**Memo**

To: Professor Pisano

From: Jessica Cadreau, Jennifer Fong, Cameron Graves, Makenna Hart, Steven Li

Team: Sweet City: Team 20

Date: 3/31/17

Subject: Sweet City Functional Deliverable Test Plan



1. **Customer Requirements**

**1.1 Safety**

Due to the interactive nature of the project, we are heavily concerned with the safety aspects. This requires DC voltage to remain under 15V and DC current to remain under 300mA in any customer exposed areas. In the final product, there should be no excessive or loose wires.

**1.2 Customer Interaction**

The overall project must be an interactive exhibit. This requirement has been satisfied on a per module basis. The solar module includes light filters that can be used to vary power output from the solar panels. By changing filters, the customer can simulate different weather patterns or time of day. This will vary the module’s visual load.

The wind module allows NG customers to change blade types. Similar to the solar module interaction, changing the blade will vary the turbine power output. Increasing or decreasing the power output will respectively brighten or dim the visual load.

The energy efficiency module uses a switching circuit to flip between incandescent and LED stadium lights in a scale model of Fenway Park. There are two switches that the customer can use to control the circuit. The first switch controls the power to the entire circuit. If the customer flips the second switch, they toggle between the two bulb types.

The final module, Smart Grid, allows the customer to trigger a blackout and watch the response. The user is able to create a “fault point” by opening a transmission line. Once the transmission line is opened, the grid reroutes power and begins to turn back on. Once the grid is 75-80% back on, the user can manually restore the fault point and the grid will be fully restored.

**1.3 Displays**

Four displays are required for the final product. Each module displays its relevant information and one larger display gives broad project information. The solar and wind module each display how much power is generated by the solar panels or wind turbines. The energy efficiency module displays power consumed by the LED and incandescent lights. The Smart Grid module contains its own display as well as the overall project information. This display shows the blackout response time, number of customers in the city, the number of customers out of power, Boston’s energy need, the city’s “Green Percentage” at the time.

**1.4 Mobility**

The SWEET City exhibit will mainly be on display at the National Grid Sustainability Hub in Worcester, but there are times it will be brought to other locations. Due to the possibility of location changes, the exhibit must split into two separate pieces and weigh no more than 30 pounds. An aluminum extrusion frame is used to keep the project sturdy while also keeping weight down.

**1.5 Theme and Branding**

The final product requires National Grid branding as well as an overall Boston theme. The branding will consist of National Grid color schemes and stickers. This will be applied after the exhibit is fully constructed. The Boston theme shows up in every module of the project with iconic landmarks such as the Rainbow Swash liquid natural gas tank in Dorchester, the Citgo Sign in Kenmore Square, Fenway Park, and the Prudential Center.

1. **Energy Efficiency Module**

**Description and Goal:**

The energy efficiency module is composed of a switching circuit. Two push button switches toggle between incandescent and LED lights. The module now fulfills project requirements of interaction and a visual load.

The overall goal of this module is to demonstrate differences in power consumption for the two bulb types. The end result will show National Grid customers the major impact of using LEDs instead of incandescent lights. Switching to LEDs not only helps the environment by significantly reducing power consumption, but can also lower a customer’s monthly electricity bill.

Completion of this energy efficiency module is another major milestone in the overall project. It is one fourth of the project circuitry. Since we can accurately depict having a button triggered and a corresponding light turn on, we can expand the circuit to potential add ons in the final product. The difference in power by using LEDs over incandescents may be used to power a model Green Line train. In addition to the circuitry, a raspberry pi code can measure and display the power consumption of the two light types.

**Procedure:**

To achieve the desired brightnesses and switching mechanisms, apply an 8V DC source to the circuit. There are two push button switches that control separate transistors and the lights themselves. The first switch is a universal on-off switch. To turn on either light set, button 1 must be pushed. When pressing button 1, a voltage is applied to an incandescent bulb as well as one side of the second switch. Pressing button 2 shuts off the incandescent bulb and turns on a white LED. Releasing the second button will turn the incandescent bulb back on, while shutting off the LED. Releasing the first button will stop the current flow to the entire circuit, which shuts off the light that was on at the time.

**Verifiable Result:**

The energy efficiency module will be considered successful if:

* Pressing button 1 lights the incandescent bulb
* Pressing buttons 1 and 2 switches from incandescent to LED
* Not pressing a button keeps both lights off
* Only one set of lights is on at a time

The button press switching mechanism achieves the “interactive” requirement for the module while also having a visual load of either an incandescent or LED. This circuit and the supplementing LCD displays help show National Grid customers the effectiveness of using LED light bulbs in their homes.

**3.0 EE Simulation and Display**

**Description and Goal:**

The Energy Efficiency module requires a simulation of power consumption by the LED and incandescent light bulbs. Although the data could be read directly from the circuit itself, a simulation has been made in order to show customers consistently the effect of using LEDs over incandescent light bulbs.

The overall goal of the simulation is to display power generated by the LED or incandescent when a button is pushed. By finishing the simulation for this module, this module will almost be complete. The only tasks left will be to build Fenway and add the finishing touches.

Every module requires a display showing power generated, consumed, or other data about the Smart Grid. Since the LCDs on the Wind, Solar, and Energy Efficiency Module are the same, figuring out how to display data for one module makes it easy to display data for the others. Since the Smart Grid display is much more difficult, knowing the basics will help with displaying more data on a larger screen.

**Procedure:**

The display code of the raspberry pi runs on a continuous loop waiting for a change in input. Applying to the energy efficiency module, a “button press” triggers the display of power consumption. Pressing another button, which switches bulb types, triggers a change in display to account for the new power consumption. Release of button 1 results in a display of 0W.

Press button 1: Display power consumption of incandescent bulbs

Press buttons 1 and 2: Display power consumption of LED

Release button 1/No button pressed: 0 W

**Verifiable Result:**

The simulation and display will be deemed successful if the LCD displays the correct corresponding values when the buttons on the Energy Efficiency circuit are pressed.

The display portion will be considered successful if:

* Pressing button 1 displays the power consumption of the incandescent bulb
* Pressing buttons 1 and 2 displays power consumption of the LED
* Not pressing a button displays “no button pressed”

These values can later be verified by measuring voltage and current with a multimeter and calculating power by hand.

**4.0 Solar Module**

**Description and Goal:**

To complete the Solar Module, two solar panels are powered using a 60W light. As the light from the bulb is blocked (as the sun would be by clouds or night,) an LED light strip will dim accordingly. The LED strip is attached to a small scale model of the “Rainbow Swash” liquid natural gas tower in Dorchester.

The overall goal is to display solar power generation to National Grid customers and allow them to actively vary a visual load. Varying the output voltage is done by covering the 60W light using provided films. Different lighting films will allow varying amounts of light through. This simulates different weather patterns or a setting sun.

**Procedure:**

To achieve the desired source voltage of between 9 and 10V, the solar panels must be wired in series. To do this, attach the positive terminal of solar panel 1 to the negative terminal of solar panel 2. The negative terminal of solar panel 1 is then connected to the negative terminal of the LED strip. The positive terminal of panel 2 connects to the positive terminal of the LED strip. With standard room lighting, the panels only supply ~7V, which is not enough to power the load. The module includes a 60 watt light to fully power the panels and drive the LED display.

**Verifiable Result:**

By supplying over 8V using the 60W light, the LEDs are lit. Placing lighting filters over the light varies the supply voltage. This, in turn, actively changes LED brightness. This achieves the “interactive” requirement for the module while also using a visual load to show National Grid customers the effects of light on solar panel output.

**5.0 Wind Module**

**Description and Goal:**

The wind module consists of a wind turbine with varying wind speeds. Wind produced from hair blow dryers will spin the blades and generate power. This generated power is used to power a model of the Citgo sign in Kenmore Square. Using different speeds the power generated by the turbine will fluctuate and the LEDs in the visual load will change brightness levels.

**Procedure:**

The parallel LED load is set in series with a current limiting resistor to keep the LEDs from burning out. The load runs in parallel with a voltage divider used as a reference voltage for data acquisition. Currently the wind turbine only produces 700mV, in order to get a higher voltage we will be using an inverting amplifier to give us a higher output voltage and power the visual load.

**Verifiable Result:**

Changing the speeds on the blow dryers allows you to vary the voltage being outputted by the generator allowing the user to see how wind speed and angles can affect how much power is being generated. Doing this achieves the interactive goal we set earlier.

**6.0 Data Acquisition - Solar and Wind**

**Description and Goal:**

The Raspberry Pis for the Solar and Wind modules have a maximum pin input of 3.3V. Since the solar panels and wind turbines output up to 12V, the circuitry of each module uses a voltage divider to step down the input voltage to usable levels. The Pi measures a stepped down voltage which is then scaled back up to the true value and is used to calculate power.

Calculating current in addition to voltage, uses too many gpio pins on the Pi. To avoid current measurement, manual testing has resulted in a diode current equation. The measured voltage and calculated current based on this voltage are used to calculate power generated by the solar panels. The power display will be scaled to realistic city value.

**Procedure:**

When the LEDs are lit, the desired output voltage of the solar panels or wind turbines is in the 9 to 12V range. Since the maximum pin voltage of the Raspberry Pi is only 3.3V, the Pi is connected in parallel to a voltage divider. It takes the stepped down analog input and converts this to a digital value using an ADC. The program designed for this module then converts the number back to its original input and stores this as a voltage variable. This is then used to calculate power which is displayed on the module’s LCD screen.

**Verifiable Result:**

The voltage value of both the original input and scaled down value should be printed on the computer screen. This value should also change based on the films being placed over the solar panel or changing the wind turbine blade. The calculated power generation will display on the module’s LCD screen.

**7.0 Smart Grid Module**

**Description and Goal:**

The Smart Grid Module consists of a grid split into quadrants. The quadrants contain LEDs that light buildings in a model of Boston. Originally, the buildings are lit and the grid has no issues. A National Grid Customer can then create a “fault point” by opening the circuit at a transmission line. Once the fault point is created, the grid will go into a blackout. After a set time interval, the grid will reroute power and come back on slowly.

**Procedure:**

The visual LED loads are broken into separate quadrants. Each LED in a quadrant is wired in parallel. This allows the circuit to function even if one of the LEDs is damaged. After opening the connection at the set fault point, the raspberry pi reads a digital 0. This shuts off the pins being used as voltage sources. After a set time interval (3< t <8 seconds,) the grid will begin to restore power. The quadrants will come on separately, at a the randomized time interval between 3 and 8 seconds. The final quadrant will not turn back on until the fault point is manually fixed by the customer.

**Verifiable Result:**

The Smart Grid Module will be considered successful if the user can trigger a blackout by breaking the specified connection. After the grid has gone out, it should begin to light up in the specified time interval. Once the user fixes the fault point by completing the circuit, the final quadrant will come back on.