Study of Renewable Capacity Values using the ELCC Methodology in the Southern Company System

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I. Introduction

The capacity value of renewable resources and other energy limited or non-dispatchable resources is often represented in the utility industry by the Effective Load Carrying Capability ("ELCC") of the resource. The Company has traditionally valued renewable resources and other energy limited supply- and demand-side resources using the Incremental Capacity Equivalence ("ICE") Factor, which is a form of ELCC based on the comparative reliability value of the resource measured by its reduction in Expected Unserved Energy ("EUE") to that of dispatchable generation capacity. During the 2021 PURPA proceedings[1] at the Georgia Public Service Commission ("GPSC" or "Commission"), the Company and the GPSC Staff agreed it would be a beneficial exercise to study the capacity value of renewable resources using a more widely used form of ELCC, which determines the reliability value of a resource by its ability to serve an increase in load while keeping reliability, as measured by Loss of Load Expectation ("LOLE"), the same. The result of these discussions was a requirement in the GPSC's Final Order[2] in the PURPA docket, issued March 11, 2021, stating that:

> The Company shall conduct an analysis of the capacity value of different renewable technologies using the ELCC method and include the results of this analysis in its 2022 IRP. At a minimum, the Company shall evaluate utility scale solar (fixed and tracking), distributed generation scale solar, wind, and battery storage (1-hour, 4-hour, 6-hour, and 8-hour).

In compliance with the Commission's order, which communicates the agreement with the GPSC Staff, following is a discussion of the current and ELCC capacity evaluation methodologies as well as the results of the ELCC study.

[1] Docket No. 4822, 16753 and 19279

[2] PURPA Final Order

II. ELCC as determined by EUE: ICE Factor

Southern Company currently uses an ICE Factor to represent capacity equivalence for an energy limited (e.g. demand response or battery) or non-dispatchable (e.g. solar or wind) resource. This capacity equivalence is determined by comparing the improvement in system reliability, as measured by EUE, accomplished by the addition of the energy limited or non-dispatchable resource to the improvement in system reliability accomplished by the addition of a fully dispatchable resource such as a Combustion Turbine ("CT"). The use of EUE in the measure of capacity value is a suitable form of ELCC, as recognized by North American Reliability Corporation ("NERC")[3].

A. ICE Method using SERVM

For energy limited resources such as batteries and demand response, ICE is determined by a direct calculation of the reliability improvement via SERVM[4] simulations. Improvements in system reliability is determined by measuring the decrease in EUE.

Starting with a Base Case (at target reserve margin), two cases are run:

1. A generic, reference CT is added to the base case at Target Reserve Margin ("TRM") and its reduction in EUE relative to the base case is calculated (EUE_{CT}).
2. The evaluation resource of nominal capacity equal to the reference CT ("Test Resource") is added to the base case and its reduction in EUE relative to the base case is calculated (EUE_{TR}).

The ICE Factor is then calculated as the ratio of the reduction in EUE of the energy limited Test Resource to the reduction in EUE of the reference CT, or:

$$ICE_{TR} = (EUE_{BC} - EUE_{CT}) / (EUE_{BC} - EUE_{TR}) * 100$$

where

[3] North American Electric Reliability Corporation, *Methods to Model and Calculate Capacity Contributions of Variable Generation for Resource Adequacy Planning*, 9 (March 2011), *available at* https://www.nerc.com/files/ivgtf1-2.pdf.

[4] Strategic Energy Risk Evaluation Model ("SERVM"). SERVM is an industry-accepted generation reliability model used for resource adequacy analyses.

ICE_{TR} ≡ ICE Factor of the energy limited Test Resource

EUE_{BC} ≡ Expected unserved energy of the base case,

EUE_{CT} ≡ Expected unserved energy of the case with the added CT, and

EUE_{TR} ≡ Expected unserved energy of the case with the added energy limited resource.

To determine the capacity equivalence of the resource, simply multiply the battery's nominal capacity by the ICE Factor.

B. ICE Method using the Capacity Worth Factor Table

For non-dispatchable resources, ICE is determined using a Capacity Worth Factor Table ("CWFT") which serves as an approximation for the full, SERVM-simulated ICE calculation. Non-dispatchable resources such as wind and solar utilize a CWFT as an efficient way to determine the ICE Factor when a single renewable resource profile is available. This method is also preferable due to the large number of resources for which simulations would need to be performed in the evaluation of bids in a competitive procurement. The CWFT is derived from the Reliability Cost report produced by the SERVM model that has been configured with the current TRM. The CWFT is an allocation of the relative worth of capacity across the various hours of the year. The hourly improvement in system reliability represents that hour's capacity worth relative to the other hours.

The capacity equivalence is calculated as the sum-product calculation of the hourly profile of the renewable resource and the CWFT.

$$\textit{Capacity Equivalence} = \sum_{i=1}^{8760} CWF(i)\ x\ profile(i)$$

where

CWF(i) ≡ the hourly capacity worth factor for the given hour from the CWFT, specified as a percent of the annual capacity worth;

profile(i) ≡ the output of the non-dispatchable resource for the given hour from the resource's expected profile

The ICE Factor is therefore determined as the ratio of the capacity equivalence to the nominal capacity rating, or

ICE Factor = Capacity Equivalence / nominal capacity.

III. ELCC as determined by LOLE

The more commonly used ELCC method determines the amount of year-round incremental or “perfect” base load that the electric system can serve with the addition of an intermittent or energy-limited resource without a change to the base level of reliability, as measured by LOLE. Because the ELCC methodology is simulating incremental load instead of making a comparison to a resource such as a CT, the ELCC will not be influenced by mechanical outages, fuel shortages, or economic dispatch constraints.

The calculation of an LOLE-based ELCC with the SERVM model begins with the system being calibrated to a seasonal level of reliability which represents an appropriate Loss of Load Expectation (“LOLE”). This system configuration becomes the target “Base Case”. The following simulation and calculation steps are then performed to determine the ELCC of an intermittent or energy limited resource, or Test Resource:

1. The Test Resource is added to the system, which typically improves overall system reliability.
2. A perpetual hourly base load (“Perfect Load”) is then added to the system until system reliability returns to the Base Case level.
3. The ratio of the Perfect Load added to re-establish the Base Case level of reliability to the nominal capacity of the Test Resource is the ELCC.

For this study, the steps above were repeated for each resource and each season (winter and non-winter) independently at three levels of penetration: 500MW, 1000MW, and 3000MW.

Model Assumptions

The SERVM model was utilized to perform this analysis using the same system assumptions that were used to perform the 2021 Reserve Margin Study[5]. This includes the use of 58 equally weighted weather years from 1962-2019 and the 2025 projected load and generation mix.

Wind

The wind resource was modeled based on an existing wind resource currently supplying energy into the Southern System[6]. The weather-year specific profiles were provided by Astrapé Consulting based on historical wind patterns.

Solar

The fixed and tracking solar resources were modeled with the use of seventeen separate solar sites distributed across the three primary states of the Southern System. Ten sites were located throughout Georgia with a system weighting of 76.7%, four sites were in Alabama with a weighting of 16.7% and three were in Mississippi with a weighting of 6.6%[7]. The selected solar expansion locations in Georgia were spread throughout the state of Georgia.

[5] Please see Technical Appendix Volume 1 for more information on the 2021 Reserve Margin Study assumptions.
[6] Currently, only a single wind profile is defined in SERVM which was utilized for this study to represent the wind test resource. Because the development of 8760-hour, 58 weather year wind profiles is resource-intensive, additional site or region-specific profiles will be developed as wind resources are procured for the Southern System.
[7] Weightings are based on estimated solar procurement across the Southern service territory over the next 5-10 years.

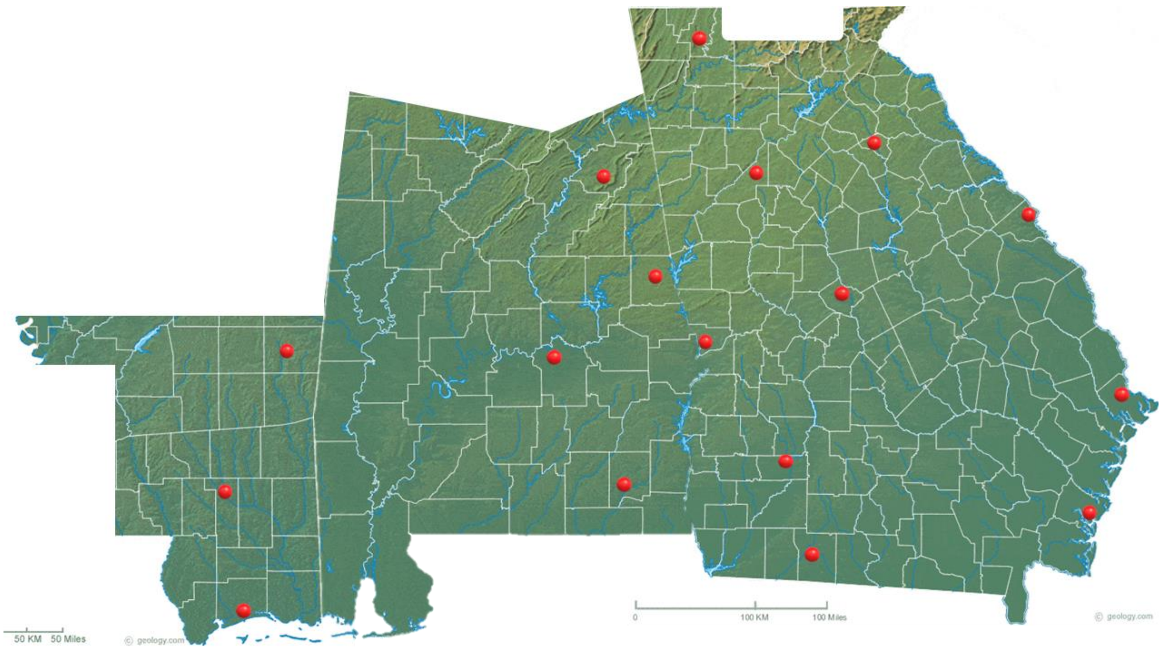

Figure III.1: Predicted Solar Expansion Sites

City	Expansion Share	Nominal Cap (MW)
GEORGIA		
Atlanta	7.7%	230.0
Athens	7.7%	230.0
Dalton	7.7%	230.0
Augusta	7.7%	230.0
Savannah	7.7%	230.0
Brunswick	7.7%	230.0
Macon	7.7%	230.0
Columbus	7.7%	230.0
Albany	7.7%	230.0
Thomasville	7.7%	230.0
ALABAMA		
Anniston	2.5%	75.0
Fort Rucker	2.5%	75.0
LaFayette	3.3%	100.0
Montgomery	8.3%	250.0
MISSISSIPPI		
Gulfport	0.7%	20.0
Hattiesburg	2.7%	80.0
Meridian	3.3%	100.0

Table III-1: Cities representing a 3,000 MW Diverse Solar Expansion Unit

The use of these separate sites ensured that the solar ELCC value was diverse and roughly represented the location of potential near-term solar expansion projects. The solar data used by the SERVM model contains only fixed and tracking solar data by city.

Distributed generation (“DG”) profiles, if they existed in the model, would not be any different than the fixed utility scale profiles. This is because the SERVM weather year profiles provide a percent output for every hour of each weather year and are not based on the nominal size of the solar site. Therefore, for the purposes of this study, no differentiation is made between DG and Utility Scale solar. Losses related to DG solar that are materially different than utility scale (“US”) solar sites are accounted for elsewhere in the Southern Company RCB Framework.

Battery Storage

Battery storage resources were modeled to provide economic and reliability benefits. The economic dispatch (or energy arbitrage) capabilities of the batteries were limited to days of low to moderate expected loads. This assumption reflects expected management of the batteries by system operators.

On days that were expected to have higher than normal loads, system operators will likely hold back the batteries to assist in the management of unforeseen reliability needs and not schedule them for otherwise economic discharges during these time periods. To assist the model in properly committing and dispatching, the batteries were also divided into 500 MW units such that the 3,000 MW penetration utilized six, 500 MW batteries.

IV. Study Results

A. LOLE-Based ELCC Methodology

ELCC values from the study are shown in Table IV-1 below.

Season	Winter			Non-Winter		
Penetration Level	500MW	1000MW	3000MW	500MW	1000MW	3000MW
Wind	50%	50%	50%	40%	40%	40%
Battery - 1 Hr	90%	90%	50%	100%	100%	40%
Battery - 4 Hr	90%	90%	95%	100%	100%	70%
Battery - 6 Hr	90%	90%	95%	100%	100%	95%
Battery - 8 Hr	90%	90%	95%	100%	100%	100%
Solar Fixed (DG or US)	0%	0%	0%	20%	20%	15%
Solar Tracking (DG or US)	10%	5%	5%	35%	30%	25%

Table IV-1: ELCC Study Results

Wind resources can support more winter load relative to the non-winter load due to higher output during overnight and early morning hours and slightly lower output during mid-day and afternoon hours. Inversely, solar resources have limited output during morning hours and are therefore not as capable of supporting winter loads. While solar output is high during mid-day and early afternoon hours, the ability to support non-winter loads becomes limited in late afternoons when temperatures and loads are still high but solar output is low.

While battery resources are energy limited, the available output is dispatchable and not limited by wind or solar patterns. For this reason, battery resources are generally effective at supporting both winter and non-winter loads. Additionally, batteries are well suited to serve operating reserves requirements which frees up other resources that would otherwise provide these reserves to serve load. The fact that these displaced, traditional, former reserve resources are now serving load and are subject to extreme temperature outages contributes to the batteries achieving less than 100% capacity values in the winter. The duration of the battery also has little impact on the ELCC if the total battery capacity is less than the minimum system operating reserve requirement (1,250 MW in this simulation). In the 3,000 MW penetration cases, there is battery capacity in excess of the operating reserve requirement available to serve load during peak load events which results in a slightly higher ICE factor except for the limited duration one-hour battery. Battery saturation is observed for one-hour resources in both seasons at the 3,000 MW level resulting in a significantly reduced ELCC. Saturation is observed for the four-hour resource in the non-winter only due to longer peak load periods relative to winter months.

B. Comparison to ICE Factors

As mentioned previously, the solar ELCC determined by increasing load was evaluated using a group of solar sites across the Southern Company service territory to simulate solar diversity. Each of the chosen sites had unique profiles for each of the 58 weather years. That said, a single average profile representing all of the chosen solar sites was not available to make a direct comparison with the ICE Factor using the CWFT methodology. However, a general comparison could be made to the generic fixed and tracking solar profiles that were utilized as part of the IRP expansion plan. Those generic profile ICE Factors, calculated using the CWFT methodology, are show in Table IV-2 below.

Season	Winter	Non-Winter
Wind	50%	20%
Solar Fixed (DG or US)	5%	25%
Solar Tracking (DG or US)	10%	35%

Table IV-2: Wind and Solar Resource ICE Factors using the CWFT

Since the CWFT is a static representation of relative capacity worth with currently modeled resources, it does not capture the capacity value impact seen at increasing resource penetration levels. Because of this, the ICE Factors in Table IV-2 are most closely comparable to the ELCC values at the 500MW penetration level.

Similarly, the wind profile that was utilized in SERVM for the ELCC methodology determined by increasing load is for a site that is not located within the Southern service territory. The generic profile that was used to calculate the wind ICE Factor with the CWFT methodology shown in Table IV-2 was created from local weather patterns. These wind profile differences limit a direct comparison between these two sets of ELCC values.

The ICE Factor by CT comparison methodology using SERVM is more suited to dispatchable resources such as batteries and demand response programs. The values shown in Table IV-3 below were calculated in early 2020 and published as part of the Georgia Power 2022-2028 Capacity RFP[8].

Season	Winter	Non-Winter
Battery - 4 Hr	70%	90%
Battery - 5 Hr	80%	90%
Battery - 6 Hr	90%	95%
Battery - 7 Hr	90%	95%
Battery - 8 Hr	95%	95%

***Table IV-3*: *Battery* Resource ICE Factors compared to a CT**

Continuous improvement in battery storage modeling software and techniques were made throughout 2021. These improvement efforts limit the ability to directly compare these ICE Factors and the ELCC study results shown in Table IV-1.

[8] The values in Table IV-3 have been rounded to the closest 5% which is consistent with the other capacity values in this document

V. Conclusion

Consistent with much of the electric utility industry, the Company uses a form of ELCC to determine capacity equivalence of energy limited or non-dispatchable resources. The form of ELCC that the Company uses is ICE Factor. ICE Factor determines capacity equivalence by comparing the reliability improvement of the resource, as measured by EUE, to a dispatchable resource. The more widely used form of ELCC compares the reliability improvement of the resource, as measured by LOLE, to a load addition. The Company believes either method is a reasonable approach to determining capacity equivalence. Both methods have advantages and disadvantages that should be carefully considered when deciding how to value capacity in the Company's reliability planning. For example, the LOLE-based ELCC method is useful in determining capacity equivalence for a resource category over a range of penetration levels, but on the other hand it would be difficult to implement on a project specific basis using individual facility generation profiles. While the two methods should not be expected to provide identical results, the LOLE-based ELCC method results are reasonably consistent with ICE Factors produced from current methodologies. Thus, the choice of one method over another is not expected to have a large impact on the Company's planning results. The Company will consider the results of this study, any advantages and disadvantages of both methodologies, and the impact on the planning process and other related activities, to make the best decision concerning capacity equivalence in future Integrated Resource Planning and resource procurement activities.