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SMARTS GRIDS: A VIEW ON ACADEMIC RESEARCH OVER THE LAST TEN YEARS

SMARTS GRIDS: UMA VISÃO DA PESQUISA ACADÊMICA NOS ÚLTIMOS DEZ ANOS

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ABSTRACT

Electric energy is used for the most diverse purposes, in situations where its supply is interrupted, the importance of systems capable of automating the energy restoration process is evident. For electricity generation and transmission, the country has a main system (a set of plants, transmission lines and distribution assets): the National Interconnected System (SIN). This immense “electric highway” covers most of the Brazilian territory and consists of connections made over time, from installations initially restricted to exclusively serving the regions of origin. Therefore, this article aims to investigate the studies proposed on Smart Grid in the last ten years on the Web of Science. For this, it adopted a bibliometric analysis seeking to identify the articles published in the period by source, research area, countries, authors and the most cited works in addition to the h-b index, the hot topics related to the theme. The results reveal that publications in the area have gradually increased over time and that most research has been published in countries with relevance in international trade, as well as countries with a high use of advanced information technologies.

Keywords: Energy Management**;** Smarts Grids; Web Of Science.

RESUMO

A energia elétrica é utilizada para os mais diversos fins, em situações onde o seu fornecimento é interrompido, evidencia-se a importância de sistemas capazes de automatizar o processo de restabelecimento da energia. Para geração e transmissão de energia elétrica, o país conta com um sistema (conjunto composto por usinas, linhas de transmissão e ativos de distribuição) principal: o Sistema Interligado Nacional (SIN). Essa imensa “rodovia elétrica” abrange a maior parte do território brasileiro e é constituída pelas conexões realizadas ao longo do tempo, de instalações inicialmente restritas ao atendimento exclusivo das regiões de origem. Sendo assim, este artigo tem como objetivo investigar os estudos propostos sobre Smart Grid nos últimos dez anos na Web of

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Science. Para isso, adotou uma análise bibliométrica procurando identificar os artigos publicados no período por fonte, área de pesquisa, países, autores e os trabalhos mais citados além do índice h-b os hot topics relacionados ao tema. Os resultados revelam que as publicações na área têm aumentado gradativamente ao longo do tempo e que a maioria das pesquisas foram publicadas em países com relevância no comercio internacional além de países com elevado uso de tecnologias de informação avançadas.

Palavras-chave: Gestão Energética, Smarts Grids, Web Of Science.

1 INTRODUCTION

Electric energy is used for the most diverse purposes, being fundamental for the economy, when the supply is interrupted, the importance of systems capable of automating the process of its restoration is evidenced. The electric energy transmission system is fundamental for the strategy of the economy, telecommunications, transport, industrial activities, among others.

This immense “electrical network” covers most of the Brazilian territory and is made up of connections made over time, from installations initially restricted to exclusive service in the regions of origin. In addition, there are several smaller systems, not connected to the SIN and, therefore, called Isolated Systems, which are mainly concentrated in the Amazon region, in the North of the country. This is because the geographic characteristics of the region, consisting of dense and heterogeneous forest, in addition to large and flowing rivers, made it difficult to build large transmission lines that would allow the connection to the SIN (AGENCY NATIONAL ELECTRICITY, ANEEL, 2016) .

Smart Grids emerge to assist in the need to modernize the electrical grid, making it more ecological and with better energy use, they are more autonomous and allow to increase the effectiveness and efficiency of energy delivery, utilities can use the existing infrastructure and minimize the need to build more power plants and substations. For Tuballa and Abundo (2016), smart grids emerge to enable renewable energy resources

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to be securely connected to the grid and, consequently, to complement the energy supply to customers, through the generation and storage of distributed energy.

Given the above, this article aims to investigate the proposed studies on Smart Grids in the last ten years in the Web of Science, this research is justified by the fact that smart grids are a great tool to assist in energy management in the world, in addition, grids Intelligent electric utilities are used in new electricity distribution projects in Brazil, confirming the importance of this study.

Therefore, it is intended, in addition to contributing to the dissemination of Smart Grids in the country, also to instigate the interest of academia and other sectors of society by knowing a little more about the subject considering its importance in terms of sustainable development, aiming at the correct use and distribution electricity generated in Brazil and in the world.

2 SMART ELECTRIC NETWORKS: SMARTS GRIDS

The literature currently available on the term "smart grid" shows a wide range of publications as we will see below. To meet the needs of this research, three databases were used to search for scientific articles: CAPES dissertation and theses catalog, IEEE explorer and the Web of Science.

2.1 SMART GRID CONCEPT AND CHARACTERISTICS

Smart Grids arise with the need to modernize the electrical network, making it more ecological and with better energy use. As Smart Grids are more autonomous and make it possible to increase the effectiveness and efficiency of energy delivery, utilities can use existing infrastructure and minimize the need to build more power plants and substations. For Tuballa and Abundo (2016), smart grids emerge to enable renewable energy resources to be securely connected to the grid and, consequently, to complement the energy supply to customers, through the generation and storage of distributed energy.

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For Sharma and Saini (2015), a Smart Grid is an electricity grid that can intelligently integrate the actions of all users connected to it, efficiently providing sources of economical and safe electricity, in addition to generating information that can serve for future decisions. As for Purkayastha and Savoie (1990), a Smart Grid refers to a state-of-the-art network that integrates information technology to the existing electrical grid, seeking to optimize and add energy efficiency to the grid, through a bidirectional exchange of information on electricity between suppliers and consumers in real time.

Tubala and Abundo (2016), in their study, state that Smart Grid does not have a universally accepted definition, which can be described in a simple or more complex way, depending on the reason for which it is being applied. For the authors, in a simplified way, Smarts Grids is an intelligent network capable of storing, communicating and making decisions. The Smart Grid system transforms the current grid into a new grid that works in a more cooperative, responsive and organic way.

According to the National Institute of Standards and Technology (NIST), the Smart Grid is a system that integrates several technologies, both in the areas of computing, communication and engineering, as well as services for the infrastructure of the electric power system. Smart electric grids enable the integration of residential systems, reducing operating costs, such as the time to detect network failures. ASmart Grid can be better understood when viewed alongside the traditional grid. Cavdar (2004) made a good comparison between the two structures. A general summary of the characteristics of the two networks is presented in frame 1.

CURRENT NETWORK	SMART GRID
Mechanization / One-way Communication	Real-time bidirectional scanning/communication
Centralized power generation	Distributed power generation
Radial Network/Less data involved	Scattered Network; Large volumes of data involved
Small number of sensors	Many sensors and monitors
Less or no automatic monitoring	Grande monitoramentoautomático
Manual control and recovery	Automatic control and recovery
Less worries about security and privacy	Prone to security and privacy issues

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Human attention to system interruptions / Simultaneous production and consumption of energy / electricity / Limited control	Adaptive Protection/Use of Storage Systems
Slow response to emergencies/ Fewer user options	Quick response to emergencies/ Wide User Choices

Frame 1 - The traditional electric grid versus the smart grid Source: Adapted from Cavdar (2004).

For Wessel (2015), smart grids or intelligent electrical networks employ an extensive set of innovative technologies and services such as monitoring, control and intelligent communication, in order to reduce costs and increase reliability and transparency. Smart electric networks are the modernization of the Electric Power System, bringing with them new paradigms, features and characteristics as described by Ghansah (2009) and Ferreira (2010).

Smart grids also allow for the inclusion of the prosumer concept, which defines the customer not only as a consumer, but also as a producer. The micro-generation and distributed generation of electricity in local units of the consumer, makes it an energy producer. Energy that is not consumed locally can be injected into the distributor's system. This injected energy will be converted into credits that can be deducted from consumption in subsequent months (ANEEL, 2014).

In the smart grid, according to Amini, Hasanpour and Jalali (2016), customers have access to electricity consumption and price data through smart meters. Thus, they are able to participate in demand response (DR) programs. With the application of Smart Grid, customers will be active parts of the network, being able to check available information about the price of electricity and make wise decisions regarding their daily electricity consumption (FARHANGI, 2010). These facts encourage customers to consume less energy during peak hours (BAHRAMI ; PARNIANI ; VAFAEMEHR, 2012).

2.1.1 Benefits of Smart Grids

According to Ramos (2012), an intelligent power grid stands out for using information technologies to facilitate the administration and management of the conventional power grid. Smart Grids aim to modernize the electrical network, which over

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the years has shown a discreet evolution. According to Toledo (2012), smart grids provide a technological advance for the management sphere, providing new data to the system, which will enable real-time actions in the equipment present in the generation and distribution of electricity.

The Smart Grid value chain will provide an active participation of the consumer in the management of their energy, enabling utilities to assess the benefits and demands needed to adapt to the new reality (TOLEDO, 2012). It is also a great opportunity to further strengthen the relationship between concessionaires and customers, whose participation will be essential for the success of such practices (SHARMA; SAINI, 2015).

The implementation of Smart Grids will benefit society as a whole, not just utilities. The practices adopted for its implementation and the results achieved are strategic and in the interest of the entire society (DELGADO, 2017; BERNARDON et al, 2015; SHARMA ; SAINI, 2015). Toledo (2012) states that the benefits of smart grid technology extend to various market players, such as customers, the environment, regulatory bodies and the national electricity system.

Regarding customers, Toledo, Gouvêa and Riella (2012) state that the application of this new device will allow the provision of new services, offering a more agile decision-making, mainly through maintenance and remote service, in addition to enabling the customer monitoring of the different degrees of electrical energy received. The concept of smart electricity grids also expands the number of interaction channels between the utility and the consumer. Many advocates of smart grids cite some or all of the attributes below as representative of their promise, pointing to them as benefits, Frame 2 presents this data.

Efficient	Able to meet growing consumer demand without adding infrastructure
Easy Integration	Accepting energy from virtually any energy source, including solar and wind, as easily and transparently as coal and natural gas; able to integrate any and all better ideas and technologies (energy storage technologies, for example), as they are market proven and ready to go

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motivator	Enable real-time communication between the consumer and the utility, so that consumers can adapt their energy consumption based on individual preferences, such as price and/or environmental concerns
opportunist	Create new opportunities and markets through your ability to capitalize on innovation where and when appropriate
Focus on quality	Able to provide the necessary power quality, free from sags, spikes, disturbances and disruptions, to drive our increasingly digital economy and the data centers, computers and electronics needed to make it work
Security	Increasingly resistant to attacks and natural disasters as it becomes more decentralized and reinforced with smart grid security protocols
Green	Slowing the advance of global climate change and offering a genuine path to significant environmental improvement in the impact of electricity serving humanity

Frame 2 - Attributes of Smart Grids
Source: Adapted from El-hawary (2014).

In other words, the possibilities that are generated from the application of Smart Grids are vast in the advent of modern technology and increase the interdependence among network users. Smart grids can provide a platform capable of maximizing reliability, availability, efficiency, economic performance and greater security against naturally occurring attacks and power outages (RIEDMULLER et al, 2008).

2.1.2 Some Impediments and Limitations of Smart Grids

For El-hawary (2014), the electrical power system presents a diversity of network needs. In some systems, well delimited and geographically concise, it is possible to use communication through reliable wired means. For example, fiber optics. Generation Systems is a classic example where this is possible. However, in distribution systems, due to the large number of devices and their high geographic dispersion, the implementation of this communication network becomes a more complex task (GTREI, 2010).

Toledo, Gouvêa and Riella (2012) report the need for electricity concessionaires to deal with the challenges of the current grid in meeting the demand for smart grids, in addition to preparing for the probable advance of technology in the area of electricity.

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With the advancement of technology, Smarts Grids become, every year, more accessible to the final consumer. But there are still several challenges to be overcome. To overcome the obstacles mentioned in this session, a lot of technological advances will be needed, where academic research will have to be present. The creation of new renewable energy programs may support the changes that will take place in the modes of transmission and storage of energy. The fact is that the need for using smart grids is growing continuously.

2.2 BIBLIOMETRY

The bibliometric study has existed since 1829 in Russia and the first research that used this technique was published in 1917, by Cole and Eales, who carried out a study of publications between 1550 and 1860 (CANCHUMANI, 2015).

Beginning in the 20th century, bibliometrics arises from the need to study and evaluate scientific production and communication activities. It consists of the application of statistical and mathematical methods that aim to describe aspects of literature and other means of communication, performing a quantitative analysis of information (ARAÚJO, 2006).

According to Canchumani (2015), the term bibliometrics was proposed by Alan Pritchard in 1969, referring to the application of mathematical and statistical methods to books and other means of communication. Over the years, bibliometrics has expanded its field of action to a smaller scale, demanding a refinement in the treatment of information and the design of more objective and more varied indicators (CANCHUMANI, 2015, p. 42).

The bibliometric research model does not focus only on measurement, but also on understanding the contextualization of production and its authors, establishing a partnership between theoretical approaches and bibliometric techniques (ARAÚJO, 2006). The purpose of using bibliometrics is to analyze the scientific production published

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in books, articles. These researches admit an evaluation of the registered information and provide statistical and mathematical models, becoming powerful tools to analyze referential data and generate subsidies for its monitoring (VANTI, 2002; SANTOS; RAUSCH, 2009).

3. RESEARCH METHOD

The present study proposes, from a bibliometric research, to analyze the proposed works on Smarts Grids in the last 10 years. This type of research seeks, through the quantification of written documents, to identify trends and possible patterns in scientific production in a given area.

Quevedo-Silva et al. (2016) comment that bibliometric articles are a commonly adopted practice in research in applied social sciences, the application of which helps to understand new themes and may contribute to identifying trends for future work. According to Marcelo and Hayashi (2013), its main characteristic is to generate indices of scientific knowledge production and its use is based on the investigation of the behavior of knowledge and literature as a component of communication processes.

Furthermore, this work is a descriptive approach, as it seeks to describe characteristics of a particular phenomenon (VERGARA, 2015), as well as to identify, obtain information and describe the characteristics of a particular issue (COLLIS; HUSSEY, 2005). As a data collection plan, the base chosen for this was the Web Of Science of the Institute for ScientificInformation (ISI).

ISI was founded in 1960 by Eugene Garfield and later – in 1992 – was acquired by Thomson Reuters Corporation, this year in which it began to be known as Thomson-ISI (GOMES, 2010; ALBAGLI, 2013). According to Pinto and Fausto (2012), the Web Of Science is a worldwide reference in terms of scientific journals, Motke, Ravanello and Rodrigues (2016) corroborate that it is a multidisciplinary database that indexes only the most cited journals in their respective areas. Capes (2000) emphasizes that, via the Web of Science, tools are available for analyzing citations, references, the h index, which makes bibliometric analysis possible.

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Soon after choosing the referred database, the keywords defined as search parameters were remanufacturing and general theoryof systems, delimiting the following fields: (a) selection by topic; (b) articles only; and (c) published in the last 10 years (2009 to 2018). In all, 10681 publications were located in the period. Then, for analysis purposes, the items listed in frame 4 were identified.

Journal
Area
countries
Universities
h-b index
authors
with more
publications
most
cited articles

Frame 4: Total articles published per year
Source: Prepared by the authors based on research data (2020).

4. ANALYSIS OF RESULTS

The research results show the main characteristics of scientific production related to the term Smarts Grids. Among the types of scientific productions, the full article published in annals of events was the most used (5,787 published articles) followed by articles in journals (3,107 processes) and expanded abstract (228 published articles), other types were also found as review of procedures , editorial among others. From the survey carried out in the Web of Science database, it is possible to identify in table 5 the total number of articles published in the period.

Year	The amount
2011	544
2012	765
2013	774
2014	1000
2015	1107

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2016	1149
2017	1264
2018	1323
2019	1355
2020	1400

Quadro 5: Total de artigos publicados por ano
Fonte: Elaborado pelos autores com base nos dados da pesquisa (2020).

The analysis of Frame 6 shows the peak of production in the year 201920, and production is still in an increasing phase. Table 6 shows the ten journals with the largest publications related to Smarts Grids.

Nº	Journal	Amount
1	*IEEE TRANSACTIONS ON SMART GRID*	378
2	*IEEE POWER AND ENERGY SOCIETY GENERAL MEETING PESGM*	256
3	*INTERNATIONAL CONFERENCE ON SMART GRID COMMUNICATIONS*	219
4	*IEEE PES INNOVATIVE SMART GRID TECHNOLOGIES CONFERENCE EUROPE*	188
5	*ENERGIES*	153
6	*IEEE ACCESS*	116
7	*RENEWABLE SUSTAINABLE ENERGY REVIEWS*	107
8	*IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS*	103
9	*INTERNATIONAL JOURNAL OF ELECTRICAL POWER ENERGY SYSTEMS*	83
10	*IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS*	82

*Obs.: exibição dos primeiros 10 registros.
Frame 6: Journal
Source: Prepared by the authors based on research data (2020).

The journal with the greatest amount of production is “IEEE TRANSACTIONS ON SMART GRID” with 378 works. The magazine "IEEE POWER AND ENERGY SOCIETY GENERAL MEETING PESGM" presents the second largest volume of works (256 works), in third is the conference "INTERNATIONAL CONFERENCE ON SMART GRID COMMUNICATIONS" with 219. It is noted that the engineering area is predominant

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among the top ten journals, in the complete survey, another 80 journals presented at least one publication. Frame 7 presents the areas of published articles.

Nº	Área	Amount
1	*ENGINEERING*	6.431
2	*COMPUTER SCIENCE*	3.218
3	*ENERGY FUELS*	2.225
4	*TELECOMMUNICATIONS*	1.817
5	*AUTOMATION CONTROL SYSTEMS*	675
6	*SCIENCE TECHNOLOGY OTHER TOPICS*	485
7	*ENVIRONMENTAL SCIENCES ECOLOGY*	212
8	*MATERIALS SCIENCE*	171
9	*INSTRUMENTS INSTRUMENTATION*	167
10	*PHYSICS*	144

*Obs.: exibição dos primeiros 10 registros.
Frame 7: Total articles published by research area
Source: Prepared by the authors based on research data (2020).

Analyzing Table 7, the data show that the great area of knowledge in Engineering dominates publications – with 6,431 articles – thus, it allows us to infer that they are the most interested in the subject. The Computer Science area presents the second largest volume, most of its articles link the Smart Grid with the internet of things. The Energy and Fuels area is the third largest producer as it is interested in studying the good use of energy and the Smart Grid can help in this process. Next, Frame 8 includes the main countries that publish works.

Nº	Países	Amount
1	Estados Unidos da América	2.006
2	China	1.805
3	Índia	683
4	Canadá	603
5	Alemanha	490
6	Itália	490
7	Inglaterra	402
8	Austrália	337
9	Coréia do Sul	314
10	Irã	284

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Frame 8: Total de artigos publicados por país
Source: Prepared by the authors based on research data (2020).

Regarding publications by countries, Table 8 shows that the United States of America and China lead the ranking - with 2,006 and 1,805 articles - respectively, precisely the two countries with great interest in reducing costs and energy use, both seeking intelligently use the electricity networks they have. Europe has three countries among the ten largest producers. For Xue et al (2018), European countries suffer for not having hydroelectric sources for energy generation and research in renewable and intelligent energy is growing on the continent. Brazil is a country with hydroelectric potential and appears as the 16th country with the largest production of the topic addressed. For Wade (2019), Brazil has the potential to be a great energy supplier if it applies resources in the adhesion of Smarts Grids. The ten largest universities are listed below (Frame 9).

Nº	**Universidades**	**Amount**
1	*CHINESE ACADEMY OF SCIENCES*	171
2	*NORTH CHINA ELECTRIC POWER UNIVERSITY*	164
3	*COMSATS UNIVERSITY ISLAMABAD CUI*	152
4	*INDIAN INSTITUTE OF TECHNOLOGY SYSTEM IIT SYSTEM*	149
5	*STATE UNIVERSITY SYSTEM OF FLORIDA*	143
6	*STATE GRID CORPORATION OF CHINA*	107
7	*UNITED STATES DEPARTMENT OF ENERGY DOE*	103
8	*UNIVERSITY OF CALIFORNIA SYSTEM*	91
9	*SHANGHAI JIAO TONG UNIVERSITY*	89
10	*AALBORG UNIVERSITY*	87

*Obs.: exibição dos primeiros 10 registros.
Frame 9: Total articles published by University
Source: Prepared by the authors based on research data (2020).

The "CHINESE ACADEMY OF SCIENCES" is the largest producer on the subject, presenting about 171 works, most of the studies aimed at saving electricity in industrial use, for Toledo (2012) China, as a major global producer, is studying new ways of reduce energy consumption in the generation of new products. The fact that the country is the second largest producer of research in the area of smart electricity grids means that it also

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has the second university with the largest volume of studies (164), which points to investments in university research in this area. Among the ten universities, four are from the United States of America and four from China, by the way two great world powers. The next section presents the “h-b” and “m” indices pointing out the hot topics related to remanufacturing.

4.1 H-B INDEX

At this stage, publications involving remanufacturing and its main topics were investigated. Based on a previous analysis of the works found in the Web of Science, 21 topics related to the theme were selected. Table 10 lists the result of combining each of these topics with the term “Smart Grid”, and the total number of publications for each combination and the index “h-b” are calculated.

Nº	Tópico	**Amount e**	**Índice h-b**
1	*ENGINEERING ELECTRICAL ELECTRONIC*	5.747	4.1
2	*ENERGY FUELS*	2.225	2.8
3	*TELECOMMUNICATIONS*	1.817	2.6
4	*COMPUTER SCIENCE INFORMATION SYSTEMS*	1.206	2.3
5	*COMPUTER SCIENCE THEORY METHODS*	1.117	2.21
6	*COMPUTER SCIENCE HARDWARE ARCHITECTURE*	831	1.97
7	*AUTOMATION CONTROL SYSTEMS*	675	1.9
8	*COMPUTER SCIENCE ARTIFICIAL INTELLIGENCE*	536	1.85
9	*COMPUTER SCIENCE INTERDISCIPLINARY APPLICATIONS*	501	1.8
10	*GREEN SUSTAINABLE SCIENCE TECHNOLOGY*	217	0.9

Quadro 10: Total de artigos publicados e o índice h-b
Fonte: Elaborado pelos autores com base nos dados da pesquisa (2020).

Banks (2006) states that for a given topic to be considered a “hot topic”, the index “m” must be greater than or equal to 2, which indicates that it has great relevance for research in the area. Thus, the first five topics shown in table 10 are qualified as hot topics. The others, according to Banks (2006), can become a "hot topics" as a research area since the remaining items have an index greater than 0, 5 and less than 2.

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4.2 ANALYSIS AMONG AUTHORS WITH THE MOST PUBLICATIONS AND THE MOST CITED ARTICLES

Table 11 shows the list of articles published by authors in the period analyzed (2010-2019). It was observed that, in the last ten years, the greatest exponent of authors in the number of published works involving the theme is concentrated in Asia.

Nº	authors	Amount
1	JAVAID N	88
2	ZHANG Y	71
3	MOUFTAH HT	49
4	KUNDUR D	41
5	VALE Z	41
6	GUNGOR VC	40
7	LI HS	40
8	LU RX	39
9	LIU Y	37
10	POOR HV	37

Obs.: exibição dos primeiros 10 registros
Quadro 11: Total de artigos publicados por autores
Fonte: Elaborado pelos autores com base nos dados da pesquisa (2020).

It can be seen in Table 11 that JAVAID N - professor of computer science at the University Islamabad - and Zhang Y professor at the Harbin Instituteof Technology, are the researchers who stand out with works on smart grids in the last decade, with 88 and 71 articles published, respectively. The vast majority of teachers in the top 10 are located in Asia. Table 12 shows the most cited articles in the Web of Science database.

Nº	Article	Total Quotes
1	*Cognitive Radio for Smart Grids: Survey of Architectures, Spectrum Sensing Mechanisms, and Networking Protocols* Por: Khan, Athar Ali; Rehmani, Mubashir Husain; Reisslein, Martin*IEEE COMMUNICATIONS SURVEYS AND TUTORIALS* Volume: 18 Edição: 1 Páginas: 860-898 Publicado: 2016	166

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2	*Integration of electric vehicles in smart grid: A review on vehicle to grid technologies and optimization techniques* Por: Tan, Kang Miao; Ramachandaramurthy, Vigna K.; Yong, Jia Ying*RENEWABLE& SUSTAINABLE ENERGY REVIEWS* Volume: 53 Páginas: 720-732 Publicado: JAN 2016	158
3	*A review of the development of Smart Grid technologies* Por: Tuballa, Maria Lorena; Abundo, Michael Lochinvar *RENEWABLE & SUSTAINABLE ENERGY REVIEWS* Volume: 59 Páginas: 710-725 Publicado: JUN 2016	154
4	*A review of residential demand response of smart grid* Por: Haider, Haider Tarish; See, Ong Hang; Elmenreich, Wilfried *RENEWABLE & SUSTAINABLE ENERGY REVIEWS* Volume: 59 Páginas: 166-178 Publicado: JUN 2016	145
5	*A survey on smart metering and smart grid communication* Por: Kabalci, Yasin *RENEWABLE & SUSTAINABLE ENERGY REVIEWS* Volume: 57 Páginas: 302-318 Publicado: MAY 2016	144
6	*Smart Grids: A Cyber-Physical Systems Perspective* Por: Yu, Xinghuo; Xue, Yusheng *PROCEEDINGS OF THE IEEE* Volume: 104 Edição: 5 Edição especial Páginas: 1058-1070 Publicado: MAY 2016	136
7	*Distributed Event-Triggered Scheme for Economic Dispatch in Smart Grids* Por: Li, Chaojie; Yu, Xinghuo; Yu, Wenwu; et al. *IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS* Volume: 12 Edição: 5 Páginas: 1775-1785 Publicado: OCT 2016	127
8	*From Demand Response in Smart Grid Toward Integrated Demand Response in Smart Energy Hub* Por: Bahrami, Shahab; Sheikhi, Aras *IEEE TRANSACTIONS ON SMART GRID* Volume: 7 Edição: 2 Edição especial: SI Páginas: 650-658 Publicado: MAR 2016	120
9	*Electric vehicle fleet management in smart grids: A review of services, optimization and control aspects* Por: Hu, Junjie; Morais, Hugo; Sousa, Tiago; et al. *RENEWABLE & SUSTAINABLE ENERGY REVIEWS* Volume: 56 Páginas: 1207-1226 Publicado: APR 2016	111
10	*The Smart Transformer Impact on the Electric Grid and Technology Challenges* Por: Liserre, Marco; Buticchi, Giampaolo; Andresen, Markus; et al. *IEEE INDUSTRIAL ELECTRONICS MAGAZINE* Volume: 10 Edição: 2 Páginas: 46-58 Publicado: JUN 2016	106

*Obs.: exibição dos primeiros 21 registros.

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Quadro 12: Artigos mais citados no período
Fonte: Elaborado pelos autores com base nos dados da pesquisa (2020).

5. FINAL CONSIDERATIONS

Brazil is a country with almost 205 million inhabitants, according to estimates by the Brazilian Institute of Geography and Statistics (IBGE), and stands out as the fifth most populous nation in the world. For electricity generation and transmission, the country has a main system (a set of power plants, transmission lines and distribution assets): the National Interconnected System (SIN). This immense “electric highway” covers most of the Brazilian territory and is made up of connections made over time, from installations initially restricted to exclusive service to the regions of origin. In addition, there are several smaller systems, not connected to the SIN and, therefore, called Isolated Systems, which are mainly concentrated in the Amazon region, in the North of the country. This is because the geographic characteristics of the region, consisting of dense and heterogeneous forest, in addition to large and flowing rivers, made it difficult to build large transmission lines that would allow the connection to the SIN (AGENCY NATIONAL ELECTRICITY, ANEEL, 2016) .

Even with its importance, electrical networks have evolved little since they were created. However, energy demand is increasing and will grow even more in the coming years. In addition, the relationship between electricity concessionaires and their customers is still restricted. In addition to these issues, energy sustainability and environmental preservation, since as cities and nations become more technologically advanced, electricity consumption rises to levels that may not be manageable without surveillance.

The analysis of publications on the Smart Grid Web of Science database between 2010 and 2019 revealed the presence of 9,281 articles, the vast majority of which belong to the Engineering area. From the analysis of the results, it was found that Javaid and Zhang are the authors with the largest number of papers published in the period and that

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the Chinese Academy of Sciences and North China Electric Power University are the ones that have published the most studies involving the subject studied.

Among the periodicals, the ones that stand out are: IEE Transactionson Smarts Grid and IEEE Power and Energy Society General Meeting PESGM. It was also found that the United States leads the ranking of countries that have published the most studies related to the Smart Grid and the predominant language in the works is English. When the year of publications was analyzed, it was noticed that there was a significant increase in the number of works that make intelligent electrical networks during the period analyzed, demonstrating this topic has gained importance in academia.

In the course of the work, it was possible to ascertain the usefulness of the Web of Science database search tool for academic research, which can be considered an important tool to aid researchers seeking information in their area of interest.

As a limitation of this study, the use of only one specific database stands out. Therefore, as a suggestion for future studies, it is recommended to increase the range of sources, such as the use of other databases that also include academic events, both national and international, in addition to other sources of scientific data. Another suggestion is to carry out a qualitative analysis of the most cited works in the proposed period.

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