OBSERVATIONS OF THE 2017 TOTAL SOLAR ECLIPSE ON SOLAR PANEL VOLTAGE OUTPUT AT THE STARR RIDGE, OREGON SNOTEL SITE AND ON A HOME SOLAR ARRAY IN NORTHERN CALIFORNIA

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ABSTRACT

The August 21, 2017 total solar eclipse which crossed the United States, offered an opportunity to observe the effect on the voltage output of a SOLAREX MSX-10, a 10-watt solar panel, located at the Starr Ridge, Oregon SNOTEL site. The panel was placed on the ground at a 10 percent angle, and aligned such that at the start of the eclipse the face of the panel was perpendicular to the sun, and would remain in full sun for the duration of the eclipse. Observations were taken at approximately 5 to 10 minute increments with a small handheld volt meter. Data points showed the drop and recovery of the panel output voltages during the eclipse. Panel output declines became most pronounced beginning at 87 percent eclipse coverage of the sun. Recovery of the panel output to voltage levels capable of providing charge to batteries occurred at 2 minutes after the conclusion of the total eclipse. Similar concurrent observations were taken on a home installed 32 panel solar photovoltaic (PV) network located in northern California. The eclipse effect on both voltages and the wattage produced by the panels were observed, and monetary losses calculated. (KEYWORDS: total solar eclipse, SNOTEL, solar panel, voltage output, Oregon)

INTRODUCTION

The occurrences of total solar eclipses offer rare opportunities to study many physical processes which rely on radiation from the sun. On August 21, 2017, a total eclipse of the sun, as defined by NASA as SAROS Series 145, Sequence number 09546, (NASA 2017), traversed the entire continental United States from the Oregon Coast in the west to the South Carolina coast in the east (see Figure 1).

The last total solar eclipse visible in the United States, was February 26, 1979 (Berman 2017), and since that time, much has changed, not only in the methods and techniques to study the eclipse phenomena, but also in the field of the production of electrical energy from solar photovoltaic (PV) panels. One of the uses of solar power at remote locations would include the SNOw TELemetry (SNOTEL) data collection network operated by the Unites States Department of Agriculture, Natural Resources Conservation Service. The footprint of the August 21, 2017 eclipse traveled across 77 SNOTEL sites in Oregon, Idaho and Wyoming, providing a unique opportunity to conduct observations of the effects of the eclipse. (Figure 1). No operational issues were expected to hamper the network sdue to the short duration of the total eclipse, since the network is designed to provide battery power in low to no light conditions. However, a review of the literature on the effect of a total eclipse on the SNOTEL network revealed no previous studies had been conducted.

In addition to the potential impact the eclipse would have on the PV's to operate many remote data collection networks, the August 21, 2017 eclipse event, would impact approximately 1900 utility scale solar PV installations, 17 of which will be in the path of the totality (EIA). System loads had to be balanced to cover the expected rapid loss and the equally rapid return of the solar component (SPP, 2017; Geggle, 2017; Assis, 2017; Cooper, 2017). To limit the scope for this study, two independent sets of observations were collected. For one portion of the field study, the voltage outputs from a solar PV panel were observed at a remote SNOTEL station, while in the second portion of the study, the voltage and wattage outputs from a commercially installed home solar

Eclipse Photo courtesy of Sean Lea.

Paper presented Western Snow Conference 2018
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PV array in the central valley of northern California were observed and the comparative loss of funds due to the eclipse calculated.

METHODS

For this study, in order to not impact the installation and operations of a functioning SNOTEL PV array, a retired SNOTEL solar PV panel was utilized. The location chosen to conduct this analysis, was the Starr Ridge SNOTEL site, located in central Oregon (Figure 1). The test solar PV panel was a SOLAREX MSX-10, 10 watt solar panel, which was retired from field use after 20 years of service. The panel was placed flat on the ground in an area which would be open to the sky for the entire duration of the eclipse. Then the panel was tilted and aligned until the voltage output was maximized. The specifications for the panel, indicated that the maximum unloaded voltage produced by the panel should be 21.1 volts (SOLAREX), however, as this panel had aged in field operation, the maximum voltages observed were 19.65 volts. In the final configuration, the panel was tilted 10 degrees up from the ground and the frame aligned in a general north to south direction. A simple digital hand held volt meter attached to the output leads was used to measure the voltage produced by the panel. Voltage measurements were taken at approximately 5- to 10-minute increments for the duration of the test (Table 1).

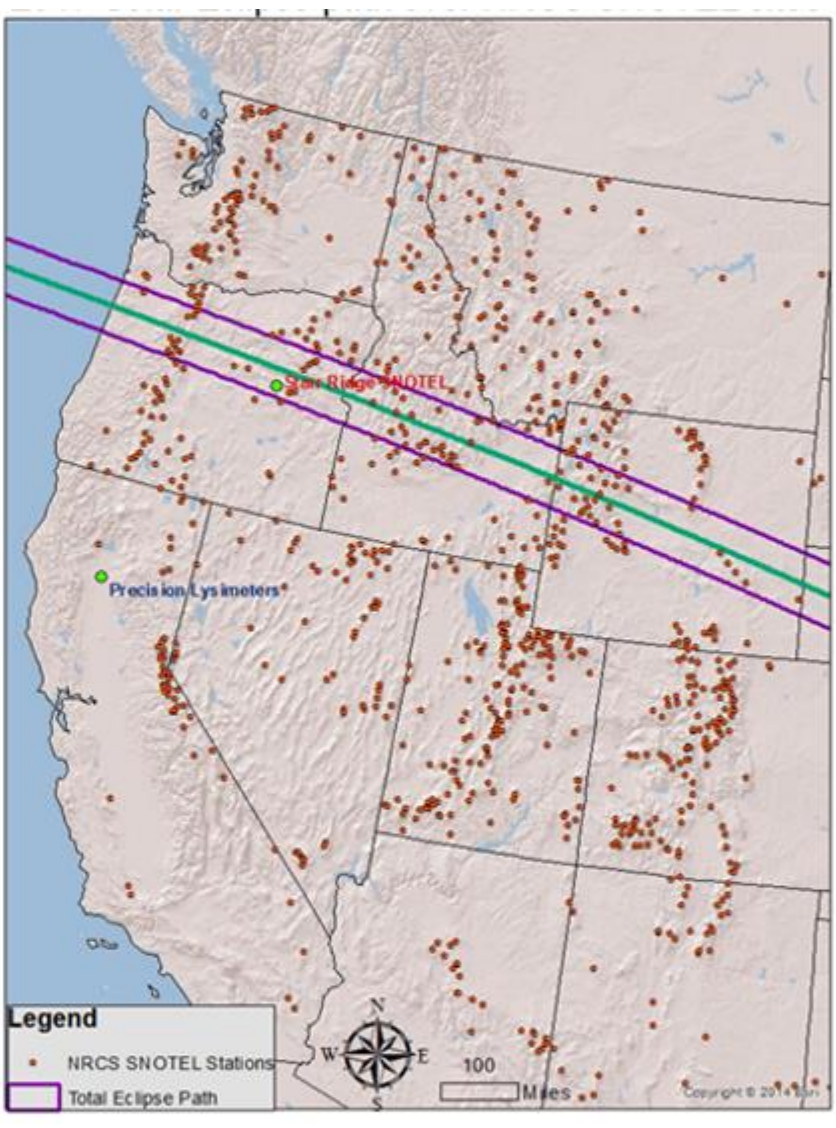


Figure 1. 2017 solar eclipse path over NRCS SNOTEL sites across the west

The second set of concurrent observations were taken from a commercially installed solar PV array at the home office of Precision Lysimeters, near Red Bluff in northern California (Figure 1). The network of 32 solar PV panels was installed in November, 2005 and produces approximately 10,000 kilowatt hours (KWH) of power annually. The PV panels are tilted 22 degrees off the horizontal and generally face to the south. Readings from the home network's voltage and wattages meters located at the grid connection would be recorded during the eclipse (Table 2). Due to operational limitations as a function of producing power for the local grid, voltages and wattages could not be observed until minimum of 300 watts were produced by the panel array. At this location, the eclipse was 85 percent of totality.

The basic voltage and wattage data were synchronized with the exact timing of the eclipse and the percent coverage of the sun for those locations utilizing the webpage sponsored by the

International Astronomical Union/NASA (Jubier, 2017). The data values were synchronized to the mid-point in the timing of the maximum duration, then applied to all the collected data in order to eliminate potential errors in observing the actual beginning of the visible eclipse.

Table 1. Solar Panel energy measurement changes during the solar eclipse on August 21, 2017 at Starr Ridge SNOTEL site in John Day, Oregon.

Starr Ridge, John Day Oregon		
August 21 minutes elapsed starting at 8:26AM	**volts**	**% Totality of the Eclipse**
0	19.65	0
22	19.18	0
22	19.27	0
27	19.23	0
29	18.95	0
32	19.91	0
39	18.72	0
42	18.7	0
44	18.52	2.7
52	18.48	13.47
67	18.28	33.68
77	18.33	47.16
87	18.15	60.63
92	17.91	67.37
102	17.32	80.84
107	16.4	87.58
109	14.96	90.27
110	13	91.62
112	10.64	94.32
113	3.14	95.66
116	0.25	99.7
117	0	100
118	0	100
119	6.67	98.76
120	12.63	97.52
122	15.72	96.28
124	17.2	93.8
129	18.32	87.61
134	18.94	81.41
144	19.2	69.01
151	19.11	60.34
165	18.85	42.99
198	18.35	2.08
199	18.33	0
214	18.15	0

Table 2. Solar Panel energy measurement changes during the solar eclipse on August 21, 2017 at Precision Lysimeters in Red Bluff, CA.

Precision Lysimeters Red Bluff, CA			
August 21 minutes elapsed starting at 9:02 AM	**volts**	**watts**	**% Totality of the Eclipse**
0		0	0
43	11.6	0	48.81
49	11.14	505	55.61
53	10.48	487	60.16
58	9.31	322	65.83
63	7.58	286	71.51
73	5.68	183	82.82
75	5.1	152	85.154
78	6.46	216	82
83	7.62	261	76.74
88	10.38	401	71.49
103	16.71	802	55.72
139	21.6	1529	17.87
156	21.65	1528	0
224	21.7	1527	0
284	22.8	1489	0
314	23.1	1542	0

OBSERVATIONS AND DISCUSSIONS

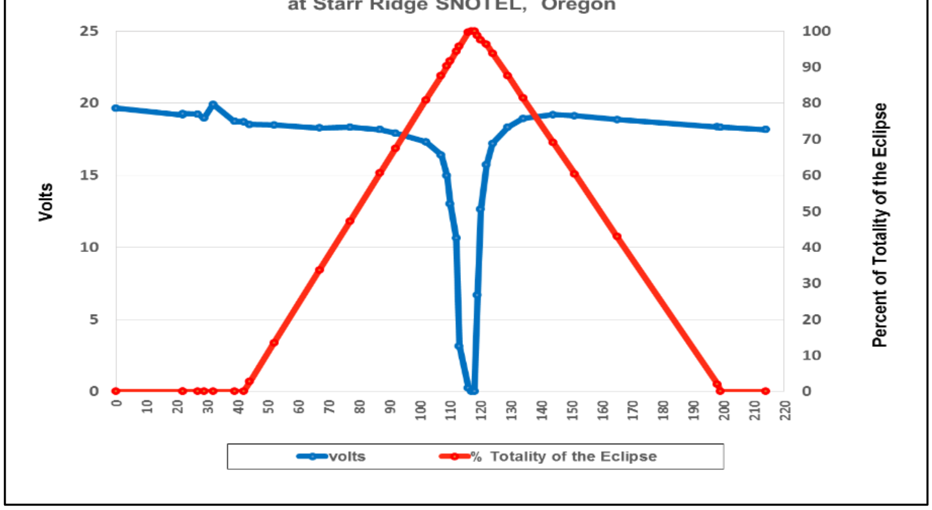
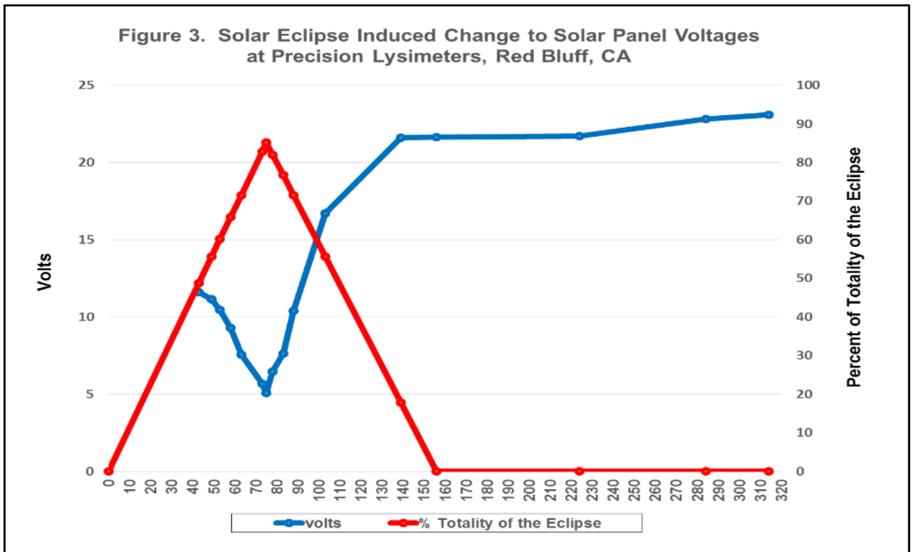


Figure 2. Solar Eclipse Induced Change in Solar Panel Volts at Starr Ridge SNOTEL, Oregon

Graphical representation of the collected voltage data from Starr Ridge SNOTEL site are presented in Figure 2. As soon as the observations began, before the eclipse, there was noticeable drop in the voltage reading at Starr Ridge, due to the fact that the geometrical relation of the panel to the sun was constantly changing. Since the initial setup of the test PV panel was conducted to optimize the output voltage at the time of set up, and there was no attempt to keep the panel aligned to maintain that optimal voltage, the output declined approximately 0.012 volts/minute (v/m) with the passage of the sun. Beginning at 47 percent coverage, there was an observer sensed drop in air temperature, which was also recorded on the temperature data at the SNOTEL site. Voltage outputs from the panel began to depart from the 0.12 v/m geometry observed decline at 60 percent coverage; by 67 percent coverage the rate of decline was 4 times the rate observed earlier; and by 87 percent coverage, voltages were decreasing at 1.87 v/m. At 91 percent coverage, the panel still produced 13 volts, but dropped to 0 in less than 7 minutes. Within 2 minutes of totality, the drop in voltage was about 0.03 volts per second. At totality, there was no output from the solar panel. On the recession of the eclipse, after totality, recovery of voltage production was very rapid at first.

Within a minute of end of totality, at Starr Ridge, the solar panel was producing 6.67 volts and by 2 minutes after totality, the panel was again producing at least 12 volts, and by the time the sun was 69 percent covered, 26 minutes past totality, voltage production had peaked at 19.2 volts.



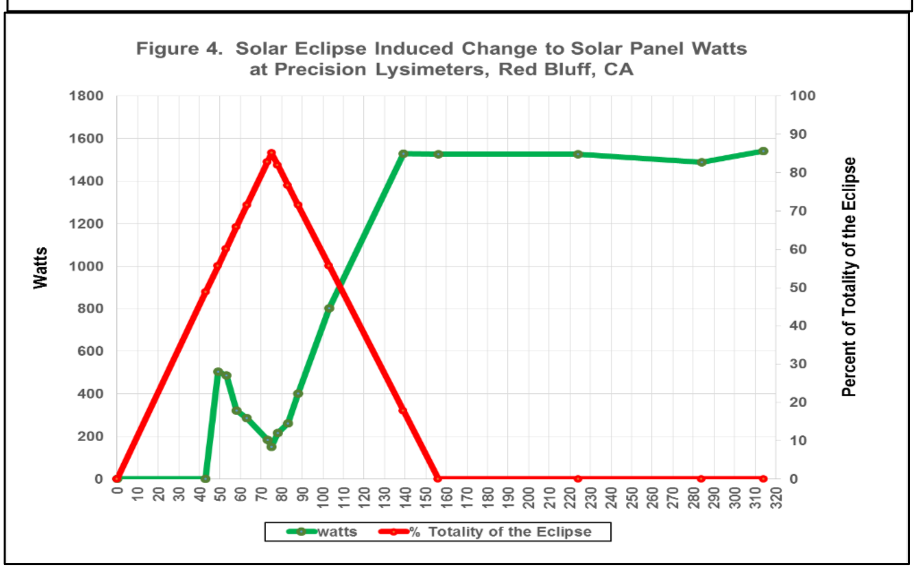


Figure 3 depicts the voltage observations at the N. California location, and Figure 4 displays the wattage measurements. Due to the operational limitations of the PV array, the first observed voltages were not available until the coverage of the sun was at 48 percent. With the larger surface area of the 32 panel array, voltage outputs were considerable different than those observed on the single panel. Declines in produced voltages were approximately 0.165 v/m until the sun was 50 percent covered. The rate of declined increase to 0.24 v/m at 65 percent coverage, and 0.29 v/m at 85 percent coverage of the sun by the moon, which was the maximum coverage of the eclipse at this location. Based on observations at Starr Ridge, more pronounced drops would begin at these approximate levels. As the sun coverage decreased after the maximum eclipse, voltages at this location continued to climb, rapidly at first, at 0.55 v/m, until 70 percent coverage. There was no observed drop in voltage which could be attributed to the panel geometry at this location. Calculations for the loss of the energy not delivered to the grid during the eclipse at the home solar array amounted to approximately .786KWH for the 2.5 hour long duration of the eclipse, which at the given payment rate of the time, amounted to an income loss of about $0.16

CONCLUSIONS

Hourly data of the internal battery voltage at the Starr Ridge SNOTEL during the eclipse showed no drop in internal voltages, indicating battery systems at Starr Ridge were in good operational order. This analysis supports the expectation that there would be no ill effects on the operations of a SNOTEL site during a total solar eclipse. It was interesting to note that even solar PV panels which had been in extensive field service are still able to produce voltages capable of maintain a minimum charge to the on-site battery system during a decrease of 90 percent of energy available from the sun. This would amount to only about 34 Watts/meter^2 based on the average amount of available energy at the earth's surface (ACS). Observing the drop of solar power, both from the movement of the sun and the drop during the coming eclipse darkness, reiterated the importance of choosing the correct directional location of a solar PV panel array to maintain voltage supplies necessary to keep batteries charged during changing daily and seasonal sunlight conditions.

Power grids were prepared for the eclipse, and had alternate energy sources available to customers. There were no shortages to the power grid. Monetary losses were relatively small especially at smaller home level of installations, but once applied to large-scale networks, the losses accumulated. In addition, the requirement to purchase additional power supplies or fuel for thermal sources would need to be recorded as a part of the operational cost incurred as a function of the solar eclipse.

ACKNOWLEDGEMENTS

The authors would like to thank the able field assistance provided by Eugenia McKenzie, Priscilla Lane-Lea, Sean Lea and Annie Humphrey

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