Solar-Powered Convenient Charging Station for Mobile Devices with Wireless Charging Capability

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Abstract – Mobile devices, such as smartphones, tablets, laptops, and music players, have been increasingly popular. There is a strong demand for charging stations for these devices, especially in public places, such as bus stops, parks, beaches, schools, hospitals, and playgrounds. This project designs a convenient charging station for the mobile devices. It is renewable and supportive for diverse charging needs. The system key design parameters are: 200-W solar panel, 12-V 900-Wh deep-cycle lead acid battery, 300-W 120-VAC pure sine-wave inverter, 8 outlets (2 wireless, 4 DC USB and 2 AC). It aims to supply an average load of 175Wh. A prototype of the station is built and tested. The testing results show that the station works properly. The control system switches the outlets on and off accurately based on the battery available energy. On a sunny day, with the solar panel and the battery operational, the system can support a full load of 150Wh until the sun is gone. When operating without the solar panel using the fully-charged battery, the system can last at least 1.5 hours. The station can serve as a convenient power source. It helps promote the use of solar energy that is beneficial to the environment.

Keywords – Battery, charging station, inverter, mobile devices, solar, voltage regulator, wireless charging.

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1. Introduction

The solar photovoltaic (PV) market continues to be on the rise and sees no sign of slowing down. Global PV installation reached 509 GW at the end of 2018 and the PV capacity is expected to double by 2022. The United States alone installed 10.7 GW of PV system in 2018 [1, 2].

Solar power has been used in a number of applications, such as lighting in remote areas, charging batteries and electric vehicles, powering small communication stations [3-8]. In recent years, there has been a dramatic increase in the usage of mobile phones on a daily basis. Solar-powered charging stations have been implemented to meet the increasing demands of mobile phone usage, especially in locations where power is not as readily accessible [9, 10]. Another impact of the rising usage of mobile phones specifically for smartphones has been the application of inductive charging. This application uses inductive coils to induce a voltage onto the smartphone charging the device wirelessly [11-13].

A simple solar-powered charging station was developed in India using only DC outputs to charge mobile devices [14]. Another solar charging system implemented in Colombia also utilized DC outputs while taking into consideration AC outputs for devices with higher power consumption [15]. A thorough analysis of the previously mentioned solar charging stations reveals some limitations of the systems. The charging station in Colombia has included AC outputs as an added advantage over the station in India with only DC capabilities, but both were still limited to wired charging.

This project attempts to design a flexible, weather-resistant, solar-powered charging station with AC and DC outlets, as well as wireless charging pads for user convenience. Furthermore, it is designed to have a table to provide further convenience to users. Chairs may be added where the users can seat to chat or read while waiting for their devices to be charged. This charging station can be used in parks, beaches, schools, playgrounds, bus stops, and any outdoor location. It would be a particularly helpful power source in remote locations where grid power is not available.

This paper is organized as follows. Section 2 presents the design of the charging table. Section 3 describes the construction of the charging station prototype and its testing results. Section 4 contains the conclusion. In the appendix, specifications of the system main components are presented, along with related calculations and coding.

2. Charging station design

The design process begins with determining an optimal power capacity for the entire station and ensuring that each individual component has the proper voltage and current ratings. The National Electric Code (NEC) [16], which sets the standard for proper electrical wiring and safety, is used as reference to ensure that this station is not only safe for public use, but also up to code.

The Yosemite National Park shuttle service was analyzed for determining relevant features, such as number of outlets, that the station should have to serve the public effectively. The shuttle service is estimated to serve 3.7 million visitors a year and is used as a reference for the station design [17]. The goal is that the station can serve as a convenient stand-alone mobile power source where grid power is not readily available. It is expected to accommodate a variety of devices such as smartphones, laptops, tablets, and radios.

Based on the Public Transportation data for Yosemite National Park [17, 18] about 10,137 people use the shuttle service daily. A total of 27 shuttles are in operation on a daily basis and there are 22 stops in total. Based on the obtained data, on average the number of people waiting for the shuttle can be calculated as 10,137/(22x27)=17. Assuming that 8 out of the 17 people waiting for the shuttle need to charge their devices, it was concluded that 2 wireless charging pads, 4 DC and 2 AC outlets (8 charging outlets in total) would suffice for the user need. It is recognized that the user demand may vary greatly, depending on locations. Surveys may be conducted to determine the demand more accurately. Though, it is easy to add more stations to meet a location specific demand. Detailed calculation of the user demand is provided in "Equations" section of the appendix.

The charging station is powered by fixed solar panels together with a Lead Acid battery to store the energy produced by the solar panels. A charge controller is used to protect the battery from excess current and voltage. The battery output power goes directly to the DC outlets while a voltage regulator and inverter are implemented to channel power to the wireless charging pads and the AC outlets, respectively. The purpose of the voltage regulator is to step down the 12-V output of the battery to 5 volts which is a suitable input for the inductive charging transmitter circuit. The inverter converts the battery 12V DC output to 120V AC at 60Hz for the AC outlets. The AC outlets are also equipped with protective GFCI according to Article 690.41 of the NEC. Figure 1 shows the block diagram for the charging station.

2.1 Solar panel sizing and estimated energy production

A proper solar panel size is determined using the data that was obtained by the Public Transportation data for Yosemite National Park [17, 18]. It is based on the fact that the station accommodates 8 people waiting for the shuttle. The power demand for the charging station comes from the 8 people, assuming that they use all 8 charging outlets at the same time. Based on the power consumption of multiple devices that require AC

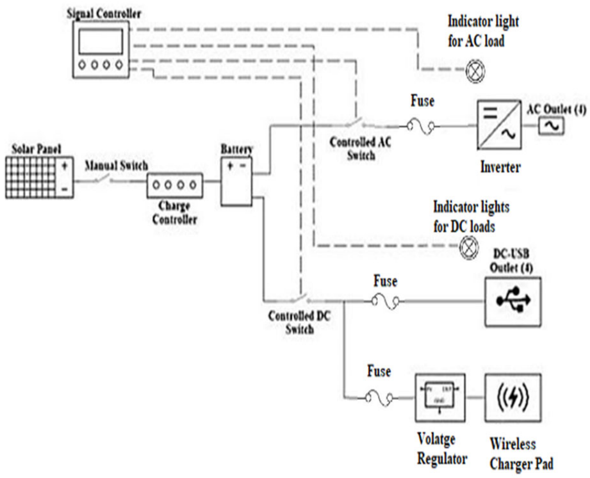


Fig. 1 Block diagram of charging station

and DC power, as well as the wireless charging power consumption, the minimum load is 110Wh and the maximum load is 240Wh when all outlets are used. Hence, the average load is 175Wh. The detailed calculation of the load is provided in appendix. Based on the load demand, a 200W solar panel is chosen to meet the average demand. Two 100-W panels may be used to obtain the 200-W capacity.

A manual switch is installed between the solar panel and the charge controller to disconnect the PV system in order to protect all the wiring systems in case of emergencies and malfunctions in accordance with NEC Article 690.1.

Estimated energy production: It is estimated that the 200-W solar panel would produce 1,100Wh per day on average (200Wx5.5 average sun hours). The average sun hours are acquired from a number of cities in California and are provided in the appendix. The purpose of using multiple cities is to ensure that the solar panel will provide sufficient energy when being placed in different locations.

2.2 Battery sizing

The battery selected is a 12-V Lead Acid deep-cycle battery with a capacity of 900Wh (12Vx75Ah=900Wh). This means that the battery can store the 200W of power of the solar panel for 4.5 hours (900Wh/200W= 4.5h). It can also store 81.8% of the energy that the solar panel produces on a daily basis (900Wh/1100Wh=0.818). We have chosen the deep-cycle battery because it is more durable than ordinary batteries and can withstand deep discharges. The approximate state of charge (SOC) corresponding to the voltage of the battery is presented in Table 7 of the appendix [19].

2.3 Inverter sizing

The inverter is selected based on the size of the battery of 900Wh. A pure sine-wave inverter of 300W at 120V continuous AC output is chosen. When the inverter is at full output of 300W it can completely drain the battery in 3 hours (900Wh/300W = 3h). Recall from Section 2.1, the average load for 2 wireless charging pads, 4 DC USB and 2 AC outlets is 175Wh. This inverter would accommodate the average load and possibly larger AC loads, assuming that users may plug in any AC device into the outlets. The inverter is equipped with the overcurrent protection and load sensors to comply with NEC Article 690.7.

2.4 Wireless charging circuit

Due to time constraint we do not develop our own inductive (wireless) charging circuit. A customized design of an inductive charging circuit requires considerable amount of time. We must design and test both the transmitter and receiver before we can use the design on compatible smartphones. We must also comply with the QI standard of inductive charging [20], which is the standard of providing 5-15 Watts to small devices. To save time, we use a pre-constructed inductive charging transmitter circuit for the station.

An inductive charging system consists of two main components, namely the transmitter circuit and the receiver circuit. For this project we focus more on the transmitter than the receiver since the receiver circuit is already implemented in certain smartphones. The transmitter circuit consists of a rectifier, a filter, a switching circuit, and an inductive coil. Since we supply the transmitter with 5V DC by using a voltage regulator, the rectifier and filter are no longer necessary. The switching circuit takes the DC voltage and switches it to create alternating current by means of MOSFETS. The alternating current is then supplied to the coil generating a magnetic field. When the transmitter coil is coupled with the receiver coil it induces a voltage on the receiver circuit allowing the battery of the receiver to be charged [21, 22].

Major factors that affect the efficiency of inductive charging include the distance between the coils and the shape of the coils of the receiver and the transmitter. This is because the coupling of magnetic flux is greater when the distance between the coils is less. Circular coils support more coupling than rectangular coils [23, 24]. Another factor is the resistance of the coils. Higher resistance causes the power to be dissipated as heat thus reducing the efficiency [25]. There are other factors that affect the efficiency but we use the main factors mentioned above to select a transmitter circuit which has three circular coils. The selection aims to obtain good magnetic coupling and freedom for users as the circuit does not strictly limit where the users place their smartphones on the wireless charging pad.

2.5 System operation and control

To ensure proper functionality and longer life span of the equipment, a microcontroller and a relay system are implemented for control and switching of relevant circuits. The used devices are: one Arduino Uno, one 2-Channel module relay board, four RGB LEDs, eight 330Ω resistors for the LEDs, one voltage regulator chip, two capacitors rated at 220uF and 47uF for the voltage regulator, and two resistors rated at 1.5kΩ and 1kΩ.

We designed the controller using voltage identification logic to continuously monitor the voltage of the battery and use that information to command switching logic of the microcontroller. One applied operation principle is to disconnect the AC outlets, the wireless charging pads, and the DC outlets appropriately at certain voltages to ensure that the battery is never fully discharged to maintain its lifespan. The design of the controller circuit is shown in Fig. 2.

The design process of the voltage identification logic and switching logic is as follows. First, we implement a voltage regulator chip with the 200μF and 47μF capacitor to step down the battery 12V output to a suitable voltage to power the Arduino. We then use the battery 12-V output and the 1.5kΩ and 1kΩ resistors in a voltage divider circuit. From the circuit the Arduino continuously senses the output voltage of the battery. The relays are powered by the battery 12V output and are fed an additional 5V from the output of the voltage regulator. By monitoring the voltage of the battery (which corresponds to the battery SOC), the switching logic would remove the 5V going to the relays at certain voltage thresholds, thereby switching the relays to cut the power to the wireless charging pads, as well as the AC and DC outlets appropriately.

To visualize the switching effect, we implemented four RGB LEDs and eight 330Ω resistors to limit the current passing through the LEDS. Figure 3 depicts the different states where our system operates. In State 1, the AC and DC charging outlets remain turned on, indicating by green LEDs. In State 2, the AC outlets are turned off, which is indicated by a red LED while the DC USB ports and the wireless chargers remain on, indicating by their respect green LEDs. In State 3, the AC and DC outlets are turned off, which is indicated by red LEDs.

From Fig. 3, the control logic works as follows. From State 1, the system enters State 2 when the battery state of charge (SOC) is between 50% and 70%. It enters state 3 when the battery SOC drops below 50%. It remains in State 1 if the battery SOC is above 70%. It remains in State 2 if the battery SOC is between 50% and 75%. It goes to State 3 if the SOC drops below 50% then goes back to State 1 when the SOC recovers to above 75%. From State 3, the system remains in State 3 when the SOC is below 55%. It enters State 2 when the SOC is between 55% and 75%, and goes back to State 1 when the SOC is above 75%.

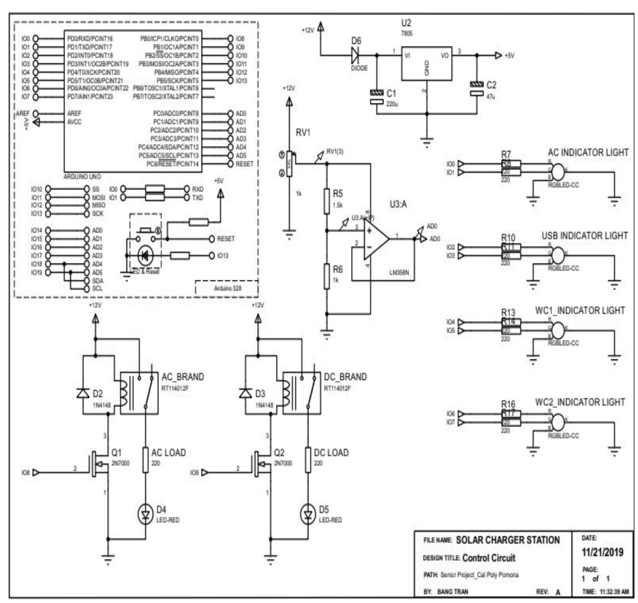
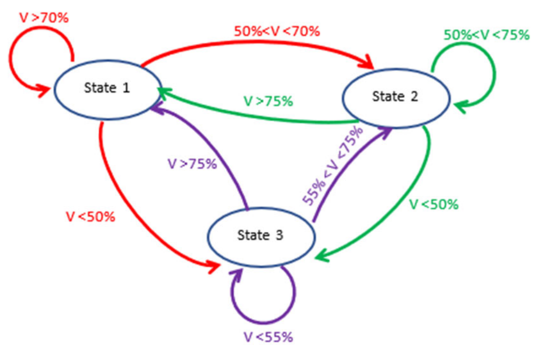


Fig. 2 Circuit design of controller



Note:

State 1: Turn ON both AC and DC loads

State 2: Turn OFF AC loads and turn ON DC loads

State 3: Turn OFF both AC and DC loads

Fig. 3 Finite state machine microcontroller logic

2.6 System protection

In accordance with NEC we implemented a fuse for public safety.

3. Implementation of charging station prototype and testing results

A prototype of the charging station is implemented as shown in Fig. 4 and its circuit is shown in Fig. 5.

Fig. 4 Charging station prototype

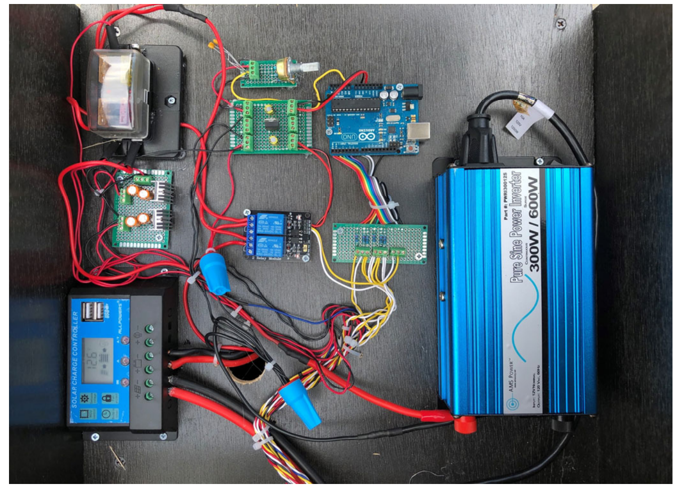


Fig. 5 Circuit of charging station prototype

We have performed various tests to verify if the prototype works properly and to evaluate its performance.

Wireless charging transmitter circuit test

Three transmitter circuits are tested and the results are provided in Table 1 through Table 3. We first tested our system using a one coil wireless transmitter circuit with a thick metal plate and found that it would charge a smartphone at a rate of 1% every five minutes (Table 1). Next, we tested our system with a one coil wireless transmitter circuit with a thin plate. We found that with a thin plate the charging rate increased to about 2% every five minutes but would revert to 1% after some time (Table 2). Finally, we tested our system with the three-coil wireless transmitter circuit and found that this circuit charged a smartphone at a rate of 3% every five minutes (Table 3).

Voltage regulator test

We tested a voltage regulator to step down the 12-V output of the battery to 5V for the wireless transmitter circuit. We found that its temperature would rise to a point that it would shut down to reduce the temperature and turn on again when the temperature was low enough. This made the voltage regulator unstable when connected to the wireless transmitter circuit. The current going through the coil was between 0.3 and 0.4A which was not enough to charge a smartphone.

We then tested a buck converter that would also step down the voltage of the battery but would not heat up as

Table 1 Charging speed of one-coil charging transmitter with thick metal plate

Time [min]	Percent Charged
0	74
5	75
10	76
15	77

Table 2 Charging speed of one-coil charging transmitter with a thin metal plate

Time [min]	Percent Charged
0	55
5	57
10	59
15	60

Table 3 Charging speed of three-coil charging transmitter

Time [min]	Percent Charged
0	65
5	68
10	71
15	73

quickly as the former voltage regulator. Hence, it is more stable than the voltage regulator. The current going through the coil was between 0.7 and 0.8A which is sufficient to charge the smartphone. However, when being integrated to the whole system the noise from the buck converter interfered with the relay switches. This caused a fluctuation in voltage that triggered the relay switches to turn on and off.

In the end we were able to obtain a voltage regulator that allowed more current to pass through. This solved the problem that we had before, giving us sufficient current passing through the coil to charge a smartphone. We also attached a heat sink to the voltage regulator. The heat sink helped dissipate any excess heat being produced by the regulator to prevent it from shutting itself down. This makes the voltage regulator stable without causing any noise-related interference with the relay switches. This test process gives us valuable experience concerning the voltage regulator selection and operation.

Microcontroller operation test

The first program that we implemented for our control system follows a simplified logic seen in Fig. 6. The logic works as follows. If the battery SOC is greater than 70%, the system turns on all outlets. If the SOC is less than 70% but greater than 50% the microcontroller turns off the AC outlets but leaves the DC USB ports and wireless chargers on. Finally, if the battery SOC is less than 50%, the microcontroller shuts down all outlets. Note that the depth of discharge of 50% is the limit for most deep-cycle batteries to preserve their lifespan.

The problem we faced when we tested this code with our entire system was that we did not consider when the battery transitions from one state of charge to another. This caused the relay switches turn on and off under the microcontroller command because of the battery SOC transition (e.g. from 70% to 69%).

The second program that we implemented to solve this issue uses finite states (Section 2.5) where the microcontroller monitors large or small changes in the battery SOC. By monitoring the changes, the microcontroller no longer directs the relay switches to turn on and off because of the battery SOC transitions. The control logic works accurately. The microcontroller program (code) is provided in the appendix.

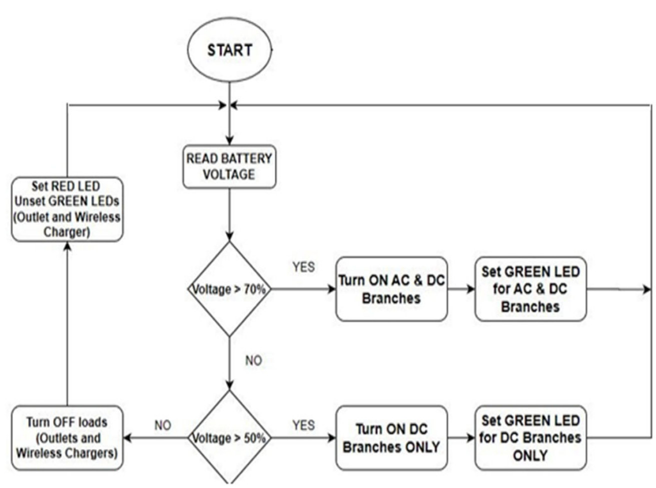


Fig. 6 Flowchart of microcontroller logic for testing

Complete system test

Due to financial constraint we used a 50-W Monocrystalline Silicon solar panel, which is smaller than our designed solar panel of 200W. We tested the station prototype under a full load of 150Wh (i.e. all outlets are used) with the solar panel and the battery operational on a sunny day and found that the system lasted until the sun is gone. For monitored duration from 11:00am to 1:00pm (3 hours) we observed that the battery had a constant voltage reading of about 12.7-12.8V.

Testing without the solar panel under the full load of 150Wh (2 laptops, 4 cellphones charged by USB ports, and 2 cellphones charged by wireless charging pads) and the battery voltage of 12.7V (i.e. fully-charged battery, see Table 7), the system lasted about 1.5 hours in total. The system first supplied the 150-Wh load for about 40 minutes, then the controller turned off the AC outlets at the battery SOC of 70% while continuing to supply the DC outlets. All outlets were turned off at the battery SOC of 50%. In other words, the station can continue to supply power for at least 1.5 hours after dark. It can last longer under partial load conditions (e.g. when it charges only cellphones, which consume less power compared to laptops). Overall, the system functions satisfactorily.

4. Conclusion

In this study, a solar-powered convenient charging station for charging mobile devices is designed. A prototype of the station is implemented and tested to evaluate its functionality and performance.

The system key design parameters are as follows: 200-W solar panel, 12-V 900-Wh deep-cycle lead acid battery, 300-W 120-VAC pure sine-wave inverter, and 8 outlets (2 wireless, 4 DC USB and 2 AC). The station aims to supply an average load of 175Wh. Based on the testing results, a number of conclusions are made, as following:

1) The system operates according to the design where all outlets work properly.
2) The control system switches the outlets on and off accurately based on the battery state of charge to preserve its lifespan.
3) On a sunny day, with the solar panel and the battery operational, the system can supply a full load of 150Wh until the sun is gone. When operating without the solar panel using the fully-charged battery, the system can last for at least 1.5 hours. It can last longer under partial load conditions.

In terms of broader impact, we expect that our study results and experience will help develop similar charging stations to provide green solar power to people in a convenient manner. This, in turns, helps promote the use of solar power which lowers carbon emissions and protects our environment.

In terms of future work, we wish to further improve our station by increasing the charging speed of the wireless charging pads. In addition, we aims to optimize the controller code so that the microcontroller can communicate with the relay switches more efficiently.

Appendix

A. Cost of components

Table 4 Cost to build the prototype

Item/ Quantity	Description	Price
Arduino Uno R3 / 1	Microcontroller	$15.82
Pure Sine Wave Inverter / 1	DC to AC Converter	$85.00
BreaDeep Universal Dual USB Charger Socket / 2	5V/3.1A Waterproof Power Outlet	$9.46
GFCI Outlet / 1	125 Volt Weather-Resistant Receptacle	$12.99
TayMac / 1	Mount Weatherproof In-Use Cover	$10.03
Bewinner Qi Standard Wireless Charger / 2	Three coil wireless charger transmitter circuit	$12.59
Mono Solar Panel / 1	50W Monocrystalline Module	$60.99
PWM Charge Controller / 1	Solar Panel Battery Intelligent Regulator	$18.99
Giantex 6 Person Wooden Picnic Table / 1	Used to design the charging station	$155.99
Solar Panel Mounting Bracket / 1	Used to attach the solar panel to the pole	$47.97
12V 24M Duracell Ultra Deep Cycle Battery / 1	Battery to store power for the system	$89.99
	Total:	**$519.82**

Note: There were some smaller items that were not recorded on this table. Incorporating these items increases the total cost to about $650.

B. Specifications of components

Table 5 Specification of solar panel

Characteristics	Details
Power Output	50W
Maximum Power Voltage [Vmpp]	17.00V
Maximum Power Current [Impp]	2.94A
Open Circuit Voltage [Voc]	20.23V
Short Circuit Current [Isc]	3.12A
Temperature Coefficient of Voc	-(80±10)mV/ °C
Temperature Coefficient of Isc	(0.065±0.015)%/°C
Temperature Coefficient of Power	-(0.5±0.05)%/°C
STC	1000W/m^2 Irradiance
Cells	Monocrystalline Silicon
Weight	7.72 lbs.
Dimension	23.07x19.88x1.88 in

Table 6 Specification of battery

Characteristics	Details
Brand	Duracell Ultra
Voltage	12V
Format	BCI Group 24M
Lead Acid Type	Deep Cycle
Capacity	75Ah
Cold Cranking Amps	615A
Chemistry	Lead Acid
Lead Acid Design	Flooded
Product Category	Marine R/V
Terminal Type	DT, SAE/M9 Threaded Post WNT
Weight	46 lb.
Length	10.75in
Width	6.75in
Height	9.375in

Table 7 Approximate battery voltage for various states of charge

State of Charge (Approx.)	12 V Battery
100%	12.70
90%	12.50
80%	12.42
70%	12.32
60%	12.20
50%	12.06
40%	11.90
30%	11.75
20%	11.58
10%	11.31
0%	10.50

Table 8 Specification of inverter

Characteristics	Details
DC input/Operating Voltage	10 to 15V
Output Voltage	120 V AC
Output Voltage Regulation	+/- 3%
Output Frequency	60Hz +/- 2%
DC amps	25 AC amps: 2.5
Battery low voltage alarm	10.5 +/- 0.5V
Battery low voltage shutdown	10.0 +/- 0.5V
No load power consumption	< 0.7 DC amps
Full load efficiency	90%, 1/3 load eff.: 95%
No load minimum operating temperature	50°F
Full load maximum operating temperature	145°F (automatic shutdown)
AC Output Socket Type	Single Type 2 -3 prong + USB Output
High input voltage protection	15V
Low input voltage shutdown	10V
Size (DxWxH)	7.25"x3.65"x2.2"

Table 9 Specification of wireless charger

Characteristics	Details
Plate Frame Size	104*52*1mm / 4*2 *0.03 in
Coil Size	approx. 92 * 52 * 2mm / 3.6 * 2 * 0.07 in
Light Indication	Breathing light
Launch Distance	5-10mm
Charging Current	1000mA
Wireless Charging Output	5V/1A
Boost Efficiency	93%
Working Frequency	110-205KHZ
Wireless Charging Conversion Efficiency	75%
Compatible with QI Standards	WPC1.1

Table 10 Sun hours for cities in California [26]

City	Summer Average	Winter Average	Year Average
Davis	6.09	3.31	5.1
Fresno	6.19	3.42	5.38
Inyokern	8.7	6.97	7.66
La Jolla	5.24	4.29	4.77
Los Angeles	6.14	5.03	5.62
Riverside	6.35	5.35	5.87
Santa Maria	6.52	5.42	5.94
Soda Springs	6.47	4.4	5.6

C. Equations

From Table 10, using the year average values to find the average sun hours in California as a whole. While considering the city of Inyokern as an outlier.

$$(5.1 + 5.38 + 4.77 + 5.62 + 5.87 + 5.94 + 5.6)/7 = 5.468hr$$

$$\approx 5.5hr$$

Estimated Power Produced by 200W Solar Panel:

P=200W*(5.5hours) = 1100Wh

Based on the Public Transportation data for Yosemite National Park an average of 17 people wait for the shuttle. On average Yosemite shuttles serve 3.7 million people yearly.

p=People who use the shuttle daily=3.7million per year * 1year/365days≈ $10137\ use\ the\ shuttle\ daily$

n=number of shuttles in operation daily=27 shuttles

s=number of stops the shuttle takes=22 stops

$$A = \frac{p}{n * s} = \frac{10137}{27 * 22} = 17.07 \approx 17\ people$$

A=Average of people waiting for the shuttle

Calculation of average load, assuming all the outlets of the system are in use at the same time, is as follows:

Min = (60Wh Laptop Charger) + 4*(10Wh USB Charger) + 2*(5Wh Wireless Charger) = 110Wh

Max = (150Wh Laptop Charger) + 4*(15Wh USB Charger) + 2*(15Wh Wireless Charger) = 240Wh

Average load = (110Wh + 240Wh)/2 = 175Wh

D. Program for microcontroller

```
/* Main.ino file generated by New Project wizard
 *
 * Created:   Sat Oct 19 2019
 * Modify :   Sun March 29 2020
 * Processor: Arduino Uno
 * Compiler:  Arduino AVR (Proteus)
 */
 void full();
 void half();
 void empty();
 float check_voltage();

 int Red_AC = B00000001;
 int Green_AC = B00000010;
 int Red_DC = B01010100;
 int Green_DC = B10101000;
 int var;
 float voltage;
 int state = 1;

void setup()
 { // put your setup code here, to run once:
 DDRD = B11111111;
 DDRB = B00111111;
 DDRC = B00000000;

 }
void loop()
 { // put your main code here, to run repeatedly:
  voltage = check_voltage();
 if (state == 1) //state 1_AC+DC loads
 {
  full();
 if (voltage>0.97) //70% of full
   {state = 1;}
 else if (voltage>0.93)//50% of full
   {state = 2;}
 else
   {state = 3;}
 }
 else if (state == 2)//state 2_DC loads
 {
  half();
 if (voltage>0.99) //75% of full
   {state = 1;}
 else if (voltage>0.93)//50% of full
   {state = 2;}
 else
   {state = 3;}
 }
 else if (state == 3)// state 3_No load
 {
  empty();
 if (voltage>0.99) //75% of full
   {state = 1;}
 else if (voltage>0.95)//55% of full
   {state = 2;}
 else
   {state = 3;}
 }
 else {}
 }//end of main
// measure % voltage compare to full
float check_voltage()
{
 int var;
 int sum = 0;
 float voltage;
 for (int k = 0; k<32 ; k++)
 {
 var = analogRead(A0);
 sum = sum +var;
 }
 voltage = sum/32.0/1024.0;//12.3 is full
 return voltage;
}
// AC+DC loads
void full()
 {//full load (greater than 50% battery)
  PORTD = (Green_AC|Green_DC);
  PORTB = B00000000;
 }
//DC load
 void half()
 {//less 50% and greater 30% of battery
```

```
  PORTD = (Red_AC |Green_DC);
  PORTB = B00000001;
 }
//No load
 void empty()
 {//less than 30% battery
  PORTD = (Red_AC |Red_DC);
  PORTB = B00000011;
 }
```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