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Impact of Adaptive Protections in Electric Microgrids, Challenges and Future Trends

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Abstract

This paper reviews and discusses the use of adaptive protections in microgrids. The main goal of the paper is to review the progress made in the last 10 years, to identify the challenges that are still present, and to note the current trends in the use of these protections in microgrids. The analysis is based on applications implemented since 2007, and on a wide bibliographical review of books, theses, patents, scholarly papers, conferences, technical reports, and experts' experiences. The paper includes a comparative table that summarizes the reviewed literature and its findings. The paper is of interest to academics who do research on development and implementation of new robust and reliable protection schemes in microgrids, and to those in the industrial sector, who implement electric microgrids, and who want to understand the impact of their protection schemes.

Keywords: Centralized and decentralized adaptive protections, Microgrids (MG), distributed generation (DG), real-time simulation (RTS).

1. Introduction

Adaptive protections are a set of *functions* that allows the adjustment of their parameters according to modifications or new system requirements, making use of communication protocols [1]. The integration of distributed generation (DG), and the use of distributed energy resources (DER) on distribution networks (DN), have made power systems more complex [2]. This has changed the dynamics of the traditional networks [3], including bidirectional power flow, variable short circuit capabilities, and different fault paths on modern networks [2,4–9]. As a result, several issues have risen in the operation of traditional protections [10–13] such as, loss of selectivity, false tripping, miss operation and faults of the anti-islanding protections [14]. These are caused by the type of source of DG, the nature of the energy resource (solar, wind, fuel) [15], the number of installed units, and the mode of operation of the microgrid (MG) (grid-connected or islanded mode) [3,16–20].

These issues have led to the consideration of new strategies for the coordination and protection of the microgrids [21–33] that change and modify optimally the traditional protection schemes to ensure the correct operation of the MG in both connecting modes. Some authors propose to adapt and use traditional protections schemes [34–39]. For example, [34] proposes a method to coordinate different types of protections (over current relay (OCR), directional over current (OCDR) and differential) that ensures the operation of the MG on the faulty zone. This method demonstrated selectivity and an appropriate operation for a specific network topology; nonetheless, before generalizations can be made, this methodology will need to be evaluated in different scenarios and topologies.

Further, [35] shows that some of the issues about the integration of DG's are resolved by using distance relays for protection of a distribution network. However, in [36] is shown that distance relays are inappropriate for applications in MGs, and a new directional element is proposed. This new element detects the direction of symmetrical faults by using the magnitude of the positive and negative sequence impedance, along with the positive sequence current and the torque angle, as well as the direction of asymmetrical faults by using the magnitude and angle of negative sequence impedance. Simulations showed that this new directional element is effective for different conditions and types of failures in the MG.

The authors in [37], propose a method to analyze and improve the response of a distance protection for a wind power DG unit connected to the distribution system. By compensating the wind intermittence, the proposed scheme changes dynamically in accordance to the variations of the power network. In [38] the authors propose a relay protection scheme with two types of settings, assisted by a communication path for a MG, with the capability of working connected to the main grid or in islanded operation mode. To maintain the proper coordination, they use directional overcurrent relays with two sets of adjustments, with a communication path with low bandwidth. This method does not require adaptive and continuous modifications on the relay settings, and its primary functionality is completely independent of the communication signal.

A new technique is introduced in [39] to solve the problem of low fault current presented in a MG in islanded operation mode. The technique connects all the loads neutral

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points of the MG to the grounding system, which results in an increase in the fault current in the islanded mode of operation and reduction of the step voltage in every node.

To guarantee a correct operation of the MG, other authors recommend protection schemes that adapt to the MG operational conditions [40–50]. For example, in [40], the concept of agents for a DG anti-islanding protection is introduced, where multi-agent systems are used to coordinate the connection status of the DG unit. The authors in [41] suggest a protection scheme with digital relays based on a differential protection with a communication network applied to a distribution system with high penetration of alternative energy resources.

On the other hand, [42] brings into the discussion, the concerns of the protections in low voltage MG. The author presents an assessment of the use of communication protocols and the application of the standard IEC 61850, and suggests how to make the operation of the communication-based protections more reliable. In [43], the authors applied communication based protection schemes with differential relays to islanded systems, and test their efficacy and accuracy via real-time simulations.

In 2011, [44] proposed the use of an adaptive overcurrent protection, based on local information, with no need of a communication system, that allows to detect faults and the state of operation of the DG unit, by updating the relay tripping characteristics and their operational status. In [45], an adaptive scheme and a adaptable protection architecture is suggested for the new digital substations. The authors in [46] considered a hierarchical protection strategy based in digital overcurrent relays with communication assistance, that responds with adaptive settings according to the network topology, and differential control schemes, that protects the specific MG efficiently.

The authors in [47], describe how the use of the standard IEC 61850 and their logical nodes allow to update the protection settings, to locate and isolate a fault, and to restore a distribution network. The authors in [48], present and adaptive overcurrent protection, integrating both, the economic and technical advantages of fuses and relays on a MG. The relays are coordinated with the maximum nominal current of the fuses at the nodes, obtaining selectivity, reliability and speed in the operation when simulated. The authors in [49], discuss other configurations for the MG, specifically, ring microgrids, that emphasizes the protection and load adaptive behavior as a way to improve the detection of faults.

In 2018, the authors in [50], present an adaptive reclosing scheme, formed by a protective relay, two circuit breakers located at the side of the source and the load, and a battery energy storage system as an uninterruptible power supply. The scheme uses the neutral current in radial distribution network with unbalanced loads, determining the neutral current characteristics at the time a fault occurs, through the transformed wavelet analysis.

In view of the above, it is noticeable, how the concept of adaptive protection begins to be relevant, and how it has become one of the best options to protect a distribution network with MG integration.

Based on the review and analysis of the literature (sources shown in Fig.1), the next section, summarizes the adaptive protections, with an emphasis on ongoing implementations, challenges, and the impact of these types of protection. Section III discusses the current trends, and section IV offers some conclusions.

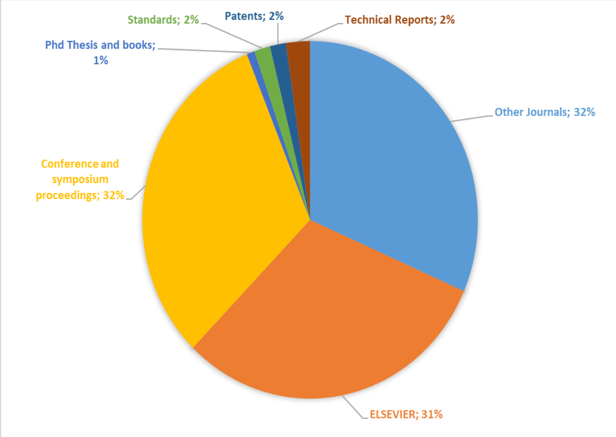

Fig. 1. Sources of reviewed literature

2. Adaptive Protections

Adaptive protections are characterized for storing several settings groups, and for applying them in the protection devices, in accordance with their operation topology. Through the implementation of communication protocols, [51,52][51,52] adaptive protections are able to modify their relay operation parameters [51,52].

Nowadays the advantages of the adaptive protection schemes are recognized over the traditional ones [53]. First, they are able to incorporate the changes in the status of the DG's and breakers in order to adjust the protective relays, and more importantly, they operate correctly.

According to [1,3,54], the adaptive protection schemes used in MGs, can be divided into two types of protections: centralized and decentralized –multi-agent - adaptive protections. A Graphical representation of each of these can be seen in [17] and [12], respectively.

2.1 Centralized adaptive protections

A centralized protection structure has the particularity of containing remote control units or central protection units that store all the information about the MG. This stored information relates to the number and type of DG units, existing loads, and the status of the breakers. The main purpose is to stablish links and monitor the equipment thru communication protocols that allow sending control signals to the protection devices.

Once the control units detect a change on the system's characteristics, be the connection or non-connection of the DG, or a failure, using local or remote data, they produce new calculations to update the operational conditions of the microgrid, and to adjust their parameters to finally isolate the failure in the best possible way [1,2].

The main components in a centralized protection scheme and its characteristics are as follows:

Centralized Control: The centralized control is located at the point of common coupling or at the station of the main re-connector; it counts with communication protocols of type IEC 61850 and IEC 61870-5-104. It incorporates all the DG's information, and carries over the control function. Common types of Centralized Controls, are the Programmable logic controllers, PLC's, which are used for decision making processes, the selection of pre-calculated setting groups, and control of the DG units, either remotely or locally, through a communication protocol based on IEC 61131-3 ([55,56][57,58]).

Grid automation controller: The grid automation controller is responsible for establishing the modes of operation of the MG automatically or manually. It takes into account all of the changes, topology modifications, protection settings, and remote control of the DG's. The signal is taken to the PLC's through the main server, where all the settings to be implemented are stored [56][59].

Information management servers: these collect and store the information obtained throughout the communication protocols from every relay, detect the system changes and gather the data when faults occur [60].

Supervisory Control And Data Acquisition: The SCADA/DMS behaves as the control center of the entire red in a centralized scheme, and performs the evaluation of all the components in the red. From this evaluation, the mode of operation of the Smart Substation Controller (SSC) is determined. This controller has the ability to modify the relay connection groups, and collect local data using sensors to determine the actual state of the network [61].

Microgrid central protection unit (MCPU): The MCPU performs the communication operation with all the relays in the MG and DG units. In accordance with status of the units, i.e., connection or non-connection, the protection equipment will update its settings and, ultimately, detect a fault in the system. Simultaneously, the control unit counts with a communication and control module (CCM), where time delays for selectivity are calculated and embedded into the protective relays. The communication scheme is achieved by a TCP/IP protocol, based on Ethernet network for instant communication [54].

2.2 Decentralized adaptive protections

A decentralized adaptive protection structure groups multiple intelligent entities named agents, which allow autonomy in the system decision-making processes [9]. These agents, which are distributed throughout the network, consist of hardware and smart software entities, including expert algorithms for task execution. The communication between the agents is achieved through protocols, which allow them to act in response to a specific assignment, and to stablish communication with the other agents, as a way to fulfill a common objective [62,63]. Adaptive protections are inserted in the DG units in the protection and control schemes [64–68], identifying and acting according with the system necessities.

According to [62], the principal elements that conform a multi-agent protection scheme are layers, and each layer is formed by several agents. The following lists the agents most commonly used:

Measurement agents: the measurement agents are located in the measurement devices of the MG; these include the current, voltage transformers, and phasor measurement units.

Protection agents: these agents use digital relays or Intelligent Electronic Devices (IED's) and overcurrent relays.

Mobile agents: *these agents* exchange information with the upper layers.

Performance agents: performance agents determine the relay settings incorporating the topological changes of the network.

System agents: these agents monitor the network using communication protocols.

Evaluator agents: these agents validate the settings information, selectivity and the operation of the relays.

In what follows, we will discuss the operational conditions, applications, the challenges, and the impacts of the decentralized and centralized adaptive protections:

2.3. Operational Conditions and applications

Operational conditions for the selection of a centralized protection: The operational conditions of a protective scheme in a MG, and the system protection needs will determine the more suitable choice between centralized or decentralized type of adaptive protection. The following are the conditions needed for the selection of a centralized protection:

Selectivity: *it requires* the implementation of more sensitive methods than those made for overcurrent protections, in order to detect faulty zones, without being affected by the generation units intermittence [69].

Communication and data transfer in short distances: a *centralized protection requires short-distance communications in order to reduce the delays on data transfers.* This is necessary to increase the reliability of the centralized protections in the process of data exchange [69].

Coordination in the operation of protective equipment: a centralized protection requires coordination in the operation of the protection devices. In this way it is possible to identify the location of a fault inside the MG through the tripping signals from the circuit breakers; hence, isolate the faulty zone without losing continuity in the network [69].

Optimal operation in the presence of dynamic changes of the MG*: this guarantees that the* adjustment and operational parameters from the protective devices are updated optimally [54,69].

System structure and protection hierarchy: due to the dynamic state of the MG, it is required to know its status continuously, to identify the connection mode of the generation units, and their protection coordination [54].

Simplicity: given that the data processing and control are directed from the central unit, the network elements like the circuit breakers, the controllers in the loads, and the generators need to be constructively simple [55].

Applications of centralized protections: Implementation of centralized adaptive protections have been reported in [56,61,70–77]. The authors of [56], report a pilot case of a MG integrated to a medium voltage distribution network, DN, in isolated mode of operation, which was implemented in Hailuoto – Finland. The system counted with a 20 kV feeder with a recloser, a 0.5 MW wind turbine, and a 1.5 MW diesel generator. The grid automation controller was located in the recloser to execute the control over the generation units, and to allow the communication process through the IEC 61850 protocol.

In [61], the adaptability of the protective relay for the DG unit is verified through real-time simulation (RTS). The authors in [70], propose an adaptive protection scheme with a microgrid central protection unit (MCPU), and 15 Intelligent Electronic Devices (IED's), which were distributed in the nodes, loads and DG units, with communications happening through a wide range wireless network, based on WiMAX technology. Its behavior was validated throughout simulations that showed the system complied with the latency requirements and protected the proposed MG.

In [71], an adaptive protection algorithm was verified in the IEEE 13 node modified model, by adjusting the protection settings in response to changes in the generation units. In [72], a Denmark 10 kV network was modified by adding loads and several DG units (1 PV, 5 wind turbines, 4 combined cycle plants). In addition, the authors test an online detection algorithm for an overcurrent adaptive protection, and a decentralized communication system to detect changes in the topology of the MG.

Using RTS, the authors in [73], report the effectiveness of an adaptive protection system for overcurrent relays for a countryside MG with DG units, changing their modes of operation using the IEC 61850 protocol. In [74], a centralized adaptive scheme with phasor measurement units (PMU's) and a control protection unit (CPU) was designed. This protection system was based on positive sequence components that were able to detect the incident and the affected zones, and protect against different types of faults and topologies in the MG.

In [75] the authors used a microprocessor relay model with a digital communication system instead of a CPU, able of detecting different type of faults and the faulty phase. Similarly, the system blocks the signal that flags the problem, protecting the MG in both modes of operation. In [76], an adaptive protection coordination scheme based in the algorithm of the Artificial Bee Colony (ABC) is presented. This protection allows an optimal directional overcurrent relay (DOCR) coordination in the IEEE 30 node with multiple DG units, where a master server is used as central unit, enabling communication with the relays as a way to select the proper settings for each device and monitoring the network changes.

In [77] a MG is modeled with distributed energy resources, electronically coupled with an adaptive protection scheme. This model ensures the MG protection for different types of contingencies, independently of its operation mode. It uses reclosers, overcurrent relays based on microprocessors, and a microgrid communication path between all the relays and the DG units. The novelty of the proposed scheme is its capacity to monitor the MG, and instantaneously update the relay fault current, according to the variations in the system.

The authors in [78], work with a patented adaptive overcurrent protection method on a pico grid formed by a MCPU, updating its mode of operation and the protection settings, in response to the location and type of fault

Operational conditions for the selection of a decentralized protection: The following are the conditions needed for the selection of a decentralized protection:

Selectivity: selectivity in a decentralized protection is achieved throughout the intelligence incorporated in the local devices, and the cooperation between agents, which allow the identification of faulty zones with great accuracy and reliability, avoiding false tripping.

Decentralized architecture: the decentralized architecture requires that the decision making and local information exchange ***be*** adjustable to the distributed characteristics of the MG [79].

Flexibility: a decentralized protection must be able to adapt to the conditions of the system, independently of the type of generation or load in the system [79].

Resilience: a decentralized protection must have the capacity to respond and isolate a fault, without interrupting its operation and objectives [79,80].

Communication and data transfer at different distances: A decentralized protection must be able to transfer data at different distances. Depending on the communication system, and on its speed, a decentralized protection system can communicate its information and monitor the system locally or remotely, offering robustness.

Local operation of protective devices: A decentralized protection must be able to perform self-validation, self-correction, and act quickly in response to a contingency [81].

Simplicity: decentralized protections must have simple agent platforms with precise algorithms that ensure an optimal use of the MG resources [82].

The use of decentralized adaptive protections for analysis, protection, isolation and restoration of the energy service after a contingency, using different methodologies have been reported in [59,83–87]. In [59], relays settings are modified off-line through simulations and the faults are cleared on-line, maintaining the selectivity of the protective devices. In [83], an expert algorithm that mimics the human cellular behavior of the immune system is adopted for the agents, improving the reliability in the equipment response and avoiding the use of the central controllers.

According to [84], multi-agent systems (MAS) are applied to achieve an efficient power management and fault restoration, forming dynamic groups for the administration of the agents, with a flexible structure. The authors in [85] propose a multi-agent system based on the magnitude and direction of the sequence current to locate and isolate a fault in a MG. The authors in [86] use the Ybus algorithm, defining Ip currents as initial conditions for the modes of operation of the MG. The communication among agents is achieved using TCP/IP protocols.

In [87], the phase angle of a current signal is compared and a communication assisted method is implemented using the protocol IEEE std. C37.118.

In [88], a decentralized adaptive protection development based on distributed logic was patented. The system divides the distribution network (DN) into multiple areas, which are composed of a busbar, an area controller, and a protective device. This method allows for the detection of any local changes in the network, and re-calculation of level of the short circuit in the specific area.

2.4. Challenges

Despite finding several examples of applications of adaptive protections with clear significant operative advantages, they are still in the process of research and development. One of the main challenges identified in the reviewed literature is the operative speed of the protection, the re-adjustment of its settings, and the minimization of the number of users affected from contingencies that can be caused by the connection and disconnection of big DG units, or by the change in the operation mode of the MG [56]. Other challenges include the improvement of the delay times and sensitivity of the adaptive protections to guarantee a correct coordination in their operation [89].

Due to all the possible scenarios in a MG, it is complicated to calculate and consider settings and adjustments in an infinite number of cases. As a result, to ensure a complete protection, the most representative and significant cases are selected [73]. Similarly, when considering different distributed energy resources, it is necessary to define the criteria for the relay settings [90].

On the other hand, like smart grids, adaptive protections depend heavily on communication systems. Therefore, all the issues that are inherent to any communication system also affect them [91]. In addition, they are vulnerable to the problems of interoperability and exchangeability [92]. and to cyber-attacks [93–95]. All these are external issues that affect their operational integrity [91].

Decentralized schemes also present many challenges that need to be addressed and resolved before they become a popular alternative [96]. These challenges include portability, security, and emerging behavior of the multi-agent systems [79]. Similarly, delay times in data transfer and communications [82,86,97], and delays on the circuit breakers operations [98] need to be improved. Furthermore, it is necessary to develop more economically efficient schemes with PMU's [87].

Additional challenges include addressing information security, [99]; obtaining standardization of the agent modules, [62], [79], [81], [99]; dealing with the impact of government regulations and achieving economic efficiency [100,101]. Furthermore, the MAS need to be implemented in real settings, and tested in systems that are more complex [101–103].

2.5. Impacts

According to the authors in [104], adaptive protections are seen as a necessary element in a smart grid and are currently among the best options for protection of MGs.

As discussed above, centralized adaptive protections rely on the network paths, and communications to detect changes in the system and adjust parameters. Therefore, events that lead to a loss of information and communication between the units will greatly affect the MG. These include cyberattacks carried out throughout the system's communication network that can cause distortions in the IED's units and transmit malicious codes that lead to buffer overflows that create inconveniences for the control of the system's data. Similarly, of importance are cyberattacks that occur in the data transmission systems like the Generic Object Oriented Substation Event (GOOSE), and the Sampled Measured Valued systems SMV, which are both part of the IEC 61850 protocol [93,105]. Because these carry vital information (alarm s, status, and control) between devices, alterations of these values could create an automation breakdown, causing a circuit breaker to miss an operation. The authors in [106] summarize the cyber security standards and privacy for smart grids.

Selecting decentralized adaptive protections in accordance to the application will reduce costs (due to the fact that voltage transformers are not used [87]); it will shorter the data transfer process and reduce the delay time while isolating a fault [86]. In addition, it will guarantee protective selectivity, offering robustness to the system [59,82,107], and accuracy and reliability in the operation of the MG [108].

Furthermore, the coordination among agents and artificial intelligence articulation [83,109,110] provide autonomy to the devices used for decision making processes, in response to the changes of the MG. This leads to an optimal use of energy resources with better reasoning times [82]. In addition, this allows to modify the system architecture, determine with precision and restore the faults dynamically [84,111], analyzing, validating, acting and managing the daily system operation [81,112,113]. Additionally, the local decision making process improves the communication system response and the errors related to them [114].

3. Future Trends of Adaptive Protections in Electric MG

As the development and implementation of micro-grids increase around the world, so will the use of adaptive protections in MGs. It is clear then that validating their operation schemes in real-time, becomes a necessary step in order to guarantee a reliable operation. Some studies have begun using real-time simulation (RTS) [69,115–119] with hardware in the loop configuration (HIL). Optimal coordination adjustments have been determined for an adaptive protective scheme before its physical implementation. Tests performed with real-time (RTS) and non-real-time simulation (NRTS) has been also compared [120], validating the selectivity, reliability and speed for the adaptive overcurrent protection systems.

Other research's has shown the use of Real Time Simulations (RTS) as a way to test communication protocols [121], like the IEC 61850 and the third generation of the Distribution Network Protocol (DNP3). Their integration into smart grids in real-time will be for sure in continuous development. The authors of [122], provide a comprehensive summary of RTS in applications in MG, outlining the test techniques, and existing methodologies in regards to the quality of power, stability, control and protections of the MG.

According to [123], the future of adaptive protections, points to the development of new and novel methods, that will address improvements in the communication systems [123–125]. Developments that make adaptive protections suitable to protect any type of fault, for example, capable of detecting high impedance faults [126], and that are capable of optimizing the protective relay capacity [126], in order to maintain the security in any type of MG (AC, DC, AC/DC) [127]. Similarly, [128] and [129] propose schemes that are more robust for hybrid, and islanded MGs, respectively, as solutions to some of the impacts discussed above.

Currently, IEEE 1547 and IEEE 2030 specifications do not include standards for the interconnection and interoperability of distributed energy resources by adaptive protections, [130], [131–133]. Therefore, progress needs to happen in the development of standards and regulations that allow for the unification of the design, planning, and operation of MGs with adaptive protections.

Tab.1 and Tab.2 summarizes, the applications, challenges, and trends for a centralized and decentralized adaptive protection respectively, discussed in the reviewed references.

Table 1. Applications, challenges, and future trends of a centralized adaptive protections

IMPACT OF ADAPTIVE PROTECTIONS IN MG				*REFERENCES*
Applications		*Challenges*	*Trends*	
Analysis, monitoring and fault diagnosis	*Fault location*	*Communication speed*	*Differential protection methods*	[69],[72]
	Fault isolation	*Improve the operative speed*	-	[54,56,69]
	Information management and system status	*Improve the communication links with the central control unit in long distances*	-	[54,69,72]
		Change in the configuration of the DG's	-	[71,73]
Protection coordination	*Relay settings modification (off-line)*	-	-	[54,55,69,71]
	Reorganization of the protections hierarchy	*Modification and update of delay times and protections adjustments*	-	[54,89]
-	-	*Limited fault scenarios*	*Calculation of settings in Real-time*	[89]
-	-	-	*More sensitive protection schemes*	[89]
			IEC-61850 based communication links	[54,89]
-	-	-	*MG security*	[127]

Table 2. Applications, challenges, and future trends of a decentralized adaptive protections

IMPACT OF ADAPTIVE PROTECTIONS IN MG				*REFERENCES*
Applications		*Challenges*	*Trends*	
Analysis, monitoring and fault diagnosis	*Fault location*	-	-	[83,85–87,99,108]
	Fault isolation	-	-	[83,86,87,100,108];
	System restoration	-	-	[83,84,86,87,108,111]
	Clearing faults on-line	-	-	[59]
Protection coordination	*Relay settings modification (off-line)*	-	-	[59,81,98,103,112]
Power and demand management	*Load ejection*	-	-	
	Efficient power management	-	-	[82,84,103,114]
-	-	*Improve delay times in data transfer*	-	[79,82,86,98]
-	-	*Economical protection schemes and less sensitives*	-	[87,100,101,111]
-	-	*Information security*	-	[79,99]
-	-	*Standardization of the agent technology*	-	[62,79,81,99,101,108]
-	-	*Real and complex systems implementations*	-	[79,84,102,103,112]
-	-		*Validate the information delay times with simulation software's and expert algorithms software's*	[59,86,98]
-	-		*Development of more simple agents and less sensitives*	[86]
-	-		*Implementation of intelligent devices, sensors, optimal measurements in different sections of the network*	[87]
-	-		*Prove the efficiency of the protection schemes in different*	[84,108,123]

IMPACT OF ADAPTIVE PROTECTIONS IN MG				*REFERENCES*
Applications		*Challenges*	*Trends*	
-	-		*faults scenarios, devices and offer a global solution* *Tests in more complex and real systems*	[79,103,112,128]

4. Conclusions

The current state and future trends of adaptive protections in MG were presented, as well as their applications, the impacts from their implementation, and the challenges that lie ahead. It was observed that more efficient schemes and reliable communication systems still need to be developed, and that research and development needs to focus on the development of systems that are less vulnerable to contingencies and cyber-attacks. The progress in decentralized adaptive schemes will need to provide protections that are more dynamic. These need to be equipped with artificial intelligence to guarantee decisions and operation autonomy, to monitor and diagnose faults, and ultimately, accomplish the correct protection coordination. In order to ensure their reliability in real-life settings, it is necessary to carry over tests and detailed validations of adaptive protections that include tests of their communication systems using real-time simulations. Adaptive protections were shown to have a positive impact on MGs, specifically in regards to selectivity, speed, and sensitivity. According to the reviewed literature, as the number of applications of adaptive protections in real and more complex settings grows, evidence on their effectiveness and reliability will be clear. As a result, adaptive protections will be seen as the proper scheme for protection of any type of microgrid.

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