gridspertise

Hosting Capacity

White Paper

Table of Contents

Hosting Capacity

The Hosting Capacity of a distribution grid identifies the maximum amount of active power, expressed in kW, that can be injected into the network by distributed energy resources (DERs) without having to perform grid-enhancement activities and avoiding the violation of operational limits.

This guarantees the balance between load and generation and ensures that the grid is correctly protected in case of faults.

Limits of Hosting Capacity

One of the main goals of DSOs (Distributor System Operators) is to ensure a good quality of service without over-stressing the grid infrastructure. **Quality of service** is measured by specific KPIs related to service continuity and quality of voltage. DSOs must comply with different standards depending on country/region (e.g. IEC 50160). Usually, there is a fixed percentage range within which voltage fluctuations are allowed (e.g. +/-10%).

The medium voltage (MV) distribution grid is usually operated radially, thus additional active power in one node of the grid will result in two effects: (i) a voltage increase in all the nodes of the same feeder, (ii) and a current increase in all the sections affected by the active power surge. The same effect on the voltage and current can be observed when the generator exchanges reactive power with the grid. This means that the Hosting Capacity is **limited by** the **maximum voltage threshold** that can be reached in the nodes and the **maximum current threshold** of the single grid sections.

Another constraint on Hosting especially when considering microgrid operations, arises from the fact that DERs are frequently connected to the grid through DC/AC converters, and they inject the maximum available power into the grid.

Injecting the maximum power could result in a production exceeding the load, which could cause a power interruption.

Therefore, electronic converters decrease the short-circuit contribution in the event of fault, hence the protection system needs to be adjusted accordingly.

This paper will mainly analyze an alternative way to increase the Hosting Capacity when limited by voltage and overload issues due to distributed generation.

Traditionally, when voltage and current constraints are violated, DSOs resolve the issue by reinforcing the grid.

The latter is costly and time-consuming due to the need for authorization processes and installation activities.

Moreover, grid reinforcement could be necessary for just a few hours per year, jeopardizing the economic sustainability of the investment.

Currently, load/generation balancing, and a proper short circuit current are guaranteed by limiting the percentage of the energy produced by DERs (thus defining the Hosting Capacity of the Grid).

An alternative way to maximize the Hosting Capacity can be to introduce smart logic for voltage control, flexibility services, etc. which means **installing smart devices on the edge capable of dynamically regulating tunable equipment and DERs**.

Simple strategies to Increase Hosting Capacity

An alternative way to increase the Hosting Capacity in a grid characterized by high DER penetration is applying **innovative methods for voltage control** and using **Demand Response** or **flexibility services**. **Voltage Control** and **Demand Response** rely on real-time state estimation algorithms, objective functions, and edge devices interacting with each other.

Traditional IEDs (such as RTUs, Protection relays, BCUs) may lack the functionalities requested by DSOs to enable flexibility **services**.

In fact, to accomplish this new goal, all the devices need to rely on a trustworthy communication infrastructure that will enable customers and DSOs to manage the grid differently.

In order to develop this kind of advanced infrastructure, the regulatory system has to allow DSOs to provide customers with economic benefits for all services they perform aimed at promoting the smooth operation of the electrical grid. This would enable the development of a new market, requiring the adoption of conventional contractual relationships between DSOs and their customers.

Demand Response applications

Demand Response can be used to locally fix the voltage or to decrease the current on sections.

For instance, the voltage at a particular node is influenced by the injection or withdrawal of active and reactive power. Even if DSOs have the capability to regulate the voltage level by controlling the OLTC (On-Load Tap Changer) of the HV/MV transformers, that are traditionally adjusted using static settings of the regulator, based on measurements on the HV/MV transformers, the DERs static settings of the OLTC regulator could limit the Hosting Capacity.

Having the possibility to set the OLTC through measurements in all the grid and state estimation algorithms, the Hosting Capacity will increase thanks to smart logics of voltage control. With technologies that are currently available on the worldwide distribution grids, if an HV/MV transformer loads feeders with mainly DERs, all the nodes will be affected by the OLTC tuning.

A critical situation occurs when the DSO increases the voltage on the MV busbar to match the voltage level on the main load feeders, resulting in DERs being disconnected due to overvoltage constraints. When this situation occurs, investments could be based on grid reinforcements (adding new substations), or the problem could be mitigated by using V/Var control and Demand Response.

In these cases, **coordination between OLTC and Demand Response** is required. For example, the DSO that uses the OLTC, fixes the voltage on the loads while DERs can regulate the voltage locally by modifying their reactive power set point.

As a first level, a single generator could self-regulate following Q(V) drop. If the regulation is not adequate, the DSO could ask for additional available reactive power to other generators on the same feeder or limit the production for the required time.

Looking at the current, if an overload on grid sections occurs, state estimation algorithms can forecast, detect and resolve the problem by asking DERs to fix the load by modifying the behavior for the required time frame.

Edge-computing as a Resource to Increase Hosting Capacity

As noted in previous chapters, customer attention to service continuity is increasing since most of our daily life-actions, like cooking, depend on electrical services. Moreover, grid operation is becoming more challenging since energy will be produced mostly by unpredictable DERs.

In order to maintain grid stability, DSOs need several measurements, signals, tools, and systems capable of processing data and enabling to make decisions in a short time frame.

Since placing the entire decision-making process at central level might overload the communication network and the central system, resulting in worse performance, the solution resides in **distributing the intelligence at the edge**.

Distributed intelligence means installing edge devices with **high computational capabilities** that enable dynamic decision making directly in the field using all the information **collected by sensors**. The central system is used for monitoring, tuning the distributed intelligence, and backing up actions in case of problems. Edge computing devices can also collect and analyze historical load profiles for specific nodes and foresee the needed voltage adjustments in case of central system/IT infrastructure unavailability.

An example of **advanced voltage control** could be achieved by installing sensors on critical nodes of the grid so that they can communicate the measurements to a master edge device on the HV/MV substation, that, considering grid conditions and measurements, makes decisions on the OLTC.

The master edge device just mentioned needs more complex algorithms compared with common PLC logic. Looking to other other use cases related to edge computing like the grid operation in an island, this can be obtained by distributing sensors along the grid that can communicate with a master edge device that makes decisions on generators, storages, and loads using local objective functions.

A similar approach, modifying the orginal function of the master edge device, could also be applied on a connected grid, for example, to reduce the exchange of reactive power with the TSO network.

The above-mentioned use cases are only some of the possible ones that could be developed by using edge devices. Bear in mind that it is possible to define hundreds of use cases, which today probably have minor priority.

The most important thing to remember is that with high computing power distributed in the field and the possibility to update its functionalities is possible to **increase customer satisfaction** and **optimize investments**.

Use cases

Applications	Description
Customer Interface Standardization	Historically, DER control systems were designed to work autonomously from DSO systems, and their interface was not standardized. With the spreading of renewable sources and the necessity to enable flexibility services, DSO need a standard interface to communicate with DERs, which could be obtained using edge devices.
DERs Observability and Controllability	A standard interface with DERs allows the DSO to collect real-time measurements to achieve full grid observability. Moreover, edge intelligence enables controllability functions that increase the hosting capacity and forward energy transition.
Edge Devices for Optimization of Grid Investments	Collected measurements of edge devices could be aggregated to plan and optimize investments on the grid. Furthermore, data could feed machine learning algorithms to detect and predict energy usage patterns.
Load Modulation using edge devices and Demand Response	Hosting capacity analysis associated with the use of edge devices could help DSOs in identifying areas with surplus capacity during off-peak periods or fault conditions, where demand response applications could be implemented. So, DSOs could enable flexibility services to their customers for load modulation or load shedding, optimizing grid congestion, and reducing peak loads.

Applications	Description
Microgrid Control	The installation of edge devices is crucial for the management of microgrid control systems. The main functions of a microgrid controller include optimizing energy resources, managing loads, and ensuring the instantaneous balance between loads and generation. Moreover, it coordinates distributed energy resources, regulates frequency and voltage, and can operate the microgrid autonomously or connected to the main grid. It also communicates with field devices and implements cybersecurity measures for reliable and efficient microgrid operation.
Voltage and Power Quality Management	Hosting capacity analysis could help maintain proper voltage levels and power quality throughout the distribution grid. By considering the spread of the DERs and their impact on the voltage profile, DSOs can operate the grid properly without violating voltage constraints and ensure good quality of service to their customers. Moreover, a master/slave edge device communication could optimize the voltage in all the grids.

Benefits

Edge computing provides several benefits to analyze Hosting Capacity, especially in evaluating the spread of DERs within the grid for the DSO. By deploying intelligent devices at the edge, capable of processing real-time measurements and communicating with a central master edge device, several advantages can be obtained. First, latency is significantly reduced, leading to quicker data processing and response times. In addition, bandwidth efficiency is improved, optimizing data transfer across the TLC network.

Moreover, if a problem affects an edge device, the rest of the grid logic will continue to function properly because of the distributed intelligence, while if all the intelligence runs on a central system, the same problem will affect the operation of the entire grid. It is therefore clear that by keeping data processing at the edge, grid resiliency will increase.

The implementation of autonomous systems with edge computing is proving to be invaluable for the renewable energy sector and for grid management.
It allows more efficient utilization of renewable resources and facilitates smarter energy distribution and management strategies.

Conclusions

The integration of Distributed Energy Resources poses various challenges for Distributor System Operators in ensuring grid stability. In fact, conducting Hosting Capacity analysis becomes essential to assess the grid's capability in accommodating DER fluctuations.

Since conventional grid reinforcement is made expensive and unsuitable by the constrain of the network's Hosting Capacity by voltage and current thresholds, by leveraging on edge computing and advanced algorithms, DSOs can find efficient solutions that enable distributed intelligence and real-time decision-making at the grid edge.

Moreover, thanks to the employment of smart logic and the integration of Demand Response mechanisms controlling voltage and current levels is possible. By adopting edge computing and distributed intelligence DSOs are able to optimize grid operations while ensuring a sustainable future for the energy sector.

Edge computing and flexibility services to improve Hosting Capacity

Gridspertise

Gridspertise offers grid intelligent devices, end-to-end cloud-edge platform solutions, and services to accelerate the digital transformation of electricity distribution grids across three main areas: metering and grid edge digitalization, network infrastructure digitalization, field operation digitalization.

The Company's portfolio is designed as an open ecosystem, easy to integrate with Distribution System Operators' existing infrastructure, combining intelligent and automated grid devices with ready-to-use modular applications, running at central level as well as on the edge.

The company was set-up in 2021 as a carve-out of Enel's twenty-year-long experience in developing, testing, and scaling up digital technologies to transform legacy distribution networks into smart grids.

Gridspertise is today jointly controlled by the Enel Group and the leading global alternative investment manager CVC Capital Partners.

Authors

Giovanni Valvo
Responsible of Technology Development Flexibility Team

Damiano Bracci
Grid Solutions Marketing Manager