ELCC Wind Study Report

SPP Resource Adequacy

8/13/2019

REVISION HISTORY

DATE OR VERSION NUMBER	AUTHOR	CHANGE DESCRIPTION	COMMENTS
2/20/2019	SPP Staff	Initial Draft	
3/20/2019	SPP Staff	Includes staff and member comments	
3/27/2019	SPP Staff	SAWG Approved Report	
8/13/2019	SPP Staff	All staff and stakeholder comments included	

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. EXECUTIVE SUMMARY

SPP Planning Criteria section 7.1.6.1 (7 & 8) is the current methodology used to calculate the accredited amount of renewable (wind/solar) capacity that can be claimed for meeting summer peak capacity requirements and winter peak capacity obligations outlined in Attachment AA[1] of the SPP Open Access Transmission Tariff (Tariff). The methodology was originally adopted in 2004, using a statistical methodology to measure wind resource performance during the top 10% of peak load hours at an 85% confidence interval with a minimum 3% accreditation during the first three years of the commercial operation of a wind resource. At that time there was less than 1,000 MW of installed nameplate wind capacity connected to the SPP system. In July 2014, an update to the methodology was approved that increased capacity accreditation by shifting to the use of the top 3% of peak load hours at a 60% confidence interval and a minimum 5% accreditation during the first three years of the commercial operation of a wind resource. At that time, approximately 6,500 MW of wind capacity was connected to the SPP system, and the new methodology was expected to increase average wind capacity accreditation in the SPP footprint from 1.4% to 10.0% based on an evaluation of seventeen wind resources totaling 2,072 MW of nameplate capacity that was under contract to load serving entities.[2] Since that time, the SPP footprint has expanded geographically and the amount of wind has increased to over 20,000 MW. In the ELCC wind study, 12,185 MWs was the amount of firm capacity used to calculate the accredited capacity. It is prudent to review the current renewable accreditation method to verify it is reflective of the ability of variable generation resources to provide capacity to meet SPP's planning reserve requirements. Over-valuing wind's contribution can result in lower levels of system reliability and increased risks of unserved load; while under-valuing, it can result in costs that are unnecessary. Therefore, an Effective Load Carrying Capability (ELCC) study was performed to both compare the accuracy of the current methodology and to assess the impacts of incremental renewable capacity, and providing the Supply Adequacy Working Group with additional information needed for implementing a new accreditation policy. ELCC is defined as the amount of incremental load a resource can reliably serve, while also considering

---

[1] https://www.spp.org/documents/58597/attachment%20aa.pdf

[2] See Criteria Changes Wind Accreditation by Generation Working Group presented to MOPC, April 15-16, 2014 and Criteria Revision Request (CRR) No. 012 – Revise Wind Powered Resource Capacity Calculation.

probabilistic parameters of unserved load caused by forced outages, load uncertainty, and other factors.

The results from the SPP ELCC study, as well as other ELCC analyses performed by utilities and other Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs) across the nation, indicate with increasing penetrations of wind and solar resources, which are relied upon to meet reserves, the capacity value provided by those resources, on a percent or per MW of nameplate capacity basis generally tends to decrease. In general, though, while the available ELCC accredited capacity from all of such resources increases as penetration increases, the accredited capacity for each of these resources will decrease on a per-MW percent. This is illustrated in Figure 1.

The yellow line indicates the total capacity available from wind increases to be 5,324 MW for an installed capacity of 38,678 MWs. However, the ELCC value of the resources decreases from 19.6% with 19,339 MW of wind to 13.8% of 38,678 MW. For reference, the current SPP accreditation methodology in Planning Criteria 7.1.6.1 is shown on the green line with an accredited percentage of 28.0%, which was consistent for all levels of nameplate amounts when considering all six years. As stated in Section 3, the accreditation value calculated for Planning Criteria 7.1.6.1 is based on the assumption that all wind is eligible to be accredited and is based on the SPP load shape (as opposed to the LRE load shape) so that a consistent comparison could be made. The apparent higher accreditation for the current methodology is because the current methodology does not take into consideration that the peak net load (load less wind output) can shift as wind generation is added, reducing wind’s capacity value contribution.

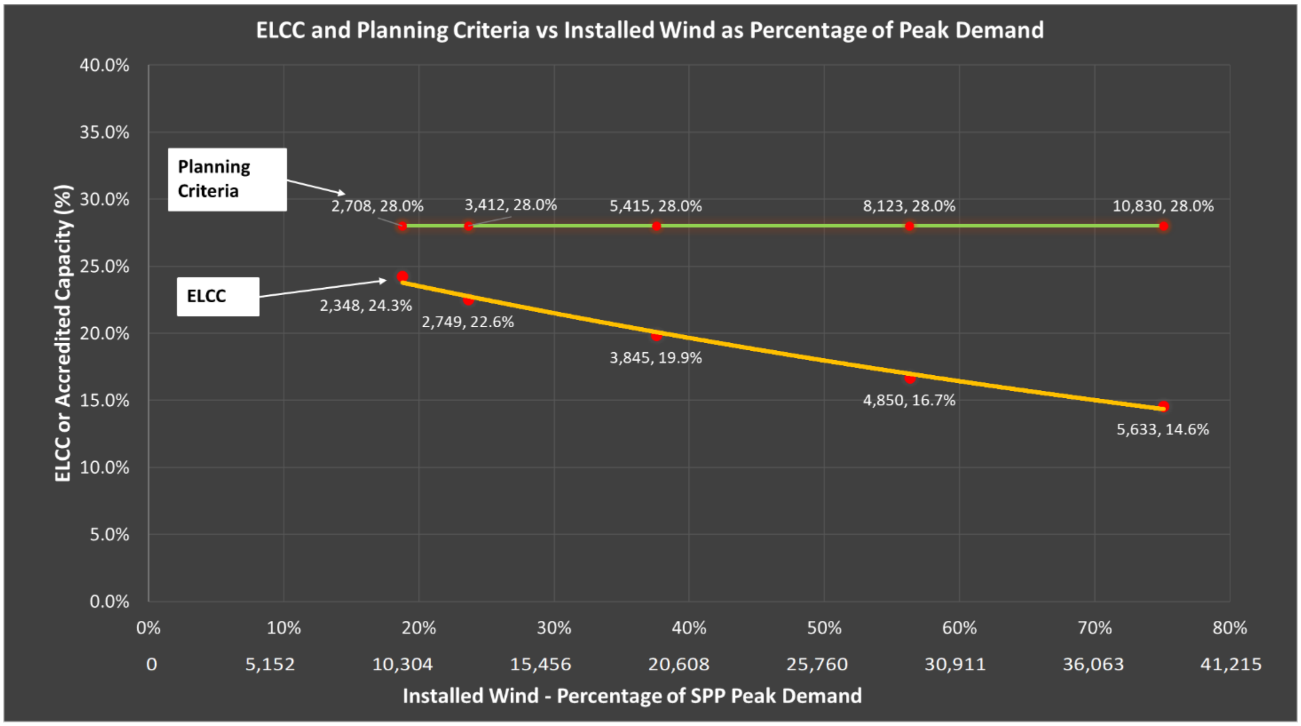

Figure 1: ELCC vs Planning Criteria methodology as wind penetration increases.

In summary, the SPP ELCC analysis:

- Determined the amount of accredited capacity from 19,339 MW of installed nameplate wind was 3,845 MW when using 2012 to 2017 historical weather patterns. [3]
- Determined the current renewable accreditation methodology in the SPP Planning Criteria would be 5,415 MW when using 2012 to 2017 historical weather patterns.
- Concluded the current SPP Planning Criteria has the capability of overstating and overestimating the value of renewable accredited capacity used for Resource Adequacy due to the increased levels of installed nameplate capacity in the SPP system, which is a reliability concern.
- Provides information to make an informative policy decision on whether or not the ELCC methodology should be adopted for the SPP region going forward

---

[3] This assumes that all of this wind is eligible to be used to meet reserves. Only a portion of this amount is currently eligible.

ACKNOWLEDGEMENTS

The scoping effort for this analysis began in April of 2018 at the SAWG. The stakeholder review process was an integral part of this study process and the participation and oversight of the SAWG was much appreciated by SPP staff. SPP staff also appreciates Astrapé Consulting for their assistance in the utilization of their expertise using the SERVM software.

2. SPP SYSTEM ELCC STUDY

BACKGROUND OF PROBABILISTIC APPROACH

Effective Load Carrying Capability (ELCC) is defined as the amount of incremental load a resource can reliably serve, while also considering probabilistic parameters of unserved load caused by forced outages, load uncertainty, and other factors. The magnitude of incremental load served which is derived in the ELCC analysis becomes the basis of the resource's accreditation. ELCC has been used for determining capacity value of resources since the 1960's when Garver demonstrated the use of Loss of Load Probability (LOLP) in the calculation of ELCC[4]. There are other utilities, Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs), including Midcontinent Independent System Operator (MISO), Xcel Energy, PacifiCorp, and California ISO (CAISO), that utilize the ELCC practices to determine capacity value of variable resources.

Using ELCC practices, a facility's accreditation (measured in MW) is a fractional probabilistic measure of the facility's nameplate rating that can be relied on to serve load. ELCC can express the value that generation contributes to a system as penetration of the specific resource type increases. Underestimating the contribution of variable generation resources to help meet forecast system peaks can result in the acquisition of unnecessary generation capacity and higher system costs. Overestimating the ability of such variable generation resources to help serve forecast system peaks can result in lower levels of system reliability and increased risks of unserved load.

The results of an ELCC study are dependent upon the selection of a specific reliability target. SPP utilizes the reliability metric of 1 day in 10 years (or 0.1 day/year), which is also used in the SPP Loss of Load Expectation (LOLE) analysis to determine the adequate planning reserve margin for the SPP region. LOLE is typically defined as the expected number of days or hours per period, usually a year, that an entity does not have enough capacity to meet firm load. If the loads are specified on an hourly basis, as is often the case, then the hourly LOLE is calculated by

---

[4] Garver, "Effective Load Carrying Capability of Generating Units," Aug. 1966

determining whether the entity has enough capacity available to serve the load for each hour of the year.

SOFTWARE

The SPP Wind ELCC Study utilized the Strategic Energy Risk Valuation Model (SERVM) software package from Astrapé Consulting. SERVM is a multi-area reliability and economic simulation tool that allows users to evaluate resource adequacy not only based on physical reliability metrics, such as the one day in ten years threshold, but also to assess the economics of such resource adequacy standards. SERVM combines the economic dispatch characteristics of production cost models with the granularity and probabilistic simulation capabilities of multi-area reliability models. The primary SERVM attributes used in the ELCC study were the LOLE metric and load increment factors to calculate the incremental amount of load needed to maintain the same level of reliability for scenarios that included and excluded the resources of interest.

MODEL INPUTS AND ASSUMPTIONS

Most of the input and assumptions (such as unit parameters, load forecast uncertainty factors, external transfers, DC Tie considerations, etc.) for the ELCC study were the same used in the 2017 Loss of Load Expectation (LOLE) Study[5]. The key differences were the exclusion of transmission limitations between modeled areas, multiple wind and load years, and varying levels of installed nameplate wind.

For the 2017 LOLE Study, 19,339 MW of wind resources and 215 MW of solar resources were assumed to be in service for study years 2019 and 2022. From the time of commencing the LOLE study (July 2017), the amount of registered wind nameplate capacity in the SPP footprint had increased to over 20,000 MW by January 2019. Therefore, 19,339 MW of wind capacity was more than adequate to analyze.

The transmission limitations between modeled areas within the SPP footprint were excluded from the ELCC analysis. The intent of the accreditation methodology, whether ELCC or SPP's

---

[5] 2017 LOLE Study: https://www.spp.org/Documents/58198/2017%20SPP%20LOLE%20Study%20Report.pdf

current Planning Criteria 7.1.6.1 methodology, is to determine the generator's ability to provide capacity to the system in relation to the appropriate need of demand, which is represented in the form of hourly historical load or energy shapes. Transmission system limitations resulting from congestion and generation deliverability are analyzed in other SPP operational and planning processes.

The 2017 LOLE Study utilized historical wind, solar, and load shapes from 2014. The ELCC analysis is performed with additional weather years using historical data in order to account for any unusual high or low "outliers" in the data. ELCC is performed on data from one historical year at a time, thus only one accredited capacity value is derived per modeled weather year. The results of each weather year, as shown below, can be trended into an average by analyzing at least five years of historical information, which will produce consistency from year to year in accrediting capacity. Thus, weather years 2012 to 2017 were analyzed.

Different levels of nameplate capacity were modeled and analyzed to reflect the trend of accredited capacity as a variable of installed penetration. The initial analysis represented 19,339 MW of installed wind. Three other values analyzed were 50%, 150%, and 200% of the 2017 LOLE Study amount, which were 9,670 MW, 29,009 MW, and 38,678 MW, respectively. These additional values were achieved by scaling the wind locations in the 2017 LOLE Study. The scaling approach was chosen as to not predict where future wind installations would be located, which could inaccurately bias the results for any future installed capacity. For example, if the selection of future wind was predominantly located in higher wind capacity areas, it could alter the results compared to the wind resource locations actually in commercial operation. Therefore this approach scales wind installations at the locations they are currently located. The 50% capacity value was studied and calculated purely for trending purposes.

A fifth value of wind generation, 12,185 MW, was also studied to represent the installed wind capacity with SPP firm transmission service[6]. This was an important benchmark comparison of the ELCC and current methodologies considering the emphasis currently placed on wind resources to have firm transmission service in the SPP Balancing Authority (BA) in order to accredit the resource. The results from this analysis were compared to the accreditation amount

---

[6] Firm transmission service value as of January 2018.

claimed through the 2018 Resource Adequacy Workbook submission process required in Attachment AA[7].

Except for the analysis on resources with firm transmission service, the methodology for scaling the installed nameplate capacity was applied to each wind resource utilized in the 2017 LOLE Study. For example, if a wind facility has a nameplate rating of 100 MW, the wind scenario of 150% will increase the existing facility rating to 150 MW, and its hourly energy values applied to the resource will be scaled accordingly for every hour to reflect the incremental percentage of 50% [(150 MW -100 MW)/100 MW * 100%].

All other inputs and assumptions used from the LOLE study remained unaltered in the ELCC analysis to isolate the accredited capacity value and its effects from multiple weather patterns. A detailed list of other assumptions and inputs can be found in the 2017 LOLE Study Report[8].

STUDY METHOD

In order to measure the ELCC of a particular resource, reliability effects need to be isolated for the resource(s). The LOLE value (days/year) of each wind scenario will be the benchmark used to determine the amount of incremental load the SPP system can serve without exceeding the reliability threshold of one day in ten years. The basic concept of an ELCC analysis focuses on two situations: one including the resource(s) of interest and the other excluding them from the system. The situation with the resource(s) should be more reliable and result in less loss of load instances, which in turn requires a higher amount of incremental load to reach 0.1 days/year in lost load. Figure 2 and Figure 3 represent the two situations and how an ELCC value is determined. The peak load in the base system represents the SPP coincident peak amount of 51,520 MW. The incremental amount of load represented by "Load 1" and "Load 2" is the amount of load needed to have a loss of load value of 0.1 days/year.

The following steps are taken:

---

[7] Submission deadline of February 15, 2018. https://www.spp.org/documents/58597/attachment%20aa.pdf

[8] https://www.spp.org/Documents/58198/2017%20SPP%20LOLE%20Study%20Report.pdf

1. Determine the incremental load amount the SPP system can withstand without exceeding the reliability threshold of one day in ten years for the SPP wind generation at 19,339 MW.

Figure 2: Diagram of system with wind resources

2. Determine the incremental load amount the SPP system can withstand without exceeding the reliability threshold of one day in ten years for the SPP wind generation at zero MW.

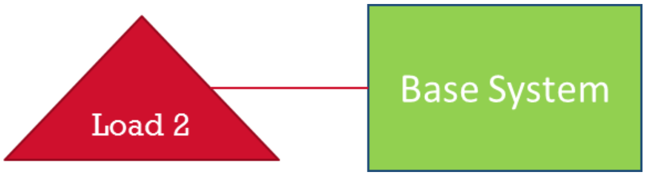

Figure 3: Diagram of system without wind resources

3. Calculate ELCC for 19,339 MW of nameplate wind. This will be done by taking the difference of load required in step one vs. the load required in step two divided by the amount of nameplate wind (19,339 MW).

$$\text{ELCC (existing wind)} = \frac{(\text{Load 1} - \text{Load 2})}{\text{Nameplate Wind}}$$

SIMULATION

Twenty (20) random seed[9] representations and seven probabilistically weighted load forecast uncertainty (LFU) levels were applied to each scenario to create additional variation in unit availability and dispatch between simulations. This is defined as one case. Fifty (50) iterations were applied to each case to reach statistical convergence and reduce the standard error between results. In total, 7,000 iterations (50 iterations * 20 seed values * 7 LFU levels) were applied to each wind scenario.

---

[9] A random seed representation assigns a pre-commitment outage and maintenance schedule before the simulations begin. As the amount of randomly generated seed values increases, the variability in iterations increases as well.

RESULTS

Thirty-six (36) total wind scenarios were analyzed: six different levels of installed nameplate capacity applied to six weather years. Figure 4 shows the results for each weather year at different levels of installed nameplate wind capacity. As the penetration of installed nameplate capacity increases, the capacity value as a fraction of the installed nameplate capacity decreases. This is due to the impact of wind's effect compared to on-peak hours when demand is at its highest, i.e. the highest expectation for lost load. During the ELCC study, dispatchable (conventional and hydro) generation is used to serve the "net load" of every hour. "Net load" refers to the amount of demand minus the output of renewable energy resources for every hour. The amount of wind generation for on-peak conditions shifts the hour of interest when considering "net load" instead of "gross load". ("Gross load" is defined as the amount of hourly demand without the consideration of energy from renewable resources.) Therefore, the larger contribution that on-peak wind generation has on shifting the peak hours of interest, the higher capacity value the resources will have. Table 1 shows the ELCC accredited percentage and MW value of each wind scenario. As an example, the 2012 ELCC value for 9,670 MW of installed wind was determined to be 1,211 MW or 12.5% (1,211 MW/ 9,670 MW).

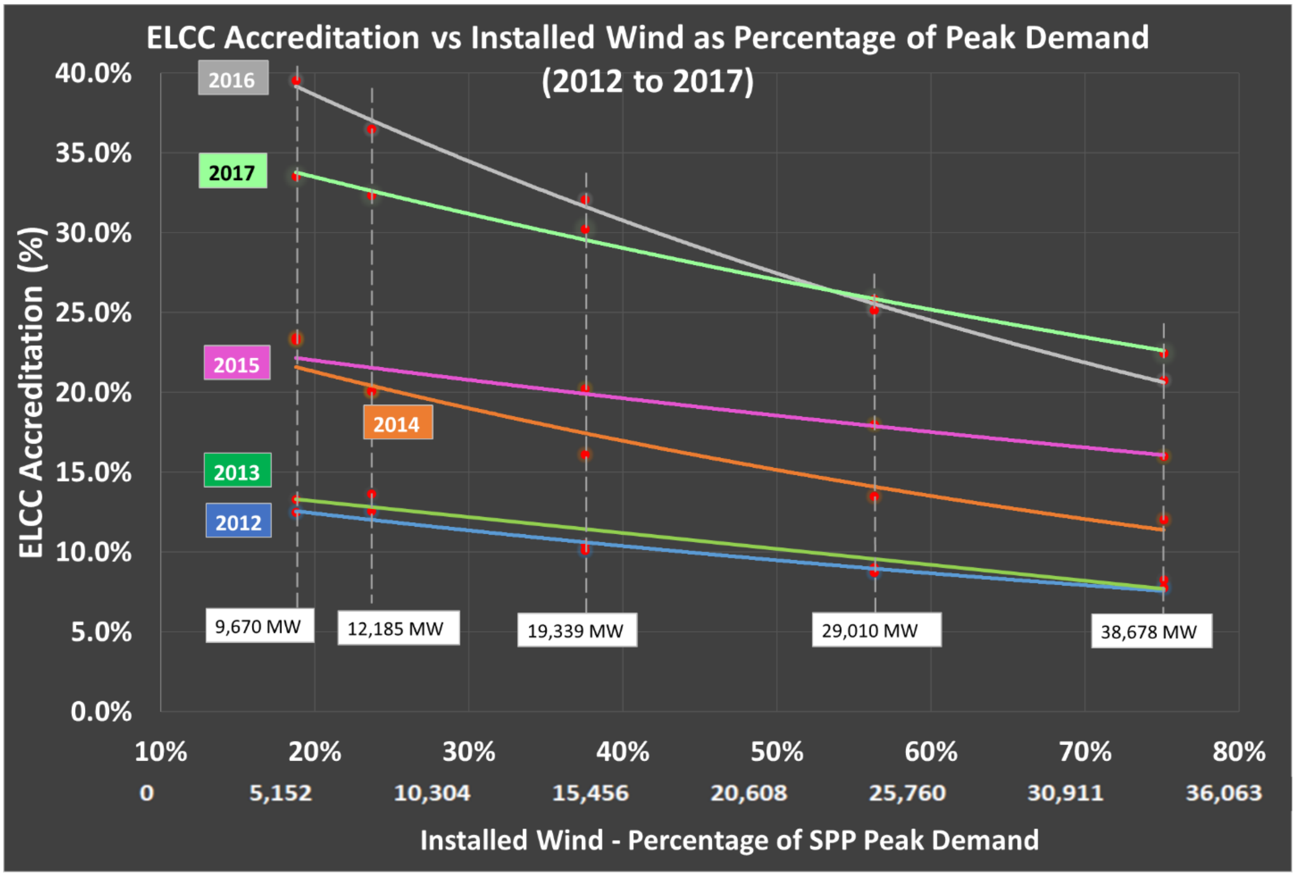

Figure 4: ELCC Results by weather year

Table 1: ELCC Results by weather year

ELCC Values for Installed Wind Amounts per Study Year

		Installed Nameplate Wind Capacity				
		9,670 MW	12,185 MW	19,339 MW	29,010 MW	38,678 MW
Weather Year	2012	12.5%, 1,211 MW	12.6%, 1,535 MW	10.1%, 1,958 MW	8.8%, 2,540 MW	7.8%, 3,009 MW
	2013	13.3%, 1,288 MW	13.7%, 1,664 MW	10.5%, 2,030 MW	9.1%, 2,627 MW	8.3%, 3,194 MW
	2014	23.4%, 2,267 MW	20.1%, 2,447 MW	16.1%, 3,117 MW	13.5%, 3,915 MW	12.1%, 4,662 MW
	2015	23.3%, 2,251 MW	20.1%, 2,452 MW	20.2%, 3,915 MW	18%, 5,219 MW	16%, 6,198 MW
	2016	39.5%, 3,823 MW	36.5%, 4,451 MW	32.1%, 6,208 MW	25.2%, 7,300 MW	20.8%, 8,037 MW
	2017	33.6%, 3,246 MW	32.3%, 3,941 MW	30.2%, 5,845 MW	25.8%, 7,496 MW	22.5%, 8,696 MW
	Average	***24.3%, 2,348 MW***	***22.6%, 2,749 MW***	***19.9%, 3,845 MW***	***16.7%, 4,850 MW***	***14.6%, 5,633 MW***

Figure 5 shows the averaged results for all six years at each installed nameplate level. It is important to consider averaging the ELCC accredited capacity from year to year to maintain consistency. Most of the entities who perform ELCC studies utilize a “rolling average” or some version of averaging to lessen the year over year impacts when considering multiple weather years.

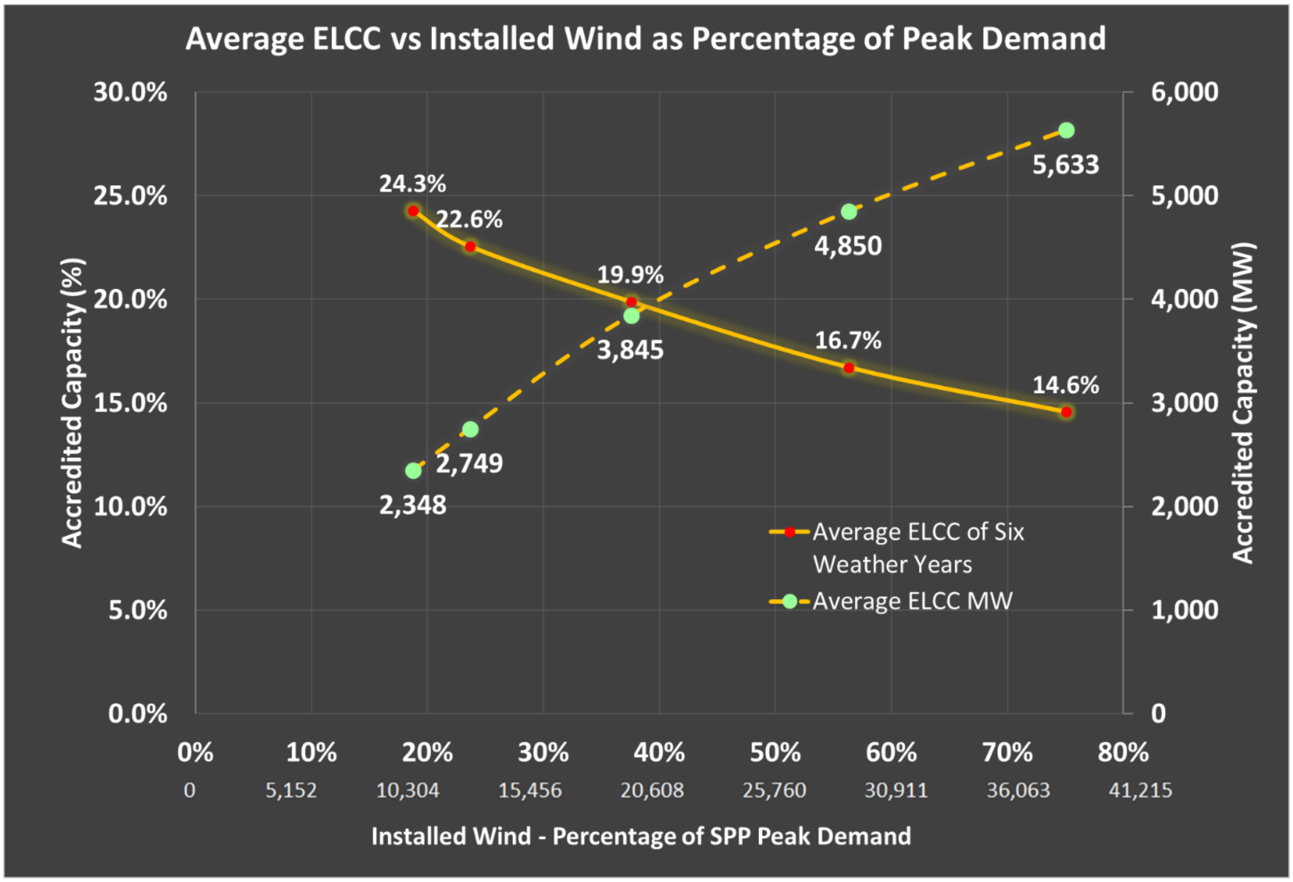

Figure 5: Average ELCC results of all six years at various installed nameplate levels

The results of the analysis show that as the amount of wind continues to increase, the available percentage of accreditation for all wind resources will decrease. This is illustrated in Figure 5. The yellow line indicates the total capacity available from wind increases to 5,633 MW for an installed capacity of approximately 38,678 MW. However, the ELCC of these resources decreases from 19.6% with 19,909 MW of wind to 13.8% with an installed capacity of 38,678 MW.

It is recognized that certain wind resources will have higher capacity factors and will perform better during peak load periods than others. Therefore, a process that allocates the total available ELCC across the SPP footprint based on location and performance is warranted. The methodology for allocating the ELCC accredited amount is addressed in the ELCC Allocation Methodology Whitepaper.

3. ANALYSIS OF CURRENT ACCREDITATION METHODOLOGY

DATA AND ANALYSIS

An additional analysis was performed using the current accreditation methodology in the SPP Planning Criteria section 7.1.6.1 (7 & 8) [10] to compare to the ELCC analysis. The current methodology is used by Load Responsible Entities (LRE) to accredit renewable generation used to meet obligations outlined in Attachment AA of the SPP Tariff. The current criteria provides historically based performance on how well the renewable resource meets the specific load, which the generation serves. Shortfalls of the current methodology are that the penetration of other renewable facilities on the system are not considered as a whole and it does not take into account the possibility that the peak hour for reliability of an LRE may “shift” when the penetration of wind resources increases under consideration of “net load”. The current method allows existing resources’ accreditation levels to not be changed or degraded by additional resources being added within the region.

The current methodology utilizes at least three years of historical information and focuses on the month, which the entity’s peak load occurs. Then, the top 3% of load hours of the month is chosen and the resource energy output for those hours is sorted to obtain the 60th percentile. For example, one entity is utilizing the capacity from a 100 MW nameplate wind facility and has been in commercial operation for the past three years. The entity’s summer peak month was August for 2016, July for 2017, and August for 2018. Each peak month has 31 days and 744 hours (31 days * 24 hours). The top 3% of peak load hours would then be chosen focusing on the top 22 peak load hours (3% * 744). The 22 hours from each year are combined together while keeping the associated actual energy output of each hour. Ranking the energy output of the 66 values, the 60th percentile value is selected to be the accredited value. In ordering the hourly values from highest to lowest, the lowest value is the 100th percentile and the highest is the 1st percentile.

---

[10] https://www.spp.org/Documents/58638/SPP%20Effective%20Planning%20Criteria_V1.9_06202019.docx

To provide a conceptual comparison the same data used in the ELCC analysis was used in the current Planning Criteria calculation for comparison. It was assumed that all installed wind capacity can be accredited. Since the ELCC analysis was performed on the SPP load shape, the Planning Criteria analysis utilized the SPP load shape in aggregate instead of individual load shapes of the LRE off-taker. The historical energy output for all wind resources was combined for each weather year. The scaling of installed nameplate capacity was applied the same way as in the ELCC analysis as well.

RESULTS

Figure 6 shows the results for each weather year at different levels of installed nameplate wind capacity for the SPP Planning Criteria methodology. As the penetration of installed capacity increases, the capacity value as a fraction of the installed nameplate capacity remains the same. This is because the incremental amount of installed capacity and energy output of other wind facilities do not have an effect on demand, which is represented as "gross load". Table 2 shows the accredited percentage and MW value of each wind scenario.

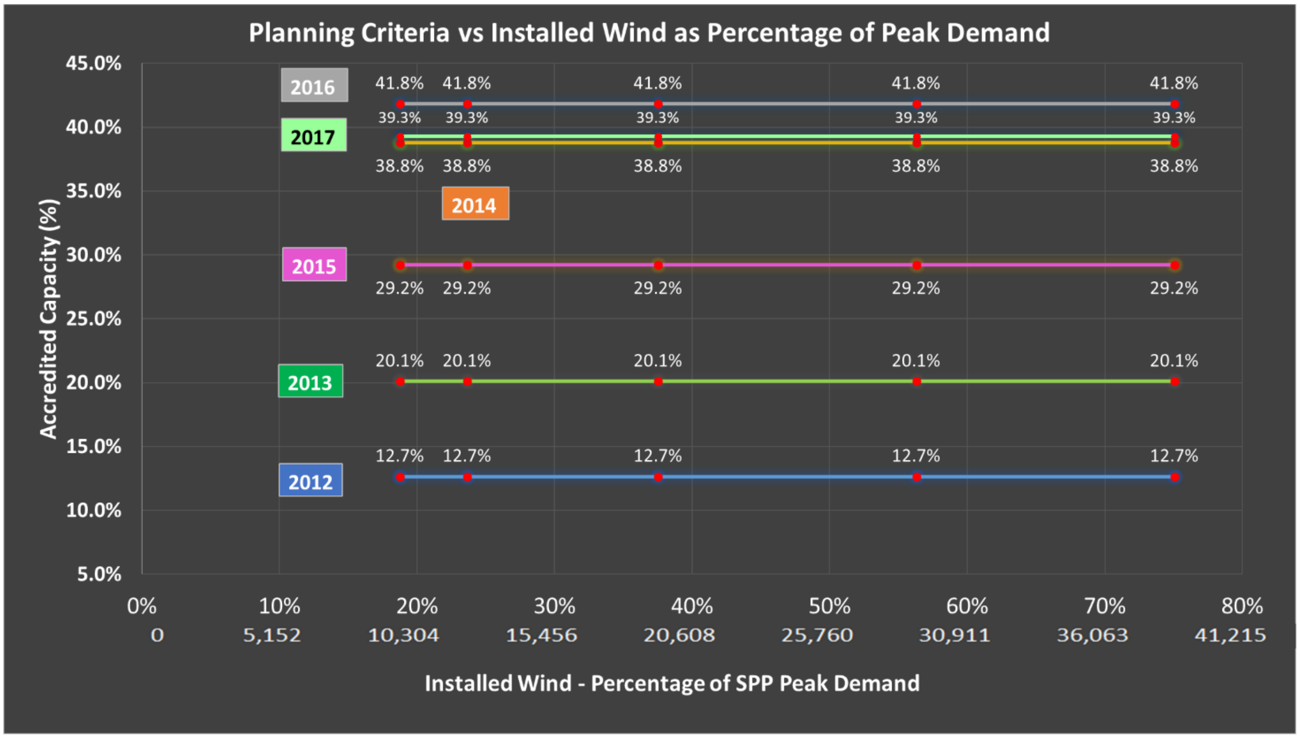

Figure 6: SPP Planning Criteria methodology for different weather years

Table 2: SPP Planning Criteria methodology applied to multiple weather years

Planning Criteria Values for Installed Wind Amounts per Weather Year						
	Installed Nameplate Wind Capacity					
Weather Year		9,670 MW	12,185 MW	19,339 MW	29,010 MW	38,678 MW
	2012	12.7%, 1,224 MW	12.7%, 1,548 MW	12.7%, 2,447 MW	12.7%, 3,671 MW	12.7%, 4,894 MW
	2013	20.1%, 1,944 MW	20.1%, 2,449 MW	20.1%, 3,887 MW	20.1%, 5,831 MW	20.1%, 7,774 MW
	2014	38.8%, 3,749 MW	38.8%, 4,728 MW	38.8%, 7,497 MW	38.8%, 11,246 MW	38.8%, 14,994 MW
	2015	29.2%, 2,824 MW	29.2%, 3,558 MW	29.2%, 5,647 MW	29.2%, 8,471 MW	29.2%, 11,294 MW
	2016	41.8%, 4,045 MW	41.8%, 5,093 MW	41.8%, 8,090 MW	41.8%, 12,135 MW	41.8%, 16,180 MW
	2017	39.3%, 3,800 MW	39.3%, 4,789 MW	39.3%, 7,600 MW	39.3%, 11,401 MW	39.3%, 15,200 MW
	Combined	28%, 2,708 MW	28%, 3,412 MW	28%, 5,415 MW	28%, 8,123 MW	28%, 10,830 MW

All six weather years were then combined together to derive an accredited capacity value that would be closer to how the methodology would be performed for an entity, i.e. at least three years of historical data. Figure 7 shows the accredited percentage of 28.0% of installed nameplate capacity was consistent for all levels of nameplate amounts when considering all six years.

The 28% in Figure 7 is representative of analysis where total wind facilities in SPP are aggregated along with SPP load in total. In actuality, wind accreditation for a specific wind facility is determined by its historic production during the peak loads of the entity, which owns the energy produced by the facility. Actual accreditation values of individual wind facilities will not necessarily equal 28% nor in aggregate average to 28%. The calculation was preformed to compare the results of the two methodologies with the same subset of data.

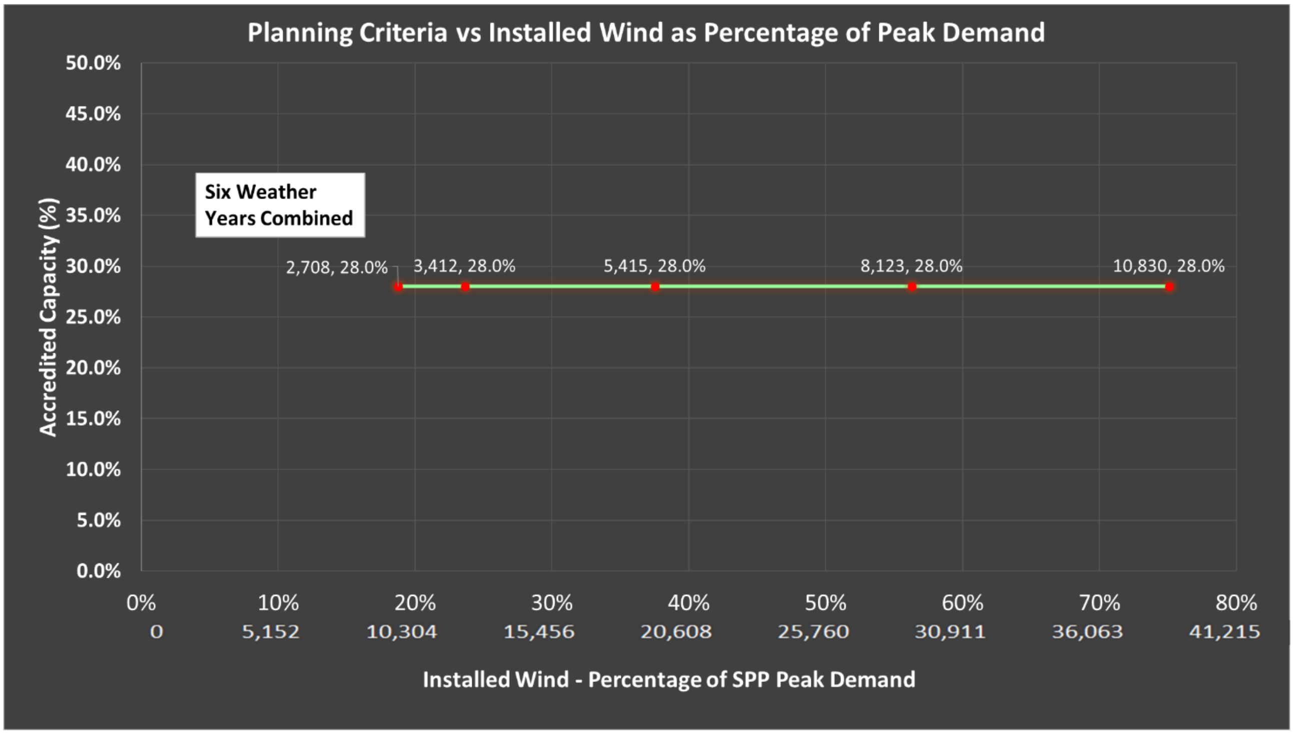

Figure 7: Combined accredited percentage for all six weather years

4. CONCLUSION

The concept(s) of ELCC is accurately estimate the value of wind and solar resources relied upon to meet system capacity needs for planning reserve purposes. The methodology is based upon an understanding that an underestimation of the contribution of variable generation resources, such as wind or solar, to help meet forecast system peaks can result in the acquisition of unnecessary generation capacity and higher system costs. Likewise, overestimating the ability of such variable generation resources to help serve forecast system peaks can result in lower levels of system reliability and increased risks of unserved load. SPP performed an ELCC analysis for the installed wind amount of 19,339 MW (amount studied in the 2017 LOLE Study in the SPP RTO/Planning Coordinator footprint and has determined the ELCC available for wind is 3,845 MW. Applying t current renewable accreditation methodology in the SPP Planning Criteria in a conceptual aggregated system wide approach results in 5,415 MW of wind accreditation (similar to the ELCC study assumptions).

ELCC expresses the value of generation to the transmission system as penetration of the specific resource type increases, whereas the SPP Planning Criteria currently does not. The ELCC analysis shows that as renewable generation increases in SPP, the gap between the expected capacity benefit for wind resources as calculated by ELCC and the expected accreditation amount by continuing to use Planning Criteria 7.1.6.1 methodology will grow from 1,570 MW with 19,339 MW of installed capacity to a deficit of 5,197 MW once installed nameplate capacity of wind reaches 38,678 MW. Figure 8 shows the average ELCC results against the results from the current SPP Planning Criteria applied in a conceptual aggregated system manner to compare the two methodologies.

The results of this study indicate the current SPP Planning Criteria has the capability of overstating and overestimating the value of renewable accredited capacity used for Resource Adequacy due to the high levels of installed nameplate capacity in the SPP system, which is a reliability concern.

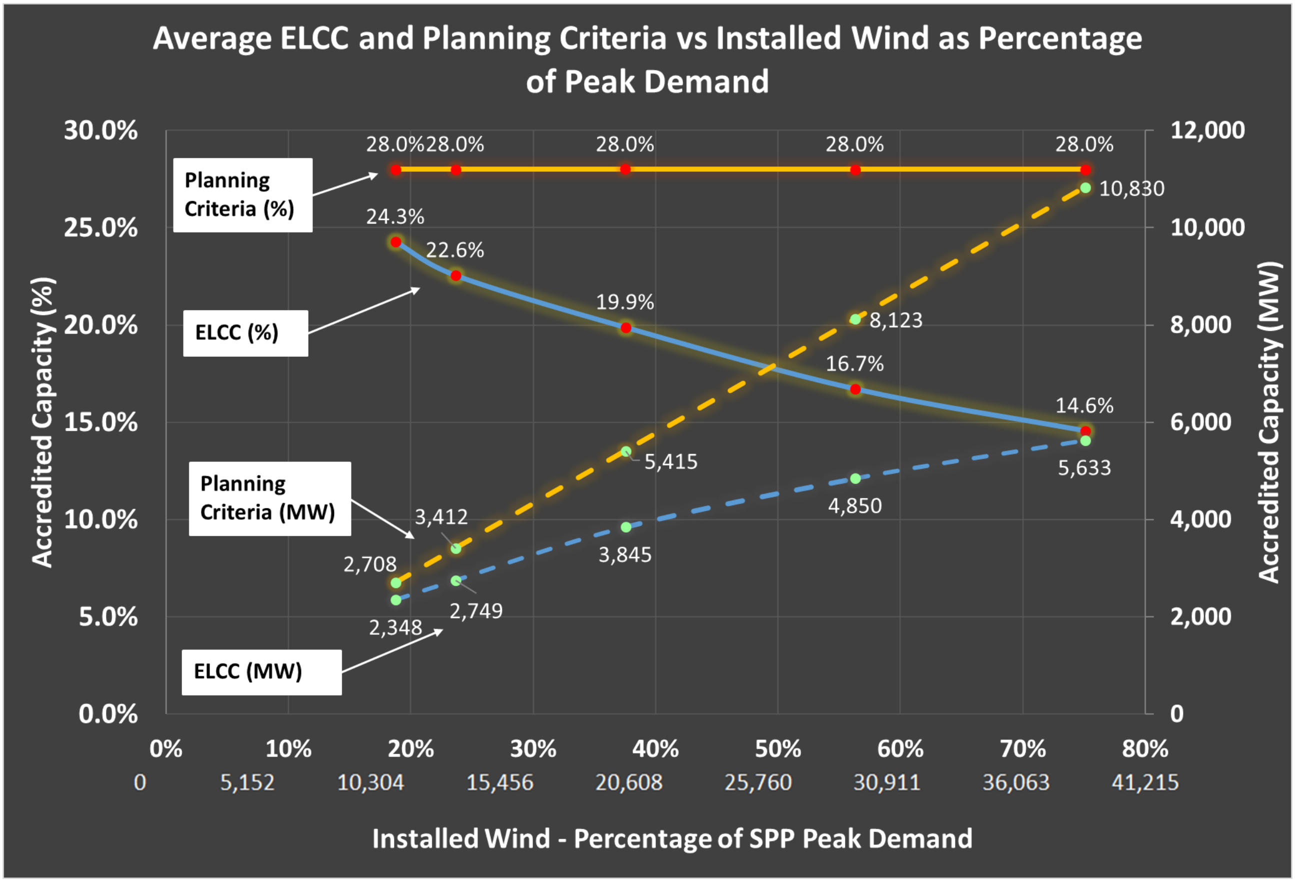

Figure 8: ELCC vs Planning Criteria methodology as wind penetration increases.

SPP Staff recommends that SPP adopt the ELCC methodology for determining accreditation of wind resources. The full implementation of an ELCC methodology is contingent upon finalization of an allocation methodology. SPP has recommended a methodology for allocating ELCC as detailed in the SPP Allocation Methodology Whitepaper.

APPENDIX A: LIST OF ACRONYMS

BA	Balancing Authority
CAISO	California ISO
ELCC	Effective Load Carrying Capability
ISO	Independent System Operator
LFU	Load Forecast Uncertainty
LOLE	Loss of Load Expectation
LOLP	Loss of Load Probability
LRE	Load Responsible Entity
MISO	Midcontinent Independent System Operator
MW	Megawatt
Tariff	Open Access Transmission Tariff
RAW	Resource Adequacy Workbook
RTO	Regional Transmission Organization
SAWG	Supply Adequacy Working Group
SERVM	Strategic Energy & Risk Valuation Model
SPP	Southwest Power Pool