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Smart Meter Implementation: a Review on Acceptation Research

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Abstract: The global electricity grid needs an update due to several factors, such as demand growth, use of renewable energy sources, reduction of environmental impact, and the need of reduction of non-technical losses of electricity. Updating the power grid involves the concept of smart grids, in which there is a bidirectional flow of real-time information on how much energy is produced, consumed, and stored. Smart meters play a fundamental role in the implementation of these smart grids. This article aims to aims to identify some essential issues regarding the residential consumers' acceptance of smart meters.. In this work, a systematic review of the literature is performed using the PRISMA protocol. The results show that interest in the topic has been increasing in recent years. In addition, applied research is carried out mainly in Europe, North America, and Asia, with some occurrences in Oceania and just one in Africa. None occurrence of applied studies in Brazil and throughout Latin America was found. The need to understand the smart meteracceptance in South America is highlighted, and the results of the present study may be used as a starting point.

Keywords: Smart Meter, Acceptance, PRISMA Systematic Literature Review.

1 Introduction

Several reasons demand an update of the electrical system on a global scale and the growth in demand. From an environmental point of view, there is a need to change how electricity is produced to avoid catastrophes associated with climate change (IPCC, 2018). After the Fukushima incident, other countries seek to make their energy matrix less dependent on nuclear energy, such as Switzerland (Moser, 2017) and Taiwan (Chen and Yeh, 2017). There is also a concern about the security of energy supply and uncertainties regarding the price of energy tariffs (Balta-Ozkan, Amerighi and Boteler, 2014). Brazil is one of the global leaders in non-technical energy losses (Rivera, Esposito and Teixeira, 2013), a factor that increases the need to make your power grid more secure. These motivations meant that, by the end of 2017, 57 countries had already presented a plan for energy efficiency goals and policies (REN21, 2018).

These challenges cannot be met by the current power grid, that was designed for constant consumption, centralized production, and whose peak production lines with consumption (Ellabban and Abu-Rub, 2016). In addition, this growing share of energy production through stochastic renewable sources, which features intermittent energy production and depends on weather conditions, needs a new electrical network with real-time bidirectional feedback communication capability, like fiber optics and wireless networks. The feedback from the smart meter informs at the same time how much energy is generated by fossil sources, renewable sources, residential consumers, in addition to what is being consumed and stored. (Ellabban and Abu-Rub, 2016). To meet these requirements, a new electrical network, called smart grid, is needed to make rational and efficient use of renewable energy sources (Hossain *et al.*, 2016).

In this context of the smart grid implementation, the smart home electricity meter consists of an essential piece of equipment in this system. The smart electricity meter results from an evolution of stages and advances in the infrastructure for measuring the energy consumed (Avancini *et al.*, 2019). While the electromechanical meter featured manual reading and billing, physical connection, and an analogical

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display, the first smart meters included functions like automated billing and remote, unidirectional automated reading of measurements (Avancini *et al.*, 2019). In the next stage of technological development, the functions of automated bidirectional measurement infrastructure, distribution control, demand response, and interruption detection and restoration (Avancini *et al.*, 2019) were also added. In the present stage of technological development, functions like data storage and management, bidirectional measurement and charging, end-to-end communication, detection and diagnosis of system failures, in-home display (IHD), and wireless connection are also part of smart meters (Avancini *et al.*, 2019). The smart meter starts to perform several functions within the smart grid, to both utilities and residential consumers. In this context, several initiatives for full-scale implementation of smart meters are being carried out across Europe, Canada, New Zealand, Australia, the United States (Buchanan, Russo and Anderson, 2015), and Asia (Chou *et al.*, 2015).

Based on the current stage of development of the smart meter, they are expected to perform the following functions: (i) provide information to consumers about their energy consumption, (ii) reduce operating costs for utilities through remote control of meters, and (iii) reduce energy waste through automated control of energy redirection during grid failures, power surges and overproduction (Avancini *et al.*, 2019). Nevertheless, another indirect advantage mentioned is the decrease in energy consumption and the electricity grid's infrastructure cost to support peak demand (Faruqui, Harris and Hledik, 2010). However, this reduction in consumption does not rely only on the smart meters but also on changes in consumer habits, which are not possible to achieve without consumer engagement (Faruqui, Harris and Hledik, 2010). Thus, it is important to understand the requirements and demands of residential customers in more detail to increase the likelihood of success in a full-scale smart grid deployment.

Given the context of the consumer's role concerning the smart grid and the importance of consumer acceptance to achieve the smart grid's full potential, this work aims to identify where is conducted and who conducts research on residential consumers' acceptance of smart meters. This paper's results may create a starting point for research on the theme in Latin America, specifically Brazil.

2 Systematic literature review

This work uses the Preferred Reporting Items for Systematic Review and Meta-Analyzes – PRISMA [13] method as a systematic literature review method. The PRISMA method consists of a protocol that describes all the items that should be presented in a systematic literature review, emphasizing the search method. In this work, the procedures recommended in PRISMA were used and applied in other studies in the engineering area (Moreno-Blanco *et al.*, 2019; Ayodele, Chang-Richards and González, 2020; Gao *et al.*, 2020), which are divided into five stages (Fig. 1). Below are detailed the procedures performed in each of the five steps of the method.

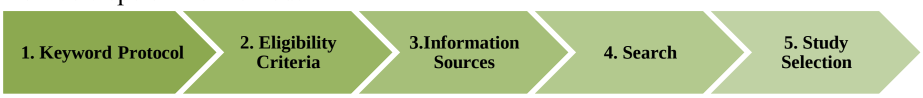

Fig. 1 Method Topics for PRISMA Search

2.1 Keyword Protocol

For the systematic review, two search fields were established, the first related to smart meters and the second to customers' acceptance. Initially, an exploratory search was carried out with the main keywords "smart meter" and "acceptance". Still based on exploratory research, it was found that the word "intelligent" can also be adopted with the same meaning in place of "smart". Likewise, "acceptation", "engagement", and "adoption" can be used to replace "acceptance". As a way of increasing the scope of the research, other possible endings for the term "meter" were included, with the use of (*), in order to cover similar terms, for example, "meter*" to cover meter, meters and metering (Fig. 2).

Medidores inteligentes	Operador	Aceitação
"Smart meter*" OR "intelligent meter*"	AND	"acceptance" OR "acceptation" OR "engagement" OR "adoption"

Fig. 2 Keywords used

2.2 Eligibility Criteria

The following eligibility criteria were defined for this selection: Studies involving smart meters and their adoption and acceptance by residential consumers.

2.3 Information Sources

Systematic literature reviews in management and engineering tend to show better results with the use of Scopus, Science Direct, and Web of Science scientific databases, as reported in several studies in the area (Alkawsi and Ali, 2018; Moreno-Blanco et al., 2019; Ayodele, Chang-Richards and González, 2020; Gao et al., 2020). Thus, Scopus, Science Direct, and Web of Science databases were used as sources of information in the present review. The results presented refer to the search carried out on March 11, 2020.

2.4 Search

A search was performed in the title, summary, and keywords fields of the articles. In databases, this type of search refers to the term "topic". The search strategy carried out in the databases is presented below.

Topic (Title - Summary - Words Key): ((" smart meter *" OR " intelligent meter *" OR " smart measur*" OR " intelligent measur*") AND (" engagement " OR " acceptance " OR " adoption " OR " acceptation ")).

2.5 Study Selection

Based on the search strategy adopted, studies were selected in the forms of article and review, in the English language and published in journals that do not come from conference papers. The search procedure used didn't include time restriction of published articles, and all articles found in search within each of the databases were included in the analysis.

The search result showed 356 articles in the three databases, which resulted in 189 different studies after removing the duplicates. The obtainment flow for the studies is displayed in Fig. 3.

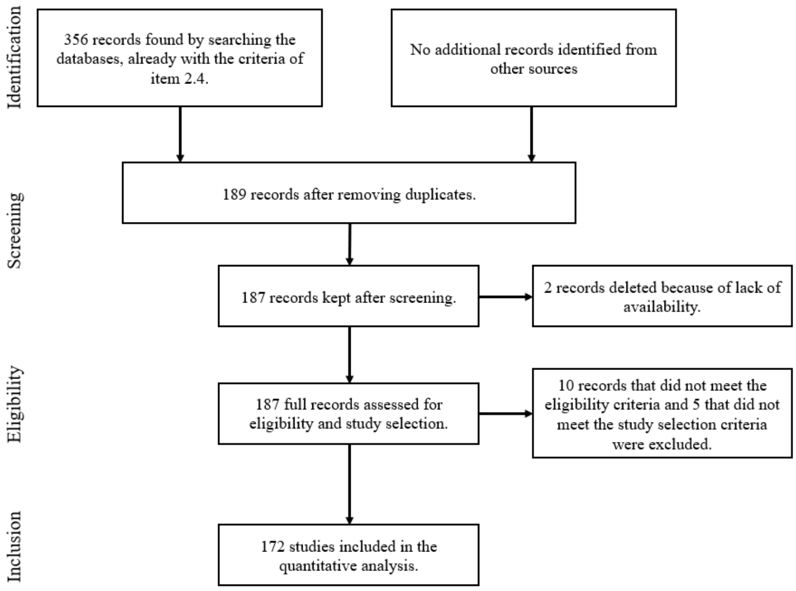

Fig. 3 PRISMA information flow

3 Results

Among the 172 articles included in the research portfolio, an analysis was made on the journals' frequency to identify which journals are most relevant to the topic. The 172 articles were published in 88 different journals, 84 of which are indexed in the SJR index. By assessing the contribution of the journals to the literature presented in **Table 1**, the most frequent journals in the area also have a high SJR impact factor. That indicates the researched topic is discussed and presented in the literature through high-reputation journals, reinforcing the current and pertinent indication of the studied theme.

Table 1 Frequency of articles per publication

Journal	Number	Frequency	SJR
Energy Policy	16	9,52%	1,99
Energy Research & Social Science	11	6,55%	2,14
Applied Energy	7	4,17%	3,46
Energy	7	4,17%	2,05
Energy Efficiency	7	4,17%	0,7
Renewable and Sustainable Energy Reviews	6	3,57%	3,29
Journal of Cleaner Production	6	3,57%	1,62
Energies	6	3,57%	0,61
IEEE Transactions on Smart Grid	5	2,98%	3,36
Energy and Buildings	4	2,38%	1,93
Sensors	4	2,38%	0,59
Environmental Modelling and Software	3	1,79%	1,73
Technological Forecasting and Social Change	3	1,79%	1,42
Sustainability (Switzerland)	3	1,79%	0,55
IEEE Transactions on Sustainable Energy	2	1,19%	3,1
IEE Transactions on Industrial Informatics	2	1,19%	1,68
Journal of Water Resources Planning and Management	2	1,19%	1,42
Utilities Policy	2	1,19%	0,93
Water	2	1,19%	0,67
Resources	2	1,19%	0,65
Behaviour and Information Technology	2	1,19%	0,56
Energy and Environment	2	1,19%	0,3
International Journal of Innovation and Technology Management	2	1,19%	0,19
Fujitsu Scientific and Technical Journal	2	1,19%	0,14
Other journals with one article	33	19,63%	-

The **Table 1** shows that the journals with the highest participation focus are on the energy area, such as Energy Policy, Energy Research & Social Science, Applied Energy, Energy, Energy Efficiency, Renewable and Sustainable Energy Reviews, and Energies. Together with the Journal of Cleaner Production, this group of journals concentrates most of the publications, reaching 39% of the selected articles. This result reinforces the literature indication that the study on smart meters is still focused on energy control, with far fewer studies on controlling water and gas consumption (Fettermann, Borriello, *et al.*, 2020; Fettermann, Cavalcante, *et al.*, 2020). Another evidence of this focus can be observed by stratifying the articles related to the type of meter studied (**Table 2**). It shows that most articles deal with smart electricity meters. The total number of articles in **Table 2** is greater than the total number of articles in the portfolio due to some of the articles in the literature address more than one type of meter.

Table 2 Articles classified by type of meter studied.

Type of Meter	Articles	Frequency
Energy meter	153	89,0%
Water meter	19	11,0%
Gas meter	2	1,2%

Regarding the period of publications, the number of publications per year in absolute terms is shown in **Table 3**. The results confirm a concentration of publications on the topic researched in the last five years. The oldest article in this selection was published in 1999 (Hartway, Price and Woo, 1999), and 54% of the selected articles were published in 2017 or later than 2017 (**Table 3**). For a more precise temporal analysis of the publications, the Scopus database data was used as a reference. The frequency of publications was reduced by the volume of articles published per year in the entire database. This procedure was carried out to estimate the relationship between the articles published on the topic and the total volume of articles published in the period. The result (**Fig. 4**) directly indicates the frequency of publications on the topic related to the database's total volume of publications. The results indicate an increasing frequency of articles published on the topic, with higher growth than the total number of publications in the database.

Table 3 Percentage of selected articles by year of publication

Year of publication	Number of articles	Percentage
2020*	9	5,23%
2019	25	14,53%
2018	32	18,60%
2017	27	15,70%
2016	20	11,63%
2015	14	8,14%
2014	22	12,79%
2013	9	5,23%
2012	5	2,91%
2011	5	2,91%
2010	3	1,74%
1999	1	0,58%

* Partial result until March 11, 2020

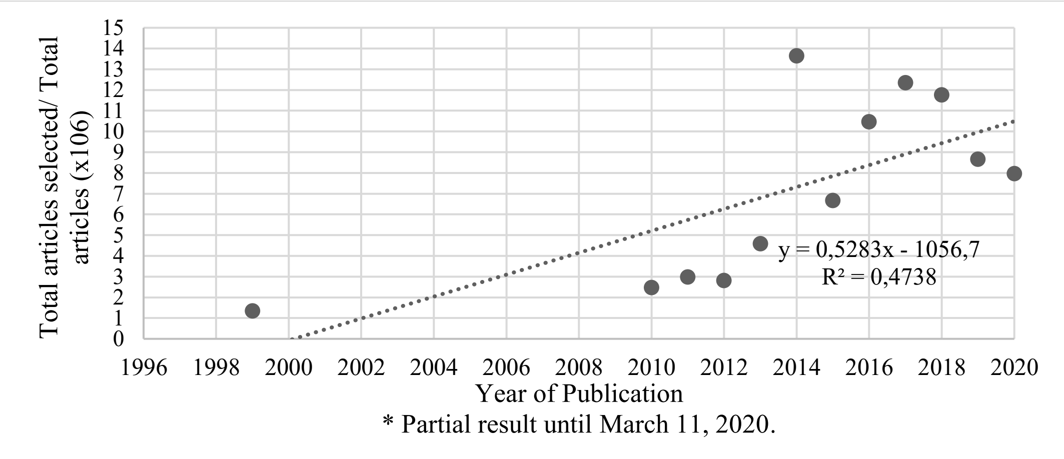

Fig. 4 Selected articles from the Scopus database relativized by year of publication.

In addition to the journals and their publication period, an analysis of the research centers was also carried out. For this purpose, the countries of origin of the institutions of each of the authors were analyzed. In all, 42 different countries were identified, present on five continents. The results indicate that research on the topic is mainly concentrated in the following countries: USA, United Kingdom, Australia, Germany, and Italy, with 49% of publications (**Table 4**). Among the research institutions present in these countries are Carnegie Mellon University (USA), Georgia Institute of Technology (USA), Oregon State University (USA), University of California Berkeley (USA), University of Reading (UK), University of Cambridge (UK), Oxford University (UK), Griffith University (Australia), University of Technology Sydney (Australia), Otto-Friedrich- Universität Bamberg (Germany), Otto-von- Guericke University (Germany) and University of Pisa (Italy) as the primary research centers on the subject.

Table 4 List of Institutions' Countries*.

Country of Origin	Articles	Frequency
USA	38	17,9%
UK	29	13,7%
Australia	13	6,1%

Country of Origin	Articles	Frequency
Germany	13	6,1%
Italy	10	4,7%
Spain	8	3,8%
Poland	7	3,3%
China	6	2,8%
Portugal	6	2,8%
South Korea	6	2,8%
Switzerland	6	2,8%
Canada	5	2,4%
Finland	5	2,4%
Japan	5	2,4%
Norway	5	2,4%
France	4	1,9%
Netherlands	4	1,9%
Austria	3	1,4%
India	3	1,4%
Saudi Arabia	3	1,4%
Sweden	3	1,4%
Taiwan	3	1,4%
Other	27	12,7%

*Some articles have institutions from different countries.

One of the characteristics of smart meters' acceptance research is the use of applied studies. These studies generally aim to understand the level of acceptance and the factors that affect smart meters' acceptance in one particular region. Upon examining the literature, 42 published studies of this type were identified. **Fig. 5** shows each city's geographic location. Research carried out in these cities includes questionnaires, interviews, focus groups, case studies, and social and field experiments.

Fig. 5 Representation of Researched Cities

Concerning applied studies on the acceptance and adoption of smart meters by consumers, a greater concentration of studies is identified in the northern hemisphere, along with a considerable number of studies in Oceania and Southeast Asia. There is only one study in Africa (Booysen, Visser and Burger, 2019) and none in South America. A large number of evaluations are verified in Europe due to an European Union (EU) guideline that states all members must achieve 80% of smart household meters implemented by 2020 (European Union, 2009). Another important aspect is that Australian applied studies are focused on smart water meters (Beal and Flynn, 2015; Beal, Gurung and Stewart, 2016; Beal *et al.*, 2018), which also happens in Spain, to a lesser extent (March *et al.*, 2017), and in the city of Cape Town, South Africa (Booysen, Visser and Burger, 2019). These three localities suffer from water scarcity (March *et al.*, 2017; Beal *et al.*, 2018; Booysen, Visser and Burger, 2019), and they use smart water meters as a tool to detect leaks in the water network.

4 Conclusion

This paper used a systematic review of the literature, the PRISMA method (Liberati et al., 2009), to identify some essential issues regarding the residential consumers' acceptance of smart meters.. A total of 172 studies were selected by following this methodology, which makes up the literature on the acceptance and adoption of smart residential meters for electricity, gas, and water by consumers. From a bibliometric analysis of the literature, it appears that the number of publications has increased at a higher rate than the total number of scientific publications in the last decade, which points to an increasing frequency of publications on the subject.

When checking the mapping of the cities where surveys were carried out on the acceptance of smart meters, there is a concentration of studies on the European and Asian continents. Some occurrences are also verified in Oceania, North America and Africa, but there is no research record with any population in South America.

Given the analyzed literature, it was evident the low research and knowledge regarding the acceptance of smart meters by Latin American consumers and consequently, in Brazil. Due to the need to use smart meters to modernize the electric grid in Brazil, in addition to the growth targets for the use of renewable resources in its energy matrix, it is necessary to research the acceptance of smart meters in Brazilian society, as in the case of different places in the world, like France (Montginoul and Vestier, 2018), USA (Bugden and Stedman, 2019), Germany (Arnold et al., 2018), Qatar (Abdmouleh, Gastli and Ben-Brahim, 2018) among others. Although the Brazilian reality is not the same as in any other country, the present work contributed to research on the acceptance of smart meters in Brazil by gathering important information and presenting the current state of the literature on the acceptance of smart meters worldwide.

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