The European Association of the Electricity Transmission and Distribution Equipment and Services Industry

Edge Connectivity: a catalyst for the digital transformation of grids

T&D Europe white paper

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Introduction

The objective of this white paper is to emphasise the importance of edge connectivity as an enabler of the sustainable and digital transition of the electrical grid. Smart meters are an essential component of edge connectivity but other devices, located behind-the-meter and in front-of-meter, are also required for this transformation.

Edge connectivity refers to the ability to collect and transmit operational data to reach transparency regarding the real time[1] state of the grid. They can come from a variety of devices located at the edge of the electrical grid, such as smart meters, sensors, and other edge devices. This data can be used to optimise grid planning, operation, and enable a wide range of use cases involving Demand Side Response (DSR), Distributed Energy Resources (DER) management, and grid optimisation.

Congestion in low voltage distribution grids

New actors in low voltage (LV) distribution grids have started to appear, such as electrical vehicles (EVs), heat pumps, prosumers, and groups of users who are forming energy communities. This change will result in new scenarios in the electrical grid flow patterns.

[1] The concept of "real time" varies in the sector, depending on the control level, ranging from seconds in the control room to microseconds for power electronics-based equipment – "real time" should be understood here as "close to real time".

The massive insertion of DERs will amplify this phenomena, and higher voltage variation and instability will be observed in LV distribution grids. It will potentially lead to congestion, which the Distribution System Operator (DSO) will need to solve to avoid an overvoltage to the rest of users in this area and create conflict in the Medium Voltage (MV) distribution network. On the other hand, the DSO must compensate increasing demands.

To mitigate this topology of problems, it is necessary to monitor the LV distribution network by the DSO to identify variations in grid behaviour patterns. ACER suggests using flexibility from end users through balancing instruments to avoid congestion. It will be necessary to identify restrictions to open local flexibility markets [1]. These markets will be dependent on national negotiations between different aggregators, which will provide flexibility to their customers to adapt restrictions from the DSOs. This type of market will unlock local solutions and products to influence consumption and/or generation. The use of active power to give support to the voltage will be one of the options to cover these types of scenarios and issues.

Least exposed types of congestion can be detected through predictive analysis, but, in some situations, it will be necessary to solve disruption quickly due to non-forecasted congestion. In this scenario, the DSO could establish a direct compromise with several users to reduce consumption and manage congestion or utilise its own sources in the LV distribution network if flexibility from the end user does not have sufficient capacity. This type of solution requires the DSO to establish connection to the end user devices through edge connectivity technologies [2], [3].

Device and data management

The electrical grid is characterised by diverse vendor products, creating a rich mosaic of Intelligent Electronic Devices (IEDs) used to monitor, control, and protect the power system through advanced automation. However, one prevalent challenge is the collection of non-operational data which often requires manual intervention. Information tends to exist in isolated pockets across various functions, hindering seamless collaboration and decision making. As we look towards the future, the scale-up of DERs results in the massive deployment of new intelligent devices on the edge, intensifying the device management complexity. Additionally, the need to effectively manage settings and configurations of the multitude of IEDs further adds to the multiple challenges the utilities face in this domain.

Adding to the intricacy is the presence of non-standard data and file formats, impeding efficient data exchange and analysis. Moreover, timely access to critical data remains limited, hampering the ability to respond swiftly to fast-changing conditions. With the rising importance of cybersecurity, ensuring the protection of critical infrastructure becomes an integral aspect of the utility's mission.

Imagine a scenario where a utility company needs to manage a wide range of devices. By using a centralised device management solution and leveraging edge connectivity, the utility can remotely monitor both operational and non-operational data. This eliminates the need for manual data collection and enables the quick and accurate identification of potential problems. The device management empowers the utility to efficiently handle inventory and device settings and ensures optimal performance and security across their devices. Field personnel can address issues promptly by accessing the devices remotely and securely, improving response time. Centralised device management solutions collect data from the edge, enabling thorough monitoring of the device's health and providing insights for preventive maintenance to minimise downtime.

By integrating this solution with other enterprise applications, the utility gains a comprehensive view of their business, optimising operations, resource allocation, collaboration, and decision-making. Edge connectivity is utilised to revolutionise sector synergies, grid and fleet management, unlocking new levels of efficiency, reliability, and operational excellence.

Communication path to the grid-edge

The grid edge has been identified as one of the most important enablers for the energy transition. As it connects the grid automation with the automation systems "behind the meter", it becomes of paramount importance for the integration of decentralised energy resources into the overall energy management.

In the past however, there was no communication across this demarcation line, as the energy management was based on the paradigm “generation follows consumption”. Therefore, only the bulk generation facilities were integrated in the grid balancing. With the ongoing replacement of fossil bulk generation by decentralised, renewable technologies, the capability to communicate with decentralised energy resources is established. Based on that, it becomes more important to be able to integrate these resources into grid balancing instruments.

smartEn [4] has already responded to this subject with a position paper that provides an overview of the behind the meter standardisation trends directly at the grid edge. This position paper does not consider the end-to-end communication requirements needed for the integration of DERs into the grid balancing.

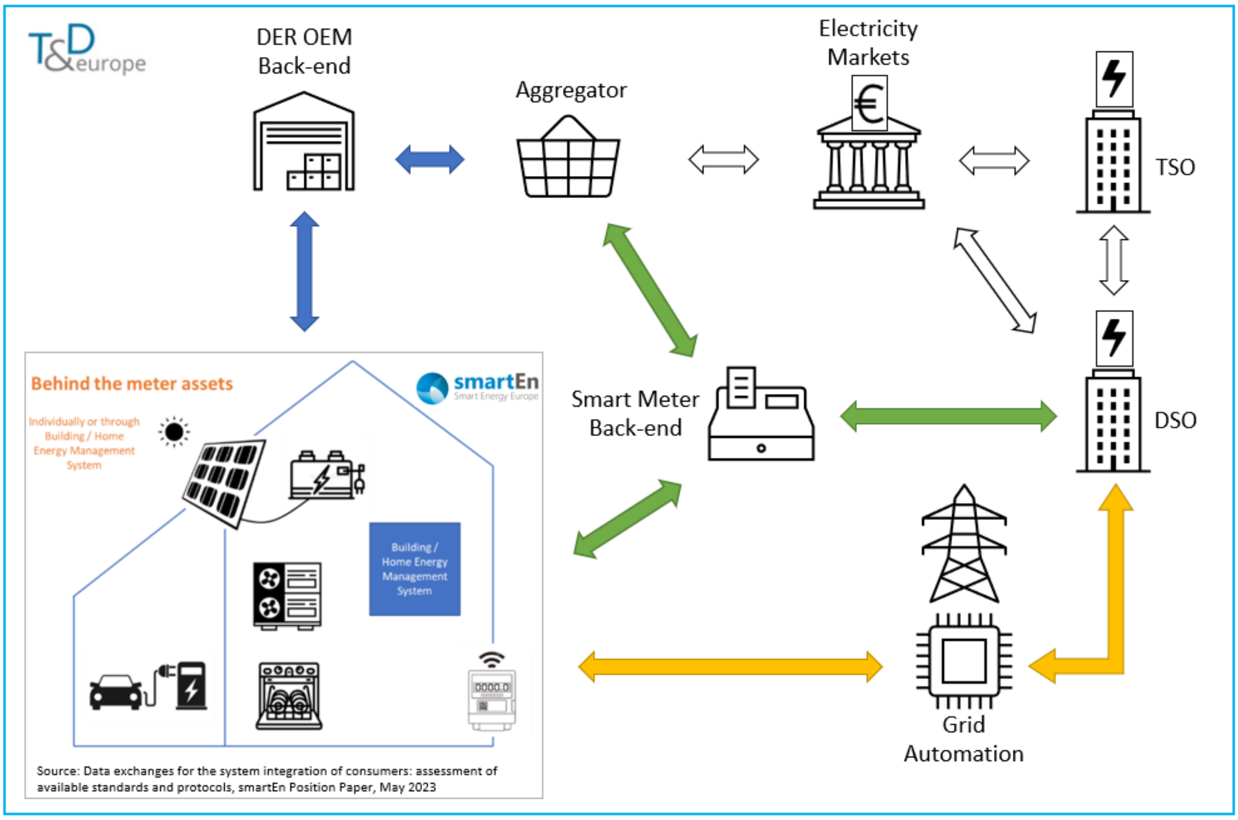

Figure: Three major communication paths towards the grid edge

- *Bottom left: smartEN*
- *Top left and right: T&D Europe contribution*

The figure above shows the three major trends for implementing this end-to-end communication. The yellow path rolls out the existing grid automation technology into the lower voltage distribution grids, which today are still operated manually. The advantage of this path is the use of proven technology. However, the current procurement and deployment costs need to be scaled down.

The green path uses the smart meter infrastructure, rolled out in many countries. The utilisation of the communication path depends strongly on the national regulations for smart metering and inherits some complexity due to the heterogeneity of the smart meter business. Furthermore, the smart meter infrastructure is often only intended to collect data from the smart meters, so the capabilities to send data to the grid edge are limited.

Recently a third option came into the game, the blue path utilises the already existing communication between the manufacturer of DER devices and its installed base. The communication link is intended to monitor the DER devices and to offer services like predictive maintenance or firmware updates. With this existing infrastructure the manufacturer can provide the pooled flexibility of its connected DER to a commercial aggregator. This can speed up drastically the roll-out of flexibility management, as one cloud-to-cloud interface enables many DERs to be integrated into the grid balancing in one step. However, in some countries, like Germany, this path is prohibited by the national regulations.

Conclusion

In these scenarios, edge connectivity plays a crucial role in establishing direct communication between the grid stakeholders and the resources at the grid's edge. By leveraging edge connectivity, the grid stakeholders gain real-time access to a wide range of data up until the grid connection point, allowing them to respond quickly to events and manage grid operations effectively.

Standardisation is essential as it ensures uniformity and consistency across the different resources and products from various vendors. With standardised protocols and interfaces, data exchange becomes seamless and effortless, fostering interoperability between different devices, systems, and applications. This interoperability not only enhances data collection and analysis for the grid stakeholders, but also promotes collaboration and integration with other operational systems. It also ensures that during the whole life cycle of a device or an asset the data is compatible and accessible across the entire power system infrastructure, streamlining decision-making and optimising operations. Interoperable systems facilitate the integration of grid edge resources, allowing the grid stakeholders to maximise the full potential of these resources while maintaining operational efficiency and reliability.

The second aspect for a successful energy transition beside interoperability is speed. Utilising existing edge connectivity between DER devices behind the meter and its manufacturers back-end systems can help to speed up the rollout of edge connectivity, as they need just a single interconnection at back-end level. This requires aligned (standardised) ontologies to allow back-end systems to understand each other when communicating and interacting. It would also require adequate control mechanisms and precaution to avoid vendor lock-in when utilising such communication paths for energy related services.

To summarise, edge connectivity, combined with standardisation and interoperability, are essential enablers, providing the foundation for seamless communication, data exchange and collaboration within the power system infrastructure in appropriate real time. By embracing these principles, the grid stakeholders can effectively leverage the distributed resources connected at the grid edge, optimise their operations, and unlock the transformative advantages of advanced technology in the power system domain.

In order to fully harness the potential of edge connectivity and realise its transformative benefits, it is imperative that substantial investments are prioritised in edge devices and software. Furthermore, expanding the market and streamlining the residential sector's participation in this evolving energy landscape can significantly unlock greater energy flexibility and reduce the transaction costs. By encouraging standardised and simplified processes, we can empower homeowners and small-scale energy producers to play a more active role in the energy grid. To ensure optimal benefits and streamline the process of grid code updates, it is imperative that a robust, harmonised standardisation and interoperability directive framework is achieved at the European level, providing consistent guidelines for every Member State.

References

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