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Architecture and use-cases for EVs to provide grid support functions

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ARCHITECTURE AND USE-CASES FOR EVS TO PROVIDE GRID SUPPORT FUNCTIONS

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The text of this System Reference Document is based on the following documents:

Draft	Report on voting
SyCSmartEnergy/287/DTS	SyCSmartEnergy/288/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this System Reference Document is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

0.1 Objective

When electric vehicles (EVs) are interconnected to the electric power system, they are capable of providing grid support functions similar to other distributed energy resources (DER), particularly energy storage units, while still not impacting any more than necessary their primary purpose of charging their batteries in a timely manner. In aggregate, such as in fleets, in community aggregations, or in microgrids, EVs can not only benefit grid operations, but, if not managed well, cause grid problems.

This document provides various use cases as examples of how EVs might be used as DERs. Since regulations, EVs, charging stations, and power systems are vastly different across the world, this document does not attempt to define any specific mechanism for EVs to provide DER grid support functions, but rather draws on IEC 61850-7-420 that defines the data models for most of the DER grid support functions, including those described in electric power requirements in IEEE Std 1547™-2018 and EN 50549.

It is expected that IEC 61850-7-420 will utilize these use cases to develop EV-specific data models for "EV as DER" as needed, and that other standards such as the IEC 63110, ISO 15118, and the IEC 63382 series[1] will be revised or will otherwise accommodate the results of these "EV as DER" requirements.

Clearly contractual arrangements will need to be made with all relevant stakeholders on which EVs, under what conditions, with which functions, and when permitted. However, those contractual arrangements are outside the scope of this document, which addresses only the technical aspects of EVs as DER.

Cybersecurity for EVs as DER is important but is not in the scope of this document.

0.2 EVs, utilities, and charging

Utilities everywhere are concerned that the charging load for electric vehicles (EVs) will greatly increase the load on the power grids. In many places, the charging load could exceed the existing demand during peak hours from residential consumers. As more electric vehicle charging points are deployed, it becomes increasingly important to manage flexibility of both the power levels and the time of charging.

The concept adopted in the past has been that EV charging would be managed by charging stations similar to gas stations, but today it is clear that EV drivers often charge at home and use phone applications, cloud-based systems, and remote service providers to manage their charging. Although charging stations are still important, they are no longer the only way EVs are charged. This shift is also complicating the design of the EV standards.

In addition, the idea that EVs could be used to support the power grid used to be regarded as strange, technically difficult, and not likely to be supported by EV owners. That idea, too, has been overtaken by events, as more and more EV manufacturers are including the ability to discharge and many pilot projects have shown that "vehicle-to-home" would be very desirable by customers, and "vehicle-to-grid" would be very popular with EV fleets and charging stations if they want to take part in market operations. In some regions, such as California, if the EVs are capable of discharging, they are included in the definition of Distributed Energy Resources.

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1 Under preparation.

Two primary groups of use cases have been identified: those concerned with the market aspects of charging, and those concerned with the grid services related to the impact of charging on the power system. A few use cases address vehicle-to-grid. Figure 2 illustrates the IEC standards used for EV grid support and market-related charging management.

For many years, academic papers have proposed using EV batteries as a form of energy storage that can provide services to the power grid even if only charging. But now there are many research and pilot projects around the world that are deploying some form of bidirectional flow of energy (charging and discharging), either as vehicle-to-grid (V2G) or vehicle-to-home (V2H), with EVs able to sell power to the main grid and even support the energy management of microgrids. One of the driving ideas behind these projects is to provide a means of storing energy in the EV from variable renewable resources, like solar and wind, for use at other times. This implies that EVs can actually be viewed as just one type of distributed energy resources (DER).

0.3 EV standardisation efforts in the IEC

Within the IEC, various committees and working groups are collaborating to define standards and guidance on how these new types of EV-related equipment should be integrated into power systems. There are several technical groups that are concerned with the physical and safety aspects of different types of equipment and others that look at how the different types of EV-related equipment are integrated into the power system.

However, integrating EVs into power systems so that they do not overload the grid and can actually support grid reliability, requires understanding the electric utility perspective. Figure 1 shows the big picture with various types of systems relevant to DERs and EVs.

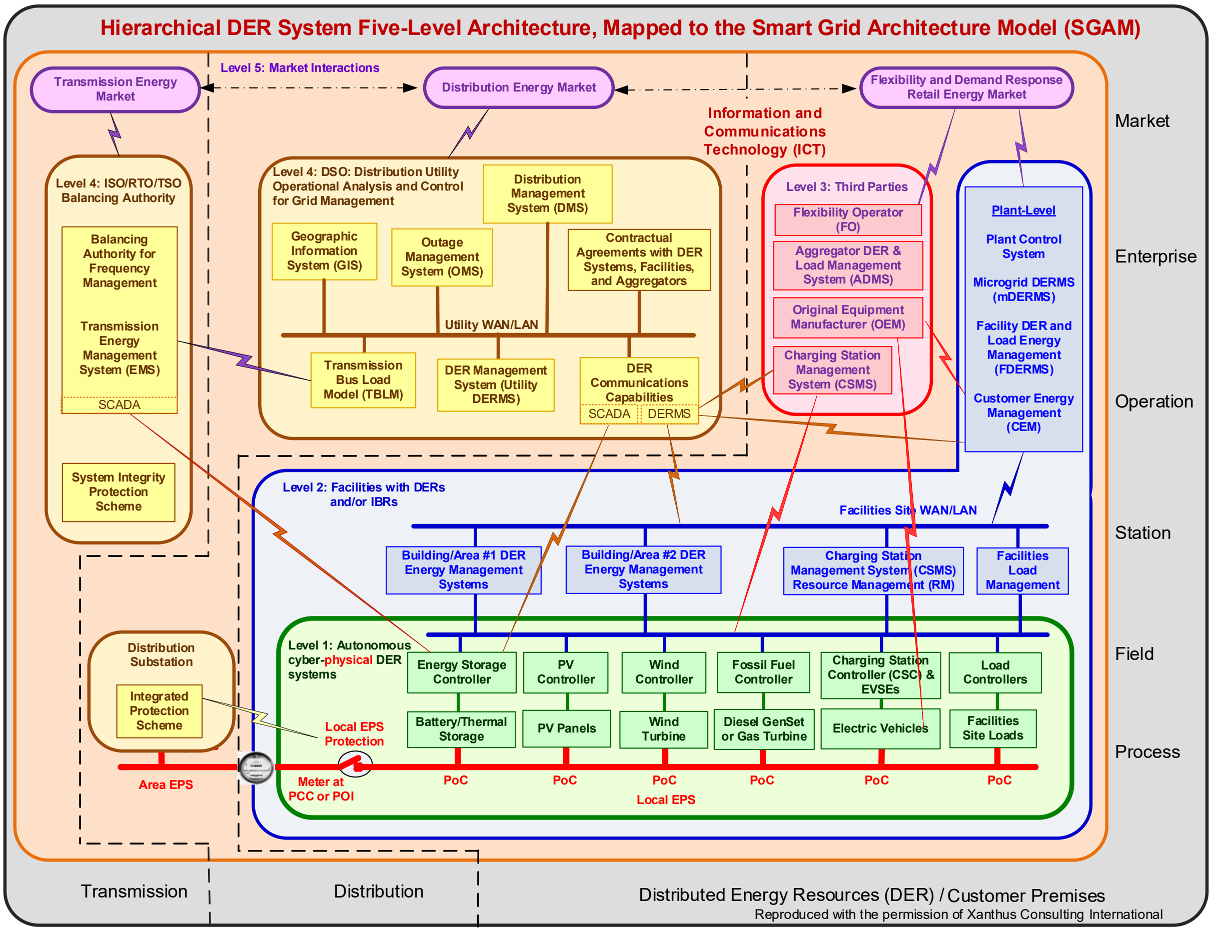

Figure 1 – EV as DER architecture within the larger grid environment

The IEC has many different groups addressing aspects of EVs and their charging from the grid. For the physical aspects, IEC TC 8 and its subcommittees work on the overall system aspects of electricity supply systems, and IEC TC 120 is responsible for standardization in the field of grid integrated energy storage systems. IEC TC 69 prepares publications related to electrical power/energy transfer systems for electrically propelled road vehicles, including some physical charger connection standards such as IEC 61851. TC 69 has also worked with the ISO to develop charging communication protocols such as the ISO 15118 series and has established joint working groups with other TCs to manage the higher-level charging infrastructure with use cases and communication protocols, currently developing the IEC 63110 series and the IEC 63382 series.

IEC TC 57 has that utility perspective and has developed sophisticated communication and automation standards for power systems control equipment and control centre systems. These standards include IEC 61850 for substations, distribution automation, and more recently DER. The common information model (CIM), covered in IEC 61968, the IEC 61970 series, IEC 62325, is focused on grid management applications and market interactions. In addition, IEC TC 65 has developed some standards describing energy management systems for industrial sites and IEC SC 23K is working on standards for energy management within residential and commercial premises. Complementing these energy standards is IEC TC13 who provides metering standards.

Figure 2 illustrates the different communication standards being applied in the EV domain.

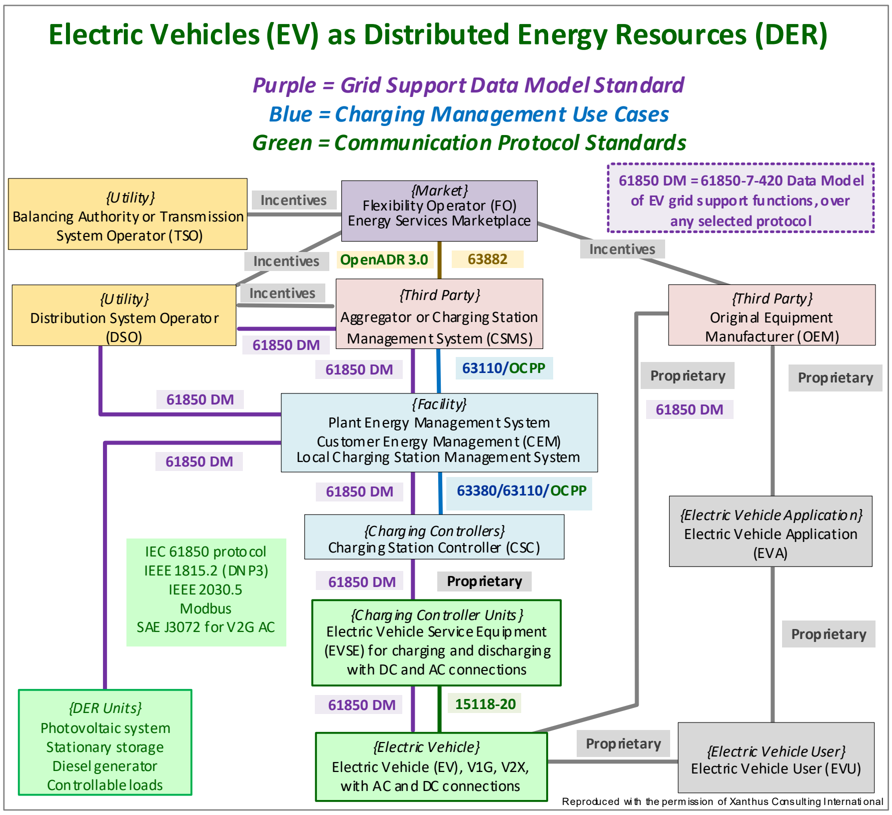

Figure 2 – IEC Standards for EV grid support and charging management

0.4 EV use cases

Many use cases have been developed that focus on the pricing and timing of energy management of charging electric vehicles. Typically, these energy management systems are concerned with optimising the cost of the energy used to charge the vehicles. These use cases rarely address the grid needs of distribution system operators who might need to impose constraints on the grid if the charging loads become too high. However, there is increasing awareness that these grid requirements also need to be take into account as more and more utility customers switch to electric vehicles. This dynamic juxtaposition of growing need for EV charging versus the strain that this charging puts on the grid is an area of growing concern around the world and will require sophisticated and flexible information and communication technologies. Different countries and regions will necessarily involve different business models, but all will need to reflect the challenges posed by such a shift in electrification requirements.

Other use cases and information models, developed more from the grid integration and grid management perspectives, have been developed related to the functions that distributed energy resources (DER) can provide. In particular, these use cases identify how these generation and storage systems can help manage grid voltage and frequency and can even ride through abnormal conditions to possibly avoid power outages. The information models were based on national grid codes originally developed for the integration of bulk generation resources, but now they have been extended to cover smaller distributed energy resources and battery storage. Thus, most of the use case development has already been done – they just need to be expanded to electric vehicle charging – and discharging – systems, thus converting EVs as uncontrolled loads to EVs-as-DERs.

0.5 Purpose of this document

This document describes the architecture and use-cases for EVs to provide grid support functions, or more familiarly called "EV-as-DER". Most of this document will be concerned with identifying realistic EV charging and discharging configurations, and the communication and control between the various actors, grid system operators, aggregators, premises energy management, and EV charging systems. The results from this document will hopefully help to take the grid-support capabilities of EVs into account as other standards are developed.

ARCHITECTURE AND USE-CASES FOR EVS TO PROVIDE GRID SUPPORT FUNCTIONS

1 Scope

The scope of this document is the assessment of how electric vehicles (EVs) can act as distributed energy resources (DER) when they are interconnected to the electric power system for charging or discharging, whether in the home, in an office complex, in shopping centres, or in EV charging stations. Although clearly the main purpose for EV interconnection to the grid is to charge their batteries, EVs can provide grid support functions while interconnected, and in some situations, can be mandated or incentivized to do so.

This document provides use cases as examples of how EVs might provide such DER functionality, based on the grid support functions defined in IEC 61850-7-420, IEEE Std 1547:2018, and EN 50549.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEEE Std 1547-2018, *IEEE Standard for interconnection and interoperability of distributed energy resources with associated electric power systems interfaces*

IEEE Std 2800-2022, *IEEE Standard for interconnection and interoperability of inverter-based resources (IBRs) interconnecting with associated transmission electric power systems*