Australian Power Quality and Reliability Centre

# Microgrids: Control, Protection & Communication

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# 1. Introduction

Microgrids are envisioned to be a critical building block of future smart grids. They integrate local distributed generators, storage units, and loads and can offer various advantages to power systems. Such benefits cannot be achieved without an adequate communication scheme and advanced control and protection systems ensuring the reliable and safe operation of microgrid under different operation scenarios.

This technical Note is the second of two dealing with microgrids. The first Technical Note discussed the definition of microgrids and their structure along with energy storage technologies. In this Technical Note, firstly, the microgrid control is examined by classifying the control strategies into three control levels and explaining the major approaches for maintaining acceptable voltage and frequency within the microgrid and achieving the active and reactive power setpoints. Further, the microgrid synchronisation with the distribution grid, which invokes certain challenges, is discussed.

The second part of this Technical Note deals with microgrid protection. The characteristics of microgrids including the connection of inverter-interfaced distributed generators (IIDGs) present different challenges for maintaining the proper protection coordination under varying operating conditions. The Technical Note discusses these challenges, the unique features of IIDGs, and the conventional and modern approaches for microgrid protection.

The final section of this Technical Note examines microgrid communication systems, their characteristics, and communication standards and physical medium technologies available for microgrids.

# 2. Control of Microgrids

The control of microgrids is a challenging task considering the range of different technologies, architectures, and operational modes. The power converters connecting DERs to microgrids require advanced control strategies for control of output voltage and current and to meet the desired active and reactive power setpoints.

If the microgrid is connected to a strong distribution network, the voltage and frequency will generally have only small variations and microgrid stability is maintained by the main distribution network. In this case, converters act as “grid-feeding” converters by injecting active and reactive power into the network and the DER unit can, therefore, be seen as a current source, whose power flow can be adjusted by varying the issued setpoints [1].

The control strategy in islanded mode is more challenging since the voltage and frequency of microgrid as well as the balance between the loads and generation must be maintained by the microgrid itself. A “grid forming” converter acts as a voltage source and regulates the voltage and frequency in the absence of the main grid.

The main functionalities of the microgrid controller can be summarised as follows [2] [3]:

- Seamless transition between the islanded and grid-connected modes of operation.
- Voltage and frequency regulation under all operational scenarios.
- Active and reactive power control to maintain the desired power-sharing.
- Ability to withstand oscillations and maintain the stability of the microgrid.
- Energy management and economic dispatch of the microgrid for maximising the benefits.

## 2.1 Control Hierarchy in a Microgrid

The objectives of microgrid control can be achieved using three control levels as shown in Figure 1.

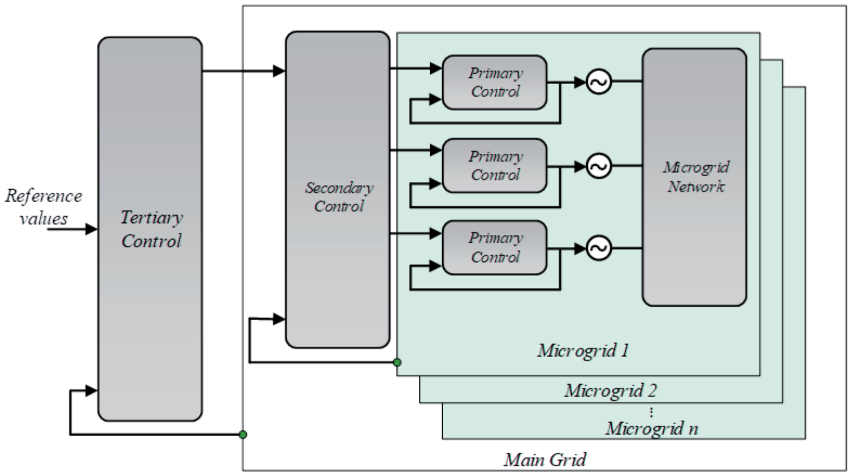


Figure 1: Hierarchical control structure for microgrids

This hierarchical scheme consists of primary, secondary, and tertiary control levels which are responsible for different control actions and operate at different time scales. The control at these levels can be realised using various control methods.

Primary control is implemented by local controllers and has the fastest response. It includes the device-level control embedded in the DER which utilises current and voltage control loops. The primary control regulates the voltage magnitude and frequency at converter terminals and the output current and fulfils the active and reactive power sharing among DERs [2]. It is also capable of islanding detection for change of control modes. Control at this level is mainly achieved using local measurements and does not require communication.

Secondary control acts as the energy management system (EMS) of the microgrid. It corrects any voltage and frequency deviations caused by the primary control operations. The optimal dispatch of DER units, power quality improvement, and synchronisation of the microgrid with the main grid are among the tasks performed at this control level [3] [4].

Tertiary control acts at the gird level and sets optimal setpoints based on needs and requirements of the utility network (e.g. active or reactive power). It coordinates the power flow between the microgrid and the main grid and communicates with the microgrid for providing the necessary services such as frequency regulation and voltage support. It also optimises the operation of a community of microgrids if there is more than one microgrid connected to the distribution network. Electricity market functions are also conceived at this level [5].

## 2.2 Primary Control

The control strategy at this level can be divided into two stages [3] [6]; a controller regulating the converter output and a control loop for controlling the DER power-sharing.

The converter controller consists of an inner current control loop and an outer voltage control loop. These control loops compare the voltage and current values measured at the converter output with the reference values to regulate the voltage and current values.

The main control strategies for power-sharing control are droop-based methods. The droop control emulates synchronous generator behaviour in adjusting the mismatch between the load and generation based on the droop curve. In conventional droop methods, the frequency and voltage of the microgrid in islanded mode is regulated using $P - f$ and $Q - V$ droop relationships.

The conventional droop method has several limitations due to characteristics of distribution lines and loads [2, 7]. This method is only applicable for highly inductive transmission lines and its application for distribution networks with low X/R ratio is problematic. Additionally, the presence of nonlinear and/or unbalanced loads adversely affects its control performance. Therefore, improved droop methods such as voltage-real power droop (VPD)/frequency-reactive power boost (FQB) droop and non-droop-based methods such as master-slave control strategies are suggested to overcome the problems of conventional droop-based methods.

## 2.3 Secondary Control

Generally, secondary control methods can be divided into centralised, distributed, and fully decentralised approaches. In centralised control schemes, one central controller communicates with local agents and makes the decisions. Decentralised control methods rely on local controllers which make decisions without data exchange with other agents. Distributed control methods differ from both centralised and decentralised methods since the local agents communicate with each other, but they also have the autonomy to make decisions.

Centralised and distributed control schemes are the main control methods for secondary control. In the centralised control scheme, the microgrid central controller (MGCC) communicates with DERs and loads using a bidirectional data link and provides the setpoints to them. It uses the information from DERs and loads, forecasting systems, and other relevant information such as the network data and constraints in order to determine the optimal dispatch of the units and decide on the appropriate commands.

The multiagent system (MAS) is the most common method for distributed secondary control. A MAS can be briefly described as a system composed of multiple intelligent agents, provided with local information, that interact with each other in order to achieve multiple global and local objectives [3]. A simple MAS control architecture is shown in Figure 2. Other popular methods of distributed secondary control are model predictive and census-based control techniques.

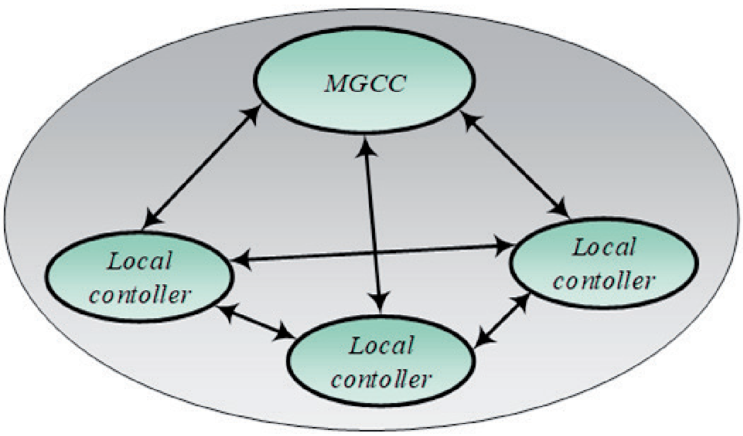


Figure 2: A sample MAS system for microgrid

The main advantage of a centralised control method is the ability to make optimal decisions based on the knowledge of the whole system. However, centralised control is prone to possible failures which may result in the collapse of the whole system. The lack of plug and play capability and extensive data interchanges are also among its drawbacks. The major benefits of distributed control include plug and play capability and increased reliability and robustness. However, the system might not operate in the optimal state. In general, the centralised control method is more suitable for stand-alone (isolated) microgrids with a fixed structure and distributed schemes are more appropriate for grid-connected microgrids with a flexible structure.

## 2.4 Microgrid Synchronisation

One of the most challenging tasks of a microgrid control system is to provide a seamless transition from islanded mode to grid-connected mode by a suitable synchronisation mechanism. Closing the breaker at the PCC without maintaining synchronisation can cause large inrush currents, damage devices, and reduce the lifetime of the microgrid equipment. Additionally, the stability of the microgrid during and after synchronisation must be ensured.

The synchronisation mechanism acts by confirming that the frequency, voltage magnitude, and voltage phase of the microgrid match those of the utility grid within the allowed tolerance ranges. These ranges are usually specified by the standards such as those defined by IEEE 1547.4 [8].

The synchronising process of a microgrid which only has one generating unit is a simple task. However, today's microgrids are comprised of a variety of DER technologies with different characteristics and unique control systems and supply different types of loads with specific features. Therefore, developing a proper synchronisation mechanism, that is able to coordinate several DER units to precisely match the grid parameters at the moment of connection, is of critical importance.

Various synchronisation methods are proposed in research studies and/or applied in microgrid projects. The most important ones are briefly explained in the following [8] [9].

**Active synchronisation methods:** Active synchronisation is achieved by an inbuilt central control mechanism that senses the frequency, voltage, and phase information of the microgrid and the utility grid and performs appropriate control actions. Active synchronisation methods require communication with DER units to adjust their voltage and frequency setpoints. These methods have higher complexities and higher capital costs; however, they offer an automatic synchronisation with high reliability.

**Passive synchronisation methods:** Passive methods employ a synchronisation check by sensing the electrical parameters at both sides of the PCC. These methods are similar to the existing synchronisation methods where a synchrocheck relay is used to calculate the differences between the frequency, voltage magnitude, and phase values. The synchronisation is permitted only if these differences fall in the pre-defined limits.

**Open-transition transfer:** In this method, the microgrid is simply de-energised before reconnecting to the main grid.

Other synchronisation methods with distinctive features are suggested that differ based on the control approach, communication needs, and so on. For example, distributed synchronisation controls are developed to overcome some of the problems associated with central control methods [10].

# 3. Protection

The protection of MV and LV systems is a well-studied concept and usually, protection coordination can be suitably maintained with conventional protective devices such as over current (O/C) relays and fuses. Although microgrids are mostly connected at these voltage levels, microgrid protection presents different challenges. Present microgrid deployments mainly rely on traditional protection methods in both islanded and grid-connected modes. Various studies have proposed novel microgrid protection schemes; however, these have not led to a commercially available protection system for microgrid applications.

## 3.1 Microgrid Protection Technical Challenges

The main challenges that affect microgrid protection are summarised in the following [11] [12]:

- Transformation of the distribution system topology from radial to mesh and the effect of DERs on feeding faults.
- Changes in microgrid modes of operation from grid-connected mode to islanded mode which implies totally different current levels.
- Changes that can happen in the microgrid configuration due to the on/off status of DGs which affect protection coordination.
- Variation in DGs contribution to the fault current based on the DG types, number, and locations, and their control modes.
- Unconventional fault behaviour of inverter interfaced DGs (IIDG) resulted from the response of voltage source converters (VSCs).

In the following, some of these technical problems are illustrated.

**Fault behaviour of IIDG units:** The control of synchronous generators (SG) reacts slowly compared with the fault duration. The fault current of a SG can be modelled using the sub-transient, transient, and steady-state components.

The IIDG reaction to faults is fundamentally different from that of the SGs. IIDG units intrinsically have a very fast dynamic and their fault response depends on their control, thus, it is not possible to define a closed-form equation to model IIDGs' faults [13].

**Low voltage ride-through:** Standards such as IEEE 1547 [14] and national codes [15] [16] have set requirements for the DGs connected at transmission and distribution systems regarding their operation during faults and voltage sags. Depending on the system codes and voltage level, these rules mandate that DGs remain connected to the network during faults and voltage sags, which is usually referred as low-voltage ride-through (LVRT) or fault ride-through capability, and to prohibit DGs from forming unintentional islands (anti-islanding protection).

LVRT capability is specified through a voltage versus time curve that defines the time that the DG should remain connected to the grid for different voltage levels. A typical LVRT curve and a more complicated LVRT curve (for renewable resources in the European Union) are shown in Figure 3 [17] [13].

The LVRT requirement is configured to ensure that the DGs do not exacerbate unfavourable network conditions by disconnecting from the grid during voltage sags and to actively contribute toward the stability of the power system by delivering reactive power [12].

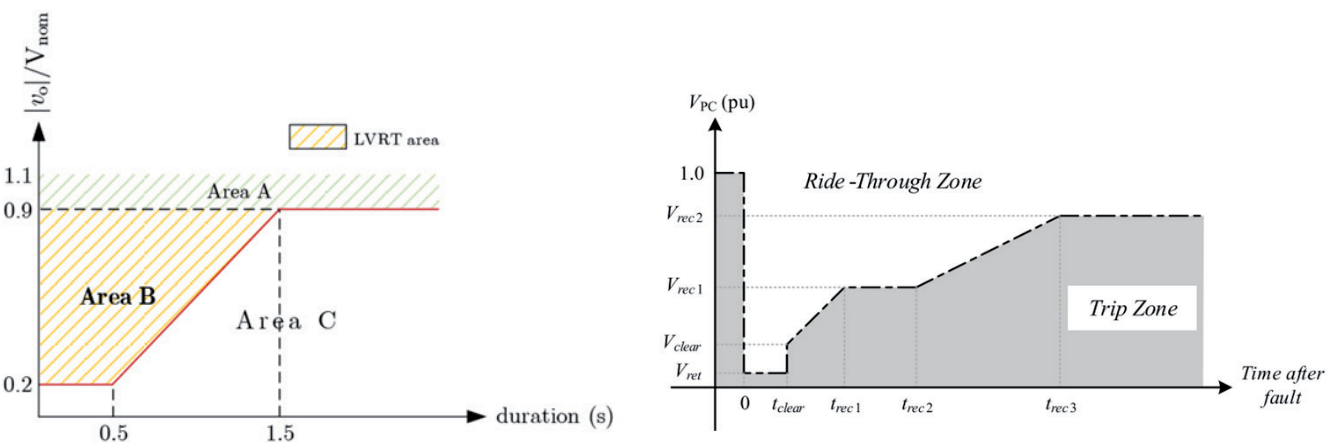


Figure 3: Fault ride-through capability of IIDGs: i) a typical LVRT curve, ii) LVRT for renewable resources in the EU

**Fault levels:** While a SG can contribute very high currents during faults, the fault current contributed by IIDGs is generally limited to approximately 2-3 times the rated current value due to the low thermal capability of power electronic devices. Therefore, in microgrids with a high share of IIDGs, the fault level can change significantly between the grid-connected mode and the islanded mode. During grid-connected mode, the fault level will be high because the distribution network is feeding the fault. However, the fault current magnitude will drop to much lower values during islanded mode. This means that fault detection methods cannot rely on high fault currents as a mechanism of detecting faults. For example, overcurrent protection will act very slowly or may not be triggered at all for some fault levels [18]. In addition, the fault magnitude will keep changing based on the changes caused by factors such as DG status and configuration. Therefore, proper protection coordination using traditional protection relays cannot be maintained easily if it at all.

**DG power factor:** Another difference between conventional SG units and IIDGs is that, in the case of IIDGs, the fault current angle is determined by the control system of the converter. Therefore, grid codes at transmission levels might require these units to produce reactive power after the initiation of the fault. For distribution networks, DGs usually operate with a power factor close to unity and they can continue to work with such power factor for faults in grid-connected mode. However, the microgrid may need reactive power support if the fault happens during islanded mode. Hence, the IIDG units are capable of sustaining operation at a wide range of power factors which need to be considered in the protection systems [17].

## 3.2 Conventional Protection

The technical challenges of microgrids adversely affect the operation of conventional protection schemes in terms of fault detection, fault polarisation, and phase selection. False operation of relays such as directional overcurrent and distance relays is possible in microgrid applications.

Due to low fault currents in IIDG-based microgrids, using a voltage-based fault detector is generally more reliable since the voltage drop is more significant than the corresponding current increase during the fault. Yet, maintaining protection coordination can be very challenging as the voltage change would be almost the same in most parts of the system because of the short length of the feeders [17].

For directional overcurrent protection, it has been shown that none of the traditional methods for identifying the direction of the fault i.e. positive-sequence, negative-sequence, zero-sequence, and phase directional elements is immune to false operation even for microgrids with a relatively simple structure. This erroneous detection stems from the distinctive IIDG response to faults that was briefly explained above. In addition, detection of the faulty phase can also be very difficult not only because of the low current magnitudes but also due to the unconventional behaviour of IIDG during faults [13]. The detection of a faulty phase is mostly useful for single-pole auto-reclosing and may not be required for microgrid applications.

Distance relays offer several advantages compared with directional overcurrent relays for active distribution networks i.e. networks integrated with DGs. Therefore, academic studies and industry practitioners have contemplated the application of these relays for active distribution networks and particularly microgrids [19]. The small fault currents of IIDGs and the substantial difference of fault magnitudes between grid-connected and islanded modes do not affect distance relays, which make them an attractive alternative for directional overcurrent relays. However, distance relays suffer from different problems when they are utilised for IIDG-based microgrids. There is a possibility of overreach and underreach issues caused by DG's outfeed and infeed currents, respectively. The major problem again results from the unconventional fault behaviour of IIDGs which can lead to false operation for both balanced and unbalanced faults [17].

Differential protection operates by measuring the input and output currents of a protected zone such as the line, transformer, or busbar. A fault is detected when the difference between the measurements exceeds a threshold. This fundamental operation principle of differential relays makes them immune to most of the problems associated with directional overcurrent and distance relays. In addition, some of the problems affecting the performance of differential relays at transmission networks, including current transformer (CT) saturation and capacitive charging currents, do not exist for distribution networks which further encourage their deployments for microgrids [13]. However, implementing differential protection is a very costly option compared with other protection systems. The high number of load nodes in distribution networks, the necessary high-bandwidth communication systems, and the need for local backups such as overcurrent relays are among the main disadvantages of differential protection systems [17].

## 3.3 Other Protection Schemes for Microgrids

Studies have increasingly considered the complexity associated with microgrid protection. In addition to (modified) conventional relays, a diverse range of solutions have been proposed for the adequate protection of microgrids. In general, the higher computation burden, higher costs, requirement for communication systems, and the lack of proper function for all the configurations are among the drawbacks of such methods. Conversely, they can achieve improved protection compared with the conventional overcurrent and distance protection systems.

Adaptive protection schemes are the most popular solution investigated for microgrids. Adaptive protection is usually referred to as a protection scheme that adjusts itself based on the power system conditions [20]. As a simple example, several settings can be pre-defined for an overcurrent relay, with the appropriate setting automatically selected by the protection relay based on the network situation. Microgrids experience different changes such as different operation modes and on/off status of DG units which significantly affect their configurations and current levels. Therefore, fixed protection settings cannot provide adequate protection in all scenarios. In this regard, various adaptive protection schemes have been suggested to maintain the protection coordination of the microgrid.  Most of the suggested adaptive protection solutions require the information exchange between the adjacent relays and/or between the relays and a central protection unit. Examples of adaptive protection schemes include metaheuristic-based approaches, fuzzy-based methods, and MAS-based approaches [20]. Several challenges are associated with the adaptive protection proposals including the necessity to continuously update the configuration of microgrid, the need for the communication system, and the calculation of fault currents under different operation scenarios [21].

Other methods such as the total harmonic distortion measurement, travelling wave-based methods, and wide-area protection using phasor measurement units (PMUs) are proposed, each offering several advantages and disadvantages.

In addition to the above, the use of physical devices for adjusting the current levels have been examined in the literature. The utilisation of energy storage units to increase fault current levels and the use of fault current limiters (FCLs) to limit the fault magnitude from the grid side or SG units are among such proposals [12] [21]. Increased costs, as well as the need for proper control and operation, are among the challenges of using such devices.

# 4. Communication Architectures for Microgrids

Many microgrid components such as DERs and loads are equipped with information and communication capabilities which allow them to receive and send data over communication links. This notion gives rise to intelligent electronic devices (IEDs) [22] which are connected with each other and also communicate with the central controller for transferring operational data and performing control actions.

Communication infrastructure plays an important role in the control and management of the microgrid. The microgrid communication network establishes bidirectional connectivity among microgrid components and guarantees its secure and optimal operation. Many microgrids still rely on legacy communication technologies. New efforts such as standards and protocols are under development which address the unique challenges of microgrids.

## 4.1 Reference Models

Information exchange between different nodes in a communication network is done through predefined protocols. In this way, a protocol suite consists of a layered architecture in which each layer function is based on one or more protocols [23]. The ISO-OSI (International Standards Organization/Open Systems Interconnection) model is the well-accepted communication architecture and includes seven layers as shown in Figure 4. This is a conceptual model that standardises the functions of a communication system without regard to its underlying structure or technology.

Recently, the use of the Internet protocol suite has been increasing due to its suitability for decentralised communication architectures in microgrids. The Internet protocol suite is a conceptual model and a set of protocols which specify how data should be packetised, addressed, transmitted, routed, and received. It is commonly known as TCP/IP since it works based on the Transmission Control Protocol/Internet Protocol (TCP/IP). This suit is structured into four layers including link or network interface, internet, transport, and application layers. TCP/IP layers are also illustrated in Figure 4.

| OSI MODEL | TCP/IP MODEL |
|---|---|
| **Application** | Application |
| **Presentation** | |
| **Session** | |
| **Transport** | Transport |
| **Network** | Internet |
| **Datalink** | Network interface |
| **Physical** | |

Figure 4: Different layers of OSI and TCP/IP models

## 4.2 Legacy Communication Networks in Power Grids

Traditional electricity networks mostly rely on centralised communication architectures where a central controller communicates with the components and makes decisions. Such frameworks are realised using SCADA (supervisory control and data acquisition) systems. SCADA systems work based on the EPA (enhanced performance architecture) model which contains only three of seven layers (layers 1, 2, and 7) defined in the OSI model [23]. Use of only three layers reduces functionality. The low data rate, asynchronous data transfer, and use of direct communication links (no internet) are among other features of these systems [22]. Various protocols are traditionally used in power systems including MODBUS, DNP3, PROFIBUS, and CANBUS.

## 4.3 The Communication Needs of Microgrids

The unique features of smart grids in general and microgrids specifically require new standards and protocols for communication. For DERs, their dispersed geographical locations, the much higher data traffic, and the real-time monitoring and control are among the novel characteristics.

Any communication network needs to satisfy the performance requirements for each microgrid application such as protection, monitoring, control, synchronisation and demand response. These requirements require different bandwidths and acceptable time delays [22]. Data transmission requirements for microgrid functions based on the IEEE, IEC, and ETSI standards are shown in Table 1 [9]. In contrast with the IEC and ETSI which specify the time requirements for each function, IEEE 2030.7 classifies the control objectives (such as power control, energy management, synchronisation, etc.) into four blocks and indicates a response time for each block.

| IEEE 2030.7 | | Maximum Latency Requirements | | |
|---|---|---|---|---|
| **Control Block** | **Action Time** | **Task** | **IEC 61850** | **ETSI** |
| **1** | Sub-sec to 5-10 min | Protection | 4 ms | 1-10 ms |
| | | Control | 16-100 ms | 100 ms |
| | | Messages requiring immediate actions | 1A: 3 or 10 ms<br>1 B: 20 or 100 ms | Not specified |
| **2** | Few sec/min | Time synchronisation | Accuracy | Not specified |
| **3** | 5-10 min to 1 day | Monitoring | 1 s | 1 s |
| **4** | 5-10 min to 1 week | Operation and maintenance | 1 s | Not specified |

Table 1: Data transmission requirements for microgrid functions

Simulation studies and practical experiments have investigated the effects of communication network problems such as packet loss, latency, and jitter on microgrid operation [9]. It has been shown that these issues can have a very negative impact on the system operation in terms of voltage, frequency and power losses.

In addition to the aforementioned characteristics, the communication system must ensure interoperability among various IEDs, communication technologies, and protocols. Furthermore, it should be flexible enough to cope with the frequent changes that happen in microgrids by adding or removing devices. Cybersecurity issues are another major concern as the number of interconnected devices grows continuously.

## 4.4 Available Standards for Microgrid Communications

Some of the available standards which address microgrid communications and network needs are IEC 61850, IEC 61968, IEEE 1547.x, and IEEE 1646. The specifications of these standards are summarised in Table 2 [22].

| Standard | Detail | Application |
|---|---|---|
| IEC 61850 | Communication between devices in transmission, distribution, and substation automation system | DER/microgrid |
| IEC 61968 | Data exchange between device and networks in the power distribution domain | Energy management system |
| IEEE 1547.x | Interconnecting DERs with electric power systems | DER/microgrid |
| IEEE 1646 | Communication requirements | Substation automation |

Table 2: International standards for microgrid communications and networking

IEC 61850 is a well-known standard which defines data models and communication protocols for IEDs in power systems. It enables the integration of all measurement, monitoring, control, and protection functions in a common protocol framework. By abstracting the definition of data items and services, it facilitates the interoperability among different IEDs and allows mapping the data objects and services to any other protocol that can meet the specified requirements [24]. Therefore, it can use legacy protocols such as MMS (Manufacturer Message Specification) for communication messaging, GOOSE (Generic Object-Oriented Substation Events) for fast messaging, and SNTP (simple network time protocol) for time synchronisation [22]. This standard also deals with the mapping of the services into a communication stack, most importantly the TCP/IP stack.

## 4.5 Area Networks at Different Levels

The communication network can be organised into different area networks based on the operation levels including home area network (HAN), building area network (BAN), industrial area network (IAN), field/neighbourhood area network (FAN/NAN), and wide area network (WAN) [25] [9].

HAN, BAN, and IAN are local area networks (LAN) used by customers. HAN is used for interconnecting smart appliances and PV and storage systems inside the home and can be used for home energy management systems. BAN and IAN are more complex networks that connect various devices and are used for automation as well as energy management tasks of buildings and industrial plants.

FAN and NAN work at the secondary substation level and establish the communication between customer networks and the WAN. They manage different tasks such as the transmission of smart meter data, load management, and distribution automation.

WAN covers a wide geographical area and handles long-distance data transmissions with a large number of communication nodes using high bandwidth communication networks. These nodes may include smart meters, phasor measurement units, transmission and distribution substations.

## 4.6 Physical Communication Links

A communication link can be realised based on different technologies using wired or wireless communication media. The selection of a communication medium technology depends on various factors such as the specific application, implementation and maintenance costs, the number of devices, the needed bandwidth and coverage.

Wired technologies offer high reliability and security but have higher costs and are less flexible to network changes. Power line communication (PLC) systems operate by sending the modulated carrier signals on the available power lines. This is a cost-effective solution, however, it faces several technical challenges owing to the propagation characteristics of power system elements.

Instead of using PLC systems, dedicated wireline networks can be used for constructing the communication system including technologies such as synchronous optical networking/synchronous digital hierarchy (SONET/SDH), Ethernet, digital subscriber line (DSL), and coaxial cables [26]. SONET/SDH networks use optical fibres for transmitting very high data rates. Ethernet is a promising technology for microgrids since it can provide decentralised communications in a reliable manner [22].

Wireless technologies are prone to environmental interference and transmission attenuation. On the other hand, they are economically viable, scalable, and more versatile than wired mediums. Recent developments in wireless technologies in terms of the data rate and security make them an attractive option for communication networks in some parts of microgrids. Various wireless technologies have been introduced including Wi-Fi (IEEE 802.11), WiMAX (IEEE 802.16), Bluetooth (IEEE 802.15.1), ZigBee (IEEE 802.15.4), and cellular network communication such as 3/4/5 G networks [25] [27].

Each of the wired and wireless technologies may be more suitable for the implementation at different control levels or area networks. For example, for transmitting the measurements and control signals at the device level, usually, wired technologies such as cables and optical fibres are used. On the other hand, PLC is the common technology for the connection between the secondary and tertiary controllers. This notion is also applicable to the area networks. HAN usually uses technologies such as Bluetooth, ZigBee, Wi-Fi, and DSL. Technologies including PLC, DSL, cellular communication and fibre-optic cables are used at higher levels for FAN/NAN. Finally, the WAN network might be established using fibres, WiMAX, and cellular communications.

# 5. Conclusion

The reliable and stable operation of microgrid depends on advanced communication, control, and protection systems. This technical Note is the second of two dealing with microgrids. The first Technical Note discussed the definition of microgrids and their structure along with energy storage technologies. In this Technical Note, the major approaches for the hierarchical control of microgrids were presented. Mainly, the conventional and modified droop methods and non-droop-based methods at the primary control level and centralised and distributed control approaches at the secondary control level were discussed. Furthermore, active, passive, and open-transition transfer methods as the major schemes for the microgrid synchronisation with the main grid were described.

For microgrid protection, firstly, technical challenges such as the unconventional fault behaviour of IIDGs and the changes in the microgrid operation modes were outlined. It was emphasised that conventional protection systems such as overcurrent and distance relays cannot provide proper protection coordination under all conditions and the costs associated with differential relays prohibit their extensive use in many cases. The proposed alternative protection methods such as adaptive protection methods were also highlighted, and their shortcomings were illustrated.

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