International Journal of Industrial Engineering, 2019;3(7):51-56.
ISSN: 2456-8449.
http://ijie.gjpublications.com

Review Article

A Study on Microgrid Technology: Some Key Aspects

Md. Mashrur Islam[1], Rubayet Hosen[2], Md. Mushfiq ur Rahman[3]

[1]Department of Electrical & Electronic Engineering,
Rajshahi University of Engineering & Technology, Bangladesh.
[2]Department of Electrical & Electronic Engineering,
Independent University, Bangladesh.
[3]Department of Electrical & Electronic Engineering,
United International University, Bangladesh.

*Corresponding author's e-mail: anisulme11@gmail.com

Abstract

Microgrid is an important terminology in power system technology. The interest on microgrid is burgeoning with the increasing demand of reliable, secure, efficient, clean, and sustainable electricity. More research and implementation of microgrid will be conducted in order to improve the maturity of microgrid technology. In this study, we have reviewed different aspects of microgrid technologies and the current achievements in this area of research. To introduce the readers with one of the most significant power technologies, microgrid technology, is the key goal of this research.

Keywords: Microgrid; Photovoltaic cell; Fuel cell; Distributed generation.

Introduction

The raising concerns on quality of generated power, especially if it is connected to the grid system, where solar power would be seen as a negative expense by net system because it has characteristics associated with uncontrolled fluctuation from energy sources [1]. This problem can be addressed by adding another generation system more controlled, such as, the addition of energy storage systems (batteries) or forming a hybrid system by adding diesel generators or micro turbines [2]. Implementation of microgrid systems provides many advantages both from the user and from the electric utility provider.

The microgrid concept has been researched and implemented intensively by many experts worldwide with significant research conducted in U.S., E.U., Japan, and Canada [3-4]. The interest on microgrid increases due to its potential benefits to provide reliable, secure, efficient, environmentally friendly, and sustainable electricity from renewable energy sources [5]. Before the microgrid concept was introduced, many researches had been conducted on distributed generation (DG). Researchers soon realized that installing individual DG in power systems may create problems as many as it solves. Hence, microgrid concept was proposed to overcome those problems [6-7].

However, microgrid can also reduce the load on the network by eliminating the impasse in meeting electricity needs and help repair network in case of errors [8]. Implementation of microgrid system will also help improve the reduction of emissions and the threat of climate change. Microgrid development done by many countries since microgrid offers many advantages such as better power quality and more environmentally friendly. Moreover the economic potential that may still be used from this system is the opportunity to utilize the waste heat from the engine generator using a combined heat and power. Application of this system with RES as an alternative generation system in the future. Surely this system requires the operating mechanism and a sophisticated control system to make the finger with a reliable and efficient, and it can all be met by the microgrid [9]. However, a review on different aspects of microgrid technology is illustrated in this paper. Authors tried to review the recent achievements on the field of microgrid technology in the present study.

Received: 28.06.2019; Received after Revision: 17.07.2019; Accepted: 18.07.2019; Published: 24.07.2019

Illustration on microgrid

A microgrids is an interconnection of distributed energy sources, such as microturbines, wind turbines, fuel cells and PVs integrated with storage devices, such as batteries, flywheels and power capacitors on low voltage distribution systems [10]. A basic microgrid architecture is shown in Fig. 1. This architecture is commonly known as the Consortium for Electric Reliability Technology Solutions (CERTS) architecture [11-12]. This microgrid consists of a group of radial feeders, which could be part of a distribution system or a building's electrical system. There are three sensitive-load feeders (Feeders A–C) and one no sensitive- load feeder (Feeder D). The sensitive-load feeders contain sensitive loads that must be always supplied; thus each feeder must have at least a micro source rated to satisfy the load at that feeder. On the contrary, the non-sensitive-load feeder is the feeder that may be shut down if there is a disturbance or power quality problems on the utility; the non-sensitive-load feeder will be left to ride through the disturbance or power quality problems [11-12]. When there is a problem with the utility supply, Feeders A–C can island from the grid using the static switch that can separate in less than a cycle to isolate the sensitive loads from the power grid to minimize disturbance to the sensitive loads. In an islanded operation, a microgrid will work autonomously, therefore must have enough local generation to meet the demands of the sensitive loads [11-12].

Furthermore, a disturbance requiring a feeder to operate individually may also occur. If this latter case is considered in the microgrid design, each sensitive-load feeder must have enough local generation to supply its own loads while the no sensitive load feeder will rely on the utility supply. Post disturbance, the microgrid will reconnect to the utility and work normally as a grid-connected system. In this grid-connected, excess local power generation, if any, will supply the non-sensitive loads or charge the energy storage devices for later uses. The excess power generated by the microgrid may also be sold to the utility; in this case, the microgrid will participate in the market operation or provide ancillary services [7, 13, 14].

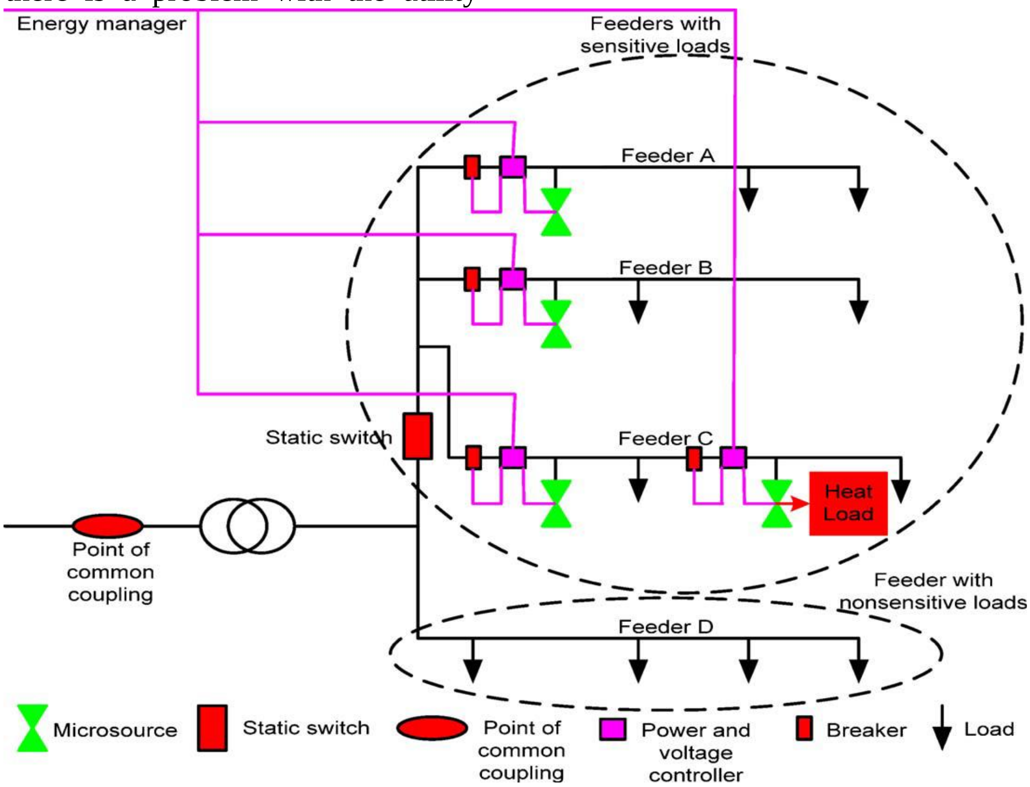

Fig. 1. Architecture of microgrid

The disconnection or reconnection processes must be specified by the point of common coupling, a single point of connection to the utility located on the primary side of the transformer. At this point the microgrid must meet the established interface requirements, such as defined in IEEE standard 1547 series [15-21]. Furthermore, the successful disconnection or reconnection processes depend upon microgrid controls. The controllers must insure that the processes occur seamlessly and the operating points after the processes are satisfied [11-12]. More detail information about the microgrid controls will be explained in the next section. The last main part of the CERTS architecture is the energy manager which is responsible to manage system operation through power dispatching and voltage setting to each micro source controller. Some possible criteria for the microgrid to fulfill this responsibility are, ensure that the necessary electrical loads and heat are fulfilled by the micro sources, ensure that the microgrid satisfies operational contracts with the utility, minimize emissions and/or system losses; and maximize the operational efficiency of the micro sources [11].

Research on microgrid has reached not only software simulation level, but also laboratory testbed and field model levels in past few years. The following are examples of testbeds for testing different components, control strategies, and storage technologies of microgrids [13, 22]; a specially designed single-phase system of the NTUA with agent control software, a general test site for distributed energy resources, called DeMoTec at ISET, and a flywheel test rig at the University of Manchester.

The increase interest on microgrids is triggered by the potential benefits of the microgrid that may provide reliable, secure, efficient, environmentally friendly, and sustainable electricity from RES. A microgrid can improve reliability and security of power distribution system, especially for sensitive loads, because micro sources will ensure that the sensitive loads will receive enough power in any operating condition. Different from function of a single distributed generator attached to a conventional distribution network, micro sources will act as main power generation instead of standby power generation. Power system efficiency may increase up to 90% if combined heat and power (CHP) is applied in the microgrid to utilize heat for local uses [23]. In addition, the efficiency increase can also result from loss reduction in transmission lines related to local power generation for local uses. Moreover, the local uses of local power generation will reduce energy or power density of transmission lines so that transmission line congestion can be reduced and investments on transmission line upgrade can be delayed [24-25]. Environmental friendliness can be achieved due to the current trend to increase the RES participations in microgrids; this participation increase will significantly reduce greenhouse gas (GHG) emissions [26–30]. Furthermore, RES can also ensure energy sustainability due to the nature of their availability; RES can gradually substitute fossil fuels that have limited sources. Ideally, energy can be harvested at no cost, besides installation, operational, and maintenance costs, from RES. However, renewable energy is naturally intermittent so that an energy storage system is required to optimize energy utilization [31-36].

Photovoltaic and Fuel Cell based Microgrid System

A lot of studies have been done on the hybrid micro-grid system. The performance and cost viability of a PV, fuel cell (FC) and battery-based hybrid grid-tied system with intermittent load conditions are analyzed in [37]. Four progressive modeling stages are designed, and five key metrics are utilized in this paper in order to determine the most effective micro-grid system. A viable cost-effective and environment-friendly system is also proposed. Integration of PV array along with FC and ultracapacitor system for energy production using short and long-term storage capacity and appropriate control strategy is proposed in [38].

The Fig. 2 depicts fuel cell based microgrid method. The performance and modeling of a smart grid monitoring system with separate solar plants (with a rated capacity of 25.5kW) and loads at different locations is analyzed in [39]. The transmission and distribution model with realistic impedance values of a 25km long transmission line using SCADA and PLC is also designed for the system. A two-level (control level and system level) strategy for energy management of DC micro-grid is presented in [40] for PV/FC/battery-based system. Dynamic management of power for PV and proton exchange membrane FC based AC/DC micro-grid system is presented in [41]. In the studies, the behavior of the systems has not been analyzed if those are connected to an IEEE 13 bus system. Fig. 3 shows microgrid technologies assisted by renewable sources like Photovoltaics and wind energy.

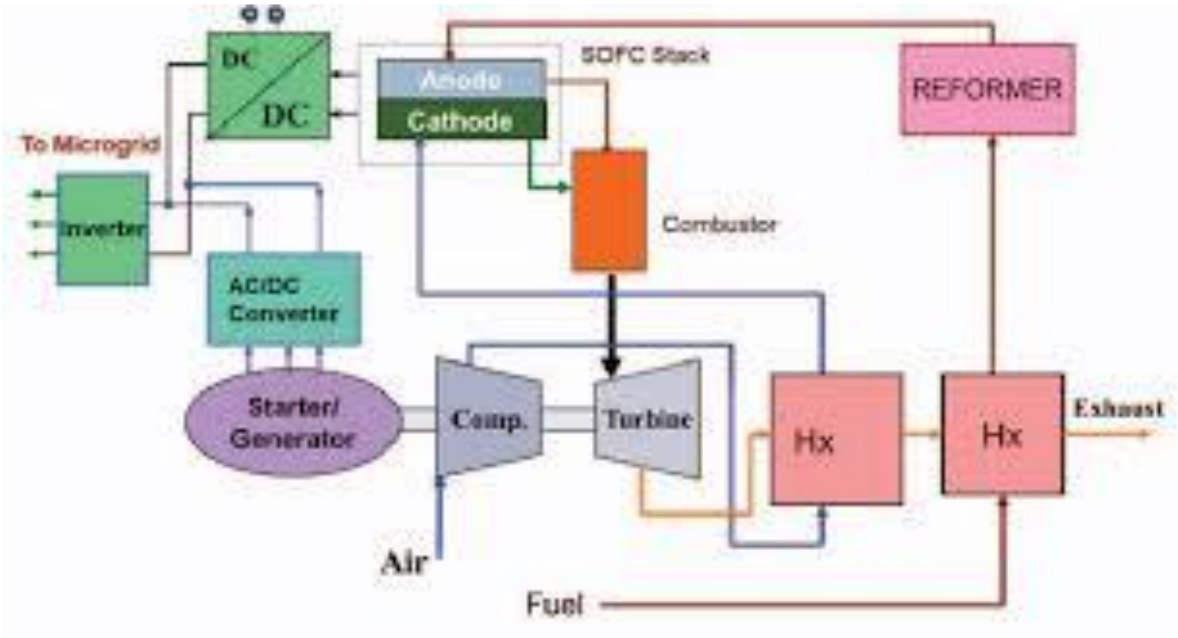

Fig. 2. Microgrid facility assisted by fuel cell

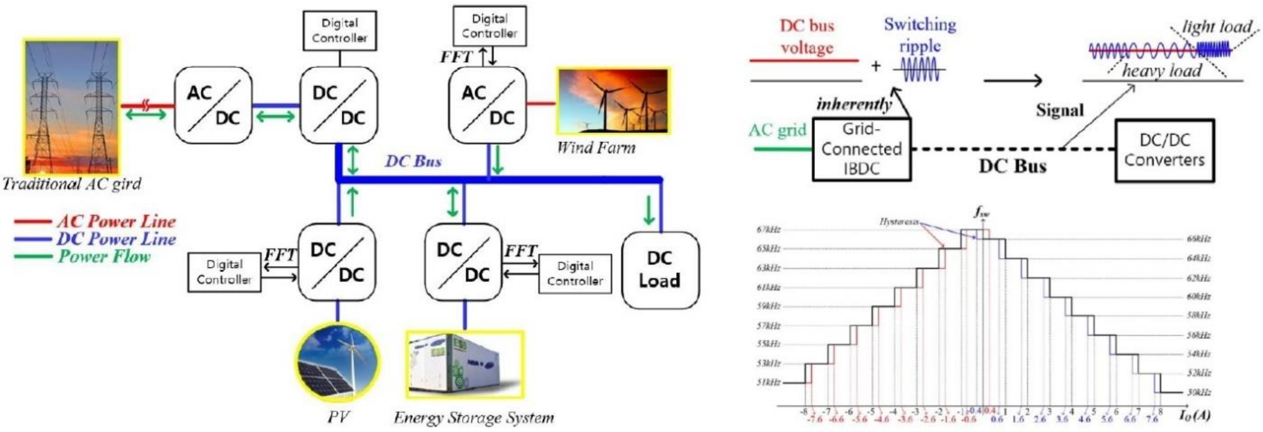

Fig. 3. Renewable energy assisted microgrid technology

The most common fuel cell among other fuel cell is proton exchange membrane fuel cells. It is very common because it can operate at a lower temperature (-20 to 1000C) and can start its operation very fast from its idle condition to full load condition. The fuel cell used in the hybrid system is 6kW. The stack fuel cell model provided by Sim Power System of MATLAB/ SIMULINK platform is utilized in the system. The parameters of the fuel cell model can be obtained from the simple polarization curve or the datasheet provided by the manufacturer.

Conclusions

Energy is one of the primary needs for survival of all organisms in the universe. Energy has dependably been a noteworthy need for the everyday human life. For socio-economic advancement, the non-stop supply of adequate energy is vital. However, microgrid technology is a rising field in power research. It can provide clean and adequate power with great consistency. In this research, we investigated different aspects of microgrid technology, which will assist the researchers during their further study.

Conflicts of interest

No conflicts of interest.

References

[1] Podder, AK, Ahmed K, Roy NK, Biswas PC. Design and simulation of an independent solar home system with battery backup. In 2017 4th Int Conf Adv Elec Eng (ICAEE), pp. 427-431. IEEE, 2017.

[2] Hatziargyriou N, Hiroshi A, Reza I, Chris M. Microgrids. IEEE Pow Energ Mag 2007;5:78-94.

[3] Willis HL. Distributed power generation: planning and evaluation. CRC Press; New York, NY 10016. USA. 2018.
[4] Jayamaha DS, Lidula NA, Rajapakse AD. Ground Fault Analysis and Grounding Design Considerations in DC Microgrids. In 2018 IEEE 4th Southern Power Electronics Conference (SPEC) 2018. pp. 1-8.
[5] Dell RM, David AJR. Energy storage-a key technology for global energy sustainability. J Pow Sour 2001;100:2-17.
[6] [6] Lasseter RH. Microgrids and distributed generation. J Energ Eng 2007;133:144-9.
[7] Mutarraf M, Terriche Y, Niazi K, Vasquez J, Guerrero J. Energy Storage Systems for Shipboard Microgrids-Adv Review. Energies. 2018;12:3492.
[8] Anastasiadis AG, AG Tsikalakis, Hatziargyriou DN. Environmental benefits from dg operation when network losses are taken into account. In Proceedings of DISTRES Conference. 2009.
[9] Hirsch A, Parag Y, Guerrero J. Microgrids: A review of technologies, key drivers, and outstanding issues. Renew Sust Energ Rev. 2018;90:402-11.
[10] Khayat Y, Naderi M, Shafiee Q, Batmani Y, Fathi M, Guerrero JM, Bevrani H. Decentralized optimal frequency control in autonomous microgrids. IEEE Trans Pow Sys. 2018;34(3):2345-53.
[11] Robert L, Abbas A, Chris M, John S, Jeff D, Ross G, Meliopoulous A, Robert Y, Joe E. The CERTS microgrid concept. White paper for Transmission Reliability Program, Office of Power Technologies, US Department of Energy, 2001;2(3):30.
[12] Zamora R, Anurag K. Srivastava. Controls for microgrids with storage: Review, challenges, and research needs. Renew Sust Energ Rev 2010;14:2009-18.
[13] Barnes M, Dimeas A, Engler A, Fitzer C, Hatziargyriou N, Jones C, Papathanassiou S, Vandenbergh M. Microgrid laboratory facilities. In 2005 Int Conf Fut Pow Sys, pp. 6. IEEE, 2005.
[14] Khan SMK, Islam MM. Heat Conduction Analysis of a Hollow Sphere made of Three Different Layers of Materials. World Sci News. 2019.
[15] [15] Islam MM, Ahmed SS, Rashid M, Akanda MM. Mechanical and Thermal Properties of Graphene over Composite Materials: A Technical Review. J Cast Mat Eng. 2019;3(1):19.
[16] IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems, IEEE Standard P1547.1TM, 2005.
[17] Application Guide for IEEE Std 1547, Interconnecting Distributed Resources with Electric Power Systems, IEEE Standard 1547.2TM, 2008.
[18] Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems, IEEE Standard 1547.3TM, 2007.
[19] Draft Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems, IEEE Standard P1547.4TM.
[20] Draft Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks, P1547.6TM.
[21] Draft Guide to Conducting Distribution Impact Studies for Distributed Resources Interconnection, P1547.7TM.
[22] Meiqin M, Chang L, Ming D. Integration and intelligent control of micro-grids with multi-energy generations: A review. In Proceedings of IEEE Int Conf Sust Energ Technol 2008, pp. 777-780.
[23] Krishnamurthy S, Jahns TM, Lasseter RH. The operation of diesel gensets in a CERTS microgrid. In 2008 IEEE Power and Energy Society General Meeting-Conversion and Delivery of Electrical Energy in the 21st Century 2008, pp. 1-8.
[24] Nigim KA, Lee WJ. Micro grid integration opportunities and challenges. In 2007 IEEE Power Engineering Society General Meeting 2007, pp. 1-6.
[25] Basu AK, Bhattacharya A, Chowdhury SP, Chowdhury S, Crossley PA. Reliability study of a micro grid system with optimal sizing and placement of DER. CIRED Seminar 2008: Smart Grids for Distribution, Frankfurt, 2008, pp. 1-4.
[26] Chicco G, Mancarella P. Distributed multi-generation: A comprehensive view. Renew Sust Energ Rev 2009;13(3):535-51.

[27] Omer A M. Energy, environment and sustainable development. Renew Sust Energ Rev 2008;12:2265-2300.
[28] Kaygusuz, Kamil. Energy and environmental issues relating to greenhouse gas emissions for sustainable development in Turkey. Renew Sust Energ Rev 2009;13:253-70.
[29] Pereira, Osvaldo Soliano, Tereza Mousinho Reis, Rafael GB De Araujo, and Felipe Freire Gonçalves. Renewable energy as a tool to assure continuity of low emissions in the Brazilian electric power sector. In 2006 IEEE EIC Climate Change Conference, 2006, pp. 1-8.
[30] Costa PM, Manuel AM, Peças JAL. Regulation of microgeneration and microgrids. Energ Pol 2008;36:3893-904.
[31] Bando S, Sasaki Y, Asano H, and Tagami H. Balancing control method of a microgrid with intermittent renewable energy generators and small battery storage. In Power and Energy Society General Meeting-Conversion and Delivery of Electrical Energy in the 21st Century, 2008.
[32] Youli S, Zulati L, Ken N. Efficiency of micro grid with storage battery in reliability, economy and environment assessments. Elec Pow Energ Sys 2009;3:154-62.
[33] Bayon A, Bader R, Jafarian M, Fedunik-Hofman L, Sun Y, Hinkley J, Miller S, Lipiński W. Techno-economic assessment of solid–gas thermochemical energy storage systems for solar thermal power applications. Energ 2018;149:473-84.
[34] Yu XY, Lou XW. Mixed metal sulfides for electrochemical energy storage and conversion. Adv Energ Mat 2018;8(3):1701592.
[35] Peng L, Fang Z, Zhu Y, Yan C, Yu G. Holey 2D nanomaterials for electrochemical energy storage. Adv Energ Mat 2018;8(9):1702179.
[36] Yang Y, Wang H, Sangwongwanich A, Blaabjerg F. Design for reliability of power electronic systems. In Power Electronics Handbook, Butterworth-Heinemann, 2018, pp. 1423-1440.
[37] Patterson M, Narciso FM, Arunachala MK. Hybrid microgrid model based on solar photovoltaic battery fuel cell system for intermittent load applications. IEEE Tran Energy Conv 2014;30:359-66.
[38] Podder AK, Ahmed K, Roy NK, Habibullah M. Design and Simulation of a Photovoltaic and Fuel Cell Based Micro-grid System. In 2019 International Conference on Energy and Power Engineering (ICEPE) 2019, pp. 1-6.
[39] Kabalci Y, Ersan K. Modeling and analysis of a smart grid monitoring system for renewable energy sources. Solar Energy 2017;153:262-75.
[40] Han Y, Weirong C, Qi L, Hanqing Y, Firuz Z, Yongkang Z. Two-level energy management strategy for PV-Fuel cell-battery-based DC microgrid. Int J Hydro Energ 2019;44:19395-404.
[41] Sharma RK, Sukumar M. Dynamic power management and control of a PV PEM fuel-cell-based standalone ac/dc microgrid using hybrid energy storage. IEEE Trans Ind App 2017;54:526-38.

****

