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Sizing strategies for electrical smart microgrids for rural customers

Estratégias de dimensionamento de microrredes inteligentes para usuários rurais

Estrategias de dimensionamiento de microrredes eléctricas inteligentes para usuarios rurales

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ABSTRACT

Micro Smart Grids are configured in the panorama of technological areas related to clean energies, as an alternative for the efficient distribution of electric energy. For this purpose, the present study aimed to carry out a documentary analysis of the sizing strategies of smart microgrids for rural users. The research was carried out from the approach of a documentary-bibliographic research. In this framework, the search was carried out in the Internet database of sites specialized in academic information and reliable sources using the descriptors: electric microgrids, strategies, sizing. For the selection of the material under analysis, the following criteria were taken into consideration: pertinence, relevance, language, place of origin, published in indexed journals during the years 2017 to 2021. Based on this, the content analysis of the information found in the literary sources collected was performed. Of the total number of documents used, seven (07) of them were considered for the analysis as they were considered to be the ones that most accurately matched the interests of this study. The results found show that: The integration of distributed energy resources (distributed generation and energy storage), are resulting in a great revolution in generation, transmission, distribution, operation and energy consumption, among others. It is concluded that microgrids become one of the support strategies for the conventional electrical grid that can help in the purpose of undertaking actions for the development of projects aimed at generating a process of allocation or improvement in the supply of electricity in rural localities.

Keywords: microgrids, sizing, rural.

RESUMO

As Micro Redes Inteligentes configuram-se no panorama das áreas tecnológicas ligadas à energia limpa, como alternativa para a distribuição eficaz de energia elétrica. Para tanto, o objetivo deste estudo foi realizar uma análise documental das estratégias de dimensionamento de microrredes elétricas inteligentes para usuários rurais. A pesquisa foi realizada a partir da abordagem da pesquisa documental-bibliográfica. Neste contexto, a busca foi realizada em banco de dados da Internet de sites especializados em informações acadêmicas e fontes confiáveis utilizando os descritores: microrredes elétricas, estratégias, dimensionamento. Para a seleção do material a ser analisado foram levados em consideração os seguintes critérios: pertinência, pertinência, idioma, local de origem, publicados em periódicos indexados durante os anos de 2017 a 2021. Com base nisso, foi realizada a análise de conteúdo das informações. realizado. encontrado nas fontes literárias coletadas. Do total de documentos utilizados, sete (07) deles foram considerados para análise por serem considerados os que mais se adequam aos interesses deste estudo. Os resultados encontrados mostram que: A integração dos recursos energéticos distribuídos (geração distribuída e armazenamento de energia) está resultando em uma grande revolução na geração, transmissão, distribuição, operação e consumo de energia, entre outros. Conclui-se que as microrredes elétricas tornam-se uma das estratégias de apoio à rede elétrica convencional que pode auxiliar no propósito de empreender ações para o desenvolvimento de projetos que visem gerar um processo de alocação ou melhoria no fornecimento de energia elétrica em cidades rurais.

Palavras-chave: microrredes, dimensionamento, rural.

RESUMEN

La Micro Redes Inteligentes se configura en el panorama de las áreas tecnológicas vinculadas con las energías limpias, como una alternativa para la distribución eficaz de la energía eléctrica. A este propósito, el presente estudio tuvo como objetivo realizar un análisis documental de las estrategias de dimensionamiento de microrredes eléctricas inteligentes para usuarios rurales. La investigación se realizó desde el enfoque de una investigación documental-bibliográfica. En este marco, la búsqueda se realizó en la base de datos de Internet de sitios especializados en información académica y de fuentes confiables mediante los descriptores: microrredes eléctricas, estrategias, dimensionamiento. Para la selección del material objeto de análisis se tomó en consideración los siguientes criterios pertinencia, relevancia, idioma, lugar de procedencia, publicados en revistas indexadas durante los años 2017 a 2021. A partir de ello, se realizó el análisis de contenido de la información encontrada en las fuentes literarias recopiladas. Se consideró del total de documentos utilizados, siete (07) de ellos para el análisis por considerar que eran las que se ajustaban con mayor precisión los intereses de este estudio. Los resultados encontrados dan cuenta que: La integración de los recursos energéticos distribuidos (generación distribuida y almacenamiento energético), están teniendo como resultado una gran revolución en la generación, la trasmisión, la distribución, la operación y el consumo energético, entre otros. Se concluye que las microrredes eléctricas se convierten en una de las estrategias de apoyo para la red eléctrica convencional que pueden ayudar en el propósito de acometer acciones para el desarrollo de proyectos tendientes a la generación un proceso de asignación o mejora en el suministro de energía eléctrica en las localidades rurales.

Palabras clave: microrredes eléctricas, dimensionamiento, rural.

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Main practical implications:
The article synthesizes the specialized literature on electrical smart microgrids, mainly in the context of rural areas. The results presented may be useful for the formulation of new policies and/or research actions in the Ecuadorian context.
Originality/value:
Due to the scarcity of studies on Electrical smart microgrids in Ecuador, the article becomes relevant and valuable by synthesizing and analyzing recent literature.

INTRODUCTION

Globally, there is a clear and shared understanding about what is expected from the materials that, in the most useful and efficient way can respond to the current challenges of the energy sector, to this end has been launched in the technological areas of various companies in the sector the approach to the development of Smart Micro Grids as a way to boost a more efficient power grid, and under the model of approaching clean energy sources. In this framework Bordón et al, (2018) have expressed "smart grids also known as Smart Grid (SG) emerged as a response to the need to modernize the electric grid, articulating control and monitoring processes with green technologies, also known as non-polluting or ecological" (p.90).

The information found usually indicates that Micro Smart Grids or Smart Grids are basically bidirectional networks, capable of transmitting electricity in both directions and, combined with new information technologies, allow the distribution of electricity from suppliers to consumers favoring the integration of renewable generation sources (Xué Research Group, 2020).

In this sense, De Alaminos et al, (2020) the technical principles and architecture of autonomous networks can have several configurations depending on factors such as the quality and quantity of generating sources, their size, the characteristics of the electrical distribution to users, type of load profiles, power demanded, etc.

The referenced authors also point out that the choice of the type of current (alternating or direct current) to be used for system operation is highly dependent on the technologies used and the energy management strategy (De Alaminos et al, 2020).

Likewise, it was found that microgrids currently represent a viable solution for electric power requirements in isolated or non-electrified areas. This new vision of electric energy management has been considered to supply consumption needs in rural areas, according to Gómez et al, (2018) smart grids or Smart Grid propose answers and solutions to the concerns of adequacy of electricity supply. Thus, the incorporation of a basic service such as electricity., allows to substantially improve the living conditions of the population, reduce social inequity, since the electricity supply also has positive effects to improve economic activity at the local level, coupled with the fact that one of the main characteristics of the design of microgrids is that, they behave as small centers of distributed generation to ensure sustainability.

The planning and control of energy resources based on the use of intelligent microgrids to improve the distribution and generation of electricity systems, as well as to improve profitability and minimize the presence of deficits in the supply of energy in rural communities, is today a sizing strategy called to make the entire electricity grid system more effective, efficient and effective.

In agreement with the previous statement Bordón et al (2018) have put forward the idea that it is important, but in addition the need to manage the actions of all the elements that make up the electrical system to optimally generate and distribute the service to the final consumer is observed. In this perspective, these same authors consider that, for this purpose, new coordination strategies must be projected to provide a safe, economic and sustainable supply, with the use of measurement and control devices and the possibility of power lines with bidirectional power flow (Bordón et al, 2018).

In this line, Chauhan et al, (2017) state that a new working scheme for Demand Side Management (DSM) System can consider direct current (DC) microgrid as it is considered a prospective system to utilize PV power more efficiently, thus, an algorithm is proposed where DC load augmentation and DC power sources such as photovoltaic (PV) and battery bank (BB) are used in an integrated manner to increase the system efficiency. By virtue of that, the BB responds to changes in a power imbalance between PV generation and demand within a stand-alone DC microgrid. Energy loss during battery charging/discharging is the big challenge for PV-supplied stand-alone DC microgrid (Chauhan et al, 2017).

In another sizing strategy that allows the distribution of electricity taking into consideration the microgrid structure Ramlia et al, (2018) propose that microgrid systems, such as solar photovoltaic (PV) and wind energy, integrated with diesel generators are promising energy supplies and are economically viable for current and future use in relation to the increase in energy demand and the depletion of conventional sources. Undoubtedly, this model for electricity distribution has a great potential to cover the electricity demands in rural areas since, due to its degree of adaptation, use of renewable resources such as solar and wind energy, it responds to a decentralized and flexible concept to manage the supply and generation of electricity for the inhabitants of remote areas of the country.

The use of hybrid microgrids is presented as another alternative for energy management Kharrich et al, (2021) are presented as a solution to many electrical energy problems. These microgrids contain some renewable energy sources such as photovoltaic (PV), wind and biomass, or a hybrid of these sources, in addition to storage systems.

Similarly, Omotayo et al (2019) present the idea of a systematic approach to provide a mix of conventional and renewable energy that is adaptable enough to operate in grid-connected and off-grid modes to provide power to a remote village. To this end, the HOMER pro software tool was used to model two scenarios of on-grid and off-grid systems, assessing in detail the techno-economic effects and operational behavior of the systems and their adverse impacts on the environment. The results showed that, for both cases, the optimal design consists of a 12 kW diesel generator, with a 54 kW photovoltaic (PV) panel, a 70 battery pack (484 kWh nominal capacity battery bank) and a 21 kW converter. This configures a flexible and reliable system architecture to ensure continuous power supply to consumers in all conditions.

On the other hand, El-Hana et al (2020) argue about a feasible and environmentally and socially favorable Microgrid sizing strategy of optimally designing a hybrid photovoltaic/wind/diesel microgrid system (HMS) for a small number of houses considering the load uncertainty for the city. The use of multi-objective evolutionary algorithm based on decomposition (MOEA/D) is presented to optimally design the photovoltaic/wind/diesel HMS considering the load uncertainty. The loss of power supply probability (LPSP) and cost of electricity (COE) are considered as objective functions of the optimization problem. In addition, two separate load cases of 5 and 10 houses are tested to verify the robustness of the approach. The obtained results are beneficial to help researchers and practitioners to select the optimal microgrid configuration.

In this sense, conceiving and adopting the principles and structures of Micro Smart Grids as strategies to make a more efficient use of electricity constitutes an important effort aligned with the notions of clean and renewable energies for the conservation and protection of the environment.

On this basis, the purpose of this work was to carry out a reflective documentary review about the sizing strategies of Smart Microgrids for rural users.

Conceptual Aspects

Electrical Dimensioning

For the sizing of the installation, the first step is an estimated power calculation, where it is necessary to detail all the power required for the normal operation of the installation (Casado, 2012).

Also, Diaz (2019) highlights that for the sizing of the system, the main components that make it up must be selected, calculations are made for the sizing of the wiring and electrical protections of the system, and the type of support structures are selected, as well as the location with the best performance within the site area.

Once all the components of the facility and the required initial budget have been selected, the annual expenses and revenues of the project are identified, in order to economically evaluate the facility and analyze the key factors that guarantee the profitability of the project (Servan Socola, 2014).

Electrical Microgrids

According to the Department Of Energy (DOE), U.S. Department of Energy) Micro Electric Grids (MRE) are defined as a set of interconnected loads and distributed energy resources working within defined electrical boundaries, acting as a single controllable entity with respect to the grid and connecting or disconnecting from that grid to allow it to operate in grid-connected or island (stand-alone) mode (Paredes et al, 2019).

The Micro-Grid is an interconnection system with the capacity to be self-sufficient and operate in isolation if necessary. It includes generation, storage and electric transport, as well as equipment to optimize the intelligent management of energy by the end user (public lighting, building automation, among others) (Llano, 2015).

Microgrids constitute a bidirectional electricity generation system that allows the distribution of electricity from suppliers to consumers, using digital technology and favoring the integration of generation sources of renewable origin, with the aim of saving energy, reducing costs and increasing reliability. The sizes of a microgrid range from 3KW to 10MW, much smaller than current large generating plants (Pascual de Vega, 2018).

The main objective of microgrids is to generate electricity as efficiently and autonomously as possible. For this purpose, they have communication and smart metering elements so that the generator-user communication is as close as possible. In this way, a demand forecast can be made in order to adapt generation and avoid transport and storage losses (Pascual de Vega, 2018).

Smart Microgrids

Smart grids are encompassed within microgrids, since without these microgrids would have no place in the energy market. Pascual de Vega (2018). A smart grid is one that can efficiently integrate the behavior and actions of all users connected to it, so as to ensure a sustainable and efficient energy system, with low losses and high levels of quality and security of supply (Pascual de Vega, 2018).

Smart grids also known as Smart Grid (SG), emerged as a response to the need to modernize the electric grid, articulating control and monitoring processes with green technologies, also known as non-polluting or environmentally friendly (Gómez et al, 2018). Smart grids are autonomous and improve effectiveness and efficiency in electric power management, allowing utilities to optimize existing infrastructure, minimizing the construction of more power plants (Kobus et al, 2015).

The Smart Grid (SG) consists of control systems, computers, communication and new technologies and equipment working together, these technologies work with the electrical grid to respond digitally to the electrical demand. Consequently, this modern grid is able to store, communicate and make decisions (Garófalo, 2020).

Smart grids have the capacity to respond to demand and balance electricity consumption with generation, as well as have the potential to integrate new electricity storage technologies, and enable the large-scale use of electric vehicles (Pascual de Vega, 2018).

Some of the advantages offered by a microgrid (MG) are energy efficiency, reduction of pollutant gas emissions and the possibility of operating in interconnected or isolated mode from a conventional power grid or another MG (Chae, 2015).

Smart Micro Grids for Rural Users

Access to electric power constitutes a key instrument for developing the capacities of rural society, offers greater freedoms to individuals, and fosters the conditions for developing social capital to carry out collective actions for the development of the rural environment (Mendieta & Escribano, 2015).

Given the autonomous operation capacity (off-grid) of micro-grids (MG), some researches Chae et al (2015) and Sánchez et al (2015) consider them as an alternative to meet the energy requirements of rural populations.

In general, non-interconnected rural populations tend to be made up of a group of houses located far from each other. This leads to consider a distribution system with dispersed generation sources, in order to reduce power transmission losses (Liang et al, 2012). The systems designed to meet these demands are called remote MG or hybrid systems. Chae et al (2015); they can also be called micro-grids with dispersed demand or SLMG (Scattered Load Microgrid).

For SLMGs to be a viable solution for energizing remote rural regions, an optimized design that has an acceptable financial cost must be guaranteed, which starts with energy planning that integrates the sizing of energy sources, the strategic location of sources, the architecture of the distribution system responsible for interconnecting generation sources with loads, and sources and loads with each other, and a dispatch strategy that guarantees the continuous and balanced operation of the SLMG (Rodriguez et al, 2017).

METHODS

The research process starts with an online search of relevant references of scientific literature in digital sites of academic nature, motivated by the fact that they are open access and disseminate the scientific production published and updated in the area of Science and Innovation. The variable studied was the scientific production related to the sizing strategies of smart microgrids for rural users. For the collection of bibliographic sources, the database was used, and the advanced search model was applied through keywords, all related to the terms smart microgrids, sizing strategies, electricity supply in rural areas.

For this purpose, the action taken was: to know the conceptual aspects of the smart micro-grid and its possible application to supply electric energy in remote locations. The set of information analyzed comes from various sources of information consulted as scientific articles and theses, which are signed by authors belonging to different countries. All publications are considered to be in the area of Science and Innovation in electric energy. They were collected considering a publication period no longer than five from 2017 to 2021.

In the search for information, the sources were selected, classified and ordered according to research topic, year of publication and relevance. Likewise, publications in the English language were considered due to their valuable contributions to this research. Finally, the documentary analysis allowed the selection of seven (07) scientific publications, whose contributions were considered the most valuable and relevant for the development of this study. According to Hernández et al (2014) documentary analysis is a process of interpretation and analysis of the information in documents to then synthesize it. For this study, content analysis allowed the generation of the research constructs. Based on this search, the results on the sizing strategies of smart microgrids for rural users are presented.

The compilation of the documents required for the execution of this work was carried out using an advanced search through descriptors such as microgrids, sizing, energy, among others, as referred to in the previous paragraphs through Google Scholar and other complementary sources such as scientific research articles, research papers related to the subject. The following criteria were required for each document to be selected:

a) Answer to the key descriptors.

b) Focus on issues related to smart microgrid sizing strategies for rural users.

c) Comply with the profile of the publications (author, type of study, publisher, research center, university or journal, country, language, etc.).

d) Provide specialized, relevant, pertinent and updated information with a validity of no more than five years, i.e., from 2017 to the current year.

RESULTS AND DISCUSSION

For the analysis of the information

Author/Year	Title	Type of Document	Results/Conclusion
Chauhan et al (2017)	Demand-side management system for autonomous DC microgrid for buildings.	Scientific article School of Electrical and Computer Engineering, Indian Institute of Technology Mandi, Mandi, India	The results show a clear shift of the burden to obtain a significant reduction in system cost given numerically as a percentage of savings.
Gomez et al (2018).	Smart Grid Overview, Features and Functionalities	Scientific article Universidad Tecnológica Santiago de Querétaro, Querétaro, Mexico	The integration of distributed energy resources (distributed generation and energy storage) into management systems is resulting in a major revolution in energy generation, transmission, distribution, operation and consumption.
Bordón et al (2018)	Micro Network Management Strategy	Research work. National Technological University (UTN)	Distributed generation and the implementation of microgrids, with the incorporation of renewable generation sources, is presented as a solution for the self-supply, provision and management of electricity supply.
Ramlia et al (2018)	Optimal sizing of hybrid photovoltaic/wind/diesel microgrid system using a multiobjective self-adaptive differential evolutionary autoadaptive algorithm.	Scientific article King Abdulaziz University, Jeddah, Makkah Province, Saudi Arabia	The optimization results using the proposed approach provided a set of design solutions for the hybrid microgrid system (HMS) that will help researchers and practitioners to select the optimal HMS configuration.
Omotayo et al (2019)	Techno-economic and sensitivity analyses for an optimal hybrid power system that is adaptable and effective for rural electrification: a case study of Nigeria.	Scientific article King Abdulaziz University, Jeddah, Makkah Province, Saudi Arabia	The results of this work provide a general framework for configuring a flexible and reliable system architecture to ensure continuous power supply to consumers under all conditions.
El-Hana et al (2020)	Multi-objective evolutionary algorithm based on decomposition for the design of hybrid photovoltaic / wind / diesel microgrid systems considering load uncertainty.	Scientific article Hafr Al Batin University. Khobar, Eastern Province, Saudi Arabia	The results obtained are beneficial in helping researchers and practitioners select the optimal microgrid configuration.
Kharrich et al (2021)	Optimal design of an isolated hybrid microgrid for enhanced deployment of renewable energy sources in Saudi Arabia.	Scientific article Mohammadia Engineering School. Rabat, Morocco	The results obtained show that the best configuration for the selected area is a hybrid PV/biomass microgrid with a net present cost (NPC) and levelized cost of energy (LCOE).

Once the information about the sizing strategies of smart microgrids for rural users has been analyzed, it has been found that the consulted authors have coincided in mentioning that Smart Microgrids or Smart Grids are basically bidirectional networks that with the support of new technologies and the integration of renewable energy sources, can supply energy to the population Bordón et al (2018); Ramlia et al (2018) and Kharrich et al (2021). From which it is inferred that it can eventually be used to supply electricity to the inhabitants of remote places of the country and thus contribute to improve the living conditions of the people.

Another of the findings found in the bibliographic materials analyzed is that there are several strategies for sizing smart microgrids, which have eventually been used to supply electricity in rural areas in various countries around the world. To this effect, in the first place, there is the direct current (DC) microgrid as it is considered a prospective system to use photovoltaic energy more efficiently (Chauhan et al, 2017). Also, in second place are microgrid systems, such as solar photovoltaic (PV) and wind power, integrated with diesel generators are promising energy supplies and are economically viable for current and future use according to Ramlia et al (2018) and El-Hana et al (2020). Continuing with smart microgrid sizing strategies, thirdly Kharrich et al (2021) present hybrid microgrids as energy sources that combine renewable energy sources such as photovoltaic (PV), wind and biomass, or a hybrid of these sources. In the same order Omotayo et al (2019) show the results of a model combining conventional and renewable energy sufficiently adaptable to operate in grid-connected modes, performed using the software tool HOMER pro, to model two scenarios of on and off-grid systems, according to these researchers it is possible to configure a flexible and reliable system architecture to ensure continuous power supply to consumers in all conditions.

It is appreciated in the framework of all these contributions that the use of smart microgrid, for driving a more efficient electricity system provides the possibility of meeting the demand for distribution and supply of electric power optimally, along with the fact that it has become a viable alternative to meet the demands of the rural population of the countries (Omotayo et al, 2019) and (El-Hana et al, 2020).

In short, the intelligent micro-grid system is configured as a solution to the problem of energy supply in some localities, associated with the important detail that it is an environmentally friendly type of energy. For rural areas, it is a means to implement a new lifestyle in line with the right of every individual to have a dignified and comfortable life.

FINAL CONSIDERATIONS

From the literature review, it has been found that the smart microgrid is currently being considered as an effective alternative for the supply of electricity, because among its several favorable features is the fact that being an integrated system of technology, renewable energy sources and traditional energy sources depending on the addressing strategy used, its use can reduce costs and increase reliability in the supply of electricity.

Similarly, it was found that smart microgrid sizing strategies can be presented as hybrid systems containing some renewable energy sources such as photovoltaic (PV), wind and biomass, as well as hybrid microgrid system (HMS) photovoltaic / wind / diesel, all designed in the interest of improving the quality of the electricity system and contribute to environmental protection, as they are low polluting sources.

In this sense, micro-grids become one of the support strategies for the conventional electricity grid that can help in the purpose of undertaking actions for the development of projects aimed at generating a process of allocation or improvement in the supply of electricity in rural localities in accordance with human rights to enjoy quality basic services and according to the demands of life in the present century

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C. elaboration of figures and tables:	50%	50%
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