

METHODOLOGY

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Methodology for identifying technical details of smart energy solutions and research gaps in smart grid: an example of electric vehicles in the energy system

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From 1st Energy Informatics.Academy Conference Asia
Beijing, China . 29-30 May 2021

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Abstract

Simulations, especially agent-based simulation, are able to facilitate the investigation of smart energy solutions and business models, and their impacts on the energy system and involved stakeholders. Technical details, alternatives, and multiple options for what-if scenarios influence simulation quality, but no methodology available to support the investigation. This paper proposes a method for identifying technical details of smart energy solutions in the energy system and identifying research gaps in the smart grid context with EV solutions as an example. The method includes the investigation of the state-of-the-art EV solutions by scoping review and the allocation of the scoping review results into the Smart Grid Architecture Model framework with three dimensions (Domains, Zones, and interoperability layers). The quantitative scoping review results in a total number of 240 references and 10 references match the criteria based on the qualitative scoping review. The results show that the most popular EV use case within the targeted scope is the V2G concept, and 6 out of the 10 references discuss the EVs' potentials to work as energy storage. Seventeen features are identified by mapping the EV use cases (solutions and business models) into the three dimensions (domain, zone, and interoperability layers) of the SGAM framework. The process at the Zone layer is the most popularly covered (mentioned 64 times), and enterprise at the Zone layer and communication in the interoperability layer are the least covered (mentioned 4 times each).

Keywords: Electric vehicle, Smart energy solution, Business model, Smart grid, Methodology

Introduction

The increasing number of renewable energy sources in the energy system can contribute significantly to reduce the impacts caused by climate change. However, it will create the challenge of grid imbalance, and demand response is a promising solution (Ma et al. 2017a). Electric Vehicles (EVs) are expected to play an important role in balancing the integration of renewable energy resources in the Smart Grid. The Danish Energy Agency estimates from an extrapolation that EVs and plug-in hybrid vehicles will account for 9% of the total Danish vehicle stocks by 2030 (Energistyrelsen 2019). EV smart charging has been well discussed together with flexible electricity prices as a means to provide demand response (Fatras et al. 2021). Moreover, in a Smart Grid with two-way power- and communication-flow between consumers and the grid it is possible to enable Vehicle-to-Grid (V2G), i.e. allowing EVs to provide power to the grid from their battery (Fatras et al. 2020). V2G can utilize EVs' battery capacity in the grid as energy storage (Li et al. 2012; McGee et al. n.d.). Especially, hourly electricity prices (Ma and Jørgensen 2018) and dynamic tariffs (Ma et al. 2021) provide significant financial benefits for EVs to provide implicit demand response, and the unbundling electricity markets (e.g., the Nordic spot markets (Zheng et al. 2016)) provides more opportunities for the explicit demand response (Ma et al. 2017b).

However, the increasing number of EVs in the distribution grid and smart charging, especially simultaneously EV charging, might cause grid overload. Meanwhile, various stakeholders are involved in different scenarios, e.g., EV owners, distribution system operators (DSO), charging box providers, and electricity suppliers are involved in EV home charging, their benefits and barriers remain unclear (Ma et al. 2018). Therefore, it is important to investigate EV-related smart energy solutions and business models, and their impacts on the energy system and involved stakeholders.

The studies in energy flexibility based on the agent-based simulation, e.g., commercial greenhouses (Howard et al. 2020a; Christensen et al. 2020a; Christensen et al. 2020b), water supply (Værbak et al. 2019), and breweries (Howard et al. 2020b), show that the agent-based simulation can serve this purpose, especially support the investigation of what-if scenarios (Ma et al. 2019). Meanwhile, related stakeholders and their interactions can be identified with the energy ecosystem modeling methodology proposed by (Ma 2019a). Furthermore, the barriers and opportunities and barriers for adopting energy flexibility have been investigated in the literature, e.g., (Ma et al., n.d.; Billanes et al. 2017).

However, technical details influence the simulation quality, and little literature has provided a methodology for identifying technical details of EVs in the energy system. Meanwhile, simulations for the what-if scenarios should be based on alternatives and multiple options, and overviews and research gaps of the related domains are essential. However, the majority of the literature is mainly case-based.

Therefore, this paper aims to propose a method for identifying technical details of smart energy solutions in the energy system and identifying research gaps in the smart grid context with EV solutions as an example. The method includes the investigation of the state-of-the-art EV solutions by scoping review and the allocation of the scoping review results into the Smart Grid

Architecture Model (SGAM) framework (CEN-CENELEC-ETSI Smart Grid Coordination Group 2012). The SGAM framework is an EU standard for the smart grid, and it not only can provide an architectural viewpoint but also technical details with its three dimensions and multiple layers (Ma et al. 2020).

This paper firstly introduces the methodologies of the scoping review method for identifying relevant articles, and the SGAM framework method for analyzing and reviewing the identified articles. The results are presented after the Methodology Section, which consists of a mapping and analysis of the identified articles in the SGAM framework. Following the Result Section, the Discussion Section discusses the findings and limitations of the presented methodology. A summary and conclusion are presented in the conclusion section.

Methodology

Literature search and collection

This paper uses the scoping review method for the literature search and collection regarding EV smart energy solutions and business models in the energy system. A scoping review aims to map rapidly the key concepts underpinning a research area (Ma et al. 2019; Arksey and O'Malley 2005). A scoping review can be used to: examine the extent, range, and nature of research activity; determining the value of undertaking a full systematic review; summarize and disseminate research findings; identify research gaps in the existing literature (Arksey and O'Malley 2005). This study uses the scoping review to summarize and disseminate the research findings. The used approach starts by designing a search string for relevant databases. The overall purpose is to find EV-related smart energy solutions and business models. Hence, five databases are chosen based on the relevance of the domain:

- Academic Search Premier EBSCO
- ACM Digital Library
- IEEE Xplore
- Web of Science
- Science Direct

Academic Search Premier EBSCO, Web of Science, and Science Direct include a wide range of research fields including engineering and social science. They are included in the paper to make sure that business-related articles are covered. Many smart energy solutions are related to information technology and computing, in particular, EVs' charging solutions. Therefore, the ACM Digital Library database is included. IEEE Xplore is included due to its focus on electrical engineering, computer science, and electronics.

The following search string is an example of a string used for the database of Web of Science.

(TI=((smart OR intelligent) AND (energ OR electric* OR heat*) AND (solution* OR technolog* OR product* OR service*)))*

The search string is modified for the other databases following their searching-system syntax. From the search results, the keywords "business model" and "solution" are used to reduce the results.

Literature analysis

In the literature search results, all titles or abstracts including EVs are chosen to be implemented in the SGAM framework. The SGAM framework provides a smart grid architecture and illustrates the complexity of the smart grid (Ma 2019b). The SGAM framework methodology consists of seven principles: universality, localization, consistency, flexibility, scalability, extensibility, and interoperability (CEN-CENELEC-ETSI Smart Grid Coordination Group 2012). The principles build the framework that is visualized in Fig. 1.

The SGAM framework represents smart grid architectures in a common and neutral view. Placing entities to the appropriate location and thereby mapping them in the framework by their domains, zones, and interoperability layers. Consistent mapping means that all layers are covered with an appropriate entity. Inconsistency (missing layers) shows that there is a need for specification or standard in order to realize the solution. By mapping the entities for a given smart energy solution, it is possible to validate the support by standards; identify gaps in respect to standards, map existing architectures into a general view, and develop smart grid architectures (Ma et al. 2019; CEN-CENELEC-ETSI Smart Grid Coordination Group 2012). The definition of each dimension and the description of all zones, domains, and operability layers are shown in Table 1.

In the SGAM framework, use cases are identified and mapped with the required information of: Name, scope, and objective; case diagram; actor names, types; preconditions, assumptions, postconditions; use case steps; information which is exchanged among actors. (CEN-CENELEC-ETSI Smart Grid

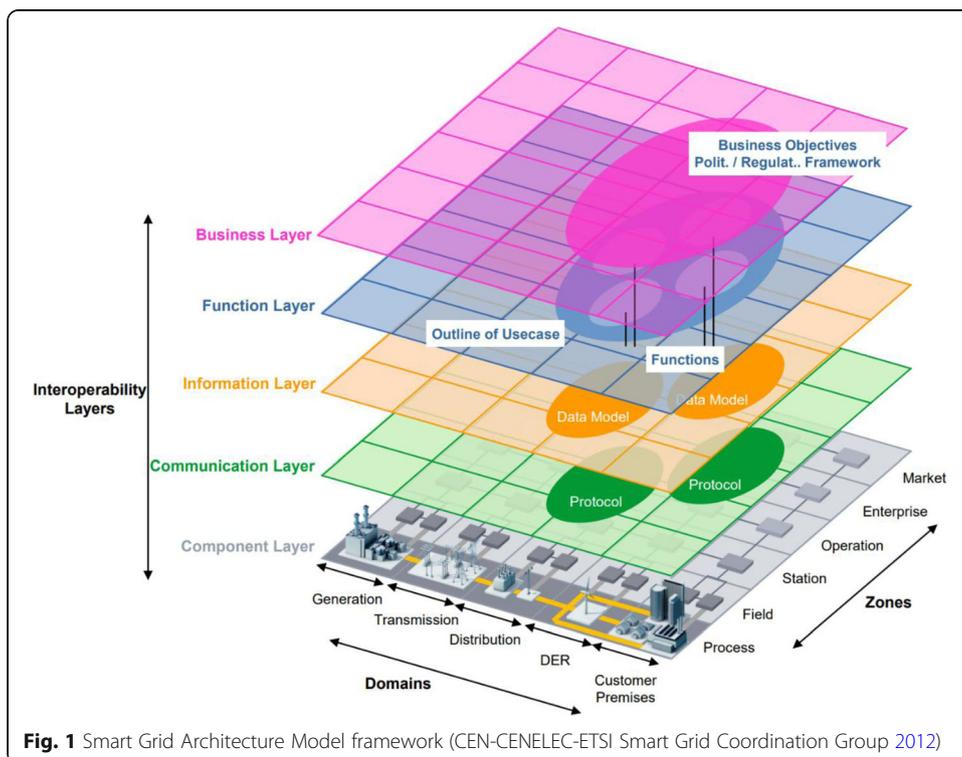


Table 1 Terms and definition in the SGAM framework (CEN-CENELEC-ETSI Smart Grid Coordination Group 2012)

		Description
Terms	SGAM Interoperability Layer	To allow a clear presentation and simple handling of the architecture model, the interoperability categories described in the GridWise Architecture model are aggregated in SGAM into five abstract interoperability layers.
	SGAM Domain	One dimension of the Smart Grid Plane covers the complete electrical energy conversion chain, partitioned into 5 domains.
	SGAM Zone	One dimension of the Smart Grid Plane represents the hierarchical levels of power system management, partitioned into 6 zones.
Domain	Generation	Representing of electrical energy in bulk quantities, typically connected to the transmission grid.
	Transmission	Representing the transmission infrastructure and organization.
	Distribution	Representing the distribution infrastructure and organization.
	Distributed Energy Resources (DER)	Representing distributed electrical resources directly connected to the public distribution grid.
	Customer Premises	Representing electricity consumers and producers of electricity. This includes industrial, commercial, and home facilities. Production from consumer generation such as photovoltaic, EV storage, batteries, micro turbines, etc. are included in this domain.
	Zone	Process
Field		Equipment to protect, control, and monitor the process of the power system, e.g. protection relays and bay controller.
Station		Areal aggregation level for field level, e.g. data concentration, functional aggregation, and local Supervisory Control And Data Acquisition (SCADA) systems.
Operation		Power system control operation in the respective domain, e.g. energy management systems in generation and transmission systems and EV fleet charging management systems.
Enterprise		Commercial and organizational processes, services, and infrastructures for enterprises (utilities, service providers, energy traders), e.g. asset management, logistics, work force management, staff training, customer relation management, billing and procurement.
Market		Market operations possible along the energy conversion chain, e.g. energy trading and retail market.
Interoperability	Business	Represents the business view on the information exchange related to smart grids. Regulatory and economic structures, policies, business models, business portfolios of market parties relate to this layer.
	Function	Function and services including their relationships from an architectural viewpoint. The functions are represented independently from actors and physical implementations in applications, systems, and components.
	Information	The information that is being used and exchanged between functions, services, and components.
	Communication	Describe protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service, and related information objects or data models.
	Component	Physical distribution of all participating components in the smart grid context.

Coordination Group 2012) uses the term “use case” for solutions in the smart grid, for example, the use case “control reactive power of Distributed Energy Resources (DER) unit”. This paper maps the use cases found in the literature into the SGAM framework based on the domains, zones, and interoperability layers. This approach is used to identify missing entities in the literature from a smart grid architecture point of view.

Five steps of the literature analysis are conducted based on the SGAM framework:

- The first step is to map all physical components from the use cases to the component layer. Examples of components are controllers, computers, the grid, EVs, and transformers. These components are derived from actors’ information, as actors can be of type, devices, applications, persons, and organizations.
- The next step is to map the business layer. The “domains” and “zones” covered by the components compose an area. The business objectives, economic, and regulatory constraints included in this area influence the mapped use case. These objectives and constraints are located in the business layer and need to be taken into account as non-functional requirements for implementations. In the third step, the needed functions from different components are mapped into the function layer, e.g. DER control for a controller and SCADA for SCADA system components.
- The fourth step is to add information flows into the information layer. The layer is divided into a business context and a canonical layer. The business context layer describes the information flow, such as sending voltage measurement. Whereas, the canonical information layer is describing the standards such as CIM standard (IEC 61968–4) which is appropriate for exchanging information objects in the “enterprise” and “operation” zones (CEN-CENELEC-ETSI Smart Grid Coordination Group 2012).
- At the last step, the communication standards are mapped into the communication layer, e.g. IEC 61850 which is the state-of-the-art communication protocol in power system automation (CEN-CENELEC-ETSI Smart Grid Coordination Group 2012). Meanwhile, it should be clear which roles are responsible for which functions when realizing the business process. In case that an entity cannot be assigned any role the

Table 2 Literature search

Search Results		
Search String	Database	Results
“Document Title::(smart OR intelligent) AND (energy OR electricity OR heat*) AND (solution OR product OR technology OR service)	IEEE Xplore	137
acmdlTitle:(+(smart intelligent) + (energy electric heat) + (solution product technology service))	ACM Digital Library	66
TI (smart OR intelligent) AND (energy OR electric OR heat) AND (solution OR technology OR product OR service)	EBSCO	32
(TI = ((smart OR intelligent) AND (energ* OR electric* OR heat*) AND (solution* OR technolog* OR product* OR service*)))	Web of Science	26
(smart OR intelligent) AND (energy OR electric OR heat) AND (solution OR technology OR product OR service)	Science Direct	21

responsibility for that element is unclear and calls for further investigation before realization.

Literature search results

This section presents the scoping review search results. Table 2 shows the used search strings for the different databases including the literature results after removing all duplicates. The removal of all duplicates is done after all searches have been performed and citations are downloaded to the reference management software tool, which in this case is EndNote X9 (Zhu et al. 2016). A literature search is done before the one seen in Table 2 for practicing search strings in different databases. The search criteria are overall based on smart energy solutions and business models within that field. The search is based only on title results to reduce the number of results. Synonyms and notations for the different searching keywords are used to make sure relevant literature is not excluded. For example, the keyword 'energy' is also representing electricity and heating.

From the searching results shown in Table 2 and the initial practicing search, a total of 558 results are found. The found results' citations are downloaded to EndNote. In EndNote a keyword search on the keywords of 'solution', 'business model', and 'solution AND (business model)' is used to remove non-relevant literature. Table 3 shows that a total number of 240 references are related to the scope.

The last step of the quantitative scoping review search process is to identify literature for the qualitative scoping review analysis. To do so, the 240 references' titles and abstracts are evaluated and assessed into different categories. The categories are physical components/technologies, software, service, smart house/building, and EV oriented. EV-oriented smart energy solutions are chosen as an example of how to use the SGAM framework in practice. Ten articles are found to be EV-oriented and are selected for the qualitative scoping review analysis. Table 4 shows the 10 articles with a description of their key aspects.

This paper analyzes the use cases in each article in detail and matches the use cases with the three dimensions of the domain, zone, and interoperability in the SGAM framework. Seventeen features have been identified through a thorough analysis process (shown in Table 5). Meanwhile, Table 11 in the APPENDIX explains how the 17 identified features are identified based on the literature analysis with the three dimensions of interoperability layer, domain, and zone of the SGAM framework.

For instance, Feature 1 represents the EV in the component interoperability layer and energy storage through V2G in the function layer. Feature 2 represents in the component layer a charging point having a communication technology. The

Table 3 Relevant search results

Keyword search	Results
Solution	189
Business model	51
Solution AND (business model)	1

Table 4 Selected references with focuses on electric vehicle-oriented solutions

Article	Ref.	Solution & Business models
Electric Vehicle Charging: Transformer Impacts and Smart, Decentralized Solutions	(Hilshey et al. 2012)	Smart charging as a solution to reduce transformer aging. 2 smart-charging strategies preventing the transformer from overload are compared. The paper uses the transformer as the charge manager at AC level I and II.
An Energy Efficient Solution: Integrating Plug-In Hybrid Electric Vehicle in Smart Grid with Renewable Energy	(Li et al. 2012)	Stochastic programming optimization to solve power management problem and minimize cumulative cost over all stages. 2 cases: optimizing for a system using thermal power plants, wind turbines, and diesel generators; a fleet of plug-in EVs that can be used as energy storage.
Vehicle to grid: electric vehicles as an energy storage solution	(McGee et al. n.d.)	A charging system design that can utilize EV battery capacity as energy storage through V2G. The system has been successfully tested on a fleet of EVs.
Security and privacy of electric vehicles in the smart grid context: problem and solution	(Nicanfar et al. 2013)	Two authentication schemes to preserve customers' privacy. This paper's focus is on the security and privacy requirements of EVs in the smart grid especially when the EV acts as energy storage.
Optimal Solution of Plug in Hybrid Electric Vehicles to Minimize Cost and Emission in a Smart Grid - A Developing Country View	(Ahmad and Sivasubramani 2015)	The paper uses a multi-objective minimization cost and emissions in the smart grid. The integration of EVs in the grid and the V2G concept are in focus.
A Novel ICT Solution for Electric Vehicles Integration on Smart Grids	(Santos et al. 2015)	An ICT architecture that supports an energy management algorithm aiming to optimize the EV charging and storage capabilities accordingly with economical and technical considerations. The energy management algorithm uses dynamic tariffs, electric loads, and end-users' preferences and comfort requirements.
Adaptive three-phase power-flow solutions for smart grids with plug-in hybrid electric vehicles	(Yang and Tseng 2015)	An adaptive three-phase power flow method. Two solution strategies are used to adapt the network typologies of radial and non-radial smart grid. The method is found to be accurate, efficient, and adaptable in smart grids with EV charging demands. The paper's focus is on solving the unbalanced power-flow problem in a smart grid having EVs and distributed energy sources.
Can innovative business models overcome resistance to electric vehicles? Better Place and battery electric cars in Denmark	(Budde Christensen et al. 2012)	An innovative business model for EVs to eliminate consumer's risk of degrading EV battery over time by leasing batteries, coordinating the charging and infrastructure. The consumer subscribes to a fixed mileage limit and charges at the charging spots and battery switching stations. Intelligent charging when electricity price is low and second-life of batteries are considered.
Business models for the integration of electric vehicles into the Austrian energy system	(Rezania and Prügler 2012)	V2G, Grid-to-Vehicle (G2V), and second life business models. Furthermore, the business models include participation opportunities in the Austrian control market.
Business model of clean energy vehicles industry based on option	(Zhong and You 2012)	Four business models: the whole EV selling model, whole EV leasing model, battery leasing model, and financial leasing model. The paper focuses on the financial leasing model (a finance company purchasing an asset and leases that asset to a client that after the leasing period typically has the opportunity to purchase the asset at a low

Table 4 Selected references with focuses on electric vehicle-oriented solutions (*Continued*)

Article	Ref.	Solution & Business models
		price). Following aspects are included: a dynamic pricing method; partial differential equation model to describe the financial aspects of the EV price; integral linear programming method; solving model by finite difference method.

charging points both charge EVs and communicate with the smart grid. Hence, it locates between the zones of Process and Field, and between the domains of Customer premises and DER. Feature 2 further includes a public key encryption system and identity-based cryptography in the communication layer. In the function layer, feature 2 represents sending user identity to a control unit. Feature 10 represents identity-based cryptography in the communication layer and EV identity in the information layer.

(Nicanfar et al. 2013) has features of 1, 2, 10, 11, 12, and its use case may include some implicit entities, however, during the analysis process, this paper only uses the descriptions stated and included in each selected article. Therefore, to realize the (Nicanfar et al. 2013)'s use case in the smart grid, some entities are needed as a minimum, e.g. communication and information standards and charging functions. All papers implicitly indicate that the grid (including transformers) is presented in the component layer with the link between all domains in the process zone. Hence, the grid is not in Table.

Table 5 Identified 17 features

Number	Feature
1	EVs or PHEVs as storage for V2G
2	Communication between EVs and the grid
3	Smart charging algorithm in the charge management device
4	EV and battery charging at charging stations
5	Optimization in fleet charging management
6	Generation units considering the number of EVs
7	EV charging based on electricity production by DERs
8	Charging equipment enables V2G
9	Participation in electricity markets
10	Communication between EVs and charging equipment
11	EV charging at public charging points/ fast-charging stations
12	Data collector or database (data center)
13	Grid operator or DSO control operations
14	Load management by DSO, energy scheduler, and data aggregator
15	Communication between EV and aggregator
16	Communication between EVs and energy scheduler and data aggregator
17	A broker between EV owner and energy market

Table 6 Domains allocated in features and selected articles

Feature number	10 selected articles										Frequency of layers in features
	(Hilshay et al. 2012)	(Li et al. 2012)	(McGee et al. n.d.)	(Nicanfar et al. 2013)	(Ahmad and Sivasubramani 2015)	(Santos et al. 2015)	(Yang and Tseng 2015)	(Budde Christensen et al. 2012)	(Rezania and Prügler 2012)	(Zhong and You 2012)	
1	DER, C	DER, C	DER, C	DER, C	DER, C	DER, C	DER, C	DER, C	DER, C	DER, C	0,0,0,10,10
2	DER, C			DER, C		DER, C			DER, C		0,0,0,4,4
3	D,DER,C								D,DER,C		0,0,2,2,2
4	D						D		D		0,0,3,0,0
5		G,T,D,DER,C							C		1,1,1,1,2
6		G	G		G						3,0,0,0,0
7		DER	DER				DER		DER		0,0,0,5,0
8			DER,C								0,0,0,1,1
9			G,T,D,DER,C			G,T,D,DER,C		G,T,D,DER,C	G,T,D,DER,C		4,4,4,4,4
10			C	C							0,0,0,0,2
11				T,D							0,1,1,0,0
12				T,D							0,2,2,0,0
13						T,D					0,0,1,0,0
14						D					0,0,1,0,0
15						D,DER,C			D,DER,C		0,0,2,2,2
16						C					0,0,0,0,1
17							T,D				0,1,1,0,0
Frequency of layers in articles	0,0,2,3,3	2,1,1,3,2	2,1,1,4,4	0,2,2,2,3	1,0,0,1,1	1,2,5,4,5	0,0,0,2,1	1,2,3,3,2	1,1,4,6,6	0,0,0,1,1	16,18,36,48,56

Note: Generation (G), Transmission (T), Distribution (D), Distributed Energy Resources (DER), Customer Premises (C)

Table 7 Zones allocated in features and selected articles

Feature number	10 selected articles										Frequency of layers in features
	(Hilshey et al. 2012)	(Li et al. 2012)	(McGee et al. n.d.)	(Nicanfar et al. 2013)	(Ahmad and Sivasubramani 2015)	(Santos et al. 2015)	(Yang and Tseng 2015)	(Buddle Christensen et al. 2012)	(Rezania and Prügglger 2012)	(Zhong and You 2012)	
1	P	P	P	P	P	P	P	P	P	P	10,0,0,0,0
2	P,F			P,F		P,F			P,F		4,4,0,0,0
3	P,F								P,F		2,2,0,0,0
4	P,F,S						P,F,S		P,F,S		3,3,3,0,0
5		O							O		0,0,2,0,0
6		P	P		P						3,0,0,0,0
7		P	P			P	P		P		5,0,0,0,0
8			P								1,0,0,0,0
9			M			M	M		M		0,0,0,0,4
10			P	P							2,0,0,0,0
11				P							1,0,0,0,0
12				S		S					0,0,2,0,0
13						O,E					0,0,1,1,0
14						O					0,0,1,0,0
15						F,S,O			F,S,O		0,2,2,2,0
16						F					0,1,0,0,0
17								SO,E,M			0,0,1,1,1
Frequency of layers in articles	4,3,1,0,0	3,0,0,1,0,0	5,0,0,0,0,1	4,1,1,0,0,0	2,0,0,0,0,0	2,2,2,3,1,1	2,0,0,0,0,0	3,1,2,1,1,2	5,4,2,2,0,1	1,0,0,0,0,0	62,23,16,14,4,10

Note: Process (P), Field (F), Station (S), Operation (O), Enterprise (E), Market (M)

Table 8 Interoperability layers allocated in features and selected articles

Feature number	10 selected articles										Frequency of layers in features
	(Hilshey et al. 2012)	(Li et al. 2012)	(McGee et al. n.d.)	(Nicanfar et al. 2013)	(Ahmad and Sivasubramani 2015)	(Santos et al. 2015)	(Yang and Tseng 2015)	(Budde Christensen et al. 2012)	(Rezania and Prügler 2012)	(Zhong and You 2012)	
1	C	C,F	C,F	C,F	C,F	C,F,B	C	C,B	C,F	C,B	10,7,3,0,0
2	CF,I			C, F,Cc		C,F			C		4,3,0,1,1
3	CF,I								F		1,2,0,1,0
4	CF							C,F	C		3,2,0,0,0
5		FB							F,I		0,2,1,1,0
6		C,F	C,F		B						2,2,1,0,0
7		C	C				C	C,B	C,B		5,0,2,0,0
8			C,F								1,1,0,0,0
9			B			B,F		B	B		0,1,4,0,0
10			I,Cc	I,Cc							0,0,0,2,2
11			C	C							1,0,0,0,0
12						C					2,1,0,0,0
13											0,1,0,0,0
14						C,F,B					1,1,1,0,0
15						F,B,I,Cc			I		0,1,1,2,1
16						C					1,0,0,0,0
17								B			0,0,1,0,0
Frequency of layers in articles	4,4,0,1,0	3,3,1,0,0	4,3,1,1,1	4,3,0,1,2	1,1,1,0,0	5,6,4,1,1	2,0,0,0,0	3,1,4,0,0	4,3,2,2,0	1,0,1,0,0	31,24,14,7,4

Note: Component (C), function (F), business (B), information (I), communication (Cc)

Result and analysis

This paper further matches the identified 17 features in the use cases in the literature (EVs' roles: solutions and business models) into each layer of the SGAM framework (shown in Tables 6, 7, and 8).

Table 6 shows how the identified features are allocated in the Domains. The Domains are presented in the table as the Generation (G), Transmission (T), Distribution (D), Distributed Energy Resources (DER), Customer Premises (C) in the SGAM framework. As shown in Table 6, the Distributed Energy Resources (DER) and Customer Premises (C) are the most frequent Domains presented in the selected articles and the features which have been discussed 48 and 56 times, respectively.

For instance, in Feature 15, use cases in (Santos et al. 2015; Rezania and Prügler 2012) include distribution (D), Distributed Energy Resources (DER), and customer premises (C) Domains. For (Santos et al. 2015), the communication standards, such as ISO 15118, and information flow (e.g. EV's State-of-Charge) are between the charging point located in Feature 2 and the energy scheduler in Feature 14. Thus, feature 15 is a link between these features, thereby covering the three Domains (distribution, DER, and customer premises). For (Rezania and Prügler 2012), the information flow of the EV's driving pattern is the link between the charging point (feature 2) and the aggregator (feature 14). Feature 6 is only in the generation (G) Domain as the feature includes thermal power plants in reference (Li et al. 2012; McGee et al. n.d.), and power plant cost minimization for (Ahmad and Sivasubramani 2015).

Table 7 shows the 17 features allocate at the Zones. The Zones are presented in the table as the Process (P), Field (F), Station (S), Operation (O), Enterprise (E), Market (M) in the SGAM framework. As shown in Table 6, the Process (P) and Field (F) are the most frequent Zones presented in the selected articles and the features which have been discussed 62 and 23 times, respectively.

For instance, in Feature 4, use cases in the 3 articles (Hilshey et al. 2012; Budde Christensen et al. 2012; Rezania and Prügler 2012) include the process (P), field (F), and station (S) Zones. For (Hilshey et al. 2012)'s use case, the process Zone is the transformation of the voltage level from medium to low voltage. Both (Budde Christensen et al. 2012; Rezania and Prügler 2012)'s use cases involve charging stations (including battery switching stations for (Budde Christensen et al. 2012)), hence the process of charging the EVs is present in this feature. The transformer in (Hilshey et al. 2012)'s use case includes protection equipment and can be part of a substation placing the use case in the field and station Zone. The charging/battery switching station in (Budde Christensen et al. 2012)'s use case contains a smart meter and control device managing the charging of the EVs placing the use case in both field and station Zone. For (Rezania and Prügler 2012)'s use case, the aggregation of charging EVs including field equipment (see Table 1) places the use case in the field and station zone.

Table 8 shows the interoperability layers that the selected article and features include. The interoperability layers are presented in the table as the component (C), function (F), business (B), information (I), and communication (Cc) that are defined in the SGAM framework. As shown in.

Table 8, the interoperability layers of component (C) and function (F) are the most frequent layers presented in the selected articles and the features which have been discussed 31 and 24 times, respectively.

For instance, in feature 2, use cases in 4 articles include the component (C) layer. For use cases of (Hilshey et al. 2012; Rezania and Prügler 2012), the component layer of feature 2 is the smart meter (Advanced Metering Infrastructure), and for use cases of (Nicanfar et al. 2013; Santos et al. 2015), the component layer of feature 2 is the charging points with communication technology. The function (F) layer for feature 6 represents a bulk and emergency generation in (Li et al. 2012) and baseload power in (McGee et al. n.d.). The business (B) layer for feature 1 represents the reduction of charge for electricity and promotes load balance in (Santos et al. 2015), subscription agreement in (Budde Christensen et al. 2012), and financial leasing from the government to public transport companies in (Zhong and You 2012).

Furthermore, the information (I) layer for feature 15 represents CANbus protocol sending a basic set of information such as State-of-Charge, State-of-Health, vehicle position, available energy, charging time, etc. in (Santos et al. 2015). In the use case of (Rezania and Prügler 2012), the information layer represents the driving pattern send from EV owner to aggregator and the tariffs and charging schedule send back to the owner from the aggregator. The communication (Cc) layer for feature 10 represents SAE J1772 charging standard and negative-side signaling using CANbus protocol in (McGee et al. n.d.). Meanwhile, the use case of (McGee et al. n.d.) includes analog communication with non-intelligent EVs and digital communication enabling V2G with intelligent EVs, and the use case of (Nicanfar et al. 2013) has an identity-based cryptography communication in the communication layer.

Discussion

Technical details for identified features

This paper finds that each feature has identical focuses on the three dimensions in the SGAM framework, based on the feature focuses, the 17 identified features can be categorized as in Table 9. Table 9 shows the current focuses of EV solutions in

Table 9 Category of 17 identified features

Category	Features
EV charging	EV charging based on electricity production by DERs (Feature 7) EV and battery charging at charging stations (Features 4 & 11)
Algorithm	Smart charging algorithm and optimization (Features 3 & 5)
Communication	Communication between EVs and others (including charging points, and the grid, energy scheduler and data aggregator) (Features 2,10, 15, 16)
Load management	Load management by DSO, energy scheduler and data aggregator (Feature 14)
Energy flexibility	V2G and participation in control/regulation market (Features 1, 8, 9)
Involved actors	Grid operator (Feature 13), datacenter and database (Feature 12), broker (Feature 17), Generation units (Feature 6)

Table 10 Communication technical details

Feature	Domain layers (G,T,D,DER,C)	Zone layers (P,F,S,O,E,M)	Interoperability layers (C,F,B,I,Cc)
Communication between EVs and the grid (Feature 2)	0,0,0,4,4	4,4,0,0,0,0	4,3,0,1,1
Communication between EVs and charging equipment (Feature 10)	0,0,0,0,2	2,0,0,0,0,0	0,0,0,2,2
Communication between EV and aggregator (Feature 15)	0,0,2,2,2	0,2,2,2,0,0	0,1,1,2,1
Communication between EVs and energy scheduler and data aggregator (Feature 16)	0,0,0,0,1	0,1,0,0,0,0	1,0,0,0,0

the literature. Therefore, if a simulation only focuses on the EV charging based on electricity production by DERs (Feature 7), it is easy to identify the technical details of this feature as shown in the corresponded row in Table 11 (in [APPENDIX](#)).

Meanwhile, features in the same category do not have the same technical details if the purposes are different. For instance, Table 10 shows that the four features in the communication categories have significant differences at the interoperability layers of the SGAM framework. These technical details and differences can support simulations to simulate the features with certain accuracy.

Gap identification in the related literature

This paper maps all use cases of EV solutions and business models in the literature into the SGAM framework not only to provide an overview of three dimensions of domains, zones, and interoperability layers but also to identify the gap in the research field.

The results show that the most popular EV use case within the targeted scope is the V2G concept, and 6 out of the 10 references discuss the EVs' potentials to work as energy storage (Li et al. 2012; McGee et al. n.d.; Nicanfar et al. 2013; Ahmad and Sivasubramani 2015; Santos et al. 2015; Rezanian and Prügler 2012). The V2G concept requires communication between EVs and the grid operators or balance responsible parties who often locate in the operation zone. In the SGAM framework, the communication layer includes communication standards which are only considered in (Santos et al. 2015). In general, all use cases in the references do not include standards in the information and communication layers. Furthermore, references, such as (Zhong and You 2012), do not consider any aspect of the smart grid architecture. Instead, (Zhong and You 2012) investigates a financial leasing business model for increasing the penetration of EVs.

As the V2G concept is not yet commercialized in the current electricity grids. Therefore, a completed mapping of the V2G use cases in the SGAM framework is recommended to investigate solutions and business models that can match the technical, market, and business requirements of a given energy ecosystem. Meanwhile, the technical details for the focused EV solutions in the literature are not precise enough to be directly implemented in simulations, maybe due to the focuses in each literature that are not for simulations.

Conclusion

This paper presents a methodology for identifying technical details of EV solutions in the energy system and identifying research gaps in the smart grid context. The

proposed methodology includes two parts: A scoping review for literature search and collection; a SGAM framework driven literature analysis, that EV solutions and their business models found in the literature are mapped into the SGAM framework with three dimensions (Domains, Zones, and interoperability layers).

Two types (quantitative and qualitative) of scoping review are applied in the paper to ensure the selected literature matches the paper's scope. The quantitative scoping review results in a total number of 240 references and 10 references match the criteria based on the qualitative scoping review. The results show that the most popular EV use case within the targeted scope is the V2G concept, and 6 out of the 10 references discuss the EVs' potentials to work as energy storage.

Seventeen features are identified by mapping the EV use cases (solutions and business models) into the three dimensions (domain, zone, and interoperability layers) of the SGAM framework. The process at the Zone layer is the most popularly covered (mentioned 64 times), and enterprise at the Zone layer and communication at the interoperability layer are the least covered (mentioned 4 times each).

Contributions

Technical details are critical inputs to ensure the simulation quality for smart energy solutions and business models. However, no systematic method serves this purpose in the literature, and the majority of the literature is case-based. The developed methodology fills this gap with an investigation of the EV solutions in the energy systems. Meanwhile, the SGAM framework provides an architecture that can facilitate this process. The SGAM framework can be utilized by researchers and companies working with solutions in the smart grid to identify needed standards for the realization of the solution.

This proposed method provides a systematic approach for identifying research gaps in the smart grid. Meanwhile, the analysis of EVs use cases by using the proposed method, provides an overview of the literature on EVs in smart grid with the aspects of smart energy solutions and business models which was not yet fully discovered in the literature. The results can be the input as alternatives and multiple options for simulations to investigate the what-if scenarios.

Limitation and future works

The paper conducts the literature search in scientific databases to investigate the technical details, and other references, e.g., patents or technical reports are not included due to the main focus of the paper is to introduce the proposed methodology. Therefore, a more comprehensive and broad search is recommended especially for the technical details that have not been covered by the scientific literature. Meanwhile, to prove the proposed methodology can contribute to the mentioned simulations, agent-based simulation for EV solutions and business models are recommended with various scenarios, e.g., EV smart charging and participation in various electricity markets.

Furthermore, although business and market are included in the SGAM model, the aspects of policies, regulations, social and financial aspects are missing in the literature due to its technical focus. Although this paper uses the term 'technical details', details from other perspectives are recommended to be included for simulating smart energy solutions and business models in which many stakeholders and aspects are involved.

Appendix

Table 11 Identified 17 features in the SGAM framework's three dimensions matching use cases in the articles

Feature number	SGAM domain-dimension	SGAM zone-dimension	SGAM interoperability layer-dimension
1 EVs or PHEVs as storage for V2G	<p>Customer premises: EVs or PHEVs on the residential side (Hilshey et al. 2012) (Li et al. 2012) (McGee et al. n.d.) (Ahmad and Sivasubramani 2015) (Santos et al. 2015) (Yang and Tseng 2015) (Budde Christensen et al. 2012) (Rezania and Prüggl 2012) EV charging/discharging in residential building area (Nicanfar et al. 2013) Photovoltaic panels including inverters on the residential demand side (Rezania and Prüggl 2012) EVs at the commercial demand side (public transport commerce) (Zhong and You 2012)</p> <p>DER: V2G enables the EVs to act as energy storage (McGee et al. n.d.) (Nicanfar et al. 2013) (Ahmad and Sivasubramani 2015) (Li et al. 2012) (Santos et al. 2015) (Rezania and Prüggl 2012)</p>	<p>Process: EVs or PHEVs consume electricity (all 10 EV solutions) EVs or PHEVs inject power back to the grid using V2G (Li et al. 2012) (Nicanfar et al. 2013) (Ahmad and Sivasubramani 2015) Conversion of solar energy to electricity (Rezania and Prüggl 2012)</p>	<p>Component: EVs or PHEVs as a physical load component (all EV solutions) V2G inverter (Rezania and Prüggl 2012) Photovoltaic including inverter (Rezania and Prüggl 2012) Onboard monitoring, communication and control electronic units and/or GPS module in EVs & chargers. (Santos et al. 2015) (McGee et al. n.d.)</p> <p>Function: EVs as battery storage through V2G (Nicanfar et al. 2013) (Ahmad and Sivasubramani 2015) (Li et al. 2012) (Santos et al. 2015) (Rezania and Prüggl 2012) Emergency power generation using V2G (McGee et al. n.d.) Data acquisition for optimizing EV charging and storage capabilities. (Santos et al. 2015)</p> <p>Business: Reduce electricity charge and promote load balance (Santos et al. 2015) Financial leasing from the government to public transport companies (Zhong and You 2012)</p>
2 Communication between EVs and the grid	<p>Customer premises: Smart meter is located at the consumer (Hilshey et al. 2012) (Rezania and Prüggl 2012) Charging points located at the home and building area network (Nicanfar et al. 2013) (Santos et al. 2015)</p> <p>DER: Charging point and smart meter receive electricity for charging from the grid (the grid is implicit going through the DER domain). (Hilshey et al. 2012) (Rezania and Prüggl 2012) (Nicanfar et al. 2013) (Santos et al. 2015)</p>	<p>Process: Smart meter measures electricity load (Hilshey et al. 2012) (Rezania and Prüggl 2012) Charging point charges EVs (converting AC power to DC). (Nicanfar et al. 2013) (Santos et al. 2015)</p> <p>Field: Smart meter sends consumer-load. (Hilshey et al. 2012) (Rezania and Prüggl 2012) Charging point communicates with the data collector (e.g. data center) via the communication components (Nicanfar et al. 2013) Charging point includes telecommunication technology for data sharing with management units. (Santos et al. 2015)</p>	<p>Component: Smart meter (Advanced Metering Infrastructure) (Hilshey et al. 2012) (Rezania and Prüggl 2012) Charging point (station or box) including communication or telecommunication technology (Nicanfar et al. 2013) (Santos et al. 2015)</p> <p>Function: Connection between the charge management device and consumer's EV charging load (Hilshey et al. 2012) Send user identity to control unit (Nicanfar et al. 2013) Communication via telecommunication technology (Santos et al. 2015)</p> <p>Information: Send EV load and receive charging signals (Hilshey et al. 2012)</p> <p>Communication:</p>

Table 11 Identified 17 features in the SGAM framework's three dimensions matching use cases in the articles (*Continued*)

Feature number	SGAM domain-dimension	SGAM zone-dimension	SGAM interoperability layer-dimension
3	<p>Smart charging algorithm in the charge management device</p> <p>Customer premises: Home charging (Rezania and Prügglér 2012)</p> <p>DER: Charge management device linked with smart meter sends and receives information crossing the DER domain</p> <p>Distribution: Charge management device located at the transformer (Hilshey et al. 2012) Public charging station in the distribution (Rezania and Prügglér 2012)</p>	<p>Process: Charge management device at the transformer (Hilshey et al. 2012)</p> <p>Charging and discharging covers home charging and public charging stations (Rezania and Prügglér 2012)</p> <p>Field: Smart charging algorithm (Hilshey et al. 2012) Home charging and public charging stations (Rezania and Prügglér 2012)</p>	<p>Public key encryption system and Identity-based cryptography (Nicanfar et al. 2013)</p> <p>Component: Charge management device (Hilshey et al. 2012)</p> <p>Function: The charge management device monitors instantaneous loads and sends charging signals to EVs (Hilshey et al. 2012) Smart charging algorithm reduces transformer aging (Hilshey et al. 2012) Charging and discharging to provide energy for the control market (Rezania and Prügglér 2012)</p> <p>Information: Send & receive charging signals to & from smart meter (Hilshey et al. 2012)</p>
4	<p>EV and battery charging at charging stations</p> <p>Distribution: The medium to low voltage transformer (Hilshey et al. 2012) Charging station is connected to the distribution grid (Rezania and Prügglér 2012) (Budde Christensen et al. 2012)</p>	<p>Process: Transform voltage to the domestic consumer level (Hilshey et al. 2012) EV electricity consumption. (Budde Christensen et al. 2012) (Rezania and Prügglér 2012) Charge batteries at the battery switching station (Budde Christensen et al. 2012)</p> <p>Field: Protection equipment in the transformer (Hilshey et al. 2012) Charging/battery switching stations contain a smart meter and control device that manages EV charging based on grid conditions (Budde Christensen et al. 2012) Field equipment is assumed to be part of the public charging station (Rezania and Prügglér 2012)</p> <p>Station: The transformer (Hilshey et al. 2012) Charging/battery switching stations (Budde Christensen et al. 2012) The public charging station includes the functional aggregation of charging multiple EVs at the same location (Rezania and Prügglér 2012)</p>	<p>Component: Medium to low voltage transformer (Hilshey et al. 2012) Distributed charging spots (Budde Christensen et al. 2012) EVs as a load at public charging spots (Budde Christensen et al. 2012) Charging infrastructure (Budde Christensen et al. 2012) Public charging station (Rezania and Prügglér 2012)</p> <p>Function: Reduce voltage level for domestic consumers (Hilshey et al. 2012) Charge or switch batteries (Budde Christensen et al. 2012) The company acts as a smart grid operator by controlling the charging spots (Budde Christensen et al. 2012)</p>
5	All domains:	Operation:	Function:

Table 11 Identified 17 features in the SGAM framework's three dimensions matching use cases in the articles (*Continued*)

Feature number	SGAM domain-dimension	SGAM zone-dimension	SGAM interoperability layer-dimension
Optimization in fleet charging management	The optimization considers thermal power plants, wind turbines, PHEV fleet, and regular load (Li et al. 2012) Customer premises Operating EVs from both home charging and public charging to help grid balance (Rezania and Prügler 2012)	The optimization is assumed to be managed by a PHEV fleet charging management systems (Li et al. 2012) The aggregator function can be seen as EV fleet management which is located in the operation zone (Rezania and Prügler 2012)	Optimization with the objective to minimize the expected cumulative cost (Li et al. 2012) Aggregator/service provider (Rezania and Prügler 2012) Business: Minimizing costs (Li et al. 2012) Information: Provide and activate control energy (Rezania and Prügler 2012)
6 Generation units considering the number of EVs	Generation: Electricity generation (Li et al. 2012) (McGee et al. n.d.) Power plant cost minimization (Ahmad and Sivasubramani 2015)	Process: Convert fuel to electricity (Li et al. 2012) (McGee et al. n.d.) Power plants minimization (Ahmad and Sivasubramani 2015)	Component: Multiple thermal power plants and backup diesel generators (Li et al. 2012) Baseload power generation units, e.g., thermal power plants. (McGee et al. n.d.) Function: Bulk generation and emergency generation (diesel generators) (Li et al. 2012) Power generation for baseload (McGee et al. n.d.) Business: Minimize generation cost and power plants emission considering the number of EVs (Ahmad and Sivasubramani 2015)
7 EV charging based on electricity production by DERs	DER: Wind turbines (Li et al. 2012) (McGee et al. n.d.) (Budde Christensen et al. 2012) Photovoltaics (McGee et al. n.d.) DERs (Yang and Tseng 2015) Energy storage (Rezania and Prügler 2012)	Process: Convert wind energy to electricity (Li et al. 2012) (McGee et al. n.d.) (Budde Christensen et al. 2012) Convert solar energy to electricity (McGee et al. n.d.) Convert energy to electricity (Yang and Tseng 2015) Electricity consumption and generation (Rezania and Prügler 2012)	Component: Wind turbines (Li et al. 2012) (McGee et al. n.d.) (Budde Christensen et al. 2012) Photovoltaics (McGee et al. n.d.) DER (not specified in paper) (Yang and Tseng 2015) Electricity energy storage (batteries) (Rezania and Prügler 2012) Business: Charging when there is a high wind electricity production at a lower electricity price (Budde Christensen et al. 2012)
8 Charging equipment enables V2G	Customer premises: EV supply equipment is located at the demand side (McGee et al. n.d.) DER: EV supply equipment enables V2G for energy storage (McGee et al. n.d.)	Process: AC is converted to DC to charge the EV battery and vice versa for V2G (McGee et al. n.d.)	Component: EV supply equipment (intelligent charging box) (McGee et al. n.d.) Function: Charging and discharging logic (McGee et al. n.d.)
9 Participation in electricity markets	All domains beside transmission: supply and consume electricity via market participation (McGee et al. n.d.; Santos et al. 2015;	Market: Participation in the energy control/regulation market (McGee et al. n.d.; Santos et al. 2015) (Budde Christensen et al. 2012)	Business: The use of EVs to bid into the regulation market (McGee et al. n.d.) The Portuguese energy market (Santos et al. 2015)

Table 11 Identified 17 features in the SGAM framework's three dimensions matching use cases in the articles (*Continued*)

Feature number	SGAM domain-dimension	SGAM zone-dimension	SGAM interoperability layer-dimension
	Budde Christensen et al. 2012; Rezania and Prüggl 2012)	(Rezania and Prüggl 2012)	Nord Pool electricity spot market (Budde Christensen et al. 2012) Austrian control energy market (Rezania and Prüggl 2012) Function: Time-of-Use tariff business model (Santos et al. 2015)
10 Communication between EVs and charging equipment	Customer premises: Communication and information between the EV and charging point on the demand side (McGee et al. n.d.) (Nicanfar et al. 2013)	Process: Communication between EV point/ supply equipment and EV (McGee et al. n.d.; Nicanfar et al. 2013)	Communication: SAE J1772 charging standard (McGee et al. n.d.) Negative-side signaling using CANbus (McGee et al. n.d.) Identity-based cryptography (Nicanfar et al. 2013) Information: Voltage level as control signal (McGee et al. n.d.) EV identity (Nicanfar et al. 2013)
11 EV charging at public charging points/ fast-charging stations	Distribution: Public charging points in distribution grid (Nicanfar et al. 2013) Transmission: Fast charging stations in transmission grid (Nicanfar et al. 2013)	Process: EV Charging (Nicanfar et al. 2013)	Component: EVs at public charging points and fast-charging stations (Nicanfar et al. 2013)
12 Data collector or database (data center)	Distribution and transmission: Data collector or databases such as data (Nicanfar et al. 2013) (Santos et al. 2015)	Station: The data collector or database is a data concentration (Nicanfar et al. 2013) (Santos et al. 2015)	Component: Data collector or database e.g. data center (Nicanfar et al. 2013) (Santos et al. 2015) Function: A cloud solution, smart grid server (Nicanfar et al. 2013)
13 Grid operator or DSO control operations	Distribution: The grid operator is the DSO (Santos et al. 2015)	Operation: The grid operator has power system control operations (Santos et al. 2015) Enterprise: Grid operators have commercial and organizational processes (Santos et al. 2015)	Function: Grid operator (Santos et al. 2015)
14 Load management by DSO, energy scheduler and data aggregator	Distribution: The load management at the DSO (Santos et al. 2015)	Operation: Load management (Santos et al. 2015)	Component: Computers/controllers (Santos et al. 2015) Function: Computers/controller as an energy scheduler and data aggregator. (Santos et al. 2015) The energy scheduler and data aggregator does load management of residential end-users based on an optimization algorithm (Santos et al. 2015) Business: The objective of the

Table 11 Identified 17 features in the SGAM framework's three dimensions matching use cases in the articles (*Continued*)

Feature number	SGAM domain-dimension	SGAM zone-dimension	SGAM interoperability layer-dimension
15 Communication between EV and aggregator	Customer premises, DER, and distribution: Communication standards and information flow between charging point and energy scheduler and data aggregator. (Santos et al. 2015) Information flow between EVs and the aggregator (Rezania and Prüggl 2012)	Field, station, and operation: Communication standards and information flow between charging point, energy scheduler and data aggregator (Santos et al. 2015) Information flow between EVs (through field equipment) and aggregator (Rezania and Prüggl 2012)	optimization is to reduce charging costs (Santos et al. 2015) Communication: ISO 15118 for charging point. IEEE 802.11.p or WiMax or 2G/3G/4G for wireless communication (Santos et al. 2015) Information: CANbus protocol sends a basic set of information such as State-of-Charge, State-of-Health, Vehicle position, available energy, charging time, etc. (Santos et al. 2015) Driving pattern sent from EV owner to aggregator (Rezania and Prüggl 2012) Tariffs and charging schedule sent to EV from aggregator (Rezania and Prüggl 2012)
16 Communication between EVs and energy scheduler and data aggregator	Customer premises: Cellular technologies are assumed together with EVs (Santos et al. 2015)	Field: Wireless connection between EVs, energy scheduler and data aggregator (Santos et al. 2015)	Component: Cellular technologies (antennas) (Santos et al. 2015)
17 A broker between EV owner and energy market	Distribution and transmission: The company controls charging spots in the distribution grid to balance the distribution and transmission grids (Budde Christensen et al. 2012)	Station and operation: Utilize the data acquired in the station to operate processes (Budde Christensen et al. 2012) Enterprise: Company Better place (Budde Christensen et al. 2012) Market: Bidding into spot markets (Budde Christensen et al. 2012)	Business: Battery leasing and EV monitoring (Budde Christensen et al. 2012) Energy demand Bidding into spot markets (Budde Christensen et al. 2012) Provide intelligent charging to the charging infrastructure (Budde Christensen et al. 2012) The company acts as a broker between the energy market and EV owner (Budde Christensen et al. 2012) Charging when electricity price is low (Budde Christensen et al. 2012) Eliminate the uncertainties about battery degradation for EV adoption (Budde Christensen et al. 2012)

Abbreviations

CO₂: Carbon dioxide; DER: Distributed Energy Resources; EU: European Union; EV: Electric Vehicle; G2V: Grid-to-Vehicle; PHEV: Plug-in Hybrid Electric Vehicle; SCADA: Supervisory Control And Data Acquisition; SGAM: Smart Grid Architecture Model; V2G: Vehicle-to-Grid

Acknowledgments

Not applicable.

About this supplement

This article has been published as part of Energy Informatics Volume 4, Supplement 2 2021: Proceedings of the Energy Informatics Academy Conference Asia 2021. The full contents of the supplement are available at <<https://energyinformatics.springeropen.com/articles/supplements/volume-4-supplement-2>>.

Authors' contributions

K.C. developed the first draft of this paper along with additional information from the corresponding work and contribution of the co-authors in the early and late stages of the project. All co-authors read, commented, and approved the final manuscript.

Funding

This work is part of the national project- Flexible Energy Denmark FED funded by Innovation Fund Denmark.

Declarations**Ethics approval and consent to participate**

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Published: 24 September 2021

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