



California ISO

2017 Solar Eclipse Report

May 1, 2017

Prepared by: Amber Motley

California Independent System Operator

CAISO Analysis of the August 21, 2017

Solar Eclipse

EXECUTIVE SUMMARY

On Monday, August 21, 2017, a total solar eclipse will pass over the Pacific Northwest (Oregon, Idaho, Wyoming etc.). The California balancing authority area will be affected by a partial eclipse between 9:02 AM and 11:54 AM PPT. As a partial eclipse, the sun will be obscured from 76% in Northern California to 62% in Southern California border area. The reduction in solar radiation will directly affect the output of the photovoltaics (PV) generating facilities and rooftop solar.

On Thursday, March 20, 2015, the European grid experienced the first ever near total solar eclipse with nearly 90 GigaWatts (GW) of solar PV on their system. With the proper planning, Europe was able to maintain grid reliability throughout the entire three hours of the eclipse¹. Due to the solar PV growth for the first time in California ISO grid history, a solar eclipse is expected to have an impact worthy of study and preparation on the operation of the California ISO balancing area.

By Aug 2017, the ISO expects to have nearly 10,000 MW's of installed capacity of commercially operational grid connected solar PV within the balancing area. Initial estimates show at the eclipse peak, for the California balancing authority area, commercial solar production will be reduced from an estimated 8,754 MW's to 3,143 MW's at the maximum partial eclipse and then return to 9,046 MW's. The normal morning solar ramp will be interrupted with a down ramp beginning at 9:02 AM followed by a greatly accentuated up ramp beginning at 10:22 until noon. In addition, the California Energy Commission has estimated there will be over 5,800 MW's of rooftop solar installed in the Balancing Area which is estimated to minimally effect the load forecast compared to the effect on grid connected, as shown in Figure 4. Assuming a clear sky, during the eclipse we will see a total load increase of around 1,365 MWs taking into consideration the effects of the rooftop solar. Note when comparing to similar days during August the Marine Layer is typically assisting reduce the rooftop solar output during the hours of the eclipse, making the above case more of a worst case scenario for the load.

Assuming proactive mitigation measures, while no interruption to reliability service is expected as a result of the solar eclipse, operationally, the solar ramp during the eclipse is expected to increase the burden on other dispatchable resources including the regulating capability of the interconnected power system in terms of available regulation capacity, regulation speed and geographical location of reserves. Although a solar eclipse is perfectly predictable the transformation from solar radiation to electric power is associated with uncertainties which call for a careful coordination throughout the entire WECC interconnected power system.

The ISO has conducted studies to evaluate the impact of the solar eclipse and possible counter measures to be taken by the ISO and stakeholders. The purpose of this document is to identify risks and solutions to mitigate the grid impacts related to the solar eclipse.

¹ www.entsoe.eu/Documents/Publications/ENTSO-E%20general%20publications/entsoe_spe_pp_solar_eclipse_2015_web.pdf

This memorandum addresses the following topics:

- The solar eclipse trajectory related to the ISO balancing authority
- Estimation of the installed commercial solar PV infeed by forecast area and estimation of solar production reduction
- Estimation of the installed roof top Solar PV capacity per area.
- EIM Effects
- Mitigation Measures
- A timeline to talk through solutions to be considered for use on August 21st, 2017.

DISCUSSION AND ANALYSIS

Solar Eclipse Trajectory

On Monday, August 21, 2017, a total solar eclipse will pass over the Pacific Northwest (Oregon, Idaho, Wyoming etc.). The California Solar production areas will be affected by a partial eclipse between 9:02 AM and 11:54 AM PPT. The sun will be obscured from approximately 76% at the higher latitudes of Northern California to approximately 62% in the lower latitudes of Southern California.

Figure 1² defines the path of the total eclipse. The northern and southern path limits are blue and the central line is red. The areas within the central path (between the blue lines) will experience a total eclipse. Areas outside of the central lines, such as California, will experience varying amount of partial eclipse (solar obscuration) based on distance from the central path.

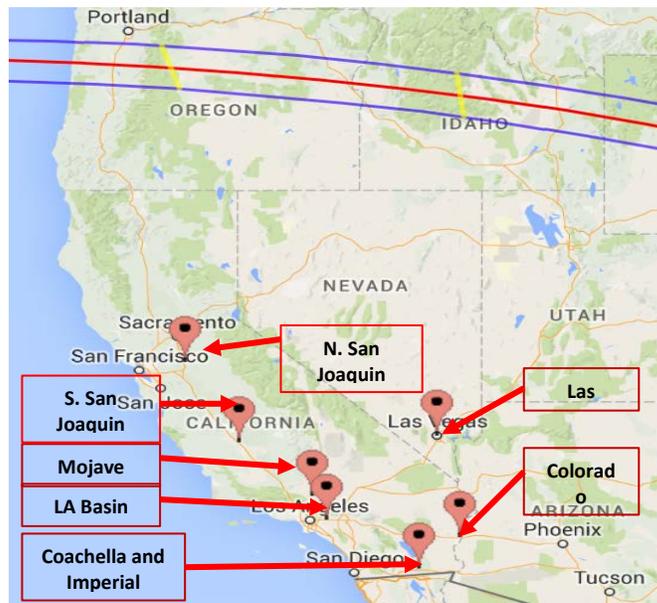


Figure 1

² <http://eclipse.gsfc.nasa.gov/SEgoogle/SEgoogle2001/SE2017Aug21Tgoogle.html>

Potential Commercial Solar Reduction

Solar obscuration defines the solar irradiance reduction striking earth at a given location such as a PV solar park. As these locations are further from the central path, the percentage of solar obscuration lessens. Each PV solar park production output will be reduced during the eclipse by the amount of solar obscuration. The solar eclipse will occur when a majority of the PV solar parks will be ramping up to the maximum amount of daily production. Production will reduce from the time the eclipse starts at 09:02 through the maximum amount of obscuration at approximately 10:22. As the eclipse wanes, the solar production return will be at a much greater ramp rate than normal production because the sun angle will have continued to increase during the time the sun was obscured. This eclipse time from 09:02 to approximately 12:00 is the period of operational interest the ISO will study to ensure adequate supplies of generations (reserves) are available to mitigate any adverse effects of a possible steep up ramp in solar production.

Forecast Area	Eclipse Start Time	Eclipse Max Time	Eclipse End Time	Eclipse % Max Obscuration	Est. Aug 2017 Area Generation Capacity	Area Production @ Eclipse Start		Area Production @ Eclipse Max ³		Area Production @ Eclipse End	
						Cap %	MW	CAP %	MWs	Cap %	MW
N. San Joaquin	9:02	10:17	11:39	76%	220	64	140	18	39	79	174
S. San Joaquin	9:03	10:18	11:41	69%	2359	69	1630	27	624	92	2170
Mojave	9:05	10:21	11:45	65%	3122	72	2265	31	970	93	2913
LA Basin	9:06	10:22	11:45	62%	134	26	35	15	20	47	64
Coachella and Imperial Valley	9:09	10:26	11:51	58%	1267	75	944	26	451	87	1104
S. Nevada	9:09	10:27	11:53	72%	1417	77	1093	25	351	83	1172
Colorado River	9:10	10:28	11:54	62%	1480	83	1231	37	540	98	1449

Table 1

Using the data from the table 1, an algorithm has been developed to calculate the amount of solar energy expected to be produced on August 21, 2017 compared to a clear August 2016 day. It is anticipated that solar PV production in MW from the start of the eclipse at 9:00 A.M. will be 7,337 MWs. Because this is a partial solar eclipse, with varying sun obscured values across California and Nevada, the solar production will never completely stop but will be reduced to a minimum of approximately 3,143 MWs at 10:22 A.M. This is a reduction of 4,194 MWs over this 82 minute period or a ramp down of - 70 MWs/min. See Figure 2.

³ The MW sum for the “area production at the eclipse maximum” (minimum area production) is less than the minimum area production represented on the graph due to the eclipse maximum times varying by each region.

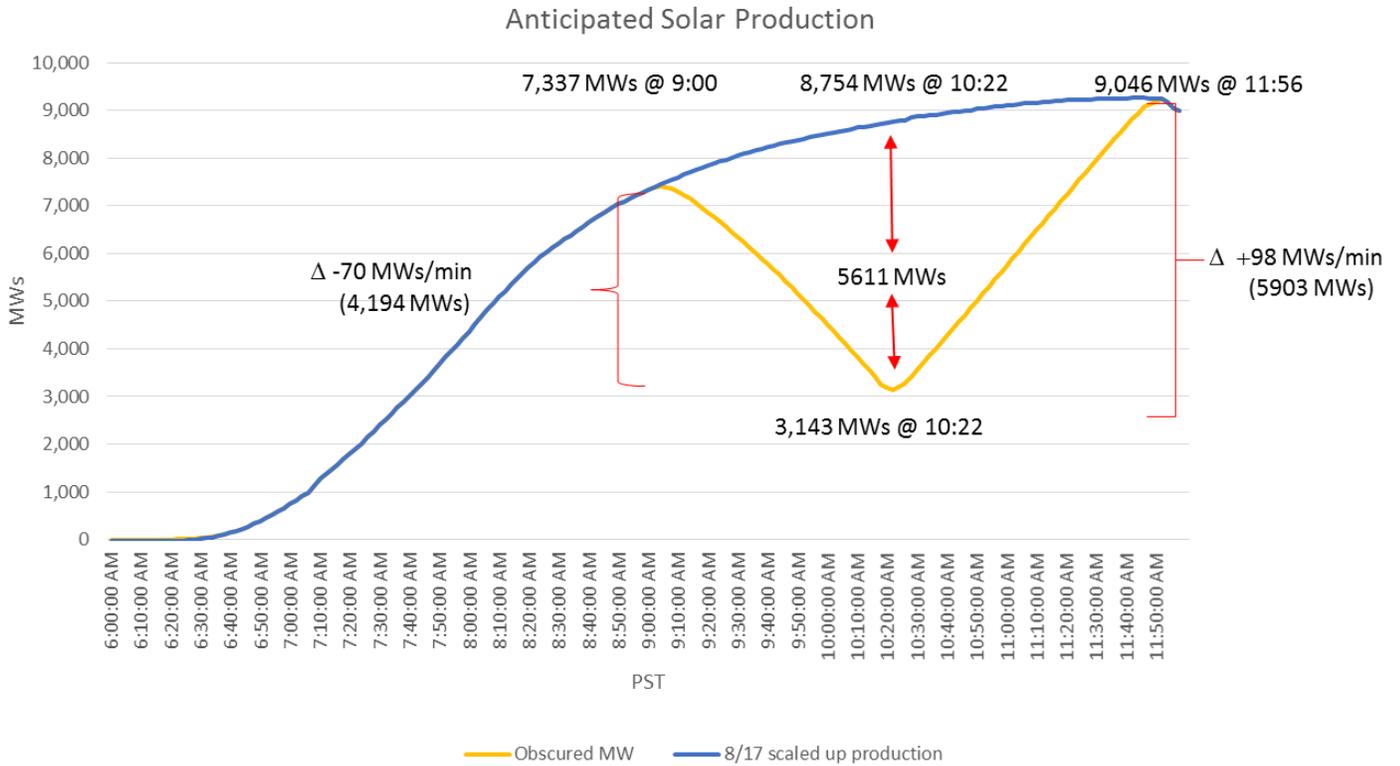


Figure 2: Forecast Grid Connect Solar Production during August 21, 2017 Eclipse

As the eclipse wanes, the return to normal production will cause an up ramp of 98 MWs/min reaching 9,046 MWs at 11:56. For reference, the estimated non-eclipse ramp from 900 A.M. to noon would be 12.6 MWs/min on a clear day.

Net Load

Figure 3 represents the net load based on the actual net load of Monday 8/22/16 versus the anticipated net load for 8/21/17. The graph representing the 8/21/17 assumes the approximate added growth of solar and wind⁴ however, Europe's experienced a decrease of 10% in wind production during the solar phenomena which for California equals approximately the amount of growth representing a net zero growth for the 2017 wind production.

⁴ From ISO RIMS_5 public reporting data base 11/16/17.

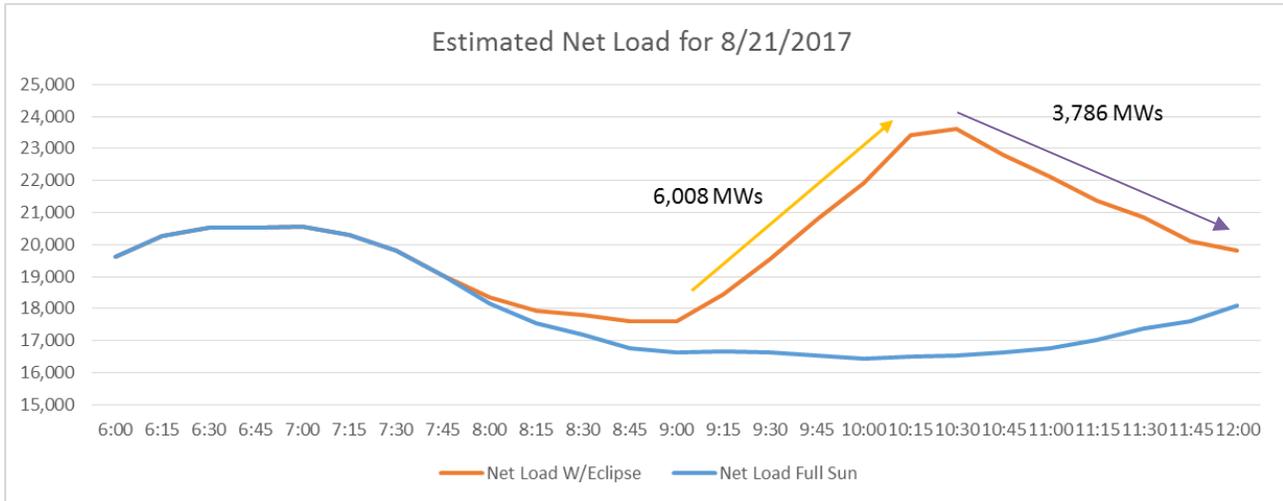


Figure 3: Net Load during Full Sun and Net Load Profile during August 21, 2017 Solar Eclipse

Roof Top PV Solar

Roof top PV solar production has grown to where it has become a significant factor when forecasting system load. Based on data collected the California Energy Commission has estimated there will be over 5,800 MWs (Figure 4) of rooftop solar installed in the balancing area which will need to be studied to see the effect of the solar eclipse on the load forecast.

Of the 5,800 MW approximately 35% or 1855 MW are commercial or industrial installations with the remainder being residential.

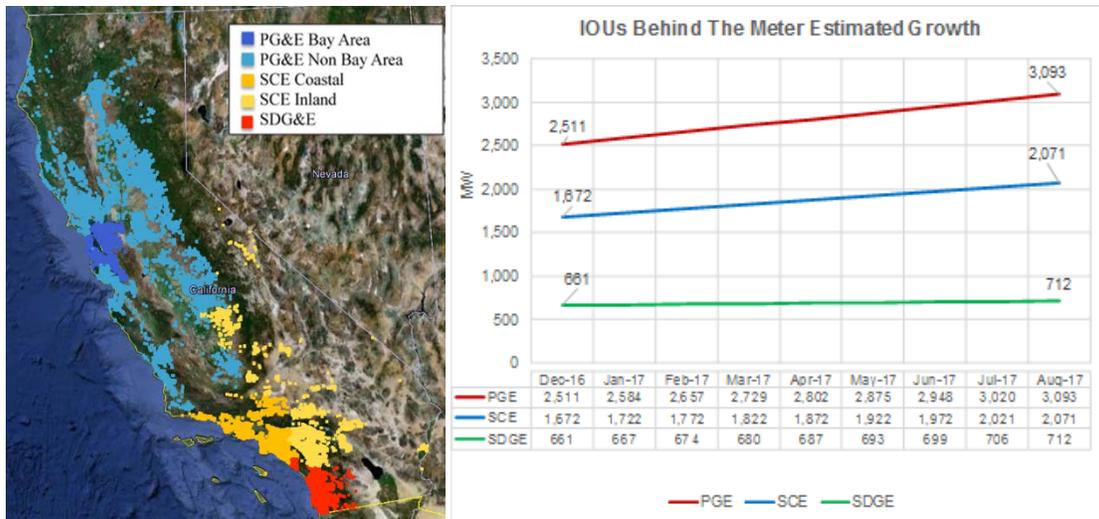


Figure 4

The ISO has developed, and implemented, a forecast model design to adjust the load forecast models by taking into account the amount of rooftop solar. Because the eclipse is a new event, it is anticipated the model will work as expected however manual adjustments may need to occur in the day ahead and real-time load forecast. Figure 5 shows the expected difference in the load shape on August 21st, 2017 using 8/22/2016 weather information. Note that the behind the meter forecasted MW numbers are representing a clear sky day with no marine layer effect.

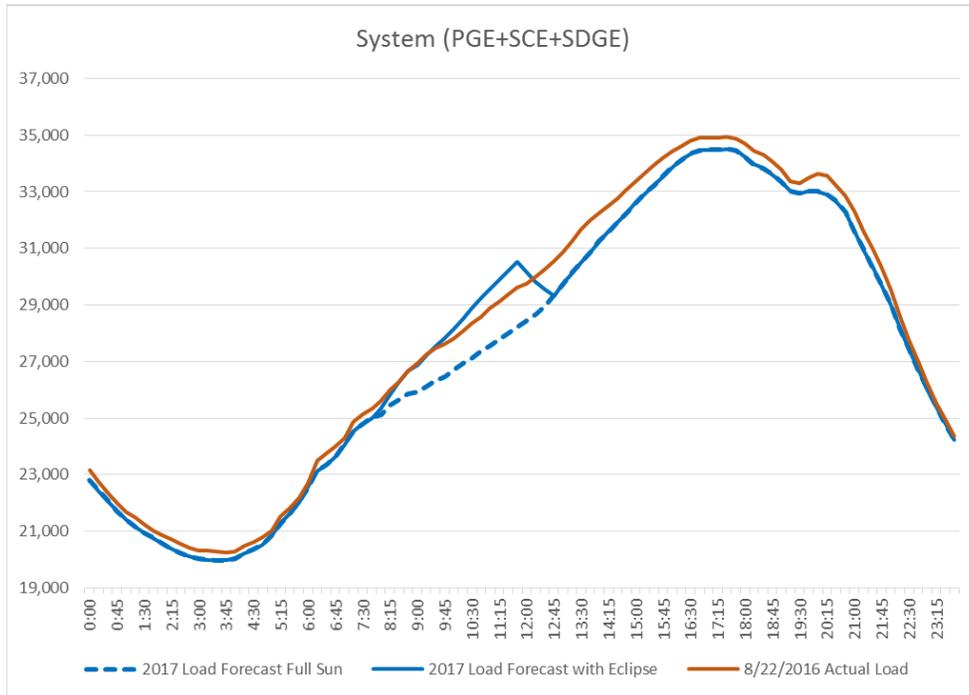


Figure 5: Forecast Gross Load Profile during August 21, 2017 Solar Eclipse

EIM Discussion

By August 21, 2017, there will be approximately 866 MWs of solar within the utilities participating in the energy imbalance market which will also be affected by the eclipse. Table 2 outlines the solar PV capacity, as listed on their respective websites.

EIM Entity	Distribution MW	Grid Connected MW
Arizona ⁵	569	506
Nevada ⁶	169	350

⁵ <http://www.arizonagoessolar.org/UtilityPrograms/ArizonaPublicService.aspx> and <https://www.aps.com/en/ourcompany/aboutus/renewableportfoliomap/Pages/home.aspx#>

⁶ <https://www.nvenergy.com/renewablesenvironment/renewablegenerations/documents/monthlyreport/March-2017-Report.pdf>; <https://www.nvenergy.com/renewablesenvironment/renewables/solar.cfm>

PacifiCorp ⁷		9
PSE ⁸		0.5
Total	738	866

Table 2

It is important to note that the majority of solar PV listed in the PacifiCorp website is located south of Salt Lake City where the sun will be obscured up to 86% at the peak time of 10:33 AM. The solar generation for Arizona will experience only about 60% obscuration.

Grid Protection Plan

Based on the results above, it is important for the ISO to maintain grid reliability while controlling to manage the significantly larger system ramps.

Below is a summary of the mitigation measures that will be used on August 21st, 2017:

Table 3: Grid Protection Options

Reserves procurement	Gas supply needs coordination.
Flex-ramp usage	Scheduling Coordinator interaction
Special operating procedures	WECC/Peak RC coordination
Use of EIM transfer capability	Hydro Generation
Internal Market Simulation	Potential use of Flex Alert
Day +2 Conference Bridge	Market Participant Coordination

Currently the ISO is obtaining behind the meter solar generation forecasts as well as large scale solar generation forecasts from two forecast service providers. The providers will be producing a forecast accounting for the solar eclipse that will automatically feed through the ISOs daily processes. The aggregate forecast for large scale solar will be available to the market participants, as well as public, through the OASIS applications.

Knowing that the critical information needed to have the most accurate forecast possible will be feeding into the market optimization as well as other processes will assist greatly in optimizing the market with the Solar Eclipse.

In addition to the above the following additional actions and processes will be followed:

- Reserves procurement:
 - Due to the predicted movement of the transmission connected solar resources the ISO plans to commit the following increased amount regulation up and regulation down to assist with the increased ramp rate of the resources.

⁷ https://www.rockymountainpower.net/content/dam/pacifcorp/doc/CCCom_Update/2017/January_2017/RMP-FactSheet.pdf

⁸ <https://pse.com/aboutpse/EnergySupply/Pages/Solar-Power.aspx>

HE	Normal Regulation Up (MW)	Normal Regulation Down (MW)	Regulation Up (MW)	Regulation Down (MW)	
9	250	250	350	350	Eclipse
10	250	250	400	400	Eclipse
11	250	250	400	400	Eclipse
12	250	250	400	400	Eclipse
13	250	250	350	350	

Table 4: Recommended Regulation during Solar Eclipse

- Flexible Ramp Product:
 - Flexible Ramp Capacity is used to account for forecast errors between RTPD and RTD markets, as well as, between RTD Advisory and Binding intervals.
 - With our Forecast Service Providers submitting the forecast taking into consideration the obscuration to the solar facilities during the Eclipse, it is not expected that there will not be an increase in forecast error during this event. This will allow the current mechanisms being utilized for the Flexible Ramp Product to be optimized.

- Market Notice to Market Participants informing them that all renewable resources must follow their Dispatch Optimization Target (DOT) to assist in controlling the reliability of the grid during the specified time in the Market Notice.

- EIM Transfers:
 - The plot below is based on actual transfers, but gives a sense of the flows and magnitudes we have been seeing between the EIM entities.
 - The EIM provides a mechanism to share and diversify resources to assist in more enhanced management of the Solar Eclipse moving across the Western United States.

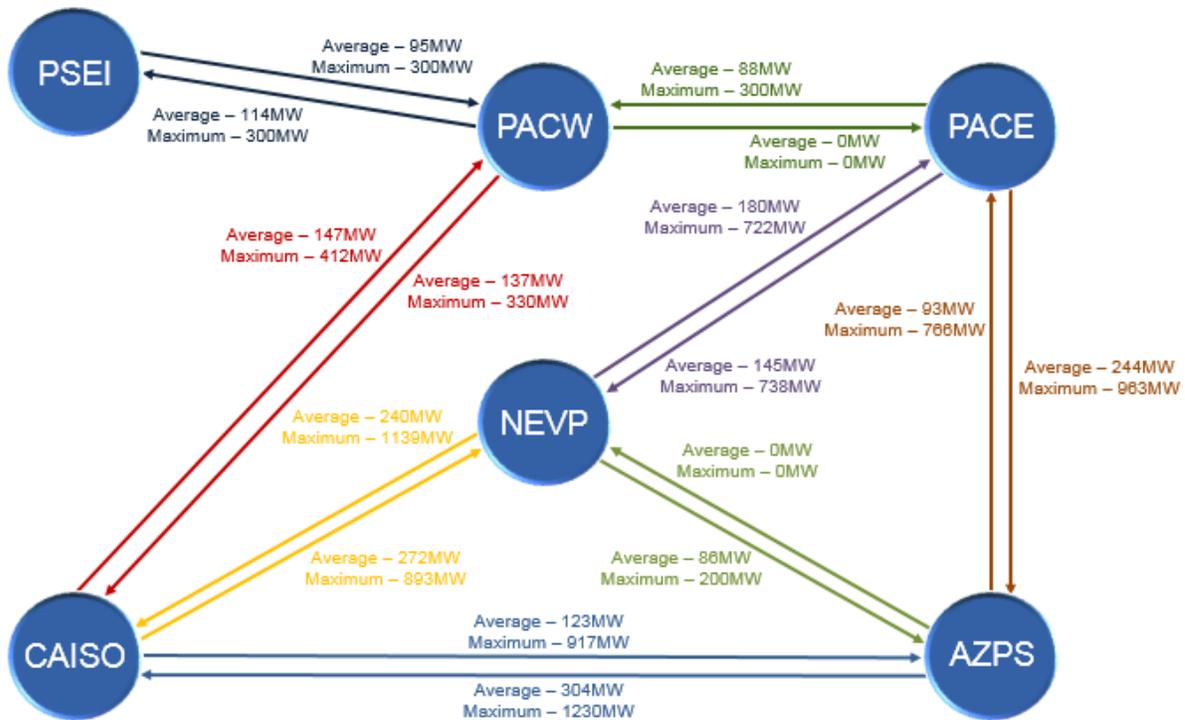


Figure 6: EIM Energy Transfer Capability in the 4th quarter of 2016

- Due to the forecasts for behind the meter and large scale renewable resources being in the market optimization, the EIM transfers will be optimized through the market dispatch.
- It is important that all EIM participants account for the solar eclipse effects on their solar renewable resource forecasts in their base schedules that are being submitted by their forecast service providers as well.
- Hydro Generation Usage
 - Due to the above average hydro year this water season it is expected that come August we will still have availability for hydro to carry regulation and/or energy during the eclipse.
 - CAISO will be working with the hydro community and inform participants of the additional need for flexibility on August 21st due to the eclipse to assist with that flexibility being available to the market optimization.
- Peak RC Coordination
 - CAISO will continue to coordinate with the Peak RC and generation community to talk through the operating plan for that day.
- Gas Coordination
 - CAISO will coordinate with Southern CA gas and thermal generators to ensure they have procured enough gas to handle generation deviations during the day of the Solar Eclipse.
- Outage Coordination
 - CAISO will be analyzing the impacts of generator and transmission outages prior to approving for August 21st.

- Consider other measures such as: 1) declare no tweak no tune for day of solar eclipse, 2) flex alerts, 3) virtual bid suspension during period of eclipse, 4) pre- curtailment of renewables, 5) ramp rate limitations on return of renewables, 6) use of demand response that is outside of the market optimization, and 7) manual operator interventions if needed.
- Develop a communication plan with media

CONCLUSION

Timeline

An estimated timeline has been developed to allow sufficient time to address any issues arising from the eclipse:

- September – Dec 2016 (Completed)
 - Announced eclipse study at the September 2016 Market Performance and Planning Forum and requested input.
 - Stakeholder web conference October 2016
 - Circulate with scheduling coordinators for comment.
 - Comments due Nov 3rd 2016.
 - Start roof top solar effects on load study.
- January – July 2017 (In Progress)
 - Develop Solar Eclipse Procedure.
 - Publish procedure.
 - Present procedure at the May Board of Governors meeting.
 - Present final procedure at the July Market Performance Planning Forum.
 - Following Event; review Solar Eclipse and identify lessons learned.