Smart Grid Integrated Digital License Plate

Capstone Project Report #1

Team Members:

Abdul Bhutta - 100785884

Yussef Elzein - 100641407

Emran Soltani - 100618333

Kumail Syed - 100661596

Walid Ayub - 100695612

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Project Advisor: Dr. Tarlochan Sidhu, P.Eng.

Capstone Coordinator: Dr. Vijay K. Sood, P.Eng., ECSE

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Abstract

In recent years, it has become evident that traditional license plates have many flaws such as security, durability, and functionality. Current license plates have proven time and time again that it is time for an update. The world is quickly going digital as technological advancements are being made every day. License plates have not yet caught up to the times. A smart digital license plate would be a tremendous upgrade moving into this electric and digital world. Current technologies such as displays, communications, and electric vehicles have created a possibility for new smart digital license plates with features such as theft detection, renewal updates, smart grid integration, and web information access. As the world is transitioning to an all-electric automotive infrastructure, the need for smart grid features will soon enough become a necessity. For this reason, integrating smart grid features such as V2G, V2H, smart charging, and smart metering into EVs is becoming crucial. This report outlines our research conducted on methods of implementing our digital license plate into the smart grid as well as research on smart features that we plan on implementing in our smart digital license plate. We will be creating our digital license plate prototype using components such as a Raspberry Pi, a high-definition display, an RFID card/reader, an SD card, and a rechargeable power bank. Our findings have proven that a smart grid integrated digital license plate is becoming increasingly advantageous in the electrification of the automotive industry. Later in this report, we also list additional helpful features that we plan on implementing into our product if time permitting. Throughout this report, our smart grid integrated license plate will be proven to have elements that are much more functional and favorable than the current metal license plates used today.

Dedication

We would like to dedicate this report to each of our group members' families who have continuously supported us throughout university in both moral and material needs. Moreover, we would like to dedicate this report to all our professors, peers, and friends for their consistent encouragement and motivation.

Acknowledgements

We would like to express our gratitude to our supervisor Dr. Tarlochan Sidhu who made this project possible. With his guidance we were able to get a thorough understanding of the project and how to execute our ideas. His continuous support fed our ambition to take this project above and beyond.

We would also like to acknowledge our capstone coordinator Dr. Vijay Sood. He was able to give us a strong detailed understanding of producing reports and how to have a complete presentation on our project.

Our sincere appreciation to Dr. Sheldon Williamson for offering his knowledge and guidance with this project. In our first meeting he provided us with many ideas on smart grid technology and possible recommendations on how to implement them.

Lastly, we would like to thank our friends and family for their continued support, especially Siear Lutfi for attending one of our meetings and encouraging us throughout.

We will be forever grateful for this capstone project as it has not only challenged us but helped us understand the process for designing, testing, building, and implementing a product from start to finish.

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List of Acronyms Used

Acronym	Meaning
ALS	Ambient Light Sensor
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading System
API	Application Programming Interface
ATM	Automated Teller Machine
AWS	Amazon Web Service
BMS	Battery Management System
CPU	Central Processing Unit
CSS	Cascading Style Sheet
DB	Database
EV	Electric Vehicle
FEAT	Feature
GCP	Google Cloud Platform
GPIO	General Purpose Input Output
GPS	Global Positioning System
GPU	Graphic Processing Unit
HTML	Hypertext Markup Language
I/O	Input / Output
ID	Identification
IESO	Independent Electricity System Operator
IP	Internet Protocol
LCD	Liquid-Crystal Display
LDR	Light Dependent Resistor
LED	Light-Emitting Diode
LTE	Long Term Evolution
MTO	Ministry of Transportation
OS	Operating System
RFID	Radio-Frequency Identification
SD	Secure Digital
SOC	System-on-Chip
SoC	State of Charge
SoH	State of Health
STRQ	Stakeholder Requirement
TC	Test Case
UC	Use-Case
US	United States
USD	United States Dollar
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home

1 Problem Identification

1.1 Problem Statement

License plates in North America have many issues when it comes to durability. The current license plates across north America are made of aluminum, a colored reflective adhesive sheeting and paint [14]. Many advancements have been made in technology and there is no reason for vehicles today not to be equipped with smart license plates. The current license plates endure issues such as peeling, theft, and readability. Moreover, the province of Ontario had recently updated their plates to blue ones with a new slogan. The goal was to refresh the plates and solve the peeling issue but, instead it made matters worse as law authorities found it difficult to see the plates at night as they weren't reflective. These new plates cost the province about 1 million dollars and shortly after were discontinued [13]. Introducing a smart digital license plate would automatically eliminate all the problems with the current license plates. Furthermore, implementing digital license plates not only would save the province issues like legibility at night, but also create cost-effective solutions for plate updates in the future.

1.2 Project Objective

The objective of this project is to design and implement a smart grid integrated license plate. Current license plates are outdated and lack many features. The license plate we plan on designing will include many smart features such as anti-theft, auto brightness, smart charging, and many more. A full list of features can be found in **Table 1** below. This futuristic and innovative smart grid integrated digital license plate will be a steppingstone for not only automotive manufacturers but transportation ministries as well.

1.3 Project Features

After many discussions, we have decided on the important features that will be included in our project. **Table 1** below lists the features that will be implemented on the left side of the table. The right side of the table lists features that will be implemented if we have adequate time.

Table 1: Digital License Plate Features

Features	Time Permitting Features
High-Definition Digital Screen	*Smart Phone Application*
Online Digital License Renewal	*Plate Visual Personalization*
Digital Plate Sticker Renewal	*Parking Metering*
Online Website	*Toll Road Payment Integration*
Auto-Brightness	*Telematics (Vehicle Locator)*
Replaceable Battery	
Anti-Theft	
V2G/V2H Integration	

Smart Metering	
Smart Charging	
EV Battery Information	
Easy Installation	
LTE Connection	
Secure Cloud Communication	
Follows License Plate Standards	
Water & Dust Resistant	

1.3.1 Estimated Cost of Project

Table 2 below shows our estimated costs for each of the components needed to build the prototype. The main costs will be the display screen at $200 and the Raspberry Pi at $260. The high cost of the Raspberry Pi is due to the industry-wide shortage of Raspberry Pi products; therefore, we have planned to set aside much of the budget for this part. Each of the estimated costs below represents the high end of the cost of parts and will most likely be higher than the actual cost of the part.

Table 2: Project Estimated Cost of Parts

Part Name	Part Estimated Cost	Total Running Cost
13.4” Display Screen	$200	$200
Raspberry Pi (4GB)	$260	$460
SD Card	$35	$495
Rechargeable Power Bank	$60	$555
RFID Card/Reader	$75	$630
Video and Power Cables	$80	$710
3D Printed Casings	$140	$850
Miscellaneous Parts	$150	$1000
Estimated Total Cost:		**$1000**

1.4 Overview of the Report

In this report, we will discuss all the developments and methods which would necessitate the transition of old-fashioned metal plates into futuristic smart grid integrated digital license plates. Throughout this project, research has been done on the smart features, hardware, and software design processes. This will demonstrate how the results of the project-related research will meet the specifications and requirements for this smart plate as well as potential future applications. The functional and marketing requirements have been listed in this report to discuss the characteristics and aspects of a digital license plate. The website will present use cases and acceptance tests to give an idea of how each situation should be handled. The project schedule is displayed using a Gantt chart.

2 Background & Research Review

2.1 Vehicle-to-Grid (V2G)

V2G or vehicle-to-grid is a new technology that allows EV car batteries to supply power back to the grid. V2G enables car owners to push back their vehicle's electrical energy back to the power grid from their electrical vehicle's battery. The idea of V2G is to draw power from electric vehicles during peak energy production hours in order to balance the variations in energy production and consumption [1]. EV batteries would essentially be used as auxiliary storage cells for electrical grids [2]. This would help stabilize the grid during peak hours preventing grid instability. Grid stability is important as the amount of energy generated must equal the amount of energy consumed. The need for energy is often volatile during peak usage hours, which may lead to the overloading of transmission lines, voltage and frequency anomalies, and/or a supply and demand mismatch [1]. The need for drawing power from EV batteries would likely only be for a few minutes a day in small discharges at a time.

Many people's concerns regarding V2G is the negative effect on EV battery health. In practice, it can be seen the battery health is mainly affected by leaving a battery fully charged and unused for long periods of time. This is the reason that vehicle manufacturers recommend charging EV batteries to at most 80% to preserve battery life. As V2G would only require small discharges at a time to balance the volatility of the grid at peak hours, it would have a minimal effect on battery life. Studies have shown that providing energy back to the grid through V2G causes no significant loss in battery capacity when compared to typical battery use such as for driving [1].

2.1.1 Bidirectional Charging

In order to give energy back to the grid, we must employ the use of bidirectional chargers. Bidirectional chargers would normally be set to charge vehicles that are plugged in however if the demand for electricity is high at a given time, the charger would receive a signal to pull energy from the vehicle back to the power grid and ultimately supply power to the houses and buildings in the region [3]. Car owners would be credited based on the amount of charge taken from their vehicles or charged for the energy taken by their vehicle if its battery charge has increased. Many EV charging stations in place today are unidirectional however, bidirectional chargers are quickly replacing the current infrastructure.

There are methods that exist today that can allow individuals to begin contributing to the V2G infrastructure such as installing a V2G bidirectional charging unit at home. People would be able to plug in their vehicles at home and use their vehicles to help stabilize their region's power grid or even provide power to their own houses or to their neighborhoods during outages. Owners would have the ability to control their vehicle's charging by setting a minimum charge so that they may ensure that they have enough charge to use their vehicle when needed.

Currently, as of October 2022, there are only 6 vehicles on the market that support bidirectional charging: Nissan Leaf, Ford F-150 Lightning, Hyundai Ioniq 5, Kia EV6, Volkswagen ID.4, and Mitsubishi Outlander PHEV. However, there are several new vehicles releasing in the next 5 years that are slated to support bidirectional charging.

2.1.2 Advantages of V2G

V2G expands storage capacity for renewable energy sources such as wind and solar. Since wind and solar energy generating systems are volatile and inconsistent due to the unpredictability of climate, V2G would allow us to store energy when the system's storage is full. EVs would be able to relieve and store the excess energy during surges due to vigorous weather conditions such as heavy winds. This means that EVs can act as a solution to grid congestion as well as prevent the need for costly upgrades to existing infrastructure.

A transportation electrification company called Pecan Street estimates that one plug-in electric vehicle is capable of powering a single home for up to five hours or five homes for about an hour [2].

2.1.3 Vehicle-to-Home (V2H)

As discussed in the previous section, it is possible to install a V2G unit at home in order to provide energy back to the grid. There are also V2H units that allow homeowners to use their vehicle's battery to power their homes. This would normally be used to power your entire home in the case of a power outage. However, in some cases if you have many appliances turned on at once, you could use the energy stored in your EV to reduce power drawn from the grid. This would be useful if you'd like to save money by using your EV's power during peak hours and charge it at night during off-peak hours where the cost of energy is comparatively lower.

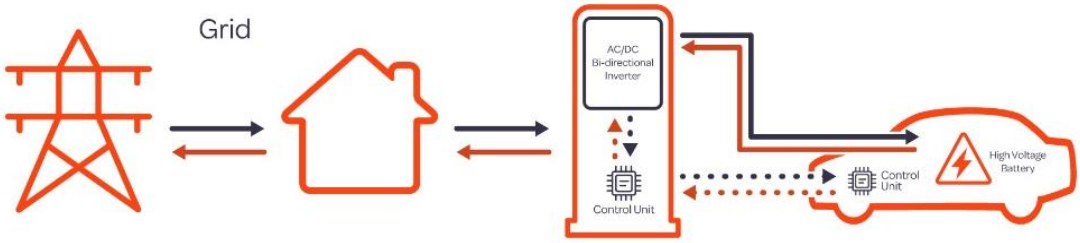

Figure 1: V2G/V2H Unit Visual [4]

While V2G technologies are rapidly progressing, there is still much progress to be made before V2G can be implemented on a large-scale level. Due to the many benefits for both EV drivers and power grid operators, there is a large push being made to accelerate the production of compatible vehicles and chargers.

2.2 Raspberry Pi

The Raspberry Pi is a microcontroller and essentially a system-on-chip (SOC) that behaves as a computer. Raspberry Pi has a CPU, memory, GPU, storage device, I/O, and network capability, all enclosed on one device. It can be used to create an embedded system to perform a specific task, such as a Smart License Plate. The device is preconfigured with an OS version named Raspbian, which allows the integration of numerous languages such as C, C++, Java, and Python. Python is one of the most used in the industry and is regarded as the future of programming language, which is why our application will be created using Python. The front end of our application will predominantly be HTML, CSS, and JavaScript. The Raspberry PI allows numerous devices to communicate and is not limited to linking external devices through the GPIO pins. GPIO, or general-purpose input-output, will integrate the outside world into the raspberry pi through the physical pins on the board. GPIO can read data (input) from various devices or output a digital signal to a device. Some devices integrated using GPIO pins are sensors, LEDs, buttons, switches, lights, GPS, and motors.

2.2.1 Location Services

The raspberry PI allows us to connect an external GPS and additional sensors to the board through the GPIO pins. However, since the raspberry pi will be connected to a network 24/7, we can use the built-in function to locate the device, which uses the IP address. The IP address will be sent to a google map geolocation API to locate the device, and the API will return coordinates (longitude/latitude) [6]. It must be taken into consideration that the results from the IP address will vary and may not be as accurate as an external GPS device. During the testing phase, it must be determined whether the location service provides data that can be used in a real-life environment or whether a GPS module will be the better option. The coordinates returned from the API can be used to display the exact location of the license plate using Google Maps.

2.3 Security

One of the significant reasons why a digital license plate is required in the future is due to the increase in license plate thefts. Criminals usually take the license plate from a similar car to what they are driving, allowing them to move freely without any consequences. There are many reasons why criminals steal plates, such as insurance fraud, a suspended license, driving a stolen car, or planning on committing a crime. There are few countermeasures to stop criminals from such activities, whether the license plate is digital or metal. Although a considerable benefit of a smart license plate is that it helps level the playing field as it can detect whether the plate has been stolen or not, which can be sent to the local authority. Integrating theft prevention within smart license plates will assist in limiting license plate theft. The theft prevention system will allow the user to remove the license plate while notifying the user that the plate has been detached from the car. If the user removed the license plate for personal reasons, the device would not enter “theft mode." If the user did not remove the license plate, they could report it stolen on the application while allowing the plate to enter a new state known as “Stolen Mode.” In this mode, if the criminal decides to attach the plate to another vehicle, it will display stolen on the plate while sending a signal allowing the electric vehicle to shut down. The prototype will demonstrate the license plate to change its state to “stolen mode” while allowing the user to have the option to disable the vehicle if they desire. The module that disables the vehicle is a highly complex embedded system and is out of this

project's scope. Therefore, a simulation of a transmitted signal will be presented, and the result from the signal will be indicated on the application.

2.3.1 Radio Frequency Identification (RFID) Reader

RFID reader, or radio frequency identification, is an integral part of security in many systems developed today. The RFID reader requires a unique identification number which grants authorization to the required environment. The RFID contains two key components: the reader/writer and the RFID tag. The RFID tag is an integrated circuit that stores a unique identification number. The RFID tag reader/writer will read the identification number when the card is placed near the reader through the card's magnetic field, which will power the card's circuit, allowing it to transmit the unique identification number stored on the card [5]. The unique identification number can be read from the raspberry pi, which can be used for authentication. In our system, the RFID tag will be attached to the LCD, while the RFID reader will be connected to the microcontroller. Each RFID tag will store the serial number of the LCD as a unique ID which will be linked to a microcontroller. As a security measure, each LCD can only be linked to the microcontroller that has authorization within the database.

2.4 Cloud Computing

We live in an era where downtime of service for the customer can be disastrous, as we witnessed one of the most significant outages in Ontario, where more than 12 million Rogers customers were left without service throughout Canada, including calls to 911 or access to ATMs. Rogers' infrastructure had issues that were not addressed, leading many displeased customers to migrate to a competitor company. This leads us to address the issue of availability, failure, and performance. Initially, in our design process, a centralized system was considered to store our application and data on a local server, but the system had a few known limitations associated with it, such as,

1. It is highly dependent on network connectivity,
2. If one component in the system fails, the whole system goes down.

a. All data is stored on the central server; if any updates are required, the server must be shut down for maintenance.

One of the significant innovations in our generation is cloud computing which helps us distribute various computing services such as servers, storage, databases, and software over the internet. Cloud computing helps with availability, failure, reducing cost, scalability, data security and much more [7]. Integration of cloud service within our application will help with the incoming requests from customers, and during various times the network traffic will fluctuate. Cloud computing can implement autoscaling to use the allocated resources required for a task to reduce cost and enhance performance.

There are a few great choices for cloud services, such as Google Cloud Platform (GCP), Amazon Web Service (AWS), and Microsoft Azure. As we are cost-constrained for our application, one of the ideal solutions is using the Microsoft Azure service, which provides a $200 credit and allows us to use the MySQL database for 12 months without additional cost. The MySQL database will be required to produce three independent databases, MTO DB, PowerGrid DB, and Smart License DB. The MTO DB and PowerGrid DB

are vital to simulate a real environment as we assume the license plates are registered with the provincial ministry of the government.

When a user signs up for our application, they must enter their license plate number and personal information. Before a digital license plate is issued to the user, the application will authenticate the information before storing the data within the database (Smart License Plate Database). An identical authentication will take place to retrieve the data from the power grid database, such as energy consumed, and energy transferred to the grid. The user can opt to pay on the website or signup for a recurring monthly payment.

2.5 Measurement of Battery Health & State

2.5.1 Battery State

Measuring a battery's state of charge (SoC) is no simple task. Currently there is no direct method available to obtain a battery's SoC. In order achieve this we must estimate the SoC indirectly using one of the following methods: measuring voltage, coulomb counting, or Kalman filter method. The first method as stated is the voltage method. When a new battery is fully charged it will read the voltage according to what the manufacturer has specified. As the battery is being discharged the voltage drops and eventually the battery becomes depleted. In order to determine the SoC for the battery as a percentage, the voltage must be compared to a battery discharge curve [15]. Take this typical 4.5V Lithium-ion battery discharge curve as an example (figure 2.5.1). The voltage curve on the graph is kept flat relatively between the approximate SoC percentages 80% - 20%. When the discharge cycle reaches approximately 10% the voltage declines rapidly resulting in a reading of when the battery will be fully depleted [18].

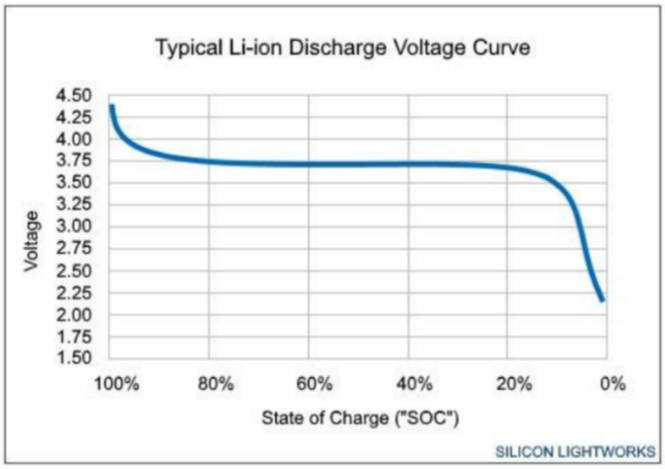

Figure 2: Graph of Typical Li-ion Discharge Voltage [19]

The second method as noted is the coulomb counting method also known as ampere counting method. To approach this method, we first need to obtain the current of the battery. This can be done using a voltmeter or any other device that can obtain the current. Once the current is obtained it must be integrated using the following formula:

$$SoC(t) = \frac{1}{C}\int_0^t I(p)\,dp$$

Figure 3: Battery State of Charge Equation [21]

Where C is denoted as the total capacity of the battery, and I is the current measured. This is a relatively quick and cheap method in estimating the SoC of a battery. The downside of this method is any errors found will accumulate over time when integrating causing it to become inaccurate [15].

The final method in estimating SoC is with the use of observers, also known as a Kalman filter. The Kalman filter uses an algorithm that constantly predicts the future SoC and corrects it by measuring the current, voltage, and temperature. For the Kalman filter to operate as accurately as possible, it must have precise dependencies when operating and accurate environmental conditions [16]. Due to the filter requiring more resources to estimate the SoC it makes it a rather complicated method compared to the voltage and coulomb counting method. Figure 2.5.3 below shows a simple diagram of a Kalman filter system.

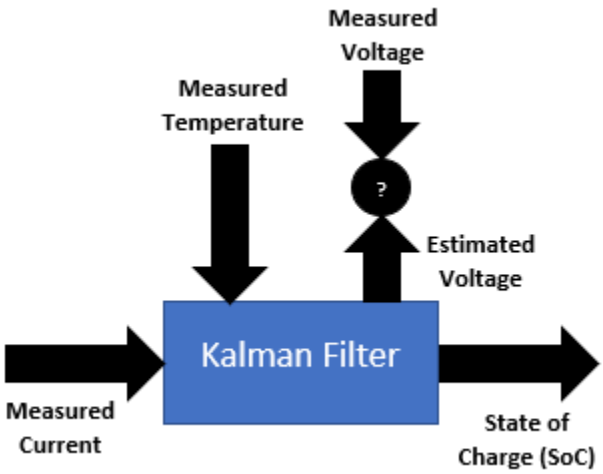

Figure 4: Kalman Filter System Diagram

2.5.1 Battery Health

Measuring the state of health of a battery is an arbitrary process that uses one simple formula. It is the current maximum capacity divided by the capacity of a new battery multiplied by 100%. The current and new capacity of a battery can be measured in Ampere Hours [17]. A simple and quick way for us to obtain battery health would be by using a Battery Management System (BMS). Electric Vehicles (EVs) all come standard with a BMS. Using the on board BMS we will be able to obtain the battery health but instead of calculating by Ah we will be calculating it by the maximum range at full charge divided by the maximum manufacturers rating. For example: If the EV at full charge is 643km and it is rated for 700 km that would mean the battery health is at 91.8%.

$$SoH = \frac{\text{Current Maximum Range}}{\text{Manufacturer Rated Range}} * 100\%$$

Figure 5: Battery State of Health Equation

2.6 Smart Metering & Smart Charging

2.6.1 Smart Metering

Smart Meter is an electronic device that processes and records energy consumption data which is connected to the local utility. It allows the user to track their power consumption and electricity expenses. One of the benefits of having a smart meter is its capability to measure energy consumption bidirectionally between the users and power suppliers [8]. This meter will be connected to the grid and integrated in the app to allow user to always view the energy consumption data and other readings.

Furthermore, the V2G process will permit EVs to feed the power back to the grid during peak hours to avoid grid instability which will be displayed on the smart meter. This adaptable power system offers users the chance to manage their energy consumption and perhaps drastically lower their monthly expenditures [9].

2.6.1.1 Types of Smart Meters

1. AMI – Advanced Metering Infrastructure

An AMI smart meter provides users with comprehensive data on power consumption from them. This lets users better regulate their power usage to lower greenhouse gas emissions and electricity expenses. It permits two-way communication between the meter and the provider. Utilities may identify system problems more rapidly by using real-time data from smart meters [8].

2. AMR – Automatic Meter Reading System

An AMR meter acts in a similar fashion to an AMI meter but the only difference is that it communicates information one-way with the energy provider on behalf of the user. The supplier will receive data from the customer's energy consumption which ensures proper invoicing and enables the consumer to see their statistics on energy use [8].

2.6.1.2 Application of Smart Meters

Electric meters currently provide a little measuring role in the operation of charging stations for electric vehicles. The management of electric car charging stations can use smart meters to fulfill the following functions through their optimization [8].

1. Remote Control

Relays and valves included in smart meters can accept remote instructions sent by the power grid firms when they want to perform switching operations. As a result, real-time remote control is possible with smart meters [8].

2. Real-time Power Measurement

Real-time measurements are possible with smart meters. The timely completion of grid line failure analysis, equipment condition monitoring, and energy bill settlement is made possible by the real-time gathering of charging data and automated analysis. Electricity suppliers may use this data to better understand power usage and consumption, as well as enhance and improve the quality of the power supply [8].

3. Communication and Network Function

The network communication function will undoubtedly be impacted by some charging facilities' subterranean or distant locations. A useful smart meter feature is that when the signal is weak, a smart meter may use power lines to convey data through power line communication and even act as a Wi-Fi hotspot to enable intelligent network connections for electric vehicles and charging stations [8].

4. Demand Response

With the owner's permission, a smart meter may receive remote instructions and modify the amount of time an electric car needs to charge based on grid load and power costs. It is beneficial to charge electric vehicles at times of low grid load or cheap electricity costs in order to lower the maximum difference of the grid load and enhance the effectiveness of power grid operation [8].

2.6.1.3 Independent Electricity System Operator (IESO)

The Independent Electricity System Operator (IESO) is responsible for running Ontario's energy system. The IESO provides essential services for the whole electrical industry, such as real-time power system management, planning for the province's future energy requirements, promoting energy efficiency, and developing a more effective electricity market to assist sector development [10].

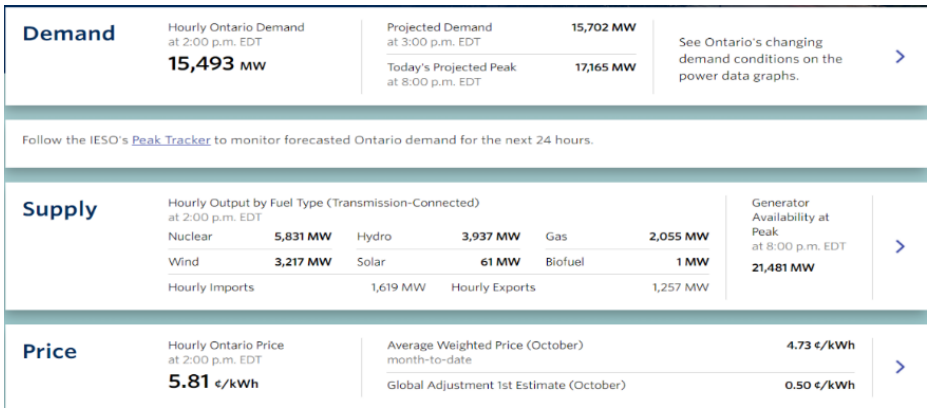

Figure 6: Real-time IESO Data [10]

The IESO would be linked to the website and all the energy consumption data would be fetched from the grid to allow the user to better keep track of the real-time peak-hours, power supply, demand, and energy rates. This would be highly beneficial for the users as they can monitor their electricity usage and save on energy bills.

2.6.2 Smart Charging

Smart Charging is one of the key elements in persevering battery health. This would allow the user's vehicle to charge the battery to an optimal 80%. Thus, making it beneficial for a battery's efficiency and long-term performance. According to the price of electricity, its accessibility, and the demands of the driver, electric vehicle (EV) charging employs intelligence to control when and how an electric car linked into a smart charger will get power for charging [9]. It needs a data link between the EV, the charger, the grid, and the cloud-based charging management platform of the charge station operator.

2.6.2.1 Smart Energy Management

In addition to smart charging for EVs, smart energy management has additional benefits. It enables the user to manage and modify energy usage depending on the grid constraints, electricity rates, and energy storage. Smart energy management makes the most of the power that is available to charge EVs while properly distributing the load among energy sources to avoid interfering with the demands of homes, businesses, or other power users.

A communication session is created between the charger and the automobile when the charging wire is plugged into an electric vehicle employing smart charging. The charger develops a communications channel with the grid at the charging infrastructure. This single, cloud-based software platform controls the chargers themselves, the charging process, and the energy sources employed [11].

2.6.2.2 Energy Optimization

It is certain that site-level constraints would affect charge station operators due to the rapid increase of EVs and their power needs for charging. When the grid is under stress, demand side response lowers electricity demand. While simultaneously reducing the charging capacity of individual charge points, the smart energy management system may use on-site renewable energy sources like solar panels or onsite batteries to supply the necessary power to charge the vehicles, extending the time to charge plugged-in cars while reducing grid stress [11].

With the aid of smart energy management, the charge station operator may keep an eye on, control, and modify energy usage in accordance with operational needs and driver- or operator-set priorities. According to the needs and restrictions of the EV and the location, the level of power delivered to chargers and energy usage may be clearly shown and adjusted. This can also prevent the utility from being fined for overstressing the system and forcing the company to buy expensive electricity from the general capacity market [11].

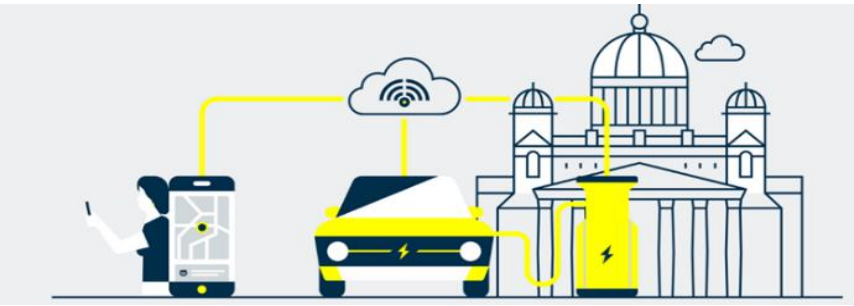

Figure 7: Smart Charging Infrastructure [12]

2.7 Auto-Brightness

Auto brightness and dimming can be achieved through an Ambient Light Sensor or ALS for short. Ambient light sensors are utilized in smart phones, tablets, LCD televisions, and automotive displays. There are currently three types of ambient light sensors: photodiodes, photonic integrated circuits, and phototransistor which is a combination of a photodetector and amplifier [18]. **Figure 8** below is an example of an ambient light circuit. This circuit includes a light dependent resistor which can change the resistance depending on its lighting environment. If the LDR senses darkness the resistance drops dramatically from millions of ohms. Thus, dimming the device in question. The same principle applies when the LDR is in a bright environment. The brightness of the device will then increase allowing a more user-friendly experience [20]. The sensors work in all types of light whether it's natural lighting or lighting from florescent or incandescent bulbs [18].

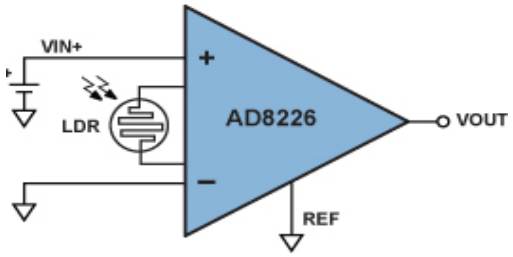

Figure 8: Ambient Light Dimming Circuit Example [20]

2.8 Ontario License Plate Legalities & Design Aspects

2.8.1 Legal Requirements

A metal plate is attached to a vehicle to identify official information about the owner and the vehicle. These plates are handed out when a driver purchases a car and brings it in for registration after paying a fee. Ontario uses these registered plates to determine and confirm ownership of the vehicles along with providing data to federal officers about when there is criminal activity. This is important when tracking or assessing taxes too. The terms license and registration are important and must be given on the command to law enforcement while you are driving in any designated lane. The penalties for not having 2 license plates, which is the requirement, or none could lead to up to $85 in fines including other issues such as not keeping it clean, improperly displayed, and other forms of placement that make it hard to identify the characters on the plate [22].

Legal actions can be taken against any driver not having their motor vehicle registered with plates that are not expired. During any stop with law enforcement or an accident that has occurred with yourself and another driver, all official documents should be presented. If in the scenario where you do not have it or refuse to show it could lead to considerable penalties like a fine anywhere between $60 to $1000 under the Highway Traffic Act [23]. This all could still be avoided because it is completely free to renew a license plate in Ontario and the requirement is just once every three years. This is all just for confirmation of various information stored under the owner's profile that is stored in their database. Information such

as whether the car is insured or not, any extra fees that may have been added on, or with regards to the fee that comes with toll routes along with any fines given [23].

The registration process requires a vehicle owner to go to any Service Ontario location where several items will be handed out after providing all necessary information about the vehicle and designated drivers. This process is put in place to identify if the vehicle was stolen or involved in a crime. Proof of purchase also must be shown, as the owner's own personal information including documents of proof of identity and an Ontario driver's license. Once the necessary steps have been completed, the Service Ontario associate will hand out the vehicle permit, and finally receive their license plate along with a plate sticker [24]. Although Ontario has ceased the sticker renewal system and has terminated the whole idea of having valid stickers on the plate, the actual license plate still needs to be renewed after a certain period.

2.8.2 Design Aspects

Before Ontario started issuing license plates to all drivers, they were able to utilize a license plate that they brought in. This period was between 1903 when the province first asked all residents living in Ontario to register their vehicles, to 1911 when the province started giving out plates through the Ministry of Transportation also known as MTO [25]. Every major country in North America concluded issuing their license plates of the exact same size for all three countries, which Ontario quickly abided by. The standardized size agreed upon was 12 inches by 6 inches or 30 cm by 15 cm, which can be mounted on every vehicle [25].

The plates are made from raw materials such as aluminum by metal manufacturers and then created by plate makers and inmates at correctional facilities. Afterwards, they proceed to add sheeting, coating, colors, and paint which makes it easily visible for law enforcement. The reflective coating on the paint makes it easy for authorities to see the plate when it's dark [26]. The production process includes the sheet being applied on a black metal canvas to add colors. This makes it reflective with the coating that is applied to the sheet. A stamp is then used to dig in the plate to create characters which are later colored in using the paint [26].

In recent years, many license plates have begun to deteriorate quicker than originally expected. Many drivers can see for themselves of their own or other vehicles they have spotted where the characters start to fade, the sheeting starting to wear off not making it visible to identify. The issue for this should be that it is legitimately old but for multiple reasons, it is happening to newly manufactured plates. Those that are going through this scenario, and not trying to do it for the sake of avoiding a toll, can have it replaced free of charge. The plates should absolutely be replaced as well because it can result in a fine.

2.8.3 Design Features

Every license plate has its own unique features such as symbols, colours, and font. The Ontario license plate has the symbol of a crown which represents the “Crown of Canada” which majority can presume as the country is under the constitutional monarchy of Queen Elizabeth as head of state. This symbol commemorates the coronation of the Queen along with King George VI from the year 1937 [27].

The crown separated the characters between the 4 letters on the left and the 3 numbers on the right, for example, ABCD – 123 [27]. Above the identification text is written the province name “Ontario” while below it is written “YOURS TO DISCOVER” which can also be found written in French as this is a bilingual country.

The font used for the Ontario license plate is also like many provinces in Canada and various states in the U.S and Mexico which makes sense since the size requirement is the same for all three countries. The font used is Driver Gothic which has up to 750 characters available throughout many languages [28]. There is no specific reason as to why the font color is blue, but license plates can come in different text colors for distinct reasons which could be because of what the car is, for example electric cars will have the characters on their plates in green symbolizing that it is not polluting the Earth with its gas emissions. Other designs and colors could be because of the status of the driver.

As of 2020 there has been a new series of designs on the Ontario license plate that was scrapped half a year into its release with a unique design coordinated with colors in the background such as different shades of dark blue that made it hard for law enforcement to see. This was expected as the whole purpose of the original design with its unique materials is for the sole purpose of it being easy to identify and read. This license plate had its own key features including a new slogan at the bottom stating “A PLACE TO GROW”. The font colors are white and a two-toned dark blue color. The background is meant to represent a new government of “progress, growth, and prosperity” [29].

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2.9 Competitor Product Comparison

2.9.1 Feature Comparison to Reviver RPlate®

Table 3: Product Comparison to Reviver RPlate® Products

	Product Comparison		
Features	**Our Product**	**Reviver RPlate (Battery)**	**Reviver RPlate (Wired)**
High-Definition Digital Screen	✓	✓	✓
Online Digital License Renewal	✓	✓	✓
Digital Plate Sticker Renewal	✓	✓	✓
Online Website	✓	✓	✓
Smart Phone Application	✓ (Time Permitting)	✓	✓
Trip & Mileage Tracking			✓
Park & Valet Mode			✓
Auto-Brightness	✓		
Replaceable Battery	✓	✓	
Anti-Theft	✓	✓	✓
Telematics (Vehicle Locator)	✓ (Time Permitting)		✓
V2G/V2H Integration	✓		
Smart Metering	✓		
Smart Charging	✓		
EV Battery Information	✓		
Easy Installation	✓	✓	
LTE Connection		✓	✓
Bluetooth		✓	
Secure Cloud Communication	✓	✓	✓
Follows License Plate Standards	✓	✓	✓
Water & Dust Resistant	✓	✓	✓
Plate Visual Personalization	✓ (Time Permitting)	✓	✓
Parking Metering	✓ (Time Permitting)		
Toll Road Payment Integration	✓ (Time Permitting)		

2.9.2 Reviver RPlate® Cost

The graphs in the figures below show the current costs for Reviver's digital license plates. The prices are listed in US dollars (USD) as the plates are only available in the United States.

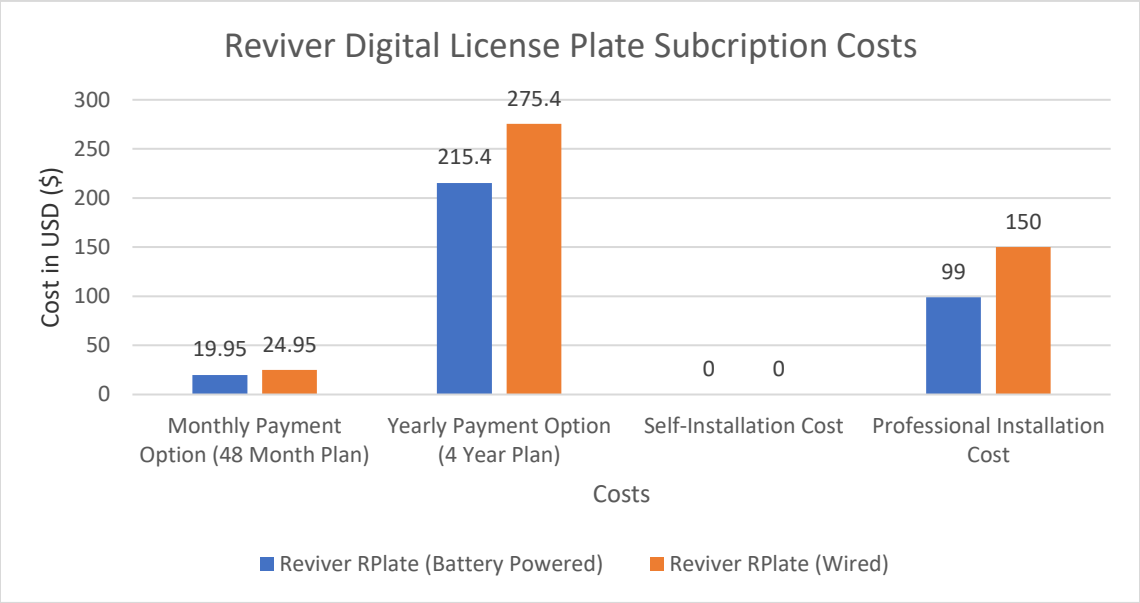

Figure 9: Reviver RPlate® Subscription & Installation Costs

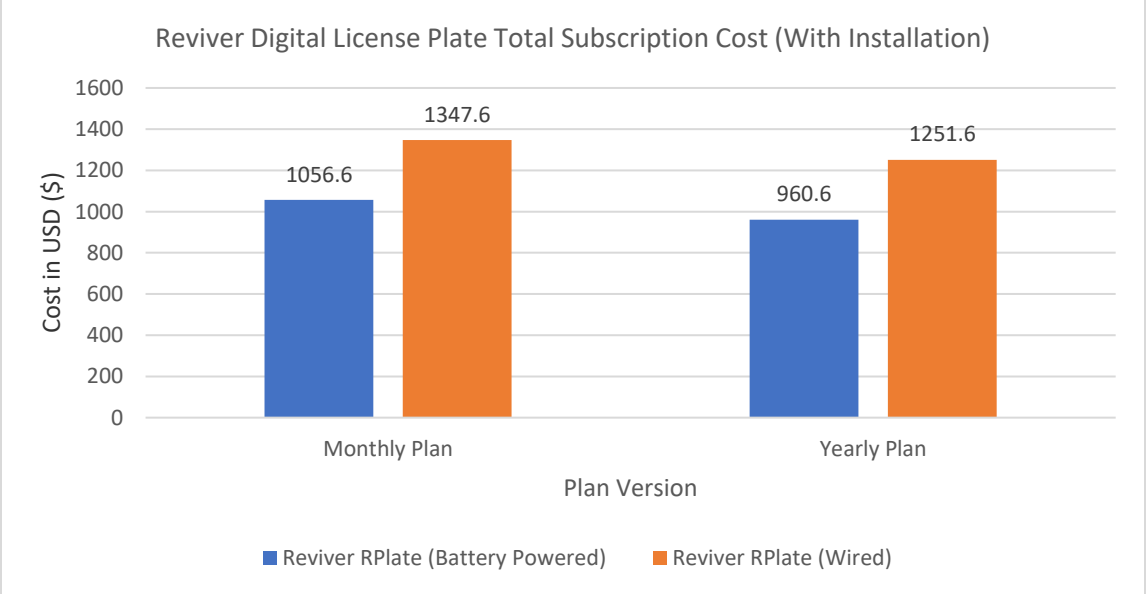

Figure 10: Reviver RPlate® Total Cost Per Subscription Plan

3 Design Process

3.1 Overall Design Process

The overall design process for the entire course can be seen in the **Figure 11** below.

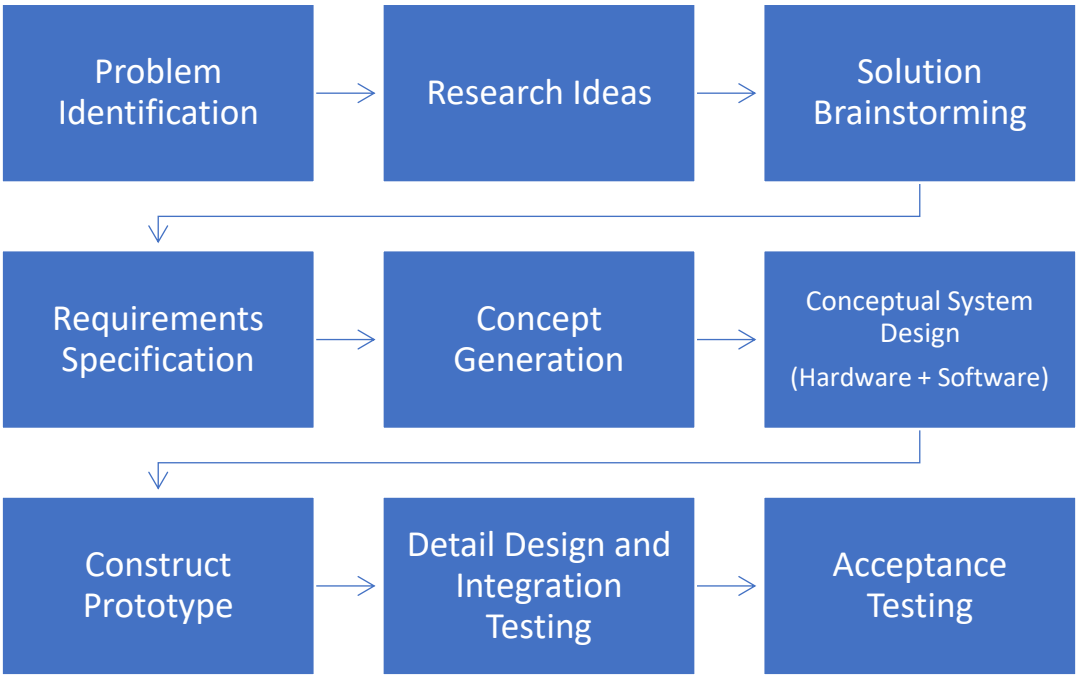

Figure 11: Overall Project Design Process

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3.2 Software Design Process

Figure 12 below represents the software design process that will be followed when designing applications such as the website. This process would also be followed if we determine that time allows us to create a mobile phone application.

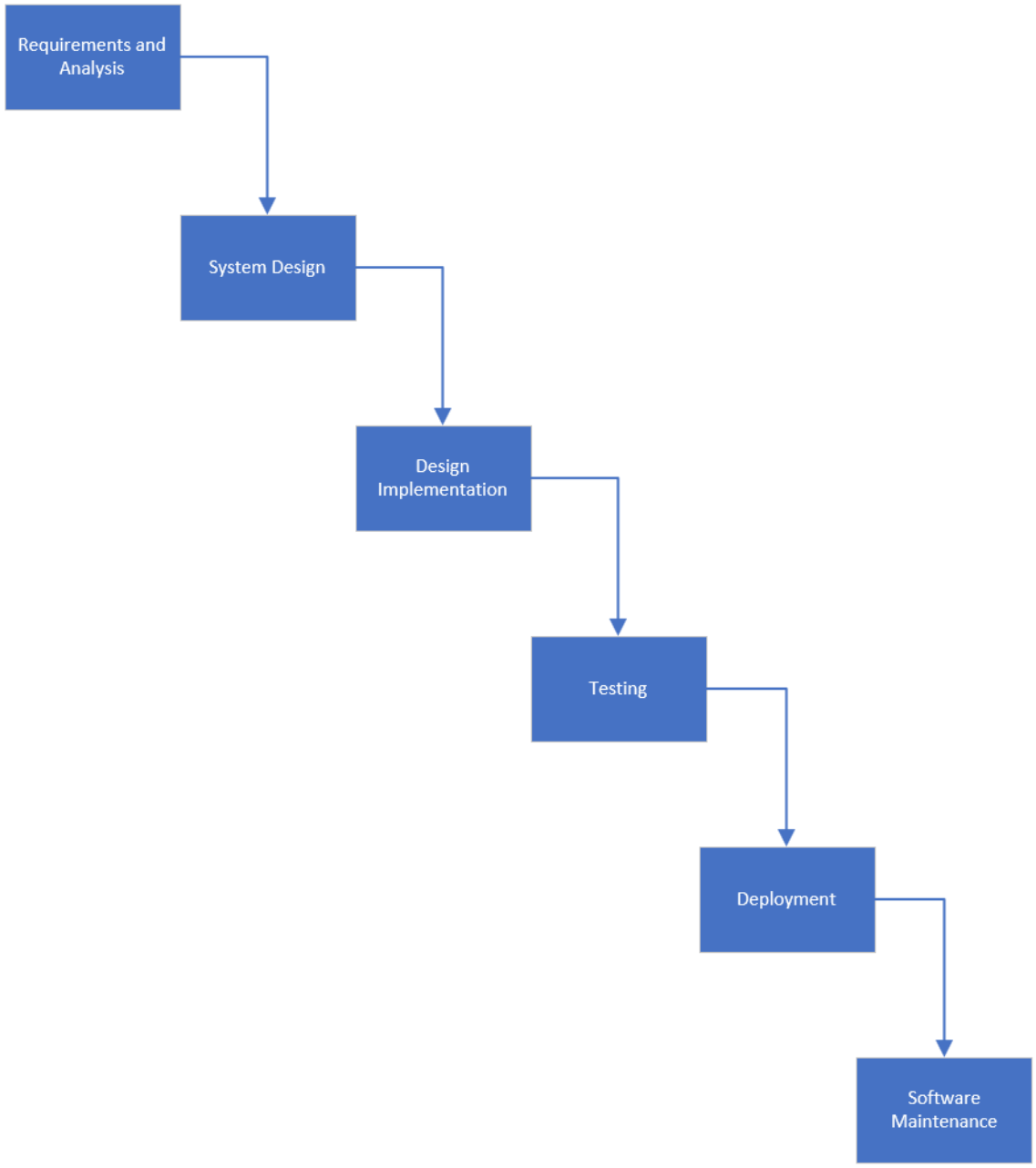

Figure 12: Software Design Process

3.3 Electrical Design Process

Figure 13 below represents the electrical design process to be followed when designing electrical circuits such as the circuits for battery health and state measurements.

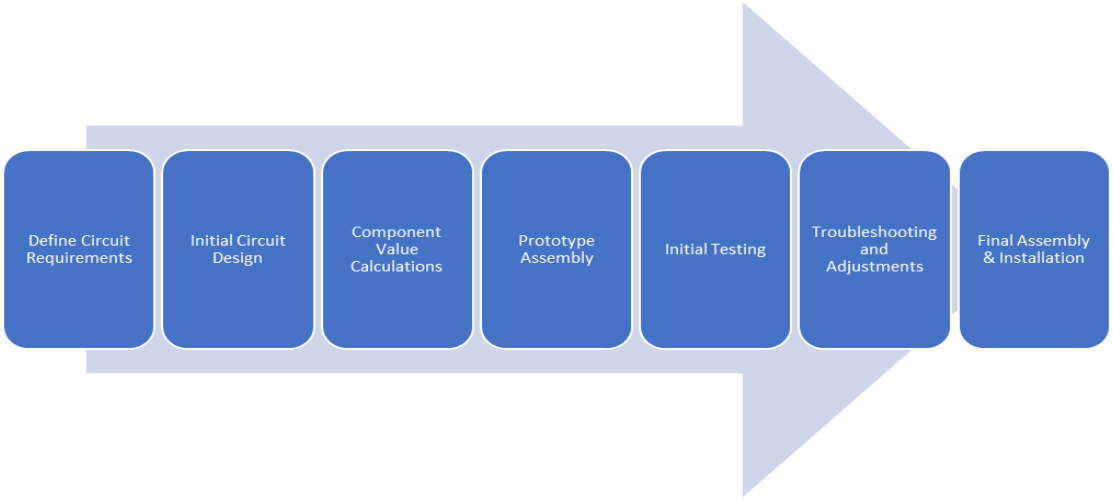

Figure 13: Electrical Design Process

3.4 Sequence Diagrams

3.4.1 Sequence Diagram for Plate Renewal

The sequence diagram in **Figure 14** demonstrates how our system will interact when plate renewal occurs.

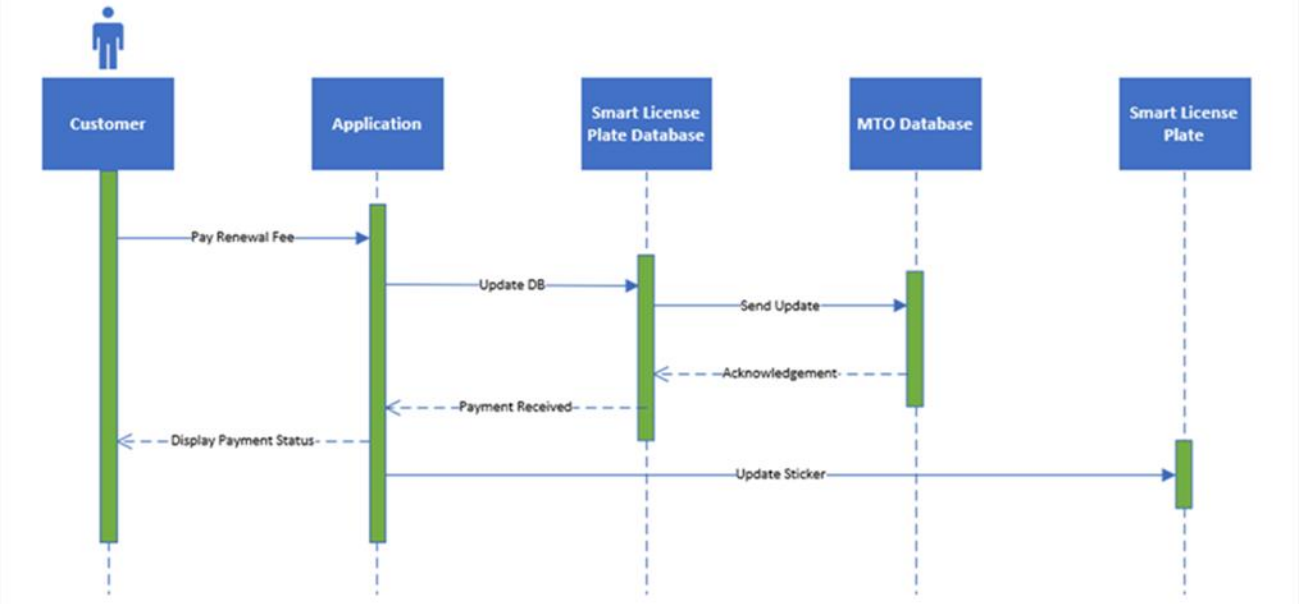

Figure 14: Sequence Diagram for Plate Renewal

3.4.2 Sequence Diagram for Stolen Plate Mode

The sequence diagram in **Figure 15** demonstrates how our system will interact when our license plate is removed from a vehicle, and stolen plate mode is activated.

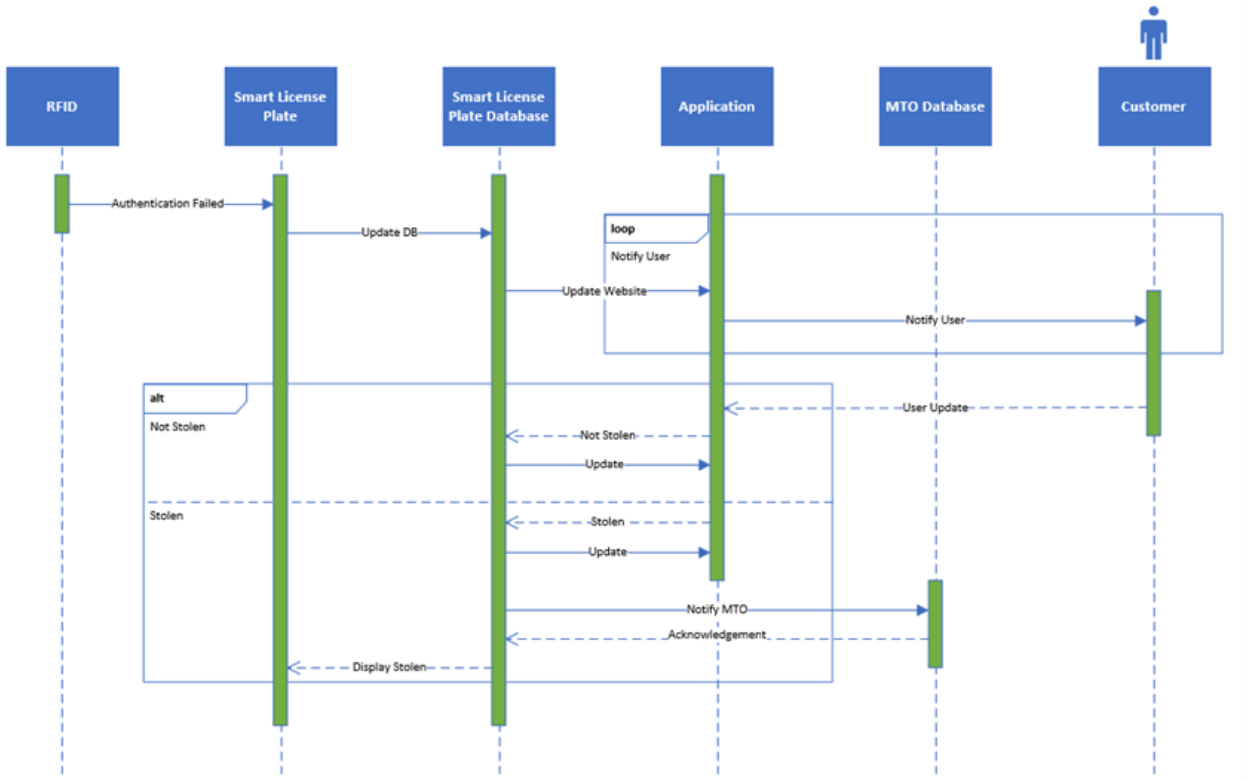

Figure 15: Sequence Diagram for Stolen Plate Mode

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4 Scenarios & Use Cases

4.1 Use-Case Diagram

Figure 16 below shows the use-case diagram for the integrated smart license plate application.

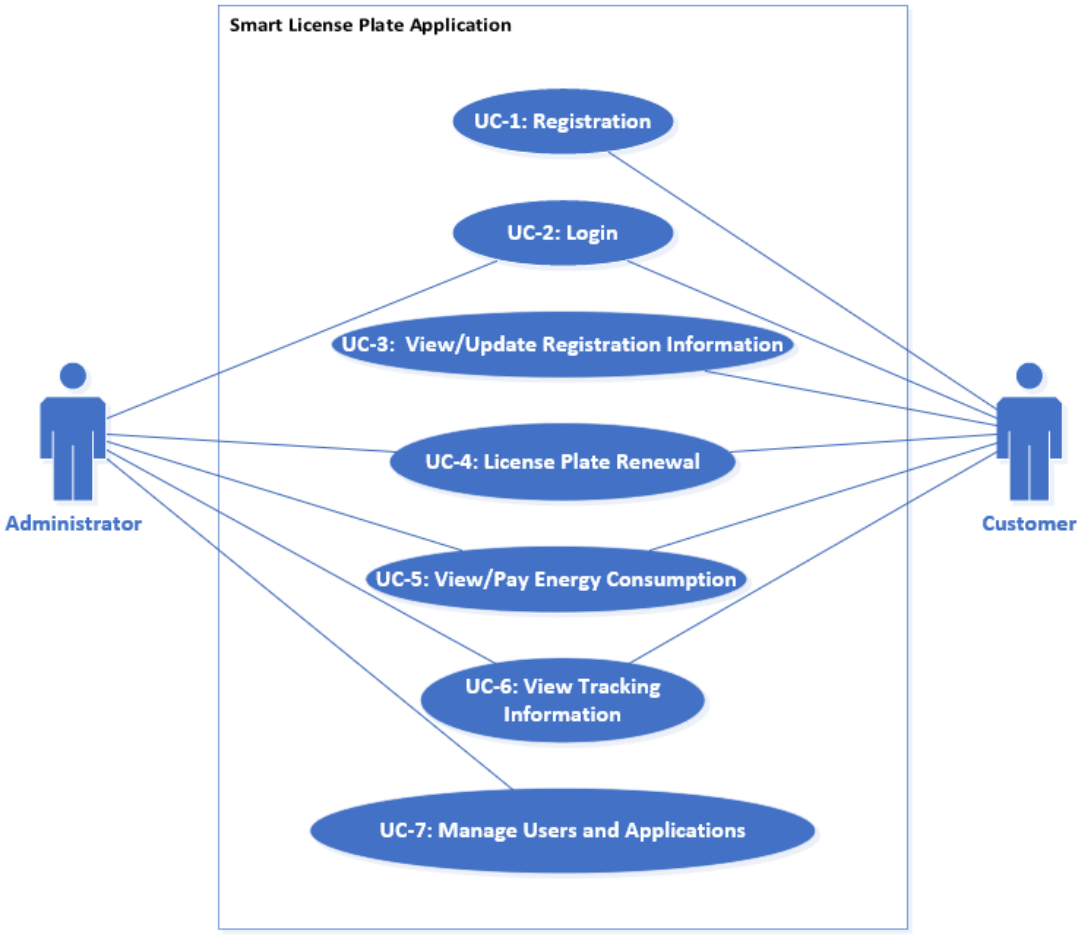

Figure 16: Use-Case Diagram for Smart License Plate Application

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4.2 Use-Cases

4.2.1 Use-Case List

Below, **Table 4.0** lists the use-cases that will be described.

Table 4.0: List of Use-Cases with ID Numbers

Use Case ID	Use Case Name
UC-1	Registration
UC-2	Log in
UC-3	View/Update Information
UC-4	License Plate Renewal
UC-5	View Energy Consumption
UC-6	View Tracking Information
UC-7	Manage Users and Applications

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4.2.2 Use-Case Descriptions

The tables below describe the use-cases depicted in **Table 4.0**.

Table 4.1: Use-Case 1

Use Case ID	**UC-1**
Use Case Name	Registration
Actors	Customer
Description	The user will have access to a page where they can register with their personal information.
Normal Flow	1. User will access the registration page 2. System will request required fields 3. User will enter the required fields 4. System validates the information and logs into system.
Pre-Condition	None
Post Condition	If successful, the actor will be logged into the system.

Table 4.2: Use-Case 2

Use Case ID	**UC-2**
Use Case Name	Log in
Actors	Administrator, Customer
Description	The user will require authorization through the login page to access the application.
Normal Flow	1. User will access log-in page. 2. System will request username and password. 3. User will enter the required fields 4. System validates the information and logs into system.
Pre-Condition	None
Post-Condition	If successful, the actor will be logged into the system.

Table 4.3: Use-Case 3

Use Case ID	**UC-3**
Use Case Name	View/Update Personal Information
Actors	Customer
Description	The actor will be able to view personal information and update if required.
Normal Flow	1. User will access personal information page 2. If user wished to update information a. System will validate information b. Confirmation Page
Pre-Condition	Actor must be logged in.
Post-Condition	If update required, the system will update the database.

Table 4.4: Use-Case 4

Use Case ID	**UC-4**
Use Case Name	License Plate Renewal
Actors	Administrator, Customer
Description	The actor will be able to renew license plate and pay through the application.
Normal Flow	1. User will access renewal page 2. The user will enter required information 3. The system will update changes and send information to MTO database.
Pre-Condition	The actor must be logged in.
Post-condition	The changes must reflect in the database.

Table 4.5: Use-Case 5

Use Case ID	**UC-5**
Use Case Name	View/Pay Energy Consumption
Actors	Administrator, Customer
Description	The actor will be able to view the energy consumed and energy send back to the grid, furthermore the actor will be able to pay the bill.
Normal Flow	1. The user will access the page. 2. The user will enter the required information. 3. The system will update the changes and send information to the power grid database.
Pre-condition	The actor must be logged in.
Post-condition	The changes must reflect in the database.

Table 4.6: Use-Case 6

Use Case ID	**UC-6**
Use Case Name	View Tracking Information
Actors	Administrator, Customer
Description	The actor will be able to view the movement of the license plate
Normal Flow	1. The user will access the page 2. The user will request tracking information 3. A map will be displayed with the Coordinates
Pre-condition	The user must be logged in.
Post-condition	None

Table 4.7: Use-Case 7

Use Case ID	**UC-7**
Use Case Name	Manage Users and Applications
Actors	Administrator
Description	The user will be able to view/modify all the license plate
Normal Flow	1. The user will access the page 2. The user will access to view all the license plates 3. The user may choose to make changes or updates a. If user made changes, update the database
Pre-condition	The user must be logged in
Post-condition	The changes must reflect in the database

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5 Stakeholder Requirements and Traceability Matrix

5.1 Stakeholder Requirements

Table 5.0: Stakeholder Requirements Specifications

Stakeholder Requirement	Description
STRQ-1	**THE USER WILL REGISTER TO CREATE AN ACCOUNT** *FEAT1: The user will register and input the following information: First Name, Last Name, Email, Password, and License Plate Number.* *FEAT2: It shall indicate all the mandatory fields.*
STRQ-2	**THE USER SHALL LOGIN WITH USERNAME AND PASSWORD** *FEAT2: The user shall login with the registered username and password.*
STRQ-3	**THE USER SHALL CHOOSE TO PAY FOR RENEWAL TICKET** *FEAT3: The user shall be able to pay the renewal fee which will be reflected in the MTO database.*
STRQ-4	**THE USER SHALL CHOOSE TO PAY FOR THE ENERGY CONSUMED** *FEAT4: The user shall be able to pay the energy consumed which will be reflected in the power grid database.*
STRQ-5	**THE USER SHALL BE ABLE TO UPDATE PERSONAL INFORMATION** FEAT5: The user shall be able to add or remove the license plate.
STRQ-6	**THE USER SHALL BE ABLE TO VIEW THE LOCATION OF THE LICENSE PLATE** *FEAT6: The user shall be able to keep track of the movement of the license plate.*
STRQ-7	**THE USER SHALL BE NOTIFIED IF THE LICENCE PLATE IS REMOVED** *FEAT7: The user shall be notified if the license plate is removed from the chassis.* *FEAT8: The user shall be allowed to report the plate stolen.*
STRQ-8	**THE APPLICATION WILL UPDATE THE REQUIRED DATABASE WITH THE USER PAYMENTS/RENEWED DATE.** *FEAT9: The user will not be able to see the changes made but the updated renewal date and payments will be kept.*
STRQ-9	**THE USER SHALL BE ABLE TO DISABLE VEHICLES WHEN STOLEN** FEAT10: The user shall have access to disable the electrical vehicle IF STOLEN ONLY!

5.2 Traceability Matrix

Table 5.1: Traceability Matrix

		Requirements								
		STRQ-1	**STRQ-2**	**STRQ-3**	**STRQ-4**	**STRQ-5**	**STRQ-6**	**STRQ-7**	**STRQ-8**	**STRQ-9**
Test Cases	**TC-1**	✓								
	TC-2		✓							
	TC-3			✓						
	TC-4				✓					
	TC-5					✓				
	TC-6						✓			
	TC-7							✓		
	TC-8				✓				✓	
	TC-9							✓		✓

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6 Acceptance Testing

6.1 Definition of Acceptance Tests

The acceptance tests in this section are written to ensure that we can verify that our product meets of stakeholder requirements.

Table 6.0: Test Case #1 – User Account Creation

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC #1				**Test ID:**	Smart-TC-01
Description:	The user will register to create an account				**Type:**	Black Box: ✓ White Box: ☐
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub				**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)				**Time:**	
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	The user will input correct information in the displayed textbox	The application will display a confirmation page.				
2	The results of registration must be correct	Account created in the database must match information				
3	Incorrect or missing information	Error message will be displayed				
Test Result:						

Table 6.1: Test Case #2 – User Login

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC #2		**Test ID:**	Smart-TC-02		
Description:	User shall be to login with user ID and password		**Type:**	Black Box: ✓ White Box: ☐		
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub		**Date:**			
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)		**Time:**			
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	The user will input correct information in the displayed textbox	The application will display a confirmation page				
2	Incorrect or missing information	The application will display an error message				
Test Result:						

Table 6.2: Test Case #3 – User Plate Renewal Payment

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	TC #3	**Test ID:**	Smart-TC-03
Description:	The user shall choose to pay for a renewal plate	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name:	Abdul Bhutta, Walid Ayub	**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)	**Time:**	

Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Incorrect or missing information	Error message will be displayed				
2	User successfully entered all fields correctly	Show confirmation receipt of payment				
3	User taken to a confirmation page	Information is updated on MTO database				
Test Result:						

Table 6.3: Test Case #4 – User Energy Payment

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC #4				**Test ID:**	Smart-TC-01
Description:	The user shall choose to pay for the energy consumed				**Type:**	Black Box: ✓ White Box: ☐
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub				**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)				**Time:**	
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Incorrect or missing information	Error message will be displayed				
2	User successfully entered all fields correctly	Show confirmation receipt of payment				
3	User taken to a confirmation page	Information is updated on PowerGrid database				
Test Result:						

Table 6.4: Test Case #5 – User Updates Personal Information

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC #5				**Test ID:**	Smart-TC-0
Description:	The user shall be able to update personal information				**Type:**	Black Box: ✓ White Box: ☐
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub				**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)				**Time:**	
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Incorrect or missing information	Error message will be displayed				
2	The user will input correct information in the displayed textbox	The application will display a confirmation page.				
3	Results of update should be correct	Account updated in the database must match information				
Test Result:						

Table 6.5: Test Case #6 – Location License Plate Location Viewing

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC # 6				**Test ID:**	Smart-TC-06
Description:	The user shall be able to view the location of the license plate				**Type:**	Black Box: ✓ White Box: ☐
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub				**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)				**Time:**	
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	The user request's location	The device enables location service				
2	Application forwards IP address to Google API	Google API return geo-location				
3	The User selects view on map	Coordinates are displayed on the map				
Test Result:						

Table 6.6: Test Case #7 – License Plate Removal

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC # 7				**Test ID:**	Smart-TC-07
Description:	The user shall be notified if the license plate is removed				**Type:**	Black Box: ✓ White Box: ☐
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub				**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)				**Time:**	
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	The plate is disconnected from the chassis	The device sends a notification to the user				
2	The user is required to select an option	A notification popup will be displayed to the user				
2a	The user selects stolen	The updated result will show on the webpage and the license plate will display “stolen”				
2b	The user selects “user removed”	No changes will be made to the license plate				
Test Result:						

Table 6.7: Test Case #8 – Application Database Refresh

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	TC # 8	**Test ID:**	Smart-TC-08
Description:	The application will update the required database with the user payments/renewed date	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name:	Abdul Bhutta, Walid Ayub	**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)	**Time:**	

Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	The updated payment request will be sent to the MTO database.	The payment update will be reflected in the MTO database				
2	The renewal data will be updated	The date of renewal will be received by the application database				
3	Sticker update on license Plate	The date of renewal will be updated and displayed on the license plate				
Test Result:						

Table 6.8: Test Case #9 – Vehicle Stolen Mode

Test Writer:	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	TC # 9				**Test ID:**	Smart-TC-09
Description:	The user shall be able to disable vehicle when stolen				**Type:**	Black Box: ✓ White Box: ☐
Tester Information						
Tester Name:	Abdul Bhutta, Walid Ayub				**Date:**	
Environment:	The acceptance testing will be done on a web browser (Google Chrome, Safari)				**Time:**	
Steps	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	The user selects stolen mode	The license plate will display stolen				
2	The user selects disable vehicle	The device will send a signal to the EV. Signal shuts down the EV.				
Test Result:						

7 Project Plan

7.1 Fall Semester Deliverable Breakdown

The table below shows the task breakdown for all deliverables due during the Fall semester.

Table 7: Fall Semester Deliverable Breakdown

Deliverable	Report Section Name	Section Deliverables	Assigned Team Member(s)	Duration (Days)
Report #1	**Report Introduction**	Abstract, Dedication, and Acknowledgements	Emran Kumail Walid	2
Report #1	**Problem Identification**	Problem Statement Problem Objective Project Features	Yussef Emran Kumail	3
Report #1	**Background and Research Review**	**Research Topics:** V2G Raspberry Pi Security Cloud Computing Measurement of Battery State & Health Smart Metering & Smart Charging Auto-Brightness Ontario License Plate Legalities & Design Aspects Competitor Product Comparison	All Members	5
Report #1	**Design Process**	Overall Design Process Software Design Process Electrical Design Process Sequence Diagrams	Abdul Yussef	3
Report #1	**Use-Cases**	Use-Case Model Use-Case Definitions	Abdul Walid	2
Report #1	**Stakeholder Requirements / Traceability Matrix**	Stakeholder Requirements Definition Traceability Matrix	Abdul Walid	2
Report #1	**Definition of Acceptance Tests**	Acceptance Tests	Abdul Walid	2

Report #1	**Project Plan**	Task Breakdown (Fall) Task Breakdown (Winter) Gantt Chart	Abdul Yussef	2
Report #1	**Contribution Matrix**	Matrix Creation and Completion	Yussef	1
Report #1	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	1
Report #1	**Report Formatting**	Format Report Naming/Organizing Tables & Figures	Yussef	1
Report #1	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Report #2	**Report Introduction**	Abstract, Dedication, and Acknowledgements	All Members	1
Report #2	**Concept Generation/Analysis**	Concept Generation Table Creation	All Members	5
Report #2	**Conceptual System Design**	Software System Designs Electrical System Design Overall System Design Design Review	All Members	10
Report #2	**Definition of Integration Tests**	Creation of Integration Tests Review of Tests	Abdul Kumail Walid	4
Report #2	**Estimated Project Cost**	Cost Estimation Cost Analysis Cost Tracking	Emran Yussef Walid	2
Report #2	**Project Plan**	Update Task Breakdown (Winter) Update Gantt Chart	Abdul Yussef	2
Report #2	**Contribution Matrix**	Matrix Creation and Completion	Yussef	1
Report #2	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	1
Report #2	**Report Formatting**	Format Report Naming/Organizing Tables & Figures	Yussef	1
Report #2	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Team Presentation & Demo	**Presentation Assembly**	Construction of PowerPoint Presentation	All Members	12
Team Presentation & Demo	**Presentation Proofreading and Formatting**	Proofreading Consistency Check General Flow Check	Emran Kumail Walid	1

Team Presentation & Demo	**Prototype Assembly**	Assembly of Prototype	Abdul Yussef	5
Team Presentation & Demo	**Presentation Rehearsals**	Assign sections for presentation Practice Presenting	All Members	3
Team Presentation & Demo	**Final Presentation**	Present to Capstone Advisor/Coordinator	All Members	1
Team Retrospective Report	**Report Preparation**	Write Team Report	All Members	10
Team Retrospective Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Team Retrospective Report	**Report Formatting**	Format Report Naming/Organizing Tables & Figures	Yussef	1
Team Retrospective Report	**Report Submission**	Submission to Capstone Coordinator	Yussef	>1
END OF FALL SEMESTER				

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7.2 Gantt Chart

Figure 17 below shows a Gantt chart demonstrating the project plan deliverables throughout the course of the project and the timeframe for their completion.

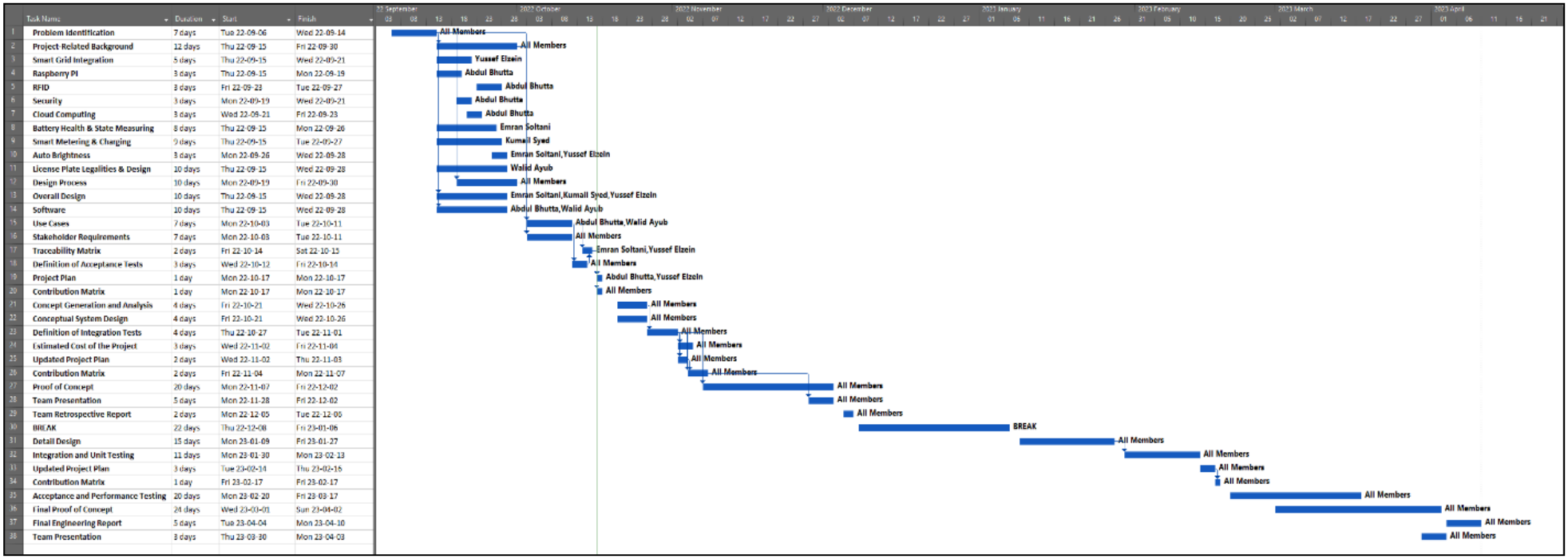

Figure 17: Gantt Chart for Digital License Plate Capstone Project

8 Contribution Matrix

The contribution matrix in the table below displays how the work for Report #1 was divided.

Table 8: Contribution Matrix for Report #1

	Group Members				
Report #1 Sections	**Abdul Bhutta**	**Yussef Elzein**	**Emran Soltani**	**Kumail Syed**	**Walid Ayub**
Section 1: Background and Research Review					
Problem Identification	✓	✓	✓	✓	✓
Section 2: Background and Research Review					
Smart Grid Integration		✓			
Raspberry Pi	✓				
Security	✓				
Cloud Computing	✓				
Battery Health & State Measuring			✓		
Smart Metering & Charging				✓	
Auto-Brightness Circuit Design			✓		
License Plate Legalities & Design					✓
Section 3: Design Process					
Overall		✓	✓	✓	
Software	✓				✓
Electrical		✓	✓	✓	
Section 4: Scenarios & Use Cases					
Use Cases	✓				✓
Section 5: Requirements / Traceability					
Stakeholder Requirements		✓		✓	✓
Traceability Matrix		✓	✓		
Section 6: Acceptance Tests					
Test Cases	✓	✓	✓	✓	✓
Section 7: Project Plan					
Task Breakdown		✓			
Gantt Chart	✓				
Section 8: Contribution Matrix					
Contribution Matrix	✓	✓	✓	✓	✓
Other: Report Corrections/Formatting		✓	✓	✓	

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