Subsystem Test: Solar Panel -> MPPT -> Battery

Conducted by: William Dorney
Date of Test: 4/7/12

Objective

The purpose of this sub system test was to ensure the solar panel could collect enough energy to fully charge the battery. Also, proper operation of the MPPT as it progressed through its various charging modes was observed.

Theory

On 4/7/12 in Rochester NY the sunrise was at 6:41 AM and the sunset was at 7:44 PM. Solar Noon occurred at 1:12 PM. Solar noon is the time at which the sun is at its highest elevation in the sky and depends on longitudinal location and date.

The load power requirements have been set to **2.0125W**. In order to closely represent a proper load, a 73.5Ω resistance value was used.

Power is calculated using Equation 1:

$$P = V * I \quad (1)$$

Ohms law is stated in Equation 2:

$$V = I * R \quad (2)$$

Battery starting voltage of 11.39V. Load resistance of 73.5Ω.

$$I = \frac{V}{R} = \frac{11.39V}{73.5\Omega} = 0.155A$$

$$P = 11.39V * 0.155A = \mathbf{1.77W}$$

Battery final voltage 12.59V. Load resistance of 73.5Ω.

$$I = \frac{V}{R} = \frac{12.59V}{73.5\Omega} = 0.171A$$

$$P = 12.59V * 0.171A = \mathbf{2.15W}$$

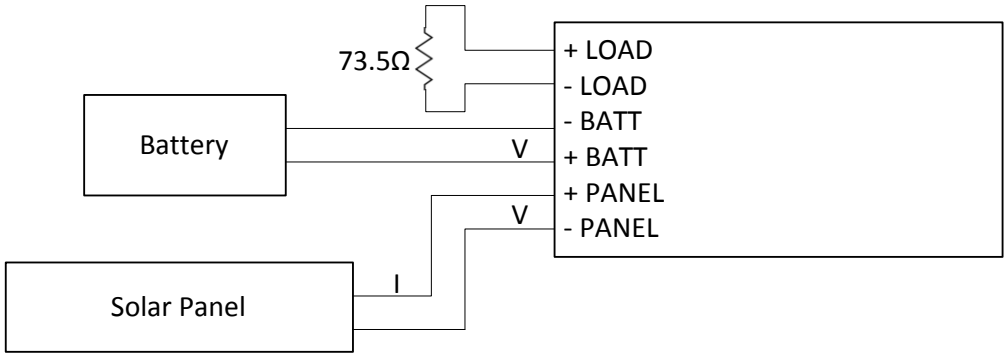

Figure 1: Block diagram of testing apparatus.

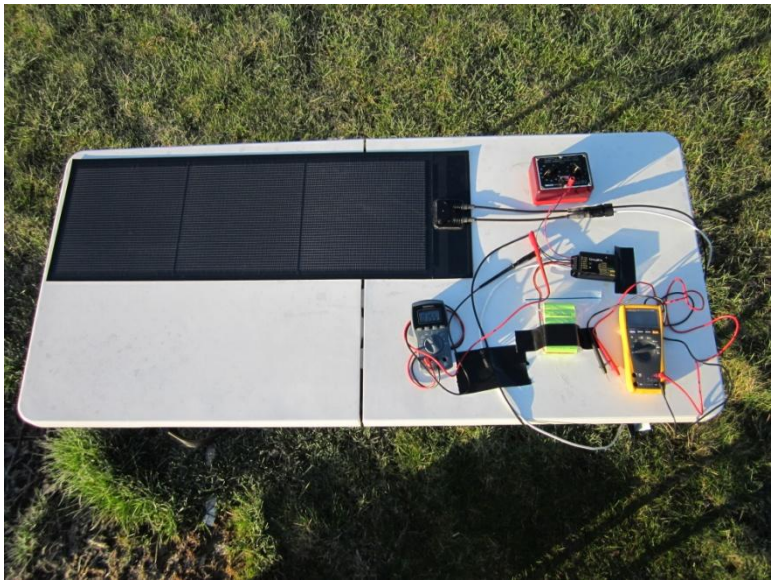
Figure 2: Picture of testing apparatus.

Units Under Test:

Solar Panel

Ascent Solar, WSLE-0240-024

MPPT & Battery Charger

Genasun, GV-5-Li-12.5

Battery

AT: Tenergy Li-Ion 18650 11.1V 10400mAh Rechargeable Battery Pack w/ PCB Protection (DGR-A)

Equipment:

Digital Multimeters, Decade Box

Results

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Voltage (V)	MPPT Indicator
7:30 AM	11.4	0.13	1.48	11.39	Standby
8:00 AM	11.45	0.26	2.98	11.44	Standby
8:30 AM	17.8	0.38	6.76	11.56	Medium Current
9:00 AM	18	0.52	9.36	11.65	Medium Current
9:30 AM	17.7	0.65	11.51	11.71	Medium Current
10:00 AM	17.7	0.76	13.45	11.76	Medium Current
10:30 AM	17.1	0.87	14.88	11.84	Medium Current
11:00 AM	17.4	0.95	16.53	11.96	Medium Current
11:30 AM	17.3	1.03	17.82	12.09	Medium Current
12:00 PM	17	1.08	18.36	12.27	Medium Current
12:30 PM	17.3	1.12	19.38	12.47	Medium Current
1:00 PM	20.39	0.72	14.68	12.59	Fully Charged
1:30 PM	21.5	0.38	8.17	12.59	Fully Charged
2:00 PM	21.7	0.22	4.77	12.58	Fully Charged

Table 1: Data collected during test

The power generated by the solar panel becomes useable starting at 8:30 AM. At that point the MPPT switches from a *Standby* mode to a *Charging at Medium Current* mode. This continues until 1:00 PM when the battery has been *Fully Charged*.

After the battery is fully charged the MPPT continues to trickle charge the battery. Without a substantial load, the solar panel power cannot be measured accurately. As a result the last accurate power recording was at 12:30PM.

Since the sun follows a symmetric path from sunrise to solar noon to sunset. Power measurements conducted between sunrise and solar noon can be extrapolated to reflect the power between solar noon and sunset. With solar noon occurring at 1:12 PM and the last accurate power recording being at 12:30 PM, an extrapolation of power over a full day was obtained with an approximated solar noon of 12:30 PM. Since there is a the 42 minute difference between the true and approximated solar noon times, the total power results using this method are slightly lower than the actual power recordings would be.

Figure 3: Sky from solar panel's perspective taken at 7:30 AM. Solar panel power of 1.48W.

Figure 4: Sky from solar panel's perspective taken at 8:30 AM. Solar panel power of 6.76W.

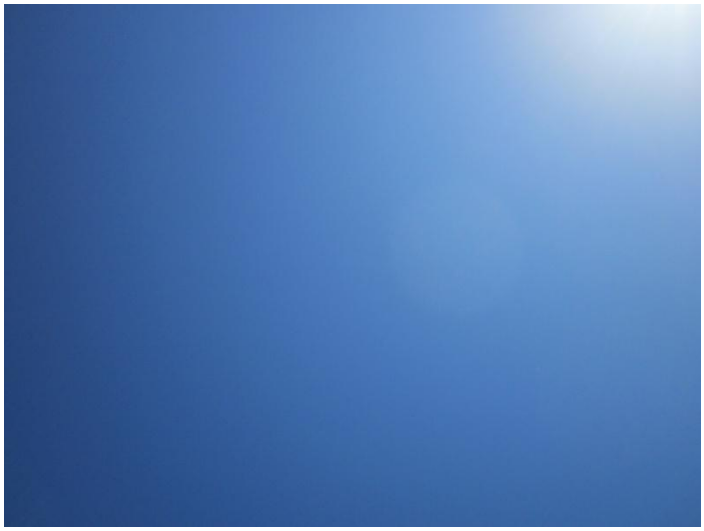

Figure 5: Sky from solar panel's perspective taken at 12:30 PM. Solar panel power of 19.38W.

Time (EDT)	Temp.	Windchill	Dew Point	Humidity	Visibility	Conditions
6:54 AM	32.0 °F	26.4 °F	25.0 °F	75%	10.0 mi	Clear
7:54 AM	36.0 °F	30.3 °F	28.0 °F	73%	10.0 mi	Partly Cloudy
8:54 AM	42.1 °F	37.7 °F	28.9 °F	60%	10.0 mi	Partly Cloudy
9:54 AM	45.0 °F	40.6 °F	23.0 °F	42%	10.0 mi	Partly Cloudy
10:54 AM	48.0 °F	-	18.0 °F	30%	10.0 mi	Partly Cloudy
11:54 AM	50.0 °F	-	15.1 °F	25%	10.0 mi	Partly Cloudy
12:54 PM	51.1 °F	-	12.9 °F	22%	10.0 mi	Partly Cloudy
1:54 PM	53.1 °F	-	14.0 °F	21%	10.0 mi	Partly Cloudy

Weather for West Henrietta NY on 4/7/12
http://www.wunderground.com/history/

Time	**Expected Equinox 3/20/12 Power (W)**	**Measured & Extrapolated 4/7/12 Power (W)**
7:30 AM	4.86	1.48
8:00 AM	7.18	2.98
8:30 AM	9.38	6.76
9:00 AM	11.42	9.36
9:30 AM	13.27	11.51
10:00 AM	14.88	13.45
10:30 AM	16.25	14.88
11:00 AM	17.33	16.53
11:30 AM	18.12	17.82
12:00 PM	18.60	18.36
12:30 PM	18.76	19.38
1:00 PM	18.60	18.36
1:30 PM	18.12	17.82
2:00 PM	17.33	16.53
2:30 PM	16.25	14.88
3:00 PM	14.88	13.45
3:30 PM	13.27	11.51
4:00 PM	11.42	9.36
4:30 PM	9.38	6.76
5:00 PM	7.18	2.98
5:30 PM	4.86	1.48

Table 2: Expected power as well as Measured and Extrapolated power over one day.

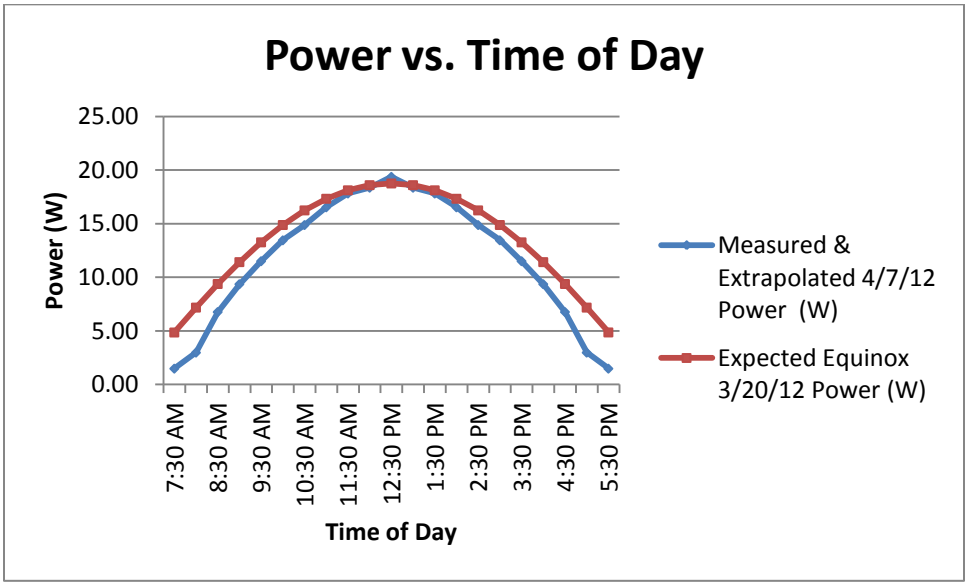

Figure 6: Power vs Time of Day for Expected power as well as Measured and Extrapolated power.

In order for the MPPT to work properly the input voltage from the solar panel must be above the 12.5V battery voltage. Thus, charging did not commence until 8:30 AM. During an 8 hour period of adequate sunlight from 8:30 AM to 4:30 PM the amount of energy collected was **118 W*hr**. This is close to the expected equinox value of 129 W*hr. Table 2 and Figure 6 display the similarities between expected and measured results. The energy required by the NSSPCM of the solar panel is **81.48 W*hr**. Thus, the subsystem can collect 36.52 W*hr more energy than required.

Conclusions

Overall this subsystem test proved that charging the battery using the MPPT battery charger and solar panel selected was indeed possible. Also, the system has enough energy harvesting capability to satisfy the needs of the NSSPCM. Originally the plan was to first drain the battery down to 9.3V then complete a full charge during the course of the day. However, sometime between 3/30/12 and 4/7/12 the battery packs protective module opened the batteries output. Measuring the battery voltage gave readings of 0V. After further research into the operation of these protective circuits it was found that simply charging the battery should bring it back to normal and reset the protective circuit. Once the solar panel, MPPT, and battery were all connected the battery did resume back to normal. As a result the starting voltage of the battery was 11.39V and it reached a full charge by 1:00 PM. Since the solar panel power cannot accurately be measured after the battery has been fully charged, the test was cut short. Luckily, enough data had already been collected to verify the subsystem will work.

Upon completion of the entire NSSPCM there are some key power tests still to be conducted. This includes going through several night and day power cycles. Also, adverse weather conditions and cloud cover should be tested for.