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A Comprehensive Review on Telecommunication Challenges of Microgrids Secondary Control

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Abstract– The development of distributed energy resources in distribution networks has created a new concept called microgrids. Their control is one of the main development issues that must be addressed before any implementation process. In this paper, a comprehensive literature review of the main hierarchical control algorithms such as centralized, decentralized, and distributed, with a focus on the secondary level, with an emphasis on their main strengths and weaknesses are discussed and compared. In these structures, communication infrastructures have been studied and compared. Microgrid communication infrastructures allow the use of different control schemes for the secondary control layer. which is given the importance of secondary control over the stable and reliable performance of microgrids, and the lack of comprehensive reference for researchers. Also, provides a literature review on current key issues regarding microgrid secondary control strategies with respect to communication network challenges. The issue of secondary control is discussed with a focus on challenges such as time delays. Also Distributed control methods at the secondary level to reduce the use of the communication network and subsequently reduce communication network delays are discussed.

Keywords: Microgrid, Secondary control, Centralized control, Decentralized control, Distributed control.

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I. Introduction

Over the past few decades, island power grids have been a viable solution for the supply of energy based on distributed generators (DGs). The development and improvement of control systems has changed the way these networks are understood and designed. This change has led to the introduction of a new concept called microgrids (MG) [1],[2]. The development of MG has a few challenges, which should be evaluated individual; The challenges include operation, control, security, and stability.

MGs can operate in islanded and connected modes [3],[4],[5]; In these operating modes, there are challenges, such as frequency maintenance, voltage stability, and accurate power sharing [6],[7]; So, a proper control structure is necessary for a reliable MG performance. In addition, choosing the appropriate communication network to increase system reliability and security to improve bandwidth, time delay and packet losses is an important challenge. The exchange of information in microgrids and different levels of control requires a communication network; Which is organized by a hierarchical control structure. The hierarchical structure has three levels of control; At the first level, the controller is responsible for maintaining voltage and frequency stability, which affects the stability of the MG due to the fast processes of the controller. The virtual impedance loop is optionally used to enhance the power quality and accuracy power-sharing of first level [8]. At the primary level, controllers are implemented using local measurements, so they will not require a complex communication network [9], [10], [11]. Due to the time required for information exchanges to distribute equal power in MG units, an unrelated approach is usually adopted for initial control [12],[13],[14],[15].

Secondary level control methods are studied in proportion to the dependence on communication networks in three structures: centralized, decentralized and distributed [16]. Since communication resources in the microgrid are limited, reducing dependence on the communication network is desirable. Therefore, this has led to more attention to distributed and decentralized structures due to reduced dependence on the communication network than the centralized structure that requires a complex communication network [17, [18], [19]. Microgrid dependence on communication networks has disadvantages such as communication disturbances. For this reason, novel control structures have been introduced in a way that the control objectives can always be guaranteed even with the communication disturbances [20],[21]. Recent studies have discussed the development of a novel secondary control to restore voltage and frequency and accurate power sharing based on event-triggered state [22],[23],[24]. Due to the high cost of communication networks, many studies have been conducted to reduce controller dependency from the secondary level to the communication infrastructure [25].

The purpose of this study is to provide an overview of the existing secondary control structure and to highlight opportunities for future studies in this field. In this regard, some articles have provided reviews on MGs [26], [27] some of which focus on MG control [28], [29], [30] and some on secondary control structure [16]. Given the significant research conducted on the communication network of microgrid, this paper focuses on the secondary control and the structures used at the secondary level by examining the reducing dependence on the communication infrastructure and looking at different approaches based on the distributed control.

The rest of this survey begins with the definition of the concept and comparison of the MG structures and the secondary control approaches are classified and compared, and the importance of this structure will be highlighted by examining the approaches based on the distributed structure in section II. In section III, the communication network used in the microgrid is categorized. Finally, Section IV will present the conclusion.

II. Secondary Control in Microgrid

In microgrid control, if a droop structure is used at the primary level, The steady state error will not be zero; Therefore, restoration for voltage and frequency deviations and further flexibility of the secondary level structure system has been proposed [31],[32]. Secondary level has tasks such as, responsible for providing reliability and reducing frequency and voltage deviations to determine the primary control operating points and economic performance of the MG [33]. The secondary controller sets the point of common coupling voltage, and the power exchange between MG and main grid. The operating points of secondary control are determined on the basis of optimization criteria for loss reduction, power quality and result in increasing economic benefits [33], [34], [35].

The secondary control can be performed in three ways: centralized [36], [37], distributed and decentralized structure [38], [39], [40], [41]. Categories of secondary controller are shown in Table 1. This classification shows the types of secondary control methods that have been presented in various papers. It helps to understand more and get a glimpse of this level of the controller.

Table 1: Categories of secondary control types.

Secondary control of MG		
Centralized	Load estimation	[42]
Decentralized	State of charge	[43]
	Life optimization of energy storage units	[44]
	Potential function	[10]
	Adaptive PI with neural network	[45]
Distributed	Distributed averaging	[46]
	Consensus Algorithm	[47],[48],[49]
	Networked control	[50],[51]
	Distributed averaging Proportional – integral	[52]
	Feedback linearization	[53]
	Multi agent system	[54],[55]

2.1. Centralized structure in microgrid

At the centralized methods, it is assumed that the loads are localized in a shared bus and the secondary control adjusts the voltage of the shared bus by a reference value [56] [57]. Since the centralized method requires an extensive communication system, it could be used to monitor and control different aspects of the MG. This approach allows the DG to be easily imported to the MG without affecting the control program. However, it is strongly dependent on the MGCC and it could be considered as a strong limitation [22]. Since all control calculations are performed at the MGCC, the failure could be affected on the entire MG, therefore, a backup system is required to improve reliability [22]. Conventional secondary control methods use a centralized structure consisting of a droop control, unit of computation, and a central control. These requirements reduce the reliability and flexibility of the MG and increase its susceptibility to disturbance, so that failure of a unit will cause a big problem in the MG. For this reason, some distributed methods are presented [56],[58],[59].

System stability is affected by delays in communication links in MG control. The existence of time delay in communication network can cause instability in microgrid [60]. This shows the importance of having a suitable control structure to eliminate the effect of time delay on microgrid performance. The Multi agent system (MAS) based distributed control has provided a promising method to eliminate the time delay effect [61].

Fig.1, shows the centralized control structure. Some of the control mechanisms used for centralized control are listed in Table 2; Also Table 3 summarizes the advantages and disadvantages of centralized structures.

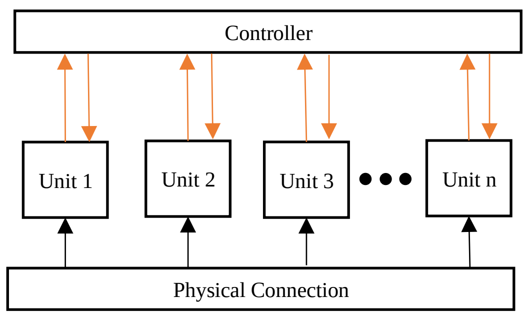

Fig. 1. Schematic diagram of centralized control scheme.

Table 2: Control method used for centralized control

Control method	Control approach	Application	Performance in the presence of communication delays	Relevant reference
Model predictive control(MPC)	-It is based on future behavior of the system and predictions. -It provides a feedback mechanism.	-Suitable for systems greatly dependent on demand. -Suitable for systems greatly dependent on renewable energy generation.	MPC can be effectively applied to systems as a secondary control even under a severe condition where the communication delays are unknown and complex.	[23]
Droop based control	In this control, an offline calculation is being performed, which is a cost effective approach.	Suitable for microgrids with limited distributed generation resources.	The controller uses complex potential functions to detect perturbations due to time delays.	[36]
Prediction based memory control	It is based on H_∞control and predictions.	Suitable for in time delay systems.	The predictor-based robust controller maintained good	[61]

			voltage regulation time-delayed systems.	

Table 3: Advantages and disadvantages of centralized control.

Advantage of centralized control	Relevant reference	Disadvantages of centralized control	Relevant reference
The centralized control scheme offers high controllability and observability.	[8]	Strong dependence on the central controller.	[8]
Ability to add a DG to the MG without affecting the microgrid central controller.		Widespread communication network causes time delay.	
It's implementation is simple and straightforward.	[22]	High costs generated by the high-bandwidth communication links.	[56]
Low-cost scheme.	[61]	This scheme also lacks flexibility and expandability.	[56]
Centralized control has the ability to collect data from all units.	[61]	Centralized structure requires a complex communication network.	[58]
		Centralized structure is more adapted to small scale single user MGs.	[41]

2.2. Decentralized structure in microgrid

The decentralized structure operates on the basis of local measurements. It means, unlike a centralized structure in decentralized controllers, each DG unit will be an independent unit [62]. Therefore, in this structure, the need for communication network is reduced and control is done locally [63]. Unlike centralized control, only local information is used, and the system can still work even if several agents fail. This control strategy is considered to be the most reliable, despite its limitations due to the absence of a communication link. The decentralized control is appropriate to reduce the complexity of communications and computing. It has three main branches, namely consensus-based algorithms, (MASs) and their combinations. In recent studies, a decentralized control structure has been developed using the MAS framework. Decentralized control based on the MAS concept for microgrids has been introduced in [64] and developed in [65]. Fig 2. shows the decentralized control scheme. Table 4 shows the studies performed on decentralized controllers. However, the decentralized structure may not effectively manage all control objectives due to lack of communication [66]. As a result, the distributed structure is developed with the advantages of both centralized and decentralized methods. The next section describes the features of the distributed structure.

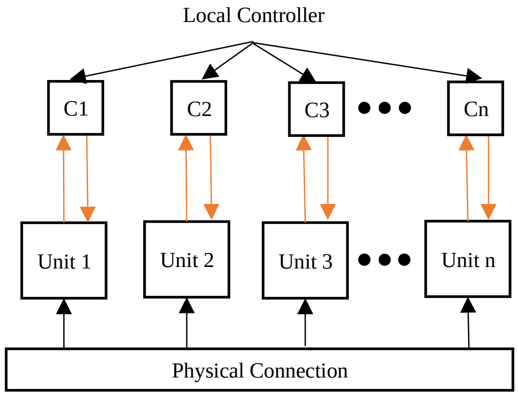

Fig. 2. Schematic diagram of decentralized control scheme.

Table 4: Control methods used for decentralized control

Control method	Performance Control approach	Application	Performance in the presence of communication delays	Relevant reference
Adaptive decentralized droop controller	The strategy is based on the static droop characteristics combined with an adaptive transient droop function.	The control structure preserves the dynamics and stability of each inverter unit at different loading conditions.	Not investigated.	[67]
Consensus	-Based on state feedback. -Without requiring continuous communication among agents.	The event-triggered consensus problem is studied for multi-agent systems with general linear dynamics under a general directed graph.	Not investigated.	[68]
Event-Triggered	The control will detect the predefined event function.	Systems of which there is time delay.	It is observed that the response of the system become more oscillatory as the communication delays increase.	[57]

2.3 Distributed structure in microgrid

The distributed control, in addition to reducing the use of communication network, also has the advantages of centralized control structure, so this structure has been developed as a suitable method for controlling microgrids [5]. The conventional structure of distributed control is illustrated in Fig.3.

Recent articles have attempted to eliminate the need for high-level control and to present a fully distributed structure, as shown in Fig.4 [69]. Generally, three challenges exist in the distributed control to MG. The first is how to restore the voltage and frequency of heterogeneous DG units to reference values simultaneously and quickly in a fully distributed method. The second, is the accurate power division according to the DG power capacity and the third challenge is independent on the MG parameters [70],[71].

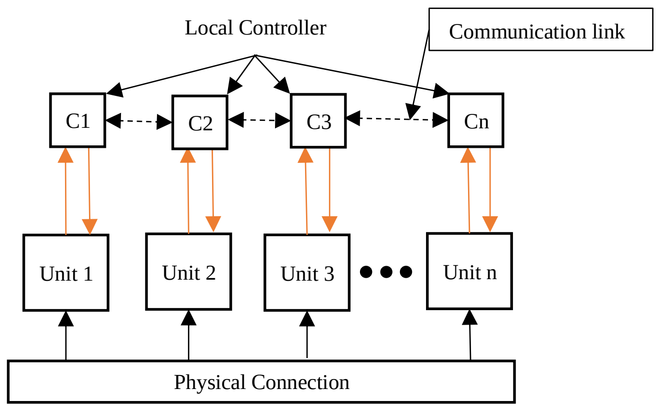

Fig. 3. Schematic diagram of the distributed control scheme.

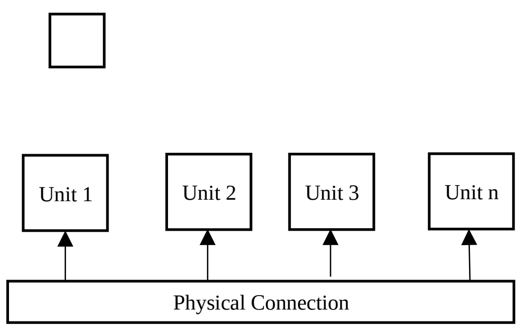

Fig. 4. Schematic diagram of the fully distributed structure.

Distributed control provides a robust secondary control framework designed to speed up the synchronization process and ensure consensus in a limited time [72]. The distributed control methods are summarized in Table 5. A review and comparison of secondary level control structures demonstrates the researchers' interest in expanding the distributed and decentralized structure in recent articles. The reason for this can be considered the importance of reducing the dependence of the control structure on the communication network and making the MG resilience to communication challenges.

Table 5: Summary of distributed control methods.

Control Technique	Method	Implementation Complexity	Other Features	Relevant reference
Distributed Control	Droop	Easy	-No dependence on communication network.	[51],[52], [53]
	MPC	Complex	It is very useful for microgrids with a large number of resources.	[54],[55], [56]
	SMC	Moderate	The closed-loop response of the system has no sensitivity to uncertainties (model parameters, perturbations, and nonlinearity).	[56],[57], [58],[59], [60]
	Event-Triggered	Complex	-Reduce control signal updates. -Reduce the possibility of data loss in data transmission.	[61],[62], [63],[64], [65],[73]
	H_∞	Complex	Suitable for delayed systems.	[74],[75], [76]

Among the distributed methods, the consensus protocol is known as a suitable approach for the distributed structure. In reason to in many research related to distributed method they have used consensus. This method will be discussed in apart section as follows.

2.3.1 Consensus-based methods

- The consensus algorithm is a distributed approach that has become popular over the years for microgrid control (MG). This algorithm is able to coordinate the distributed generator in an MG by sharing information. In the consensus method, the definition of communication interactions and the rules governing information exchange is based on Multi-Agent System (MAS) theory [77], [78], [79], [80]. How to design an appropriate control with the goal that all agents can achieve a common value in the MAS consensus algorithm is a fundamental issue. Widespread participation of agents makes the control and management of MAS centrally costly or even impractical. Therefore, distributed control has been developed using local information exchange between neighbors through shared communication networks. Several studies on distributed consensus control for MAS have been conducted in recent years [80], [81]. The application of other types of consensus methods [82- 96] has also been discussed in the literature, summarized in Fig.5.

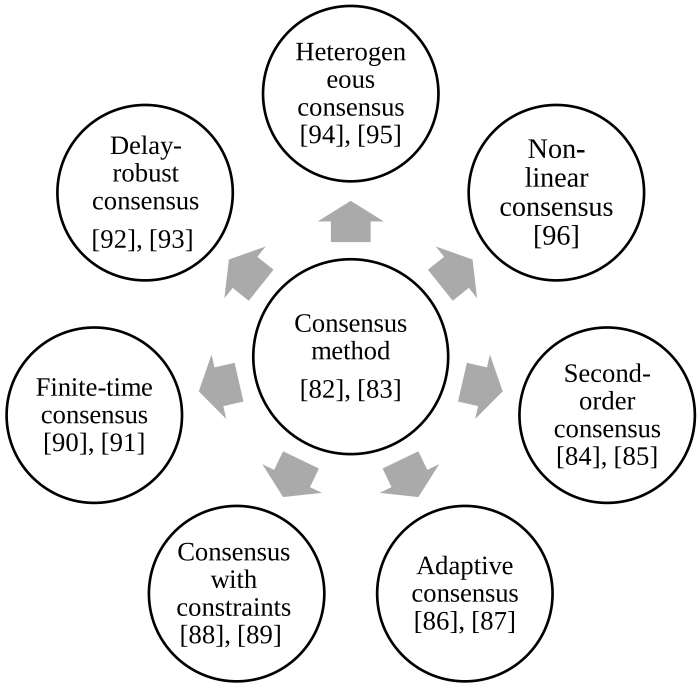

Fig. 5. Types of consensus methods.

In the conventional approach of consensus algorithm, distributed generation control systems have access to measured data and control signals through a communication network. Due to limited communication resources, saving computing resources will be important. Continuous use of the communication network can intensify communication disruptions such as long delays, increase packet loss and reduce throughput, and inevitably reduce the stability, performance and reliability of the system. The event-triggered consensus control is a positive solution for maintaining MAS control function. It also reduces the overuse of communication and computing resources [97], [98].

The event-triggered method has been increasingly applied at the secondary control level of MG, as it maintains stability, reducing the exchange of information between DGs. To study event-triggered control under the consensus method, this structure can be divided into two types. The first structure is the model-based event-triggered scheme. In this structure, event trigger control is defined based on estimated errors

[99]. The second structure is an event-based sampling data that includes methods such as event-based sampling scheme, sampled data-based sampling scheme [100] and self-commissioned sampling scheme [101]. The event triggered structure has advantages and disadvantages, which are summarized in Table (6).

Table 6: Advantages and disadvantage of event triggered control scheme

Scheme	Disadvantage		
	High Frequency of Control Updates	Requirement on Continuous Communication:	Limitations of System Dynamics
Model-based event-triggered	[117],[118],[119], [120],[121],[122]	-	-
Event-based sampling scheme	[102],[103],[104],[105], [106],[107],[108],[109],[110]	[102],[103],[111],[112],[113], [114],[115],[116]	[102],[107],[105],[106],[107] ,[108], [111],[112],[113] ,[114],[115],[116],
Sampled-data-based event-triggered	[123],[124],[125],[126]	-	[123],[124],[125],[126]
Self-triggered sampling	[127],[128],[129]	-	-

III. Communication network

The study of the communication networks has been examined in two parts, communication network modelling by graph theory and communication protocols.

3.1 Graph theory

Considering an islanded MG with multiple DGs, the communication network among the DGs can be modelled by a graph. In a MG graph, the nodes indicate the DG and the edge of their communications links [130]. So the multi-agent system is presented as a graph where $V = \{v_1 . v_2 . v_3 \dots . v_n\}$ is the set of agents, $\varepsilon \subseteq V \times V$, $\varepsilon = \{e_1 . e_1 e_2 \dots e_n\}$ an edge set, The associated adjacency matrix $A = [a_{ij}] \in R^{n\times n}$ with $a_{ii} = 0$. The Laplacian matrix is given by L=D-A; Where D is the degree matrix and $L = L_{ij} \in$

$R^{n\times n}$, L is symmetric positive semi-definite [131]. In Table 7, the graph structure is divided into two subsections.

Table 7: Types of graphs for communication network modelling in microgrids.

Graph theory			
Type	Advantages	Disadvantages	Relevant references
Directed	• Asymmetric property of directed graph.	• Complex	[84],[85],[86]
Undirected	• Low demand for communication Channel. • communication equipment. • low resource cost. • high scalability. • robustness against delay.	• Asymmetric property of directed graph.	[87],[92]

3.2 Communication protocol

For proper microgrid performance in addition to the appropriate control structure, the choice of a communication protocol can have a significant impact on microgrid performance. In other words, it is appropriate for the communication protocol to be in line with the microgrid control objectives and not to complicate or increase the cost of implementation. In recent studies of microgrid control, various communication protocols have been studied with the aim of reducing costs and accelerating the development of microgrids [132], [133]. In [132], the communication structure based on IEC 61850 has been used as a suitable and promising solution to maintain network security, increasing microgrid reliability.

The study of communication network can be divided into two types using wired and wireless [134]. Wired networks such as PLC and fiber optics are subject to more noise and communication disturbances due to environmental conditions than wireless modes. The use of wired methods can also lead to the complexity of the communication network and limit them to a specific location. Therefore, wireless networks such as Wi-Fi, WiMax, ZigBee, SigFox with a suitable control structure in order to prevent communication disturbances seem more cost-effective and appropriate [134], [135], [136]. Communication disturbances in wireless networks are studied in the next section.

3.3 Communication Disturbances

It was previously stated that the distributed structure has a better performance compared to other control structures, however, due to the dependence on the distributed structure on the communication network, microgrids are exposed to communication constraints and disturbances. In this regard, communication constraints, such as time delay, packet -loss, cyber-attack, communication network failed and noise is the most important communication disturbances in the microgrid, which will lead to loss of synchronization of physical variables or even microgrid instability [130]. Therefore, designing a control structure that can maintain microgrid stability in the presence of disturbances caused by communication networks will be important [131], [137], [138]. Consensus-based distributed control has been considered as a suitable approach for communication constraints, so that in [139] a consensus-based control is introduced considering time-varying delays and noise. Another approach to avoiding communication constraints is to use time-based graph theory; In [140] using communication network modelling by time-varying graph theory, microgrid has been significantly improved against data loss, communication network failed and time delay.

In addition to the disturbances caused by the communication network, cyber-attacks can affect the performance of the microgrid in such a way that it can cause the collapse of the microgrid, which has been studied in [141] by the software-defined networking (SDN) approach. Failure in the communication network is one of the disturbances affecting the performance of the microgrid controller, which is studied in [142] a proposed approach for the reconstruction of communication lines. Table 8 summarizes the control methods used in the presence of communication disturbances. Among the communication disturbances studied, time delay has been studied by researchers in recent studies due to its importance in maintaining stability. Therefore, it has been studied in section 3.3.1.

Table 8: Control methods used against communication disturbances

Control methods	Communication disturbance	Effect of communication disturbances on microgrid	Related Literature
Noise-resilient control	Gaussian noise	The communication links are subjected to uncertain noises, which can significantly affect the synchronization performance of MG control.	[143]
Distributed noise resilient	Additive type of noise	The communication links are subjected to additive communication noise, which can significantly affect the Voltage and frequency of MG control.	[144]
Event-triggered SMC-virtual leader	Channel noise	The channel noise can significantly affect the Voltage and frequency of MG control.	[145]
Cooperative control	Measurement noises	Causes instability in the microgrid voltage.	[146]
	Link failure	-Link failure has a direct effect on transient control performance and weakens it.	[147]
Fully distributed cooperative	Packet loss	Communication packet loss leads to longer transient regulating time for the DGs.	[148]
Cyber-physical cooperative control	Packet loss	The packet loss has a direct impact on communication data. Moreover, the large loss rate will cause the interruption of communication.	[149]

3.3.1 Communication Delays on Secondary Control

Data transmission by communication networks such as WiFi, WiMax, Internet, Ethernet and ZigBee in microgrid is associated with time delay [150], [151]. Time delay in communication networks at the worst case it can cause poor and unstable performance of microgrids. To investigate the time delay in communication networks, it can be divided into two groups; input delay and communication delay [152].

The distributed control structure is an effective method for microgrid control in the presence of time delay [153]. However, this structure has limited resistance to time delays. So, finding the delay margin so that the microgrid performs well is a challenging issue. Taylor series [154], Linear matrix inequality [155], [156], Simulation-based [157], [158], Experiment/HIL [159] are well-known methods for determining the delay margin in microgrids. In addition, in [159] an extensive study has been conducted on methods for determining the time delay margin in microgrids. Table 9 summarizes the four control structures in order to study the types of delays and how to calculate the delay margin, as well as the effect of the control method on time delay.

Table 9: The effect of secondary control methods on time delay in microgrid

Method	Type of time delay	Performance of the MG in the presence of delay	Delay margin	Effect of proposed controller	Reference
SMC	Time-varying delay	Time delays will make control signals for reference voltage waveforms delayed, which causes phase shift between reference LPG voltage and microgrid voltage.	Time-varying	The accuracy of random delay estimation τ (t) and microgrid states estimation x(t) can be adaptively improved by SMC control.	[160]
	Time-varying delay	The estimated stochastic delay.	Time-varying.	This control schemes has shown the benefits for dealing with long time delays using the predictive structure plus the robustness of the sliding mode theory.	[161]
MPC	constant communication link time delay	The voltage observer-based DMPC cannot achieve accurate voltage recovery under time delay.	Simulation (0.2s)	Compared to conventional control schemes, this scheme can fully take into account the constraints caused by the time delay and achieve an adjustable balance between node voltage and power-sharing.	[162]
	Variable and unknown communication delays	Unstable eigenvalues.	Simulation (1.11 s)	The MPC based secondary control system is considerably more robust in terms of maximum delay allowed.	[34]
Consensus	Communication link time delay	The RMS currents have some oscillations before the consensus is achieved.	Simulation (1 s)	This structure shows the excellent performance of consensus algorithms in terms of resistance to time delay in a short time.	[163]
	Communication link time delay	Increasing of communication delays lead to higher fluctuations and slower agreement rates.	Simulation (10 ms)	Compared to existing controllers, the proposed controller gave a faster convergence rate based on the finite-time consensus protocol.	[157]
	Communication link time delay	The closed-loop system response becomes oscillatory and the convergence becomes slow under communication time delays.	Simulation (800 ms)	Demonstrates significant robustness against load disturbances, and successfully tolerates, small as well as large, communication time-delays.	[159]
	Communication link time delay	The communication delay will Reduce the convergence speed of the control system.	Simulation (400 ms)	Simulation results verify the effectiveness of the proposed strategy, especially, it has strong robustness to communication delay.	[164]
Event triggered	Communication link time delay	Worsening of microgrid performance in maintaining stability.	Simulation (0.1 s)	The simulation results confirm the effectiveness of the proposed strategy against large time delays. However, in the proposed method, the convergence speed is slow.	[162]
	Communication link time delay	Worsening of microgrid performance in maintaining stability.	Simulation (15 ms)	The proposed control is resistant to time delays of less than 15 (ms). However, with increasing delay, the system becomes unstable.	[165]

Conclusion

One of the challenges in microgrids is the proper control system. In this paper, the structure of secondary control with the definition of three levels of primary, secondary and tertiary was examined and it was shown that each has different requirements in terms of communication performance. In this study, it was found that the primary level is a time-sensitive mechanism that ensures voltage and instantaneous frequency control, so communication-less control methods are adopted. The secondary level, unlike the primary level, is more dependent on the communication network. Depending on the communication network, this level was divided into three structures; centralized, decentralized and distributed. Comparison of control structures showed that distributed control has many advantages over a centralized design (e.g., higher reliability and resistance to unit failure), it may require more complex data transmission through communication lines. Dependence on the communication network in the distributed control structure requires the study of the controller behavior in the presence of communication disturbances. Thus, "how to stabilize data transmission with communication disturbances in the limited network resources of an MG" is one of the challenges in controlling MG. Finally, this study provided a comprehensive overview of the secondary level with respect to the communication network in MG and the behavior of controllers in the presence of communication disturbance. It is recommended that communications attacks and their impact on the secondary level control structure and MG performance be investigated in future work.

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References

[1] H. Xie, S. Zheng and M. Ni, "Microgrid Development in China: A method for renewable energy and energy storage capacity configuration in a megawatt-level isolated microgrid.," in *IEEE Electrification Magazine*, vol. 5, no. 2, pp. 28-35, June 2017.

[2] W. Gu, G. Lou, W. Tan and X. Yuan, "A Nonlinear State Estimator-Based Decentralized Secondary Voltage Control Scheme for Autonomous Microgrids," in *IEEE Transactions on Power Systems*, vol. 32, no. 6, pp. 4794-4804, Nov. 2017.

[3] T. R. Oliveira, W. W. A. Gonçalves Silva and P. F. Donoso-Garcia, "Distributed Secondary Level Control for Energy Storage Management in DC Microgrids," in *IEEE Transactions on Smart Grid*, vol. 8, no. 6, pp. 2597-2607, Nov. 2017.

[4] L. Che, M. Khodayar and M. Shahidehpour, "Only Connect: Microgrids for Distribution System Restoration," in *IEEE Power and Energy Magazine*, vol. 12, no. 1, pp. 70-81, Jan.-Feb. 2014.

[5] Chmiel, Z. and S.C. Bhattacharyya, “Analysis of off-grid electricity system at Isle of Eigg (Scotland): Lessons for developing countries”in *Renewable Energy*, vol. 81, 2015: p. 578-588, doi: 10.1016/j.renene.2015.03.061.

[6] S. K. Sahoo, A. K. Sinha and N. K. Kishore, "Control Techniques in AC, DC, and Hybrid AC–DC Microgrid: A Review," *in IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 6, no. 2, pp. 738-759, June 2018.

[7] A. Cagnano, E. De Tuglie, P. Mancarella, “Microgrids: Overview and guidelines for practical implementations and operation” in *Applied Energy*, 2020.vol. 258: p. 114039.

[8] J. M. Rey, P. Martí, M. Velasco, J. Miret and M. Castilla, "Secondary Switched Control With no Communications for Islanded Microgrids," in *IEEE Transactions on Industrial Electronics*, vol. 64, no. 11, pp. 8534-8545, Nov. 2017.

[9] S. Peyghami, H. Mokhtari and F. Blaabjerg, "Decentralized Load Sharing in a Low-Voltage Direct Current Microgrid With an Adaptive Droop Approach Based on a Superimposed Frequency," in *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 5, no. 3, pp. 1205-1215, Sept. 2017

[10] A. Mehrizi-Sani and R. Iravani, "Potential-Function Based Control of a Microgrid in Islanded and Grid-Connected Modes," in *IEEE Transactions on Power Systems*, vol. 25, no. 4, pp. 1883-1891, Nov. 2010

[11] T. Dragičević, "Model Predictive Control of Power Converters for Robust and Fast Operation of AC Microgrids," *in IEEE Transactions on Power Electronics*, vol. 33, no. 7, pp. 6304-6317, July 2018

[12] I. Serban, S. Céspedes, C. Marinescu, C. A. Azurdia-Meza, J. S. Gómez and D. S. Hueichapan, "Communication Requirements in Microgrids: A Practical Survey," in *IEEE Access*, vol. 8, pp. 47694-47712, 2020.

[13] M. Yazdanian and A. Mehrizi-Sani, "Distributed Control Techniques in Microgrids," in *IEEE Transactions on Smart Grid*, vol. 5, no. 6, pp. 2901-2909, Nov. 2014

[14] D. E. Olivares et al., "Trends in Microgrid Control," in *IEEE Transactions on Smart Grid*, vol. 5, no. 4, pp. 1905-1919, July 2014.

[15] J. C. Vasquez, J. M. Guerrero, J. Miret, M. Castilla and L. G. de Vicuña, "Hierarchical Control of Intelligent Microgrids," in *IEEE Industrial Electronics Magazine*, vol. 4, no. 4, pp. 23-29, Dec. 2010.

[16] Y. Khayat et al., "On the Secondary Control Architectures of AC Microgrids: An Overview," in *IEEE Transactions on Power Electronics*, vol. 35, no. 6, pp. 6482-6500, June 2020.

[17] Y. Khayat et al., "Decentralized Optimal Frequency Control in Autonomous Microgrids," in *IEEE Transactions on Power Systems*, vol. 34, no. 3, pp. 2345-2353, May 2019.

[18] M. Castilla, A. Camacho, P. Martí, M. Velasco and M. M. Ghahderijani, "Impact of Clock Drifts on Communication-Free Secondary Control Schemes for Inverter-Based Islanded Microgrids," in *IEEE Transactions on Industrial Electronics*, vol. 65, no. 6, pp. 4739-4749, June 2018.

[19] P. Martí, J. Torres-Martínez, C. X. Rosero, M. Velasco, J. Miret and M. Castilla, "Analysis of the Effect of Clock Drifts on Frequency Regulation and Power Sharing in Inverter-Based Islanded Microgrids," in *IEEE Transactions on Power Electronics*, vol. 33, no. 12, pp. 10363-10379, Dec. 2018.

[20] G. Lou, W. Gu, Y. Xu, W. Jin and X. Du, "Stability Robustness for Secondary Voltage Control in Autonomous Microgrids With Consideration of Communication Delays," in IEEE Transactions on Power Systems, vol. 33, no. 4, pp. 4164-4178, July 2018.

[21] Chen, M. and X. Xiao,"Secondary voltage control in islanded microgrids using event-triggered control*"*. In *IET Generation, Transmission & Distribution*, 2018. Vol. 12(8): p. 1872-1878.

[22] S. Sahoo and S. Mishra, "An Adaptive Event-Triggered Communication-Based Distributed Secondary Control for DC Microgrids," in *IEEE Transactions on Smart Grid*, vol. 9, no. 6, pp. 6674-6683, Nov. 2018.

[23] K. T. Tan, X. Y. Peng, P. L. So, Y. C. Chu and M. Z. Q. Chen, "Centralized Control for Parallel Operation of Distributed Generation Inverters in Microgrids," in *IEEE Transactions on Smart Grid*, vol. 3, no. 4, pp. 1977-1987, Dec. 2012.

[24] Y. Zhang, A. M. Shotorbani, L. Wang and B. Mohammadi-Ivatloo, "Distributed Secondary Control of a Microgrid With A Generalized PI Finite-Time Controller," in *IEEE Open Access Journal of Power and Energy*, vol. 8, pp. 57-67, 2021.

[25] Q. Li, C. Peng, M. Wang, M. Chen, J. M. Guerrero and D. Abbott, "Distributed Secondary Control and Management of Islanded Microgrids via Dynamic Weights," in *IEEE Transactions on Smart Grid*, vol. 10, no. 2, pp. 2196-2207, March 2019.

[26] A.A. Memon, K. Kauhaniemi, "A critical review of AC Microgrid protection issues and available solutions", in *Electric Power Systems Research*, 2015.vol. 129: p. 23-31.

[27] Stadler, M., et al., *Value streams in microgrids: A literature review.* Applied Energy, 2016. 162: p. 980-989. *Renewable and Sustainable Energy Reviews*, 2015. Vo. 52: p. 1123-1134.

[28] Y. Han, H. Li, P. Shen, E. A. A. Coelho and J. M. Guerrero, "Review of Active and Reactive Power Sharing Strategies in Hierarchical Controlled Microgrids," in *IEEE Transactions on Power Electronics*, vol. 32, no. 3, pp. 2427-2451, March 2017.

[29] E. Unamuno, J. A. Barrena "Hybrid ac/dc microgrids—Part II: Review and classification of control strategies", in Renewable and Sustainable Energy Reviews, 2015,vol.52. Pages 1123-1134.

[30] M.S. Mahmoud, S. Azher Hussain, M.A. Abido, "Modeling and control of microgrid: An overview". In *Journal of the Franklin Institute,* 2014. Vol. 351(5): p. 2822-2859.

[31] S. Anand, B. G. Fernandes and J. Guerrero, "Distributed Control to Ensure Proportional Load Sharing and Improve Voltage Regulation in Low-Voltage DC Microgrids," in *IEEE Transactions on Power Electronics*, vol. 28, no. 4, pp. 1900-1913, April 2013,

[32] I. U. Nutkani, W. Peng, L. P. Chiang and F. Blaabjerg, "Secondary Droop for Frequency and Voltage Restoration in Microgrids," 2015 17th European Conference on Power Electronics and Applications (EPE'15 ECCE-Europe), Geneva, Switzerland, 2015, pp. 1-7.

[33] T. L. Vandoorn, J. D. M. De Kooning, B. Meersman and L. Vandevelde, "Communication-based secondary control in microgrids with voltage-based droop control," PES T&D 2012, Orlando, FL, USA, 2012, pp. 1-6.

[34] C. Ahumada, R. Cárdenas, D. Sáez and J. M. Guerrero, "Secondary Control Strategies for Frequency Restoration in Islanded Microgrids With Consideration of Communication Delays," in *IEEE Transactions on Smart Grid*, vol. 7, no. 3, pp. 1430-1441, May 2016.

[35] Z. Li, Z. Duan, G. Chen and L. Huang, "Consensus of Multiagent Systems and Synchronization of Complex Networks: A Viewpoint," *in IEEE* Unified *Transactions on Circuits and Systems* I: Regular Papers, vol. 57, no. 1, pp. 213-224, Jan. 2010.

[36] Yao, Gang, et al. "A central control strategy of parallel inverters in AC microgrid." IECON 2013-39th Annual Conference of the IEEE Industrial Electronics Society. IEEE, 2013.

[37] A. Bidram and A. Davoudi, "Hierarchical Structure of Microgrids Control System," in IEEE Transactions on Smart Grid, vol. 3, no. 4, pp. 1963-1976, Dec. 2012.

[38] O. Palizban and K. Kauhaniemi, "Secondary control in AC microgrids challenges and solutions," 2015 International Conference on Smart Cities and Green ICT Systems (SMARTGREENS), Lisbon, Portugal, 2015, pp. 1-6.

[39] A. Bidram, A.Davoudi , F. L. Lewis , Z. Q, "Secondary control of microgrids based on distributed cooperative control of multi-agent systems". In *IET Generation, Transmission & Distribution*, 2013. Vol.7(8): p. 822-831.

[40] Q. Shafiee, J. M. Guerrero and J. C. Vasquez, "Distributed Secondary Control for Islanded Microgrids—A Novel Approach," in *IEEE Transactions on Power Electronics*, vol. 29, no. 2, pp. 1018-1031, Feb. 2014.

[41] K.S. Rajesh, S.S. Dash, Ragam Rajagopal, R. Sridhar, "A review on control of ac microgrid. Renewable and sustainable energy reviews",in Renewable and Sustainable Energy Reviews, 2017. Vol. 71: p. 814-819.

[42] T. Wu, J. Liu, Z. Liu, S. Wang and B. Liu, "Load power estimation based secondary control for microgrids," 2015 9th International Conference on Power Electronics and ECCE Asia (ICPE-ECCE Asia), Seoul, Korea (South), 2015, pp. 722-727.

[43] X. Lu, J. M. Guerrero, K. Sun and J. C. Vasquez, "An Improved Droop Control Method for DC Microgrids Based on Low Bandwidth Communication With DC Bus Voltage Restoration and Enhanced Current Sharing Accuracy," in *IEEE Transactions on Power Electronics*, vol. 29, no. 4, pp. 1800-1812, April 2014.

[44] J. Li, J. Su, Y. Shi, M. Mao, X. Yang and N. Liu, "Microgrid secondary frequency control method based on life optimization of energy storage units," 2014 International Power Electronics and Application Conference and Exposition, Shanghai, China, 2014, pp. 1143-1147.

[45] Mahmoud, M.S. and S.A. Hussain, "Adaptive PI secondary control for smart autonomous microgrid systems" In *International Journal of Adaptive Control and Signal Processing*, 2015. 29(11): p. 1442-1458.

[46] J. W. Simpson-Porco, Q. Shafiee, F. Dörfler, J. C. Vasquez, J. M. Guerrero and F. Bullo, "Secondary Frequency and Voltage Control of Islanded Microgrids via Distributed Averaging," in *IEEE Transactions on Industrial Electronics*, vol. 62, no. 11, pp. 7025-7038, Nov. 2015.

[47] D. Wu, T. Dragicevic, J. C. Vasquez, J. M. Guerrero and Y. Guan, "Secondary coordinated control of islanded microgrids based on consensus algorithms," 2014 IEEE Energy Conversion Congress and Exposition (ECCE), Pittsburgh, PA, USA, 2014, pp. 4290-4297.

[48] P. Danzi, C. Stefanovic, L. Meng, J. M. Guerrero and P. Popovski, "On the Impact of Wireless Jamming on the Distributed Secondary Microgrid Control," 2016 IEEE Globecom Workshops (GC Wkshps), Washington, DC, 2016, pp. 1-6.

[49] E. A. Coelho et al., "Small-Signal Analysis of the Microgrid Secondary Control Considering a Communication Time Delay," in *IEEE Transactions on Industrial Electronics*, vol. 63, no. 10, pp. 6257-6269, Oct. 2016.

[50] Q. Shafiee, Č. Stefanović, T. Dragičević, P. Popovski, J. C. Vasquez and J. M. Guerrero, "Robust Networked Control Scheme for Distributed Secondary Control of Islanded Microgrids," in *IEEE Transactions on Industrial Electronics*, vol. 61, no. 10, pp. 5363-5374, Oct. 2014.

[51] A. Kahrobaeian and Y. A. Ibrahim Mohamed, "Networked-Based Hybrid Distributed Power Sharing and Control for Islanded Microgrid Systems," in *IEEE Transactions on Power Electronics*, vol. 30, no. 2, pp. 603-617, Feb. 2015

[52] J. W. Simpson-Porco, F. Dörfler, F. Bullo, Q. Shafiee and J. M. Guerrero, "Stability, power sharing, & distributed secondary control in droop-controlled microgrids," 2013 IEEE International Conference on Smart Grid Communications (SmartGridComm), Vancouver, BC, Canada, 2013, pp. 672-677.

[53] A. Bidram, A. Davoudi, F. L. Lewis and J. M. Guerrero, "Distributed Cooperative Secondary Control of Microgrids Using Feedback Linearization," in *IEEE Transactions on Power Systems*, vol. 28, no. 3, pp. 3462-3470, Aug. 2013.

[54] Zhao Wang, Hongbo Sun and D. Nikovski, "Distributed secondary voltage controller for droop-controlled microgrids to improve power quality in power distribution networks," 2016 IEEE Power and Energy Society General Meeting (PESGM), Boston, MA, USA, 2016, pp. 1-5

[55] Yu, Z., et al., "A novel secondary control for microgrid based on synergetic control of multi-agent syste". In Energies, 2016. Vol.9(4): p. 243.

[56] X. Lu, X. Yu, J. Lai, J. M. Guerrero and H. Zhou, "Distributed Secondary Voltage and Frequency Control for Islanded Microgrids With Uncertain Communication Links," in *IEEE Transactions on Industrial Informatics*, vol. 13, no. 2, pp. 448-460, April 2017.

[57] M. Chen, X. Xiao and J. M. Guerrero, "Secondary Restoration Control of Islanded Microgrids With a Decentralized Event-Triggered Strategy," in *IEEE Transactions on Industrial Informatics*, vol. 14, no. 9, pp. 3870-3880, Sept. 2018.

[58] N. M. Dehkordi, N. Sadati and M. Hamzeh, "Distributed Robust Finite-Time Secondary Voltage and Frequency Control of Islanded Microgrids," in *IEEE Transactions on Power Systems*, vol. 32, no. 5, pp. 3648-3659, Sept. 2017.

[59] N. M. Dehkordi, N. Sadati and M. Hamzeh, "Fully Distributed Cooperative Secondary Frequency and Voltage Control of Islanded Microgrids," in *IEEE Transactions on Energy Conversion*, vol. 32, no. 2, pp. 675-685, June 2017.

[60] A. Asheibi et al., "Stability analysis of PV-based DC microgrid with communication delay," 2018 9th International Renewable Energy Congress (IREC), Hammamet, Tunisia, 2018, pp. 1-6.

[61] F. Guo, Q. Xu, C. Wen, L. Wang and P. Wang, "Distributed Secondary Control for Power Allocation and Voltage Restoration in Islanded DC Microgrids," in *IEEE Transactions on Sustainable Energy*, vol. 9, no. 4, pp. 1857-1869, Oct. 2018.

[62] M. Mehdi, C. Kim and M. Saad, "Robust Centralized Control for DC Islanded Microgrid Considering Communication Network Delay," in IEEE Access, vol. 8, pp. 77765-77778, 2020.

[63] Bharath, K., H. Choutapalli, and P. Kanakasabapathy, “Control of bidirectional DC-DC converter in renewable based DC microgrid with improved voltage stability”,in *International Journal of Renewable Energy Research (IJRER)*, 2018. Vol. 8(2): p. 871-877.

[64] Rokrok E, Golshan MEH. “Adaptive volatge droop scheme for volatge source converters in an islanded multibus microgrid”. IET Gener Transm Distrib 2010;4(5):562–78

[65] Hajimiragha A, Zadeh MRD. “Research and development of a microgrid control and monitoring system for the remote commu- nity of Bella Coola: Challenges, solutions achievements and lessons learned”, In: Proceedings of the IEEE International Conference on Smart Energy Grid Engineering (SEGE’13), Aug; 2013.

[66] G. Lou, W. Gu, J. Wang, W. Sheng and L. Sun, "Optimal Design for Distributed Secondary Voltage Control in Islanded Microgrids: Communication Topology and Controller," in *IEEE Transactions on Power Systems*, vol. 34, no. 2, pp. 968-981, March 2019.

[67] Mohamed, Yasser Abdel-Rady Ibrahim, and Ehab F. El-Saadany. "Adaptive decentralized droop controller to preserve power sharing stability of paralleled inverters in distributed generation microgrids." IEEE Transactions on Power Electronics 23.6 (2008): 2806-2816.

[68] Yang, Dapeng, et al. "Decentralized event-triggered consensus for linear multi-agent systems under general directed graphs." Automatica 69 (2016): 242-249.

[69] S. Anand, B. G. Fernandes, and J. Guerrero, “Distributed control to ensure proportional load sharing and improve voltage regulation in low voltage DC microgrids,” IEEE, Trans. Power Electron., vol. 28, no. 4, pp. 1900–1913, Apr. 2013.

[70] F. Guo, L. Wang, C. Wen, D. Zhang, and Q. Xu, “Distributed voltage restoration and current sharing control in islanded DC microgrid systems without continuous communication,” IEEE Trans. Ind. Electron., vol. 67, no. 4, pp. 3043-3053, Apr. 2020.

[71] B. Fan, J. Peng, J. Duan, Q. Yang, and W. Liu, “Distributed control of multiple-busmicrogrid with paralleled distributed generators,” IEEE/CAA J. Automatica Sinica, vol. 6, no. 3, pp. 676–684, May 2019.

[72] F. Gao, S. Bozhko, G. Asher, P. Wheeler, and C. Patel, “An improved voltage compensation approach in a droop-controlled DC power system for the more electric aircraft,” IEEE Trans. Power Electron., vol. 31, no. 10, pp. 7369–7383, Oct. 2015.

[73] F. Mohammadi et al., “A bidirectional power charging control strategy for plug-in hybrid electric vehicles,” Sustainability, vol. 11, no. 16, Aug. 2019.

[74] F. Guo, C. Wen, J. Mao, J. Chen and Y. Song, "Distributed Cooperative Secondary Control for Voltage Unbalance Compensation in an Islanded Microgrid," in *IEEE Transactions on Industrial Informatics*, vol. 11, no. 5, pp. 1078-1088, Oct. 2015.

[75] R. A. F. Ferreira, H. A. C. Braga, A. A. Ferreira and P. G. Barbosa, "Analysis of voltage droop control method for dc microgrids with Simulink: Modelling and simulation," 2012 10th *IEEE/IAS International Conference on Industry Applications*, Fortaleza, Brazil, 2012, pp. 1-6.

[76] S. Gholami et al., “Robust multiobjective control method for power sharing among distributed energy resources in islanded microgrids with unbalanced and nonlinear loads,” Int. J. Electr. Power Energy Syst., vol. 94, Jan. 2018.

[77] J. Shamma, “Coperative Control of Distributed Multi-Agent Systems”. Hoboken, NJ, USA: Wiley, 2007.

[78] F. L. Lewis, H. Zhang, K. Hengster-Movric, and A. Das, “Cooperative Control of Multi-Agent Systems (Communications and Control Engineering)”. London, U.K.: Springer, 2014.

[79] R. O. Saber and R. M. Murray, ‘‘Consensus protocols for networks of dynamic agents,’’ in Proc. Amer. Control Conf., vol. 2, 2003, pp. 951–956.

[80] A. Bidram, A. Davoudi, and F. L. Lewis, “Cooperative Synchronization in Distributed Microgrid Control”. Cham, Switzerland: Springer, 2017.

[81] K. E. Antoniadou-Plytaria, I. N. Kouveliotis-Lysikatos, P. S. Georgilakis, and N. D. Hatziargyriou, ‘‘Distributed and decentralized voltage control of smart distribution networks,’’ IEEE Trans. Smart Grid, vol. 8, no. 6, pp. 2999–3008, Nov. 2017.

[82] U. Münz, A. Papachristodoulou, and F. Allgöwer, ‘‘Delay robustness in consensus problems,’’ Automatica, vol. 46, no. 8, pp. 1252–1265, Aug. 2010.

[83] C. Nowzari, E. Garcia, and J. Cortés, ‘‘Event-triggered communication and control of networked systems for multi-agent consensus,’’ Automatica, vol. 105, pp. 1–27, Jul. 2019.

[84] J. Qin, W. X. Zheng, and H. Gao,‘‘Convergence analysis for multiple agents with double-integrator dynamics in a sampled-data setting,’’ IET Control Theory Appl, vol. 5, no. 18, pp. 2089–2097, Dec. 2011.

[85] J. Qin, W. Xing Zheng, and H. Gao, ‘‘Coordination of multiple agents with double-integrator dynamics under generalized interaction topologies,’’ IEEE Trans. Syst. Man, Cybern. B, Cybern., vol. 42, no. 1, pp. 44–57, Feb. 2012

[86] W. Yu, P. DeLellis, G. Chen, M. di Bernardo, and J. Kurths, ‘‘Distributed adaptive control of synchronization in complex networks,’’ IEEE Trans. Autom. Control, vol. 57, no. 8, pp. 2153–2158, Aug. 2012.

[87] Z. Li, W. Ren, X. Liu, and L. Xie, ‘‘Distributed consensus of linear multiagent systems with adaptive dynamic protocols,’’ Automatica, vol. 49, no. 7, pp. 1986–1995, Jul. 2013.

[88] A. Nedic, A. Ozdaglar, and P. A. Parrilo, ‘‘Constrained consensus and optimization in multi-agent networks,’’ IEEE Trans. Autom. Control, vol. 55, no. 4, pp. 922–938, Apr. 2010

[89] P. Lin and W. Ren, ‘‘Constrained consensus in unbalanced networks with communication delays,’’ IEEE Trans. Autom. Control, vol. 59, no. 3, pp. 775–781, Mar. 2014.

[90] L. Weiss, ‘‘Converse theorems for finite time stability,’’ SIAM J. Appl. Math., vol. 16, no. 6, pp. 1319–1324, Nov. 1968.

[91] L. Wang and F. Xiao, ‘‘Finite-time consensus problems for networks of dynamic agents,’’ IEEE Trans. Autom. Control, vol. 55, no. 4, pp. 950–955, Apr. 2010.

[92] D. P. Spanos, R. Olfati-Saber, and R. M. Murray, ‘‘Dynamic consensus on mobile networks,’’ in Proc. 16th IFAC World Congr., 2005, pp. 1–6

[93] Z. Li, Z. Duan, G. Chen, and L. Huang, ‘‘Consensus of multiagent systems and synchronization of complex networks: A unified viewpoint,’’ IEEE Trans. Circuits Syst. I, Reg. Papers, vol. 57, no. 1, pp. 213–224, Jan. 2010.

[94] Y. Zheng, Y. Zhu, and L. Wang, ‘‘Consensus of heterogeneous multiagent system,’’ IET Control Theory Appl., vol. 5, no. 16, pp. 1881–1888, 2011.

[95] J. M. Kim, Y. H. Choi, and J. B. Park, ‘‘Leaderless and leader-following consensus for heterogeneous multi-agent systems with random link failures,’’ IET Control Theory Appl., vol. 8, no. 1, pp. 51–60, Jan. 2014.

[96] Q. Hui, W. M. Haddad, and S. P. Bhat, ‘‘On robust control algorithms for nonlinear network consensus protocols,’’ Int. J. Robust Nonlinear Control, vol. 20, no. 3, pp. 269–284, Feb. 2010.

[97] D. V. Dimarogonas, E. Frazzoli, and K. H. Johansson, ‘‘Distributed eventtriggered control for multi-agent systems,’’ IEEE Trans. Autom. Control, vol. 57, no. 5, pp. 1291–1297, May 2012.

[98] X. Ge and Q.-L. Han, ‘‘Distributed formation control of networked multiagent systems using a dynamic event-triggered communication mechanism,’’ IEEE Trans. Ind. Electron., vol. 64, no. 10, pp. 8118–8127, Oct. 2017.

[99] X. Yin, D. Yue, S. Hu, C. Peng, and Y. Xue, “Model-based eventtriggered predictive control for networked systems with data dropout,” SIAM J. Control Optim., vol. 54, no. 2, pp. 567–586, 2016.

[100] X.-M. Zhang and Q.-L. Han, “Event-triggered dynamic output feedback control for networked control systems,” IET Control Theory Appl., vol. 8, no. 4, pp. 226–234, Mar. 2014.

[101] W. P. M. H. Heemels, K. H. Johansson, and P. Tabuada, “An introduction to event-triggered and self-triggered control,” in Proc. 51st IEEE Annu. Conf. Decis. Control, 2012, pp. 3270–3285.

[102] D. V. Dimarogonas, E. Frazzoli, and K. H. Johansson, “Distributed event-triggered control for multi-agent systems,” *IEEE Trans. Autom. Control*, vol. 57, no. 5, pp. 1291–1297, May 2012.

[103] Z. Zhang, F. Hao, L. Zhang, and L. Wang, “Consensus of linear multi-agent systems via event-triggered control,” *Int. J. Control*, vol. 87, no. 6, pp. 1243–1251, 2014.

[104] C. Nowzari and J. Cortés, “Distributed event-triggered coordination for average consensus on weight-balanced digraphs,” *Automatica*, vol. 68, pp. 237–244, Jun. 2016.

[105] E. Garcia, Y. Cao, H. Yu, P. Antsaklis, and D. Casbeer, "Decentralised event-triggered cooperative control with limited communication," *Int. J. Control*, vol. 86, no. 9, pp. 1479–1488, 2013.

[106] S. S. Kia, J. Cortés, and S. Martínez, "Distributed event-triggered communication for dynamic average consensus in networked systems," *Automatica*, vol. 59, pp. 112–119, Sep. 2015.

[107] H. Yu and P. J. Antsaklis, "Output synchronization of networked passive systems with event-driven communication," *IEEE Trans. Autom. Control*, vol. 59, no. 3, pp. 750–756, Mar. 2014.

[108] X. Yin, D. Yue, and S. Hu, "Adaptive periodic event-triggered consensus for multi-agent systems subject to input saturation," *Int. J. Control*, vol. 89, no. 4, pp. 653–667, 2016.

[109] G. S. Seyboth, D. V. Dimarogonas, and K. H. Johansson, "Event-based broadcasting for multi-agent average consensus," *Automatica*, vol. 49, no. 1, pp. 245–252, 2013.

[110] L. Xing, C. Wen, F. Guo, Z. Liu, and H. Su, "Event-based consensus for linear multiagent systems without continuous communication," *IEEE Trans. Cybern.*,vol. 47, no. 8, pp. 2132–2142, Aug. 2017.

[111] Y. Fan, G. Feng, Y. Wang, and C. Song, "Distributed event-triggered control of multi-agent systems with combinational measurements," *Automatica*, vol. 49, no. 2, pp. 671–675, 2013.

[112] W. Zhu, Z.-P. Jiang, and G. Feng, "Event-based consensus of multi-agent systems with general linear models," *Automatica*, vol. 50, no. 2, pp. 552–558, 2014.

[113] H. Li, X. Liao, T. Huang, and W. Zhu, "Event-triggering sampling based leader-following consensus in second-order multi-agent systems," *IEEE Trans. Autom. Control*, vol. 60, no. 7, pp. 1998–2003, Jul. 2015.

[114] Y. Cheng and V. Ugrinovskii, "Event-triggered leader-following tracking control for multivariable multi-agent systems," *Automatica*, vol. 70, pp. 204–210, Aug. 2016.

[115] W. Zhu and Z.-P. Jiang, "Event-based leader-following consensus of multi-agent systems with input time delay," *IEEE Trans. Autom. Control*, vol. 60, no. 5, pp. 1362–1367, May 2015.

[116] W. Hu, L. Liu, and G. Feng, "Output consensus of heterogeneous linear multi-agent systems by distributed event-triggered/self-triggered strategy," *IEEE Trans. Cybern.*, vol. 47, no. 8, pp. 1914–1924, 2017.

[117] E. Garcia, Y. Cao, and D. W. Casbeer, "Decentralized event-triggered consensus with general linear dynamics," *Automatica*, vol. 50, no. 10, pp. 2633–2640, 2014.

[118] D. Yang, W. Ren, X. Liu, and W. Chen, "Decentralized eventtriggered consensus for linear multi-agent systems under general directed graphs," *Automatica*, vol. 69, pp. 242–249, Jul. 2016.

[119] H. Zhang, G. Feng, H. Yan, and Q. Chen, "Observer-based output feedback event-triggered control for consensus of multi-agent systems," *IEEE Trans. Ind. Electron.*, vol. 61, no. 9, pp. 4885–4894, Sep. 2014.

[120] Z. Zhang, L. Zhang, F. Hao, and L. Wang, "Leader-following consensus for linear and Lipschitz nonlinear multiagent systems with quantized communication," *IEEE Trans. Cybern.*, vol. 47, no. 8, pp. 1970–1982, Aug. 2017.

[121] A. Adaldo *et al.*, "Event-triggered pinning control of switching networks," *IEEE Trans. Control Netw. Syst.*, vol. 2, no. 2, pp. 204–213, Jun. 2015.

[122] D. Liuzza, D. V. Dimarogonas, M. Di Bernardo, and K. H. Johansson, "Distributed model based event-triggered control for synchronization of multi-agent systems," *Automatica*, vol. 73, pp. 1–7, Nov. 2016.

[123] Y. Zhao, L. Ding, G. Guo, and G. Yang, "Event-triggered average consensus for mobile sensor networks under a given energy budget," *J. Frankl. Inst.*, vol. 352, no. 12, pp. 5646–5660, 2015.

[124] X. Meng and T. Chen, "Event based agreement protocols for multi-agent networks," *Automatica*, vol. 49, no. 7, pp. 2125–2132, 2013.

[125] F. Xiao, X. Meng, and T. Chen, "Sampled-data consensus in switching networks of integrators based on edge events," *Int. J. Control*, vol. 88, no. 2, pp. 391–402, 2015.

[126] E. Garcia, Y. Cao, and D. W. Casbeer, "Periodic event-triggered synchronization of linear multi-agent systems with communication delays," *IEEE Trans. Autom. Control*, vol. 62, no. 1, pp. 366–371, Jan. 2017.

[127] Y. Fan, L. Liu, G. Feng, and Y. Wang, "Self-triggered consensus for multi-agent systems with Zeno-free triggers," *IEEE Trans. Autom. Control*, vol. 60, no. 10, pp. 2779–2784, Oct. 2015.

[128] C. De Persis and P. Frasca, "Robust self-triggered coordination with ternary controllers," *IEEE Trans. Autom. Control*, vol. 58, no. 12, pp. 3024–3038, Dec. 2013

[129] C. Nowzari and J. Cortés, "Team-triggered coordination for real-time control of networked cyber-physical systems," *IEEE Trans. Autom. Control*, vol. 61, no. 1, pp. 34–47, Jan. 2016.

[130] Lu, Xiaoqing, and Jingang Lai. "Communication constraints for distributed secondary control of heterogenous microgrids: A survey." *IEEE Transactions on Industry Applications* (2021).

[131] Z. Zhang et al., "An Event-Triggered Secondary Control Strategy With Network Delay in Islanded Microgrids," in IEEE Systems Journal, vol. 13, no. 2, pp. 1851-1860, June 2019.

[132] Ali, Ikbal, and SM Suhail Hussain. "Communication design for energy management automation in microgrid." *IEEE Transactions on Smart Grid* 9.3 (2016): 2055-2064.

[133] Bayindir, Ramazan, et al. "A comprehensive study on microgrid technology." *International Journal of Renewable Energy Research (IJRER)* 4.4 (2014): 1094-1107.

[134] Yadav, Monika, Nitai Pal, and Devender Kumar Saini. "Microgrid control, storage, and communication strategies to enhance resiliency for survival of critical load." *IEEE Access* 8 (2020): 169047-169069.

[135] Gabert, Scott G., et al. "Data Acquisition and Control of Microgrid Using ZigBee–A senior design project." *2013 North Midwest Section Meeting*. 2021.

[136] S. Ghosh, C. K. Chanda and J. K. Das, "A Comprehensive Survey on Communication Technologies for a Grid Connected Microgrid System," 2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS), 2021, pp. 1525-1528.

[137] Yan, Huaicheng, et al. "Adaptive event-triggered predictive control for finite time microgrid." *IEEE Transactions on Circuits and Systems I: Regular Papers* 67.3 (2020): 1035-1044.

[138] Feng, Yiwei, Jing Ma, and Xin Wang. "Robust H∞ Control of Networked System In Microgrid Under Random Packet Loss." (2021).

[139] Dehkordi, Nima Mahdian, et al. "Voltage and frequency consensusability of autonomous microgrids over fading channels." IEEE Transactions on Energy Conversion 36.1 (2020): 149-158.

[140] Nojavanzadeh, Donya, et al. "Scale-free Cooperative Control of Inverter-based Microgrids with General Time-varying Communication Graphs." *IEEE Transactions on Power Systems* (2021).

[141] Jin, Dong, et al. "Toward a cyber-resilient and secure microgrid using software-defined networking." *IEEE Transactions on Smart Grid* 8.5 (2017): 2494-2504.

[142] C. X. Dou, B. Zhang, D. Yue, and Z. Q. Zhang, "Cyber-physical cooperative control strategy for islanded micro-grid considering communication interruption," Int. Trans. Elect. Energy Syst., vol. 29, no. 1, pp. 1–28, 2019.

[143] Shrivastava, Sonam, Bidyadhar Subudhi, and Susmita Das. "Noise-resilient voltage and frequency synchronisation of an autonomous microgrid." IET Generation, Transmission & Distribution 13.2 (2019): 189-200.

[144] Dehkordi, Nima Mahdian, et al. "Distributed noise-resilient secondary voltage and frequency control for islanded microgrids." IEEE Transactions on Smart Grid 10.4 (2018): 3780-3790.

[145] Dou, Chunxia, et al. "A novel hierarchical control strategy combined with sliding mode control and consensus control for islanded micro-grid." IET Renewable Power Generation 12.9 (2018): 1012-1024.

[146] Afshari, Amir, et al. "Resilient cooperative control of AC microgrids considering relative state-dependent noises and communication time-delays." IET Renewable Power Generation 14.8 (2020): 1321-1331.

[147] Lu, Xiaoqing, et al. "A novel distributed secondary coordination control approach for islanded microgrids." IEEE Transactions on Smart Grid 9.4 (2016): 2726-2740.

[148] Zhao, Chanjuan, et al. "Distributed cooperative secondary networked optimal control with packet loss for islanded microgrid." IET Generation, Transmission & Distribution 13.20 (2019): 4733-4740.

[149] C. Peng, H. Sun, M. Yang and Y. -L. Wang, "A Survey on Security Communication and Control for Smart Grids Under Malicious Cyber Attacks," in IEEE Transactions on Systems, Man, and Cybernetics: Systems, vol. 49, no. 8, pp. 1554-1569, Aug. 2019.

[150] Pérez-Guzmán, Ricardo Enrique, et al. "Modelling Communication Network for Intelligent Applications in Microgrids-Part II." 2018 IEEE International Conference on Automation/XXIII Congress of the Chilean Association of Automatic Control (ICA-ACCA). IEEE, 2018.

[151] Aghaee, Fateme, et al. "Distributed control methods and impact of communication failure in AC microgrids: A comparative review." Electronics 8.11 (2019): 1265.

[152] Wang, D.; Wang, Z.; Chen, M.; Wang, W. "Distributed optimization for multi-agent systems with constraints set and communication time-delay over a directed graph". Inf. Sci. 2018, 438, 1–4.

[153] Dong, Chaoyu, et al. "Dc microgrid stability analysis considering time delay in the distributed control." Energy Procedia 142 (2017): 2126-2131.

[154] A. F. Khalil and J.Wang, “A new stability and time-delay tolerance analysis approach for networked control systems,” in Proc. 49th IEEE Conf. Decis. Control, Dec. 2010, pp. 4753–4758.

[155] C. Dou, D. Yue, J. M. Guerrero, X. Xie, and S. Hu, “Multiagent systembased distributed coordinated control for radial dc microgrid considering transmission time delays,” IEEE Trans. Smart Grid, vol. 8, no. 5, pp. 2370–2381, Sep. 2017.

[156] M. Dong, L. Li, Y. Nie, D. Song, and J. Yang, “Stability analysis of a novel distributed secondary control considering communication delay in dc microgrids,” IEEE Trans. Smart Grid, vol. 10, no. 6, pp. 6690–6700, Nov. 2019.

[157] Z. Wang, W. Wu, and B. Zhang, “A distributed control method with minimum generation cost for dc microgrids,” IEEE Trans. Energy Convers., vol. 31, no. 4, pp. 1462–1470, Dec. 2016

[158] X. Chen, M. Shi, H. Sun, Y. Li, and H. He, “Distributed cooperative control and stability analysis of multiple dc electric springs in a dc microgrid,” IEEE Trans. Ind. Electron., vol. 65, no. 7, pp. 5611–5622, Jul. 2018.

[159] Y. Hu, X. Wang, Y. Peng, J. Xiang, and W. Wei, “Distributed finite-time secondary control for dc microgrids with virtual impedance arrangement,” IEEE Access, vol. 7, pp. 57 060–57 068, 2019.

[160] Yan, Huaicheng, et al. "A novel sliding mode estimation for microgrid control with communication time delays." *IEEE Transactions on Smart Grid* 10.2 (2017): 1509-1520.

[161] Niu, Yugang, Daniel WC Ho, and James Lam. "Robust integral sliding mode control for uncertain stochastic systems with time-varying delay." *Automatica* 41.5 (2005): 873-880.

[162] Q. Yang, J. Zhou, X. Chen and J. Wen, "Distributed MPC-Based Secondary Control for Energy Storage Systems in a DC Microgrid," in IEEE Transactions on Power Systems, vol. 36, no. 6, pp. 5633-5644, Nov. 2021.

[163] C. Burgos-Mellado et al., "Single-Phase Consensus-Based Control for Regulating Voltage and Sharing Unbalanced Currents in 3-Wire Isolated AC Microgrids," in IEEE Access, vol. 8, pp. 164882-164898, 2020.

[164] P. Cai, C. Wen and C. Song, "Consensus-Based Secondary Frequency Control for Islanded Microgrid with Communication Delays," 2018 International Conference on Control, Automation and Information Sciences (ICCAIS), 2018, pp. 107-112.

[165] Xing, Lantao, et al. "Distributed Secondary Control for DC Microgrid with Event-triggered Signal Transmissions." IEEE Transactions on Sustainable Energy (2021).