A systematic mapping study of micro-grid architectures

Un estudio de mapeo sistemático de arquitecturas de micro-red

J. A. Mera-Paz ; R. F. Colmenares-Quintero ; G. P. Maestre-Gongora

***Abstract*—Generation and energy consumption are a major issue in different countries around the world. Nowadays, projects under development seek the modernization of electric power generation and distribution systems. One of the main strategies is the design of context-adaptable micro-grid architectures. The micro-grid concept focuses on a controlled, monitored and highly autonomous use of electric power supported on information technologies, for the optimization of energy transfer, minimize risks and increase the system's quality, efficiency and reliability. This article, therefore, aims to identify, classify and compare different micro-grid architectures, based on their applicability and research trends. A systematic mapping study of micro-grid architectures is conducted to examine the experimental and theoretical contributions made by the scientific community. This article categorizes and quantifies the different studies related to the subject, identifying and analyzing the strengths and opportunities for improvement in the applicability of micro-grid architectures. The trends observed highlight five strategies as the most relevant, whose different characteristics contribute to an automated and intelligent organization of the distribution, control and supervision of electricity according to supply versus demand.**

***Index Terms*—Affordable and clean energy, micro-grid applications, micro-grid architectures, regional development, smart grid, sustainable cities, sustainable development goals.**

***Resumen*—La generación y el consumo de energía son un problema importante en los diferentes países del mundo. Hoy en día, los proyectos en desarrollo buscan la modernización de los sistemas de generación y distribución de energía eléctrica. Una de las estrategias principales es el diseño de arquitecturas de micro-redes adaptables al contexto. El concepto de micro-red se centra en un uso controlado, monitoreado y altamente autónomo de la energía eléctrica apoyada en las tecnologías de la información, para optimizar la transferencia de energía, minimizar los riesgos y aumentar la calidad, eficiencia y confiabilidad del sistema. Este artículo, por lo tanto, tiene como objetivo identificar, clasificar y comparar diferentes arquitecturas de micro-red, en función de su aplicabilidad y tendencias de investigación. Se lleva a cabo un estudio de mapeo sistemático de las arquitecturas de micro-red para examinar las contribuciones experimentales y teóricas realizadas por la comunidad científica. Este artículo clasifica y cuantifica los diferentes estudios relacionados con el tema, identificando y analizando las fortalezas y oportunidades para mejorar la aplicabilidad de las arquitecturas de micro-red. Las tendencias observadas destacan cinco estrategias como las más relevantes, cuyas diferentes características contribuyen a una organización automatizada e inteligente de la distribución, el control y la supervisión de la electricidad de acuerdo con la oferta en función de la demanda.**

***Palabras claves*— Aplicaciones de micro-redes, arquitecturas de micro-red, ciudades sostenibles, desarrollo regional, energía asequible y limpia, red inteligente, objetivos de desarrollo sostenible.**

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J.A. Mera Paz, Master in strategic telecommunications management, Research Professor in Engineering at Universidad Cooperativa de Colombia. (e-mail: julian.mera@campusucc.edu.co)

R.F. Colmenares-Quintero, Post Doc PhD in Aerospace Engineering. National Head of Research in Engineering and Prof Dr at Universidad Cooperativa de Colombia. (e-mail: ramon.colmenaresq@campusucc.edu.co)

G.P. Maestre-Gongora. PhD in Systems Engineering and Computer Science. She is now with the faculty of Engineering, Universidad Cooperativa de Colombia. Medellin. (e-mail: gina.maestre@campusucc.edu.co)

I. Introduction

CURRENTLY, the conditions of climate change, greenhouse gases and other factors related to the production of electricity by sources such as coal, gas, oil and its derivatives, have created great concern around the world. As a response, renewable and non-conventional energies have gained strength for being considered as a desirable alternative[1]. Research on renewable energies has parallelly boosted the development of projects that seek the modernizing of energy generation and distribution systems by adapting and creating architectures of electric micro-grids with a higher rate of alternative or renewable energy use, and that offer a faster response to incidents or failures. The micro-grid concept was born in the industrialization age and it consists of a vast centralized network that support the provision of electric service for many consumers, from primary electric sources usually based on coal or oil.

The incorporation of renewable energies to the grid would be especially beneficial for municipalities or towns in rural areas that do not have access to utilities companies and electricity services called Non-Interconnected Zones (NIZ) [2],[3]. However, studies made by Gellings and Twidell have identified that implementing a large centralized network for generation and distribution of energy is not economically feasible in rural areas or NIZ [4],[5]. Instead, the use of small micro-networks is seen as a viable alternative with a high commercial potential, able to integrate renewable energies and effectively manage and control the energy consumption. Moreover, micro-grids are functionally unique systems able to respond to transmission or energy transfer needs. The network structure based on information technologies allows for highly autonomous monitoring and control processes, and the achievement of (1) optimization of energy transfer, (2) risk reduction and (3) increased system quality, efficiency and reliability.

By means of a mapping study, this article aims to identify and analyze the trends in the use of micro-grids as a mean for modernizing the consumption of energy [6].

II. METHODOLOGY

The systematic mapping methodology is based on the formulation of research questions from a prior review of the state of the art of scientific contributions[7]. From these questions, the study unfolds in a way to offer a general overview of the research topic, as well as to categorize and quantify the different studies found. In here, scientific productions analyzed were limited to the past 4 years (2014 – 2018), period during which micro-grids architectures in renewable energy systems gained strength [8].

The methodological approach established by[9],[10] defines the following steps:

1) Definition of research questions
2) Search of primary contributions
3) Selection of contributions according to inclusion and exclusion criteria previously established
4) Classification of articles
5) Data extraction and aggregation

In this work, the previous steps are adapted as shown in Fig.1 for stablishing the final methodology to be followed [11].

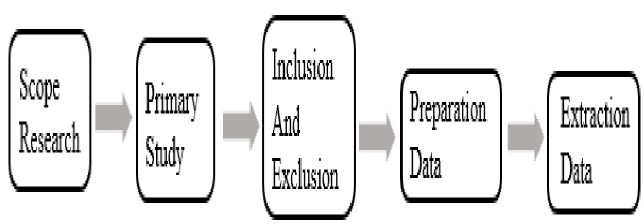

Fig. 1. Mapping study methodology

A. Research Scope

The research scope of the mapping study is defined by the five research questions described below:

RQ1. What are the theoretical contributions of the scientific community to the application of micro-grids architectures in the field of electrical energy?
RQ2. What are the trends of experimentation and studies in the architectures of micro-grids?
RQ3. What technological factors are common in the design of micro-grids architectures?
RQ4. What are the applications of micro-grids architectures for renewable energies?
RQ5. Who are the main researchers in the topic of micro-grids architectures for renewable energies?

Each question is thought to scan different aspects in the topic of micro-grids as follows: Questions RQ1 and RQ2 aim to quantify and classify the contributions according to their type, purpose and context, in order to achieve a focused analysis on techniques and trends; Question RQ3 focuses on understanding different architectures' design and modelling; finally, Question RQ4 and RQ5 add information linked to the object of the article.

TABLE I.
MEASURED ROOMS BY DEPARTMENT.

Research question	**Purpose**
RQ1: What are the theoretical contributions of the scientific community to the application of micro-grids architectures in the field of electrical energy?	Identify the most relevant concepts and theories about the application of micro-grids architectures in the field of electrical energy.
RQ2: What are the trends of experimentation and studies in the architectures of micro-grids in the field of electrical energy?	Classify the tendencies of application or use of techniques, diagrams, studies and / or experiments in the architectures of micro-grids.
RQ3: What technological factors are common in the design of micro-grids architectures?	Identify common structures and factors among the designs of micro-grids architectures.
RQ4: What are the applications of micro-grids architectures for renewable energies?	Classify the use or application of micro-grids architectures in the field of renewable energies.
RQ5: Which are the main researchers in the topic of micro-grids architectures for renewable energies?	Identify the experts on the subject, the time and means of publication used. Classify research trends.

B. Primary Studies

The selection of the primary contributions that will build up the database of the mapping study is performed following the PICOC approach. This method focuses primarily on the population and, through different questions, it helps to identify essential key aspects in a research [12]. The description of the PICOC approach, acronym for Problem, Intervention, Comparison, Outcome and Context, is found in Table II.

TABLE II.
SELECT DATABASE.

Characteristic	Question
Intervention	Who reads it? What does it speak about and what context does it have? How is the subject discussed?
Comparation	What other products can it be compared with?
Results	What does it seek to achieve, improve or contribute to?
Context	What is the organization, or the focus, and under what circumstances is the subject treated?

The bibliographic databases used at the searching stage are: Science Direct, Dialnet, Scopus, Springer, Engineering Village e IEEE Explore, due to their compliance and ideal characteristics suitable for carrying out a mapping study.

C. Conduct search for primary studies

The search is structured with the following keywords: “Smart grid”, “Architecture micro-grid”, “micro grids“, “trends micro-grid”, “renewables energies” and “technological factors”, which can be combined in different forms (permute) to give a total number of 720 possible different search parameters ($6! = 6 \cdot 5 \cdot 4 \cdot 3 \cdot 2 \cdot 1 = 720$). In addition to the keywords, the search was refined to scope the period between 2014 to 2018.

This screening methodology delivered a total of 5,890 documents between book chapters, gray literature, technical reports and journal articles. In order to bring queries closer to the desired results, the use of search operators is considered, as [13] says: "An effective search equation would be the one formed by descriptors and their corresponding qualifiers combined with each other by means of the most appropriate Boolean operators" as OR; AND and NOT.

Table III. Shows the number of documents per database found. Nevertheless, although key words may be present in their content, they do not necessarily delve into the subject nor they help to answer the stablished research questions. To sort out the unrelated findings, an inclusion and exclusion criteria was defined and applied.

TABLE III.
NUMBER OF PRIMARY STUDIES FOUND PER DATABASE.

Databases	Documents
Scopus	2.530
IEEE EXplore	1.685
Engineering Village	618
Springer	510
Science Direct	432
Dialneyt	115
TOTAL	**5.890**

D. Inclusion and exclusion criteria

The Inclusion Criteria (IC) are:

- IC-1: The document proposes an approach to the topic under study (method, technique, model, architecture, tool, methodological framework).
- IC-2: The document proposes a solution, experiment or technical revision to architectures, systems, designs or models of micro-grids.
- IC-3: The document mentions the application of micro-grids in the field of electrical energy.
- IC-4: The document mentions applications of architectures in micro-grids for renewable energies.

The Exclusion Criteria (EC) are:

- EC-1: Outcomes of interest have not been reported or are reported in an not appropriate, consistent manner.
- EC-2: Title and abstract does not include any keyword
- EC-3: Types of Publication: Editorial Material, Notes or Corrections are not considered
- EC-4: The document does not propose an approach to the topic in its title, abstract and keywords.

The operators are applied with the use of the search string, under the following process:

1. Execution of searches with the use of operators
2. Delete documents that are duplicated
3. Review titles and abstracts, applying inclusion and exclusion criteria.
4. List final documents.

After carrying out the process in 6 iterations, we obtain a total of 620 documents that meet the inclusion and exclusion criteria. The final number of documents found per scientific database is found in Table IV. These 620 documents are the base for the extraction and analysis of data needed to provide an answer to the research questions stablished before.

TABLE IV.
NUMBER OF DOCUMENTS PER DATABASE AFTER APPLICATION OF INCLUSION AND EXCLUSION CRITERIA.

Databases	Documents
Scopus	250
IEEE EXplore	130
Engineering Village	95
Springer	65
Science Direct	55
Dialnet	25
TOTAL	**620**

E. reparation and extract data

Preparation of data is performed using the software SPSS (Statistical Package for the Social Sciences) - IBM SPSS [14]. The first step is to encode the variables: name, type of data, length or width, in order to give relevance to the variables: author, title of the document, year of publication, source, content of document and architecture (See Fig. 2).

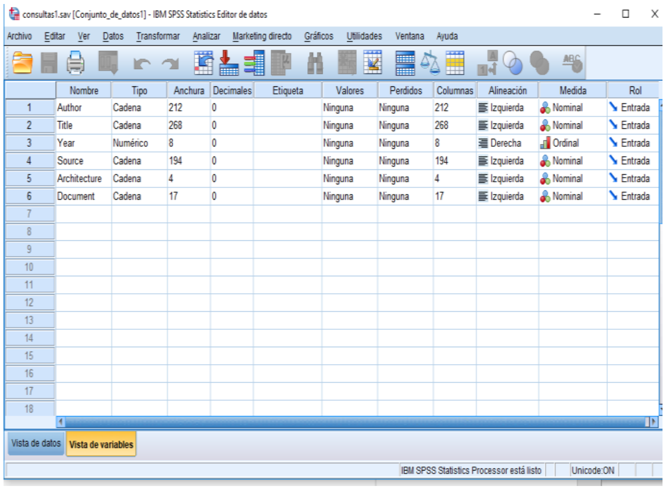

Fig. 2. Coding of variables. Source

This step allows coefficients and indicators to be defined. Next, a series of analysis and calculations, i.e. linear, multivariate analysis [15], segmentation and crossed tables, confirm that the data are in optimal conditions for a statistical analysis and allow conclusions in trends to be drawn.

The verification of the data's quality helps to recognize, eliminate and minimize errors present both in the data and results. The process consists of:

1.Error avoidance in data bank construction: Perform literature review and selection of keywords, with this evaluation of psychometric properties, it is guaranteed that the standard error of the measure is kept at a minimum and also generated a pilot study.

2. Qualification and identification of frequent errors: it is important to bear in mind that the following errors are common or frequent in projects:
- Lack or excess of data
- Data that is not entered
- Duplication of data
- Typing error
- Incorrect variable typing

3. Cleaning of data: Repetitive cycles or iterations are carried out that allow to discern, diagnose and correct data with errors. This activity is carried out by the analyst, expert in the research topic.

In this case, the histograms, contingency tables and the summary of the statistics of each iteration are used.
The psychometric properties used in the mapping system, inclined towards the reliability and validity of the data, the following activities are applied:

- Internal consistency analysis: Average the data altogether, getting each variable to measure a characteristic or portion of what it is wanted in the research process.
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- Discrimination capacity analysis: Elements are established in a way to reinforce the consistency of theone-dimensional character of the variables.
- Factorial Study: the group structure is established, whose content and parameters allow to carry out a statistical analysis.

In sequence to the research questions, an analysis is made based on the results supported by IBM SPSS software. The results highlight five relevant architectures described in more detail below.

III. RESULTS

RQ1: What are the theoretical contributions of the scientific community to the application of micro-grids architectures in the field of electrical energy?

The scientific production around applications of micro-grids architectures for the energy sector has been experiencing a substantial increase due to major concerns that greenhouse gases and climate change arise, which sums to the need of implementing and integrating alternative energy sources.

A. *SGAM – Smart Grid Architecture Model* [16]

SGAM is characterized by a neutral technological position. This architecture entails a set of interoperability layers that permits the interaction between conventional and renewable energies:

Business layer: Outlines the business objectives, regulatory and political framework, based on cases of use and micro-grid functions.
Information Layer: Structure and models data. A communications layer where protocols and regulations for communication are established.

Components Layer: Consist of location of domains - generation, transmission, distribution, distributed energy resources (DER), facilities for customers - and other areas - process, field, station, operation, company and marketing. From the compendium of options the architecture provides a comprehensive methodology for achieving a proper functioning micro-grid. The management of cases of use [17] [18] allows the sharing of information between projects that implement similar cases, with different technical solutions. The result is the operation of a so-called intelligent network.

Table V. shows the description and operation of SGAM components [19].

TABLE V.
SGAM COMPONENTS. SOURCE: ADAPTED FROM CEN-CENELEC-ETSI., 2014

Component	Description
Domain - Level	
Generation	Electric power generated by fossil fuels, hydroelectric, nuclear, wind, solar, photovoltaic, thermal, among others, connected to the transmission system
Transmission	Infrastructure and organization to transport electricity over wide distances.
Distribution	Infrastructure and organization to distribute electricity to users.
Distributed energy resources (DER)	Resources directly connected to the public distribution grid, using small scale generation technologies (range from 3 Kw to 10 MW)
Benefits for clients	Infrastructure of users and producers, commercial, industrial and household type.
Zones - Level	
Market	Marketing of electric power
Company	Structure of procedures and services towards organizations
Operation	Activities of energy distribution management, virtual plants and cargo management to electric vehicles.
Station	Data concentration, automation and local monitoring and supervision systems.
Field	Equipment for assurance, protection and analysis of processes.
Process	Transformation of the physical and chemical elements involved in the energetic process
Interoperability - Layers	
Deal	Political framework, regulatory level, political, economic analysis, modeling and business capacity
Function	The conditions and capacities of the energy system companies are defined.
Information	Data and information that is transferred between functions, services and components.
Communication	Standards and protocols established for the flow of communication
Component	Basic layer referring to the electrical physical system, where are the devices, interfaces and other equipment for the technological control of information and communications.

B. SGM – Smart Micro Grid [20],[21]

It is based on the concepts of intelligent grids and has a micro-grid configuration, wich allows interoperability functions. It relies on three main layers that articulate the architecture’s operation:

Operations Control Layer: Where monitoring, control and supervision is carried out. This layer has a centralized control that uses sensors and automated control systems for creating a distributed operating network capable of managing the micro-grid‘s electrical power and resources. It has an emphasis on detection and solutioning of failures. It is also characterized for the implementation of methodologies based on traditional and evolutionary processes. The application of agile methodologies to date for this type of architecture is not evident in the documents.

Processes Layer: Where all business and regulatory processes are managed.

Station Layer: Where activities such as functional and non-functional procedures, registration, storage, protocols and guidelines of infrastructure, equipment and communications are established and where information is administered.

C. AMI – Advanced Metering Infraestructure [22],[23],[24]

This architecture slightly breaks down the paradigm of layers or levels as there is a strong bidirectional combination of engineering, communication and management stages where architecture becomes a system that combines smart meters, communication grids and systems for data management. It is an interesting concept that allows us to understand the behavior of supply and demand management. Some documents mention the complex security risk situations due to possible data alteration. However, other documents argue that the solutions are within the reach of regulatory frameworks and public policies for the architecture's adequate use and implementation [25], [26]. It is also worth highlighting AMI's quick response to needs of demand, which is possible due to its principle of monitoring the distributed energy quality, the efficient use of electricity and the tendency to reduce environmental impact. Some of the projects highlight the application of technological development methodologies focused on the agility and response to the user, such as scrum [27] extreme program[28], lean [29] Kanban [30] among others [31],[32].

D. ADA – Advanced Distribution Automation [33],[34],[35]

ADA architecture consists of bi-directional smart meters. An increase of energy distribution automation processes is possible with an integrated real time monitoring system that optimizes the efficiency of energy delivery. The overall result is the reduction of failures and interruptions, and a rise in the quality of service expectations. The architecture's fundamental basis are a set of sensors, transducers and Smart Electronic Devices (SED), that work together to gather a large amount of information concerning the micro-grid behavior using a Scada system - supervision, control and data acquisition. The micro-grid is managed with greater speed, reliability and efficiency. CEATI reports - Centre for Energy Advancement through Technological Innovation [36], [37], define and show that for the grid to be intelligent it must include an automated monitoring system build up by sensors. This mechanism improves reliability, makes monitoring of equipment maintenance automatic and allows product monitoring to be based on a supply and demand analysis, all in all, to improve the quality of service.

Documents that mention ADA architecture explain that there are experiments and projects in progress in which ADA implementation demonstrates a reduction and control of the voltage force, a conservation and management of electric current flow or intensity, a detection of faults with greater accuracy, an analysis of the monitoring system and integrated supervision, and the obtaining of results and reports of the micro-grid operation.

E. DER–Distributed Energy Resources [38], [39]

This architecture seeks to promote the use of energy resources by optimizing operations with a proper planning and design of the energy network. For this, a distributed system of power generation is established. In planning, the analysis of geographic zones and the social and economic impact of the region are key [40]. An interesting feature of DER architecture is its adaptability to conventional electrical energy systems by means of sensors and a microgeneration system with connections and control of alternating current (AC) to direct current (DC) [41].

It is able to monitor, control and supervise the system for energy storage (ESS), which allows it to virtualize the use of load fluctuations by adapting to variables that influence supply and demand [42]. The DER approach possesses the advantage of: losses in the system, detect failures in real time, optimize the index of an interruption's average duration, distribute energy more efficiently, account for an improved cost-benefit ratio.

In [43], the DER architecture integrates renewable (solar and thermal) and conventional energies to reduce greenhouse gas emissions and improve the use of electric power in a shopping center in Sydney, Australia. After the implementation, the author compares the results considering:

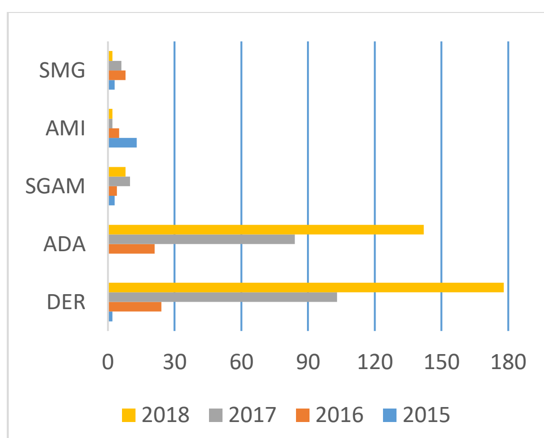
1. Compensation of costs and emissions
2. Cost of reduced emissions achieved in each investment scenario
3. Investment benefits with respect to the business in a usual scenario.

The results show a reduction of energy costs by 8.5% and carbon dioxide emissions by 29.6%. In addition, it is predicted that a greater investment in the construction of a DER micro grid that uses 90% of renewable energy can reduce carbon dioxide emissions by 72% and energy costs by 47%. In the authors' words: "the study demonstrates effectiveness, efficiency and flexibility of the DER architecture for micro-grid in changing market conditions".

RQ2: What are the trends of experimentation and studies in the architectures of micro grids in the field of electrical energy?

The mapping study made evident a preference in the use of DER and ADA architectures in the past 2 years (2017 - 2018). This trend is clearly seen in Table VI where a comparison of number of published scientific production per architecture per year is made. DER and ADA architectures are the most used in experimentation, with real applicable projects in renewable energy.

TABLE VI. NUMBER OF PUBLISHED SCIENTIFIC PRODUCTION PER ARCHITECTURE PER YEAR.



From all the documents revised, we found that the mentioning of the architectures has been scarce and that the depth of the research is focused towards ADA and DER due to its characteristics and good results obtained. Apparently, the other architectures have been mildly investigated or perhaps their mention in documents is not very relevant because of the initial costs involved and the little research in this regard. The 43% of the documents assert that the application of each architecture depends on the context, accompaniment of the information and communication technologies and the automation processes.

RQ3: What technological factors are common in the design of micro grids architectures in the field of electrical energy?

The common technological factors in micro-grid architecture design for electrical energy are communication, control, supervision, maintenance, security and data storage, and distributed and automated systems [44].

There are non-technological factors, it is important to consider the flow of electricity as a bidirectional element, the analysis of supply vs. demand, storage capacity, use policies, flexibility, availability and cybersecurity.

ICT advances are also related to the opportunities for applying architectures in micro-networks, which is why cloud computing concepts, the internet of things, advanced sensors, data mining, business intelligence, among others, are relevant [45].

RQ4: What are the applications of micro grids architectures for renewable energies?

Micro-grids architectures were found to have greater relevancy in the fields of computer sciences, engineering and energies, as seen in Fig. 3. The aforementioned fields account for the higher percentages of publications reviewed in our mapping study. In addition, Micro-grids architectures have proven to be particularly beneficial for providing solutions to specific needs for specific organizations or communities, usually in non-interconnected areas[46].

A common factor is that once the planning is done, several alternatives are generated with a systematic model. Then, simulations are made using software such as HOMER, Vipor, Hybrid2, RETScreen, iHOGA, INSEL, TRNSYS, iGRHYSO, HYBRIDS, TRNSYS, iGRHYSO, HYBRIDS, RAPSIM, SOMES, SOLSOR, HySim, HybSim, IPSYS, HySys, Dymola / Modelica [47].

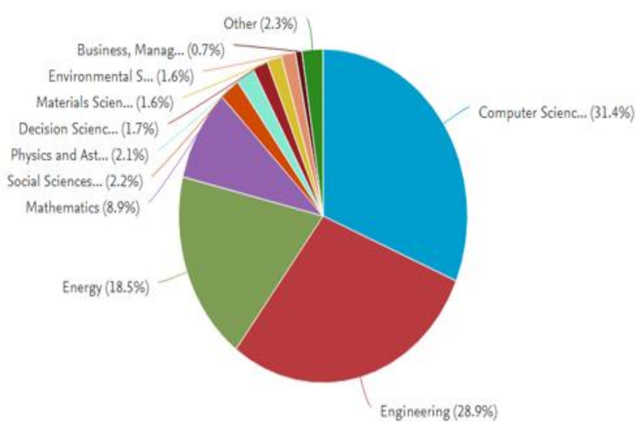


Fig. 3. Areas that relate architectures in micro-grids.

Software support allows additionally to run economic and technical analysis based on conditions obtained. However, the aforementioned software do not take into account social or political factors, which are relevant components that vary according to region and context, and should be considered for decision making.

RQ5: Which are the main researchers in the topic of micro grids architectures for renewable energies?

For this question, we selected as main criterion of evaluation the number of documents on which each author participate in every of the 620 documents in this study's database. As evidenced in Fig. 4, Professors Josep M Guerrero and Juan Carlos Vásquez from the Aalborg University in Denmark, are the most published researchers in subjects related to architectures of micro grids in renewable energies.

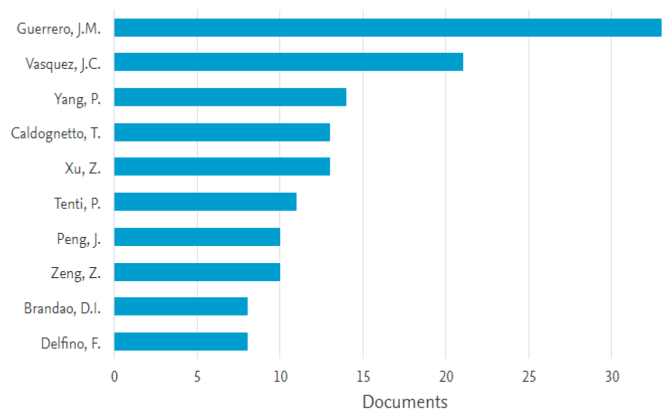


Fig. 4. Researchers vs quantity of documents published.

IV. Discussion

The systematic mapping performed in this study clearly evidence the trends in micro electrical grid architectures. It is observed that 70% of the documents use architectures as a methodological approach for providing a solution to a specific problem. Architectures have also the ability to adapt to its context. According to the findings, the architecture is a fundamental base for the implementation of a micro grid and thus, needs to take into account political, economic, technical, environmental, social and cultural factors, demand response has already been proven to have great potential to contribute to increased system efficiency while bringing additional benefits, especially to consumers. [48]. Table 7 shows a set of general factors characterized in this study that helps determine the design, implementation and start-up of a micro grid architecture.

TABLE VII. GENERAL FACTORS

General factor	Design	Implementation	Operation
Organizational / Political	Define the client and beneficiaries	Final agreements between provider, client and beneficiaries	Follow-up on agreements
	Develop adaptation plan to the new technology and risk mitigation	Verification and monitoring of plans	Validation and updating of plans
	Visualization of potential external support or support for strengthening the project	Analysis of potential external backups for possible future improvements	Proposals of potential external support for the architecture improvement
	Create risk adaptation and mitigation plan	Consolidation of risk response strategies and teams.	Monitoring and updating of the risk plan
Econo mic	Cost - benefit analysis	Investment budget	Economic and financial plan for sustainability
	Adequate distribution of the investment budget	Analysis of possible sources of financing	Management of consumption in terms of supply vs. demand
Technical	Infrastructure, equipment and resources with quality standards	Verification of facilities with service guarantees for what was planned	Validation and testing for quality assurance of services and facilities
	Creation of processes, procedures, manuals, roles, hierarchies, etc.	Follow up on the processes, procedures and decision making.	Continuous improvement to processes, procedures and decision making.
	Selection of qualified and certified human talent	Ensuring adequate conditions for the performance of personnel functions	Update and training for the strengthening of staff skills
Environm ental	Analysis of the region and the environmental context	Plan to reduce environmental effects	Improvement of environmental conditions, reducing greenhouse gas generators
	Environmental impact assessment	Validation of operational analysis plan vs. environmental analysis	Plan to reduce factors that affect the environment
Social	Analysis of the need of the community or organization	Alternative processes of awareness and dialogue with the community or organization	Manage a project that is identified and appropriate by the community or organization
	Define communication channels and value proposition towards the community	Use communication channels assertively. Socialize value proposition, demonstrating the benefits and real positive impacts	Manage information and communication with the community.
	Analysis of the local development plan	Strategies to support local development activities, from the emphasis of the project	Manage information and communication with state authorities.
Cultural	Preparation of the plan for community awareness and ownership of the project	Contributions of the community or organization at an intellectual and logistic level	Maintenance of positive impacts and relevant experiences generated by the project
	Respect and understanding of the needs of the community	Plan of awareness and appropriation of the project, respecting the cosmovision's of the community or organization	Support the appropriation of the project.

Significant advances have been made to standardize processes through micro-grid architectures for the integration of renewable and conventional energy, managed through distribution systems and distributed storage systems. Among these, there is ISA-95 which seeks the electrical distribution standard to provide intelligence and flexibility to micro-grids [49].

The development of this mapping study revealed that the number of associated topics and terminology in micro-grid architectures is broad. Despite the observable correlation between ICT and micro-grids, the link between quality assurance is limited. This is critical because all architectures talk about systematization of processes with the use of variables, functionalities, models, modules and interfaces. Therefore, the applicability of a quality testing process in software products will increase reliability within the life cycle of the project. [50] [51]

Micro-grid architectures evolve in accordance with technological advances. Trends such as sensors, internet of things, big data, among others, become increasingly relevant for they incorporate flexibility and adaptability to architectures, hence becoming a determining factor for their development and implementation.

It is an indisputable fact that conventional and renewable electric power are fundamental for the development of any country, since it promotes the industrial and commercial sectors, as well as providing welfare and comfort to the population.[52]

V. CONCLUSION

The concern for climate change and the effects of greenhouse gases have allowed renewable energies to boom in the world. This has generated a transformation and evolution in the planning, design, implementation, monitoring and control of electrical energy networks through the search for new technologies and forms of connection. In this context, architectures for micro-grids appear as an efficient solution towards this transformation.

Getting to know the trends of use of architectures, their components and functionalities for the micro-grid, represent a fundamental element to provide solutions to communities or organizations not interconnected or with needs to efficiently manage the flow of energy and minimize the risks of environmental impact.

The studies, investigative processes and publications are contributions, as a motivating entity to future research works that allow to validate the real application of the architectures and their results.

In the academic field the publication of documents goes hand in hand with technological growth. The union of ICT to the concept of micro-grid contributes to the generation of strengthened architectural developments, which allow projects to have research and academic support, for optimal decision making.

After conducting the investigative process, it is concluded that there is a trend in the use of architectures for micro-grid, which along with the advances in the technological development for renewable energies and aims at the pursuit of achieving the objectives of sustainable development, for academic institutions a great research opportunity is presented.

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Julian Andres Mera Paz, Research Professor of the Engineering Department of the Cooperative University of Colombia. Master in strategic telecommunications management and is currently studying a doctorate in projects with an ICT research line, his main research areas include telematic networks and services, architectures and software, energy and technological quality projects. He has worked as a co-researcher on national and international projects. Research Interests: Software quality, Smart cities, Information Technology Management, Data Analytics, Enterprise Architecture and IT Project Management.
ORCID: https://orcid.org/0000-0003-4695-8022

Ramon Fernando Colmenares Quintero, National Head of Research in Engineering and Prof Dr at Universidad Cooperativa de Colombia. Scientific research in the energy sector through design and development of renewable energy, software development and environmental and economic models, simulation and modeling based on sustainability and multi-objective optimisation (i.e. exploratory techniques - genetic algorithms and expert systems - artificial intelligence). Simulation of conventional and renewable energy systems. Member of the European Network COST (European Cooperation in Science & Technology). Supervisor in MSc projects related to advanced simulation and optimisation. Principal investigator of international projects in partnership of the industry between Colombia, United Kingdom, Netherlands and European Union.
ORCID: https://orcid.org/0000-0003-1166-1982

Gina Maestre-Gongora, Received a Ph.D. degree in Systems Engineering and Computation from Universidad del Norte (2018), a master's degree in Engineering (2011) and a bachelor degree in Systems Engineer (2005) from the Universidad Industrial de Santander. Professor/researcher in Universidad

Cooperativa de Colombia, Campus Medellin. Professor of Postgraduate studies in: Information Technology Management and Information Management. She has published over 15 peer-reviewed articles in international journals and is currently Associated Researcher of COLCIENCIAS. Investigator of national and international projects in partnership of the industry between Colombia, United Kingdom, Netherlands and European Union. Research Interests: Smart cities, Information Technology Management, Data Analytics, Enterprise Architecture and IT Project Management.
ORCID: https://orcid.org/0000-0002-2880-9245