TecnoLógicas
ISSN: 0123-7799
ISSN: 2256-5337
tecnologicas@itm.edu.co
Instituto Tecnológico Metropolitano
Colombia

Introduction of Aggregators to Colombian Electricity Distribution Networks Through a Business Vision

Castro Montilla, Leidy Daniela; Carvajal, Sandra Ximena
Introduction of Aggregators to Colombian Electricity Distribution Networks Through a Business Vision
TecnoLógicas, vol. 25, núm. 54, e2362, 2022
Instituto Tecnológico Metropolitano, Colombia
Disponible en: https://www.redalyc.org/articulo.oa?id=344271354010
DOI: https://doi.org/10.22430/22565337.2362

Artículos de investigación

Introduction of Aggregators to Colombian Electricity Distribution Networks Through a Business Vision

Introducción de agregadores a las redes de distribución eléctrica colombiana a través de una visión de negocio

Leidy Daniela Castro Montilla
Universidad Nacional de Colombia, Colombia
ledcastromo@unal.edu.co
https://orcid.org/0000-0001-9185-0235

Sandra Ximena Carvajal
Universidad Nacional de Colombia, Colombia
sxcarvajalq@unal.edu.co
https://orcid.org/0000-0001-6774-9065

DOI: https://doi.org/10.22430/22565337.2362
Redalyc: https://www.redalyc.org/articulo.oa?id=344271354010

Recepción: 21 Marzo 2022
Aprobación: 06 Junio 2022
Publicación: 12 Agosto 2022

Abstract:

The main objective of this article is to establish the most significant parameters that enhance the insertion of Independent Information Management Agents (GIDI), based on an analysis of different international experiences where these agents are known as Aggregators, to later be able to establish a business strategy around the functions and products that can be offered within a Colombian energy market. For this, it starts from a study of art focused on the different experiences at a global level, in this way with the help of dynamic systems and systemic thinking, the main parameters that govern the optimal functioning of these agents in the market are determined and finally through the Canvas model, establish a business strategy using the results of the systemic analysis. In this sense, it is obtained what characteristics potentiate the entry of the agents and it is established the best scenario and under what opinions the proposed system can be evaluated. Finally, a business option can be established by trading demand response programs and as a feasible scenario to analyze the proposed model.

Keywords: Advanced Measurement Infrastructure, Demand Response Program, Independent Information Manager (GIDI), modernization of the distribution network, smart grid.

Resumen:

El presente artículo tuvo como objetivo principal establecer los parámetros más significativos que potencializan la inserción de Agentes Independientes de Gestión de la Información (GIDI) a partir de un análisis de diferentes experiencias internacionales en donde estos agentes se conocen como “agregadores”, para luego establecer una estrategia de negocio entorno a las funciones y productos que puedan ofrecer dentro de un mercado energético colombiano. Para ello, se partió de un estudio del arte enfocado en los diferentes casos de éxito a escala global; de esta forma, con ayuda de los sistemas dinámicos y del pensamiento sistémico, se determinaron los principales parámetros que rigen el óptimo funcionamiento de estos agentes en el mercado y, finalmente, por medio del modelo Canvas, se estableció una estrategia de negocio empleando los resultados del análisis sistémico. En este sentido, se obtuvieron las características que potencializan la entrada de los agentes y se estableció dentro de qué escenario y bajo qué dictámenes se puede evaluar el sistema propuesto. Finalmente, se establece una opción de negocio mediante el comercio de programas de respuesta a la demanda como un escenario factible para analizar el modelo propuesto.

Palabras clave: Gestor independiente de información, infraestructura de media avanzada, modernización de la red de distribución, programa de respuesta a la demanda, red inteligente.

1. INTRODUCTION

The electrical system has established itself as an important pillar in the evolution and development of humanity, to the point of being considered the main engine of world economic growth [1]. With the arrival of the fourth industrial revolution, the increase in energy demand, climate change, the insertion of consumers as an active part of the electricity system, the progressive increase in distributed generation sources or other factors, have forced electrical networks to be coupled to the characteristics of the 21st century, so that it can provide an affordable, effective, clean, reliable, and efficient electricity service.

In this way, the concept of an intelligent network or Smart Grid arises, considering it the network of the 21st century, where enabling technologies, hardware, software, or practices are combined that together give way to a more reliable, versatile, secure, accommodating network, resistant, that is, more useful for consumers [2]. Being the Advanced Measurement Infrastructure (AMI) a clear example of these modernizing technologies and which according to resolution 219 of 2020 of the CREG is defined as "the infrastructure that allows two-way communication with users of the electric power service, that integrates hardware (advanced meters, measurement management centers, routers, concentrators, antennas, among others), software and communications architectures and networks, which allow the operation of the infrastructure and the management of the data of the power distribution system electricity and measurement systems" [3].

In this sense, the Colombian government has shown its interest in the deployment of AMI implementation in the Colombian distribution network through the issuance of CREG resolution 131 of 2020, modified by CREG 219 of 2020, which stipulates the guidelines for the implementation of the AMI in the National Interconnected System (SIN from its Spanish initials) [3]. This resolution establishes a new role within the structure of the Colombian electricity sector, which consists of the independent management of both data and information, as well as their exchange, management, integration, analytics, and added value. Consequently, a new aggregating agent emerges which will be responsible for carrying out these functions and takes the name of Independent Information Manager (GIDI for the acronym in Spanish), this agent can be independent of the other actors in the service provision chain or be within the same [4].

The purpose of this article, which was part of the X SICEL-2021, is to establish a business plan focused on the implementation of GIDI agents within the electricity market. The remunerative offer focuses on determining demand response programs in such a way as to optimize the insertion of advanced metering systems into the Colombian electricity distribution networks. The proposed methodology is based on an analysis of international experiences regarding the business opportunities of introducing agents in charge of information management to the electricity markets, known globally as aggregators. Later, this information will be classified to establish the causal model that relates the variables that influence the role played by the GIDI in the electricity sector when implementing AMI systems in Colombian electrical networks.

2. METHODOLOGY

To meet the objectives of this article, the following methodology is proposed, composed of four stages:

2.1 Stage one

First, a search and compilation of information are carried out, focused on the role played by aggregating agents GIDI within the AMI implementation processes and as a demand response innovation program based on international experiences.

2.2 Stage two

In the second stage, the technological surveillance, planning, and definition of parameters will be carried out, focused on the process of implementation of a new GIDI agent within the Colombian electricity sector and thus can carry out a prospective analysis, to observe the environment. application of these agents in the long term.

2.3 Stage three

In this stage, the information processing and analysis will be carried out, and with systemic thinking, it is possible to determine the variables that influence the optimal performance of the GIDI within the provision of electricity service in Colombian distribution networks. From the variables already established, a causal diagram is generated that allows visualizing their interaction in the system. With the causal diagram, it is possible to analyze the different scenarios that represent a business opportunity for GIDI agents, based on the evaluation of policies, plans, regulations, and national and international forecasts.

2.4 Stage four

In the fourth stage, the design of a business model will be proposed that identifies the key aspects to implement a remunerative offer from the GIDI as the new agents in the Colombian electricity market, through a canvas model that allows visualizing in a way clearer and more structured the essential terms that optimize the implementation of the value proposition within a current Colombian regulatory framework.

3. PRELIMINARY RESULTS OF CASE STUDY IN COLOMBIA

This section presents the results obtained from the development of the stages proposed in the previous section.

3.1 Stage one

The different advances in smart grid infrastructure technologies, information, and communication worldwide, as well as the deregulation of the electricity market, have given way to innovations on the side demand response, emerging a new type of energy service provider, which is known as aggregators [5].

These aggregators correspond to a new actor in the electricity market and its definition and applicability although it varies depending on the international context in which it has been applied, generally refers to an organization that may be independent or a participant in the current market and acts as mediators between consumers and markets, within which the suppliers of distributed energy resources are involved (including the demand response programs, distributed generation, and energy storage), as well as the participants of the electricity system that wish to exploit these services [5],[6],[7],[8],[9].

In this sense, aggregators can operate in the framework of different scenarios that allow the exposure of end-users to the electricity markets efficiently, these application areas are shown in Table 1.

TABLE 1.
The potential to introduce aggregating agents to different sectors

Customer segments	Scope	
	Description	References
Smart home	In the household sector, the potential to introduce the new agents of the energy market is given thanks to the automation of homes and digitalization, allowing that energy supply and demand can be matched almost in real-time, enabling the integration into the network products that can help optimize energy consumption, such as smart meters, thermostats, heating, and cooling devices.	[10]-[14]
Smart mobility	In the transport sector, the potential is focused on the advancement in the implementation of electric vehicles in the market, which means that car batteries could be integrated into the grid as a storage facility for surplus energy and become a source of energy supply when the car is not in use.	[15]-[20]
Smart utilities	In an intelligent network where there is a high insertion of DERs, the services provided by the aggregators help reduce the operating costs of the system, thereby reducing market prices. In addition, the aggregating agents that group DERs to participate as a virtual power plant (VPP) in the energy markets, can provide a balancing service in electricity markets in real-time in a small amount but faster than large, centralized generators	[21]-[25]
Public lighting	In this sector, the potential of aggregators focuses on being able to adjust the energy behavior within the public lighting system, in such a way that the flexibility of the energy footprint of the system (the difference between the maximum and minimum energy consumption), can be used to reduce costs and increase revenue in other settings.	[26]-[29]
Smart storage	Aggregators could reduce the disparity between private and system value by providing economic incentives to the consumers to relinquish control of their storage resources and use it more efficiently for the benefit of a larger electricity system.	[30]-[34]

Source: Created by the authors.

The objective of the literature review was to explore, classify, and compare different electricity market architectures and investigate their application areas, key elements, and relationships.

Once the application areas have been determined, certain opportunities related to the different architectures and possibilities of transactions in the electricity market can be established, among which are those shown in Table 2.

TABLE 2.
Electricity market architectures

Market design	Electricity market architectures
	Description
Virtual Power Plant – VPP	[illegible]
Retail Market	[illegible]
Blockchain Aggregators	[illegible]

Source: Created by the authors.

3.2 Stage two

Currently, the electrical distribution network in Colombia is generally electromechanical, with unidirectional communication, centralized generation, with few sensors, monitoring, and manual restoration, it sometimes presents few options for Information and Communication Technologies (ICT) implementation for customers [46].

Additionally, Law 1715 of 2014, seeks to promote the development and use of Non-Conventional Sources of Energy, mainly those of renewable nature, in the national energy system, through their integration into the electricity market, while it promotes the management of energy efficiency, which encompasses both energy efficiency and demand response [47].

On the other hand, the Energy and Gas Regulation Commission (CREG), which is the Colombian entity in charge of regulating electricity and gas services as established in Law 142 and 143 of 1994 [48], through the proposed resolution 219 of 2020 [3], which modifies resolution 131 of 2020, has established the conditions to the implementation of advanced metering infrastructure in the SIN within a regulatory framework in which the modernization of the electricity sector is promoted by implementing of AMI and with this emerges the new information management agents with the name of GIDI[49].

Additionally, the Ministry of Information Technologies and Communications of Colombia, through the Reference Guide for the adoption and implementation of projects with blockchain technology for the Colombian State, prioritizes the implementation of emerging technologies of the Fourth Industrial Revolution that facilitate the provision of services of the State through new models including DLT (Distributed Ledger Technology), massive data analysis (Big data), artificial intelligence (AI), Internet of Things (IoT), among others and thus optimize the management of public resources in projects of Information Technologies through the use of demand aggregation instruments and prioritization for cloud services [50].

The company XM oversees the Settlement and Administration of Accounts for the charges using the National Interconnected System networks that are assigned and to calculate the regulated income of the carriers, by the provisions contained in the regulation issued by CREG. In this sense XM for its part, to support the deployment of non-synchronous generation sources with a nominal capacity greater or equal to 5 MW mainly, has put forward a proposal that establishes the minimum technical and operational requirements for the integration of non-synchronous sources to the SIN and in this way, a flexible operation is maintained in the face of the challenges that arise as a result of the increase in the installed capacity of the variable sources to the SIN [51]

Within this Colombian context, projects of pilot plans concerning communication tools and advanced measurement are beginning to be reflected, as is the case of the "Pilot Smart Metering" plan in Bogota DC by the company CODENSA, which is sought through the implementation of AMI technology, reduce energy losses due to theft, increase the quality of electric power service, decrease operating costs in suspension, inspection, and reconnection activities [52].

The project "Intelligent Supervision and Advanced Control (ISAAC) Phase III" in Antioquia by XM seeks to design the architecture, the functional ecosystem, and a protocol for the future supervision and control systems in real-time, proposing a vision toward a radial evolution of SCADA / MES systems [53].

And other projects that, together with the initiatives and regulations already established, require that the current electrical system be prepared to guarantee the supply of a quality, affordable, efficient, and resilient service, giving way to innovations on the side of the demand response, through the implementation of new aggregators to the market, for which it needs agents in charge of managing the data and information, and these are called by regulation as GIDI, which become integrated into the Colombian electricity sector and give way to venture into new market architectures that could generate different business opportunities related to the changes foreseen in the Colombian distribution networks.

3.3 Stage three

The canvas business model defines the system and solves the problem of identifying who the users are, seeking a solution to their needs to deliver value-added satisfaction. It is an autonomous model that allows analyzing all the elements, and it is not the total sum of all the dimensions.

In this research, the canvas model was chosen to analyze the business model of the GIDI in Colombia because integral sustainability must be analyzed, which must be composed of technical, economic, environmental, and social criteria. The multidimensionality of the analysis and the interrelation with different market agents were studied using system dynamics.

The model is composed of nine sections that are logically connected to analyze and improve the understanding of all the basic aspects of the business [54]. Below the sections coupled with the proposed project will be described, where the GIDI agents appear as new actors in the electricity sector with the opportunity to provide services on the demand side to consumers, and in this way, end-users may participate in the energy market through explicit demand response programs receiving incentives for being part of them [55],[56],[57].

3.3.1 Value proposition

A business model is proposed within which GIDI agents can participate in the energy market through interaction between public servants and consumers in such a way that an optimal control strategy for load programming is developed that allows information managers to establish contracts through incentive-based demand response programs, which consist of agreements between the GIDI and the public utility company, which agrees to pay the GIDI, in exchange for a reduction in the identified electrical power and the operating costs of the system, thanks to an incentive payment arrangement between information agents and consumers, who commit to reducing their electrical loads or regulating their electrical equipment in exchange for direct incentives or reflected in a decrease in the electricity bill [21], [55], [56], [58], [59].

3.3.2 Customer segments

Based on the value proposition, the key actors to optimize the functions of the GIDI are identified as consumers and the network operator.

3.3.3 Channels

The main channels through which the GIDI interacts with the other actors of the business model are focused on direct participation in the wholesale and regulation market, bidding in the reserve market, and through the communication and control infrastructure [55], [60].

3.3.4 Customer relation

GIDI agents will interact with clients through a payment system and an efficient and customer-friendly control system, also through training and consulting service, whic

3.3.5 Revenue streams

The income paid to the GIDI comes from the payment of the market in response to demand, and other incentives on the part of the network operators and regulators [55], [56], [58].

3.3.6 Key resources

The most important resources within the distribution channels focus on the local control system, and the customer databases, including the demand pattern and the energy market information [55],[56].

3.3.7 Key activities

The key activities carried out by the GIDIs focus on accessing customers through energy providers or other channels by providing consulting systems and analysis of the demand pattern, as well as participating in the demand response market. either through a wholesale or retail market or by offering ancillary services, and by controlling customers' charging systems, by controlling their household appliances and paying them for their energy flexibility [21], [55], [56], [58], [59].

3.3.8 Key partners

Key partners include GIDI agents, network operators, consumers or end-users, control system providers, and different government entities, represented by different policies and regulations that support demand response programs [55], [56], [58].

3.3.9 Cost structure

The key resources and activities within this business model are based on demand response control systems, which include investment in communication and control infrastructure on both, the user side and the GIDI side, economic retribution to consumers, tariffs for access to energy markets [55], [56], [58].

Currently, the electrical distribution network in Colombia is generally electromechanical, with unidirectional communication, centralized generation, with few sensors, monitoring, and manual restoration, it sometimes presents few options for Information and Communication Technologies (ICT) implementation for customers [46].

3.4 Stage four

Based on the literature review, supportive examples, and different functional roles of GIDI, three interrelated elements of the GIDI business model were identified: Customer segments, revenue model, and regulation incentives. These three elements are analyzed below, following a causal diagram (Figure 1) [61].

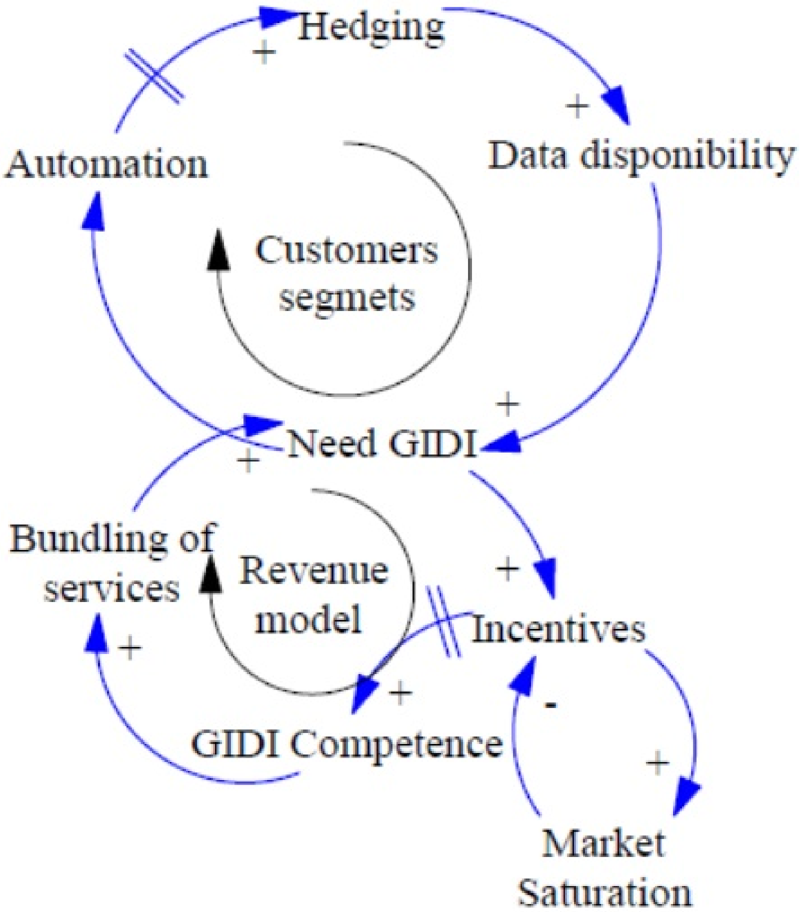

FIGURE. 1.
Causal diagram of the implementation of the GIDI as a business proposal
Source: Own elaboration

To analyze the interaction between the variables within a system that encourages and optimizes the introduction and implementation of the new GIDI agents inside the Colombian energy market, the system is analyzed in three segments, where the segment related to customers is based on the idea that in the face of the different advances in Colombia today in a technological, social and regulatory sense, there are increasingly automated systems and different measurement and communication infrastructures that in turn increase the coverage of the energy market, which begins to expand its limits towards retail markets, giving way for end-users to have the opportunity to actively participate in the electricity market.

In this sense, by having a broader coverage and an advanced and automated technological infrastructure that allows obtaining more extensive and detailed information on consumers and market activity, there is a quantity of data and information that increases exponentially and in turn reflects the need for an organization or a sector that is capable of managing, collecting and using this extensive database optimally and efficiently and in this way present a business model possibility within the Colombian electricity grids

By increasing the need for GIDI in the provision of electricity service as a business opportunity by offering services related to the response to demand, it increases the incentives and economic rewards received by these agents when interacting between consumers and other provider companies of energy services, but it is regulated by saturation in the market, since increasing the agents that can provide these services, the rewards received by each one will decrease (regulation segment)

On the other hand, by fostering competition in the sector of these new agents, the bundling of services within the electricity sector is promoted, since a greater number of distributed energy resources, demand response programs, storage power systems, and other services can be included in the distribution network. which in turn ratifies the importance of introducing GIDI agents to the electricity sector, which is going through a process of transition towards the modernization of the Colombian electricity grid.

4. CONCLUSIONS

After analyzing the different successful cases at a global level focused on the introduction to the electric energy sector of a new information management agent, known as aggregators in an international context and which takes the name of GIDI within the Colombian electricity market, observes that within a process of energy transition towards a modern electricity distribution network, where new technologies and advanced metering infrastructure are beginning to appear, information management takes on a very important role and offers a business opportunity in front of programs of demand response, and represents an approach to innovation within the energy market.

In this sense, and based on different experiences, it can be observed that a viable option to implement in the Colombian electricity system (which is beginning to venture into the implementation of a smart grid), focuses on incentive-based demand response programs (such as direct load control (DLC), interruptible load (IL), emergency demand response, load as a capacity resource, spinning/responsive reserves, non-spinning reserves, regulation service, and demand bidding and buyback) because under this market strategy, social problems are effectively taken into accounts, such as consumer satisfaction and privacy, compared to demand response programs Based on prices, these methods also allow consumers to interact directly with the energy market by bidding against their energy restriction, which will encourage consumers to participate in these programs and benefit from them without altering their style of life or their personal space.

On the other hand, when analyzing these proposals, it can be deduced that to implement and develop a profitable business offer, it is necessary to analyze the characteristics of the electricity network at the end-user level, in such a way that an optimal demand response program can be established depending on the sector (it could be residential, commercial or industrial) since the variability between each of these sectors makes it difficult to establish a single business program for all consumers in general.

Acknowledgments

The development of this article is part of a research process approved within the financing of a scholarship granted by the Faculty of Engineering and Architecture of the National University of Colombia, Manizales headquarters.

REFERENCES

[1] M. Santa María, N.-H. Von Der Fehr, J. Millán, J. Benavides, O. García, E. Schutt, *El mercado de la energía eléctrica en Colombia: Características, evolución e impacto sobre otros sectores*, 1ra Ed., Colombia, Cuadernos Fedesarrollo 30, 2019. http://hdl.handle.net/11445/171

[2] F. P. Sioshansi, *Smart Grid - Integrating Renewable, Distributed & Efficient Energy*, USA, Menlo Energy Economics. 2012.

[3] Comisión de Regulación de Energía y Gas (CREG), Resolución No. 219 de 2020 (29 de diciembre de 2020). Colombia, 2020.

[4] Comisión de Regulación de Energía y Gas (CREG), Condiciones para la implementación de la infraestructura de medición avanzada en el SIN, no. 1063. 2020.

[5] J. Ikäheimo, C. Evens, S. Kärkkäinen, "DER Aggregator business: the Finnish case", Reporte VTT-R-06961-09DER. https://www.presentica.com/doc/11259937/der-aggregator-business-the-finnish-case-pdf-document

[6] S. Burger, J. P. Chaves-Ávila, I. J. Pérez-Arriaga, C. Batlle, "The Value of Aggregators in Electricity Systems" *MIT Cent. Energy Environ. Policy Res*., Jan. 2016. https://energy.mit.edu/publication/the-value-of-aggregators-in-electricity-systems/

[7] X. Lu, K. Li, H. Xu, F. Wang, Z. Zhou, Y. Zhang, "Fundamentals and business model for resource aggregator of demand response in electricity markets", *Energy*, vol. 204, p. 117885, Aug. 2020. https://doi.org/10.1016/j.energy.2020.117885

[8] International Renewable Energy Agency, "Aggregators Innovation Landscape Brief", Abu Dhabi, 2019. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Innovation_Aggregators_2019.PDF

[9] M. Hashmi, S. Hänninen, K. Mäki, "Survey of smart grid concepts, architectures, and technological demonstrations worldwide", in *2011 IEEE PES Conf. Innov. Smart Grid Technol. Lat. Am. SGT LA 2011 - Conf. Proc.*, Medellín, 2011, pp. 1–7. https://doi.org/10.1109/ISGT-LA.2011.6083192

[10] Ö. Okur, P. Heijnen, Z. Lukszo, "Aggregator's business models in residential and service sectors: A review of operational and financial aspects", *Renew. Sustain. Energy Rev.,* vol. 139, p. 110702, Apr. 2021. https://doi.org/10.1016/j.rser.2020.110702

[11] A. Stratigea, G. Somarakis, M. Panagiotopoulou, "Smartening-Up Communities in Less-Privileged Urban Areas —The DemoCU Participatory Cultural Planning Experience in Korydallos—Greece Municipality" in *Smart Cities in the Mediterranean. Coping with Sustainability Objectives in Small and Medium-sized Cities and Island Communities*," Switzerland, Springer Nature, 2017, pp. 85-112. https://link.springer.com/book/10.1007/978-3-319-54558-5

[12] R. H. Katz *et al.,* "An information-centric energy infrastructure: The Berkeley view", *Sustain. Comput. Informatics Syst.,* vol. 1, no. 1, pp. 7–22, Mar. 2011. https://doi.org/10.1016/j.suscom.2010.10.001

[13] K. Bruninx, H. Pandžić, H. Le Cadre, E. Delarue, "On the Interaction between Aggregators, Electricity Markets and Residential Demand Response Providers", *IEEE Trans. Power Syst.,* vol. 35, no. 2, Washington, 2020, pp. 840–853. https://doi.org/10.1109/TPWRS.2019.2943670

[14] M. Khoshjahan, M. Soleimani, M. Kezunovic, "Optimal participation of PEV charging stations integrated with smart buildings in the wholesale energy and reserve markets", in *2020 IEEE Power Energy Soc. Innov. Smart Grid Technol. Conf. ISGT 2020*, Washington, 2020, pp. 20–24. https://doi.org/10.1109/ISGT45199.2020.9087686

[15] A. Sanchez Miralles, T. Gomez San Roman, I. J. Fernández, C. F. Calvillo, "Business Models Towards the Effective Integration of Electric Vehicles in the Grid", *IEEE Intelligent Transportation Systems Magazine*, vol. 6, no. 4, pp. 45–56, Oct. 2014. https://doi.org/10.1109/MITS.2014.2329327

[16] T. Gómez San Román, I. Momber, M. R. Abbad, A. Sánchez Miralles, "Regulatory framework and business models for charging plug-in electric vehicles: Infrastructure, agents, and commercial relationships", *Energy Policy,* vol. 39, no. 10, pp. 6360–6375, Oct. 2011. https://doi.org/10.1016/j.enpol.2011.07.037

[17] J. Mullan, D. Harries, T. Bräunl, S. Whitely, "The technical, economic and commercial viability of the vehicle-to-grid concept", *Energy Policy,* vol. 48, pp. 394–406, Sep. 2012. https://doi.org/10.1016/j.enpol.2012.05.042

[18] S. L. Andersson *et al.,* "Plug-in hybrid electric vehicles as regulating power providers: Case studies of Sweden and Germany", *Energy Policy,* vol. 38, no. 6, pp. 2751–2762, Jun. 2010. https://doi.org/10.1016/j.enpol.2010.01.006

[19] M. D. Galus, M. Zima, G. Andersson, "On integration of plug-in hybrid electric vehicles into existing power system structures", *Energy Policy,* vol. 38, no. 11, pp. 6736–6745, Nov. 2010. https://doi.org/10.1016/j.enpol.2010.06.043

[20] C. Gouveia, D. Rua, F. J. Soares, C. Moreira, P. G. Matos, J. A. P. Lopes, "Development and implementation of Portuguese smart distribution system", *Electr. Power Syst. Res*., vol. 120, pp. 150–162, Mar. 2015. https://doi.org/10.1016/j.epsr.2014.06.004

[21] Q. Wang, C. Zhang, Y. Ding, G. Xydis, J. Wang, J. Østergaard, "Review of real-time electricity markets for integrating Distributed Energy Resources and Demand Response", *Appl. Energy,* vol. 138, pp. 695–706, Jan. 2015. https://doi.org/10.1016/j.apenergy.2014.10.048

[22] C. F. Calvillo, A. Sánchez-Miralles, J. Villar, F. Martín, "Optimal planning and operation of aggregated distributed energy resources with market participation", *Appl. Energy,* vol. 182, pp. 340–357, Nov. 2016. https://doi.org/10.1016/j.apenergy.2016.08.117

[23] L. Gkatzikis, I. Koutsopoulos, T. Salonidis, "The role of aggregators in smart grid demand response markets", *IEEE J. Sel. Areas Commun.,* vol. 31, no. 7, pp. 1247–1257, Jun. 2013. https://doi.org/10.1109/JSAC.2013.130708

[24] M. Tavasoli, M. H. Yaghmaee, A. H. Mohajerzadeh, "Optimal placement of data aggregators in smart grid on hybrid wireless and wired communication", in *2016 4th IEEE Int. Conf. Smart Energy Grid Eng. SEGE* 2016, Oshawa, 2016, pp. 332–336. https://doi.org/10.1109/SEGE.2016.7589547

[25] E. Peeters, D. Six, M. Hommelberg, R. Belhomme, F. Bouffard, "The ADDRESS project: An architecture and markets to enable active demand", in *2009 6th Int. Conf. Eur. Energy Mark.*, Leuven, 2009, pp. 1–5. https://doi.org/10.1109/EEM.2009.5207145

[26] S. Karnouskos, D. Ilic, P. G. Da Silva, "Using flexible energy infrastructures for demand response in a Smart Grid city", in *IEEE PES Innov. Smart Grid Technol. Conf. Eur.,* Berlin, 2012, pp. 1–7. https://doi.org/10.1109/ISGTEurope.2012.6465859

[27] H. Pires, A. M. Carreiro, G. Pereira, R. Carreira, J. P. Trovao, J. Landeck, "IP@Smart - Energy management system applied to eco-efficient public lighting networks", in *2014 IEEE Veh. Power Propuls. Conf. VPPC 2014,* Coimbra, 2014, pp. 1-6. https://doi.org/10.1109/VPPC.2014.7007094

[28] M. Delfanti, G. Esposito, V. Olivieri, D. Zaninelli, "SCUOLA project: The hub of smart services for cities and communities", in *2015 Int. Conf. Renew. Energy Res. Appl. ICRERA 2015*, vol. 5, Palermo, 2015, pp. 1502–1506. https://doi.org/10.1109/ICRERA.2015.7418658

[29] S. Karnouskos, "Demand Side Management via prosumer interactions in a smart city energy marketplace", in *IEEE PES Innov. Smart Grid Technol. Conf. Eur.,* Manchester, 2011, pp. 1–7. https://doi.org/10.1109/ISGTEurope.2011.6162818

[30] G. Castagneto Gissey, D. Subkhankulova, P. E. Dodds, M. Barrett, "Value of energy storage aggregation to the electricity system", *Energy Policy*, vol. 128, pp. 685–696, Feb. 2019. https://doi.org/10.1016/j.enpol.2019.01.037

[31] S. Burger, J. P. Chaves-Ávila, C. Batlle, I. J. Pérez-Arriaga, "A review of the value of aggregators in electricity systems", *Renew. Sustain. Energy Rev.,* vol. 77, pp. 395–405, Sep. 2017. https://doi.org/10.1016/j.rser.2017.04.014

[32] J. E. Contreras-Ocaña, M. A. Ortega-Vazquez, B. Zhang, "Participation of an energy storage aggregator in electricity markets", *IEEE Trans. Smart Grid,* vol. 10, no. 2, pp. 1171–1183, 2019. https://doi.org/10.1109/TSG.2017.2736787

[33] S. Bhattacharyya, T. van Cuijk, R. Fonteijn, "Integrating Smart Storage and Aggregators for Network Congestion Management & Voltage Support in a Pilot Project in Eindhoven", in *25th Int. Conf. Electr. Distrib. (CIRED),* Madrid, 2019, pp. 3–6. http://dx.doi.org/10.34890/186

[34] H. Lotfi, R. Ghazi, “Optimal participation of demand response aggregators in reconfigurable distribution system considering photovoltaic and storage units”, *J. Ambient Intell. Humaniz. Comput*., vol. 12, no. 2, pp. 2233–2255, Jul. 2020. https://doi.org/10.1007/s12652-020-02322-2

[35] I. Lampropoulos, G. M. A. Vanalme, W. L. Kling, “A methodology for modeling the behavior of electricity prosumers within the smart grid”, in *IEEE PES Innov. Smart Grid Technol. Conf. Eur. ISGT Eur.,* 2010, pp. 1-8. https://doi.org/10.1109/ISGTEUROPE.2010.5638967

[36] C. Kieny, B. Berseneff, N. Hadjsaid, Y. Besanger, J. Maire, “On the concept and the interest of Virtual Power plant: Some results from the European project Fenix”, *2009 IEEE Power Energy Soc. Gen. Meet. PES ’09*, 2009, pp. 1–6. https://doi.org/10.1109/PES.2009.5275526

[37] K. El Bakari, W. L. Kling, “Development and operation of virtual power plant system”, in *2011 2nd IEEE PES Innov. Smart Grid Technol. Conf. Eur.*, 2011, pp. 1–5. 10.1109/ISGTEurope.2011.6162710.

[38] S. Littlechild, “Retail competition in electricity markets - expectations, outcomes and economics”, *Energy Policy,* vol. 37, no. 2, pp. 759–763, Feb. 2009. https://doi.org/10.1016/j.enpol.2008.09.089

[39] C. Defeuilley, “Retail competition in electricity markets”, *Energy Policy,* vol. 37, no. 2, pp. 377–386, Feb. 2009. https://doi.org/10.1016/j.enpol.2008.07.025

[40] R. Haider, D. D’Achiardi, V. Venkataramanan, A. Srivastava, A. Bose, A. M. Annaswamy, “Reinventing the utility for distributed energy resources: A proposal for retail electricity markets”, *Adv. Appl. Energy*, vol. 2, p. 100026, May. 2021. https://doi.org/10.1016/j.adapen.2021.100026

[41] T. Zhang, H. Pota, C. C. Chu, R. Gadh, “Real-time renewable energy incentive system for electric vehicles using prioritization and cryptocurrency”, *Appl. Energy,* vol. 226, pp. 582–594, Sep. 2018. https://doi.org/10.1016/j.apenergy.2018.06.025

[42] J. Guo, X. Ding, W. Wu, “An Architecture for Distributed Energies Trading in Byzantine-Based Blockchains,” *IEEE Trans. Green Commun. Netw.*, vol. 6, no. 2, pp. 1216–1230, Jun. 2022, https://doi.org/10.1109/TGCN.2022.3142438

[43] Y. Wang, Z. Su, Q. Xu, T. Yang, N. Zhang, “A Secure Charging Scheme for Electric Vehicles with Smart Communities in Vehicular Networks”, *IEEE Trans. Veh. Technol.,* vol. 68, no. 9, pp. 8487–8501, 2019. https://doi.org/10.1109/TVT.2019.2923851

[44] M. Sabounchi, J. Wei, “Towards Resilient Networked Microgrids: Blockchain-Enabled Peer-to-Peer Electricity Trading Mechanism”, in *2017 IEEE Conf. Energy Internet Energy Syst. Integr.,* pp. 2017, 1-5. https://doi.org/10.1109 / EI2.2017.8245449

[45] M. L. Di Silvestre *et al.,* “Blockchain for power systems: Current trends and future applications”, *Renew. Sustain. Energy Rev*., vol. 119, Mar. 2020. https://doi.org/10.1016/j.rser.2019.109585

[46] B. Morales Quintana, N. G. Salcedo, “Estado del arte de las redes inteligentes ‘smart grid’”, universidad Tecnológica de Bolívar, 2012.

[47] Unidad de Planeación Minero-Energética (UPME), “Guía práctica para la aplicación de los incentivos tributarios de la Ley 1715 de 2014”, Minist. Minas y Energ., pp. 1-28, 2014.

[48] MME, “Decreto Mme 1623 De 2015”, 2015. www.lexbase.biz

[49] Comisión de Regulación de Energía y Gas (CREG), Se establecen las condiciones para la implementación de la infraestructura de medición avanzada en el SIN -Resolución 131 de 2020 (25 de junio de 2020). Colombia, 2020.

[50] S. Espinosa, “Blockchain reference guide adoption and implementation of blockchain technology for the Colombian State”, Minist. Inf. Technol. Commun., 2021.

[51] XM S.A. E.S.P., “Propuesta de Requerimientos Técnicos para la Integración de Fuentes de Generación No Síncrona al SIN”, p. 28, 2017. https://www.xm.com.co/Documents/Propuesta_Requerimientos/Propuesta_Requerimientos.pdf

[52] L. M. Banguera Gómez, “Estudio, análisis y modelamiento de los sistemas eléctricos de distribución en el contexto de redes eléctricas inteligentes industria 4.0 y automatización dentro de convenio marco de cooperación interinstitucional 080 de 2019 entre la Universidad Distrital Francisco José de Caldas y la RAPE (Región

administrativa y de planeación especial)", Universidad Distrital Francisco José de Caldas, 2020. https://repository.udistrital.edu.co/handle/11349/24730

[53] E. Maya *et al.,* "Informe auditoría de cumplimiento XM Compañía de Expertos en Mercados", 2017. URL

[54] C. Santandreu Mascarell, L. Canós Darós, J. Marín-Roig Ramón, "Business Model Canvas y redacción del Plan de Negocio", Universitat Politécnica de València, Jun. 2014. https://riunet.upv.es/handle/10251/38381

[55] Z. Ma, J. D. Billanes, B. N. Jørgensen, "Aggregation potentials for buildings-Business models of demand response and virtual power plants", *Energies*, vol. 10, no. 10, Oct. 2017. https://doi.org/10.3390/en10101646

[56] R. Alasseri, A. Tripathi, T. Joji Rao, K. J. Sreekanth, "A review on implementation strategies for demand side management (DSM) in Kuwait through incentive-based demand response programs", *Renew. Sustain. Energy Rev.,* vol. 77, pp. 617–635, Sep. 2017. https://doi.org/10.1016/j.rser.2017.04.023

[57] M. Babar, T. A. Taj, T. P. I. Ahamed, E. A. Al-Ammar, "The conception of the aggregator in demand side management for domestic consumers", *Int. J. Smart Grid Clean Energy*, vol. 2, no. 3, pp. 371–375, Oct. 2013. https://doi.org/10.12720/sgce.2.3.371-375

[58] C. A. Cardoso, J. Torriti, M. Lorincz, "Making demand side response happen: A review of barriers in commercial and public organisations", *Energy Res. Soc. Sci.,* vol. 64, pp. 101443, Jun. 2020. https://doi.org/10.1016/j.erss.2020.101443

[59] J. Wang, S. Kennedy, J. Kirtley, "A new wholesale bidding mechanism for enhanced demand response in smart grids", in *Innov. Smart Grid Technol. Conf. ISGT 2010,* Gaithersburg, 2010, pp. 1-8. https://doi.org/10.1109/ISGT.2010.5434766

[60] N. O#Connell, P. Pinson, H. Madsen, M. O#Malley, "Benefits and challenges of electrical demand response: A critical review", *Renew. Sustain. Energy Rev*., vol. 39, pp. 686–699, Nov. 2014. https://doi.org/10.1016/j.rser.2014.07.098

[61] J. D. Sterman, Business dynamics: systems thinking and modeling for a complex world, Irwin/McGraw-Hill Boston, 2000.

Notes

- **AUTHOR CONTRIBUTIONS**
  Leidy Daniela Castro carried out different research processes, search for information, and oriented and under the advice of the author Sandra Ximena Carvajal who carried out arduous surveillance of the investigative process and established the bases and foundation for the formulation of the causal model of the implementation of the GIDI agents through the establishment of demand response programs within the Colombian electrical distribution systems, to then jointly establish the business model and conclusions of the investigative article.
- **CONFLICTS OF INTEREST**
  The authors declare that there is no conflict of interest.

Información adicional

How to cite / Cómo citar: L. D. Castro-Montilla; S. X. Carvajal, "Introduction of Aggregators to Colombian Electricity Distribution Networks Through a Business Vision," *TecnoLógicas*, vol. 25, nro. 54, e2362, 2022. https://doi.org/10.22430/22565337.2362