THE HOSTING CAPACITY PROCESS

October 2020

Introduction

The electric industry is faced with making decisions on how to effectively yet efficiently plan for new devices in the changing distribution system. These new devices primarily include distributed energy resources (DER) but also include loads. A foundational component of such planning processes is the ability of the distribution system to "host" these devices – aka hosting capacity.

Hosting capacity is not just an analysis, but a complex process that combines the collection of input data and the selection of analytical parameters that ultimately define how the results can be applied. The hosting capacity process has evolved in different ways for various utilities and across different tools, but the most important part, the results, have been shown to be similar when the inputs and analytical parameters are aligned. Thus, the analytical engine can vary among tools while still producing comparable results. Results from such analyses can be used in a range of applications from planning to interconnection studies and mapping.

This paper will highlight some of the factors that make hosting capacity complex, including that:

- The hosting capacity process involves setup, analysis, and interpretation of results.
- The end-use application of hosting capacity results defines the setup and analysis.
- The process is evolving with the future needs of distribution engineers.

Hosting capacity is defined as an estimate of the amount of DER that can be accommodated anywhere on the distribution system without adversely impacting power quality or reliability under existing control configurations and without requiring infrastructure upgrades.

Hosting Capacity is a Complex Process

Electric utilities have run power flow and protection studies for decades. Leveraging their unique understanding of the system and engineering judgement, these studies are performed by dedicated engineers that focus on the intricacies of the specific case studies. With the increase in DER on the distribution system, these same studies and expertise have been used to understand the DER impacts and are a critical component of calculating hosting capacity. Hosting capacity is typically referred to as an analysis method or a value, but in reality is a process made up of three key steps.

The first step, **data**, represents the models and information needed to start the hosting capacity process. This data has not historically been readily available, and many utilities are continuing to build-out the robust data set required. The second step, **analysis**, represents the methodology, impact factors considered, and tools needed to calculate hosting capacity. There are multiple approaches to calculating hosting capacity and each have pros and cons. The third and final step, **application**, represents the use of the hosting capacity results for specific purposes. Most commonly this includes using hosting capacity as part of the planning process or to inform interconnection decisions. Each of these steps represents a unique challenge that continues to evolve to meet the needs of the industry. At the same time, the steps are not in isolation from one another as each step of the process is dependent and has an impact on the others.

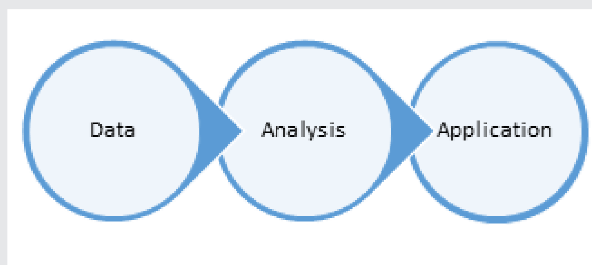

Figure 1. Hosting Capacity Process

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This white paper was prepared by EPRI.

This process and the complexity surrounding it is not unique; hosting capacity studies utilize the same fundamental inputs and methods that are used for traditional planning studies. A key difference is that the hosting capacity process is intended to enable efficient evaluation across an entire system instead of what has historically been examination of more targeted case studies. To do so, the hosting capacity process must be informed by engineering judgement in order to ensure impacts are captured appropriately.

The complexity of the hosting capacity process should not be taken for granted as each step continues to evolve. This includes collecting and handling the enormous amount of data that can be utilized as well as establishing the analytical framework to achieve results that enable the desired application. The critical balance of the hosting capacity process is to meet the need of the end-use application in an effective and efficient manner.

Using the Right Data

The data used in the hosting capacity process come from a range of sources such as GIS, field measurements, and engineering judgement. Gathering and validating this data takes significant effort and is an ongoing exercise. Often times, the data may not be up to date (does not represent current or as-built conditions) or is not something the utility has historically needed to capture and track. Because of this, many utilities are in the process of building out the data sets required to perform hosting capacity studies. Doing so is not insignificant and takes time and infrastructure to do properly. In other cases, utilities may have granular data sets available, but are still evaluating how to best utilize them. While the tendency is to think that more detailed data is better, having more granular and specific data inputs can increase the uncertainty and ability to apply the results.

These realities – data sets are evolving and not all data is good data – are an important consideration in the hosting capacity process. While utilities are working on building out the necessary data sets, many are performing hosting capacity studies with the data they have available. The result is that hosting capacity may be calculated on a less granular level or with a reduced set of metrics based on the amount and quality of available data.

Regardless of data utilized, it is constantly changing. As that data changes, the analyses must be refreshed to be consistent with the data at hand. This creates an additional challenge to synchronize data with simulation studies. Ultimately, the input data has a very strong influence on the final outcome of the hosting capacity process.

Performing the Analysis

The analysis step includes the methods, impact factors, and tools applied in the hosting capacity process. Each of the components of analysis give utilities flexibility when conducting the hosting capacity study. However, with that flexibility also comes choices that can fundamentally impact the final solution.

There are various hosting capacity methods that have been developed across the industry, ranging in complexity from iterative approaches to algorithm-based approaches to approaches that leverage both. Most methods focus on point-by-point hosting capacity, however, some methods also, or instead, examine the ability of the distribution system to accommodate a distributed set of new devices. Hosting capacity methods[1] are included within most vendor software platforms such as Cyme and Synergi as well as third-party tools such as EPRI's DRIVE™. This gives utilities options for the tools they use to conduct studies and the impact factors[2] they choose to consider.

Impact factors represent a critical piece of the hosting capacity analysis as the selection of the grid and DER device characteristics considered influence the result. One impact factor, such as how to consider/control voltage regulators within the study, can produce contrastingly different solutions for the same input data. Other impact factors, such as load levels to consider in the study, allow the utility to observe the range in hosting capacity at any particular location. Each impact factor and how they are considered, however, compounds the analysis that must be conducted to find the full range in solutions.

When hosting capacity is being calculated across an entire system in an automated fashion, engineers must predetermine all impact factors that should be included in the hosting capacity analysis. Different impact factors should be used depending on the end-use application of the results and available data.

[1] *Impact Factors, Methods, and Considerations for Calculating and Applying Hosting Capacity*. EPRI, Palo Alto, CA: 2018. 3002011009.

[2] *Impact Factors and Recommendations on How to Incorporate Them When Calculating Hosting Capacity*, EPRI, Palo Alto, CA: 2018. 3002013381.

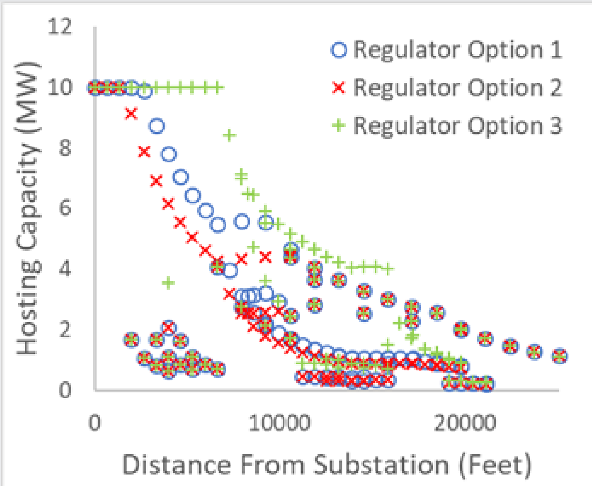

Figure 2. Sample Analysis Impact Factor

Every Application is Unique

Having a clear understanding of which applications the hosting capacity results will inform is critical to determining what data is required and how the analysis approach should be applied. The primary applications informed by hosting capacity results include interconnection study screening and system planning. The impact factors considered can differ for each type of study. Interconnection screening applications are best informed by examining the ability to accommodate a device at a specific location, while system planning studies are best informed by examining the ability to accommodate multiple devices spread throughout a feeder. Traditional interconnection studies focus on worst-case conditions, while system planning studies focus on a range of conditions and potential scenarios.

For interconnection, the focus is on considering a specific location to ensure that under any situation (grid configuration, device operation, load condition) the device does not cause any adverse impacts to the grid. While hosting capacity varies over time the minimum value influences interconnection. Because of this, the hosting capacity process must capture the absolute minimum hosting capacity that applies to the considered device. If not, the system would be at risk of power quality and reliability issues, limiting the utility's ability to manage the system to meet all customer's needs.

Planning has more uncertainty, so the focus is on considering a range of conditions and scenarios rather than determining an absolute minimum hosting capacity.

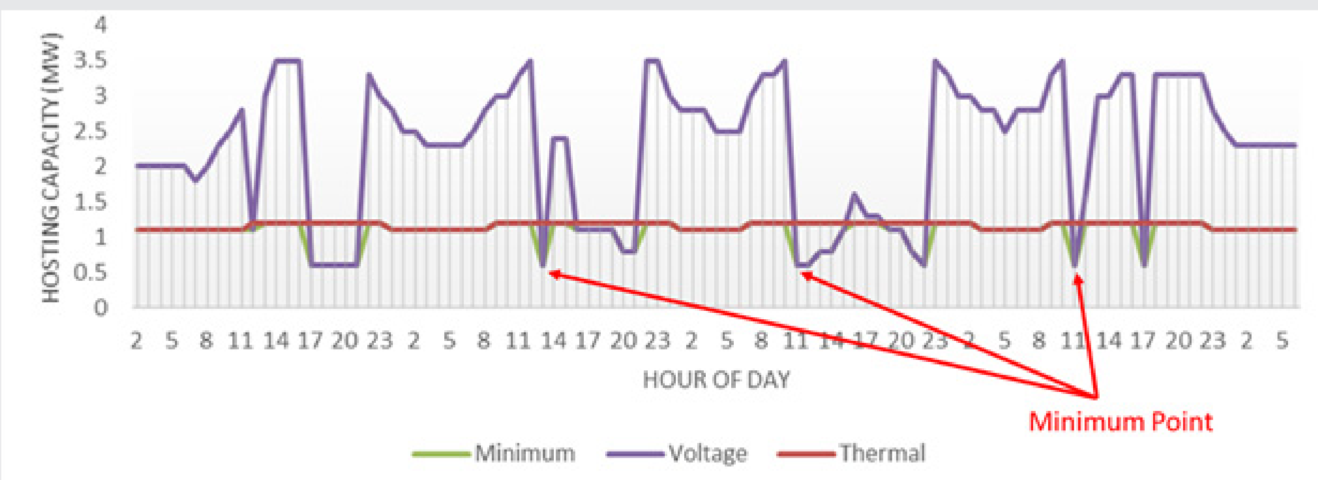

Figure 3. Variation in Hosting Capacity Over Time and Metric (Minimum Point Influences Interconnection Application)

Time and Resources for Hosting Capacity Process

Factoring the complexity of data and analytics together, the overall hosting capacity process can quickly become an extensive exercise. It is important, then, to recognize the limitations of model-based calculations. This is particularly true as it relates to system-wide studies compared to specific interconnection or planning studies where the engineer can dig deeper into the details of the analyzed conditions. In system-wide studies, the best available data and assumptions are used, thus the results can only "estimate" the potential impacts of new devices. This is true no matter which hosting capacity methodology is utilized. Given the understanding that hosting capacity analysis results will never be the same as a specific interconnection or planning study, it is critical to consider the cost-effectiveness of time and resources spent based on how the results will be used.

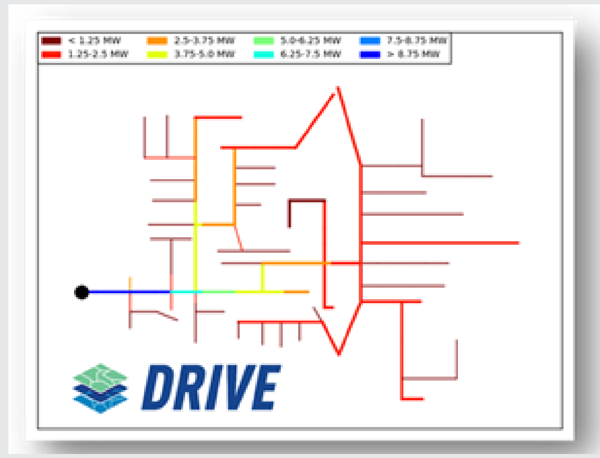

Figure 4. Interconnection Application

Results of a Hosting Capacity Study

Hosting capacity results are only an estimate of the penetration that the system can accommodate. This is important to understand when interpreting the results of the end-use applications – Interconnection, Planning, and Mapping.

Interconnection

DRIVE™ and most other tools calculate hosting capacity with the granularity needed to **inform** interconnection studies. After examining the hosting capacity at each location independently, the engineer has knowledge of the penetration that can be accommodated at the proposed location identified in an interconnection request.

However, the use of hosting capacity results to inform specific interconnection applications is only aligned if the resource characteristics and conditions analyzed are the same in the hosting capacity study and the specific interconnection request. Specific characteristics of devices such as PV (interfaced to the system via inverters) should be used in the hosting capacity analysis to inform PV interconnection requests. Similarly, characteristics such as power factor setpoints or special controls should be used in the hosting capacity analysis if similar setpoints and controls will be applied in the interconnection study. The misconception is that hosting capacity study can replace an interconnection study. However, the depth and specifics of an interconnection study (such as solar panel movement/tilt, generator control, feeder buildout, etc.) are well beyond the scope of the hosting capacity study.

Planning

Distribution system planning can leverage location-specific hosting capacity results, but a more effective approach is to examine the ability to accommodate multiple devices on the feeder. Distributed hosting capacity is the penetration that a feeder can accommodate if devices are distributed across the feeder at multiple locations.

Considering a distribution of devices is aligned with this application because system planning typically focuses on a 5-10 year planning horizon after which not one, but many devices might come online. Because the analysis involves a distribution, the hosting capacity is not calculated for a specific location but rather the feeder as a whole. Feeders that are more constrained in their ability to accommodate widespread resource adoption can be identified.

The hosting capacity results are again an estimate but can inform planning by identifying the feeders that might benefit the most from system investments. Hosting capacity results from this type of analysis should not be used to inform interconnection reviews as they do not calculate location specific hosting capacities.

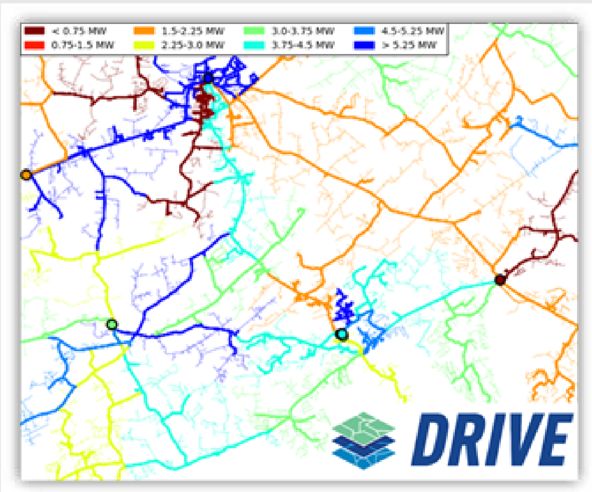

Figure 5. Planning Application

Mapping

Portraying hosting capacity on a map has become a common request in order to convey results to DER developers. Given the complexity of the analysis and uncertainty with input data, mapping presents a challenge to utilities, both in developing accurate results and presenting them in a way that can be interpreted correctly. Supporting information should be provided to clarify the underlying analysis, assumptions, and the impact of its use. However, if the maps are overly complicated, they will lose value.

Maps are informative but not definitive due to the underlying input data and impact factors considered in the analysis. Mapping should focus on providing an indication of impact but stop short of providing results with high uncertainty. Analyses, such as those considering time-based impacts and often performed for detailed studies, produce time-based granular results but increase the uncertainty on the validity of those results system wide. Thus, those results should be reserved for detailed studies conducted after identifying optimal locations within maps.

Evolving Analytics

Evolving analytics are an important part of improving the overall hosting capacity process. Tools are developing and enhancing their analytical framework to make their analyses more efficient, accurate, consider new hosting capacity metrics, and to inform additional applications.

Efficiency

As analytics become more complex, analysis efficiency is an important aspect. To improve efficiency, the underlying methods are being refined. An example of this refinement could be as simple as parallel processing where multiple cores within a computer are used to analyze multiple metrics (such as overvoltage and voltage deviation) separately but at the same time. Another example of refinement includes reducing the number of power flows required to reach a hosting capacity solution. Reducing the number of power flows can be done in many ways. One way is to properly consider the right variables, such as number of load levels, that need to be considered in the analysis. Another way to reduce power flows is to implement advanced techniques to non-uniformly "iterate" through higher penetration levels until a hosting capacity solution is found.

Accuracy

Validation

Because methods are constantly evolving, validation should be ongoing to make sure methods are providing consistent and accurate results moving forward. Below is a sample validation where the hosting capacity solution is plugged back into the base model to observe the actual voltage impact. In this case, the hosting capacity solution found that the voltage would reach the 1.05 Vpu limit with 1.0 MW of PV at the particular location. With that amount of PV modeled in the feeder, the voltage is right at the limit, thus validating the hosting capacity solution. Similar validations can be made for all hosting capacity metrics.

Method Comparisons

In conjunction with validation, ongoing comparisons should be conducted between various hosting capacity methods/tools. Since the analytics within tools have evolved separately, based on input from tool developers, stakeholders, research, and utilities, different assumptions have been made and built into the analytical engines. Comparisons should bring light to these methodology differences such as how the analysis iterates between penetration levels, what impact factors are considered, and what options are brought out to the users.

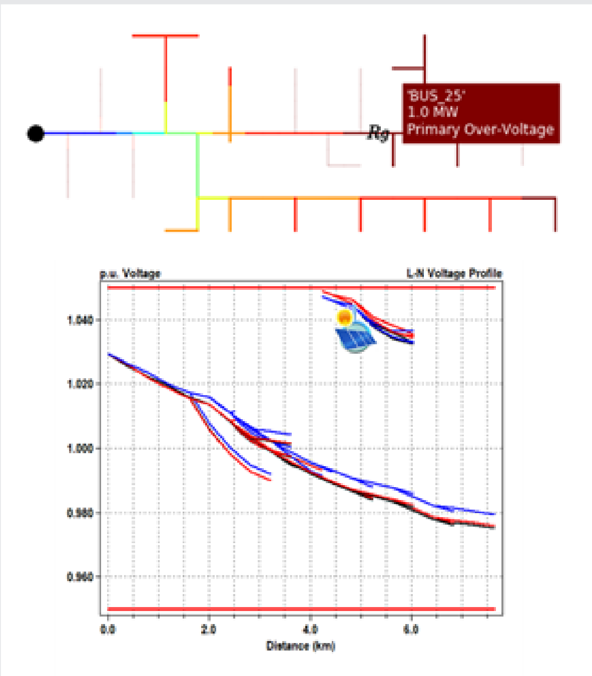

Figure 6. Validation of Methodology

New Metrics

New metrics can be established by which hosting capacity is quantified. One such metric, typically reserved for detailed studies, considers alternative configurations of the distribution system. This examines the ability of the system to maintain operational flexibility. Currently, there is limited depth in hosting capacity analytics that takes place around considering alternative configurations of the system.

As analytics evolve, the tools can better incorporate the impact of alternative configurations within a hosting capacity study. Given the importance, EPRI has implemented and evaluated several methods that consider reconfiguration in the DRIVE™ tool. Below is an example how hosting capacity can change based on different configurations of the system.

New Applications

Evolving analytics provide new capabilities to tools. Hosting capacity studies have primarily focused on how much load or generation can be accommodated without any adverse impacts and without requiring upgrades. This hosting capacity value, however, does not quantify how much load or generation can be integrated at that

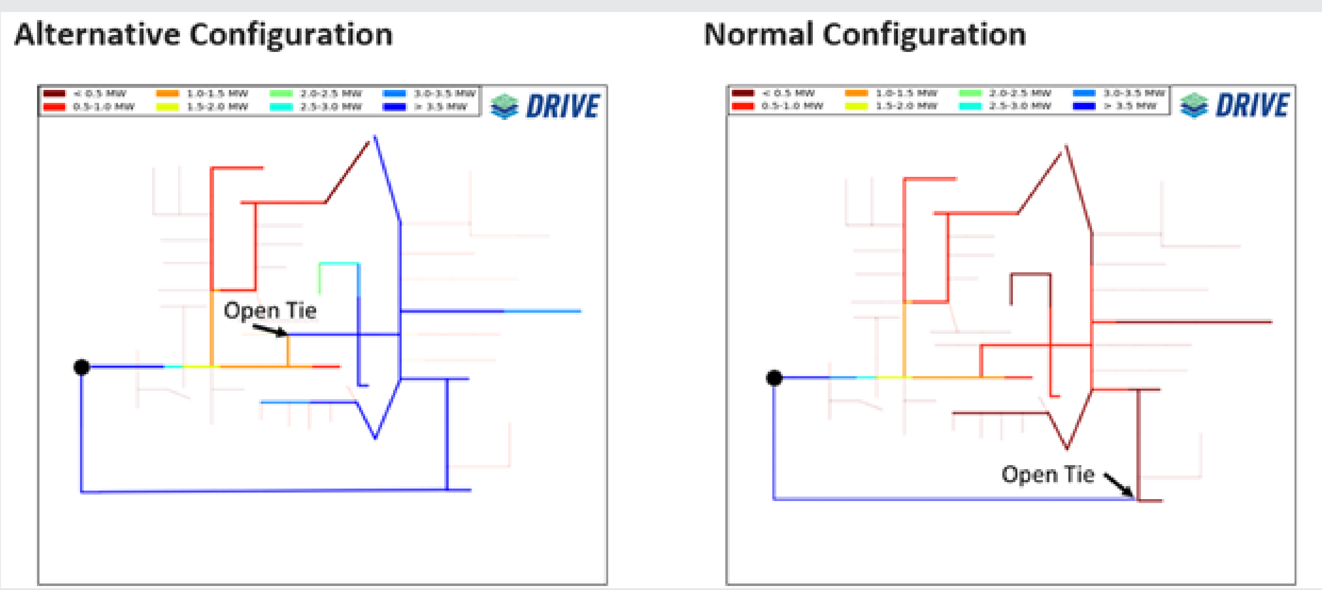

Figure 7. Expansion of New Metrics

same location after alleviating adverse impacts through grid and/or customer mitigation. Mitigation options add an additional layer of complexity on top of the already complex assessments of hosting capacity.

Previous research[3] has shown that detailed analyses can apply mitigation options to reassess hosting capacity on a feeder. However, those assessments are detailed making them burdensome to perform on a broad scale because the engineer must design the applicable changes as well as manually manipulate the feeder model.

EPRI has been working to develop improved analytics that make this process less burdensome. Utilizing new methods, the predefined implementation of mitigation options is applied and automated in conjunction with DRIVE™ to reassess the location-specific hosting capacity. The added layer of the analysis provides the engineer with a quick reference to simple solutions that would increase the size of a resource that can be integrated.

Conclusion

The hosting capacity process is constantly evolving and becoming more complex to keep up with the pace of change in the industry. As this process evolves, it will be important for the industry to continue to improve each aspect – data, analysis, applications. The primary goal of hosting capacity is to provide additional insight on distribution system impacts that were not available a few years ago. While informative, hosting capacity results are an estimation and have limitations in how they should be applied. By understanding its limitations and focusing on the resulting applications, utilities can ensure that the hosting capacity process is implemented in an effective and efficient manner.

[3] *Mitigation Methods to Increase Feeder Hosting Capacity.* EPRI, Palo Alto, CA: 2018. 3002013382.

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