

**Uma revisão da literatura Sobre Técnicas de Inteligência Artificial Aplicadas a
Redes Inteligentes de Autocura**

**A Review of Literature on Artificial Intelligence Techniques Applied to Self-
Healing Smart Grids**

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ABSTRACT

The development of self-healing in smart grids is an attractive research topic. The application of artificial intelligence (AI) techniques for this purpose has been studied recently, and works published in this area show the effectiveness of AI. This article's purpose is to conduct a literature review of research articles published in recent years between 2014 and 2019, with the main theme related directly to self-healing and AI. Compared to the total number of articles published in smart grids, there is a

small number of papers with this specific theme, mostly concentrated in Multi-Agent System (MAS). Performing an attribute agreement analysis, it is possible to look for relations between common characteristics of the articles and the chosen AI technique option. The methodology is applicable for educational and research purposes to facilitate the learning and investigation process.

Keywords: Smart Grid, Self-healing, Artificial Intelligence, Literature Review.

RESUMO

O desenvolvimento da autocura em redes inteligentes é um tópico de pesquisa atraente. A aplicação de técnicas de inteligência artificial (IA) para este fim é estudada recentemente e trabalhos publicados nesta área mostram a eficácia da IA. Assim, o objetivo deste artigo é realizar uma revisão bibliográfica de artigos de pesquisa publicados nos últimos anos entre 2014 e 2019, com o tema principal relacionado diretamente à autocura e IA. Comparado ao total de artigos publicados em redes inteligentes, há um pequeno número de artigos com esse tema específico, principalmente concentrados em Sistemas Multiagentes. Realizando uma análise de concordância de atributos, é possível buscar relações entre características comuns dos artigos e a opção de técnica de IA escolhida. A metodologia é aplicável para fins educacionais e de pesquisa para facilitar o processo de aprendizagem e investigação.

Palavras-chave: Redes Inteligentes, Autocura, Inteligência Artificial, Revisão da Literatura

1 INTRODUCTION

Electrical power systems (EPS) encompass the generation, transmission, and distribution of electricity. Thus, to promote the efficiency and reliability of these systems, many technologies call advances in the areas of automation, computing, telecommunication, and engineering have contributed to focusing on the development of technologies to act directly in EPS (Liserre et al., 2010). A smart grid was developed from the conjuncture of these various areas to stimulate technological advances in electrical infrastructure (Liserre et al., 2010).

According to DOE (2003), "smart grid seeks to provide energy in an automated way between the plant, the device and all intermediate points, ensuring a bidirectional flow of electricity and information, in addition to monitoring and controlling all customers and network nodes". The European Regulators Group for Electricity and Gas (ERGEG) Smart Grid: "it is an electrical network that aims to ensure economically efficient and sustainable distribution, obtaining high levels of quality and safety, by integrating the behaviors and actions of all consumers and generators and those who do both connected to it" (ERGEG, 2009). According to Shum et al. (2016), smart grids use computer monitoring to control and communicate across technologies to promote more excellent reliability, safety, and efficiency (economic and energy) of power generators and distributors. According to Wollenberg (2005) and Brown (2008), smart grids aim to improve the durability of systems through

the integration of alternative and renewable energy sources, as well as through the use of automated controls and communication systems. Finally, Giordano et al. (2013) and Elgenedyet al. (2015), describe that smart grids may help to I) integrate systems of renewable energy sources, such as electric vehicles and distributed generators into the grid; II) provide energy in an efficient, sustainable, and reliable manner; III) prevent and restore interruptions, and IV) respond to consumer demands, such as obtaining more significant control over electricity consumption and their participation in the energy market.

A smart grid can provide benefits such as self-healing, which is one of the most important features for making a network "smart" (El-Ghareeb et al., 2017; Zhang et al., 2018). This concept refers to the ability of the distribution network to recover from a disturbance, isolating a problem, restoring loads in the shortest possible time, and reducing the number of customers affected (Elgenedy et al., 2015). When compared to traditional distribution systems, self-healing systems improve the reliability and quality of the distribution system (Zheng and Cong, 2017). According to Elgenedyet al. (2015), self-healing may create systems that are safe, fault-tolerant, and resilient. Self-healing can be a useful tool when applied to the logic in the Intelligent Electronic Devices (IEDs) themselves, and when enhanced by Artificial Intelligence (AI) (Fonseca, 2017).

Seeking to improve protection, AI can be employed to remedy fault-related problems caused by smart grid disturbances and the implementation of Self-healing (Tong et al., 2017). The application of AI techniques to power system's reliability analysis has been gaining momentum in recent decades, because AI may overcome significant disadvantages of traditional methods (Wu et al., 2017). According to Vanajakshiet al. (2010), the models adopted by the AI techniques capture the uncertainty between the real cause and effect scenarios by incorporating the available knowledge with probabilities and probability inference calculations. According to Rigas et al. (2014), AI helps in operational aspects by supporting planning and decision making. AI allows one to implement essential functionalities that are still performed by humans, such as self-healing. According to Oualmakranet al. (2012), a distribution network used within the smart grid, coupled with self-healing and AI, includes the added benefits of I) a quick restoration; II) more loads restored, and III) less need to send field technicians to solve the problems. Lastly, Kamdar et al. (2018) describe that to assist the self-healing service, several AI techniques such as fuzzy logic, genetic algorithm, intelligent agents, and artificial neural networks are applied to provide accurate diagnoses of power outages. These AI techniques offer efficient and reliable results, robustness, reliability, and efficiency (Spatti, 2011).

Thus, this paper reviews how state of the art AI techniques cited are being employed in self-healing systems to assist in monitoring and restoring power outages in smart grids. The remainder of this article is structured as follows: Section 2 describes the research methodology used, section 3 exposes the results and discussions of this search, and section 4 discusses the final considerations and future work.

2 RESEARCH METHODOLOGY

The research methodology selected for this study was the literature review, intending to gather information on a subject studied through various research sources to update the reader on a particular topic (Cronin et al., 2008). Thus, the review work should include an objective strategy for conducting a search and selecting information for the study (Carnwell and Daly, 2001). The use of this methodology allowed identifying possible gaps in the area of study and identifying new research opportunities from different perspectives. The process of selection, classification, and analysis of works was carried out by the authors of this article. Whenever necessary, meetings were held, whose purpose was to analyze the results of the articles and resolve the differences.

To cover the topics of interest in this review, we formulated four research questions (RQ). These questions considered relevant and general aspects important for this study and guide the development of this review to meet the proposed objective (see Table 1).

Table 1. Research questions for the review.

ID	Research Question (RQ)
RQ1	Amount of works published in recent years?
RQ2	What characteristics and AI techniques used in the works?
RQ3	Which AI techniques among those described in this research are being used most?
RQ4	What application areas are researches addressing?

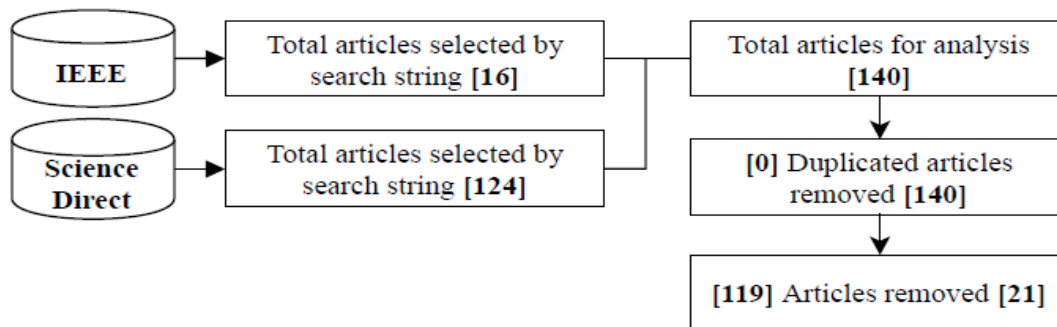
This review containing scientific articles from the IEEE Xplore and ScienceDirect electronic databases, from 2014 to 2019. The period was elected to investigate how recent research is adopting genetic algorithms, fuzzy logic, artificial neural networks, or multi-agent systems together with self-healing. Finally, to identify the works, the following search string was elaborated:

("smart grid") AND ("self-healing") AND ("Genetic Algorithms" OR "Fuzzy Logic" OR "Artificial neural networks" OR "Neural networks" OR "Intelligent Agent" OR "Multi-Agent")

As all researched articles were not aligned with the objective of this research, a screening process was necessary to obtain only the relevant articles. As shown in Figure 1, 140 works were found.

The first step was to analyze the existence of duplicate work, but none were found. Soon after, a review of the titles and abstracts of the studies was carried out, verifying adherence to the theme of the literature review (What AI techniques cited are being employed in self-healing systems to assist in monitoring and restoring power outages in smart grids?), leading to the exclusion of 119 articles. Finally, 21 papers were selected for coding. After the complete reading of the included papers, they went through a tabulation process whose objective was to select basic information (bibliographic data, date of publication, summary, etc.), and a synthesis of the work was written by the researchers who conducted the review.

Figure 1. Steps of the selection process.



3 RESULTS AND DISCUSSIONS

This section presents the results and discussions of the data extracted from the 21 studies analyzed. In tables 2 and 3 we categorized the number of articles obtained from each database, by year and by theme. While the research on smart Grid was massive, there was scant narrow amount of research in both IEEE Xplore and ScienceDirect that involved all three concepts under review. The limited number of publications could be associated with the preliminary publications exploring the combined effects of smart Grid, self-healing, and AI techniques, beginning around 2010.

Table 2. Number of articles by theme in IEEE Xplore.

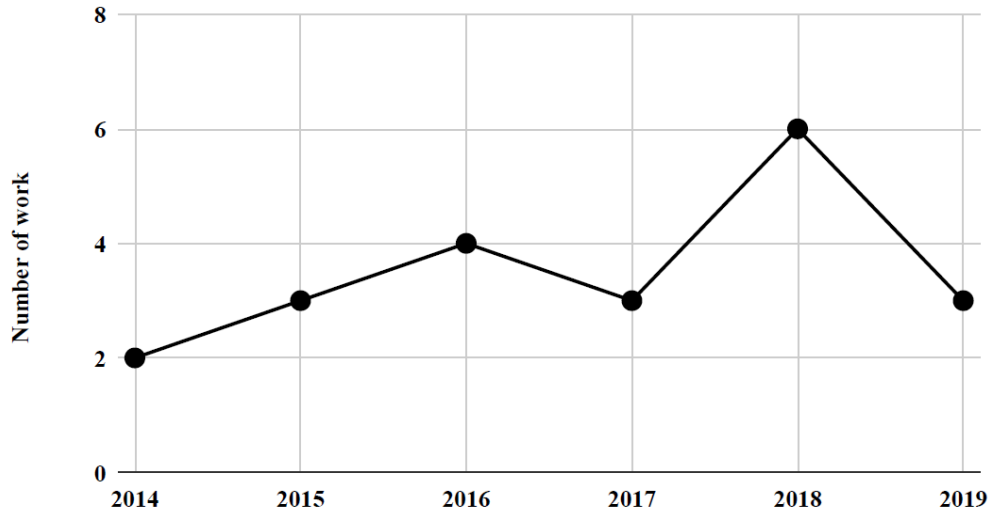
IEEE	2014	2015	2016	2017	2018	2019
Smart Grid	2777	2925	3311	3329	3639	2142
Smart Grid and Self-Healing	30	21	35	31	34	16
Smart Grid, Self-Healing and Artificial Intelligence	2	1	4	4	2	3

Table 3. Number of articles by theme in ScienceDirect.

ScienceDirect	2014	2015	2016	2017	2018	2019
Smart Grid	1017	1328	1450	1756	2005	2165
Smart Grid and Self-Healing	39	48	41	41	56	54
Smart Grid, Self-Healing and Artificial Intelligence	20	19	15	17	26	27

According to Figure 2 and responding to the QR1, it is observed that in the databases used in this work in the last three years, there has been a 33% increase in the number of publications, including the three concepts of smart grid, self-healing, and AI techniques compared to previous years. This increased interest demonstrates that researchers are seeking methods to improve smart grid reliability through the use of self-healing and AI applications El-Ghareeb et al. (2017).

Figure 2. Year of publication.



The relationship between the most recurrent themes in the articles approached in this work table 4, and the applied artificial intelligence techniques were investigated to responding to the QR2. To evaluate these relationships, we used the attribute agreement analysis, a method available in the Minitab software, housed within the quality tools section. The objective of this analysis was to investigate how the most prominent characteristics in the articles influence the choice of AI technique.

Table 4. Characteristics of papers included in the review.

Id	References	AI Technique	Featured Features
#1	Kamdar et al. (2018), Avila et al. (2015), De Santis et al. (2015), Dou and Liu (2014), El-Sharafy and Farag (2017), Ji et al. (2016), Jain et al. (2018), Ghorbani et al. (2015), Meskina et al. (2018), Ospina and Quijano (2016), Sekhavatmanesh and Cherkaoui (2018), Ren et al. (2019), Shirazi and Jadid (2018), Shirazi and Jadid (2019), Tebekaemi and Wijesekera (2019), Xia et al. (2014)	MAS	Decentralized processing
#2	El-Sharafy and Farag (2017), Jain et al. (2018), Oliveira et al. (2017), Xia et al. (2014)	MAS/FL	Island operation (standalone microgrids)
#3	Avila et al. (2015), Dou and Liu (2014), Xia et al. (2014), El-Sharafy and Farag (2017), Meskina et al. (2018), Sekhavatmanesh and Cherkaoui (2018), Shirazi and Jadid (2019), Oliveira et al. (2017), Shirazi and Jadid (2019)	MAS/FL	Forecast (short term)

#4	De Santis et al. (2015), Dou and Liu (2014), El-Sharafy and Farag (2017), Meskina et al. (2018), Ospina and Quijano (2016), Shirazi and Jadid (2018), Sekhavatmanesh and Cherkaoui (2018), Ren et al. (2019), Tebekaemi and Wijesekera (2019)	MAS/FL	Multiobjective approach
#5	Shum et al. (2016), El-Ghareeb et al. (2017), Kamdar et al. (2018), Ghorbani et al. (2015), Ji et al. (2016), Sekhavatmanesh and Cherkaoui (2018), Shirazi and Jadid (2018), Shirazi and Jadid (2019), Abu-Elanien et al. (2018), Zhu et al. (2016)	MAS/FL/ANN	Speed (processing/reset)
#6	El-Sharafy and Farag (2017), Jain et al. (2018), Oliveira et al. (2017), Xia et al. (2014), Dou and Liu (2014), Sekhavatmanesh and Cherkaoui (2018), Shirazi and Jadid (2019), Ospina and Quijano (2016), Ren et al. (2019)	MAS/FL	Demand response (load management, DES)
#7	Xia et al. (2014), Tebekaemi and Wijesekera (2019)	MAS	Provides attack security

Fuzzy Logic (FL), Multi-Agent Systems (MAS), Artificial Neural Networks (ANN), Distributed Energy Storage (DES)

The strongest relations found in the analysis are presented in table 5. The results demonstrated a strong relationship between a decentralized processing approach and the option to use multi-agents one. Nineteen out of the 21 articles matched; representing 90.48% of the total papers (95% CI: 69.62; 98.83). The second strongest relation was the works involving processing speed, with only 11 matched articles, representing 52.38% (95% CI: 29.78; 74.29). The conclusion is that only the first relationship is accepted as significant, all the others are discarded. The verification performed using Pearson correlation, in Minitab, confirms this result by analysis of the P-values.

Table 5. The strongest relations found.

Analyzed Attributes	Matched	Percent	95% Confidence Interval (CI)
Decentralized processing and Multi-Agent System	19	90.48	(69.62; 98.83)
Speed (processing/reset) and Multi-Agent System	11	52.38	(29.78; 74.29)
Multiobjective approach and Multi-Agent System	10	47.62	(25.71; 70.22)
Demand response (load management, DES) and Multi-Agent System	39	47.62	(25.71; 70.22)
Forecast (short term) and Multi-Agent System	20	42.86	(21.82; 65.98)

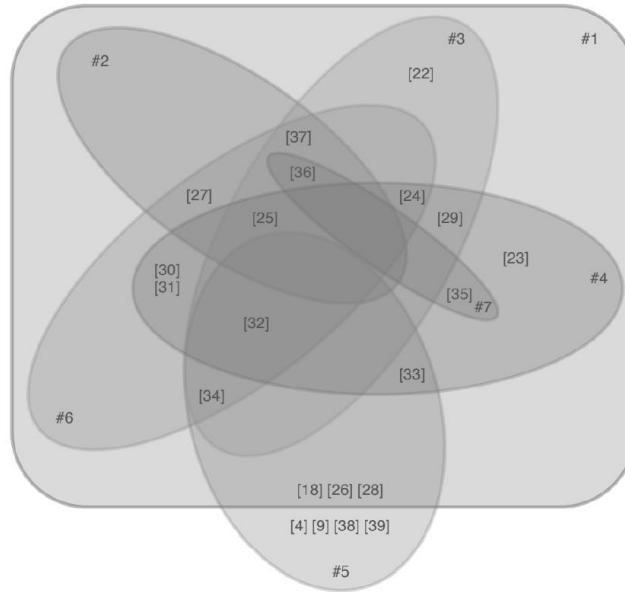
Distributed Energy Storage (DES)

Responding to the QR3, among the selected papers that constituted this review, 85% are associated with the use of intelligent agents, which demonstrates that this technique is currently the most used. Their popularity may be related to their ability to act autonomously and be adaptable by learning through interaction with their environment and adapting to changes in operating conditions. Furthermore, these systems act in a decentralized manner (Ospina and Quijano, 2016). This feature is in line with the modeling of a Smart Grid, in which the concept of decentralization is highlighted.

As already demonstrated, the search string used in this work consisted of several AI techniques, but no search was found applying genetic algorithms (GA) focusing on self-healing. As much as some works like (Abu-Elanien et al., 2018) and (De Santis et al., 2015) report that using GA, with other objectives, leads to an improvement in the network’s ability to self-recover.

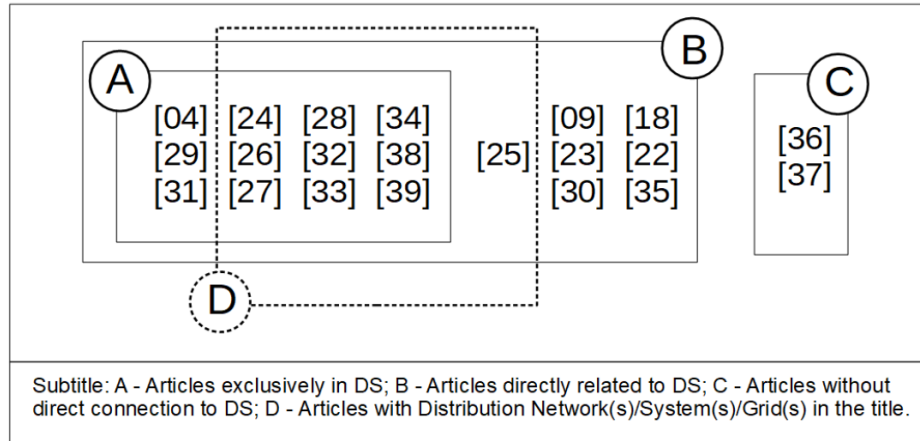
The information in table 4 can be presented in a graphic format, allowing the visualization of similarity or thematic proximity between articles, as can be seen in figure 3. This representation is useful for identifying works with similar or opposite approaches and little-explored combinations.

Figure 3. Graphic format of the most recurrent themes.



Regarding the application area and responding to the QR4, it is assessed that 19 of the 21 articles have a direct relationship with Distribution Systems (DS), of which 12 are developed exclusively in DS. Only two studies, Xia et al. (2014) and Oliveira et al. (2017), do not have a direct relationship with DS, dealing with isolated operation situations. Few works, such as Avila et al. (2015) and Tebekaemi and Wijesekera (2019), address the topic of Transmission. This dominance of the distribution area can be easily seen by the fact that 10 of the articles have in their titles one of the following terms: Distribution Network(s), Distribution System(s), or Distribution Grid(s). The analysis of this aspect is represented in figure 4.

Figure 4. Application area of the articles.



The following sections summarize the main objectives and characteristics of the works selected for this literary review. Based on this information, it is possible to identify how the AI techniques are being employed in self-healing systems to assist in monitoring and restoring power outages in smart grids.

3.1 FUZZY LOGIC AND/OR ARTIFICIAL NEURAL NETWORKS

Researchers required to recognize information integral to determining a typical failure condition amid a large amount of information available on an intelligent network like the smart-grid system found in Rome (Italy) (De Santis et al., 2015). The researchers tried to design an efficient recognition model, through the use of fuzzy sets, to discern potential failures in a real smart grid system. Avoiding such failures or recovering from them quickly, if possible, automatically, is of interest to both the system operator and the consumer.

The work of Oliveira et al. (2017) proposes a methodology for the management of smart micro-networks, which keeps the largest possible amount of time in the energy supply. This work uses a method, that considers which renewable energy sources are available, and also the energy currently stored. A method based on fuzzy logic establishes the control actions of the micro-networks. The ANFIS is a development tool for forecast construction, described in the works of Liang and Cheng (2002) and Lopes et al. (2005), which uses fuzzy logic and provides data to the controller so that he can make decisions. Considering the data recorded in the database it is possible to forecast the charge/energy generation for the next half hour, forming a history used in the forecast. Forecasting actions are performed offline and treated as inputs to the network controller.

The article by Abu-Elanien et al. (2018), presents several approaches to the problem of automatic reconfiguration of the distribution network. The artificial intelligence techniques, as fuzzy

logic and artificial neural networks, include variations in the modeling of the problem and method options for the solution. The evaluation of the advantages and disadvantages of each and comparisons between them is highlighted to guide future research. The evolution of measurement infrastructure, distributed generation, and storage devices are used to achieve the proposed objectives.

3.2 INTELLIGENT AGENTS

The research of Dou and Liu (2014) brings a hierarchical strategy of management and control of the distribution network, reaching a considerable insertion of the distributed resources. The structure system is composed of multiple agents, through intelligent switching of operations. Simulations carried out verified that, following the occurrence of considerable disturbances in the network and load changes, the hierarchical hybrid control, build on the Multi-Agent system, could maintain better performance, about safety and stability, in addition to a minimum operational cost.

A structure, build on two layers, containing multi-agents, for the development of a self-healing smart grid was proposed by Xia et al. (2014). The system stability is guaranteed by the highest layer using the multi-step Taylor series function method, based on data from the wide-area measurement system. The lower layer, within the multi-agent, protects the system through effective failure prevention and proper coordination. The mentioned structure shows the smart grid self-healing ability, to safeguard itself preventing failures and coordinating generations, in both reliable and flexible manners.

The authors' proposal Avila et al. (2015), consists of a multi-agent system, capable of restoring automatically the energy distribution networks. As a contribution of the work, it presents an algorithm capable of forecasting demand in the short term, being that this forecasting capability is used to acquire the restoration based on the capacity. To demonstrate the feasibility and importance of the forecast methodology, the mentioned algorithm is executed to provide the restoration in two different categories, by including or not the technique of forecasting.

The work of Ghorbani et al. (2015) makes use of multi-agent systems to locate, isolate, and restore faults in power distribution systems. Considering the distribution system, in case of an existing failure, the multi-agent system is capable of rapidly isolates the fault and perform the service restoration in the fault-free zones. The agents integrate the operation to advantageous centralize or decentralize the coordination strategies, through coordination hierarchically systematized. The proposed multi-agent system comprises the zone (AZ), feeders (AA), and substation agents. The AZ is responsible to locate and isolate the fault considering the provided local information and assists AA to perform the

reconfiguration and restoring. A new mechanism used to support make-decision, called Q-learning, is added to AA for the restoration process.

The reference of Ospina and Quijano (2016) presents a model capable of optimizing and either minimize the load shedding, necessary to restore the balance during system operation, in a fault condition as a loss of generation, considering in this condition the energy distributed by the generators. In the same way, the model considers in each node, the relevance of a load under the new demand. The mathematical modeling is developed, as well as the coordination algorithm of the distributed energy resources. The adopted approach is based on multi-agent systems, and several applications are studied with game theory tools.

According to Ji et al. (2016), the ability to self-correct failures in the distribution network is a problem of optimization of multi-objective, multi-temporal, and multidimensional configuration. The approach used is based on a multi-agent system, where an automatic recovery architecture is built. The bidirectional flow characteristic of smart grids, made possible by the presence of distributed generation from renewable sources, is used for this purpose.

Reference Shum et al. (2016) presents approaches, specified in the FIPA (Foundation for Intelligent Physical Agents, to create models and simulations, taking into account protocols related to the multi-agent system. The approach uses a simulation platform to investigate multidisciplinary interdependence among the multi-agent, communication, and electrical systems. To show the benefits, the researches highlight the effect in the system performance due to different configuration in the network.

The work of Zhu et al. (2016) addresses the use of self-healing, in the distribution network, through services for troubleshooting, isolation, and restoring, employing resources as multiple interacting intelligent agents and mining technology, and others as parsing of a big quantity of information. This work employs new technologies, such as relays applicable to power networks, developed under new processing techniques, in addition to proposing the use of agents, who recover services from the distribution network, being regulators and buses, from state and sub-state. The implementation of the system with multiple agents uses the Java programming language and JADE (Java Agent Development Framework).

Systems adopting the multiple agent concepts implement techniques for fault location isolation, as algorithms to smart grids self-recover, specifically in the energy distribution system, associated with MATLAB SIMULINK and FIPA-ACL. According to (MAN, 1995) the energy distribution system acts as a standard of communication between agents. The developed algorithm helped to locate and

isolate single and multiple faults in a few seconds, which previously occurred manually in a time between 35 to 70 minutes.

The research carried out by El-Sharafy and Farag (2017) proposes, for an environment containing multiples agents, a process for distributed restoration in the network, considering a solution based on intelligent distribution on networks, grouped in multi-networks. Load, distributed generation, and combined load - distributed generation transfer is introduced, to transfer the energy among near microgrids during the restoration. The researchers take into account the ability to form non-predefined island micro-networks, post-restoration, and maximizing service restoration. Finally, an algorithm, widely evaluated concerning its effectiveness and robustness, that uses the optimal asynchronous partial overlay (OptAPO) technique is used in a multi-agent environment to solve distributed problems, through the search for a distributed constraint agent.

The authors Jain et al. (2018) developed an algorithm, built under a robust and consistent architecture for compatible agent functions, to automatically perform the restoration of distribution system services, which have distributed energy resources, including or not the micro-network capability. The restoration algorithm object (based on the distributed Prim algorithm), is the formation of the operational microgrids, that have considerable sizes, and sections coupled up to the network, or not connected to it, after the interruption. These actions improve the stability of the system, minimizing the susceptibility to changes in the load and demand by aggregation.

The paper in Sekhvatmanesh and Cherkaoui (2018) adopts the multi-agent concept in the smart grid and applies it to create a structure capable of recovering itself applicable for the catering activities. Then an interaction mechanism was assigned to an agent, to provide a model, of a part of the network, that would integrate the restoration process, with less switching operations possible, using an optimization technique, in the gurobi tool, to recover maximum loads. This proposal, being a global solution, is highly scalable, not requiring high-performance processors in order to achieve the required precision, according to tests carried out on distribution network, with 70 buses, modeled in the Matlab/Yalmip environment.

The objective of Meskina et al. (2018) is to present the research and application of systems, which are capable of detect failures, perform isolation and recovery systems adopting a hierarchy and distributed system, which containing multiples agents.

According to Kamdar et al. (2018), even though the smart grid performs continuously and confidently supply to the end-user, it is inevitable that failures and interruptions occur. The use of automation can mitigate these problems, considering that this work offers an approach not centralized,

by adopting a system structure of multiples agent and deployed in the Virtual Test Bed and LabVIEW platforms to obtain the network restoration in a fast and reliable way.

The work in Shirazi and Jadid (2018) proposes a method build on agent perspective to provide restoration in intelligent distribution systems to the services involved in it. It was suggested the use of three agent types as the feeders, zone, and switching, which can provide both communication and cooperating, employing services provided to the customers for which the services are not working properly. Local data is the base to perform the restoration and is compound by system information as the condition, the location where the fault has occurred, and the operational boundaries. Several scenarios were considered to have comparisons in the approach, by using multiple agents including several conditions for the loading.

Similarly, the work of Shirazi and Jadid (2019) purposes the method, build on agent perspective, including the distributed generation (DG) agent in the architecture comprised by the feeder, zone, and switching agents. Agents can provide communication and cooperate through services provided to the customers for which the services are not working properly. Through the DG agent, in conjunction with an artificial neural network, the forecast of distributed generation is carried out. A plan was defined to restore the services according to data from the local as the conditions, limitations, and the site of the failure. Several scenarios were considered to have comparisons, considering the configuration with DG or without it, in the approach using multiple agents including several conditions for the loading.

In Tebekaemi and Wijesekera (2019), a communication model for autonomous and decentralized control of an intelligent network is presented. It is expected that this network will be able to protect itself and recover from both physical disorders and cyber-attacks. The proposed decentralized communication structure (JADE), together with intelligent electronic devices (IEDs), forming a Multi-Agent System (MAS), allows the intelligent reconfiguration of the distribution network in an autonomous way.

Finally, Ren et al. (2019) propose a method build on an agent to maintain the smart grid reliable during the process to rebuild it, taking into account the load balancing for an architecture compounded by multiples agents. The strategy to recover the grid capacity regards the reinforcement learning adopting an algorithm called Wolf Pack (WPA). In this approach, researchers take into account the limitations of the network as well as the dynamic load of the system, creating a simulation of the physical entities through differentiation and abstraction of various agents integrated into the WPA algorithm, which is executed to create an optimized and more reliable scenario, compensating for load

balancing. The network was modeled in JAVA in two scenarios to be validated in terms of reliability and expandability of the optimized objects, for different restoration scenarios.

4 CONCLUSIONS AND FUTURE WORK

Considering the importance of self-healing for smart grids and the feasibility of applying AI techniques, this literature review presented that there are under-explored spaces for research on this subject. Research that investigates the application of techniques, other than MAS and comparing performance between them can yield interesting work. The results of the Attribute Agreement Analysis indicate that the definition of the main characteristics of a case study can substantiate the process of choosing the technique which deserves further investigation.

This article can also help students and researchers write future literature reviews. This review is also intended to serve as an example for the preparation of well-structured literature reviews by students in the field. Finally, this work is aligned with the principles of knowledge assessment, dissemination, and popularization, seeking to accelerate the development process.

As future work, an area currently highlighted is the use of Vehicle-to-Grid (V2G), a technology that allows electric (or hybrids) vehicles to supply power to the distribution network in specific situations, avoiding interruptions or helping to restore supply and reducing consumption peaks, allowing for a more economical dimension of the system. According to Kempton and Tomić (2005), the use of AI in V2G for energy management is one of the most promising applications since the provision of this service leads to payments to the vehicle owner. The use of the vehicle's idle time by V2G can compensate part of its life cycle cost without affecting the availability required by the driver. Parsons et al. (2014) highlight that all of these benefits can be maximized with proper use of AI methods, thus being a possibility for future studies. Another proposal for future work, it is suggested to expand the search string used in research methodology, including new AI techniques such as machine learning and deep learning. Also, it is interesting to include new databases in the research, as possible new relevant works can be found and added, improving the state of the art of this research.

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