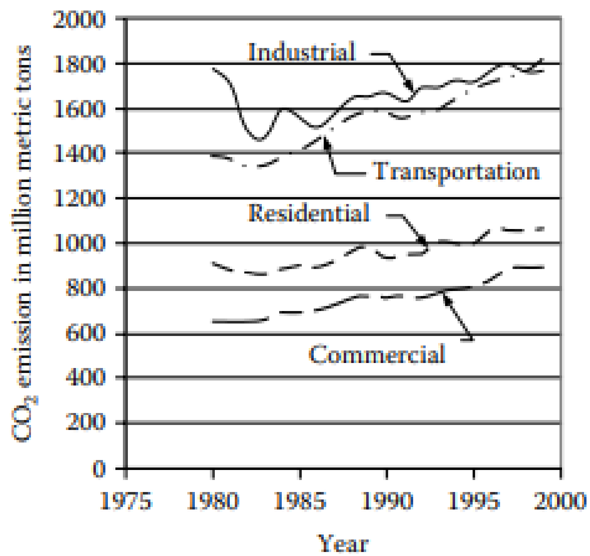

Figure 1.17: Evolution of CO2 emission

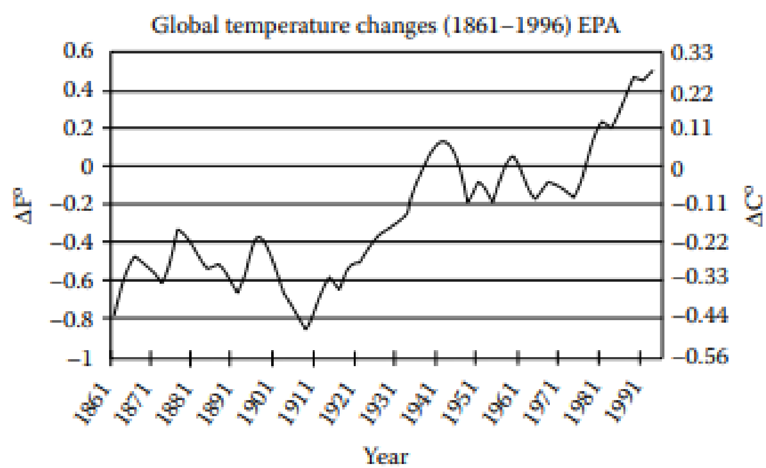

Figure 1.18: Global earth atmospherie [3]

reasons. A 2000 estimation of the undiscovered oil resources by the US Geological Survey is given in Table 1.1

Although the R/P ratio does not include future discoveries, it is significant. Indeed, it is based on proved reserves, which are easily accessible to this day. The amount of future oil discoveries is hypothetical, and the newly discovered oil will not be easily accessible. The R/P ratio is also based on the hypothesis that the production will remain constant.

Table 1.1: U.S. Geological survey estimate of undiscovered oil in 2000

Region	Undiscovered Oil in 2000 in Billion Tons
North America	19.8
South and Central America	14.9
Europe	3.0
Sub-Saharan Africa and Antarctic	9.7
Middle East and North Africa	31.2
Former USSR	15.7
Asia Pacific	4.0
World (potential growth)	98.3 (91.5)

It is obvious, however, that consumption (and therefore production) is increasing yearly to keep up with the growth of developed and developing economies. Consumption is likely to increase in gigantic proportions with the rapid development of some largely populated countries, particularly in the Asia-Pacific region. Figure 1.19 shows the trend in oil consumption over the last 20 years. Oil consumption is given in thousand barrels per day (one barrel is about 8 metric tons). Despite the drop in oil consumption for Eastern Europe and the former USSR, the world trend is clearly increasing, as shown in Figure 1.20 The fastest growing region is Asia Pacific, where most of the world's population lives.

Induced Costs

The problems associated with the frenetic combustion of fossil fuels are many: pollution, global warming, and foreseeable exhaustion of resources, among others. Although difficult to estimate, the costs associated with these problems are huge and indirect, and may be financial, human, or both.

Costs induced by pollution include, but are not limited to, health expenses, the cost of replanting forests devastated by acid rain, and the cost of cleaning and fixing monuments corroded by acid rain. Health expenses probably represent the largest share of these costs, especially in developed countries with socialized medicine or health-insured populations. Costs associated with global warming are difficult to assess. They may include the cost of the damages caused by hurricanes, lost crops due to dryness, damaged properties due to floods, and international aid to relieve the affected populations. The amount is potentially huge. Most of the petroleum-producing countries are not the largest petroleum consuming countries.

In searching for a solution to the problems associated with oil consumption, one has to take into account those induced costs. This is difficult because the cost is not necessarily asserted where it is generated. Many of the induced costs cannot be counted in asserting the benefits of an eventual solution. The solution to these problems will have to be economically sustainable and commercially viable without government subsidies in order

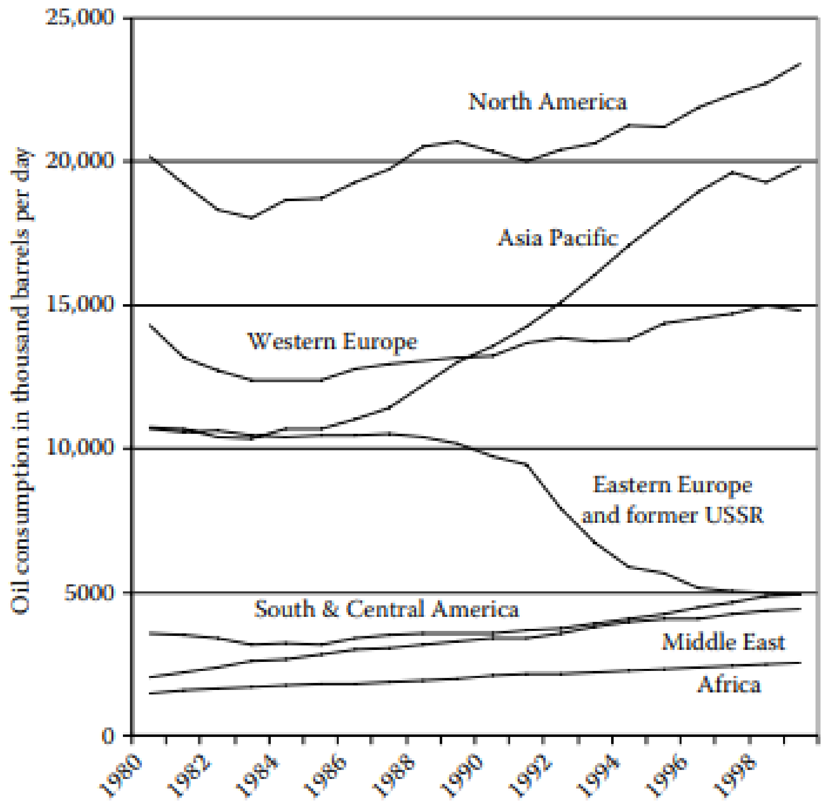

Figure 1.19: Oil consumption per region

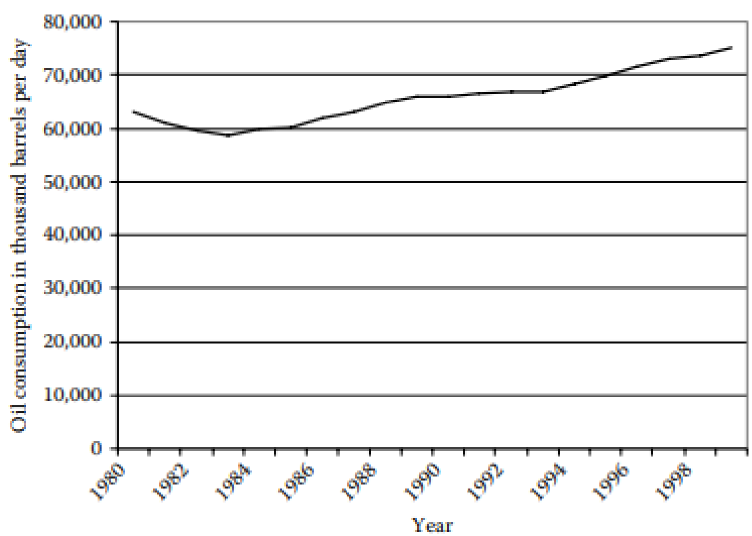

Figure 1.20: World oil consumption

to sustain itself in the long run. Nevertheless, it remains clear that any solution to these problems— even if it is only a partial solution—will indeed result in cost savings, which will benefit the payers.[9]

1.5.2 Benefits of electric cars on the environment

Research has shown that electric cars are better for the environment. They emit fewer greenhouse gases and air pollutants than petrol or diesel cars. And this takes into account their production and electricity generation to keep them running.
The major benefit of electric cars is the contribution that they can make towards improving air quality in towns and cities. With no tailpipe, pure electric cars produce no carbon dioxide emissions when driving. This reduces air pollution considerably.
Put simply, electric cars give us cleaner streets making our towns and cities a better place to be for pedestrians and cyclists. In over a year, just one electric car on the roads can save an average 1.5 million grams of CO2. That's the equivalent of four return flights from London to Barcelona.
EVs can also help with noise pollution, especially in cities where speeds are generally low. As electric cars are far quieter than conventional vehicles, driving electric creates a more peaceful environment for us all.
Making electric cars does use a lot of energy. Even after taking battery manufacture into account, electric cars are still a greener option. This is because of the reduction in emissions created over the car's lifetime The emissions created during the production of an electric car tend to be higher than a conventional car. This is due to the manufacture of lithium-ion batteries which are an essential part of an electric car. More than a third of the lifetime CO2 emissions from an electric car come from the energy used to make the car itself. As technology advances, this is changing for the better.
Reusing and recycling batteries is also a growing market. Research into the use of second-hand batteries is looking at ways to reuse batteries in new technologies such as electricity storage. One day we could all have batteries in our homes being used to store our own energy. Opportunities like this will reduce the lifetime environmental impact of battery manufacture.[10]

1.6 Batteries and energy storage for EV's

1.6.1 Definition

A battery is a device that converts the chemical energy contained in its active materials directly into electric energy by means of an electrochemical oxidation-reduction reaction. In the case of a rechargeable system, the battery is recharged by a reversal of the process. This type of reaction involves the transfer of electrons from one material to another through an electric circuit. In a non-electrochemical redox reaction, such as rusting or burning, the transfer of electrons occurs directly and only heat is involved. As the battery electrochemically converts chemical energy into electric energy, it is not subject, as are combustion or heat engines, to the limitations of the Carnot cycle dictated by the second law of thermodynamics. Batteries, therefore, are capable of having higher energy conversion efficiencies.

Figure 1.21: car battery

1.6.2 Types

Electrochemical cells and batteries can be classified in two big categories, primary (non-rechargeable) and secondary (rechargeable), depending on their capability of being electrically recharged these are some types of electrochemical batteries:

Primary cells or batteries

Primary batteries cannot be easily or effectively recharged, it is designed to be used once and discarded. Primary cells in which the electrolyte is contained by and absorbent where there is no liquid electrolyte are called “dry cells”.
Primary batteries are usually inexpensive, lightweight, and it is a source of power for portable electrical and electronic devices, the advantages of the primary batteries are the good life shelf, high energy density at a low discharge rates and ease of use.
Small capacity batteries applications are lighting, photographic equipment, toys...etc., although large high-capacity primary batteries are used in military applications, standby power systems, and many other applications.

Figure 1.22: A variety of standard of primary cells and batteries

Secondary or rechargeable cells or batteries

Secondary batteries can be recharged to their original state by passing current in the opposite direction to that of the discharge current, this type of batteries is called “storage batteries” or “accumulators “.
There are two main categories of secondary batteries applications:

- The first category is in which the battery is used as an energy storage device.
- The second category is in which the battery is used as a primary battery or a primary source of energy.

Secondary batteries are characterized by high power density, high discharge rate, flat discharge curves, and good temperature performance, their energy density is lower than of the primaries.
Rechargeable batteries applications are automotive and air craft systems, emergency no-fail and standby power systems, hybrid and fully electric vehicles.[11]

Figure 1.23: A rechargeable lithium polymer mobile battery

1.6.3 Batteries used in electric vehicles

The types and number of applications requiring improved or advanced rechargeable batteries are constantly expanding one of the applications of these batteries are electric and hybrid vehicles, in addiction the performance the performance, life and cost requirement for the batteries used in many of these new and existing applications are becoming increasingly more rigorous.
Commercially available batteries may not be able to meet these performance requirements. Thus, a need exists for both conventional battery technology with improved performance and advanced battery technologies with characteristics such as high energy and power densities, long life, low cost, little or no maintenance, and a high degree of safety.
Battery performance applications depend on the application, for examples:

- High specific energy and energy density to provide adequate vehicles driving range.

- High power density to provide acceleration.
- Capability of accepting high power.
- Long cycle life with little maintenance.
- Low cost.

1.7 A brief description of different charging systems

there are two types of charging systems for electric vehicles:

1.7.1 Plug in charging system

Figure 1.24 summarize all charging levels for plug-in charging system.

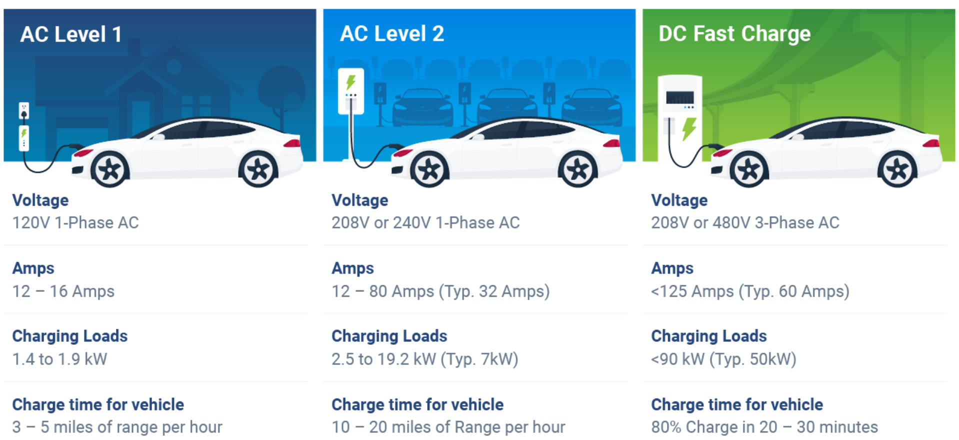

Figure 1.24: Different charging levels for plug in charging system

1.7.2 Wireless charging system

Wireless car charging is an enhanced version of smartphone charging with several differences. “Wireless inductive charging allows an electric vehicle [EV] to automatically charge without the need of cables,” said Michael Rai Anderson, CEO of Plugless Power, in an interview with Power Electronics News.[12]

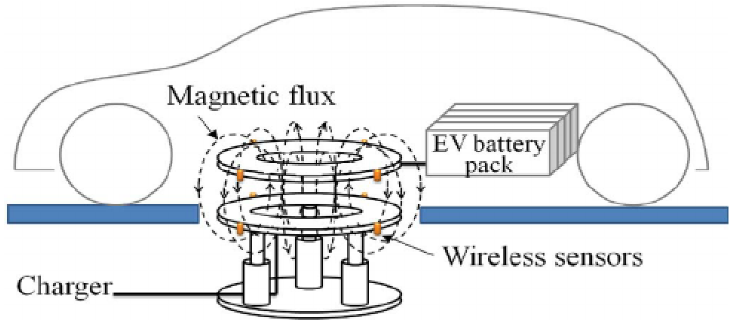

Figure 1.25: Wireless charging system

1.8 Conclusion

In this chapter, we have presented a state of the art on electric vehicles, a brief history and the elements that compose this kind of vehicle was presented first, the advantages and disadvantages were also discussed. Electric vehicles, being ecological and clean, will certainly be the new means of transportation that will take an increasingly important place in the market in the near future, and will therefore replace in the coming years the thermal cars that are much too polluting, and especially not eternal. The production of energy necessary for the operation and manufacture of electric vehicles, take part in global warming, which allows us to say that finally the electric car is not as ecological, unless it is produced from renewable energy, such as solar or hydraulic energy. Several architectures of electric vehicles are currently possible and present various performances and functionalities. The points that block the complete arrival of the electric vehicle are now known, the manufacturers offer very efficient solutions in terms of technology and power despite this, some points still need to be improved to allow the real immersion of the electric vehicle in the populations, especially regarding the autonomy, the price and the infrastructure necessary for its expansion, so which do not seem to be possible in the short term.

Chapter 2

Modelisation of wireless charging system for EV's

2.1 Introduction

A wireless power transfer method to power and electric equipment is based on Faraday's law and is a recent (less than 20years) development in the field of home appliance. Inductive coupling method based on electromagnetic induction developed by M.Faraday in 1831. The latest application of this technology is wireless Power Transfer (WPT) system.Based on the current energy situation, there is an increasing interest in electric vehicles . The WPT technology draws attention as next generation technology for charging electric vehicles batteries, the non-contact electricity transmission technique has also attracted attention for medical applications and many other application. as we can see in the figure 2.1 the different devices and wireless charging range depending on the transmission length and the transmitted power. [8] In this chapter we discuss about different types

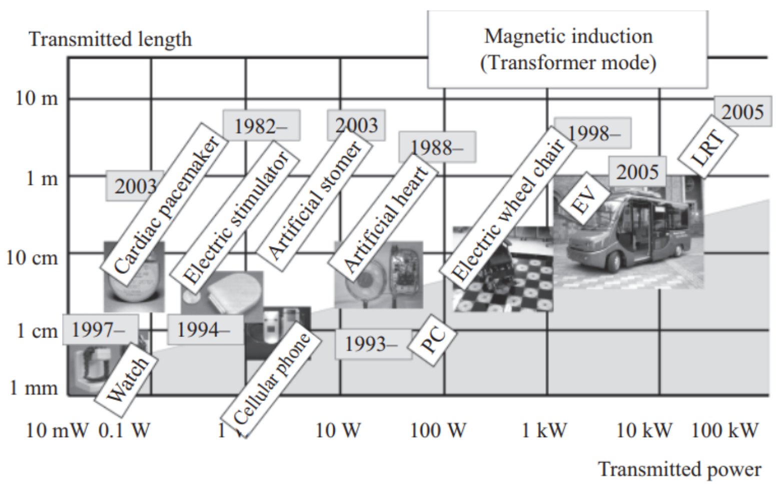

Figure 2.1: Classification of devices targeted by WPT applications

of wireless power transfer and see the difference between them, study power converters and coupling circuit. Also talking about control system and its components.

2.2 General functions and components of the wireless charging system

The Wireless charging system takes energy from AC power supply as power grid or DC power supply such as solar cells and converted it to high-frequency electric signal by using high-frequency inverts. The wireless transmitting device transfer electrical energy through, then the receiving system converts the receiving electrical energy to DC electric signal to charge the battery of the electric vehicle. [8]

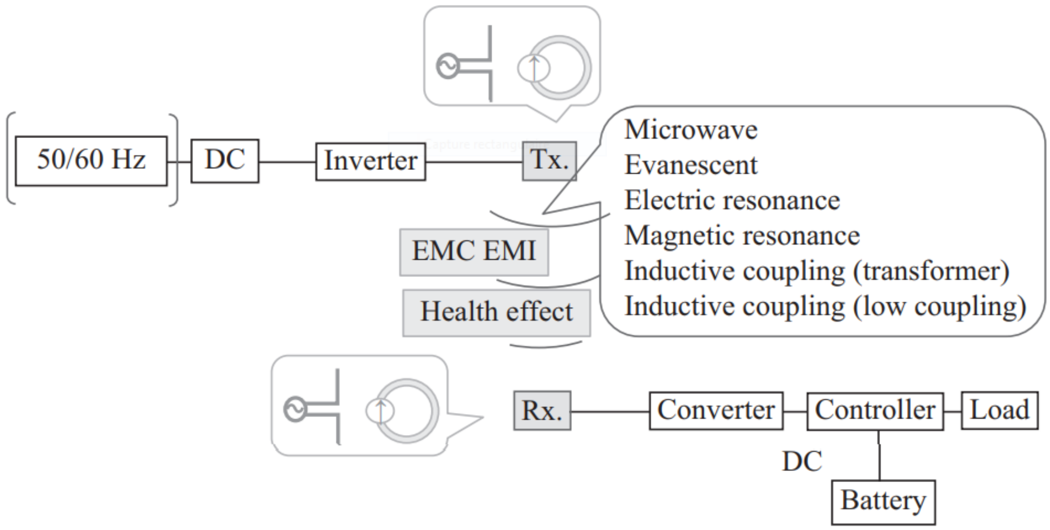

Figure 2.2: Block diagram of wireless Power Transfer system

Non-contact power transmission could be done using different methods as shown in the figure 2.3:

- Laser/light power
- Microwave power
- Electrostatic induction
- Magnetic resonant induction
- Inductive coupling

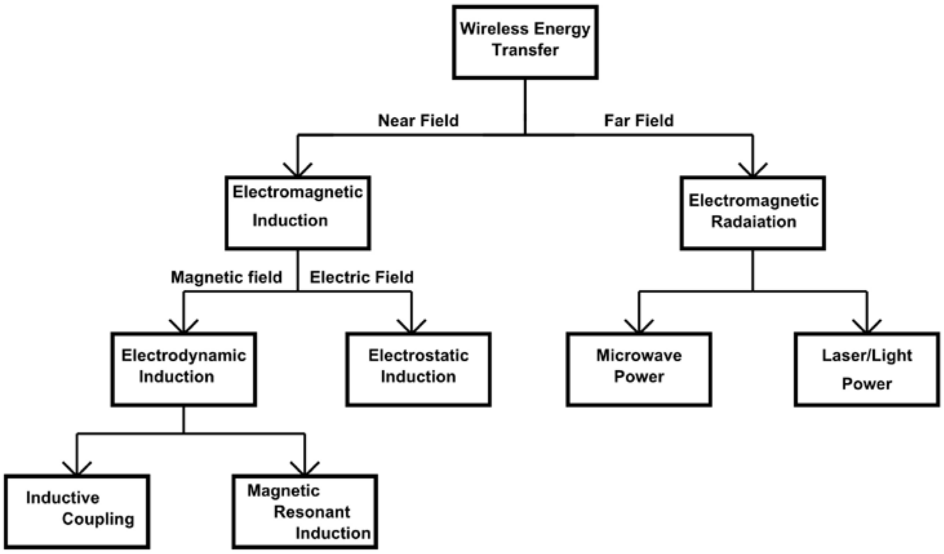

Figure 2.3: Various wireless charging technologies

The choose of the wireless power transfer method depend on the characteristics and the parameters and the situations of the charging system, table 2.1 shows the difference between thees technologies[13]

Table 2.1: Comparison of the main wireless power transfer WPT technologies

	Electric Field	Magnetic Field		Electromagnetic Field	
	Capacitive coupling	**Inductive Power transfert**	**Resonant Inductive coupling**	**RF Energy Transfert, Microwaves**	**Laser Beaming**
Range	Short	Short	Mid	Far	Far
Frequency	Hz-MHz	kHz-MHz	kHz-MHz	GHz	>THz
Propagation	Non-Radiative	Non-Radiative	Non-Radiative	Radiative	Radiative
Strength	Very high	Very High	High	Low	High
Multicast	No	No	Yes	Yes	No
Mobility	No	No	Yes	Yes	No
Coupling device	Metal Plate Electrodes	Wire Coils	Turned wire coils	Parabolic dishes, Phased array, rectennas	Lasers, photocells, lenses
Safety	Yes	Yes	Yes	Safety constraints may apply	Safety constraints may apply

As mentioned in the table has the best characteristics in term of range and strength and mobility and safety which makes it the best choice a wireless charging system for electric vehicles

The system needs a command part to control the charging processes and to inform the user of the system about the charging and gives information's like state of charge, time of charge and other things.The micro-controller of the system (Arduino in this case) control all the inputs and the outputs, it gives the command signals to the power converters, measure the power flow and the energy consumed during the charging process and communicate with the car system to indicate the SOC of the battery using wireless communication to know when to stop charging the battery, and other systems like presence indication system to indicate when the electric vehicle is in the right place to start charging

2.3 Power part

2.3.1 Rectifier Block (AC/DC BLOCK) (for charging system)

Three-phase bridge rectifiers are typically used in high-power applications because they have the highest transformer utilization for three-phase systems. This is a full wave rectifier. It can operate with or without a transformer and provides a six-pulse output voltage ripple. The diodes are numbered in the order of conduction, and each diode has a conduction angle of $\frac{2\pi}{3}$. The diode sequence is D1 - D2, D3 - D2, D3 - D4, D5 - D4, D5 - D6, and D1 - D6.[12]

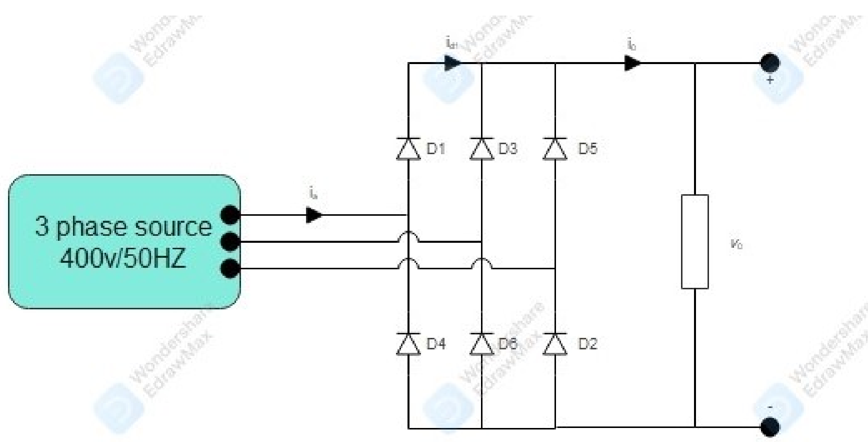

Figure 2.4: Three phases bridge rectifier

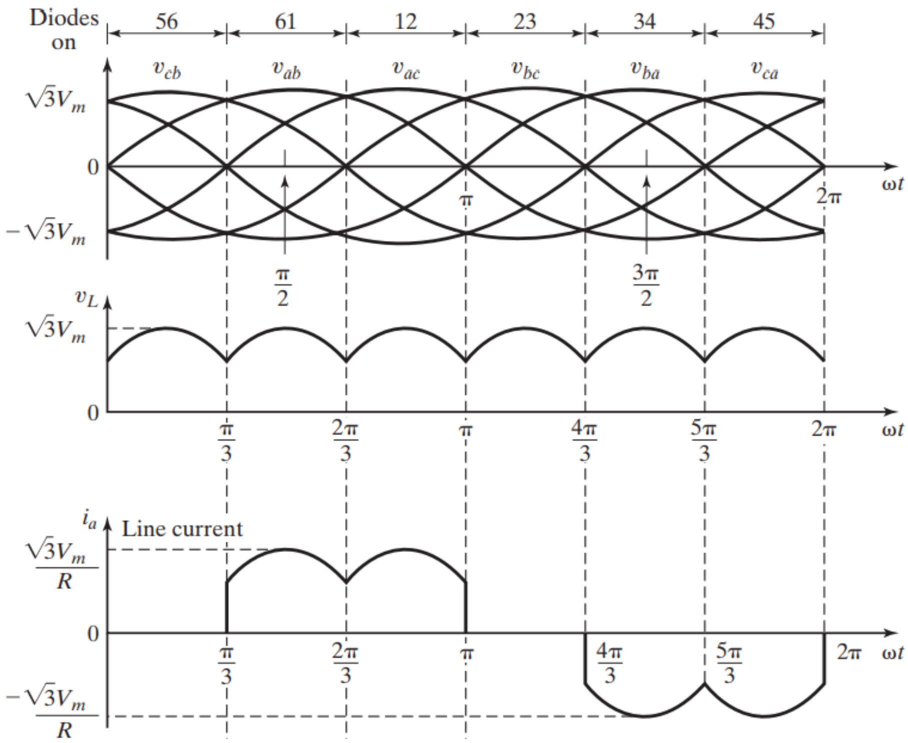

Figure 2.5: waveforms and conduction time of diodes

The obtained signal is not perfectly continues, so, we need to introduce a capacitor to make it continuous.

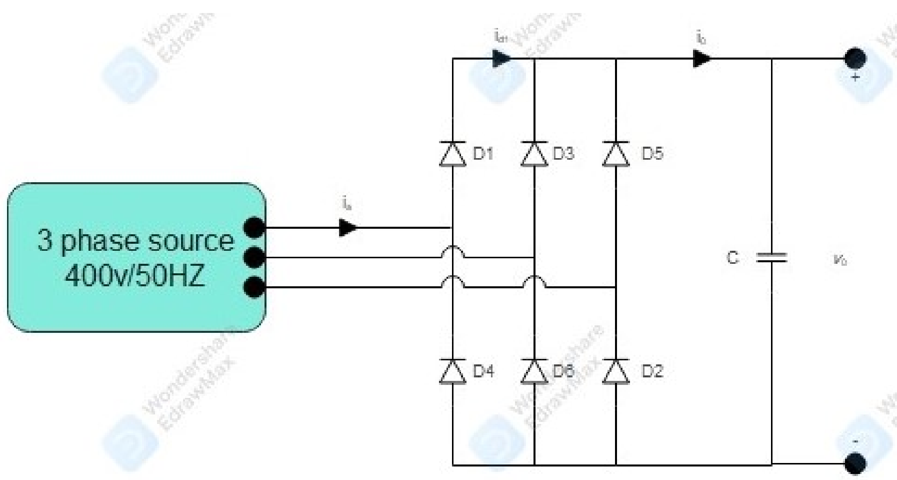

Figure 2.6: Three phases bridge rectifier with capacitor (full wave rectifier)

The signal will be:

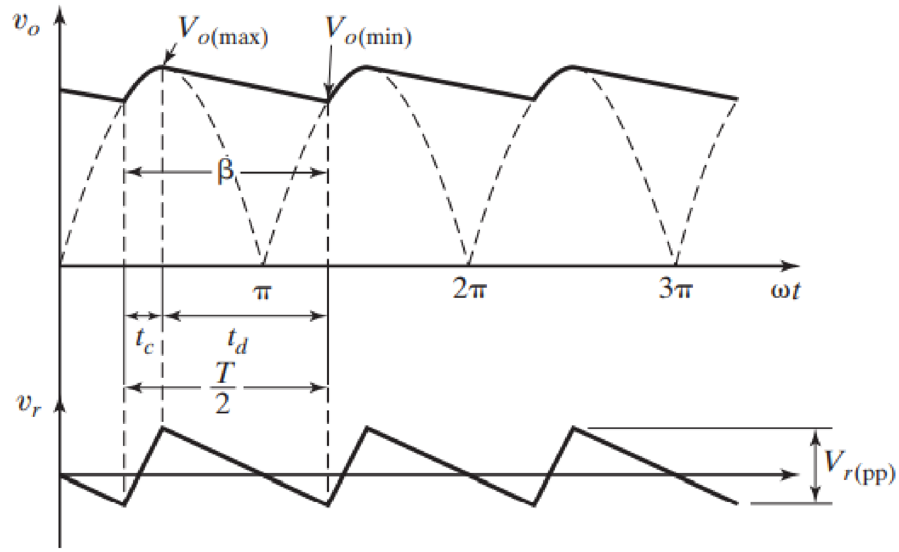

Figure 2.7: Waveform for full-wave rectifier)

The output ripple voltage, which is the difference between maximum voltage Vo(max) and the minimum voltage Vo(min), can be specified in different ways:

The peak value of output voltage:

$$V_o(max) = V_m \tag{2.1}$$

The peak–peak output ripple voltage, Vr(pp):

$$V_r(pp) = V_o(max) - V_o(min) = V_m - V_o(min) \tag{2.2}$$

The ripple factor of output voltage:

$$RF_v = \frac{V_r(pp)}{V_m} = V_m - \frac{V_o(min)}{V_m} = 1 - \frac{V_o(min)}{V_m} \tag{2.3}$$

The minimum value of output voltage:

$$V_o(min) = V_m(1 - RF) \tag{2.4}$$

2.3.2 Inverter block (DC/AC)

A single-phase bridge voltage inverter (VSI) is shown in the figure 2.8 below. It consists of four Transistors.

The choice of transistor

There are many types of switch-mode power supply (SMPS) transistors to choose from today. Two of the more popular versions are the metal-oxide semiconductor field effect transistor (MOSFET) and the insulated-gate bipolar transistor (IGBT). Historically speaking, low-voltage, low-current and high switching frequencies favor MOSFETs. High-voltage, high-current and low switching frequencies, on the other hand, favor IGBTs.[14]

Table 2.2: Comparison of different Transistors

Characteristics	MOSFET	IGBT
Frequency	High (greater than 200khz)	Low (less than 20khz)
Voltage	Low (less than 250v)	High (greater than 1000v)
Cycles	Long-duty	Low-duty

So, MOSFETs are the best transistor technology for our inverter because of:

- Lower rise and fall times, which has allowed for operation at higher switching frequencies.
- Improved switching speeds.
- Improved dynamic performance that requires even less power from the driver.
- Lower gate-to-drain feedback capacitance.
- Lower thermal impedance which, in turn, has enabled much better power dissipation.

Principal

When transistors Q1 and Q2 are turned on at the same time, the input voltage Vs appears across the load. When transistors Q3 and Q4 are turned on at the same time, the voltage across the load is reversed, -Vs. The output voltage waveform is shown below.

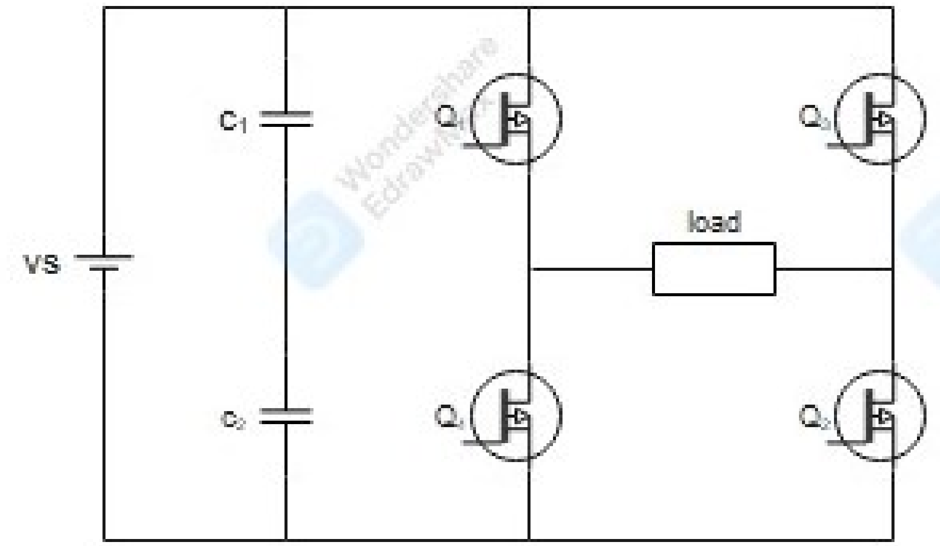

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Figure 2.8: single-phase bridge voltage inverter

The table shows five switch states. Transistors Q1, Q4 in Figure 2.8 are used as switching elements S1 and S4, respectively. When two switches: one previous and one next are turned on at the same time, so that the output voltage is Vs, the switch state is 1, if these switches are turned off at the same time, the switch state is 0.

The rms output voltage can be found from:

$$V_0 = \sqrt{\frac{2}{T_0}\int_0^{\frac{T_0}{2}} V_s^2 dt} = V_s \tag{2.5}$$

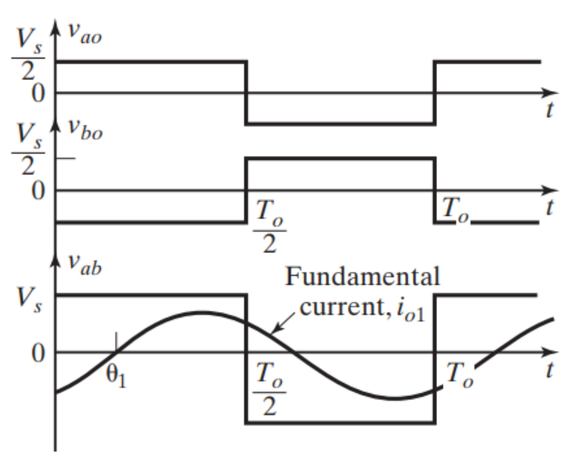

Figure 2.9: Waveforms

Table 2.3: Switch states for a single-phase Full-Bridge Voltage-source Inverter

State No.	State	Switch state	Vao	Vbo	Vo	Components conducting
1	S1 and S2 are on and S4 and S3 are off	10	Vs/2	-Vs/2	Vs	S1 and S2 if i0>0 D1 and D2 if I0 <0
2	S4 and S3 are on and S1 and S2 are off	01	-Vs/2	Vs/2	-Vs	D4 and D3 if i0>0 S4 and S3 if I0 <0
3	S1 and S3 are on and S4 and S2 are off	11	Vs/2	Vs/2	0	S1 and D3 if i0>0 D1 and S3 if I0 <0
4	S4 and S2 are on and S1 and S3 are off	00	-Vs/2	-Vs/2	0	D4 and S2 if i0>0 S4 and D2 if I0 <0
5	S1, S2, S4 and S3 are all off	off	-Vs/2 Vs/2	Vs/2 -Vs/2	-Vs Vs	D4 and D3 if i0>0 D1 and D2 if I0 <0

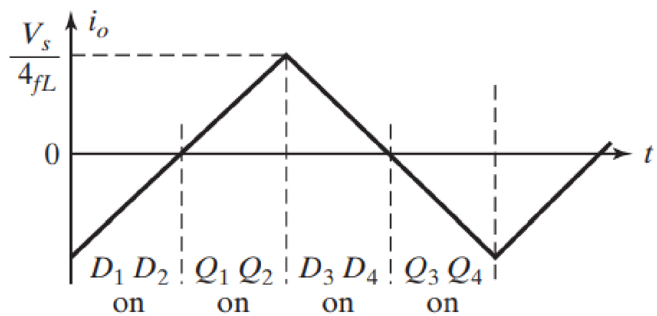

Figure 2.10: Load current with highly inductive load

Modified Sinusoidal Pulse-Width Modulation

The modified PWM sinusoidal waveform is used for power control and power factor optimization. The main concept is to divert the delayed current in the grid to the voltage grid by modifying the PWM converter. Therefore, there is improvement in power efficiency and optimization of power factor. The modified sinusoidal pulse width modulation (MSPWM) is shown in the figure 2.11. The fundamental wave component is increased, and the harmonic characteristics are improved. It reduces the switching times of power devices and also reduces switching losses.[12]
The m_{th} time $t_m$and angle $_m$of intersection can be determined from:

$$t_m = \frac{\alpha_m}{\omega} = t_x + m\frac{T_s}{2} \quad \text{for m=1,2,3,...p} \tag{2.6}$$

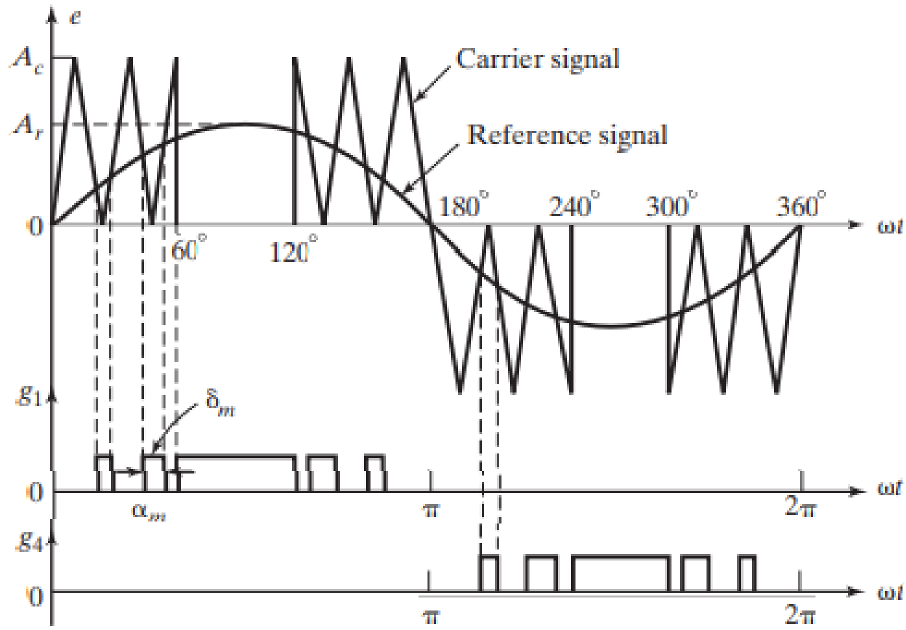

Figure 2.11: Modified sinusoidal PWM modulation

2.3.3 Rectifier Block (AC/DC BLOCK) (for the vehicle)

We used four diodes bridge rectifier, as shown in Figure 2.12. During the positive half-cycle of the input voltage, the power is supplied to the load through diodesD_1 and D_2. During the negative cycle, diodes D3 and D4 conduct. The waveform for the output voltage is shown in Figure 2.13. The peak inverse voltage of a diode is only V_m.This circuit is known as a bridge rectifier, and it is commonly used in industrial applications.[12]
The average output voltage is:

$$V_{dc} = \frac{2}{T}\int_0^{\frac{T}{2}} V_m sin\left(\omega t\right) dt = \frac{2V_m}{\pi} = 0.6366V_m \tag{2.7}$$

We added the capacitor to the circuit to make the waveform perfectly continues.

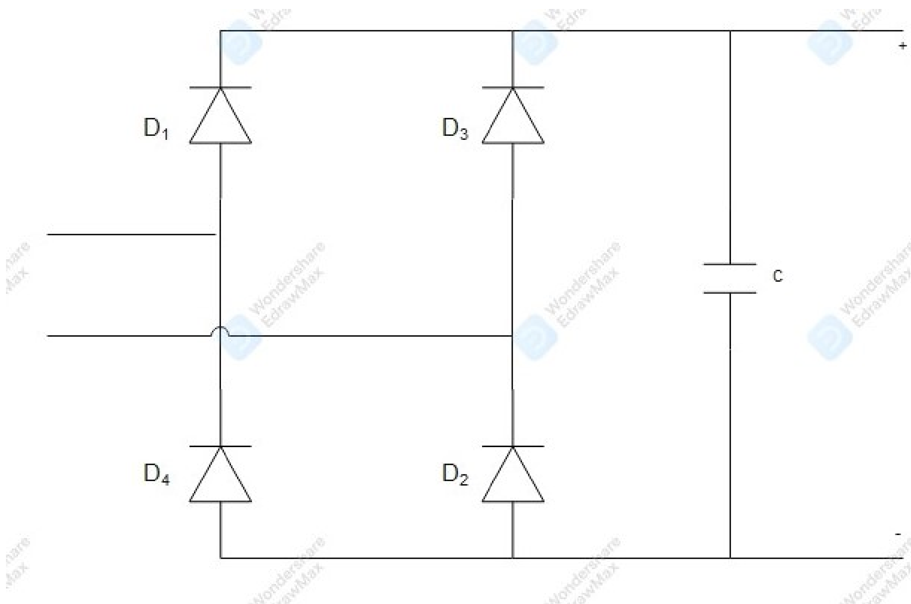

Figure 2.12: Full-wave rectifier circuit using four diodes

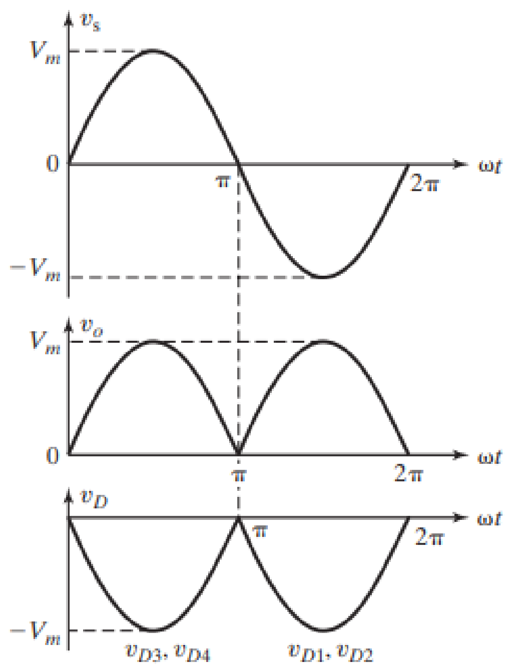

Figure 2.13: Waveforms

2.4 Command and control part

Different Sensors and actuators are used in the control and command part depends on the function and the utility:

2.4.1 Micro-controller

Both charging station and electric vehicle posses a micro-controller to process data of wireless charging system and controle the system,to do that the Arduino Mega 2560 board is based on an ATMega2560 clocked at 16 MHz. It has 54 I/Os including 14 PWM, 16 analog and 4 UARTs. It is ideal for applications requiring more complete features than the Uno [4].

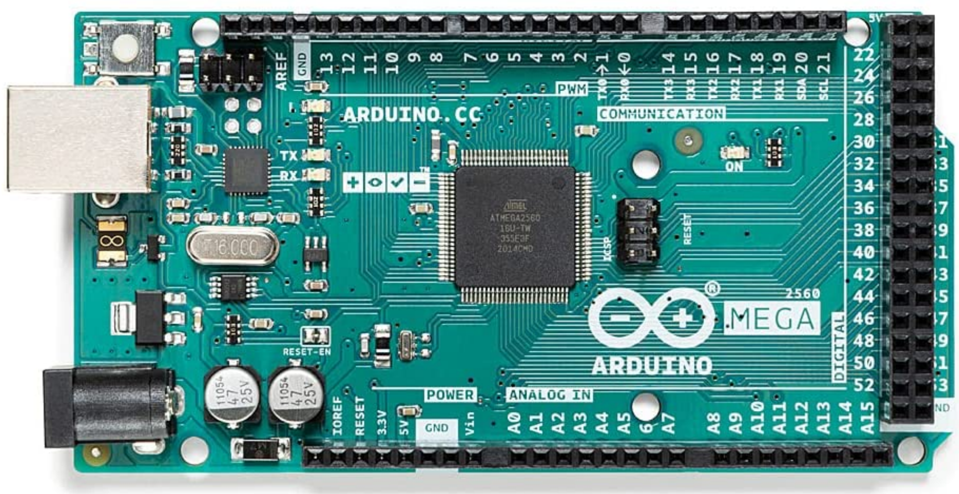

Figure 2.14: Arduino mega [4]

Table 2.4: Arduino mega characteristics [4]

Parameters	Value
Microcontroller	ATmega2560
Operating Voltage	5V Input Voltage
Input Voltage (Recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Iputs Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

2.4.2 The HC-SR04 ultrasonic sensor

To start charging the electric vehicle, it need to be placed in the right place, to achieve that the system we use an Ultrasonic sensor which is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. The Ultrasonic waves travel faster than the speed of audible sound (i.e. the sound that humans can hear).
Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and the receiver (which encounters the sound after it has travelled to and from the target)[5] .

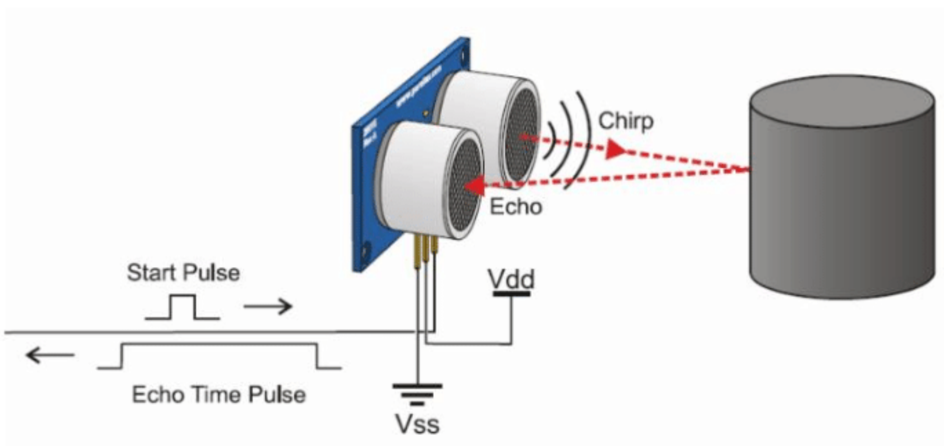

Figure 2.15: Ultrasonic-sensor diagram[5]

To calculate the distance between the the sensor and the object the sensor measures the time it takes between the emission of the sound by the transmitter to its contact with the receiver.The formula for this calculation is:

$$d = \frac{1}{2}TC \tag{2.8}$$

d:The distance between the sensor and the object
T:Time pulse
C:Speed of sound (around 343 m/s)

2.4.3 State of charge calculation

The state of charge is one of the most important parameters for batteries, in general the SOC (State Of Charge) of a battery is defined as the ratio of current capacity $Q(t)$ and the nominal battery capacity Q_n. The nominal capacity represent the maximum amount of charge that a battery can store and it's given by the manufacturer.The state of charge can be defined as follow: [15]

$$SOC = \frac{Q(t)}{Q_n} \tag{2.9}$$

There is a various estimation methods and they are classified according to the methodology.estimation methodologies are classified as following:

- **Direct measurement**: this method uses physical battery properties, such as the voltage and impedance of the battery
- **Book-keeping estimation**: this method uses discharging current as the input and integrates the discharging current over time to calculate the SOC.
- **Adaptive systems**: the adaptive systems are self-designing and can automatically adjust the SOC for different discharging conditions. Various new adaptive systems for SOC estimation have been developed.
- **Hybrid methods**: the hybrid models benefit from the advantages of each SOC estimation method and allow a globally optimal estimation performance. The literature shows that the hybrid methods generally produce good estimation of SOC, compared to individual methods.[15]

The Book-Estimation method use charging current (in case of charging and discharging current in case of charging) as input data.in the Book-Estimation method we use the Coulomb Counting Method which estimate SOC from $I(t)$ by the following equation:

$$SOC(t) = SOC(t-1) + \frac{I(t)}{Q_n}\Delta t \tag{2.10}$$

As seen in equation 2.10 State of charge estimation method needs an instate current measurement, to do that we use a current sensor acs755xcb-100.

2.4.4 Inverter command circuit

To obtain a high frequency electric signal in the inverter output, we use the Sinusoidal PWM (Puls Width Modulation) command technique. Pulse Width Modulation (PWM) or Pulse Duration Modulation (PDM) is a method of reducing the average power delivered by an electrical signal by effectively breaking it up into discrete parts. Controls the average voltage (and current) supplied to the load by rapidly opening and closing the switch between the source and the load. The longer the switch is on compared to the off time, the higher the total power delivered to the load. Generally speaking, the PWM method may be grouped into classes, depending on the modulation technique:

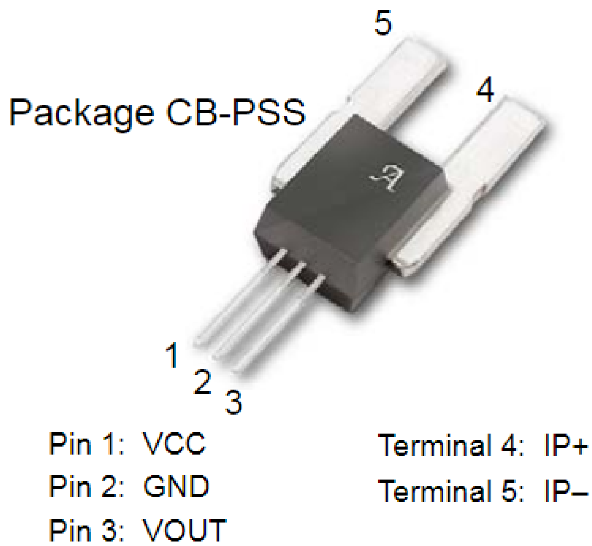

Figure 2.16: Current Sensor

1. Non-sinusoidal PWM, in which all pulses have the same width and are normally modulated equally to control the output voltage, as shown in the four-pulse-per half-cycle

2. Sinusoidal PWM, which allows the pulse width to be modulated sinusoidally; i.e., the width of each pulse is proportional to the instantaneous value of a reference sinusoid whose frequency equals that of the fundamental components as shown in the six-pulse-per-half-cycle [12]

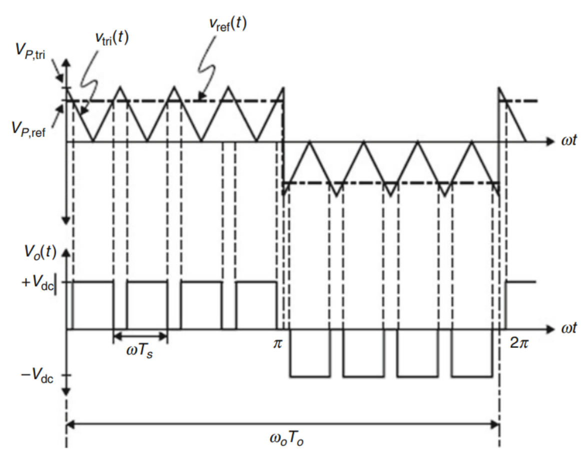

Figure 2.17: Typical waveform for equal-pulse PWM techniques

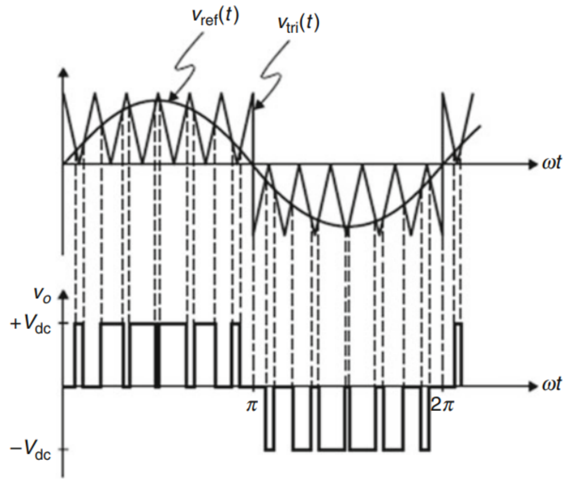

Figure 2.18: Typical waveforms for sinusoidal PMW technique

$v_{tri}(t)$: Repetitive triangular waveform (also known as a carrier signal)
$V_{P,tri}$: The peak value of the triangular waveform
T_s, f_s: The period and the frequency of the triangular waveform (also known as a carrier or switching frequency)
v_{ref}: Reference signal that can be either a square or a sinusoidal waveform (also known as a control signal)
$V_{p,ref}$: The peak value of the reference signal
T_O, f_O: The desired inverter output period and output frequency, which are equal to the period and frequency of the reference or control signal
m_a: Inverter amplitude modulation index
m_f: Inverter frequency modulation index
k: Number of pulses per half-cycle
The amplitude and frequency modulation indices are defined as follows:

$$m_a = \frac{V_{P,ref}}{V_{P,tri}} \tag{2.11}$$

$$m_f = \frac{f_s}{f_O} \tag{2.12}$$

$$m_a = \frac{V_{P,ref}}{V_{P,cont}} \tag{2.13}$$

The output voltage signal in sinusoidal PWM can be obtained by comparing a control signal, vcont, against a sinusoidal reference signal, vref, at the desired frequency. At the first half of the output period, the output voltage takes a positive value $+V_{dc}$ whenever the reference signal is greater than the control signal In the second half of the output period,the output voltage takes a negative value V_{dc} whenever the reference signal is less than the control signal. The control frequency f_{cont} determin the number of pulses per

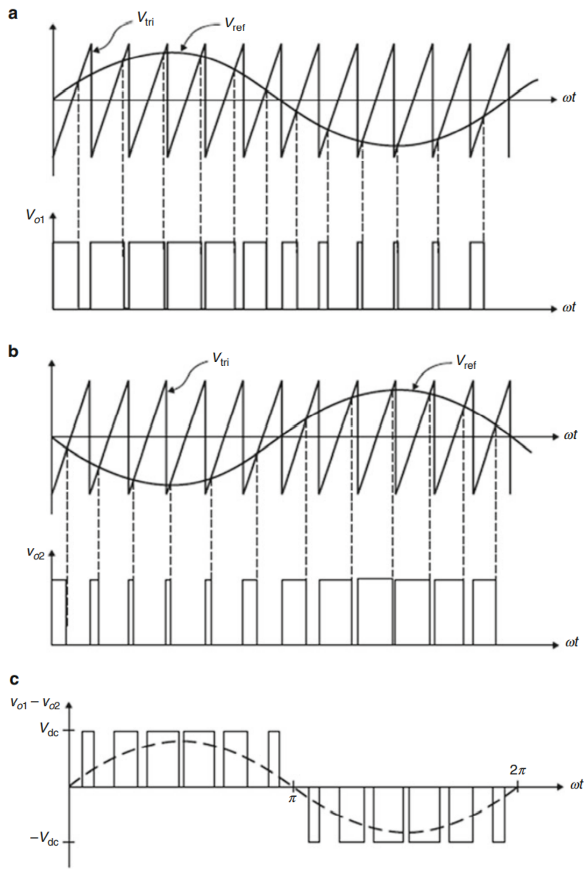

Figure 2.19: Uni-polar PWM output (a) A positive sinusoidal reference to produce vo1 and (b) positive sinusoidal reference to produce vo2 (c) The differential output $v_{o1} = v_{o1} - v_{o2}$

half-cycle of the output voltage signal. also the output frequency f_O is determined by the reference frequency f_{ref} The amplitude modulation index, ma, is defined as the ratio between the sinusoidal magnitude and the control signal magnitude:

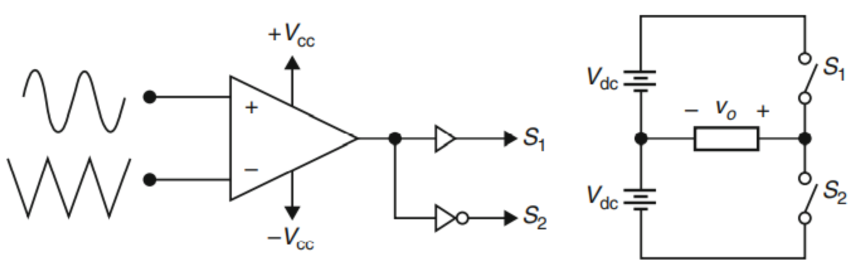

Figure 2.20: Simplified circuit shows how signals are generated in sinusoidal PWM inverters

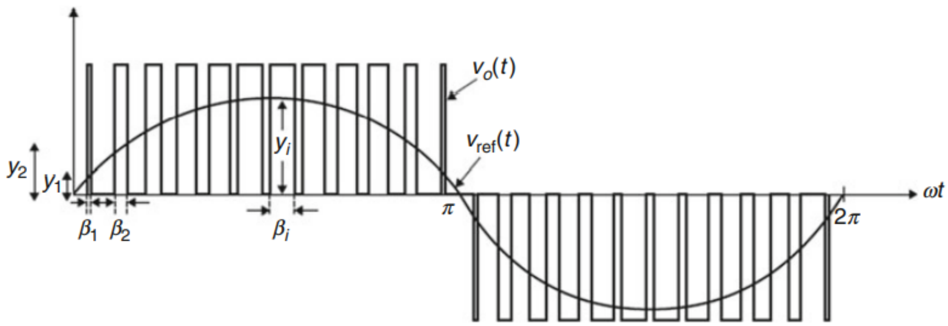

Figure 2.21: PWM figure to illustrate the constant ratio between the width and height of a given pulse

2.4.5 Bluetooth comunication

To exchange information and charging process parameters between the charging station and the electric vehicle we use the Bluetooth technology which is an omnidirectional wireless technology that provide limited-range data transmission over a 2.4 GHz frequancy band allowing connections with a wide variety of portable and fixed devices that normally would be cabled together, it can communicate at a distance up to 10 m and it's most widely used transmission mode, transmission power is limited to 2.5 milliwatts.[16]

using the HC-05 Bluetooth module showen in figure 2.22 to communicate between EV and charging station using SPP (Serial Port Protocol) module, its designed to makes an easy way to interface with with controller or PC

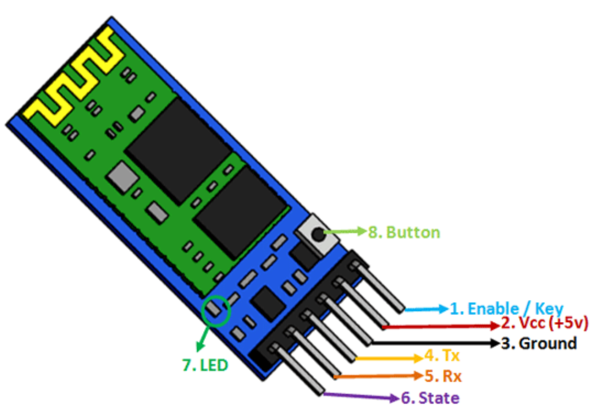

Figure 2.22: HC-05 Bluetooth Module pinout

HC-05 pins are defined in table 2.5 :

Table 2.5: HC-05 Bluetooth pins

[16]

Pin name	Working
Enable	The purpose of this pinout is to set data value at a high and low level
Vcc	At this pinout, the input supply is provided to the module. Its operating voltage is plus five volts.
Ground	Ground (0V)
Tx	Serial Transmitting Pin.
Rx	Serial Receiving Pin
State	This Pin is connected to an LED, shows the operating state of the HC-05 Bluetooth module.

2.4.6 Energy meter

Energy meter system use current sensor(shown in previous paragraph) and voltage sensor which is in this case voltage divider that reduce high voltage to a range of 0 to 5V to be adapted with the micro-controller input voltage as seen in Figure 2.23 :

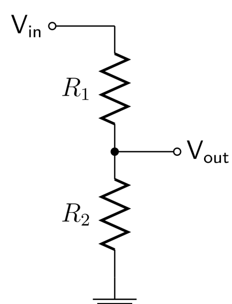

Figure 2.23: Voltage divider circuit

R1 and R2 are chosen to gives the ration that reduce the high voltage as seen in the following equation:

$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in} \tag{2.14}$$

The input voltage and current data are used to calculate the power flow and energy consumed and other information and could be displayed in the charging station screen display or the electric vehicle screen display depending on the choice of the producer

2.5 Coil design

One of the essential part of the wireless charging system is the coil which is the part that transmit energy through the space between the charging system and the electric vehicle and it's the transmitting and the receiving organs of the system :

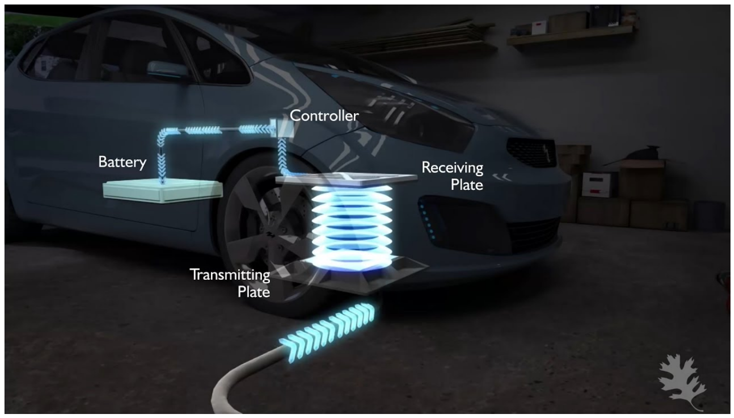

Figure 2.24: Wireless power transfer demonstration

As seen in figure 2.24 the transmitting and the receiving organs named transmitting plate and receiving plate are responsible for wireless power transfer.
The power transfer system could be represented as the following circuit in figure 2.25, in which the transmitting and the receiving coils are represented by an mutual inductance (Tx and Rx), R1 and R2 represent the resistance of coils, and capacitors C1 and C2 to create the resonance circuit (LC circuit). K represent the coupling factor which is the

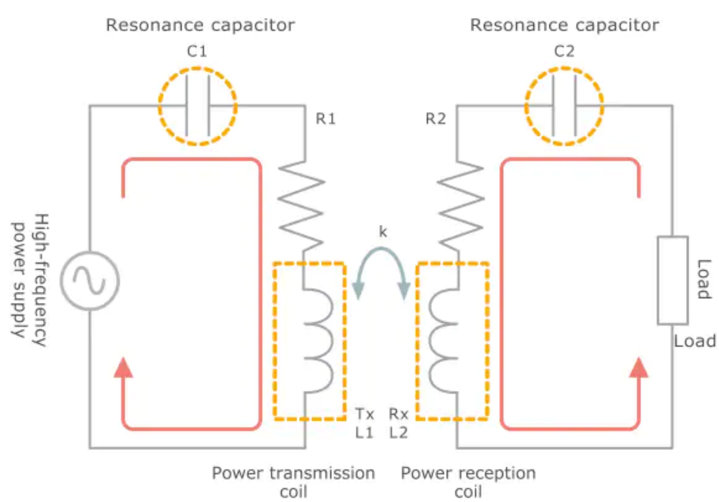

Figure 2.25: Simplified circuit of resonant coupling

fraction of magnetic flux created by the current in one coil which connect with one other coil is also known as coupling coefficient between the two coils.k is included between 1 and 0 and is defined as follow :

$$k = \frac{M}{\sqrt{L_1 L_2}} \tag{2.15}$$

k=1 when the flux made by one coil completely connects with the additional coil and can be called magnetically closely coupled.

k=0 when the flux made by one coil doesn't connect at each of the coil and therefore the coils have been thought to be magnetically isolated. [17]

Transmitting and receiving coils designs has physical limits that depend on the Electric vehicle and charging station such as the area and the thickness that should be the minimum possible to prevent the weight problem and to adapt with the electric vehicle design, from those conditions the parameters of the Tx and Rx are taken to calculate the inductance of the coils.

The type of coil this application is flat spiral coil because of its very small thickness that fit better with the electric vehicle, flat coil also has another advantage which is spacing between wires that reduce danger of heating that could damage the wires.as shown in figure 2.26:

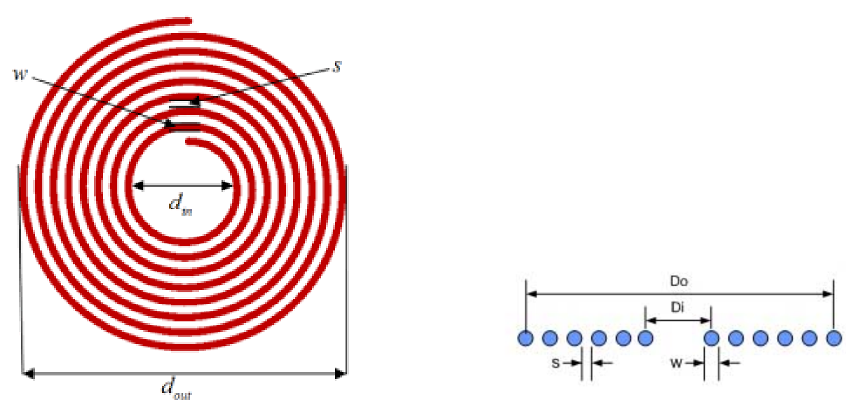

Figure 2.26: Spiral flat coil physical parameters

D_o: Outer diameter
D_i: Inner diameter
w: Wire diameter
s: Turn spacing

The inductance of the transmitting and the receiving coil must be identical so the voltage of the transmitting circuit and remain the same in the receiving circuit, The induction of this Spiral flat coil is calculated as follow [18]:

$$L = \frac{N^2(D_{outer} - N(w+p))^2}{16D_{outer} + 28N(w+p)} \cdot \frac{39.37}{10^6} \tag{2.16}$$

L: Spiral coil inductance
D_{outer}: Outer diameter
N: Number of turns
w: Wire diameter
p: Turn spacing

The other parameters of wireless power transfer is resistance which is the resistance of wires in both the transmitting coil and the receiving coil that is calculated by calculating the wire length using an approximating by considering the spiral coil is formed from circles of different diameters

$$D_o = D_i + (2N(w+p)) \tag{2.17}$$

wire length is calculated as follow:

$$w_l = \pi N(\frac{D_i + D_o}{2}) \tag{2.18}$$

w_l: wire length of spiral coil then we calculate the resistance as follow:

$$R = \rho\frac{w_l}{S} \tag{2.19}$$

R: Spiral coil wire resistance (Ω).
ρ: Electrical resistivity (Ω/m).
S : $wiresection(m^2)$.
To transfer power at a height rate the impedance of the transmitting circuit must be reduced at it lowest levels by adding a capacitors to the LR circuit, as we can see in the following equations the impedance of the transmitting circuit: [19]

from the first circuit :

$$U_1 = (R_1 + j\omega L_1 + \frac{1}{j\omega C_1})I_1 - j\omega M I_2 \tag{2.20}$$

U_1: Voltage source of transmitter circuit (V).
C_1: Compensation capacity of transmitting circuit (F).
R_1: Resistance of transmitter coil (Ω).
L_1: Inductance of transmitter coil (H).

ω: signal pulsation (rad/s). from the second circuit:[19]

$$j\omega M I_1 = (R_L + R_2 + j\omega L_2 + \frac{1}{j\omega C_2})I_2 \tag{2.21}$$

I_1: Current of the transmitting circuit (A).
I_2: Current of the receiving circuit (A).
C_2: Compensation capacity of receiving circuit (F).
R_L: Load resistance (Ω).
R_2: Resistance of receiving spiral coil (Ω).
from equation 2.20 and 2.21 we define the impedance as follow:

$$Z_2 = R_L + R_2 + j\omega L_2 + \frac{1}{j\omega C_2} \tag{2.22}$$

and:

$$Z_1 = (R_1 + j\omega L_1 + \frac{1}{j\omega C_1}) + \frac{\omega^2 M^2}{|Z_2|^2} Z_2^* \tag{2.23}$$

Z_1: Impedance of the transmitting circuit (Ω).
Z_2: Impedance of the receiving circuit (Ω).
impedance is composed of real part and imaginary part: [19]

$$Z_{2reel} = R_L + R_2 \tag{2.24}$$

where:

$$Z_{2ima} = j\omega L_2 + \frac{1}{j\omega C_2} \tag{2.25}$$

by choosing the resonance frequency as $\omega_r = \frac{1}{\sqrt{L_1 C_1}} = \frac{1}{\sqrt{L_2 C_2}}$ we got $Z_{1ima} = Z_{2ima} = 0$ and so the impedance of the WPT system will be at it lowest value which will increase the current value.now the impedance is reduced, we will define the expression of power transfer efficiency to see if it depends on other factors :

$$P_{in} = U_1 I_1 = \frac{U^2(R_L + R_2)}{R_1(R_L + R_2) + \omega^2 M^2} \tag{2.26}$$

$$P_{out} = R_L I_2^2 = \frac{R_L \omega^2 M^2 U^2}{(R_1(R_L + R_2) + \omega^2 M^2)^2} \tag{2.27}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{R_L}{R_L + R_2 + \frac{R_1(R_L+R_2)}{\omega^2 M^2}} \tag{2.28}$$

P_{in}: WPT circuit input power (W).
P_{out}: WPT circuit output power (W).
η: Wireless power transfer efficiency.

as seen in expression 2.28 the efficiency of power transfer depend of other factors as the resistance of both coils, the resonance frequency and the mutual inductance between the transmitting and the receiving coil that also depend on the parameters of those two and the distance between them.The Neumann formula 2.29 is used to calculate the mutual inductance between two circular wire loop as seen in figure 2.27:

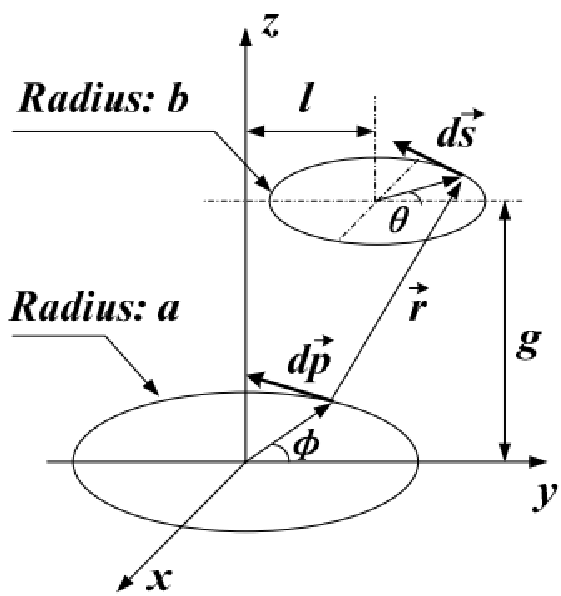

Figure 2.27: Spatial configuration for each set of wire loops [6]

$$M = \frac{\mu_0}{4\pi} \oint_p \oint_s \frac{d\overrightarrow{p}.d\overrightarrow{s}}{r} \tag{2.29}$$

where :

$$d\overrightarrow{p} = a(-\sin\phi\overrightarrow{x} + \cos\phi\overrightarrow{y})d\phi \tag{2.30}$$

$$d\overrightarrow{s} = b(-\sin\theta\overrightarrow{x} + \cos\theta\overrightarrow{y})d\theta \tag{2.31}$$

$$d\overrightarrow{p}.d\overrightarrow{s} = ab\cos(\phi - \theta)d\phi d\theta \tag{2.32}$$

withe the distance r is:

$$r = \sqrt{a^2 + b^2 + g^2 + l^2 - 2ab\cos(\phi - \theta) - 2al\cos\phi + 2bl\cos\theta} \tag{2.33}$$

where a is the radius of the primary coil and b is the radius if the secondary coil and g is the distance between the two coils and l is the lateral distance. combining equations from 2.29 to 2.33 and using Newton's generalized binomial theorem to expand the integral expression up to the seventh order, and the two coils are co-axially placed (l=0) then the simplified mutual inductance between the two wire loops can be expressed as:

$$M = \frac{\mu_0 \pi a^2 b^2}{16\rho^3}(1 + \frac{15a^2b^2}{128\rho^4} + \frac{315a^4b^4}{16384\rho^8} + \frac{15015a^6b^6}{4194304\rho^{12}}) \tag{2.34}$$

where $\rho = \sqrt{\frac{a^2+b^2+g^2}{4}}$ and $\mu_0 = 1.2566 \cdot 10^{-6} mKgs^{-2}A^{-2}$ is the magnetic constant,sins the coil used for the WPT system commonly include multiple turns of wire loops, the mutual inductance between two planar coils is a sum of all the possible combinations of single wire loops. Thus, the total mutual inductance between the two circular coils is[6] :

$$M_{total} = \sum_{i=1}^{n_p} \sum_{j=1}^{n_s} M_{ij} \tag{2.35}$$

To calculate the sum of all possible combination of single wire loops the radius of the first coil and the second coil will change depending on the number of turns as follow:

$$a = D_{inner/a} + 2(i-1)(w+p); \tag{2.36}$$

$$b = D_{inner/b} + 2(j-1)(w+p); \tag{2.37}$$

2.6 Conclusion

In this chapter we saw that wireless charging system contain two parts that work in parallel, Power part and control part. Power part is the power circuit that takes electric from grid to the battery of the electric vehicle using multiple stages of power converters as rectifiers and height frequency inverter, also control part that is used to manage the charging process by measuring and controlling power flow using different sensors and actuators with help of micro-calculator to be able to control charging process and make it easy for the user.

We have seen also general aspect about wireless power transfer with its different methods and then we chooses the best method that suits the electric vehicle application case, then we modeled the wireless power transfer circuit to be able to calculate its parameters and to simulate the system in the next chapter.

Chapter 3

Simulation of the wireless charging system

3.1 Introduction

The objective of this chapter is to simulate the wireless charging system using simulink and ISIS, and calculate system parameters using scripts that involves theoretical calculus mentioned in the previous chapter to discuss system behaviour and display system ouput power

3.2 Software used for simulation:

In this simulation of wireless charging system we will use two software to simulate power part and command and control part, those software's are:

3.2.1 Matlab

MATLAB® combines a desktop environment tailored for iterative analysis and design processes A programming language that directly expresses matrix and array math. it includes live Editor for creating scripts that combine code, output, and formatted text into executable notebooks. (from Matlab official website) Matlab is one of the most famous languages, similar to other languages Programming languages such as C++, C, Java, etc. are available through their own integrations A development environment and a set of libraries. , but in the initial stage it was called the Matrix programming language [7].

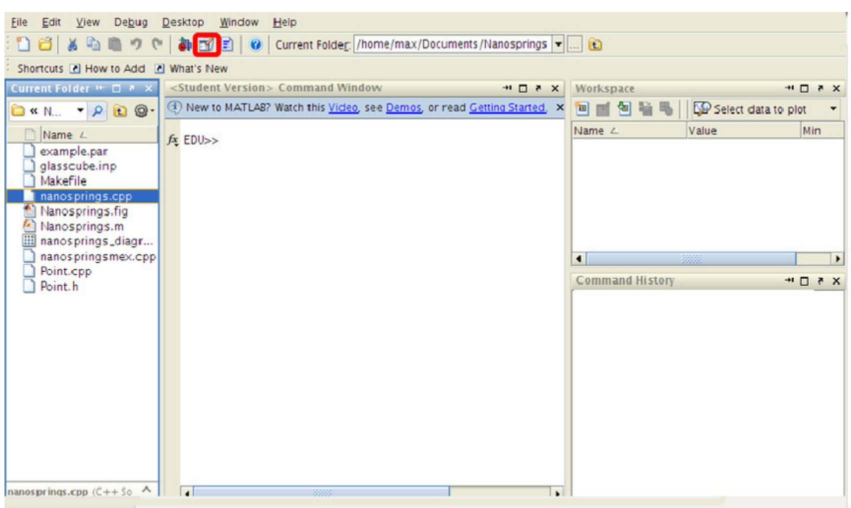

Figure 3.1: Matlab environment[7]

3.2.2 ISIS proteus

ISIS is the software used to draw schematics and simulate the circuits in real time. The simulation allows human access during run time,thus providing real time simulation. it is used to simulate, design and drawing of electronic circuits. It was invented by the Labcenter electronic. By using proteus you can make two-dimensional circuits designs as well

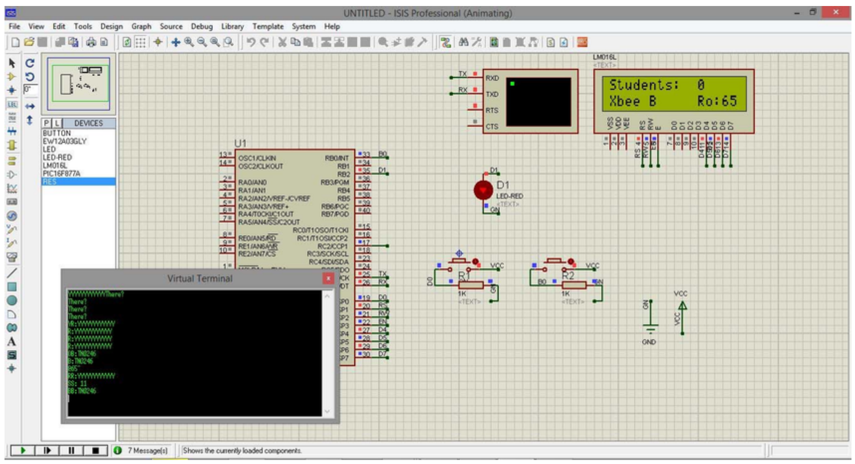

Figure 3.2: ISIS proteus environment

3.3 Parameters calculation

In wireless charging system, power transfer depends on some parameters like battery parameters and coil parameters. Coils parameters are calculated using the following script **??** by giving inputs parameters that are outer diameter,number of turns, wire width, spacing between wires, distance between coils, the parameters are giving as follow:

Table 3.1: Coils parameters calculation inputs

Parameters	Values
Outer diameter	1 (m)
Number of turns	5
Wire diameter	0.006 (m)
Spacing between cables	0 (m)
distance between coils	0.2 (m)

Using Matlab script in which we implemented equations demonstrated in section 2.5, the results are the coils parameters, and they are shown in the following table:

Results of the script are classed in table 3.2 :

Table 3.2: Coils parameters

Parameters	Values
Inductance	5.499292e-05 (H)
Inner diameter	9.400000e-01 (m)
Length of wire	1.522900e+01 (m)
Resistance of wire	8.568333e-03 (Ω)
Mutual inductance	3.144731e-05 (H)
Capacity	6.381695e-08 (F)
Coupling coefficient	5.718428e-01

3.4 Matlab simulation

Using simulink, we build the wireless charging system, shown in the Figure 3.3

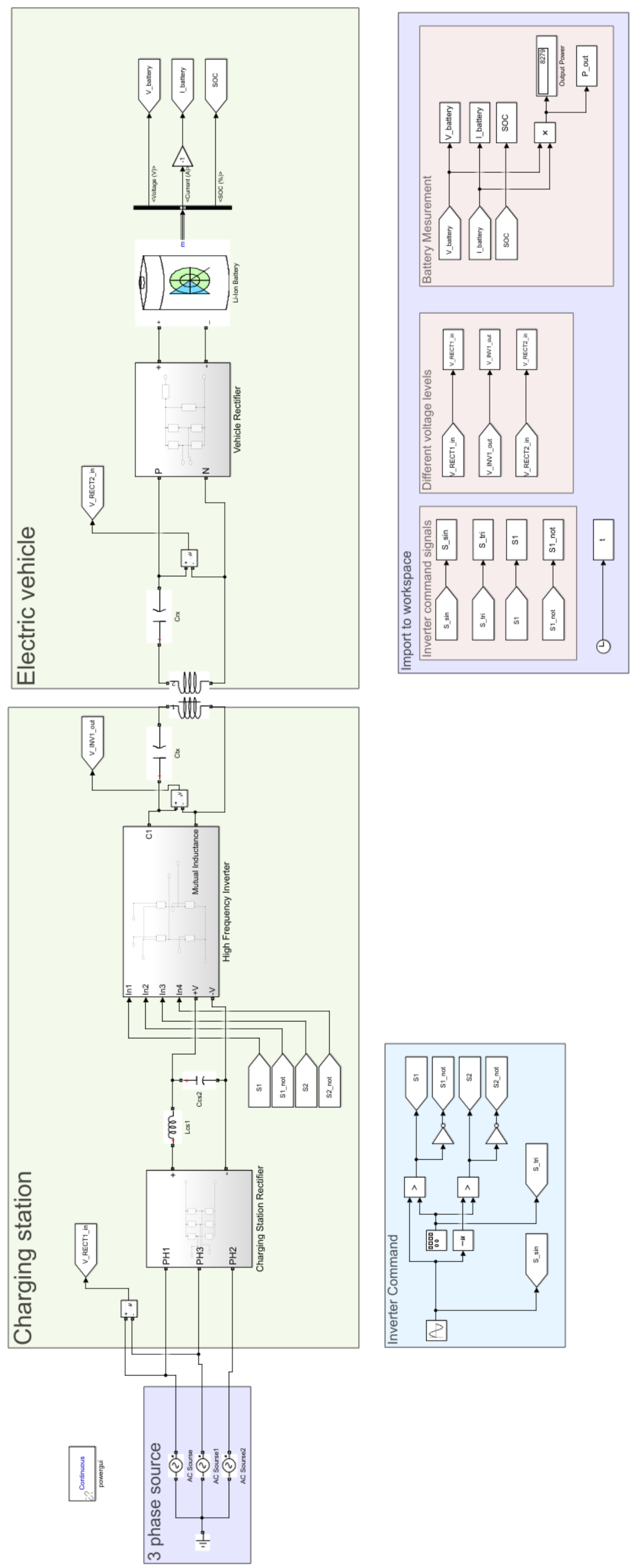

Figure 3.3: Wireless charging system overview

Wireless charging system main supply is electric grid,by taking 3 phase source of 380V/50Hz :

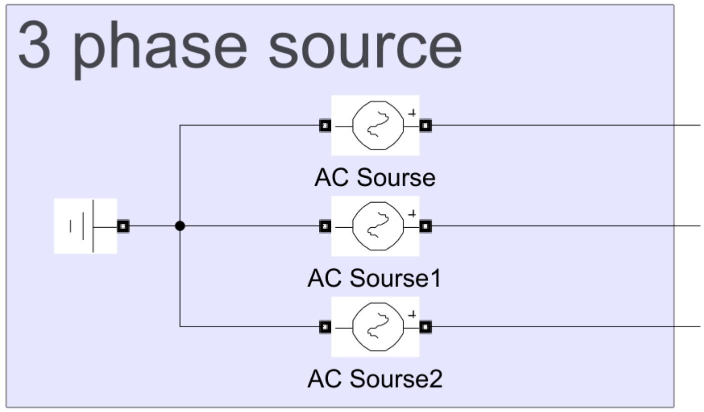

Figure 3.4: 3 phase source block

Figure 3.5 shows the input voltage of the system

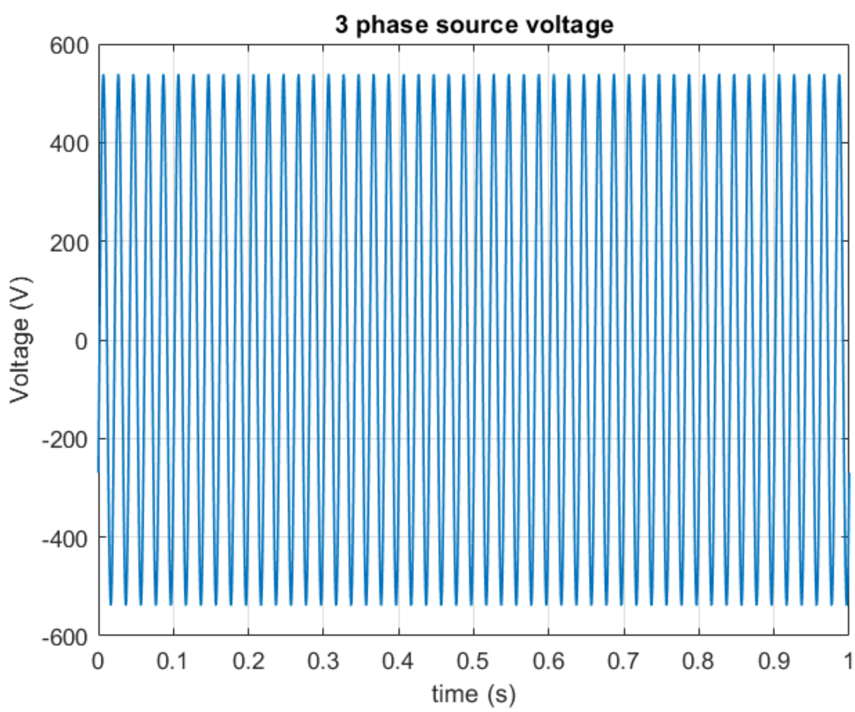

Figure 3.5: 3 phase source signal

The following block is charging station block that contain the rectifier block,the height frequency inverter block, and the transmitting part of the coupling circuit

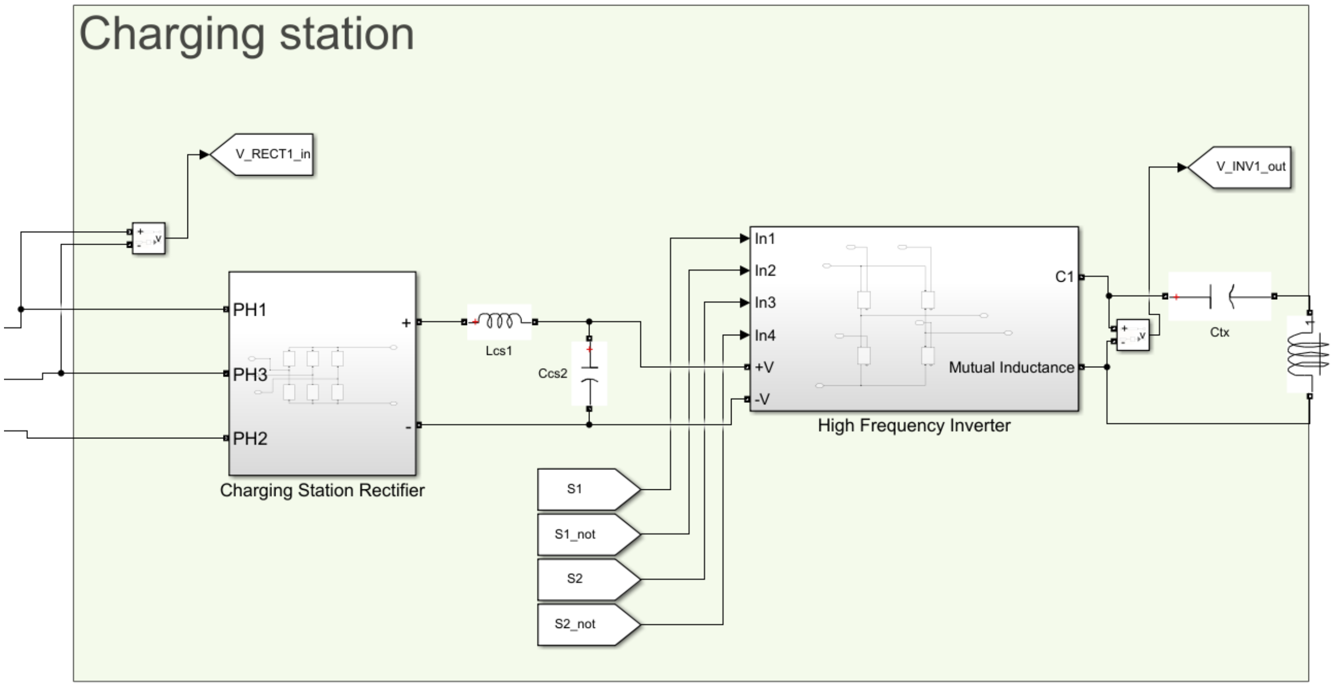

Figure 3.6: Charging station block

Figure 3.7 shows the circuit of the 3phase rectifier that contain 6 diodes, and aim to turn the input 50 Hz AC voltage to DC voltage with maximum value of $380 \times \sqrt{2}V$

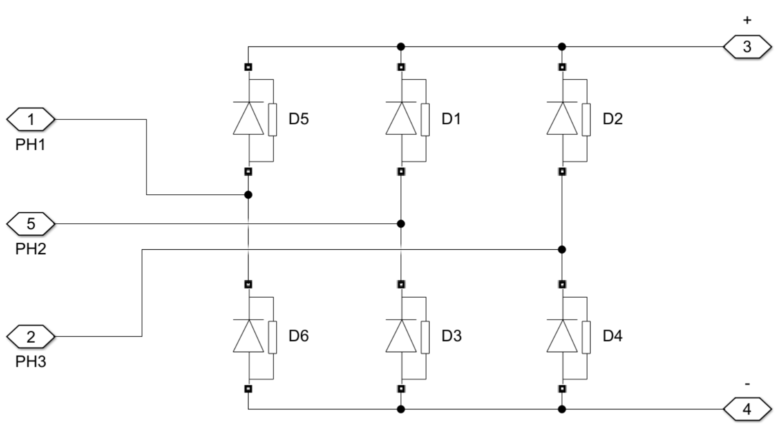

Figure 3.7: Charging station rectifier block

The height frequency inverter block shown in the Figure 3.8 contain 4 MOSFET transistors commanded by the inverter command block using PWM (Pulse Width Modulation) method to obtain an output signal with the required frequency of 85kHz (based on already existing international standardization approaches in IEC, ISO and SAE [20])

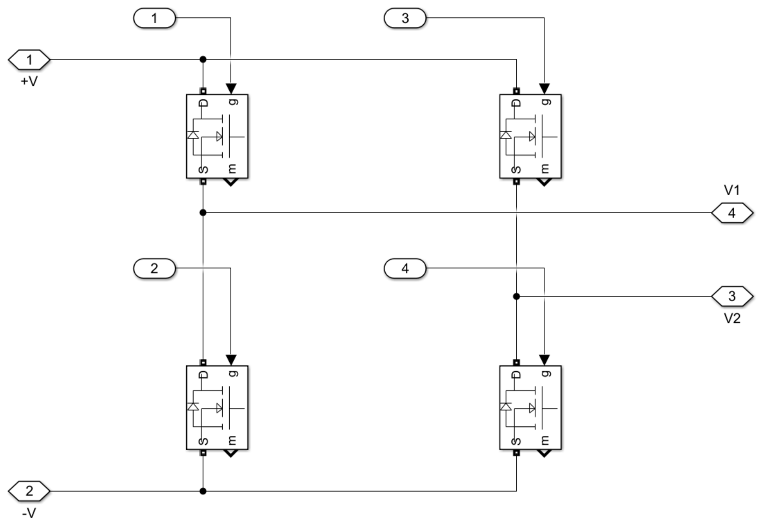

Figure 3.8: Inverter circuit

The inverter command part contain sinusoidal signal generation block and triangular signal generation block, comparatives and logic not block to generate 4 output command signals that goes to each transistor to prevent the PWM command, the command signals are shown in Figure 3.9:

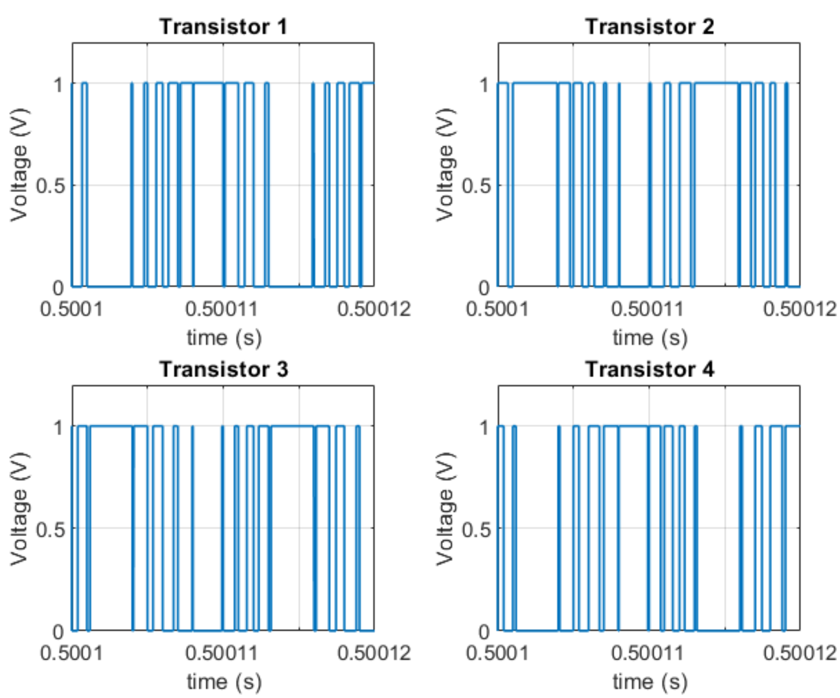

Figure 3.9: Transistors command signals

Using the PWM command, we obtain the output signal shows in figure 3.10 which is

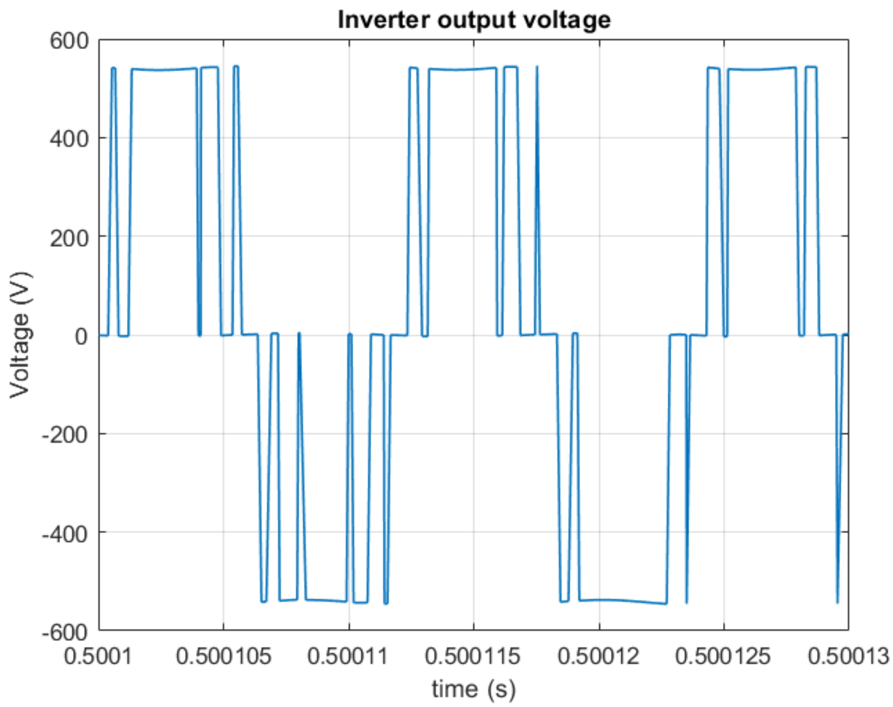

Figure 3.10: inverter output signal

voltage at the coils terminals :

The AC 85kHz signal goes to the transmitting coil to generate a magnetic field that goes through the second coil to generate voltage in the receiving circuit, while the capacity is used to compensate the reactive power, in order to increase the current of wireless power transfer, the parameters of the coupling circuit are taken from table 3.2 in the Figure

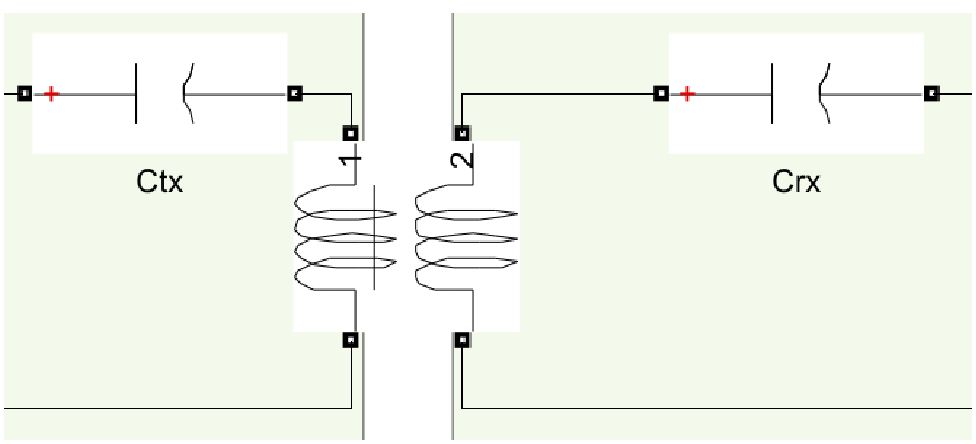

Figure 3.11: Coupling circuit

Coupling circuit receiving part is contained on the electric vehicle block,that contain rectifier to turn AC 85kHz electric signal coming from charging station to DC electric signal to charge the electric vehicle battery as seen the figure 3.12.

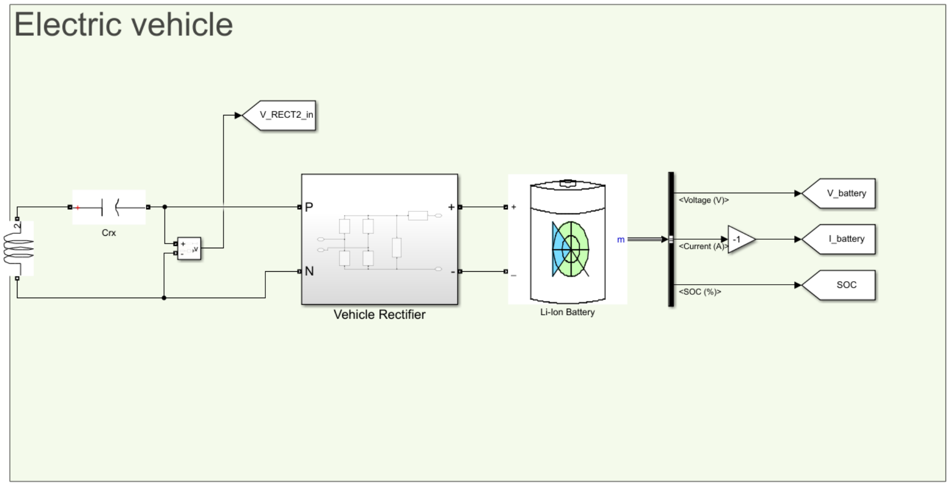

Figure 3.12: Electric vehicle block

Single phase rectifier block is circuit that contain 4 diodes, filtering capacity and inductance to minimise rectification perturbation due to high frequency input signal as shown in Figure 3.13.

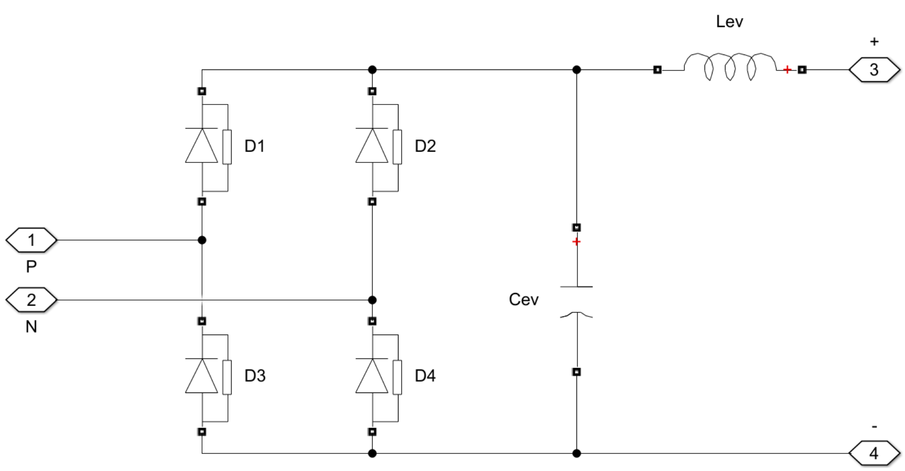

Figure 3.13: Electric vehicle rectifier block

rectifier block is connected to the Lithium-ion battery block shown in Figure 3.14 ,to charge the $100kWh$ electric vehicle battery with the following parameters that are shown in the table 3.3:

Table 3.3: Lithium-ion battery parameters

Battery parameter	value
Nominal voltage	360 V
Rated capacity	277 Ah
cutt-off voltage	270 V
Internal resistance	0.012996 R
capacity at nominal voltage	250.5043 Ah

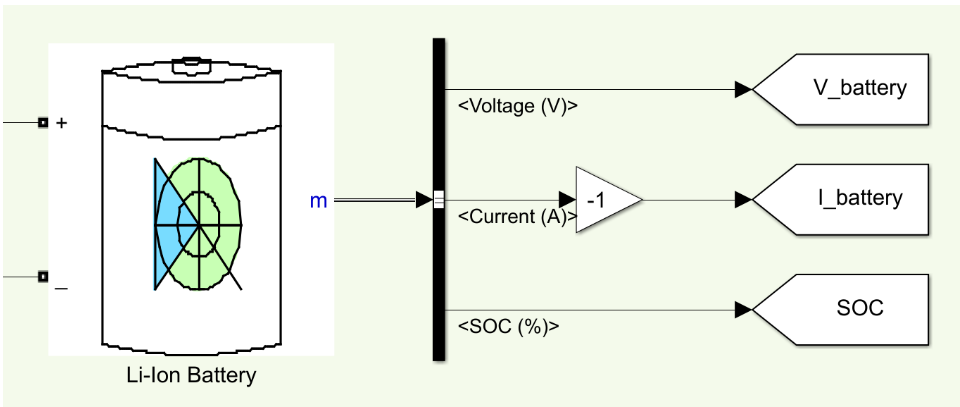

Figure 3.14: Battery block

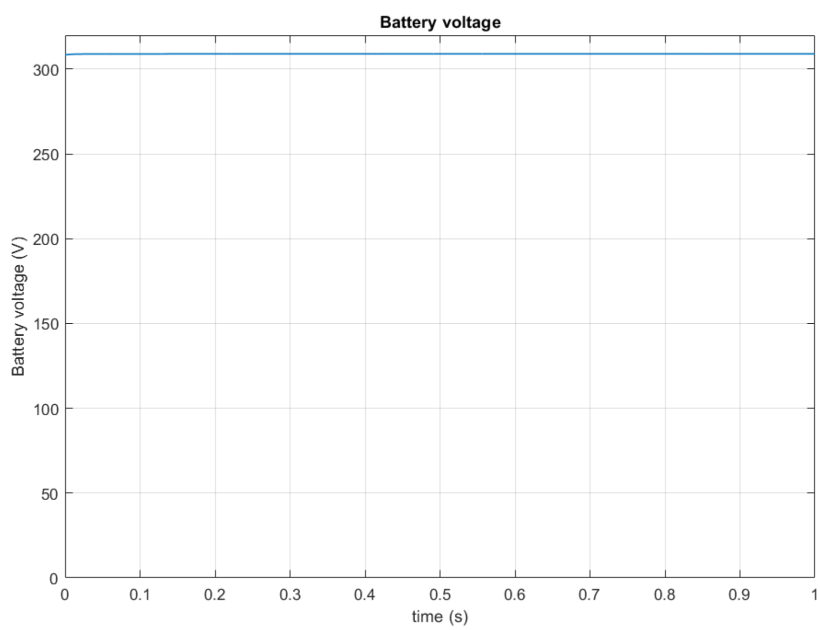

Figure 3.15: Battery voltage

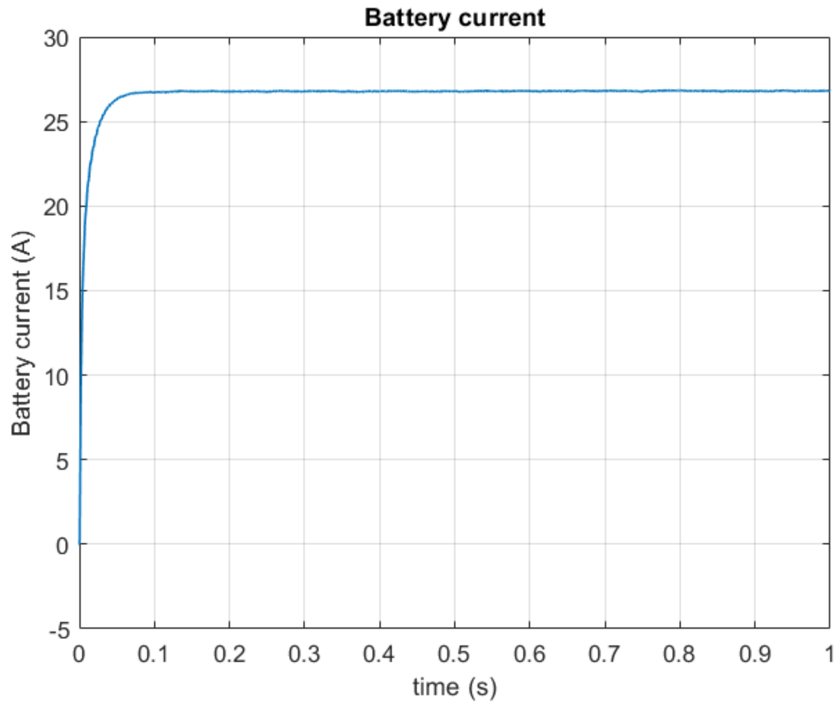

Figure 3.16: Battery input current

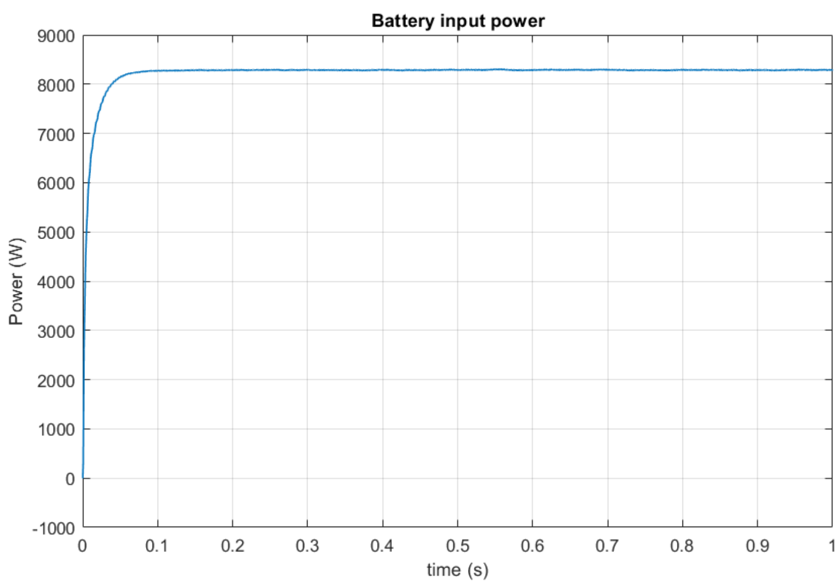

Figure 3.17: Battery input power

By measuring battery voltage,current,SOC and power we can see that the Wireless charging system perform well and gives an constant current of approximately $27Ah$ and a constant charging power of $8,5kW$, also the current stabilizes and reaches its maximum value in sort time (less then 0.1 s).

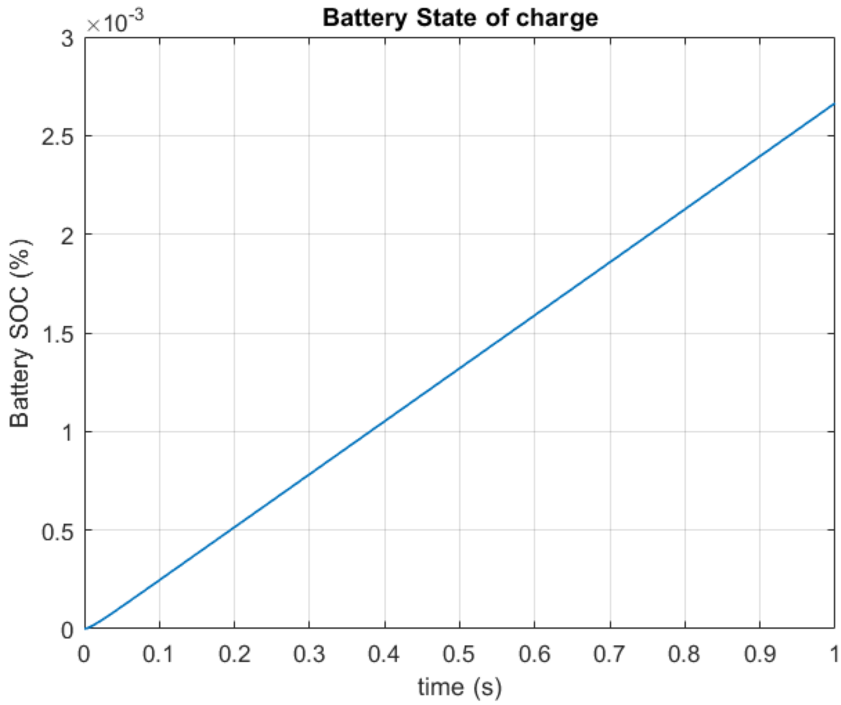

Figure 3.18: Battery SOC(State Of Charge)

We've simulated our system in a period of 1s due to the multiple number of blocks contained in our system and due to it's complexity. taking in consideration the linear evolution of state of charge shown in figure 3.18, we can estimate that time to charge battery from 0% to 100% is approximately $10h16min$

3.5 Command and control

In order to transfer power from source(grid) to the electric vehicle battery is save and autonomous way, control system is deployed in parallel with the power circuit simulated previously in order to give the user of the system the ability to command the charging procedure and to get informed about battery state of charge and time left to complete charging, also payment information's, in order to focus on the control system of the wireless charging system, we've replaced the power circuit by a simple circuit just to show how sensors and relay are placed and how they perform in real wireless charging system as seen in Figure 3.19:

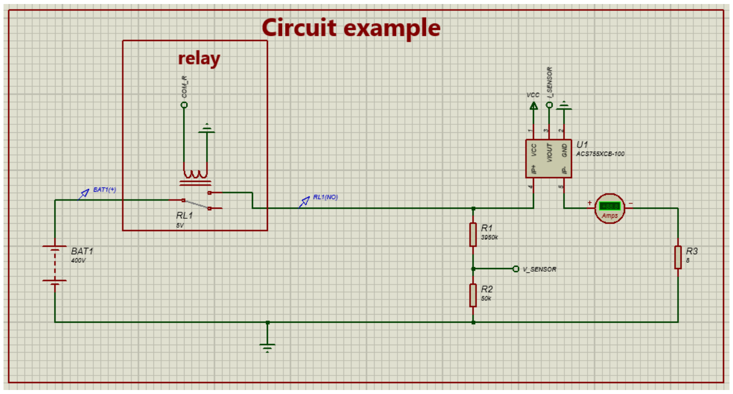

Figure 3.19: Simplified power circuit

3.5.1 Command an control part simulation

Figure 3.20 shows command and control circuit of the charging station and figure 3.21 shows the Electric vehicle command and control circuit.

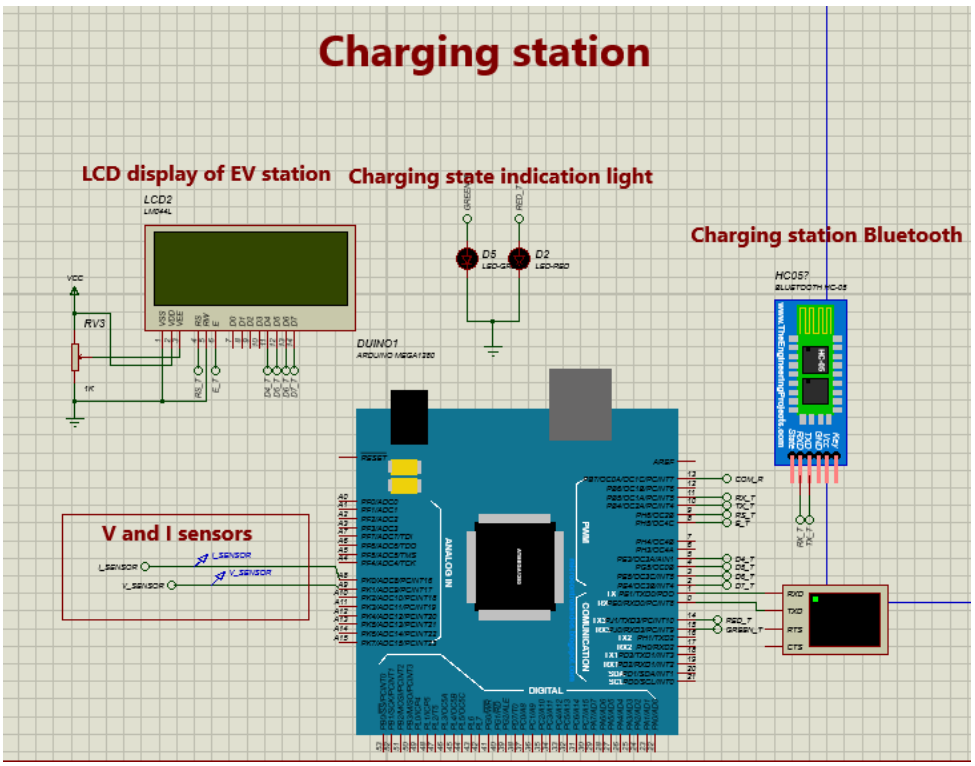

Figure 3.20: EV charging station

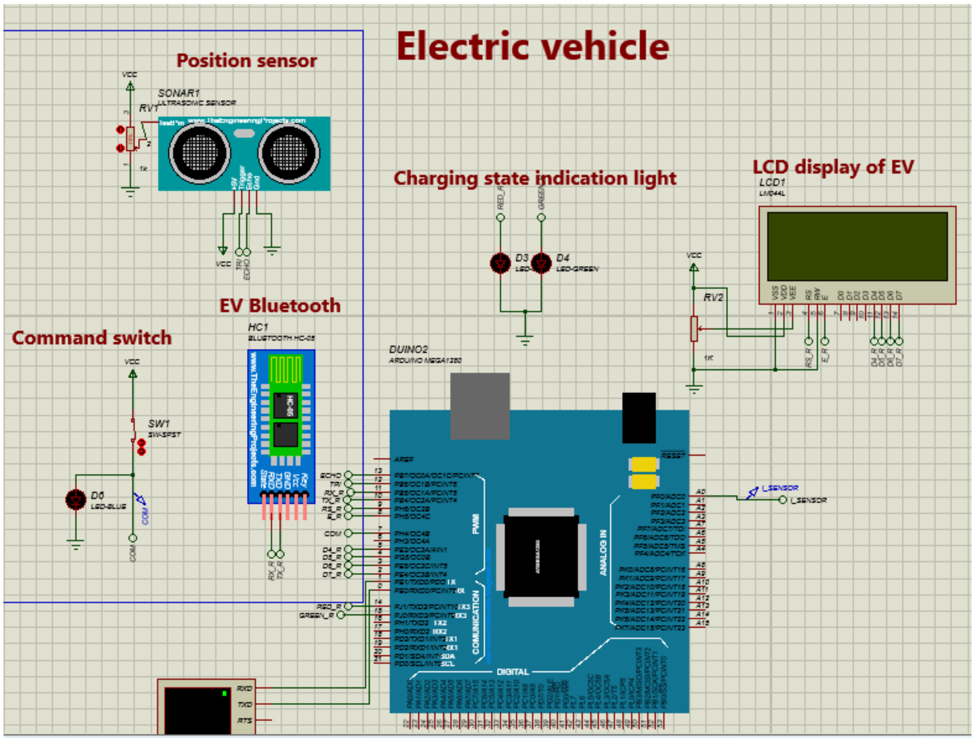

Figure 3.21: EV

the following figure 3.22 is the general structure of the command and control part of wireless charging system:

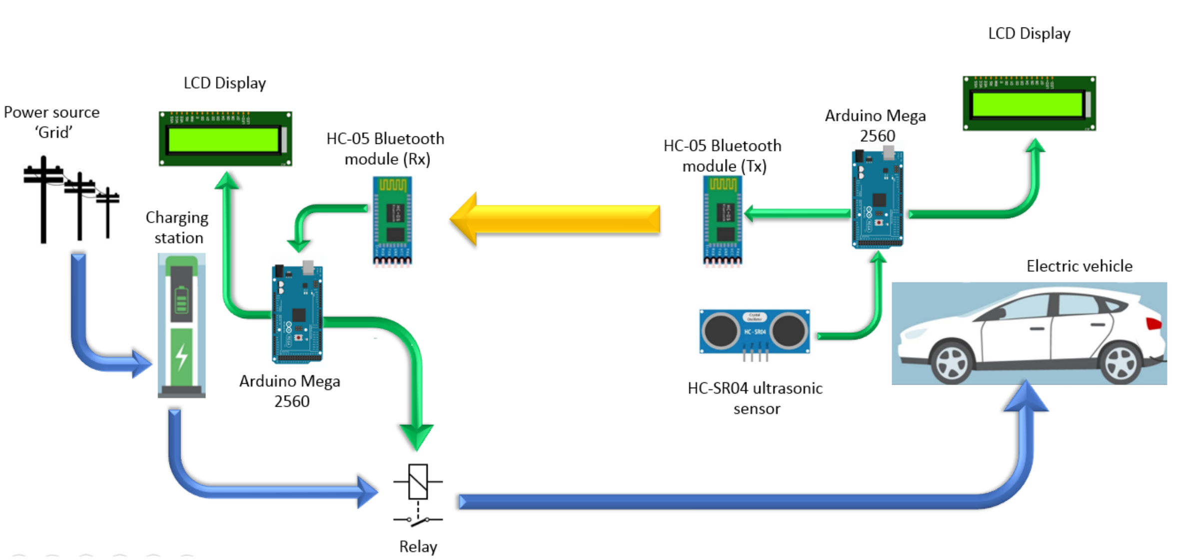

Figure 3.22: Command and control part of WCS

The following organizational chart 3.23 represent the algorithm that WCS command and control part :

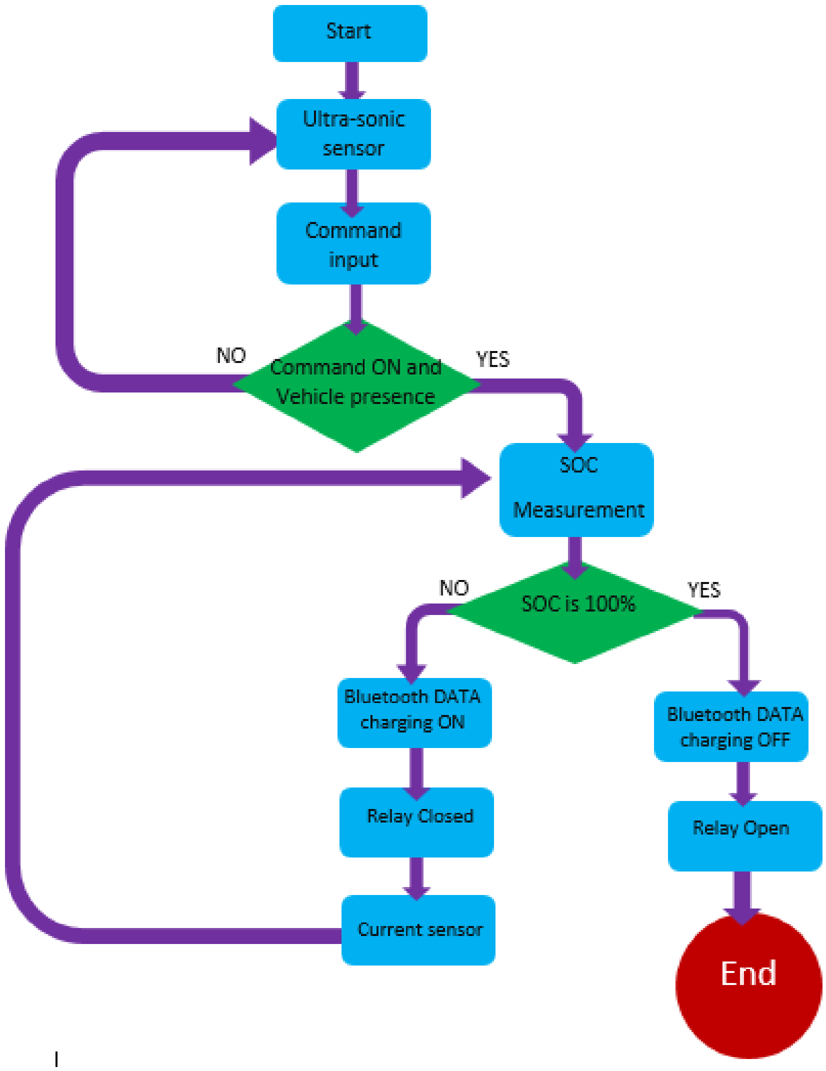

Figure 3.23: Algorithm of command and control part of WCS

3.5.2 Results

As we seen in figure 3.24 the screen display of the electric vehicle indicate that the electric vehicle is not charging unless its positioned in the right place to the wireless charger or the user indicate to start charging. if the two condition already mentioned are verified, charging process begin, and battery SOC and time left to fully charge the battery are shown in the lCD display.

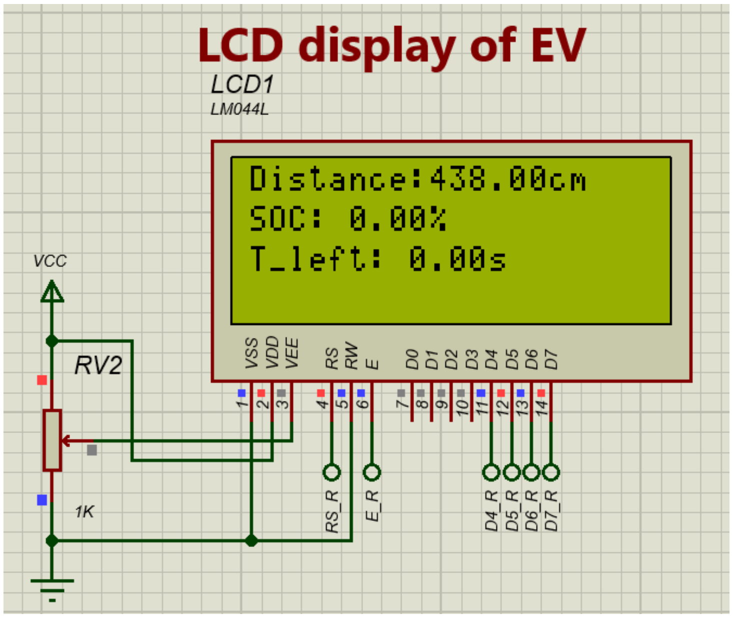

Figure 3.24: Electric vehicle LCD display (a)

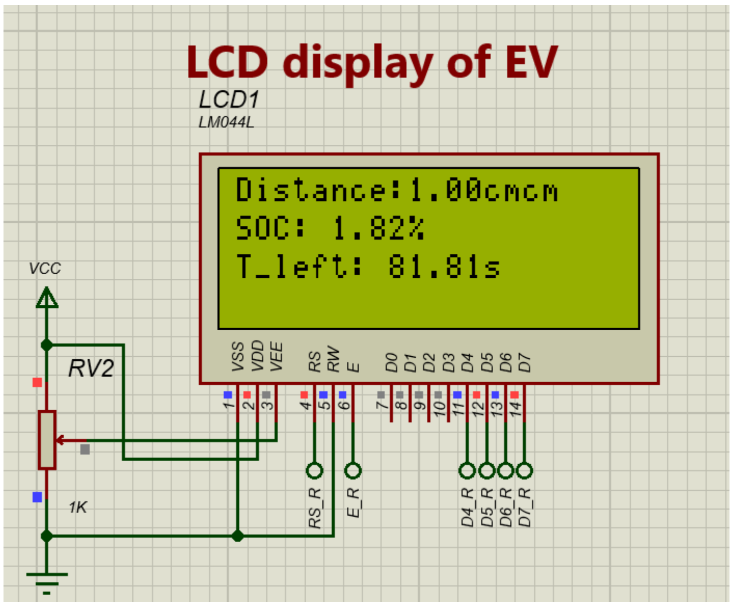

Figure 3.25: Electric vehicle LCD display(b)

In the charging station part, if there's no car placed in the charging transmitting part of the charging system, LCD display is as shown in figure 3.26 when charging process begin, LCD screen display the following data: Power, Energy consumed and price to the used "Values were not taking in consideration" as seen in Figure 3.27.

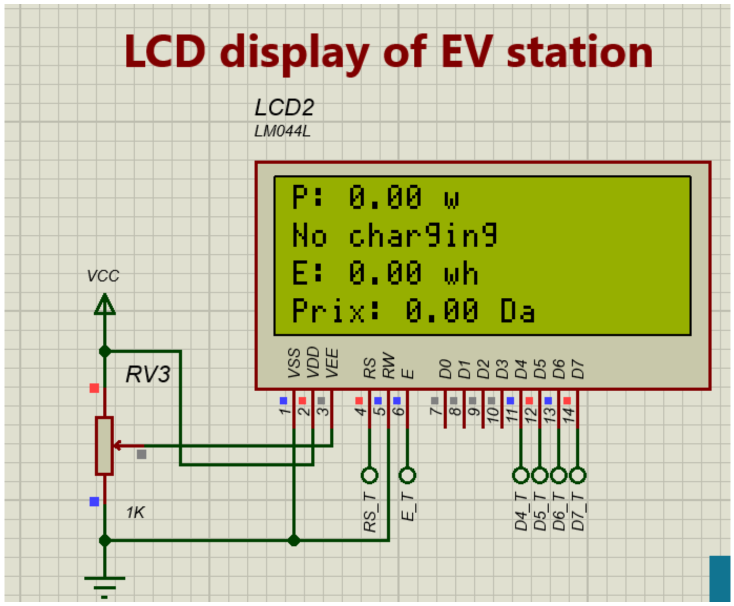

Figure 3.26: Charging station LCD display(a)

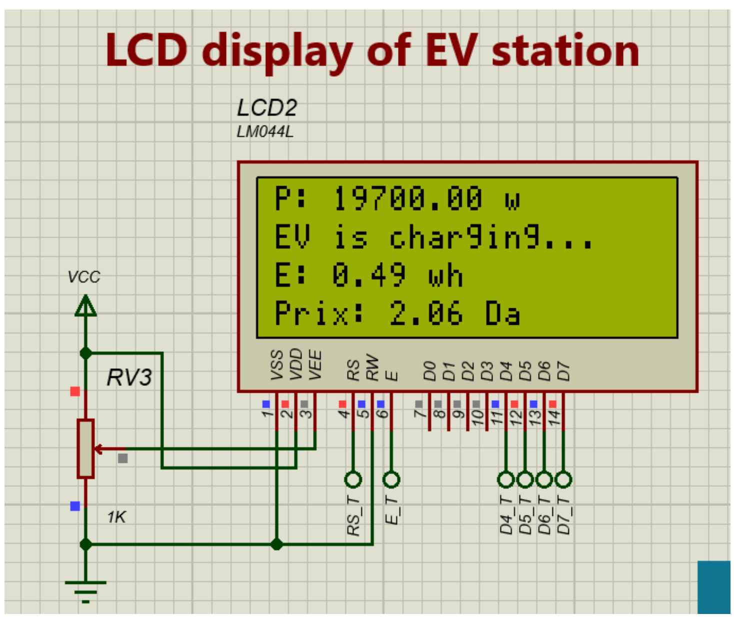

Figure 3.27: Charging station LCD display(b)

when battery SOC attempt 100%, electric vehicle send information to charging station to stop charging,and display Energy consumed and price of that energy.

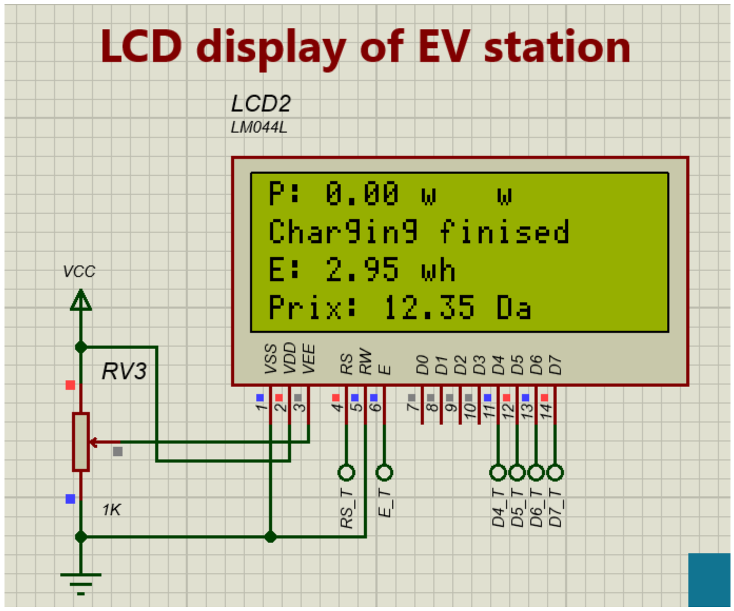

Figure 3.28: Charging station LCD display(c)

3.6 Conclusion

In this chapter we simulated the wireless charging system using Simulink to simulate power circuit and ISIS to simulate control circuit that is divided into two part, first part contained in the charging station and the second part contained in the electric vehicle. We have calculated circuit parameters depending on physical limits as diameter to attempts maximum possible charging power using Matlab script and implement the results to the simulation to obtain results as seen in this chapter, wireless charging system output power is 8.5kW with charging current that attempt 27Ah which is able to charge a 100 kWh electric vehicle battery in less than 11 hour.

General conclusion

The work presented in our final study project concern a modelisation and simulation of wireless charging system for electric vehicles. we've studied the modelisation and simulation of the system in both aspects that are power circuit and control circuit. Since no-renewable resources are being replaced by renewable resources due to their advantages and the environmental impacts, electric vehicles aim to replace internal combustion engine vehicles due to their clean effect on the environment. one of the problems that face electric vehicles that we treated on our project is charging process that represent a big problem due to the need of human interaction and dangers it can cause while using high power cables to charge electric vehicles, so we've proposed an save and autonomous charging method that need no human interaction.

In **chapter 1**, we presented the current state of electric vehicles, beginning with a brief history of electric vehicles and the elements that make up such vehicles, discussing their advantages and disadvantages. Ecological and clean electric vehicles will definitely become the new means of transport, and in the near future it will occupy an increasingly important position in the market and thus will mainly replace polluting thermal vehicles, not forever. The energy generation required to operate and manufacture an electric vehicle participates in global warming, which allows us to say that an electric vehicle will ultimately not be as environmentally friendly unless it is powered by a renewable energy source such as solar or hydro. Several electric vehicle architectures are currently possible, offering different performance and capabilities.

In **chapter 2**, we have seen that a wireless charging system consists of two parts that work in parallel, the power part and the control part. The power section is the circuit that uses multi-level power converters as rectifiers and high-frequency inverters to transfer current from the grid to the EV battery, and is also the control section used to control the charging process by measuring and controlling the current from different sensors and actuators . Microcomputer controls the charging process, which is convenient for users to use. We also learned about general aspects of wireless power transfer through various methods, then we choose using the best method for the electric vehicle use case, we model the wireless power transfer circuit so that we can calculate its parameters and simulate the system in the next chapter.

In **chapter 3**, we used Simulink analog circuit and ISIS analog control circuit to simulate a wireless charging system in two parts, the first part is contained in the charging station and the second part is contained in the electric vehicle. We calculated circuit parameters based on physical constraints such as diameter to try the maximum possible charging power using a Matlab script and implemented the results into simulations to obtain the results shown in this chapter. The wireless charging system has an output of 8.5 kWh and a charging current of 27 Ah to charge a 100 kWh EV battery in less than 11 hours.

Therefore, the results obtained after several simulation tests using simulink and ISIS in chapter 3,show that Wireless charging system is capable of producing an output power that can charge a 100 kWh (100 kWh has the range of 615 km) in less then 11h with autonomous way , which makes it perfect choice for home application and parking.

This work has allowed us to expand our knowledge in the field of power electronics and micro-controllers programming, such as: different power converters as rectifier and inverter,micro-controllers programming,using Bluetooth communication protocol, as well as simulation tools as Matlab,Simulink and ISIS to simulate and validate results of the wireless charging system.

Our perspectives of this project is to give a push to do realisation of Wireless charging system based on our model and simulation results, another perspective is to develop the wireless charging system technology from the static to the dynamic charging.

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Abstract:

This project presents a modelisation and simulation of wireless charging system for electric vehicles, the purpose of this project is to model a system that could charge electric vehicles without the need of charging cable just by using magnetic field using on the resonance coupling method to achieve highest power transfer. The system contains two major parts, power circuit part and command and control part.

Different software were used to simulate the wireless charging system, MATLAB Simulink was used to simulate power circuit, and ISIS Proteus was used to simulate command and control circuit. obtained results shows that wireless charging system output power could attained 8,5 kW which is more than slow charging.

Keywords: Wireless charging, resonance coupling, Coupling coils, Power converter, Charging station, Electric vehicle.

Résumé :

Ce projet présente la modélisation et la simulation d'un système de charge sans fil pour les véhicules électriques, le but de ce projet est de modéliser un système qui pourrait charger les véhicules électriques sans avoir besoin de câble de charge en utilisant simplement le champ magnétique en utilisant la méthode de couplage par résonance pour atteindre le plus haut transfert de puissance.

Différents logiciels ont été utilisés pour simuler le système de charge sans fil, MATLAB-Simulink a été utilisé pour simuler le circuit de puissance, et ISIS Proteus a été utilisé pour simuler le circuit de commande et de contrôle. Les résultats obtenus montrent que la puissance de sortie du système de charge sans fil peut atteindre 8,5 kW, ce qui est supérieur à la charge lente.

Mots clés : Chargement sans fil, couplage par résonance, Bobines de couplage, Convertisseur de puissance, Station de charge, véhicule électrique.

ملخص :

يقدم هذا المشروع نمذجة ومحاكاة نظام الشحن اللاسلكي للسيارات الكهربائية ، والغرض من هذا المشروع هو نمذجة نظام يمكنه شحن السيارات الكهربائية دون الحاجة إلى كابل شحن فقط باستخدام المجال المغناطيسي باستخدام طريقة اقتران الرنين لتحقيق أعلى نقل للطاقة. يحتوي النظام على جزئين رئيسيين. الجزء الأول هو دارة الطاقة.و الجزء الثاني هو دارة القيادة والتحكم

تم استخدام برامج مختلفة لمحاكاة نظام الشحن اللاسلكي ، وتم استخدام ماتلاب - سيمولينك لمحاكاة دارة الطاقة ، وتم استخدام إيزيس بروتيوس لمحاكاة دارة القيادة والتحكم

تظهر النتائج التي تم الحصول عليها أن طاقة التي يخرجها نظام الشحن اللاسلكي يمكن أن تصل إلى 5.8 كيلو واط ، وهو أعلى من الشحن البطيء

كلمات مفتاحية :

الشحن اللاسلكي ، اقتران الرنين ، لفائف اقتران ، محول الطاقة ، محطة الشحن ، السيارة الكهربائية