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Microgrids, the best platform for economic and environmental productivity of renewable resources: An introduction to its concept, components, challenges, and opportunities

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Abstract
In recent years, for reasons such as the limitation and pollution of fossil fuels, as well as the growing electricity demand, the international community has paid more attention to renewable energies. On the other hand, the application of renewable energies to generate electricity requires the provision of appropriate infrastructure and platforms in power system. These have led to the emergence of a concept called microgrid. However, due to the structural differences between microgrids and traditional power systems, they face several challenges. This paper presents the concept of microgrids, equipment used for them, and their challenges and research gaps. This review shows that, by removing the technical barriers and addressing the challenges ahead, microgrids can be considered as a promising platform to optimize the utilization of renewable energy resources. It is expected that power systems in the future will be of microgrid type.

Keywords: Renewable resources, Microgrid, New energy, Internet of energy

1. INTRODUCTION

In recent years, increasing global demand for electricity, climate change, and problems with fossil fuels such as environmental issues and poor productivity have increased the stress on renewable energies [1-3]. One of the important obstacles in this path, which is addressed in this article, is the lack of infrastructure and a suitable platform for the application of renewable energy resources. This issue has been the main motivation for the introduction of microgrids [1]. In other terms, microgrids were proposed to increase the penetration of renewable energies into the electrical energy distribution system while making it more reliable and requiring low complex algorithms [4]. Microgrids, if used within a proper operations strategy, can also bring technical, environmental, social, and economic benefits and provide a suitable approach to meet the growing electricity demand [1, 4-5].

Thus, microgrids are currently the best platform for economic and environmental productivity of renewable generations and future electrical energy systems are expected to be of this type [6-8]. Although microgrids offer opportunities such as more efficient use of renewable energies, there are multiple challenges with them. The purpose of this article is to discuss the challenges and opportunities facing microgrids while introducing their concept and components.

2. Overview of types and components

2.1. Types of microgrids

Microgrids are operated in two modes; connected to the main grid and islanded. When connected to the grid, microgrids can play a role as network support to balance the supply and demand chain of the main grid [2], reduce the peak [9], control the frequency and voltage, and improve the flexibility and reliability [2]. On the other hand, staggering construction and operational costs of transmission lines have provided a good opportunity for the construction of microgrids in rural areas and away from the network [10]. Under these conditions, the installation of island microgrids leads to optimized transmission costs and energy losses [11]. Island microgrids are used in spaceships and ship decks, as well [12].

Economically, microgrids are divided into two groups of physical and commercial microgrids. Physical microgrids are used to meet technical demands, including balancing the supply and demand chain on the network, while commercial microgrids are applied to achieve economic benefits and a higher share in the electricity market [2].

Based on their voltage type, microgrids can be divided into three groups; AC, DC, and hybrid. Since existing infrastructures are usually based on AC, AC microgrids are more likely to be implemented, especially those being connected to the grid. In contrast, DC microgrids have multiple advantages such as lower losses, reduced power conversion steps, ease of control and operation, no harmonic and transient problems of AC networks, and no synchronization in connecting resources to each other where there is a need to build a microgrid infrastructure, especially in island conditions [13-15].

Finally, based on their application, microgrids are divided into three groups: remote, campus, and industrial microgrids [16]. Military microgrids are sometimes considered the fourth group [10]. Different categorization of microgrids is illustrated in Figure 1.

2.2. Components

Microgrid loads are one of the most important components that have been reformed in recent years. For example, constant-power loads, common in microgrids, adversely affect the response of the system to disturbances [17].

Generating units are another component of microgrids. Due to the design motivation and operation of microgrids, most of the generation resources are renewable. The most important of these products include solar panels, wind farms, and small hydropower plants. However, their uncertainty and harmonic effects resulting from the electronic power equipment employed in them, are important challenges of these types of generating units [18-19].

In the presence of renewable resources with a changing output, storage devices play a crucial role. These devices in smart grids contribute to peak-shaving and load-shifting strategies [20], participate in the regulation of frequency-active and voltage-reactive power [20], provide power storage to regulate electricity markets, solve network congestion problems, and delay network investments [14,20]. Noteworthy, due to the unstable nature of new energies, the reliability of the system in an island mode depends on the capacity of energy storage devices [12].

Microgrids typically have a communication infrastructure between the central controller, switches, primary controllers, and measuring components and equipment [21]. Given that power grids will have a significant set of intelligent electronic devices in the future, the development of communications and control systems, and standardization of network architecture will be of high priority [22]. Moreover, demand response programs, energy storage subsystems, and DGs used in microgrids will create extra and original needs in the field of automation, management, and control, while the scope of studies will also be extended [8].

2.3. Electricity market

The installation of DGs close to the demand source has increased the number of market players. The shift from the centralized to distributed network control that is taking place in microgrids has provided an opportunity for distributed system users to play an effective role, and in addition, the market has given new players opportunities such as the ability to participate in transactions. With the introduction of microgrids, the development of investment in the electricity market is getting simpler and enables actors to be involved in different markets [2].

2.4. Energy management systems

As noted above, due to the nature of their components, issues such as the uncertainty of renewable resources and reliability, compared to traditional power systems, have become more prominent in microgrids. Nevertheless, the combination of different energy resources can provide an opportunity to deal with random aspects and manage various possible events [23]. Consequently, designing an efficient energy management system can help improve the reliability of the system and increase the service life of energy storage equipment [24-25].

Results and Discussion

Due to structural differences between microgrids and traditional power systems, each part of the study in the field of microgrids faces new challenges, most of which are related to renewables and the distribution of generation resources, and consequently, uncertainty and degradation of power quality. An important part of the problems is the instability due to the low inertia of the microgrid, for which solutions such as the use of flywheels, battery storage, and traditional energy resources have been proposed, whereas these energy storage devices also face several problems including maintaining charge balance, coordination between storage devices, and economic inefficiency. On the other hand, connecting microgrids to each other, which has been proposed as an approach to increase the capacity of microgrids and improve the reliability and stability of microgrids, involves significant challenges in the load flow and communication infrastructure. Therefore, it is necessary to effectively manage various renewable generations. Table 1 lists some of the most important challenges facing microgrids in different areas of work. Some solutions to these challenges have already been proposed by multiple research groups, however, there are still many research gaps that require further research.

3. Conclusions

In this article, by reviewing the latest reports, components, the concept, and applications of microgrids were introduced and the current challenges facing this technology were discussed. Structural differences between microgrids and traditional power systems have caused new challenges and opportunities for power system operators in every part of the network, including load centers and generating units. Furthermore, new components and concepts such as storage devices, converters, and communication

Table 1. Most important challenges facing microgrids

Research area	Related challenges
Voltage and Frequency stability	Stability issues in grid-connected mode
	Low inertia of microgrid and renewable generations and its control
	Issues related to Droop control
	Vulnerability and instability of bus voltage in DC microgrids due to changes in renewable output
	Instability issues and voltage recovery in the presence of wind turbines
	Transient instability in DC and hybrid microgrids
	Instability due to loss of generation unit
	Load-related instabilities
Energy storages	Maintaining the state of charge balance in energy storage units
	Size of energy storages and economic issues
	Issues related to electric vehicles
	Coordination between flywheels with battery energy storage systems and generators and related control issues
Converters	Design
	Control
Interconnected Microgrids	Power flow between microgrids
	Management of integration of distributed generations
	Communication infrastructures
	Improving voltage profile, efficiency and reliability
Energy management	Optimizing energy management in the presence of demand response programs
	Demand response management
	Environmental issues
	Management of subscriber energy storage equipment
	Energy balance and reliability
Management of different operating modes - Management of communication between different voltage levels in DC microgrids	Automatic switching between different operating modes
	Bipolar microgrid problems (relationship between different voltage levels)
Communication infrastructures	Communication delays
	Use of different communication systems
Campus and military microgrids	Economic and technical analysis, design and operation
	Control issues
Electricity market	Reduce energy consumption and fuel costs
	Optimal utilization of special microgrids

infrastructure have resulted in unexpected and sometimes complex issues. New challenges and opportunities in areas such as design and energy management systems were also discussed in this article. Collectively, despite the challenges ahead, the microgrid is believed to be the best platform for economic and environmental efficiency of renewable energies and will be extensively applied in the near future. Therefore, microgrids have been highly regarded by researchers, while noted issues and gaps have created many research opportunities.

References

[1] Faisal R. Badal, Purnima Das, Subrata K. Sarker and Sajal K. Das, A survey on control issues in renewable energy integration and microgrid, *Protection and Control of Modern Power Systems*, March 2019.

[2] Ritu Shrivastwa, Ahmad Hably, Kaouthar Melizi, Seddik Bacha, Understanding Microgrids and Their Future Trends, *IEEE International Conference on Industrial Technology (ICIT 2019)*, Melbourne, Australia, Feb. 2019.

[3] A .Haghighi and A .Babapoor, Using of renewables energies such as effective way to reduce environmental pollution, *Journal of Renewable and New Energy*, vol. 5, pp. 41-51,2018. (in Persian)

[4] Kayode Timothy Akindeji, Rémy Tiako, Innocent E. Davidson, Use of Renewable Energy Sources in University Campus Microgrid – A Review, *2019 International Conference on the Domestic Use of Energy (DUE)*, Wellington, South Africa, 25–27 March 2019.

[5] M. Bagheri, E. Zare, A. Abadi and A. Enzebati, Investigating the Effect of Using Renewable Resources on Electricity Supply Demand Presenting a two-objective Mathematical Model, *Journal of Renewable and New Energy*, vol. 6, pp. 38-46, 2019. (in Persian)

[6] A. S. Dobakhshari, S. Azizi and A. M. Ranjbar, Control of microgrids: Aspects and prospects, *2011 International Conference on Networking, Sensing and Control*, Delft, 2011, pp. 38-43.
[7] J. Zeng, Q. Wang, J. Liu, J. Chen and H. Chen, A Potential Game Approach to Distributed Operational Optimization for Microgrid Energy Management With Renewable Energy and Demand Response, *in IEEE Transactions on Industrial Electronics*, vol. 66, no. 6, pp. 4479-4489, June 2019.
[8] T. Mohn, Campus microgrids: Opportunities and challenges, *2012 IEEE Power and Energy Society General Meeting*, San Diego, CA, pp. 1-4, 2012.
[9] C. Marnay, N. DeForest and J. Lai, A green prison: The Santa Rita Jail campus microgrid, *2012 IEEE Power and Energy Society General Meeting*, San Diego, CA, pp. 1-2, 2012.
[10] P. Brijesh, K. Jiju, P. R. Dhanesh and A. Joseph, Microgrid for sustainable development of remote villages, *TENCON 2019 - 2019 IEEE Region 10 Conference (TENCON)*, Kochi, India, pp. 2433-2438, 2019.
[11] Faisal Mumtaz, Islam Safak Bayram, Planning, Operation, and Protection of Microgrids: An Overview, *Energy Procedia*, Vol. 107, pp. 94-100, 2017.
[12] G. V. Somanath Reddy, V. P. Mini, N. Mayadevi and R. Hari Kumar, Optimal Energy Sharing in Smart DC Microgrid Cluster, 2020 IEEE International Conference on Power Electronics, *Smart Grid and Renewable Energy (PESGRE2020)*, Cochin, India, pp. 1-6, 2020.
[13] Tan Shucheng, Dong Ge, Zhang Hui, Zhi Na, Xiao Xi, Virtual DC machine control strategy of energy storage converter in DC microgrid, *2016 IEEE Electrical Power and Energy Conference (EPEC)*, Ottawa, ON, Canada, 12-14 Oct. 2016.
[14] T. K. Roy, M. A. Mahmud, A. M. T. Oo, M. E. Haque, K. M. Muttaqi and N. Mendis, Nonlinear adaptive backstepping controller design for controlling bidirectional power flow of BESSs in DC microgrids*, 2016 IEEE Industry Applications Society Annual Meeting*, Portland, OR, pp. 1-8, 2016.
[15] Z. Yi, X. Zhao, D. Shi, J. Duan, Y. Xiang and Z. Wang, Accurate Power Sharing and Synthetic Inertia Control for DC Building Microgrids With Guaranteed Performance*, in IEEE Access*, vol. 7, pp. 63698-63708, 2019.
[16] L. Hadjidemetriou et al., Design factors for developing a university campus microgrid, *2018 IEEE International Energy Conference (ENERGYCON)*, Limassol, 2018, pp. 1-6.
[17] B. Blanco-Contreras, J. Meneses-Silva, P. Mendoza-Araya and G. Jiménez-Estévez, Effect of constant power load models on the stability of isolated Microgrids, *2019 IEEE CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON)*, Valparaiso, Chile, pp. 1-6, 2019.
[18] Syed Qalb-E-Abbas Kazmi, Abdul Waheed Khawaja, Zunaib Maqsood Haider, Tauheed-ur-Rahman, Syed Muhammad Ali Musa Kazmi, Voltage Stability of Wind Turbine Based Micro Grid Using Simulation Platforms, *2019 International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET)*, Istanbul, Turkey, 26-27 Aug. 2019.
[19] S. Arif, A. E. Rabbi and T. Aziz, Post-Fault Operation Scenerio in a Wind Integrated Microgrid: Voltage Recovery Issue and Solution, *2019 IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC)*, Macao, Macao, pp. 1-5, 2019.
[20] M. Brenna, F. Foiadelli, M. Longo, S. Bracco and F. Delfino, Smart microgrids in smart campuses with electric vehicles and storage systems: Analysis of possible operating scenarios, *2016 IEEE International Smart Cities Conference (ISC2)*, pp. 1-6, Trento, 2016.
[21] M. Farrokhabadi et al., Microgrid Stability Definitions, Analysis, and Examples, in *IEEE Transactions on Power Systems*, vol. 35, no. 1, pp. 13-29, Jan. 2020.
[22] S. Beheshtaein, M. Savaghebi, J. C. Vasquez and J. M. Guerrero, Protection of AC and DC microgrids: Challenges, solutions and future trends, *IECON 2015 - 41st Annual Conference of the IEEE Industrial Electronics Society*, Yokohama, pp. 005253-005260, 2015.
[23] F. K. Bidi, C. Damour, D. Grondin, M. Hilairet and M. Benne, Model Predictive Control for Micro Grid stabilisation in case of loss of units, *2019 IEEE 58th Conference on Decision and Control (CDC)*, Nice, France, pp. 3266-3271, 2019.
[24] D. M. R. Korada, M. K. Mishra and R. S. Yallamilli, Dynamic Energy Management in DC Microgrid using Composite Energy Storage System*, 2020 IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy (PESGRE2020)*, Cochin, India, pp. 1-6, 2020.
[25] H. Du, S. Liu, Q. Kong, W. Zhao, D. Zhao and M. G. Yao, A microgrid energy management system with demand response, *2014 China International Conference on Electricity Distribution (CICED)*, Shenzhen, pp. 551-554, 2014.