**College of Engineering**

**Department of Electrical Engineering**

Spring 2019-2020

# Senior Design Project

# Final Report

# SMART SOLAR CARPORT SYSTEM

**In partial fulfillment of the requirements for the Degree of Bachelor of Science in Electrical Engineering**

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# *Abstract*

The use of renewable energy sources, such as solar energy, is readily available to a wider audience because of the falling costs of installing PV panels. Industrial sites and office buildings provide a great potential for Photovoltaic (PV) panels with their large unused spaces such as flat roofs or unshaded parking lots. For the non-commercial side, it includes homes, universities, and marketplaces. Hence, the project of having smart solar carports system aims to provide Prince Mohammad Bin Fahd University (PMU) with a modernized power system. Furthermore, the project adopted the concept of renewable and green energy by generating electricity and power from solar panels mounted on the carport. The designed solar carport system composed of subsystems intended to provide smart solutions and integrate various aspects in the world of smart electrical systems such as electrical vehicle (EV) charging system, green home system, and local storage system. Green home is a building that aims to preserve precious natural resources and improve our quality of life, and local storage to overcome variation of power generated from PV panels.

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# 1. Introduction

## 1.1 Project Definition

The project aims to provide renewable grid independent residential power system to Prince Mohammad Bin Fahd University (PMU) which is a smart solar carport system. The project adopts the concept of renewable and green energy by generating power and electricity via photovoltaic array (PV) i.e. solar panels mounted on carport. The designed smart carport system consists associated with subsystems such as electric vehicles (EV) charger, local storage system, and green home system. The system intends to provide smart solutions and integrate various aspects in the world of smart electrical systems and increase the electric mobility in educational facilities. Green home is a building that aims to preserve precious natural resources and improve the quality of life, in our project this will be established by solar energy to power electrical households (residential loads).

## 1.2 Project Objectives

- Enhance PMU reputation in the aspect of renewable energy and smart solutions by generating renewable energy at PMU campus.
- Reduce electricity expenditures and hedge against future cost increases, i.e. electric bills
- Adopt and encourage environmentally-friendly transportation with electric vehicles and their chargers in future, chiefly at educational facilities.
- Improve parking experience for students, staff, and visitors.
- Afford electric vehicle (EV) charging station.
- Encourage environmentally-friendly transportation towards residential renewable system.

## 1.3 Project Specifications

- Generates renewable energy using solar PV panels mounted on carport with maximum output of 480 W.
- Contains energy storage (battery) for 150 Ah, 12 V which acts as a backup source capable to provide continuous power for 3.75 hours for maximum load of 480 W.
- Charges Electrical Vehicle (EV) with charger output of 220 V.
- Contains DC/AC Inverter with output of 75 W.
- Energizes electrical household appliances (residential loads) up to 75 W.

## 1.4 Product Architecture and Components

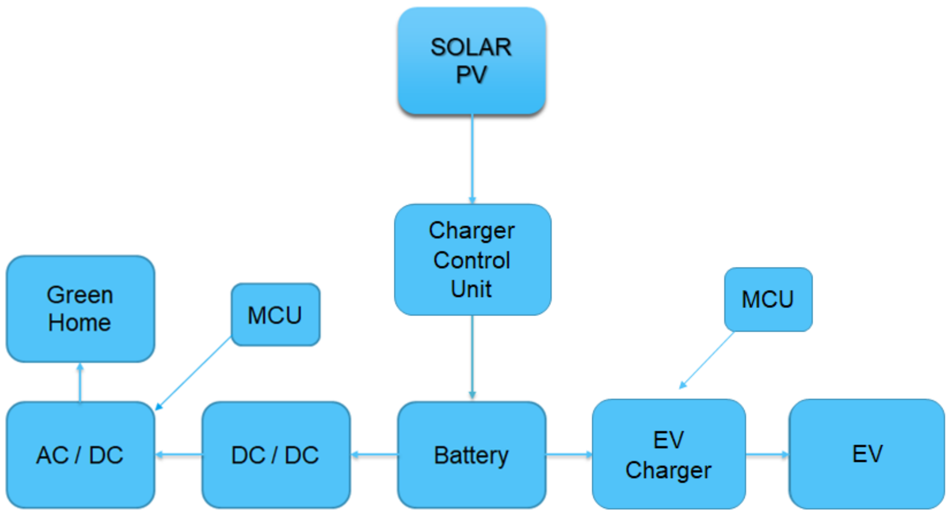


**Figure 1.1: Block diagram of smart solar carport system.**

The block diagram of the entire system is shown in Figure 1.1. It includes battery storage system, DC/DC converter, and DC/AC inverter to convert the DC output of the solar panels to AC in order to power up green home appliances. Sinusoidal pulse width modulation (SPWM) technique will be used to perform DC to AC conversion. In this technique a sinusoidal waveform is sampled, where each sample represents the percentage duty cycle of PWM. These duty cycles are saved in the memory of the micro-controller as an array to make a look-up table. Micro-controller utilizes stored duty cycles to generate gate control signals which are fed to H-bridge inverter to obtain the desired output voltage and frequency signal. In addition to powering up the green home, EV charging facility will be provisioned in the carport. The EV charger will use voltage and current sensors to measure the charging current and voltage to calculate the actual charging power. It will have the functionality of variable EV charging rates which is currently nonexistent in the EV chargers available in the market

The primary benefit of having a solar carport is that it provides flexibility in the way of customizing and design solar projects since the direction of solar panels and the angle at which they are placed has a large impact on the amount of energy being produced. Hence, a solar carport can be structured to optimize the positioning of solar panels, whereas this may not be as simple for a rooftop solar panel system. Furthermore, the solar carport has been integrated with a green home system and electric vehicle (EV) charger in order to encourage society towards smart and green transformations and utilize renewable sources on daily applications by which it increases the electric mobility. In addition, since the power being produced by solar panels will be affected due to sunlight exposure, a local storage system (battery) has been used to overcome the variation of power being produced by solar systems. It intends to funnelled into the EV battery and power the green home loads after being processed by DC/AC inverter and DC/DC converter and it is an important element to have self-independent (grid-independent) power system. Overall, a solar carport gives a significant amount of flexibility over how to use the solar energy and it is a greet option for residential and commercial purposes.

## 1.5 Applications

The main applications of smart solar carport system are as follows:

- Provide renewable energy to PMU by generating solar power.
- Provide electrical charging system for electrical vehicles (EV).
- Power green homes via solar energy and battery bank.
- Provide battery bank system to have grid independent renewable system.

# 2. Literature Review

## 2.1 Project background

The information in this section carried out with the purpose of highlighting the importance of renewable energy, solar systems, solar carports, and electrical vehicle (EV) charging systems. Furthermore, the research findings intended to be utilized as sources of material, hence, only similar and relevant projects that their scope corresponds with our scope will be analyzed and discussed in this chapter.

The increasing adoption rate of renewable energy demand especially towards solar technology has led to both surprising innovations as well as obvious and practical applications. One such application of solar technology is found in solar carports. Solar carports are solar panels mounted above car parking spaces and offer a flexible and cost-effective way to install solar power as they do not require any extra space. Moreover, Solar carports are an offshoot of traditional carports, which provide shade and protection for your vehicle by which the panels themselves serve as a dual-purpose solution for both covering the owner's vehicle and for producing clean and renewable energy.

## 2.2 Previous Work

**[1] - Smart grid solar-powered charging station (2015, University of York)**

York University provided solar energy to its electric vehicle commuters since December 10, 2015. The Faculty of Environmental Studies by Dr. Jose Etcheverry with his research team developed and built a smart grid solar-powered charging station that can store solar electricity and withstand the bitter cold of a Canadian winter.

**Figure 2.1: Solar Carport at University of York**

This innovative project is an excellent example of our project scope by which it uses clean, renewable energy while also encouraging the use of electric vehicles in order to transport into smart systems. Moreover, the solar carport and charging station is a start toward reducing emissions. It is an on the ground practical and local response to climate change, and an innovative smart grid approach for increasing electric mobility solutions on campus. We intend to design the solar carport system with solar electric vehicle charging port with the goal of inspiring new practical local solutions and additional innovations towards renewable and green energy, smart grid and off grid systems. Therefore, our project differs by implementing a green house system in addition to battery bank system in order to overcome the variation of PV production and charge EV's more sufficiently.

**[2] - System design for a solar powered electric vehicle charging station for workplaces (2016, Department of Electrical Sustainable Energy, Delft University of Technology)**

This paper investigates the possibility of charging battery electric vehicles at workplace in Netherlands using solar energy carport system. This paper with the provided design of solar carport system as shown below in Figure 2.2 has been chosen due to the huge similarity with our project definition and deliverables by which the feasibility of integrating a local storage (battery bank) to the EV charger to make it grid independent has been evaluated as it is one of our main deliverables and subsystems. Firstly, the use of renewable energy sources such as solar energy is accessible to a wider audience because of the falling cost of PV panels. Industrial sites and office buildings can provide a great potential for photovoltaic (PV) panels with their large surface on flat roofs. Examples include warehouses, industrial buildings, universities, factories, etc. This potential is largely unexploited today. Secondly, EVs provide a clean, energy efficient and noise-free means for commuting when compared with gasoline vehicles. The motive is to maximize the use of PV energy for power systems and electricity generation and EV charging with minimal energy exchange with the grid.

**Figure 2.2: Design of solar powered EV charging station.**

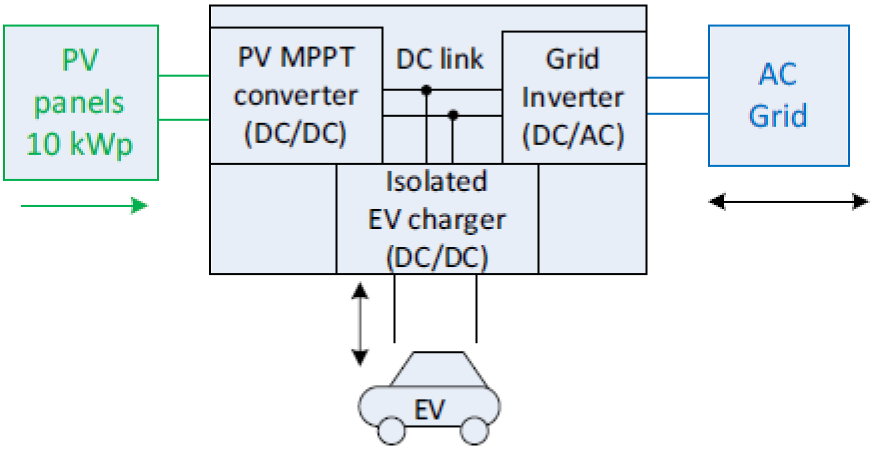


**Figure 2.3: System architecture of the grid connected 10 kW three-port EV–PV charger.**

A major disadvantage of charging EV from PV is the variability in the PV production. Smart charging provides for flexibility of EV charging in order to closely match the PV production. One method to overcome the PV variation and it will be implemented in our project is to use a local storage (battery bank) in the PV powered EV charging station. The storage is typically charged when there is excess solar energy and is then used to charge the EV when solar generation is insufficient and to energize the green home after the DC being converted to AC via DC/AC invertor. However, the EV charging block diagram as shown in Figure 2.3 demonstrates what the paper has designed regarding its EV charging system, the PV panels will provide 1 kW instead of 10 kW to reduce the cost, and the DC/AC (invertor) output will be connected to the green house for small loads up to 220 V.

**[3] - Solar carport module (2019, Patent Application Publication for King Abdulaziz University, Jeddah)**

This patent publication talks about the energy production systems relying on photovoltaic panels with different configurations and/or arrangements to enhance sunlight exposure have been employed. Notably, conventional solar carports that rely on photovoltaic panels mounted onto elevated structures con figured to receive vehicles, e.g. parking structures and garage roofs, to generate electricity while minimizing usable space occupied by the photovoltaic panels have been adopted and explained in this paper in which it corresponds with our project deliverables. This paper as well highlighted an obstacle that will occur with solar carport, the photovoltaic panels may easily be covered by light obstructing materials, e.g. dust, sand, leaves, and other debris, which can affect energy production, and cleaning and servicing these photovoltaic panels may often be required. The publication claims are similar to our deliverables as follows: a solar carport module comprising a support structure to provide shelter to a vehicle, the support structure having a pair of trusses rotatable affixed to a ground surface on which the vehicle is parked. Photovoltaic (PV) panels mounted above the carport (shelter) to provide solar electricity. Battery assembly that electrically connects the plurality of photovoltaic panel to receive, regulate, and store the solar electricity produced by PV panels. The addition in our project will be in the EV charging system and green home system, instead of just generating electricity, the produced energy intended to be utilized to charge EV vehicles and energize a green home.

**[4] - Integrated Energy Management of a Plug-in Electric Vehicle in Residential Distribution Systems with Renewables (2017, Lorestani, A., Aghaee, S. S., Gharehpetian, G. B., & Ardehali, M. M.)**

This paper illustrates microgrids, residential distribution, EV charging and renewable systems and therefore highlighted the advantages of such systems. Integrating renewable energy generation such as solar power into the existing power grid becomes more important nowadays. Meanwhile, electric vehicles (EVs), particularly the plug-in electric vehicles (PEVs), for green transportation have attracted increasing attention because of the intermittent nature of solar power.

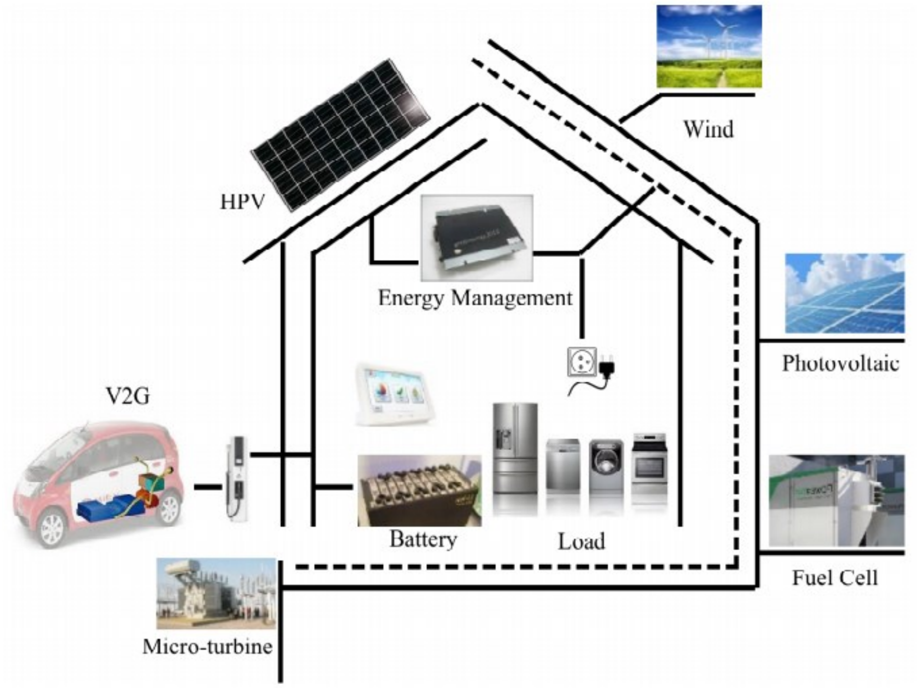


**Figure 2.4: Smart home scheme with V2G system**

The residential micro-grid or Smart House (SH) designed for their paper as shown in Figure 2.4 does not correspond much with our project since it has more subsystems and sources of energy. The distributed energy resources considered are a micro-turbine, an active generator (photovoltaic module associated with battery), and the battery of a PEV while the wind turbine is not going to be implemented in our project. Moreover, no home energy management system (HEMS) has been considered in our project in which it communicates with the different devices constituting the load and all the energy sources by smart meters. Therefore, the designed home has photovoltaic (PV) system as a renewable energy source while the PV will be mounted above the carport shelter in our project. In our project, solar carport system is composed by the PV system (above shelter), battery bank, plug-in electrical vehicle charging system, and green home system.

## 2.3 Comparative Study

| Projects | 1 | 2 | 3 | 4 | Our Project |
|---|---|---|---|---|---|
| Solar Carport | ✓ | ✓ | ✓ | | ✓ |
| EV charging system | ✓ | ✓ | | ✓ | ✓ |
| Residential Load (Green home) | | | | ✓ | ✓ |
| Local storage system ( Battery Bank) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Grid independent | ✓ | | | ✓ | ✓ |

**Figure 2.5: Projects comparison**

In accordance to what explained in section 2.2, our project is different by complaining all the features and subsystems. In other word, the designed solar carport system at PMU will be built using solar panels mounted on carport (solar carport) aiming to provide renewable energy to charge electric vehicles and energise residential loads. The system will be associated with local storage system to overcome the variation of power produced from the solar panels and to provide sufficient power to EV charger and green home at any time to make it grid independent.

# 3. System Design

## 3.1 Design Constraints

### *3.1.1 Design Constraints: Sustainability*

Sustainability and sustainable energy is one which is able to meet the growing demand of life without compromising the demand of the people that would require it in future. Solar power is the most utilized and common source of renewable energy sources, moreover, renewable energy has a direct relationship with sustainable development through its impact on human development and economic productivity. Therefore, renewable power systems provide great opportunities in energy security and since renewable energy supplies are obtained naturally from ongoing flows of energy in our surroundings, it should be sustainable. For renewable energy to be sustainable, it must be limitless and provide non-harmful delivery of environmental goods and service. The smart solar carport system is renewable and sustainable energy source as a way of converting the sun energy into electrical energy, solar panels make use of the single most sustainable resource on the planet which is the light of sun.

### *3.1.2 Design Constraints: Environmental*

Solar energy creates clean, renewable power from the sun and benefits the environment. Alternatives to fossil fuels reduce carbon footprint at home and abroad, reducing greenhouse gases around the globe. Solar is known to have a favorable impact on the environment. Having a solar carport system that can be used for residential and commercial purposes, can reduce demand for fossil fuels, limit greenhouse gas emissions, and shrink the carbon footprint. Therefore, the project encourages the society towards electric vehicles (EV's) in which they are better for the environment and emit less greenhouse gases and air pollutants over their life than a petrol or diesel car.

### *3.1.3 Design Constraints: Economic*

The smart solar carport system is an off-grid system i.e. not connected to the main grid. In this system, the generated solar energy is stored in batteries and the DC power stored in the batteries is converted into AC power by an inverter in order to energize the green home or any other residential and commercial loads. Hence, the system is an excellent cost saving feature when planned properly and is capable of reducing electricity bills. Moreover, using residential solar power systems associated with electric vehicle charger can help reduce the costs of charging an electric vehicle even further while simultaneously reducing fossil fuel consumption. Combining the purchase of an electric car with the installation of a solar panel system allows for even more savings throughout the lifetime of both the vehicle and the solar panel system.

In addition to reducing reliance on fossil fuels for charging, a solar panel system can offset electricity costs and generate free energy.

## 3.2 Design Methodology

In accordance with the provided project block diagram in Chapter 1 , Figure 1.1, Table 3.1 below demonstrates the design methodology and how tasks were divided into two semesters.

**Table 3.1: Design methodology**

| During Design Methodology & Project Management: |
|---|
| ❖ PHASE I: INITIATING AND PLANNING<br>• Research and development regarding smart carports, renewable energy, solar panels, EV charging systems, etc. Therefore, literatures will be reviewed to get more knowledge and collect information as much as needed.<br>• Procurements, i.e. identifying the needed components and start purchasing stage from vendors.<br>• Project management and planning, design a critical path of the project with list tasks, milestones (deadlines) and action items for each team member responsible. |
| ❖ PHASE II: DESIGN<br>• Design and identify project subsystems and alternatives ways to implement each one.<br>• Design subsystem I (Green home) and identify the needed components to implement the design.<br>• Design subsystem II (Battery bank) and identify the needed components to implement the design.<br>• Integrate and test subsystems I and II and make necessary calibration and improvements. |
| **During Assessment III:** |
| ❖ PHASE III: PROJECT COMMISSIONING<br>• Design other subsystems (EV charging system) and implement using appropriate components.<br>• Test and analyze each subsystem and make necessary improvements.<br>• Integrate all subsystems and perform final testing. |
| ❖ PHASE IV: PROJECT CLOSING<br>• Write final report and presentation. |

# 3.3 Product Subsystems and Components

**Table 3.2: System components**

| Component | Specifications | Selection Reason |
|---|---|---|
| **IGBT** | SK 25 GH 12T4<br>VCES 1200 V<br>IC 25 A | The IGBT is H Bridge and it has HIGHER current and power rating. We selected H bridge as it is cheaper and more compact than individual IGBTs |
| **DC/DC Converter** | 12 to 220V DC high adjustable output voltage boost converter, 70 W rating | To boost the battery voltage DC before the inverter circuit. |
| **H- bridge Rectifier** | H- Bridge diode rectifier KBPC3510 35A | It is suitable to rectify the AC supply to the required voltage for the EV charger |
| **DC Current Sensor** | SCK3-50A dc current sensor | A good quality and accurate dc current sensor used on the EV charger circuit to control the charging current to EV |
| **DC Voltage Sensor** | 300V/5V , Model HV6023 | It was selected because it has the desired output that fit the Arduino analog channels and the range of primary voltage from the EV charger circuit. Its accuracy is high as 1 % as well. |
| **Ferrite Core Transformer** | EE70 3 KW to 220-380V push pull ferrite core high frequency converter transformer | It has the desired voltage output for EV charger circuit and it designed to work with high frequency switching to step up the |

| | | |
|---|---|---|
| | | dc voltage and then rectify the transformer output |

### *3.3.1 Product Subsystem1: Green home structure*

Home structure: (aluminum, cork, and **wood**), wood

Carport structure: (**aluminium**, wood), aluminium

DC/AC inverter: (**design inverter**, purchase an inverter), design DC/AC inverter

Power: (on-grid, **battery**, **and solar**), battery and solar and completely of-grid system

Isolation circuit for DC/AC inverter: (**optocoupler PC817**, transformer), optocoupler PC817

Gate driver transistors for DC/AC gate driver circuit: (MOSFET's, **IGBT's**), H-bridge consists of four IGBT's

Circuit board: (**Universal circuit board**, Printed circuit board (PCB), prototype circuit), universal circuit board 30x25 cm

Microcontroller: (**Arduino Mega**, Arduino UNO), Arduino Mega

### *3.3.2 Product Subsystem2: Local storage system*

Battery: ( 100Ah, **150Ah**, 200Ah), 150 Ah and 12 V

## 3.4 Implementation

In this project, solar panels have mounted on roof of a car parking to build carport at PMU. The main purpose of the carport is to supply power to green home consisting of few residential appliances. In addition, the carport will be provisioned with the electric vehicle (EV) charging station (socket) to charge EVs parked in the carport. The major source of energy is the battery energy storage system that is charged using solar PV panels as shown in Figure 3.1. To prevent under- and over-charging of the battery energy storage system, a charge controller is employed as shown in Figure 3.2.

**Structure work (Solar carport and green home):**

The structure work of our project is one of the critical activities that needed to be designed, confirmed, and implemented early to prevent ant structure issues, both structures i.e. the green home and carport designed using software named SolidWorks, available at PMU's campus.

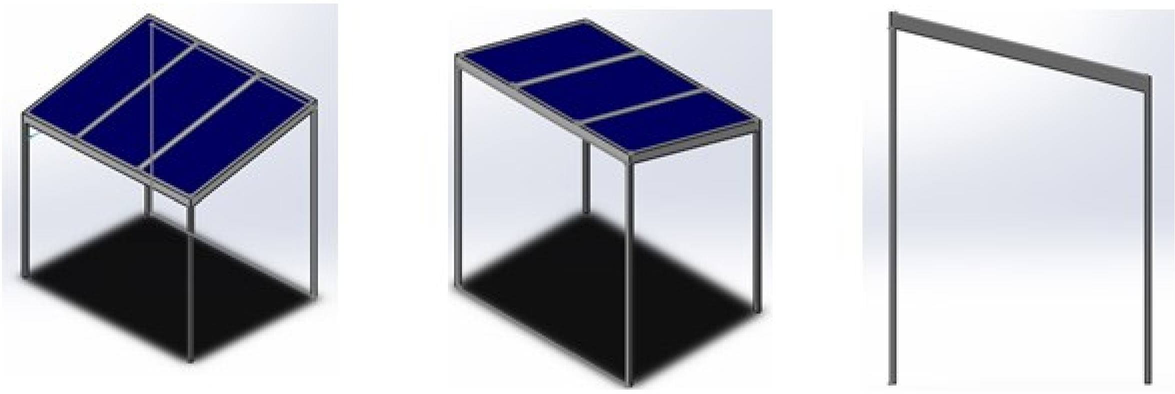

**Figure 3.1: Solar carport design using SolidWorks.**

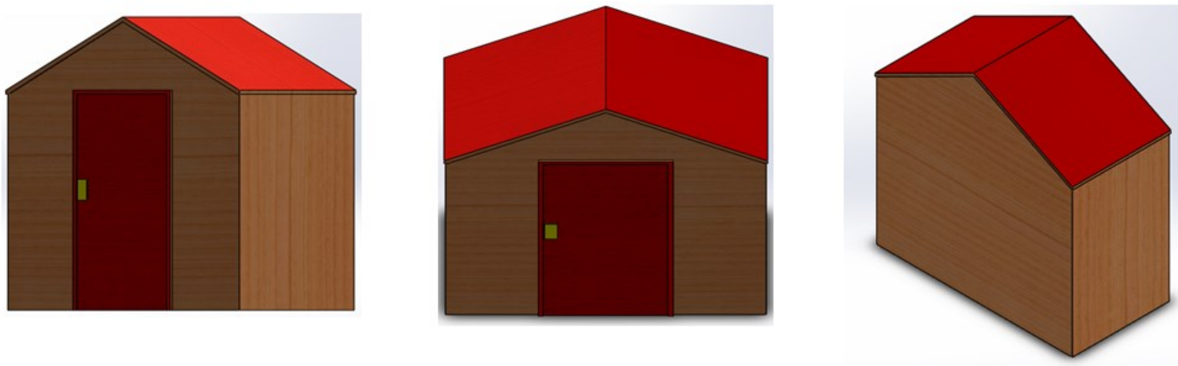

**Figure 3.2: Green home design using SolidWorks.**

The green home structure is made of wood structure since it is less expensive and easy to work with, the purpose was to build a home that suits for one or two examiner.

Therefore, we design the green home to have a width of 240 cm, a length of 120 cm, and a height of 240 cm, which will be suitable for two people to be inside the home. The materials we have used for the green home are:

- Plywood sheets 240x120 cm (8 pieces).

- Pressure-Treated Lumber 220 cm (10 pieces).
- Pressure-Treated Lumber 180 cm (10 pieces).
- Screws.

The green home aims to show that we can energize it by our smart system. Therefore, we decide to have different AC loads in the green home to be supplied. The total amount of the load to be supplied is up to 75 W. The residential loads in the green home consist of:

- LED Light (12 W).
- Electric Fan (30 W).
- Laptop Charger (30 W).
- AC Power Sockets.


**Figure 3.3: Implemented solar carport.**


**Figure 3.4: Charge controller output.**

**Subsystem I (DC/AC Inverter):**

An inverter is a power electronic device capable of transforming a direct current (DC) into an alternating current (AC) at a given voltage and frequency. In our project, the inverter is required to supply the green house appliance that operates in alternating current (AC) 220 V (60 Hz frequency). Moreover, inverters are used in stand-alone photovoltaic (PV) systems for powering electrical devices by transforming the generated DC from solar panels into AC to energize the green home.

The designed DC/AC known as square wave inverter, the square wave inverter is a type of inverter which converts solar DC power to AC power.

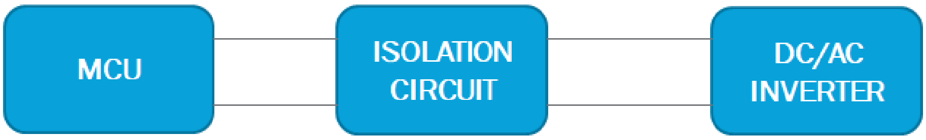


**Figure 3.5: DC/AC inverter block diagram.**

The inverter inputs are square wave signals generated by the Microcontroller unit (MCU) Arduino Mega by using the technique of pulse width modulation (PWM) in addition to an isolation circuit followed by H-bridge consisting of four IGBT's. Each IGBT intended to operate as a voltage switche in accordance with the input signal. The use of IGBT's in the output stage and the PWM technology makes this inverter ideal for all types of loads. In addition to the pulse width modulation, the protection part, i.e. isolation will be established by using PC817 which is a 4 Pin optocoupler, normally used in embedded project for isolation purposes.

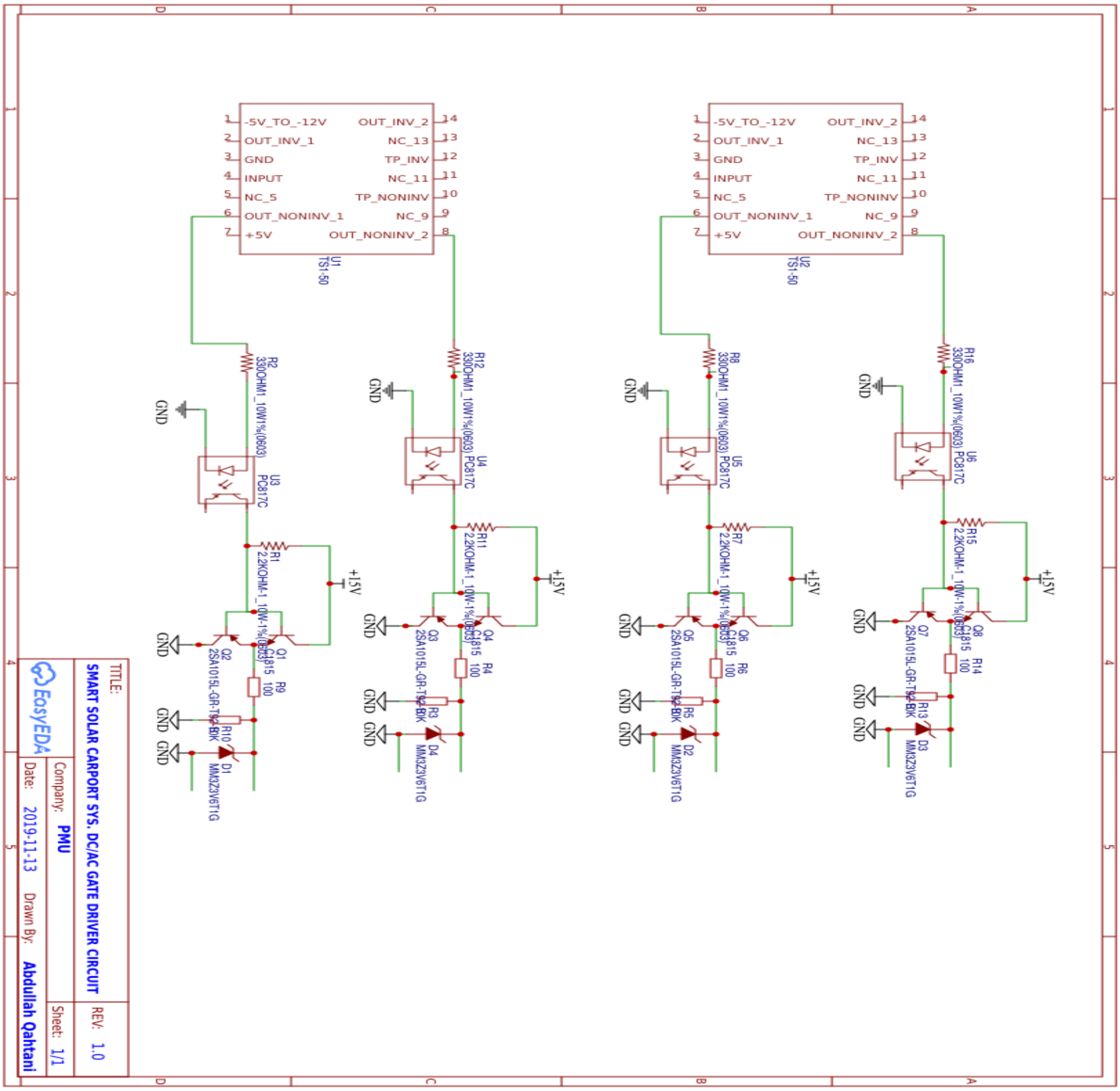


**Figure 3.6: Design of DC/AC gate driver circuit.**

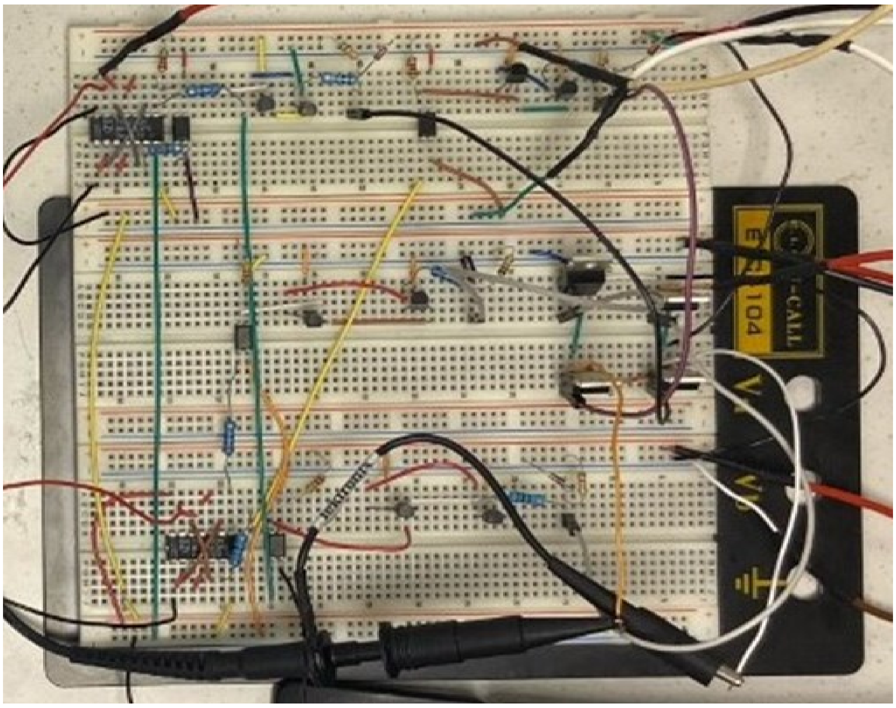

**Figure 3.7: Gate driver circuit (prototype version).**

The inverter has been modified built on a permanent circuit as shown in Figure 3.8 in which is an upgrade for the prototype version of any circuit and it provides reliable circuitry. A typically permanent circuit board using universal board offers a simple platform to arrange the electronic components in a compressed and efficient way based on the design and how the designer desired to build it by soldering and offer varied advantages which make them the perfect choice for projects since it lasts and lives longer. The advantages of enhancing our gate driver circuit to permanent soldered circuit are as follows:

- Compact size and saving of wire: the interconnection between the components is made through solder flux (iron) instead of wires and jumpers using the soldering technique.
- Immune to movement: since all components on the circuit board held fixed to the board, it does not allow them to move irrespective of the movement of the board itself.
- Reliability: all the above factors bring reliability in the performance of the circuit.

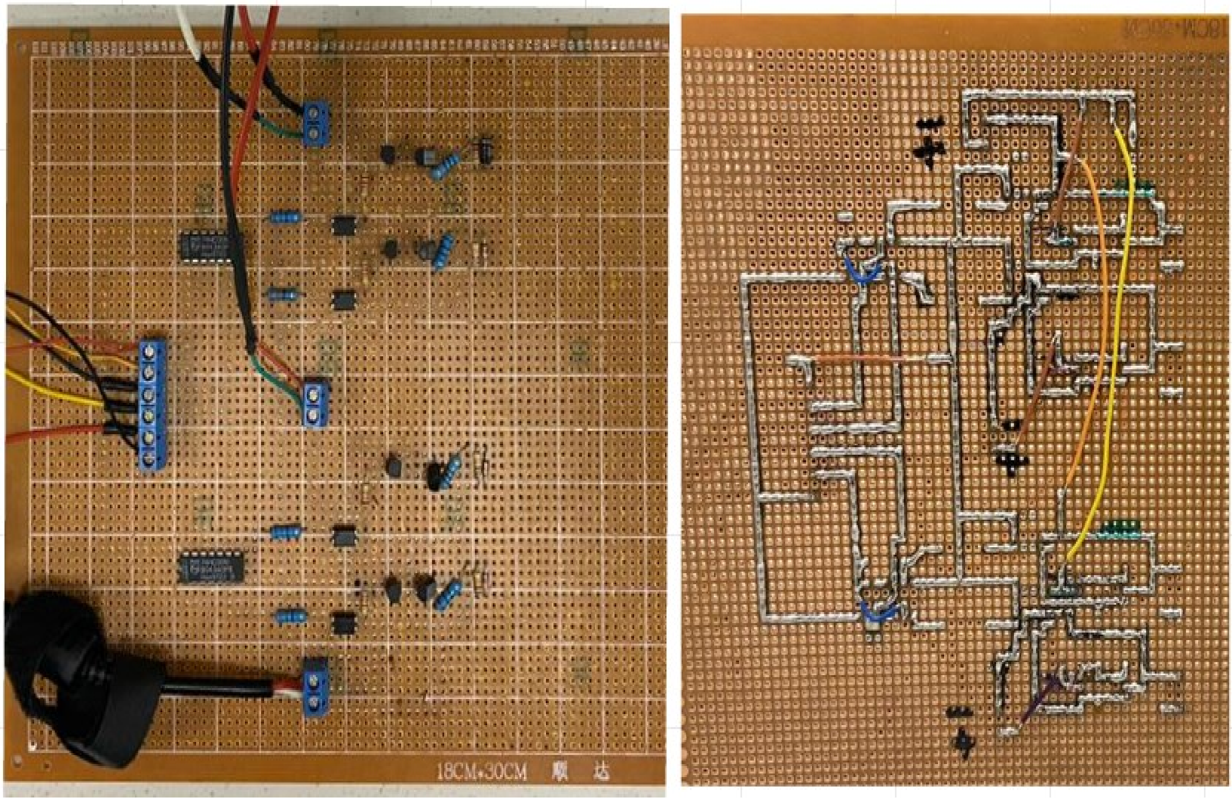


**Figure 3.8: DC/AC inverter gate driver circuit.**

The inverter needed to be connected with the DC/DC inverter and the purchased IGBT to obtain the AC waveform and power loads.

**Subsystem I (DC/AC and DC/DC programing):**

To operate our DC-AC inverter as well as our DC-DC converter, we used the Arduino microcontroller to generate the required signals and be able to read from the sensors that are connected to our systems. We chose the Arduino Mega 2560 board since it includes multiple PWM, Hardware Serial, as well as both digital and analog pins.

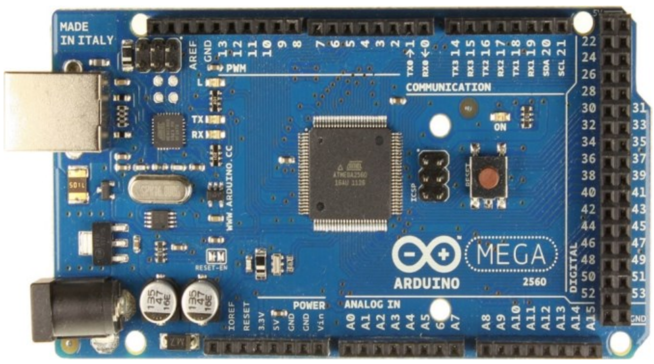


**Figure 3.9: Arduino Mega 2560.**

For the inverter, it was desired to generate two pairs of signals, a total of four, with each pair having a signal that is an inverse to later simulate the negative cycle of an AC signal. The signals were generated by using PWM, where we generated the four square wave outputs. As seen from the picture taken from the output of an oscilloscope, we successfully created our four signals. Through the code, we were also able to control the frequency of the signals. The output of our first iteration of the code can be seen in Figure 3.10 below.

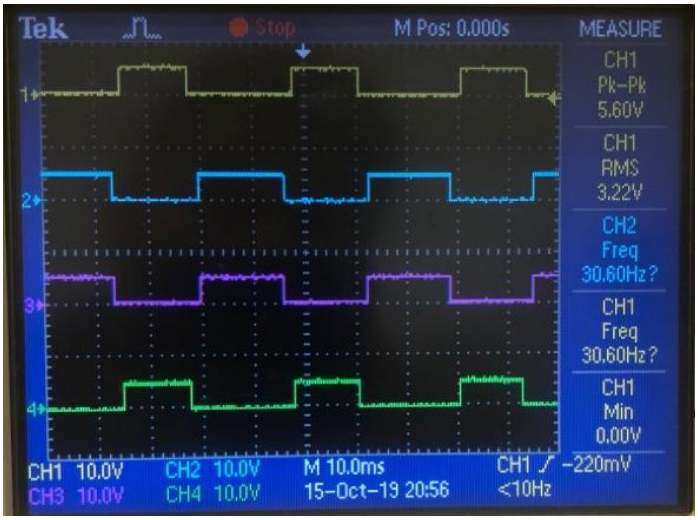


**Figure 3.10: Generated PWM signals.**

Furthermore, the designed DC-AC inverter known as a square wave inverter, so to imitate the actual signals found in AC systems, which is a sinusoid, it was required to modify the utilized code to generate a sinusoid square wave signal, known as sinusoid pulse width modulation (SPWM). To create such a signal, we will be using the method of the modified square wave signal, where the maximum peak of the square wave signal will act as a polling signal with a high frequency to trace the points of a sinusoid signal. From the figures below, we can also control the power of the sinusoid signal by decreasing or increasing the PWM value of the polling signal, as shown in Figure 3.10.

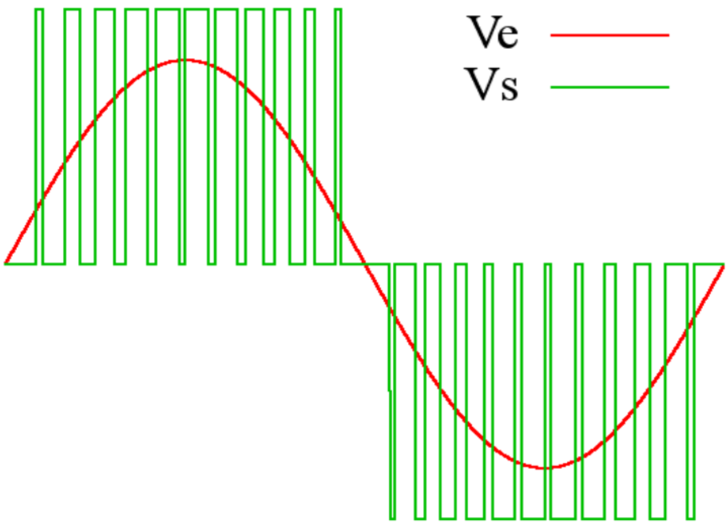


**Figure 3.11: SPWM signal.**

Before writing the code, we set a few parameters which we need to use to create the controlling inputs for the signal. The first is our sample for the sinusoid signal, which we used 30 samples total. The desired output frequency that we need is 60 Hz or 16.66ms, with 30 samples that gives us a sampling time of 555µs or a frequency of 1.8 kHz. With this information, we continued to the next step which is to make sure we are now using timer interrupts and Phase-Correct PWM since we need to generate a discontinuous PWM signal that samples our sinusoid signal, which can be seen in Figure 3.12. Through the use of timers that are built into the Arduino boards, we can set all the modes and inputs through the following registers that are specified to the built-in timers from the Table in Figure 3.13.

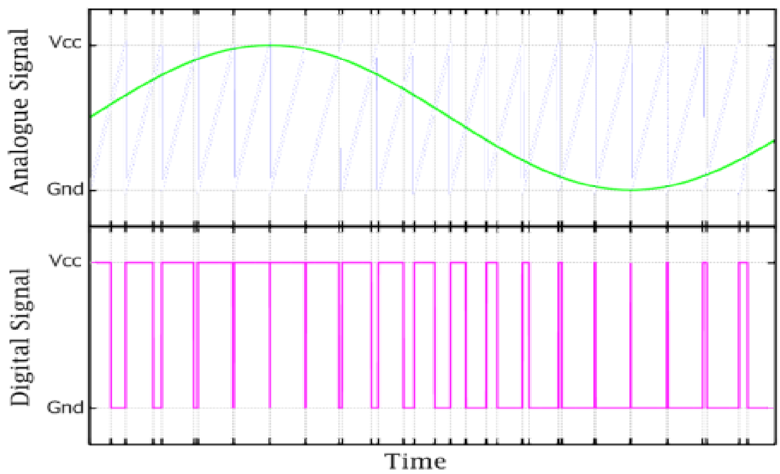


**Figure 3.12: SPWM signal.**

TCCRx – Timer/Counter Control Register

TCNTx – Timer/Counter Register(Actual Timer Storage)

OCRxA/B/C – Output Compare Register

TIMSKx – Timer/Counter Interrupt Mask Register

TIFRx – Timer/Counter Interrupt Flag Register

The Overflow interrupt is the interrupt we chose since it coincides with our desired functionality. The OVF interrupt uses the register named ICR, Input Capture Register. The limit register that is being configured by us is ICRx register, which controls the value of which the counting timer must stop and start again. Furthermore, the values that are being inputted to the PWM registers are OCRxA and OCRxB where each register corresponds to the signal pairs. To find the value of ICR register needed to acquire our sampling frequency, we used the following equation:

$$ICRx = \frac{fclk}{(fdesired - 1) \times prescaler}$$

, where $f_{clk}$ is the Arduino Mega clock frequency, which is 16 MHz, and with our chosen set prescaler of eight, we get the value of ICRx to be 1111. Since we are running four signals, the value needed to be tuned to the final value of 555. Once we have calculated and set all the parameters we rewrote the code to accommodate the change in functionality with the resulting oscilloscope output shown in Figure 3.14.

Table 16-4. Waveform Generation Mode Bit Description[1]

| Mode | WGM13 | WGM12 (CTC1) | WGM11 (PWM11) | WGM10 (PWM10) | Timer/Counter Mode of Operation | TOP | Update of OCR1x at | TOV1 Flag Set on |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | Normal | 0xFFFF | Immediate | MAX |
| 1 | 0 | 0 | 0 | 1 | PWM, Phase Correct, 8-bit | 0x00FF | TOP | BOTTOM |
| 2 | 0 | 0 | 1 | 0 | PWM, Phase Correct, 9-bit | 0x01FF | TOP | BOTTOM |
| 3 | 0 | 0 | 1 | 1 | PWM, Phase Correct, 10-bit | 0x03FF | TOP | BOTTOM |
| 4 | 0 | 1 | 0 | 0 | CTC | OCR1A | Immediate | MAX |
| 5 | 0 | 1 | 0 | 1 | Fast PWM, 8-bit | 0x00FF | BOTTOM | TOP |
| 6 | 0 | 1 | 1 | 0 | Fast PWM, 9-bit | 0x01FF | BOTTOM | TOP |
| 7 | 0 | 1 | 1 | 1 | Fast PWM, 10-bit | 0x03FF | BOTTOM | TOP |
| 8 | 1 | 0 | 0 | 0 | PWM, Phase and Frequency Correct | ICR1 | BOTTOM | BOTTOM |
| 9 | 1 | 0 | 0 | 1 | PWM, Phase and Frequency Correct | OCR1A | BOTTOM | BOTTOM |
| 10 | 1 | 0 | 1 | 0 | PWM, Phase Correct | ICR1 | TOP | BOTTOM |
| 11 | 1 | 0 | 1 | 1 | PWM, Phase Correct | OCR1A | TOP | BOTTOM |
| 12 | 1 | 1 | 0 | 0 | CTC | ICR1 | Immediate | MAX |
| 13 | 1 | 1 | 0 | 1 | (Reserved) | – | – | – |
| 14 | 1 | 1 | 1 | 0 | Fast PWM | ICR1 | BOTTOM | TOP |
| 15 | 1 | 1 | 1 | 1 | Fast PWM | OCR1A | BOTTOM | TOP |

**Figure 3.13: Waveform Generation Mode.**

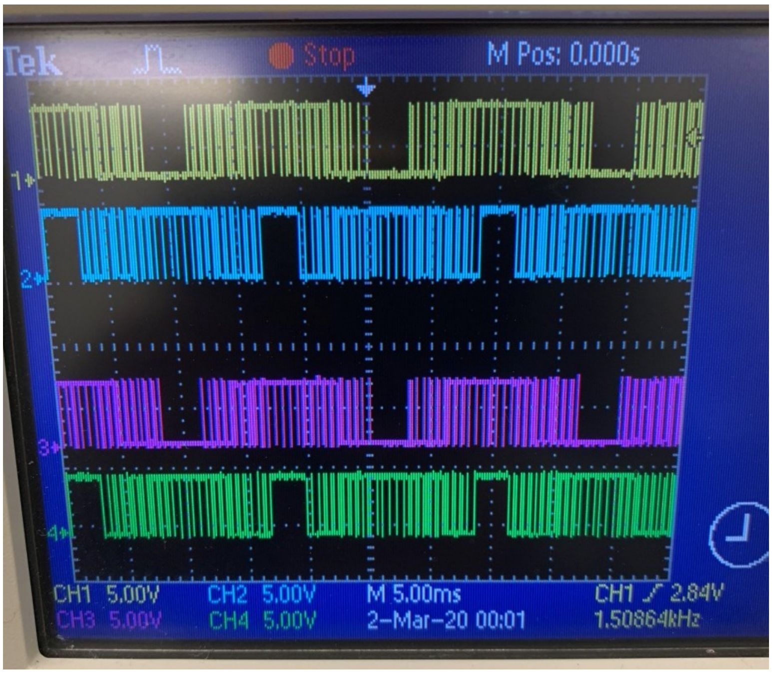


**Figure 3.14: Generated SPWM signal.**

**Subsystem II (Local storage system):**

The project associated with 150 Ah, 12 V sealed lead acid battery and it is the major source of energy to overcome the variation of power being produced and to provide sufficient energy to power and support the other subsystems i.e. EV charger and green home.

**Subsystem III (DC/DC converter for electrical vehicle charger):**

DC-DC converters are power electronics devices known to either step up or step down the input DC voltage into the desired DC output using semiconductors devices as switches. The dc-dc converters can be divided into two main types: hard-switching pulse width modulation (PWM) converters, and resonant and soft-switching converters. In this project, PWM dc-dc converters have been chosen to be designed and utilized since they have been very popular for the last three decades, and are widely used at all power levels. Advantages of PWM converters include low component count, high efficiency, constant frequency operation, relatively simple control and commercial availability of integrated circuit controllers, and ability to achieve high conversion ratios for both step-down and step-up applications. A disadvantage of PWM dc-dc converters is that PWM rectangular voltage and current waveforms cause turn-on and turn-off losses in semiconductor devices, which limit practical operating frequencies to hundreds of kilohertz. Rectangular waveforms also inherently generate EMI.

Hence, the EV charger can be built using a buck boost converter known as step-down converter after rectifying the ac output obtained from subsystem I (Green home). Step-down choppers find most of their applications in high performance dc drive systems, for example, electric traction, electric vehicles, and machine tools. The dc motors with their winding inductances and mechanical inertia act as filters resulting in high-quality armature currents. The average output voltage of step-down choppers is a linear function of the switch duty ratio. The designed dc-dc converter can be viewed as a dc transformer that delivers to the load a dc voltage or current at a different level than the input source. This dc transformation is performed by electronic switching means, not by electromagnetic means such as in conventional transformers. The full-bridge converter is used at high (several kilowatts) power and voltage levels. The voltage stress on power switches is limited to the input voltage source value. A disadvantage of the full-bridge converter is a high number of semiconductor devices. The purpose of using the full bridge is to convert the AC voltage from the inverter that has been designed for subsystem I into DC in order to be utilized as an input for the EV charger buck converter.

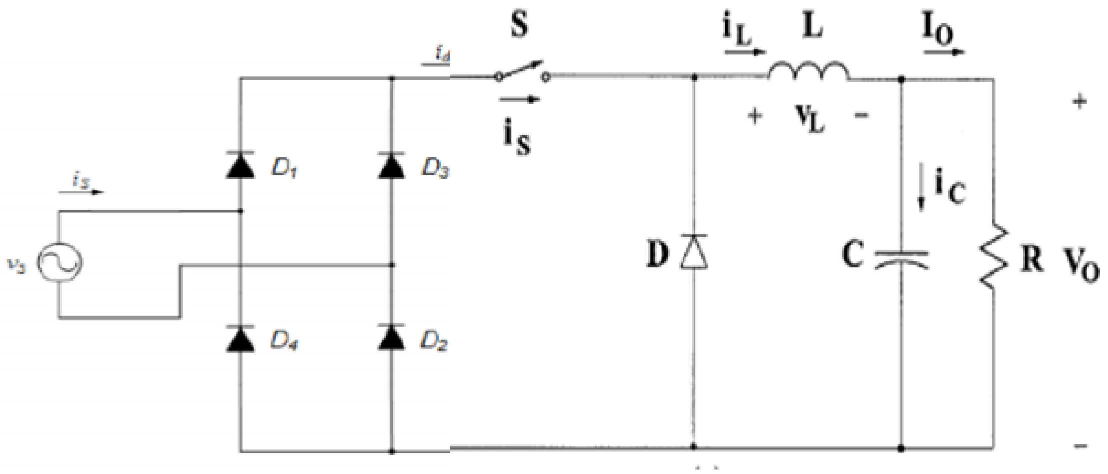


**Figure 3.15: EV charger circuit.**

# 4. System Testing and Analysis

## 4.1 Subsystem 1: Solar carport and green home

The system requires not less than 450 W to function properly. This is the cumulative sum of subsystems wattages to power the residential loads up to 75 W, and to charge an electrical vehicle up to 350 W. The mounted PV array on the carport has three solar PV panels in parallel with an output of 180 W and 12 V for each panel, thus, the mounted array would be sufficient enough to provide 480 W.

The PV array is associated with charger controller as explained earlier to charge and discharge the battery from the array in which the battery considered as the primary and major source of energy to the project. The test performed at PMU's campus and the charge controller with the battery was able to generate around 12 V as shown in Figures 4.1-4.2.


**Figure 4.1: Charge controller output.**


**Figure 4.2: Implemented solar carport.**

The DC/AC inverter has been tested as well at PMU's lab, the DC/AC gate drive circuit has successfully generated square waves from the utilized microcontroller (Arduino) in order to be modulated and converted into Sinusoid Pulse Width Modulation (SPWM) signal as shown in Figures 4.3-4.5.

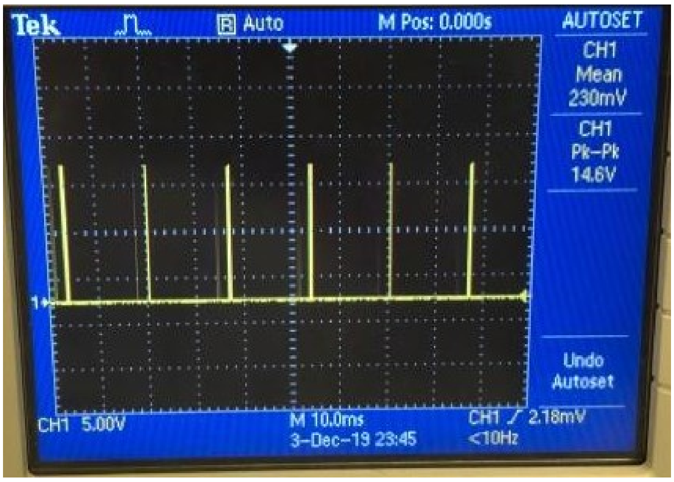


**Figure 4.3: DC/AC gate drive circuit output.**

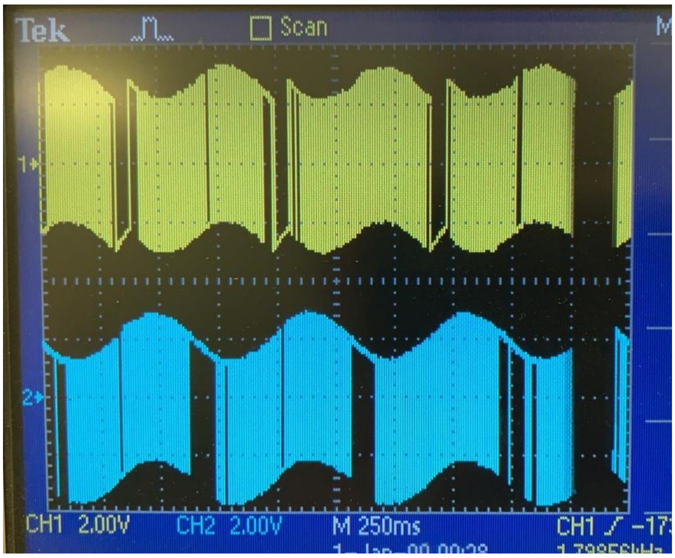


**Figure 4.4: Generated Sinusoid using Arduino.**

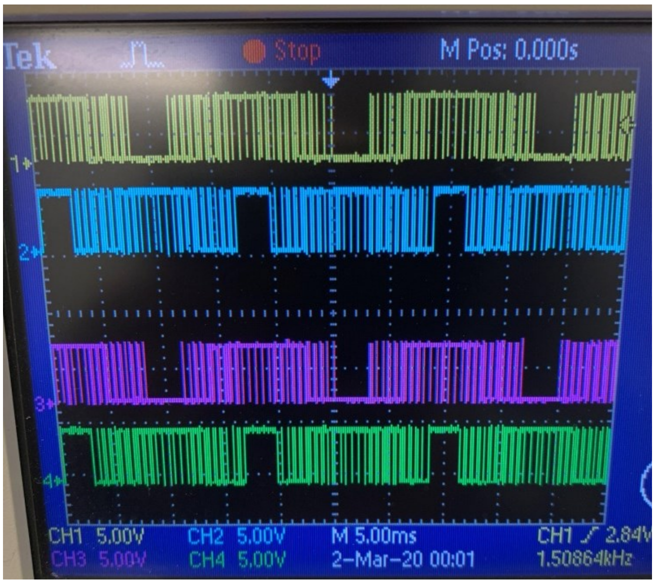


**Figure 4.5: Generated SPWM signal.**

## 4.2 Subsystem 2: Electrical vehicle charger

**Design I (DC/DC Boost converter):**

Figure 4.6 shows the DC/DC boost converter considered for the design of subsystem 2.

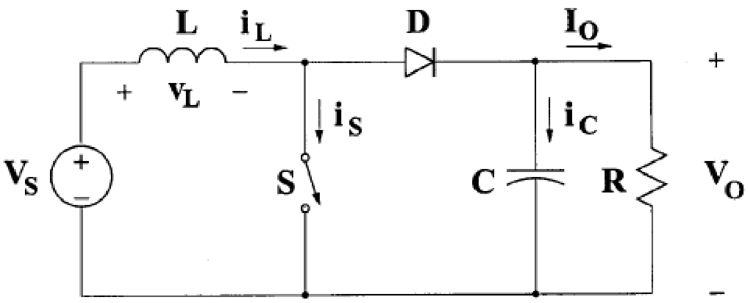


**Figure 4.6: DC/DC boost converter.**

The equations needed for obtaining R, L, and C are:

$$R = \frac{V}{I} \quad (1.1)$$

$$L = \frac{(1-D)^2 DR}{2f} \quad (1.2)$$

$$C = \frac{DVo}{VrRf} \quad (1.3)$$

$$D = \frac{Vo}{Vs} \quad (1.4)$$

Parameters:

Vo max = 250 V

Vo min = 175 V

f= 45k Hz

Vr=1%

I max = 5 A

I min = 1 A

Calculations:

Using equation (1.1), the values of R are as follows:

$$R\ min = \frac{Vo\ max}{I\ max} = \frac{250}{5} = 50\ \Omega$$

$$R\ max = \frac{Vo\ min}{I\ min} = \frac{175}{1} = 175\ \Omega$$

Using equation 1.4, the values of D are as follows:

$$D\ max = \frac{Vo\ max}{Vs} = \frac{250}{12} = 20.83$$

$$D\ min = \frac{Vo\ min}{Vs} = \frac{175}{12} = 14.58$$

Using equation (1.2), the values of L are as follows:

$$L\ max = \frac{(1 - Dmax)^2 DmaxRmax}{2f} = \frac{(1 - 20.83)^2(20.83)(175)}{(2)(45k)} = 15.92\ \mathrm{H}$$

$$L\ min = \frac{(1 - Dmin)^2 DminRmin}{2f} = \frac{(1 - 14.58)^2(14.58)(50)}{(2)(45k)} = 1.55\ \mathrm{H}$$

Using equation (1.3), the values of C are as follows:

$$C\ max = \frac{DmaxVmax}{VrRmaxf} = \frac{(20.83)(250)}{(1\%)(175)(45k)} = 66.12\ m\mathrm{F}$$

$$C\ min = \frac{DminVmin}{VrRminf} = \frac{(14.58)(175)}{(1\%)(50)(45k)} = 115.5\ m\mathrm{F}$$

**Design II (DC/DC buck converter):**

Figure 4.7 shows the DC/DC buck converter considered for the design of subsystem 2.

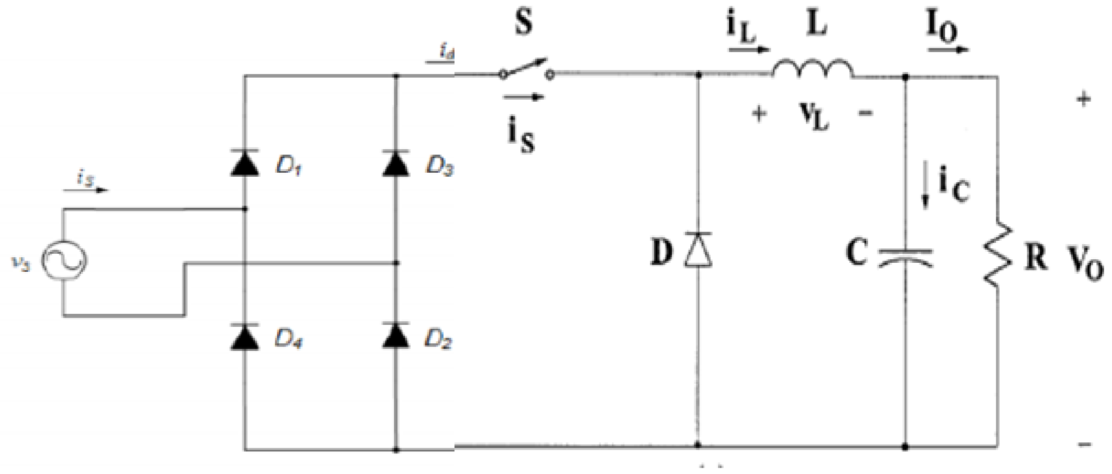


**Figure 4.7: DC/DC buck converter.**

The design equations are:

$$R = \frac{V}{I} \quad (2.1)$$

$$L = \frac{(1-D)R}{2f} \quad (2.2)$$

$$C = \frac{(1-D)Vo}{8VrLf2} \quad (2.3)$$

$$D = \frac{Vo}{Vs} \quad (2.4)$$

$$R = \frac{220}{5} = 44\ \Omega$$

$$D = \frac{Vo}{Vs} = \frac{220}{320} = 0.6875$$

$$L = \frac{(1-D)R}{2f} = \frac{(1-0.6875)*44}{2*45k} = 0.3\ m\text{H}$$

$$C = \frac{(1-D)Vo}{8VrLf2} = \frac{(1-0.6875)*220}{(8)(1\%)(0.3m)(45k)(45k)} = 1.414\ m\text{F}$$

## 4.3 Overall Results, Analysis and Discussion

Tests have been performed at PMU's campus, the optimum result for such project is the investment towards the power and energy sector, especially renewable energy as it is a trending research topic and one of the main outcomes of Saudi Vision 2030. The circuitry operated as designed, generated square wave pulses from microcontroller and solar array generated the desired amount of electricity. The environment of renewable power system and grid independent power systems is promising and plays an important role in any economy. We do encourage power students to continue working and enhancing the project, developing the scope and have their own finger prints.

# 5. Project Management

### 5.1 Project Plan

The project designed to be completed in four phases. In the first phase, all the required components are acquired and the carport has been designed. Solar carport has been implemented in addition to completing the inverter control designed in the second phase. The third phase involves building the green house structure, inverter testing with some residential loads, and initial designing of EV charge controller. In the fourth phase, the final testing of EV charger will be done. Table 5.1 summarizes the project plan.

**Table 5.1: Project phases and plan**

| | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr |
|---|---|---|---|---|---|---|---|---|
| **Phase 1** | x | x | x | x | x | | | |
| **Phase 2** | | | x | x | x | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Phase 3** | | | | | x | x | x | |
| **Phase 4** | | | | | | | x | x |

# 5.2 Contribution of Team Members

Table 5.2 summarizes the contribution of team members in the project.

**Table 5.2: Team member's contribution**

| Task | Abdullah (ANQ) | Abdullah (AMG) | Abdulaziz (AAA) | Saif (SFS) | Task Total |
|---|---|---|---|---|---|
| **Search & acquire components** | **10%** | **70%** | **10%** | **10%** | **100%** |
| **Design Subsystems** | **70%** | **10%** | **10%** | **10%** | **100%** |
| **Test Subsystems** | **25%** | **25%** | **25%** | **25%** | **100%** |
| **Write Reports & Presentations** | **70%** | **10%** | **10%** | **10%** | **100%** |
| **Programing** | **10%** | **10%** | **10%** | **70%** | **100%** |
| **Implementation activities (Carport and green home)** | **10%** | **10%** | **70%** | **10%** | **100%** |

# 5.3 Project Execution Monitoring

Weekly progress meetings with team members carried out with the purpose of providing updates regarding what has been accomplished, what is due to be completed and what challenges have anticipated within the week. In addition, biweekly meetings were conducted with project advisor to have feedback and provide him with updates regarding the project progress and to discuss the remaining tasks. Lastly, WhatsApp group has been created and all parties have been added (students and advisor) for easy access and quick response.

## 5.4 Challenges and Decision Making

The main challenge that has been faced is shipments' delays due to coronavirus (COVID-19). Unfortunately, the Saudi market with its key player vendors has a lack of power electronics components such as DC/DC converters, DC/AC inverters, IGBT etc. Hence, most of the project procurements were ordered from abroad, mostly from China. As a result of COVID-19, the shipments got delayed for more than two and a half months.

Accordingly, to overcome the spreading of coronavirus, schools have suspended till further notice and we were under quarantine, which has a significant impact in our progress by which we could not either conduct meetings nor implement and test the project.

Another challenge has to be acknowledged is the background information regarding power electronics. As explained, most of the designed and integrated subsystems are directly linked to power electronics which are unfortunately not listed so far in the study plan for electrical engineering students.

Moreover, two of the subsystems required manpower to be installed i.e., solar carport and green home structure. The group faced difficulties to have support from PMU maintenance department with its representatives to support us regarding the implementation of our work.

## 5.5 Project Bill of Materials and Budget

Table 5.3 summarizes the budges of the project.

**Table 5.3: Budges of the project**

| Item | Quantity | Unit Price (SAR) | Total (SAR) |
|---|---|---|---|
| Solar Panel 160W | 3 | 300 | 900 |
| Battery 150Ah, 12V | 1 | 800 | 800 |
| Charge Controller | 1 | 200 | 200 |
| Metal and Wood structure | 1 | 2000 | 2000 |
| Arduino Mega | 2 | 150 | 150 |
| H- Bridge Rectifier | 2 | 50 | 100 |
| H Bridge IGBT | 1 | 400 | 400 |
| DC/DC Converter | 1 | 100 | 100 |
| DC Voltage Sensor | 1 | 200 | 200 |
| Ferrite Core Transformer | 1 | 250 | 250 |
| Current Sensor | 2 | 130 | 260 |
| Miscellaneous | 1 | 2000 | 2000 |
| Total | | | 7360 |

# 6. Project Analysis

## 6.1 Life-long Learning

This project enabled us to implement the knowledge we have gained and acquired and developed our conceptual by brainstorming towards new solutions and experiencing various aspects of our discipline. We have given the opportunities to learn, implement, and examine power electronics topics such as DC/DC converters and DC/AC inverters and integrate them to come up with new solutions that lead to the specification and the project scope. Therefore, we had the chance to design, build, and program our own circuits using permanent breadboards and Arduino platforms in which it leaded us to face new challenges and gained more experience and knowledge. In addition, the project has a significant influence and developed our research skills. Different types of project management, self-learning, time management, and cost management techniques have been used.

## 6.2 Impact of Engineering Solutions

According to the Saudi Vision 2030, a massive number of renewable energy resources will be utilized and installed in the coming few years. The renewable energy sources, such as, Solar PV and Wind Turbines are sporadic in nature since they depend on climatic conditions. To cope with their intermittent nature, battery energy storage systems are required to provide the necessary support when there is a fluctuation in power generation from renewable sources. The electric vehicles can thus provide energy to grid operating in a vehicle-to-grid (V2G) mode. Currently, the number of electric vehicles in Saudi Arabia is very low. Therefore, only two EV chargers have been installed in the whole kingdom so far. However, electric vehicles will become ubiquitous in the near future since they have received international acceptance. The large-scale integration of electric vehicles into the grid requires extensive investigation. Hence, with the completion of this project, the project can play a key role towards Vision 2030 by implementing grid independent renewable energy systems on the residential scale and examine controllable charging rate EV chargers. Thus, research on controlling the charging rates of electric vehicles can assist in accommodating high penetration level of renewable energy resources into the grid without negative impacts.

## 6.3 Contemporary Issues Addressed

There are many issues that are addressed in our project for Saudi Arabia and worldwide such as introducing simple EV charger solution that can be available at private and public parking lots. Moreover, it solves the issue of un-utilized parking spaces for both residential and commercial entities to generate power from renewable energy, hence, it reduces grid demand and uses more nature source (solar energy).

# 7. Conclusions and Future Recommendations

## 7.1 Conclusions

The scope of this project and our optimum goal was to design and provide a grid independent smart solar carport parking system that generates renewable energy to power green home and charge electric vehicles. This has been established by mounting a PV array (3x1), three panels in parallel on a carport, the system integrated with battery in order to be grid independent system.

We would like to thank the efficient faculty and staff of Electrical Engineering Department at Prince Mohammad Bin Fahd University for their continuous support. Their efforts allowed us to experience remarkable senior project within the field of our interest. Moreover, we would like to thank our project advisor, Mr. Saifullah Shafiq for his kind guidance, support, and the knowledge he shared with us.

We could not have completed this senior project, nor any course of our degree, without the assist, love, and support from all who ever taught us including our teachers, instructors and professors.

## 7.2 Future Recommendations

In future, a fully solar powered electric vehicle along with autonomous charge controller can be designed in collaboration with Mechanical Engineering and Computer Science Departments. Also, some machine learning techniques can be used to improve the performance of EV charger.

## 7.3 Future Work and Expected Final Prototype

The team successfully designed all subsystems and completed procurements stages and received all required equipment and components in order to perform the final implementation and integration process of subsystems. The remaining tasks are integrating the purchased H-bridge IGBT to be connected with the DC/AC inverter as a final step to obtain AC waveform. After soldering IGBT with gate driver circuit (DC/AC inverter), the output is taken to the designed green home. The green home designed to be wood structure with residential loads up to 75 W associated with energy system (Battery) 150 Ah, 12 V. Moreover, the DC/DC converter needed to be implemented with the purchased full bridge, the converter output is taken from DC/AC inverter in order to have grid independent (stand-alone) project, the converter chosen to be buck converter intends to step down the voltage into 175 V which is the required level to charge the electrical vehicle.

The remaining tasks estimated to be completed within one and half week. The final prototype was planned to have the green home structure next to the implemented carport and the electric vehicle (EV) was planned to park inside the carport.

The performed tasks and designed subsystems are efficient to eventually met the specifications and project deliverables as follows:

- Generates renewable energy using solar PV panels mounted on carport with maximum output of 480 W.
- Contains energy storage (battery) for 150 Ah, 12 V which acts as a backup source capable to provide continuous power for 3.75 hours for maximum load of 480 W.
- Charges Electrical Vehicle (EV) with charger output of 220 V.
- Contains DC/AC Inverter with output of 75 W.
- Energizes electrical household appliances (residential loads) up to 75 W.

Figures 7.1-7.3 illustrate the expected final prototype of the project after implementing all sybsystems.

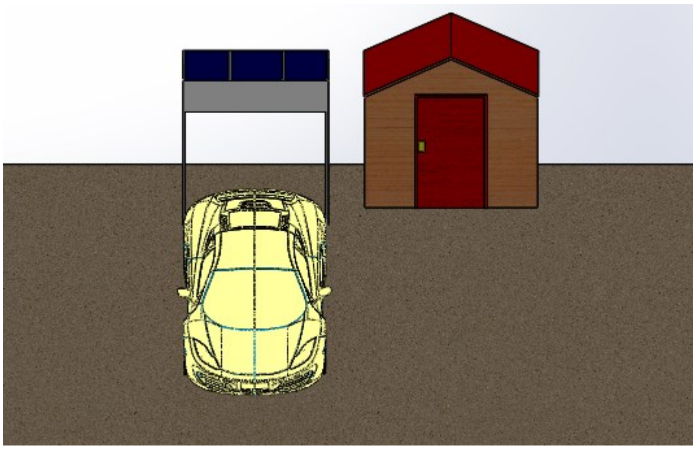

**Figure 7.1: Final prototype.**

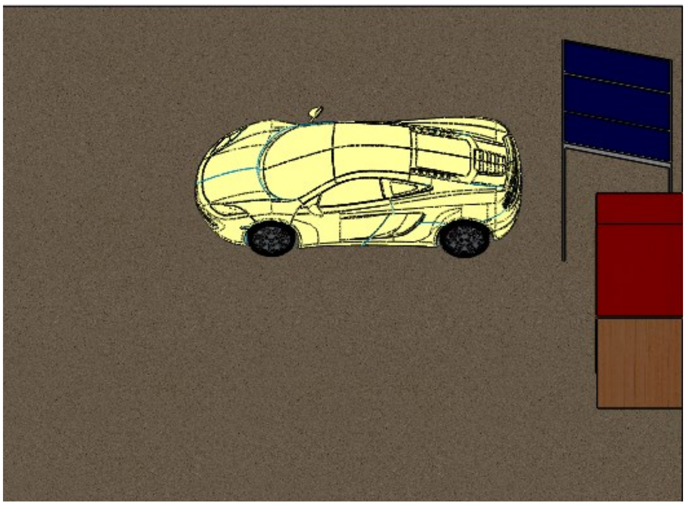

**Figure 7.2: Final prototype.**

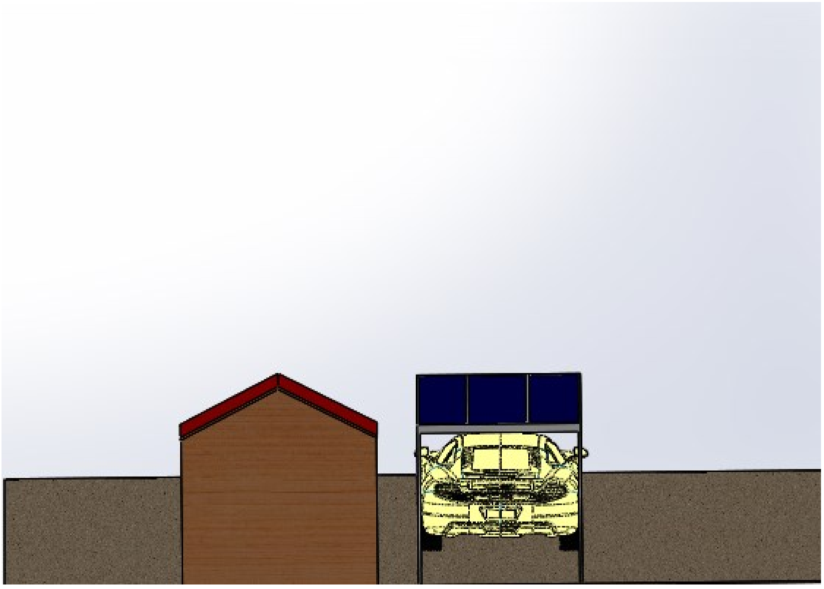

**Figure 7.3: Final prototype.**

# 7.4 Limitation and Challenges

Unfortunately, due to the ongoing situation regarding COVID-19, most governments around the globe have temporarily closed educational institutions in an attempt to contain the spread of the COVID-19 pandemic in of being lockdown (under quarantine). Hence, the closure of schools, colleges and universities not only interrupts the teaching for students around the globe, but also postpones all our activities which require on site implementation, testing at PMU labs.

Fortunately, the Electrical Engineering Department at Prince Mohammad Bin Fahd University adopted virtual meetings and online classes from the first day of the pandemic scenario via blackboard, but still we could not complete or progress our project further.

# 8. References


1. Sandramc. (2017, September 26). Environmentally-friendly vehicles get a charge out of York University. Retrieved September 30, 2019, from https://news.yorku.ca/2015/12/09/york-u-unveils-first-solar-charging-station-for-electric-vehicles/.
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5. Rashid, M. H. (2014). *Power electronics handbook: devices, circuits, and applications*. Upper Saddle River, NJ: Prentice Hall.

# Appendix A: Progress Reports


**Prince Mohammad Bin Fahd University (PMU)**
Department of Electrical Engineering

**Design Methodology & Project Management**
Instructor: Dr. Samir El-Nakla


**FALL 2019/2020**

## PROJECT PROGRESS REPORT I

# SMART SOLAR CARPORT SYSTEM AT PMU

**TEAM MEMBER**:


| | |
|---|---|
| **Abdullah N. Al-Qahtani (Project Leader)** | **201501245** |
| Abdullah M. Al-Ghamdi | 201402209 |
| Abdulaziz A. Al-Abdulwahab | 201602677 |
| Saif F. Al-Sharif | 201502262 |

**PROJECT ADVISOR**

Mr. Saifullah Shafiq


Date October 14, 2019

This paper intended to provide a progress report and it briefly illustrates the performed tasks regarding the project of smart solar carport system at Prince Mohammad Bin Fahd University (PMU) starting from week one till October 14th, 2019

## PERFORMED TASKS AND ACTIVITIES

- **Weekly progress meetings:** The weekly progress meeting is one way of keeping in touch with the project advisor, team members. These meetings are intended to ensure a project stays on track and to give team members the chance to intervene early if problems arise. These meetings have specific agenda to assure that everything is working just fine and the entire project team is following the schedule that they need to religiously consider. The weekly progress meetings during the project work will be held at the same time and on the same day each week that is on Tuesday at 7 pm. Several meetings have been conducted with Mr. Shafiq and all members have participated. These meetings carried out with the purpose of introducing the team and our topics that correspond with our interest, deciding and finalizing the topic, identify the system and subsystems and lastly but most importantly, discuss the progress of the project.
- **Project proposal:** Typically, a project proposal is the initial framework for establishing the concept of the project and includes what is required to accomplish, an explanation of objectives, and plans for achieving them. It is common for a project proposal in the engineering environment to include a block diagram and specifications to illustrate the significance of this specific project idea, and explain the origins of the project.
- **Develop project critical path activities table:** In project management, a critical path is the sequence of project network activities which add up to the longest overall duration, regardless if that longest duration has float or not. Therefore, critical path analysis is commonly used with all forms of projects, including construction, software development,

research projects, and product development, engineering, and plant maintenance, among others. Any project with interdependent activities can apply this method of mathematical analysis. The essential technique for using critical path method (CPM) is to construct a model or table of the project that includes the following:

- A list of all systems, subsystems and activities required to complete the project (typically categorized within a work breakdown structure),
- The time duration that each activity and task will take to complete,
- The dependencies between the activities (subsystems and subtasks)
- Milestones or deliverable items.

| # | Subsystem | Planned Dates | | Actual Dates | | Progress Update | Action items/Comments |
|---|---|---|---|---|---|---|---|
| | Main tasks | Start Date | End Date | Start Date | End Date | | |
| 1 | PROCUREMENTS | | | | | | |
| 1.11 | Battery 100 A/ 150A | Week4 | week4 | | | | |
| 1.12 | Solar panel 250w | Week4 | week4 | | | | |
| 113 | MPPT 1000 w/ 40 A | Week4 | week4 | | | | |
| 1.14 | DC/DC | Week4 | week4 | | | | |
| 1.15 | DC/ AC | Week4 | week4 | | | | |
| 1.16 | IGBT 1200 V / 30A | week4 | week4 | | | | |
| 1.17 | Arduino Mega | Week4 | week4 | | | | |
| 1.18 | IGBT 1200 V/ 300 A | Week4 | week4 | | | | |
| 1.19 | Isolation circuit for DC/AC | Week4 | week4 | | | | |
| 1.2 | Isolation circuit for EV charger | Week4 | week4 | | | | |
| 1.21 | Sensors V/I | Week4 | week4 | | | | |
| 1.22 | Structure cost | Week4 | week4 | | | | |
| 1.23 | Miscellaneous | Week4 | week4 | | | | |
| 2 | BATTERY BANK | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| 3 | GREEN HOME | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

Figure 1 - Project Critical Path Activities Table

Thankfully, more efficient table has been provided to us from Dr. Nakla that shares the same targets with what has been designed as demonstrated in Figure 1. Hence, the provided table as shown below in Figure 2 will be utilized instead of the old version.

| SMART SOLAR CARPORTS SYSTEM AT PMU | | | | | | |
|---|---|---|---|---|---|---|
| Abdullah N. Al-Qahtani 201501245 ' Project Leader | | | | | | |
| Abdullah M. Al-Ghamdi 201402209 | | | | | | |
| Abdulaziz A. Al-Abdulwahab 201602677 | | | | | | |
| Saif F. Al-Sharif 201502262 | | | | | | |
| Project Adisor: Mr. Saifullah Shafiq | | | | | | |
| ACTIVITY | PLAN START | PLAN DURATION | Assigned To | ACTUAL START | ACTUAL DURATION | PERCENT COMPLETE |
| Form teams | 1 | 1 | ALL | 1 | 1 | 100% |
| Select topic & advisor | 2 | 1 | ALL | 1 | 1 | 100% |
| Write proposal and plan | 2 | 1 | ANQ | 2 | 1 | 100% |
| Background research & PPT1 | 3 | 2 | ANQ | 3 | 2 | 25% |
| Search and acquire components ( Procurements) | 3 | 3 | AMG, AAA | 4 | 1 | 25% |
| Design subsystem 1: Green Home System | 4 | 3 | ALL | 4 | 3 | 0% |
| Activity 07 | 5 | 4 | .. | 5 | 3 | 0% |
| Activity 08 | 5 | 2 | | 5 | 3 | 0% |
| Activity 09 | 5 | 2 | | 5 | 3 | 0% |
| Activity 10 | 6 | 5 | | 6 | 5 | 0% |
| Activity 11 | 6 | 1 | | 5 | 2 | 0% |
| Prepare midterm Presentation | 7 | 3 | | 7 | 3 | 0% |
| Activity 13 | 8 | 2 | | 8 | 2 | 0% |
| Activity 14 | 9 | 3 | | 9 | 3 | 0% |
| Design subsystem 2: Battery Bank System | 9 | 4 | | 8 | 4 | 0% |
| Test subsystem 2 | 10 | 2 | | 10 | 2 | 0% |
| Activity 17 | 10 | 1 | | 11 | 2 | 0% |
| Design of Structre | 11 | 2 | | 12 | 2 | 0% |
| Carport Design & Implementation | 12 | 2 | | 12 | 1 | 0% |
| Green Home Design & Implementation | 12 | 2 | | 12 | 2 | 0% |
| Prepapre final report | 12 | 3 | | 12 | 3 | 0% |
| Prepapre final presentation | 13 | 2 | | 13 | 2 | 0% |

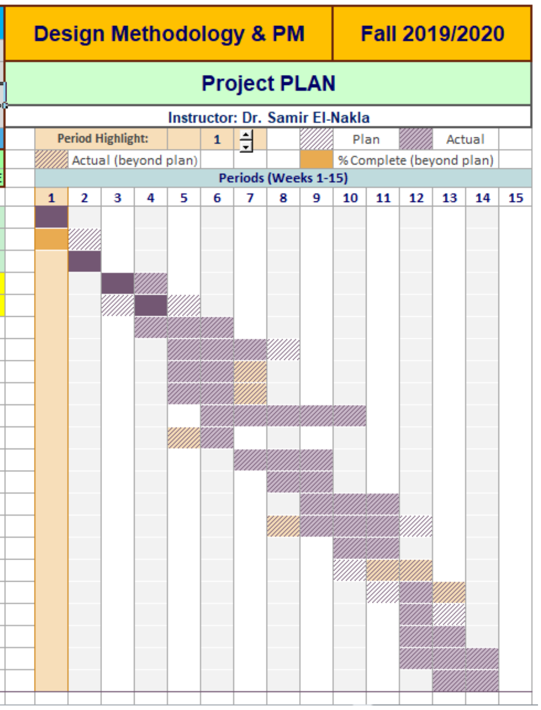
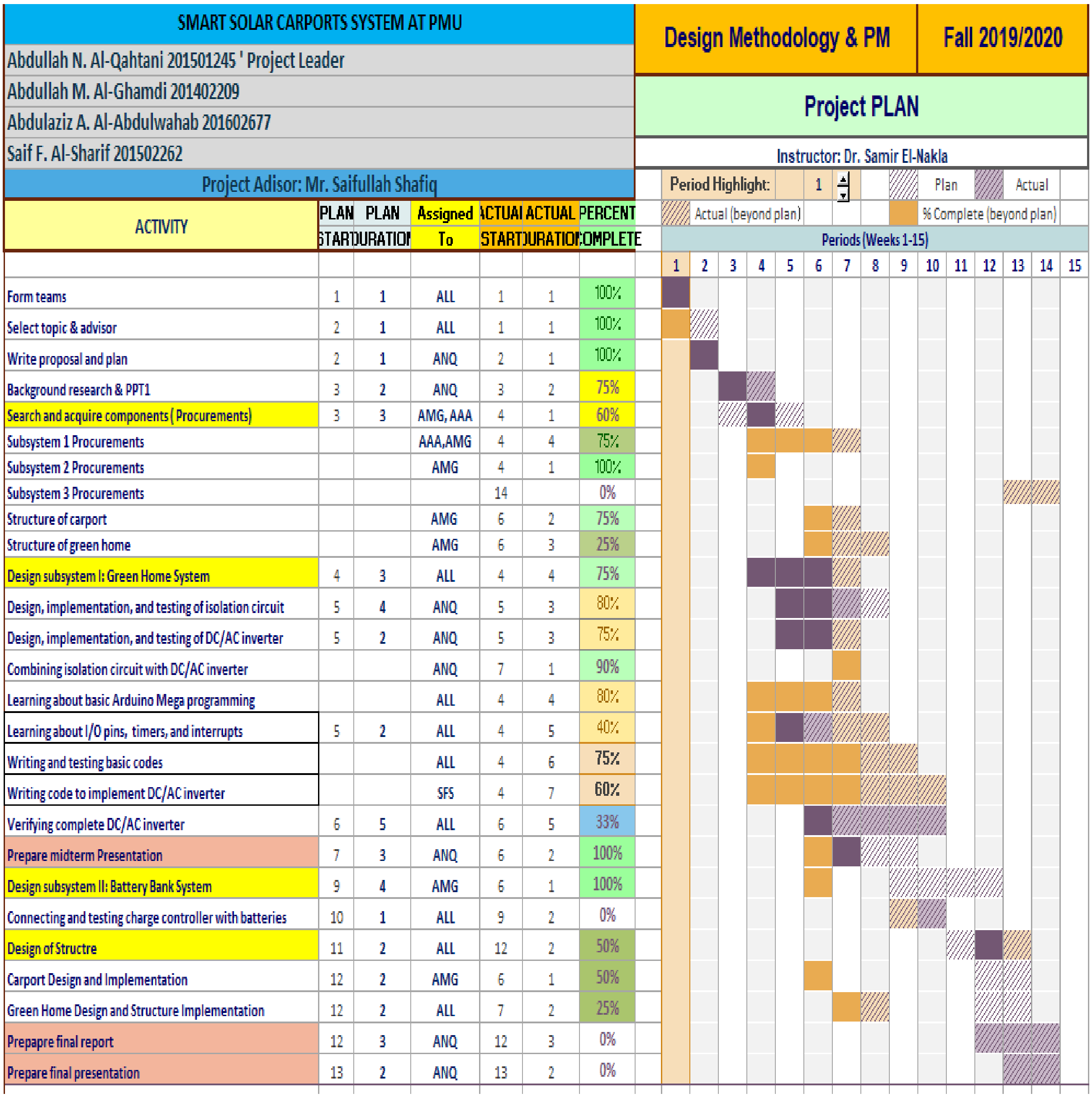



Figure 2 - Project Plan Table

- **Literature review, researches and material sources in terms of projects:** A literature review or narrative review is a type of review article. A literature review is a scholarly paper, which includes the current knowledge including substantive findings, as well as theoretical and methodological contributions to a particular topic. Hence, a literature review has been prepared and submitted on October 1, 2019 and it has highlighted the findings of the relevant projects that their scope of work matches with ours. These references, i.e. projects intended to be utilized as the main database and material source by which it facilitates the needs of methods, solutions, identifying possible challenges and theoretical backgrounds.
- **Finalizing the project plan for Design and Methodology course during FALL 19/20:** During the begging of week five, on Saturday September 28, 2019, a meeting has been conducted with the aim of finalizing the project plan for the fall semester 19/20 as shown above in **Figure 2**. The main agenda was to confirm what subsystems will be performed

and accomplished during this semester. In addition, we have identified the subtasks and activities that are required to complete each subsystem.



SMART SOLAR CARPORTS SYSTEM AT PMU | Design Methodology & PM | Fall 2019/2020

Abdullah N. Al-Qahtani 201501245 ' Project Leader

Abdullah M. Al-Ghamdi 201402209

Abdulaziz A. Al-Abdulwahab 201602677

Saif F. Al-Sharif 201502262

Project Adisor: Mr. Saifullah Shafiq

Project PLAN

Instructor: Dr. Samir El-Nakla

Period Highlight: 1 | Plan | Actual | Actual (beyond plan) | % Complete (beyond plan)

Periods (Weeks 1-15)

| ACTIVITY | PLAN START | PLAN DURATION | Assigned To | ACTUAL START | ACTUAL DURATION | PERCENT COMPLETE |
|---|---|---|---|---|---|---|
| Form teams | 1 | 1 | ALL | 1 | 1 | 100% |
| Select topic & advisor | 2 | 1 | ALL | 1 | 1 | 100% |
| Write proposal and plan | 2 | 1 | ANQ | 2 | 1 | 100% |
| Background research & PPT1 | 3 | 2 | ANQ | 3 | 2 | 75% |
| Search and acquire components ( Procurements) | 3 | 3 | AMG, AAA | 4 | 1 | 60% |
| Subsystem 1 Procurements | | | AAA,AMG | 4 | 4 | 75% |
| Subsystem 2 Procurements | | | AMG | 4 | 1 | 100% |
| Subsystem 3 Procurements | | | | 14 | | 0% |
| Structure of carport | | | AMG | 6 | 2 | 75% |
| Structure of green home | | | AMG | 6 | 3 | 25% |
| Design subsystem I: Green Home System | 4 | 3 | ALL | 4 | 4 | 75% |
| Design, implementation, and testing of isolation circuit | 5 | 4 | ANQ | 5 | 3 | 80% |
| Design, implementation, and testing of DC/AC inverter | 5 | 2 | ANQ | 5 | 3 | 75% |
| Combining isolation circuit with DC/AC inverter | | | ANQ | 7 | 1 | 90% |
| Learning about basic Arduino Mega programming | | | ALL | 4 | 4 | 80% |
| Learning about I/O pins, timers, and interrupts | 5 | 2 | ALL | 4 | 5 | 40% |
| Writing and testing basic codes | | | ALL | 4 | 6 | 75% |
| Writing code to implement DC/AC inverter | | | SFS | 4 | 7 | 60% |
| Verifying complete DC/AC inverter | 6 | 5 | ALL | 6 | 5 | 33% |
| Prepare midterm Presentation | 7 | 3 | ANQ | 6 | 2 | 100% |
| Design subsystem II: Battery Bank System | 9 | 4 | AMG | 6 | 1 | 100% |
| Connecting and testing charge controller with batteries | 10 | 1 | ALL | 9 | 2 | 0% |
| Design of Structre | 11 | 2 | ALL | 12 | 2 | 50% |
| Carport Design and Implementation | 12 | 2 | AMG | 6 | 1 | 50% |
| Green Home Design and Structure Implementation | 12 | 2 | ALL | 7 | 2 | 25% |
| Prepapre final report | 12 | 3 | ANQ | 12 | 3 | 0% |
| Prepare final presentation | 13 | 2 | ANQ | 13 | 2 | 0% |

Figure 3 - Finalized Project Plan For Design and Method.

- **DC/AC inverter circuitries design and implementation**: An inverter is a power electronic device capable of transforming a direct current (DC) into an alternating current (AC) at a given voltage and frequency. In our project, we have to supply the green house appliance that operates in alternating current (AC) 220v (60Hz frequency) but we do not have the AC power available, hence, we can power it by using an inverter. It is therefore indispensable to use it to power by DC, electrical devices that work in AC. Moreover, inverters are used in stand-alone photovoltaic (PV) systems for powering electrical devices by transforming the generated DC from solar panels into AC to energize the green home.

  The DC/AC inverter that will be designed and used in our project is known to be as square wave inverter. The square wave inverter is a type of inverter which converts solar DC power to AC power. The square wave inverter is simpler in design and more efficient than a sine wave inverter.

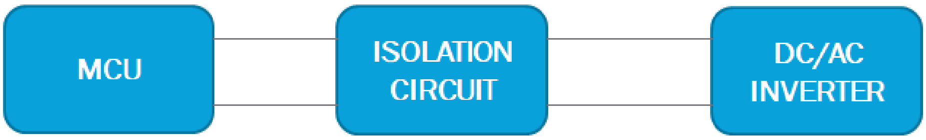



Figure 4 - DC/AC inverter block diagram

The inverter inputs are square wave signals generated by the MCU (Arduino Mega) to using the technique of Pulse With Modulation (PWM) in addition to an isolation circuit followd by MOSFET's in order to be used as voltage switches in accordance with the input signal. The use of MOSFET's in the output stage and the PWM technology makes this inverter ideal for all types of loads. In addition to the pulse width modulation, The protection i.e. isolation will be established by using PC817 which is a 4 Pin optocoupler, normally used in embedded project for isolation purposes.

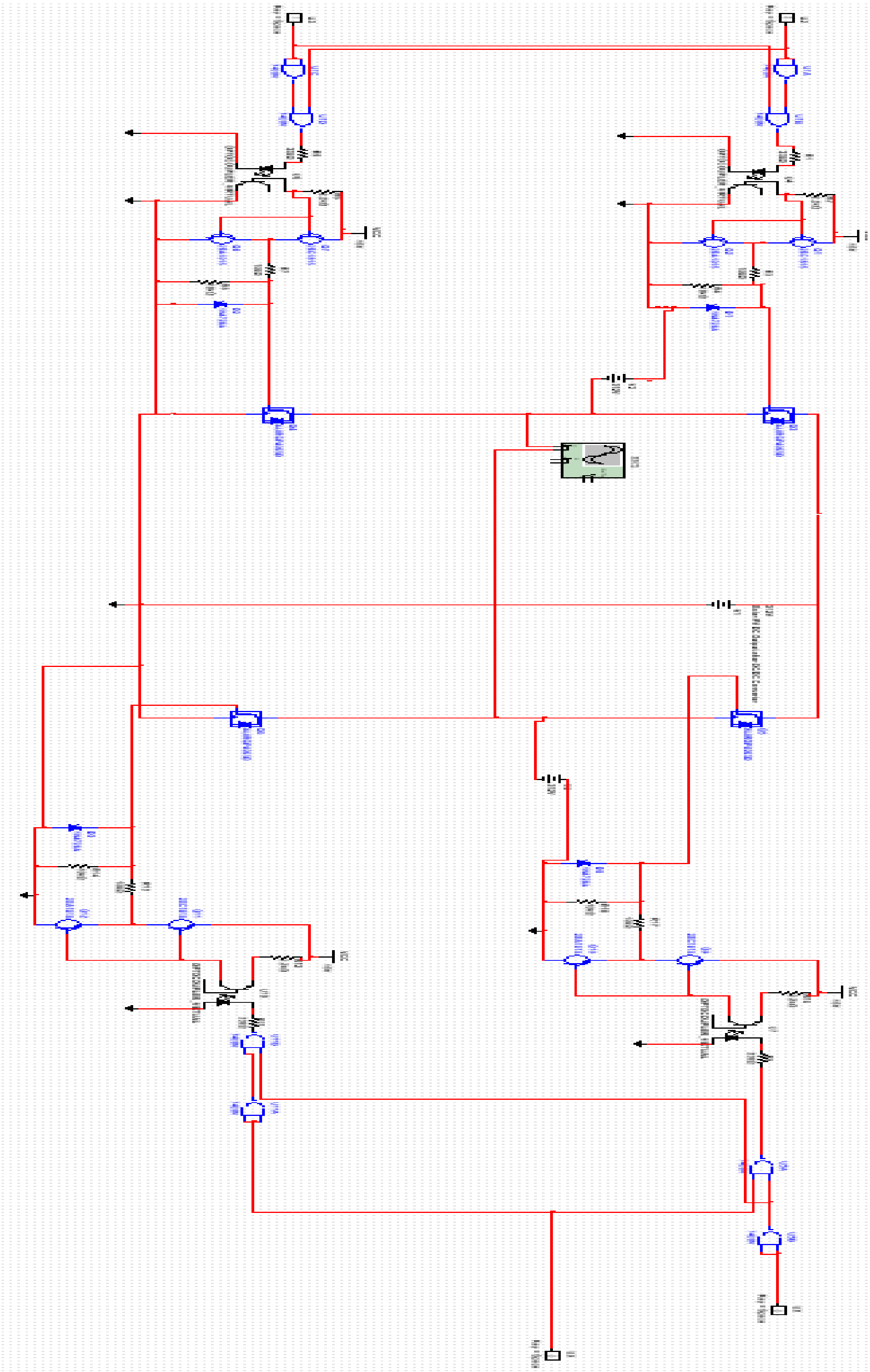


Figure 5- Gate driver circuit design

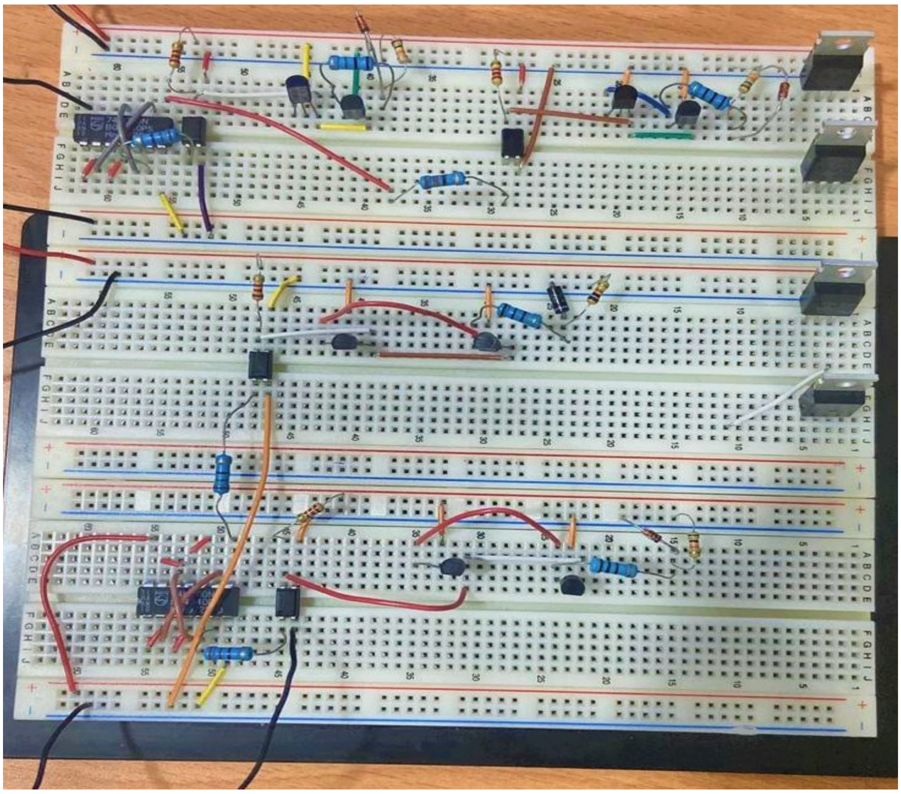


Figure 6 - Implementation of gate driver circuit

- **Coding and programing regarding PWM signals for DC/AC (invertors) and gate drive circuits**: The purpose of the code is to generate four PWM signals, each with a pair that's the complement of the other, to operate the transistor switches of the dc/ac inverter. We used direct register manipulation as shown in **Figure 7** to control the behaviour of each pair as they are generated together from the board.

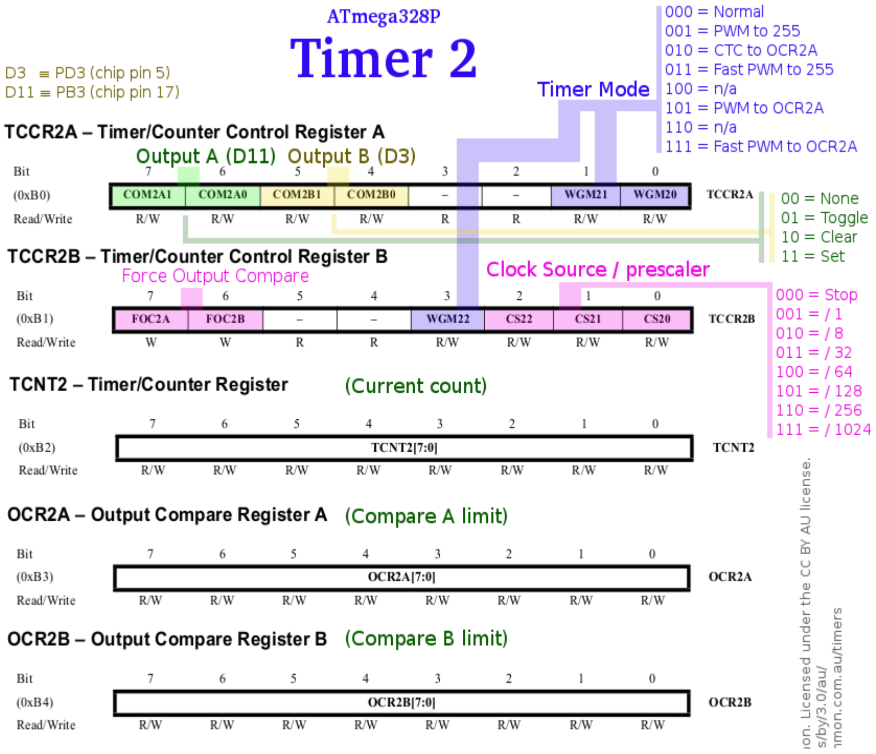



Figure 7 - Timer and counter registers

The timers that were used in our code are timer1 and timer 3, TCCR2A/B, and timerX, TCC2RXA/B. These timers are 8 bits wide and can be controlled through setting each individual bit to form the 8 bit sequence it holds into the register. The code still need to be finalized and tested next week.

❖ **Procurements**: The procurements stage has been divided into three sections as follows:

1. Procurements subsystem I (Green home and solar carport), excluding the structure cost, **75% COMPLETED**
2. Procurements subsystem II (Battery bank), **COMPLETED**
3. Procurements subsystem III (EV charging system)
4. Structure of carport, **COMPLETED**
5. Structure of green home, **IN PROGRESS**

We have started the procurements of subsystem I by purchasing the following items:

- PC817( Isolation element) x6

- 7400 x4
- A1015 (Transistor) x5
- C1815 (Transistor) x5
- Connectors 2 pins x10
- Zener diode 15V/1W x5
- IRF840 (MOSFET) x6
- Resistors (6k, 2.2k, 10) Ω x6 of each
- Arduino Mega x1
- Circuit breadboard x5
- Jumpers x1
- Adapter 15V, 5A, 75W x3
- IGBT H-bridge x1
- Charge control unit x1

All the mentioned components above are electronic components in which they will be utilized in subsystem I (Green home) in DC/AC invertor and its circuitries as explained earlier, therefore, some components will be used in the solar panel and powering.

❖ **Structure design, solar panels and battery**: We bought the solar panels, 3 x 160 W with 12V output and we were able to reduce the cost by 60 % by scaling down the capacity of the solar panels (810 SAR vs 2000 SAR). We also bought one battery only instead of two batteries to optimize the cost; the battery size is 12v, 150Ah with cost of 800 SAR. Moreover, we have started the fabrication of the steel structure of the carport and battery box with cost of 1200 SAR. Dimension of the carport structure is shown in below figure.

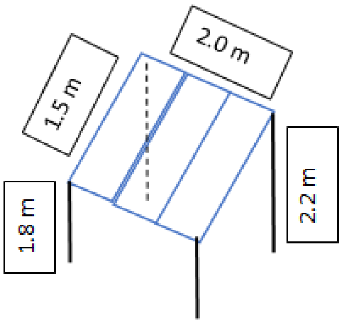



Figure 8 - Solar Carport design

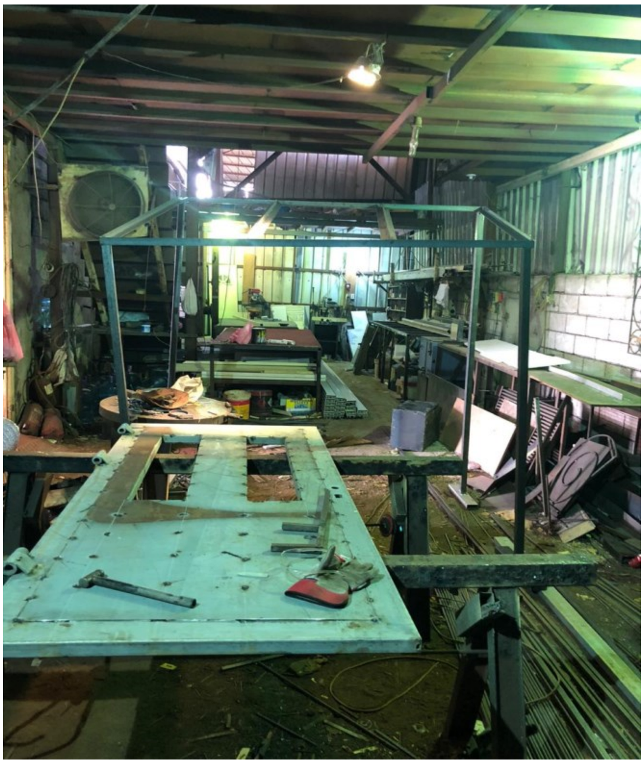


Figure 9 - Solar Carport

## PLANNING

The listed bullets below represent the main goals for the coming weeks within the second reporting period regarding progress reports as well as weekly progress meetings.

1. Finalize, examine, and test all codes regarding DC/AC inverter
2. Finalize, examine, and test gate drive circuit and DC/AC inverter

3. Finalize, examine, and test gate sine-wave inverter
4. Start designing the green home structure, find workshops and vendors
5. Start Implementing solar carport
6. Start searching for components regarding EV charging system

**Prince Mohammad Bin Fahd University (PMU)**
Department of Electrical Engineering

**Design Methodology & Project Management**
Instructor: Dr. Samir El-Nakla

**FALL 2019/2020**

## PROJECT PROGRESS REPORT II

# SMART SOLAR CARPORT SYSTEM AT PMU

**TEAM MEMBER**:

| | |
|---|---|
| **Abdullah N. Al-Qahtani (Project Leader)** | **201501245** |
| Abdullah M. Al-Ghamdi | 201402209 |
| Abdulaziz A. Al-Abdulwahab | 201602677 |
| Saif F. Al-Sharif | 201502262 |

**PROJECT ADVISOR**

Mr. Saifullah Shafiq

Date November 4, 2019

This paper intended to provide a progress report and it briefly illustrates the performed tasks regarding the project of smart solar carport system at Prince Mohammad Bin Fahd University (PMU) October 14, 2019 – November 4, 2019

## PERFORMED TASKS AND ACTIVITIES

- **Modify, examine, and test code regarding DC/AC inverter (gate driver circuit):**

  In accordance with progress report I regarding gate driver circuit, the desired inputs are four square waves. This can be established as it has been explained earlier by using the method of timers manipulation, the chosen timers were timer 1 and timer 2.

```
void setup()
{
  pinMode(10, OUTPUT);
  pinMode(9, OUTPUT);
  TCCR2A = B01010000;
  TCCR2B = B01000011;
  OCR2A = 127;
  OCR2B = 156;
  pinMode(11, OUTPUT);
  pinMode(12, OUTPUT);
  TCCR1A = (TCCR1A & 0b11111100) | 0b00000011;
  TCCR1B = TCCR1B & B11111000 | B00000011;
  OCR1A = 127;
  OCR1B = 156;
}
void loop()
{
}
```

The code still going to be modified and tested with the gate driver circuit, the modification is needed to increase the frequency from 30 Hz into 60 Hz as shown in **Figure 1** to satisfy the Saudi engineering standards and to be sufficient enough to handle and energize the available appliances in the Saudi market.

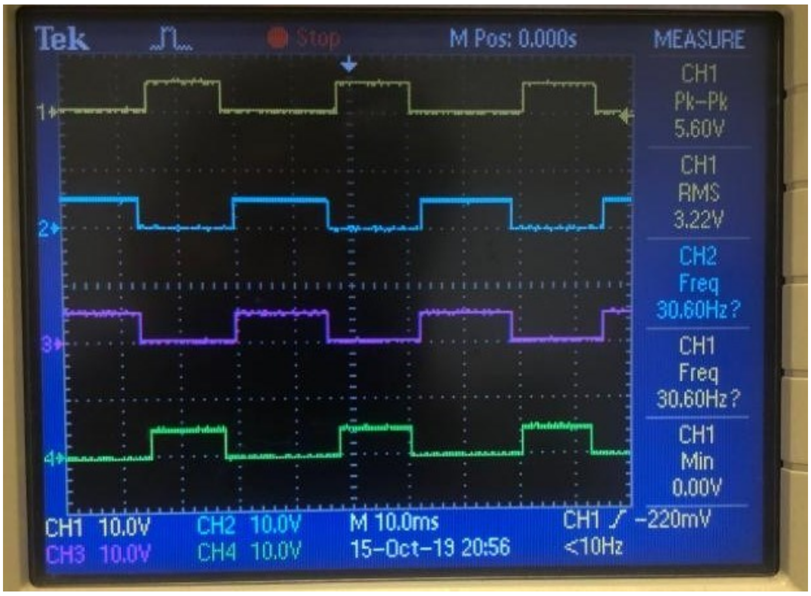



Figure 1 - Square waves waveforms

- **Modify, examine, and test DC/AC inverter (gate driver circuit):**

After generating the required input, the circuit has been re-organized and built in order to save board space and most importantly to facilitate the tracking process if there is any failure during testing.

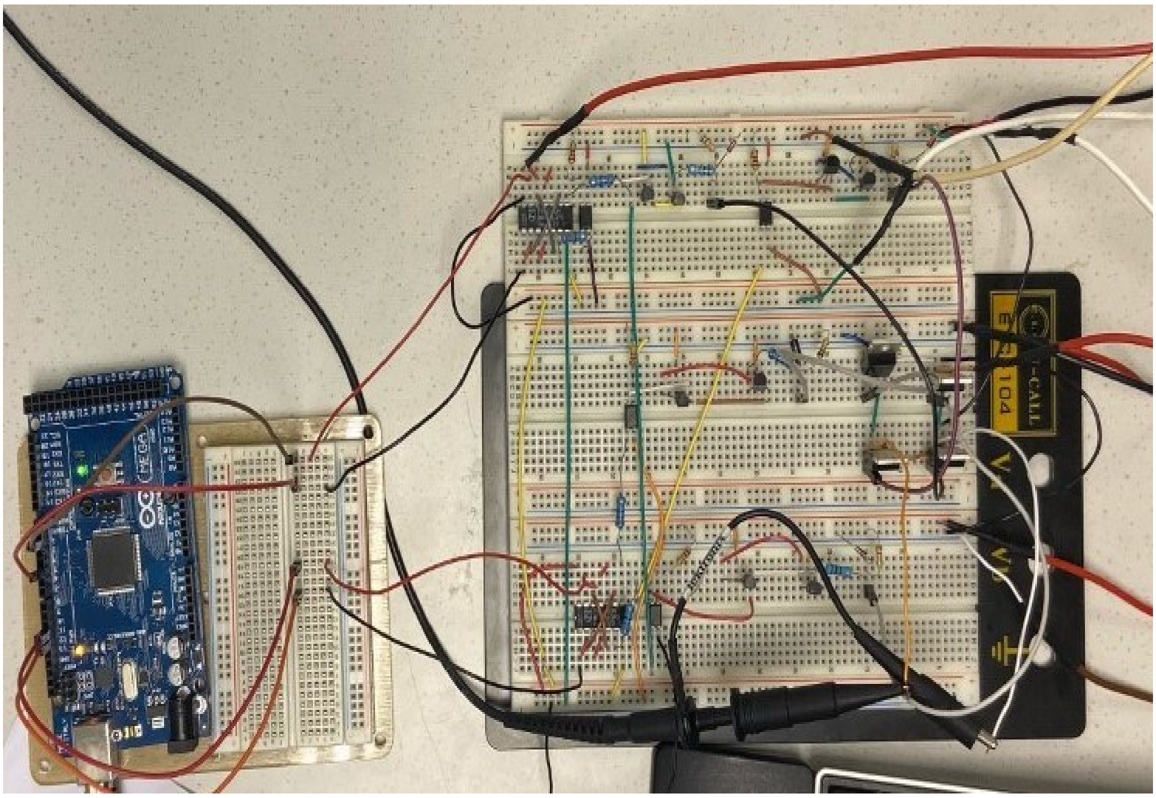


Figure 2 - Gate driver circuit

The circuit has to be modified further by implementing a sine wave inverter to prevent loads issues such as heat.

When the battery stores electricity in the DC form, green home loads or in general, household electrical appliances use only AC current. The role of an inverter either square wave or sin wave inverter is to convert the DC electricity stored in a battery into AC electricity to be used by the house loads. An inverter, on the basis of its circuit, converts the DC current to either sine wave AC current or square wave AC current. From a safety perspective, the output of a sine wave inverter resembles AC current very closely when compared to the square wave output, the sine wave output is quite pure. Most loads get heated up when square wave inverter is used. Shortly, a square wave inverter is sufficient to energize most loads and appliances but it is less safe for the appliances, whereas a sine wave inverters are highly safe.

- **Prepare mid-term presentation using prezi:**

  The mid-term presentation has been designed and created through prezi website in which it provides more presentation templates, animations, and features.

  Please use the link below to present the presentation regarding smart solar carport system at PMU

  **https://prezi.com/7urmcxlulbaq/?utm_campaign=share&utm_medium=copy**

- **Green home structure:** One of the main deliverables of the project is to provide and store sufficient energy generated by solar panels mounted on carport in order to energize residential appliances and charge electrical vehicles. Therefore, in accordance with the submitted project plan, the green home scheduled to be completed by this semester beside the carport structure and storage system. Hence, we have purchased the required materials to start building and fabricating the green home structure, The structure will be built using wood instead of steel to facilitate the fabrication and in-campus tasks such as building and implementation.

- **Allocation of project location:** The project location has been chosen with taking into confederation several critical parameters that might affect the power production and the efficiency of the solar panels such as; sunlight exposure, reflected shadow from buildings, sunrise angle, and the project visibility.

  Accordingly, the chosen location as shown below in **Figure 3** has been proposed to the department and the approval has been received in a timely manner, hence, the team with its member would like to take the chance deliver its appreciation and thanks to, Acting chair for the electrical engineering department Dr. Samir El-Nakla, Project advisor Mr. Saifullah Shafiq, and all PMU staff for facilitating the request process

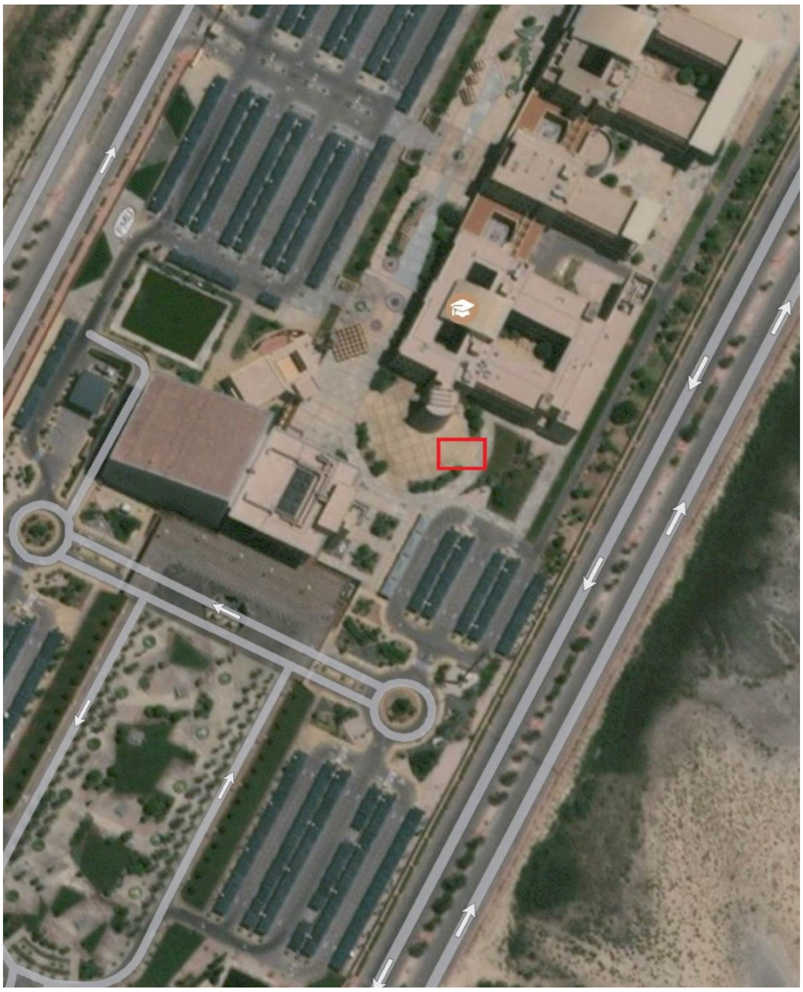


Figure 3 - Project location

- **Procurements:**
  - Green home structure
  - IGBT/MOSFET modules (SK 25 GH 12T4)

The purchased item above (IGBT/MOSFET modules) is an insulated gate bipolar transistor (IGBT) which is a three terminal power semiconductor device primarily used as an electronic switch in power electronics and a greet replacement for MOSFET's. The specific purchased item designed as H-bridge of four IGBT's and it intends to be utilized in the DC/AC inverter (gate driver circuit) instead of using direct MOSFET's since it has a high current carrying capacity.

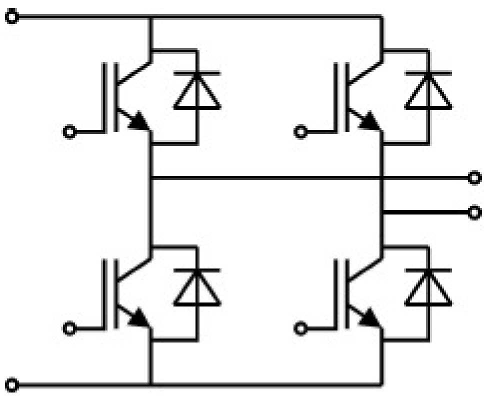


Figure 4 - Circuit diagram for SK 25 GH 12T4

❖ **Project plan:**

In this semester we intended to perform the following;

- Design and implement solar carport structure
- Design and implement green home structue
- Design, implement, and test DC/AC inverter circuitry
- Design and implement local storage system (Battery)
- Start procurments for subsystem III stage I i.e. EV charging system

SMART SOLAR CARPORTS SYSTEM AT PMU

Abdullah N. Al-Qahtani 201501245 ' Project Leader
Abdullah M. Al-Ghamdi 201402209
Abdulaziz A. Al-Abdulwahab 201602677
Saif F. Al-Sharif 201502262

Project Adisor: Mr. Saifullah Shafiq

Design Methodology & PM | Fall 2019/2020

Project PLAN

Instructor: Dr. Samir El-Nakla

| ACTIVITY | PLAN START | PLAN DURATION | Assigned To | ACTUAL START | ACTUAL DURATION | PERCENT COMPLETE |
|---|---|---|---|---|---|---|
| Form teams | 1 | 1 | ALL | 1 | 1 | 100% |
| Select topic & advisor | 2 | 1 | ALL | 1 | 1 | 100% |
| Write proposal and plan | 2 | 1 | ANQ | 2 | 1 | 100% |
| Background research & PPT1 | 3 | 2 | ANQ | 3 | 2 | 100% |
| Search and acquire components ( Procurements) | 3 | 3 | AMG, AAA | 4 | 1 | 90% |
| Subsystem 1 Procurements | | | AAA,AMG | 4 | 4 | 100% |
| Subsystem 2 Procurements | | | AMG | 4 | 1 | 100% |
| Subsystem 3 Procurements | | | | 14 | | 0% |
| Structure of carport | | | AMG | 6 | 2 | 90% |
| Structure of green home | | | AMG | 6 | 3 | 90% |
| Design subsystem I: Green Home System | 4 | 3 | ALL | 4 | 4 | 75% |
| Design, implementation, and testing of isolation circuit | 5 | 4 | ANQ | 5 | 3 | 80% |
| Design, implementation, and testing of DC/AC inverter | 5 | 2 | ANQ | 5 | 3 | 75% |
| Combining isolation circuit with DC/AC inverter | | | ANQ | 7 | 1 | 90% |
| Learning about basic Arduino Mega programming | | | ALL | 4 | 4 | 80% |
| Learning about I/O pins, timers, and interrupts | 5 | 2 | ALL | 4 | 5 | 80% |
| Writing and testing basic codes | | | ALL | 4 | 6 | 75% |
| Writing code to implement DC/AC inverter | | | SFS | 4 | 7 | 75% |
| Verifying complete DC/AC inverter | 6 | 5 | ALL | 6 | 5 | 33% |
| Prepare midterm Presentation | 7 | 3 | ANQ | 6 | 2 | 100% |
| Design subsystem II: Battery Bank System | 9 | 4 | AMG | 6 | 1 | 100% |
| Connecting and testing charge controller with batteries | 10 | 1 | ALL | 9 | 2 | 0% |
| Design of Structre | 11 | 2 | ALL | 12 | 2 | 50% |
| Carport Design and Implementation | 12 | 2 | AMG | 6 | 1 | 90% |
| Green Home Design and Structure Implementation | 12 | 2 | ALL | 7 | 2 | 90% |
| Prepapre final report | 12 | 3 | ANQ | 12 | 3 | 0% |
| Prepare final presentation | 13 | 2 | ANQ | 13 | 2 | 0% |

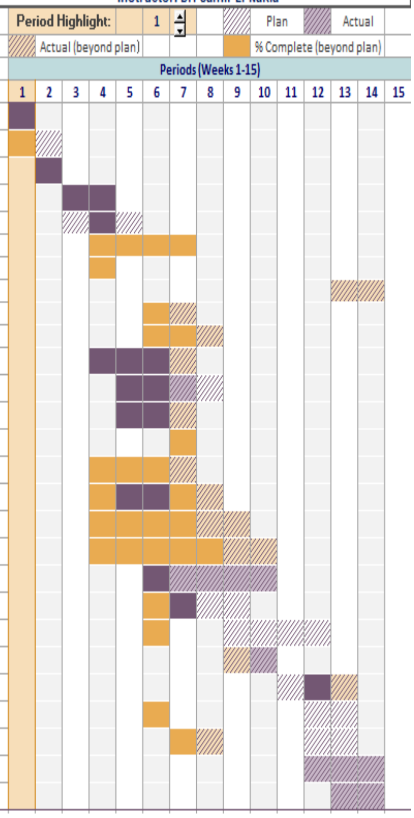



Figure 5 - Project plan I (Design Methods)

For the coming semester i.e. during assessment III:

- Search and learn about EV charging systems and charging principles
- Learn about DC/DC converters (types, advantages, disadvantages, and circuitry)
- Know how to design DC/DC converters
- Finalaize procurments III
- Design subsystem III (EV charger)
- Design/fabricate DC/DC converter
- Implement and test DC/DC converter
- Implement and test EV charger
- Implement the entire project
- Test the project

- Final report
- Final presentation

**SMART SOLAR CARPORTS SYSTEM AT PMU**

Abdullah N. Al-Qahtani 201501245 ' Project Leader
Abdullah M. Al-Ghamdi 201402209
Abdulaziz A. Al-Abdulwahab 201602677
Saif F. Al-Sharif 201502262
Project Adisor: Mr. Saifullah Shafiq

**Pdesign & Methods Project Plan II** | **Spring 2019/2020**

**PROJECT PLAN FOR ASSESSMENT III**

SUBMITTED TO DR. SAMIR EL-NAKLA

Period Highlight: 1 | Plan | Actual | Actual (beyond plan) | % Complete (beyond plan)

Periods (Weeks 1-15)

| ACTIVITY | PLAN START | PLAN DURATION | Assigned To | ACTUAL START | ACTUAL DURATION | PERCENT COMPLETE |
|---|---|---|---|---|---|---|
| Learn and serch about EV charging systems | 1 | 1 | | | | 0% |
| Learn about EV charging principles | 1 | 1 | | | | 0% |
| Learn about DC/DC converters | 1 | 1 | | | | 0% |
| Know how to design DC/DC converters | 2 | 1 | | | | 0% |
| Finalaize procurments III | 3 | 1 | | | | 0% |
| Design subsystem III (EV charger) | 3 | 2 | | | | 0% |
| Design/fabricate DC/DC converter | 4 | 2 | | | | 0% |
| Implement and test DC/DC converter | 6 | 1 | | | | 0% |
| Implement and test EV charger | 7 | 1 | | | | 0% |
| Implement the entire project | 8 | 2 | | | | 0% |
| Test the project | 9 | 2 | | | | 0% |
| Prepapre final report | 10 | 1 | | | | 0% |
| Prepapre final presentation | 11 | 1 | | | | 0% |

Figure 6 - Project plan II (ASSESSMENT III)

## PLANNING

The listed bullets below represent the main goals for the coming weeks within the second reporting period regarding progress reports as well as weekly progress meetings.

7. Modify, finalize, and test codes regarding sine wave inverter
8. Finalize, examine, and test gate drive circuit and DC/AC inverter circuitry
9. Design and fabricate PCB’s regarding DC/AC inverter circuitry
10. Start Implementing the solar carport
11. Start implementing the green home
12. Start searching for components regarding EV charging system

**Prince Mohammad Bin Fahd University (PMU)**
Department of Electrical Engineering

**Design Methodology & Project Management**
Instructor: Dr. Samir El-Nakla

**FALL 2019/2020**

## PROJECT PROGRESS REPORT III

# SMART SOLAR CARPORT SYSTEM AT PMU

**TEAM MEMBER**:

| | |
|---|---|
| **Abdullah N. Al-Qahtani (Project Leader)** | **201501245** |
| Abdullah M. Al-Ghamdi | 201402209 |
| Abdulaziz A. Al-Abdulwahab | 201602677 |
| Saif F. Al-Sharif | 201502262 |

**PROJECT ADVISOR**

Mr. Saifullah Shafiq

Date December 8, 2019

This paper intended to provide a progress report and it briefly illustrates the performed tasks regarding the project of smart solar carport system at Prince Mohammad Bin Fahd University (PMU) November 4, 2019 – December 8, 2019

## PERFORMED TASKS AND ACTIVITIES

- **Implementation and testing of solar carport:**

  The scope of this project is to generate renewable energy through solar panels mounted on carport in which the generated power will be utilized to power residential loads and most importantly provide sufficient power to charge electric vehicles. Hence, the solar panels and carport structure has been installed in the proposed location after been approved. Implementing the carport and installing the solar panels in advance provide greet opportunity to students, faculty, staff, and university visitors to observe and experience such systems.

Figure 1 - Proposed location


Figure 2 - Solar Carport at PMU


Figure 3 - Solar carport output

After the implementation, the charge controller installed and the designed carport successfully generated solar energy with output voltage of 13.7 V as shown in **Figure 3**.

Furthermore, the team with its member would like to thank, Acting chair for electrical engineering department Dr. Samir El-Nakla, Project advisor Mr. Saifullah Shafiq, and PMU maintenance department with its staff for their support regarding the implementation.

- **Design and build a permanent DC/AC inverter (gate driver circuit):**

Permanent circuit is an upgrade for the prototype version of any circuit and it provides reliable circuitry. A typically permanent circuit board using universal board offers a simple platform to arrange the electronic components in a compressed and efficient way based on the design and how the designer desired to build it by soldering and offer varied advantages which make them the perfect choice for projects since it lasts and live longer. The advantages of enhancing our gate driver circuit to permanent soldered circuit are as follows:

1. Compact size and saving of wire: the interconnection between the components is made through solder flux (iron) instead of wires and jumpers using the soldering technique.
2. Immune to movement: since all components on the circuit board held fixed to the board, it does not allow them to move irrespective of the movement of the board itself.
3. Reliability: all the above factors bring reliability in the performance of the circuit.

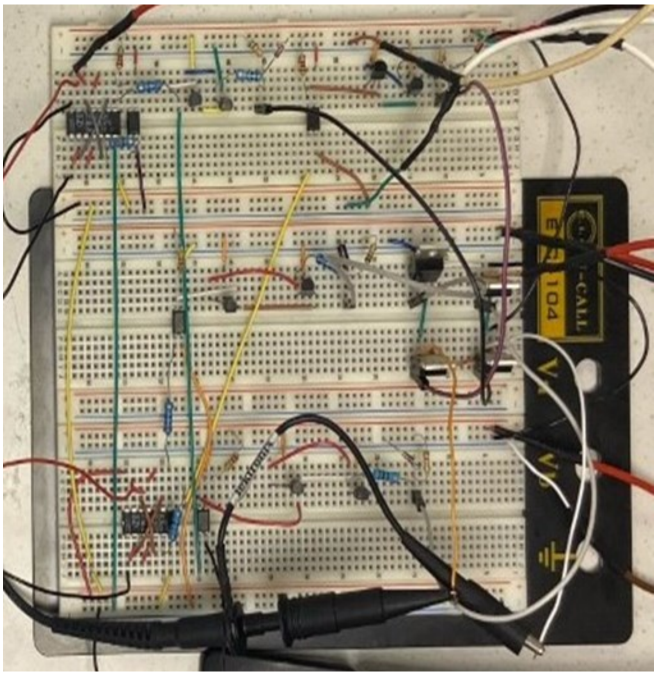


Figure 4 - Gate driver circuit (prototype version)

The utilized universal board has a dimension of (30 x 25) cm to provide space if further enhancement needed.

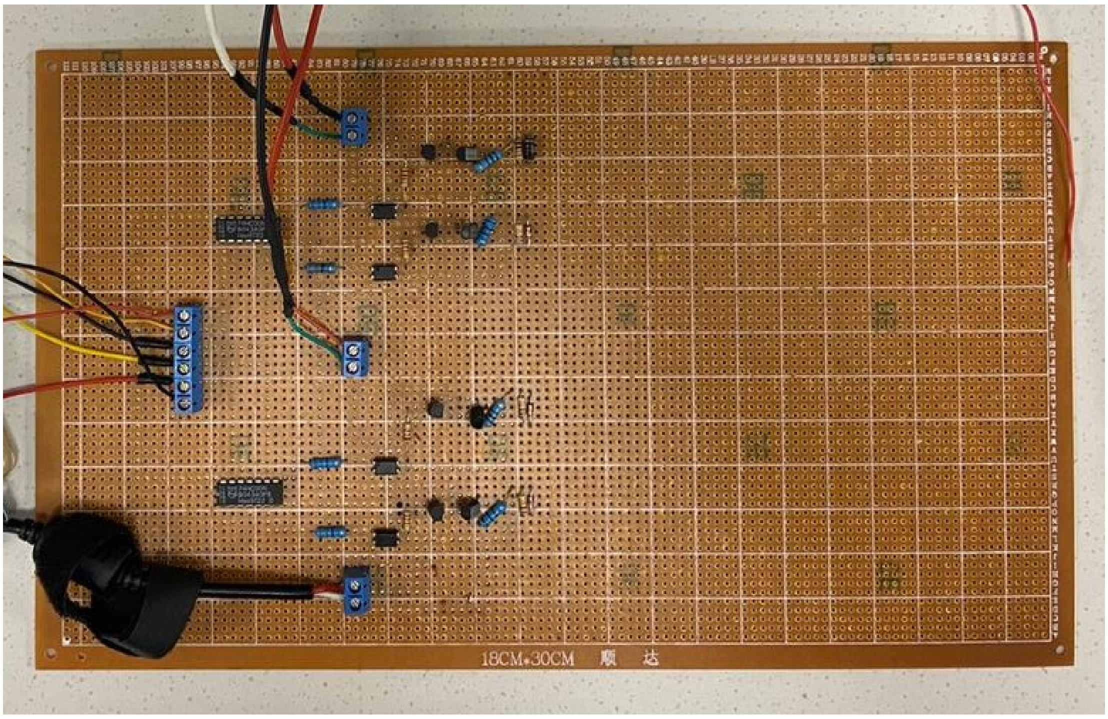



Figure 5 - Modified gate driver circuit

The circuit has been tested and successfully converted DC inputs into square waves with value around 15V as desired per the design and depends on the input values.

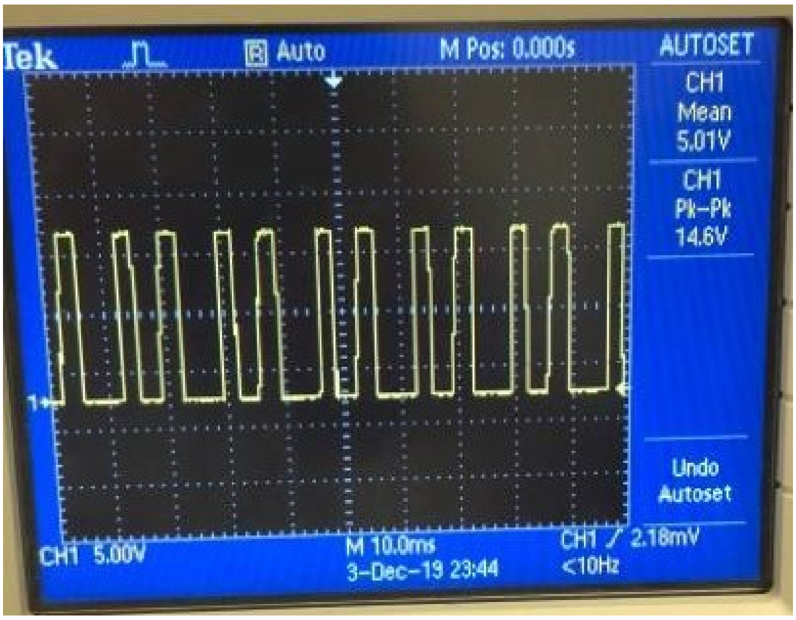



Figure 6 - Output of gate driver circuit

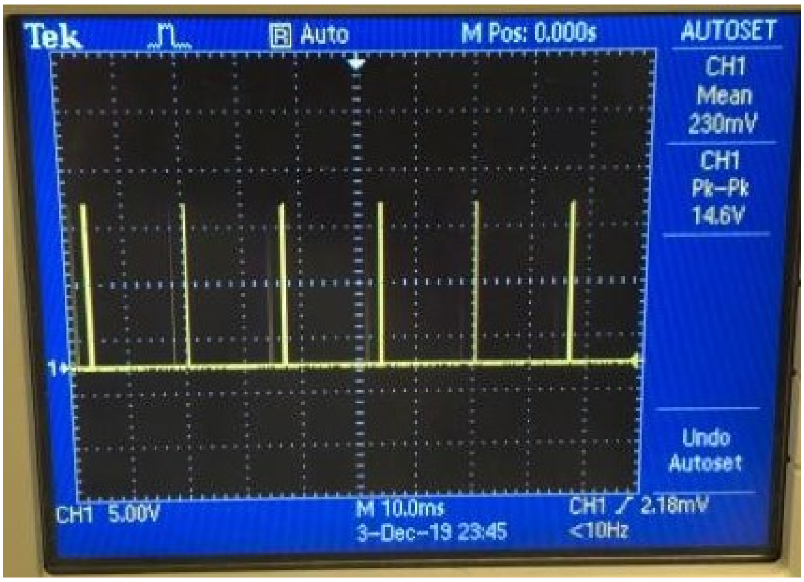



Figure 7 - Output of gate driver circuit

- **Modify and develop the code for DC/AC inverter (gate driver circuit):**

In relation to the previous code, the square wave inverter, we further improved our inverter to a sinusoid signal instead of a square wave since all AC electrical signals are sinusoids at 60 Hz. The same technique was used with direct register manipulation to change the output frequency and inverting two signals to create four signals in total, each with its inverse. In addition, we controlled the counting register to set our own maximum number for which the timers to count up then down to and from. We also used interrupts to abruptly stop and start the generation of the signals to correctly match our sampling frequency. The resulting manipulation creates PWM signals, which are still square waves, to match the peaks of a sinusoid, which is also are stored in an array, that translates to outputting a close to ideal sinusoid signal that is favourable rather than the square wave.

The procedure began with the known base clock of our Arduino Mega, which is 16 MHz, combined with our intended output frequency of 60 Hz. By having a total of 30 samples, we calculated the needed sampling frequency by taking the inverse of our output frequency resulting in a time of 16.6667 ms, dividing that by the number of samples we get the time for each sample, 0.5556 ms. The inverse of 0.5556 gives us our sampling frequency of 1.8 kHz. The next step is to find the number needed to be sent to the counting register to configure the PWM signals, which is done by first choosing a pre-scaler, which are present in the counter register themselves, where we chose the number 64 which is then multiplied by the inverse of the clock frequency resulting in a time of 4 µs. The last step is to divide the time of each sample by the total time it takes for a clock cycle to pass resulting in the number 139, which is what was sent to the counting register.

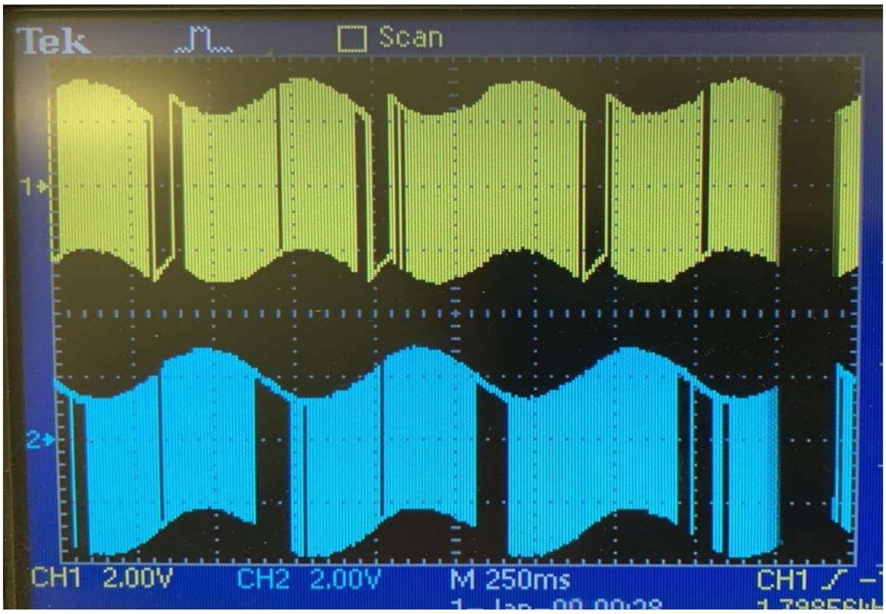



Figure 8 - Generated sinwave using Arduino

## PLANNING

A design session will be conducted soon with Mr. Shafiq regarding electric vehicle (EV) charger, DC/DC circuitry, and if there are any modification needed for the submitted project plan for ASSESSMENT III. After designing the charger, procurement III will be started within the final exam in order to prevent any delivery issues. Moreover, the team decided to postpone the implementation of green home structure till March 2020 after winter in order to save the wood structure from raining conditions.

### ASSESSMENT III: LAST PROGRESS REPORT

| | | |
|---|---|---|
| Title: SMART SOLAR CARPORT PARKING SYSTEM | Advisor: Mr. Saifullah Shafiq | Design II (ASSE 3) — Spring 2020 |
| Abdullah N. Al-Qahtani 201501245 ' Project Leader (ANQ) | | Project PLAN & Progress |
| Abdullah M. Al-Ghamdi 201402209 (AMG) | | ProgRpt No. 5 |
| Abdulaziz A. Al-Abdulwahab 201602677 (AAA) | | Submission date: April18, 2020 |
| Saif F. Al-Sharif 201502262 (SFS) | | Instructor: Dr. Sadiq Alhuwaidi |

Period Highlight: 7 — Plan — Actual — Actual (beyond plan) — % Complete (beyond plan)

Periods (Weeks 1-15)

| ACTIVITY | PLAN START | PLAN DURATION | Assigned To | ACTUAL START | ACTUAL DURATION | PERCENT COMPLETE |
|---|---|---|---|---|---|---|
| Learn about DC/DC converters (Power Electronics) | 1 | 1 | ANQ | 1 | 1 | 100% |
| Learn about EV charging principles | 1 | 1 | ALL | 1 | 1 | 100% |
| Design subsystem III (EV charger) | 2 | 4 | ALL | 2 | 5 | 100% |
| Design DC/DC converters (BOOST, XFMR and XFMR-LESS) | 2 | 4 | ANQ | 2 | 6 | 100% |
| Finalise DC/AC inverter (IGBT implementation) | 5 | 1 | ANQ | 4 | 5 | 80% |
| Search for components | 2 | 10 | AMG | 2 | 6 | 80% |
| Procurements | 2 | 10 | AMG | 2 | 6 | 85% |
| Programing | 2 | 10 | SFS | 3 | 5 | 90% |
| Test DC/AC inverter | 5 | 1 | ALL | 5 | 4 | 70% |
| Determine green home loads | 4 | 1 | AAA , SFS | 4 | 1 | 100% |
| Design green home structure | 5 | 1 | AAA | 4 | 4 | 100% |
| Structure implementation of subsystem I (Green home) | 7 | 2 | AAA , SFS | 5 | 7 | 30% |
| Test DC/DC converter | 8 | 2 | ANQ , AMG | | | 0% |
| Install residential loads and test Subsystem I (Green home) | 8 | 1 | ALL | | | 0% |
| Implement and test EV charger | 9 | 1 | ALL | | | 0% |
| Implement the entire project | 9 | 1 | ALL | | | 0% |
| Test the project | 10 | 3 | ALL | | | 0% |
| Prepapre final report | 11 | 1 | ANQ | | | 100% |
| Prepapre final presentation | 12 | 1 | ANQ | | | 90% |

Progress Details:

Completed final report with the requested sections

Issues (delay ...):

# Appendix B: Bill of Materials

| Item | Quantity | Unit Price (SAR) | Total (SAR) |
|---|---|---|---|
| Solar Panel 160W | 3 | 300 | 900 |
| Battery 150Ah, 12V | 1 | 800 | 800 |
| Charge Controller | 1 | 200 | 200 |
| Metal and Wood structure | 1 | 2000 | 2000 |
| Arduino Mega | 2 | 150 | 150 |
| H- Bridge Rectifier | 2 | 50 | 100 |
| H Bridge IGBT | 1 | 400 | 400 |
| DC/DC Converter | 1 | 100 | 100 |
| DC Voltage Sensor | 1 | 200 | 200 |
| Ferrite Core Transformer | 1 | 250 | 250 |
| Current Sensor | 2 | 130 | 260 |
| Miscellaneous | 1 | 2000 | 2000 |
| Total | | | 7360 |

# Appendix C: Datasheets

Shenzhen Socan Technologies Co.,ltd T:86-755-86242301 F:86-755-86242301 W:WWW.SZSOCAN.COM @:SALES@SZSOCAN.COM

**SCK3 Series Open Loop Hall Effect Current Sensor**

| SCK3 Series Open Loop Current Sensor | | | Ipn=50A, 100A, 200A, 300A, 400A, 500A, 600A | | | | |
|---|---|---|---|---|---|---|---|
| Model / Parameters(25°C) | SCK3- | | | | | | |
| | 50A | 100A | 200A | 300A | 400A | 500A | 600A |
| Nominal Rms Current (Ipn) | ±50AT | ±100AT | ±200AT | ±300AT | ±400AT | ±500AT | ±600AT |
| Measuring Range (Ip) | 150AT | 300AT | 600AT | 750AT | 900AT | 900AT | 900AT |
| Load resistance Rmax | ≥10kΩ | | | | | | |
| Output Voltage | ±4V or ±5V | | | | | | |
| Working voltage | DC ±12V~±15V(±5%) | | | | | | |
| Accuracy @ Ta=25°C | ±1% FS | | | | | | |
| Linearity @ Ta=25°C | ±1% FS | | | | | | |
| Withstand voltage | 2.5kVrms/50Hz/min | | | | | | |
| Input Offset Voltage | < ±30mV | | < ±15mV | | | < ±50mV | |
| Offset temperature characteristics | < ±0.1%/°C | | | | | | |
| Thermal drift of Vo | < ±2mV/°C | | < ±1mV/°C | | | | |
| Hysteresis offset | < ±30mV | | < ±20mV (if=F.S. 0<--- --->Nominal RMS Current) | | | | |
| Response time | < 5uS | | | | | | |
| Current consumption | <±13mA | | | | | | |
| Operating temperature | -20~+80 °C | | | | | | |
| Storage temperature | -40~+85 °C | | | | | | |




## Model: HV6023

Sub-plate installation,Crimping terminal input/output;
Current limiting resistance and sampling resistance built-in.
Detect DC,AC and pulse voltage.

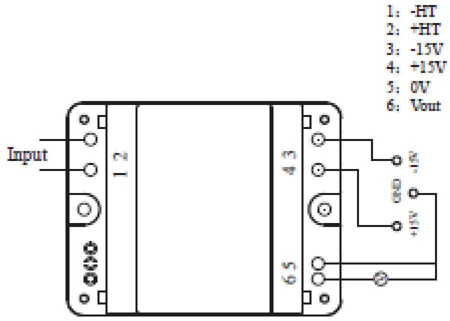
### Technical indicators:

Flame resistance: UL94-V0
Working temperature: -10~+70℃
Storage temperature: -40~+85℃
Dielectric strength: 3.5KV 50Hz 1min

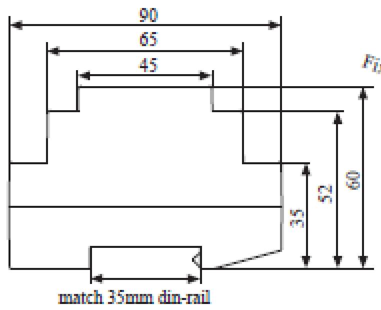
### Electrical parameters:

| | | | |
|---|---|---|---|
| $V_P$ | Rated input | ±300 | V |
| $V_{PM}$ | Input measured range | ±450 | V |
| $V_{OUT}$ | Rated output | ±5 | V |
| X | Accuracy | 1 | % |
| $\varepsilon_L$ | Linearity | <0.1 | % |
| $V_C$ | Supply voltage(±5%) | ±15 | V |
| $I_C$ | Current consumption | <35 | mA |
| $R_L$ | Load impedance | | Ω |
| $V_{OE}$ | Zero offsetTA=25℃ | | mV |
| $T_R$ | Response time | | μs |
| N.W | Weight | | g |

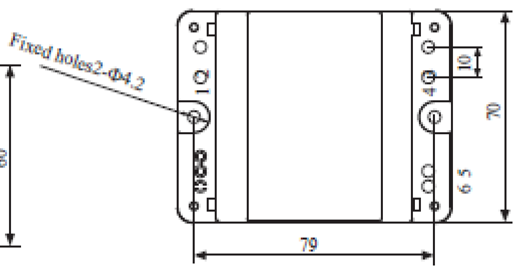
### Connection Diagram:




### Dimensions (in mm):




Front view




Top view

# Appendix D: Program Codes

**Arduino codes:**

**FOUR SIGNALS CODE #1:**

```
void setup()
{
 pinMode(9,OUTPUT);
 pinMode(10,OUTPUT);
 pinMode(11,OUTPUT);
 pinMode(12,OUTPUT);
 TCCR2A = 0b01010000;
 TCCR2B = 0b01000011;
 OCR2A = 127
 OCR2B = 156
 TCCR1A = (TCCR1A & 0b11111100) | 0B00000011;
 TCCR1B = (TCCR1B & 0b11111100) | 0B00000011;
 OCR1A = 127
 OCR1B = 156
}
void loop()
{
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

**FOUR SIGNAL sPWM:**

```
//int sinewave[] =
{53,60,67,73,80,87,93,99,93,87,80,73,67,60,53,47,40,33,27,20,13,7,1,7,13,20,27,33,40,47};
int sinewave[] =
{53,60,67,73,80,99,99,99,99,99,80,73,67,60,53,47,40,33,27,20,1,1,1,1,1,20,27,33,40,47};
//int sinewave[] = {0,25,50,75,100};
int i = 0;
double limit = 556;


void setup()
{
TCCR3A = 0;
TCCR3B = 0;
 pinMode(5, OUTPUT);  // on 3A Timer 3
 pinMode(2, OUTPUT);  // on 3B Timer 3
 pinMode(6, OUTPUT);  // on 4A Timer 4
 pinMode(7, OUTPUT);  // on 4B Timer 4
 Serial.begin(9600);
bitSet(TIMSK3, TOIE3);
sei(); // enable all interrupts
ICR3 = limit;
OCR3A = (sinewave[i])*limit/100;
OCR3B = (sinewave[i])*limit/100;
/*-----------------------------------------------*/
```

```
/*-------------------- Timer 3 --------------------*/
TCCR3A = _BV(COM3A1)  // Non-inverting PWM on OC3A
        | _BV(COM3B0)  // PWM on OC3B:
        | _BV(COM3B1)  // Inverting mode
        | _BV(WGM31);  // Phase correct PWM 16 bit

TCCR3B = _BV(CS31) | _BV(WGM33); // Prescalar = 8
/*-------------------------------------------------*/
ICR4 = limit;
OCR4A = (sinewave[i])*limit/100;
OCR4B = (sinewave[i])*limit/100;
/*-------------------- Timer 4 --------------------*/
TCCR4A = _BV(COM4A1)  // Non-inverting PWM on OC3A
        | _BV(COM4B0)  // PWM on OC3B:
        | _BV(COM4B1)  // Inverting mode
        | _BV(WGM41);  // Phase correct PWM 16 bit

TCCR4B = _BV(CS41) | _BV(WGM43); // Prescalar = 8
/*-------------------------------------------------*/
/*-------------------------------------------------*/

}
void loop()
{
}
```

```
ISR(TIMER3_OVF_vect)
{
 i = i + 1;
 if(i == 30)
 {
 i = 0;
 }
 if(sinewave[i] == 0 || sinewave[i] == 100)
 {
  OCR3A = ((sinewave[i])*limit/100);
  OCR3B = ((sinewave[i])*limit/100);
  OCR4A = ((sinewave[i])*limit/100);
  OCR4B = ((sinewave[i])*limit/100);
 }
 else
 {
  OCR3A = ((sinewave[i])*limit/100)-30;
  OCR3B = ((sinewave[i])*limit/100)+30;
  OCR4A = ((sinewave[i])*limit/100)-30;
  OCR4B = ((sinewave[i])*limit/100)+30;
 }
}
```