MICROGRID: STRUCTURES, CONTROL METHODS, STANDARDS AND CHALLENGES

Monesha SAHAYAM **Ganesh Kumar SRINIVASAN**
Department of Electrical & Electronics Engineering, CEG Campus, Anna University, Chennai, India, 600025,
smonesha92@gmail.com, ganeshkumar@annauniv.edu

Abstract: *In this paper, the various structures of the microgrid such as AC, DC, Hybrid, Urban DC and Ceiling DC Microgrids are explained. In addition, various energy management schemes are detailed. The benefits, drawbacks and various applications of microgrid structures also showcased with interactive figures and flowcharts. Moreover, to control the various parameters such as voltage, current, and power in MG, different control strategies are discussed. Further, different earthing methods are explained along with the standards like IEEE and IEC which helps in implementation of perfect microgrid system.*

Keywords: *Microgrid, Hybrid, Urban DC, Ceiling DC, energy management, earthing, standards.*

1. Introduction

Deployment of renewable energy sources reduces the environmental impact. Distributed Generation (DG) which utilizes renewable energy sources is gaining popularity for their high power quality, improved efficiency, high reliability, reduced emissions, high security and effective load management [1-3]. This makes DG as a part of microgrid (MG). MG is a group of DG, energy storage system and local loads which are connected to the utility grid. It acts as a single controllable system. An MG can operate in either grid connected mode or islanded mode through suitable control techniques. In [1, 2] concepts of MG, control techniques used and energy management aspects are explained. The special feature of MG is that it can isolate itself from the grid during any faults, blackouts and it is reviewed in a detailed manner [3]

Sizing of components and allocations in MG is a challenging task [4-8]. In [4], a triple –objective optimal sizing method using dynamic strategy is followed for an islanded hybrid energy MG to obtain reduced power loss, cost and thus maximizing the utilization of renewable energy sources. [5] Verified the optimum sizing of energy storage by optimizing the energy flow. The authors verified the energy storage sizing using MATLAB and concluded that the PV system without the energy storage will reduce the cost and not reliable from the operational point of view. [6] Presented an optimized method to reduce the power loss by optimally allocating distributed generations and capacitors. The authors preferred particle swarm optimization technique for the placement of DGs and capacitors to maximize the profit in a 33-bus and 69-bus test systems. [7] used HOMER software for checking the viability of hybrid MG. Further, they indicated the merits of hybrid grid deployment in the rural area. [8] has developed a hybrid energy system with an optimal unit sizing model which reduces the total cost of the hybrid MG. The author has chosen three rural parts from south India for the implementation of the proposed methodology.

Various modes of MG operation are accomplished using various control techniques [9-19]. [10] implemented a multi-stage frequency control for microgrids using PI control and fuzzy logic controller. Comparison of both controllers indicates that fuzzy controller performs better than PI controller. [10] developed coordinated control of dual interfacing converters for harmonic compensation without the knowledge of grid voltage phase-locked loop and the detection of the load current and the supply voltage harmonics. [11] demonstrated the multi-agent system based hierarchical energy management strategies for MG to realize maximum economic and environmental benefits. [12] presented a current as well as voltage control method for a converter used in hybrid MG. The proposed controller in hybrid MG does not require remote measurement with communications. [13] justified that generalized droop control fails to share power when line impedance is considered in DG units. To eliminate this difficulty, feed forward neural network based droop control method is proposed and verified. [14] designed an adaptive suboptimal second order sliding mode for grid-connected MG. The authors proved the stability nature of the proposed control strategies by simulation.

In hierarchical control, the primary and tertiary controller is used for power flow regulation [16]. In average current sharing control, the distributed configuration is done for enhancing the system reliability [17]. In average voltage sharing control, the terminal voltage is regulated [17]. In cooperative distributed control [17], three regulators namely, voltage, reactive power, and active power regulators are used. In model predictive control [18], optimization of the system behavior is done. [19] investigates about secured data exchange between different devices which are connected inside a Home Area Network (HAN). The basic knowledge of the passivity based control is discussed in [46-50].

This paper explains the various structures of MG, control methods, aspects of energy storage, energy management, earthing and standards in MG.

2. Different Structures of MG

Depending on the DG units and the loads connected the MG can be classified as DC MG, AC MG, Hybrid MG, Urban DC MG, and Ceiling MG.

2.1. AC MG

In AC MG (Fig. 1), power can be utilized by local loads or excess power can be injected grid. The main benefit of AC MG is the use of transformers. For proper operation of the MG, synchronization is essential. AC MG is used for high power applications [20-25].

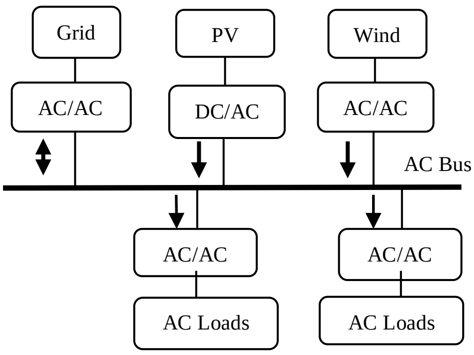

Fig. 1. Structure of AC MG

2.2. DC MG

DC MG produces low energy loss in comparison to AC MG. Fig. 2 shows the structure of MG which operates at various DC voltages and a common DC bus voltage. As there is no reactive power only the regulation of voltage amplitude must be done to connect the DC sources to the DC bus, the control operation becomes easy. DG MG eliminates AC-DC conversions. It requires proper operating ranges for the DC voltages and the protection devices for efficient working. Utilization can be easily carried out with the help of the voltage regulator. It is used for low voltage level applications [26-34].

The main advantages of using DC MG are as follows [37]:

- The absence of phase and frequency synchronization.
- Reduced energy conversion stages.
- It can be used for DC loads directly and AC load with the conversion.
- DC bus structure is more compact and thus increase the efficiency of plug-in hybrid electric vehicles and electric vehicles.

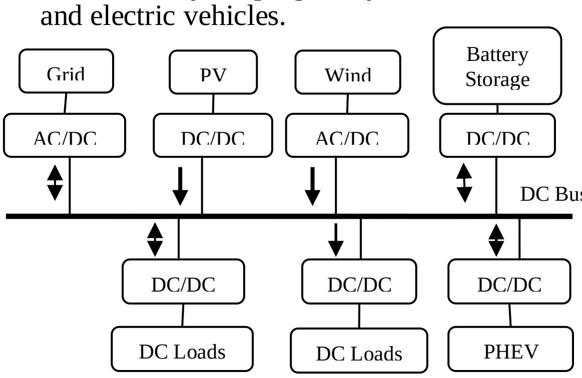

Fig. 2. Structure of DC MG

2.3. Hybrid AC/DC MG

This MG is a combination of AC MG and DC MG (Fig. 3). The AC MG is directly connected to the utility grid and the DC MG is connected through an interlinking converter, the design of this type of grid is done by considering the power flow, different types of loads, reliability and cost [35, 36, 43]. Due to the development of power electronic devices and its controllers, higher reliability, efficiency, flexibility is achieved.

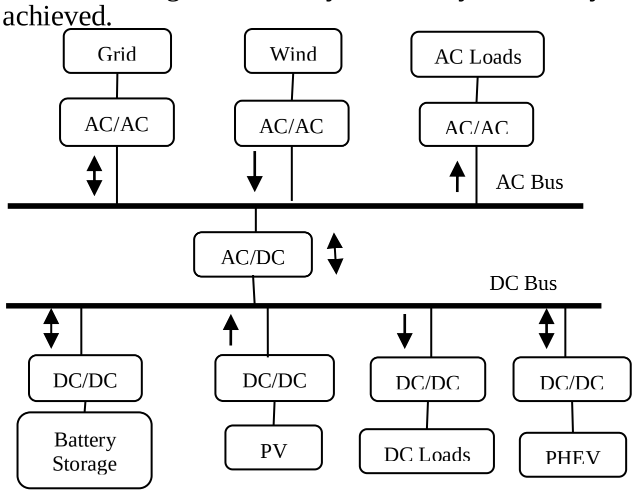

Fig. 3. Structure of Hybrid AC/DC MG

The Tianjin University MG Testbed (TUMT) is a highly integrated and reconfigurable MG testbed with hybrid distributed energy sources. The compensation, topologies and the facilities used by the TUMT are discussed in [25].

2.4. Urban DC MG

Urban DC MG is located in an urban building which acts as a producer as well as a consumer [28]. Various parameters of Urban DC MG are controlled using an adaptive controller; Different modes of MG can be easily handled by this controller via static switches. Further, this controller optimizes the penetration of new distributed generating sources (Fig. 4).

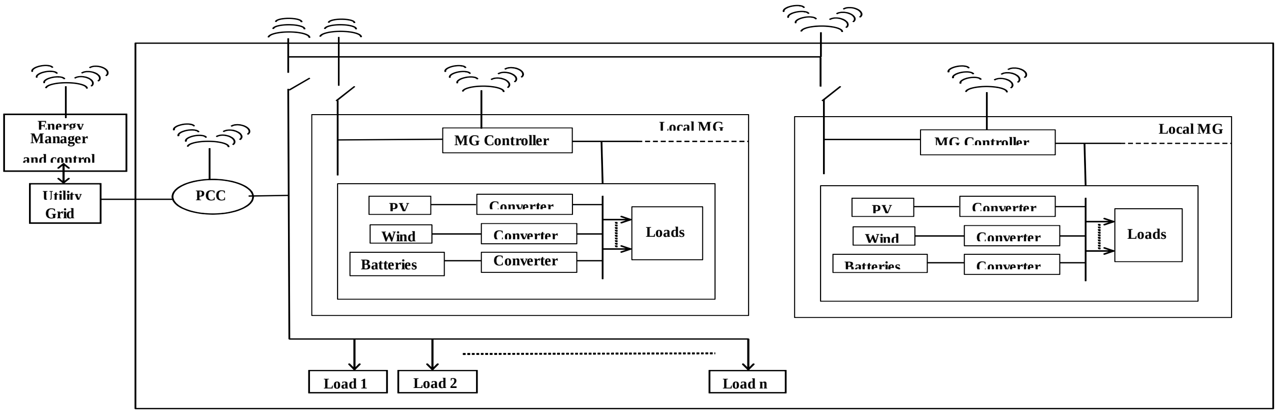

Fig. 4. Urban DC MG

2.5. Ceiling DC MG

Ceiling DC MG is popular due to the direct utilization of DC from rooftop PV panel without multiple conversions. In [45] outer proportional integral controller is used for regulating the DC voltage whereas inner three hysteresis controllers are used for forcing the input current to follow the input voltage in phase and thus improving the power factor.

3. MG Control Layer

A three-level control structure is typically adopted for the MG operation [1,2, 28, 38, 44].

Primary Control: Regulation of the output voltage of the inverters and handling the proportional load sharing among inverters is done at this level of control. It is used for coordinating and dispatching the MG for maintaining the economy and security of the distribution network.

Secondary Control: Restoration of the voltage and frequency deviations which are caused by the primary control level is done at this level and the set points for the inverter voltages are updated. It is used for forecasting the load demand and the DG output and the operation plans are developed and adjusted based on the information for controlling the DG units, Energy storage and the loads.

Tertiary Control: The power exchange between consumers is facilitated in this level of control. A market operator is incorporated in the distribution network operator control which is situated in the utility grid. It is used to achieve the economic-emission reliability dispatch. The implementation of this control is done by using optimization-based control techniques.

4. Overview of MG Energy Management Control

Energy management control is important for optimizing, monitoring and regulating the performance of a system for coordinating the distributed energy sources supplying the demand. The main objective is to use the renewable energy sources fully through economic power dispatch and online optimization.

4.1. Central Control

Monitoring and control of the entire MG have done with the available communication information. This control uses Phase locked loop (PLL) circuit for ensuring the consistency between the synchronizing signal and the frequency of the output voltage. The current shared modules define the current reference for each module. This depends highly on communication and a centralized controller, which reduces the reliability of the system. The measured data of all the DG units are collected by the centralized controller based on which it controls the control variable of each equipment [22, 23].

4.2. Master/Slave Control

Initially starting of the parallel connected module is done with automatic software setting or mode-selecting switch which makes the inverter act as the master and is used for regulating the output voltage and defines the current reference. The equal distribution of the current is done by the slave units which track the current reference from the master control. But the whole system will fail if the master unit fails. Improved power sharing can be achieved using this control without PLL [23].

4.3. Distributed Control

In this control, each inverter has an individual circuit for control and there is no need for the central controller. For tracking the same average reference current there is a need for an additional loop for current control provided by the current sharing bus. If there is a failure in any module it can be easily removed and the rest of the units can be operated normally in parallel [1, 23].

4.4. Passivity-Based Control (PBC)

In [1, 15, 39, 40, 42, 46-51], energy- based control, i.e., passivity- based control (PBC) is preferred for the stable operation of the MG. Energy-shaping approach is the essence of PBC technique. PBC for power electronic circuits are usually synthesized with a stabilization objective in mind, i.e., to achieve a constant output voltage or a constant current in the circuit branches. PBC exhibits stability and robustness in a number of systems. Due to this, PBC finds its applications in the systems like Renewable energy systems, electric drives, bilateral tele-operation, flexible manipulators, flight control, continuous stirred tank reactors and aircraft automatic landing systems.

In PBC, all the systems are modelled in terms of conservative forces, disruptive forces and energy acquisition part. The control function of PBC for any system is derived in such a way that, the error in the energy satisfies Lyapunov's stability.

In PBC, two different control methods viz., Exact Tracking Error Dynamics Passive Output Feedback (ETEDPOF) and Energy Shaping and Damping Injection (ESDI) are adopted. Flow charts for both schemes are shown in Fig. 5 and Fig. 6.

In ETEDPOF implementation, when the Lyapunov's condition is not satisfied, LaSalle's Theorem can be used for assessing the stability study. Due to the bounded nature of control input in power electronic converters, system can be semi- globally asymptotically stable. The passivity based control is shown in Fig. 7.

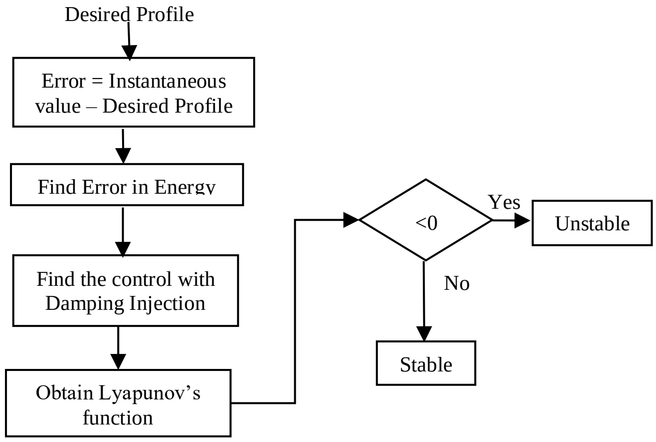

Fig. 5. Flow chart for ESDI implementation

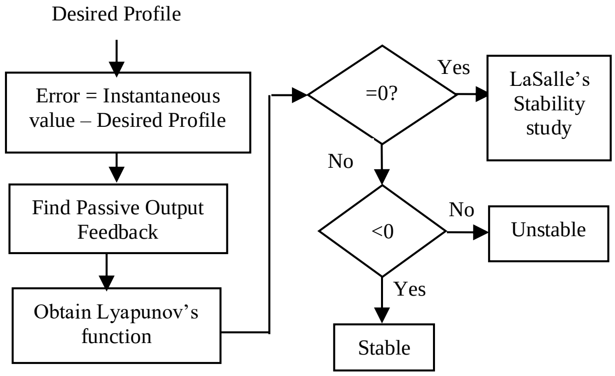

Fig. 6. Flow chart for ETEDPOF implementation

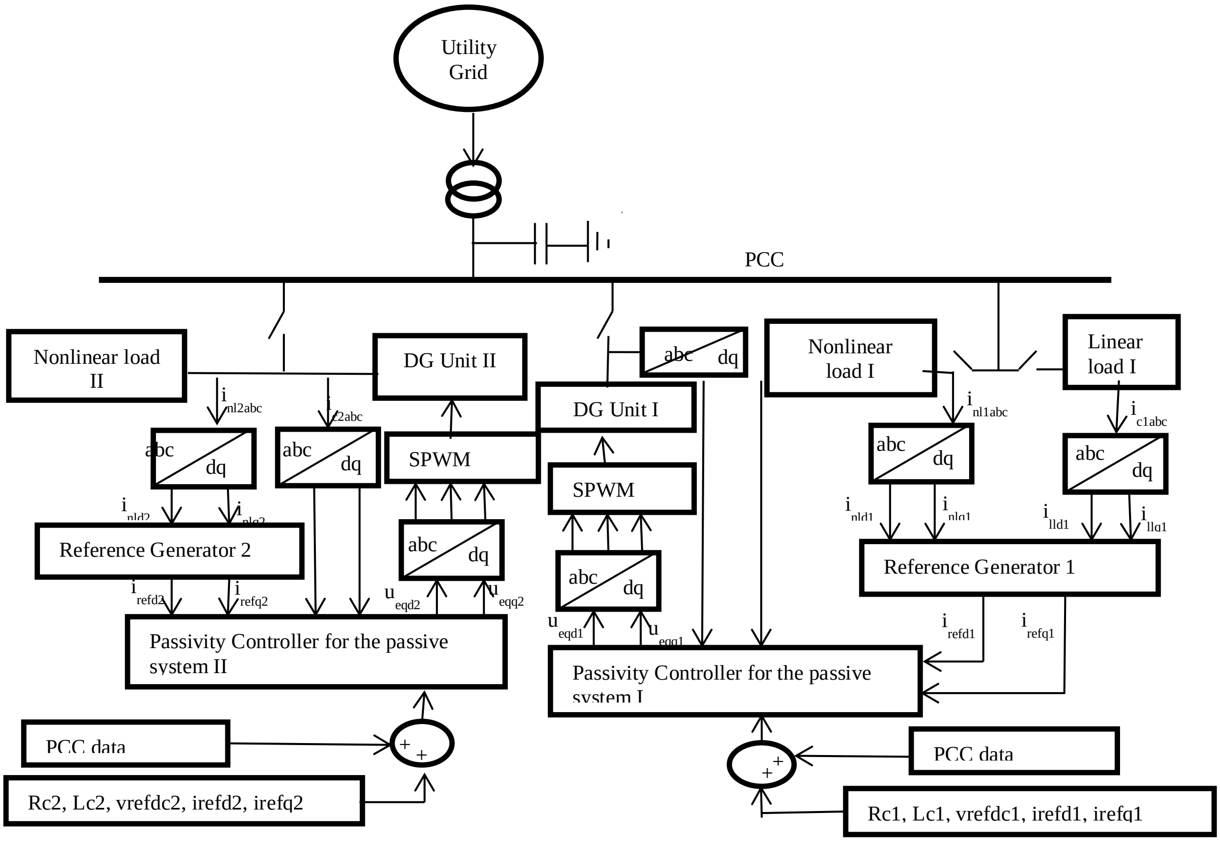

Fig. 7. Passivity based Control

5. Energy Storage

The main drawback in MG is to predict the availability of renewable energy sources. For example, one cannot expect solar power during night as well as in cloudy day. Hence, energy storage becomes essential in MG [41]. By incorporating energy storage systems, reliability of MG operation is enhanced [32, 33]. Some of the energy storage systems [33] are mentioned in Table 1.

Further energy storage systems can be classified based on the discharge time of the energy [37] and it is given in Table 2.

Table 1
Energy Storage Systems

Type of Energy Storage	Examples
Mechanical	• Pumped Hydro • Compressed air • Flywheel
Electrochemical	• Secondary batteries (lead acid, NiCd, NaS, etc.) • Flow batteries (redox flow, hybrid flow) • Super capacitors
Chemical	• Fuel cell
Electrical	• Super conducting Magnetic Energy Storage
Thermal systems	• Heat Storage

Table 2
Types of Energy Storage Systems

Type	Discharge time Specification	Energy to Power Ratio	Examples
Short discharge time	seconds to minutes	<1	• capacitor banks • superconducting magnetic energy storage • flywheels
Medium discharge time	minutes to hours	Between 1 and 10	• lead-acid batteries • lithium-ion batteries • sodium sulfur (NaS) batteries • Fly Wheel energy storage
Long discharge time	Days to Months	>10	• hydrogen (H2) • synthetic natural gas • pumped hydro storage • redox batteries.

6. Earthing

Earthing is a safety measure and if there is any problem in earthing of the distribution system, it is a threat for the personnel and equipment safety [31]. The types of earthing are as follows:

Functional Earthing: It includes logic earthing, shield earthing, working earthing and signal earthing.

Protective Earthing: A part of the electrical equipment or the system is connected to the earth by an earthing device for ensuring the personnel and equipment safety. The protective conductor is used for earthing the exposed conductive part of the equipment in an electrical system and for preventing electric shock.

System Earthing: Earthing of the neutral point of the power source. The neutral conductor is connected to the neutral point of the system and transmits electricity.

The earthing of the distribution systems is in three forms TN, TT and IT. TN is further divided into three forms, namely TN-C, TN-S and TN-C-S. In the earthing form IT, T means a power source point is directly earthed, I means the power source and the earth are isolated or it is directly earthed using a high impedance. In the form TN, T means direct earthing of the exposed conductive part; N means the exposed conductive part is connected to the neutral earthing of the power source. C indicates the combination of N conductor and PE conductor. S indicates the separation of the two conductors.

7. IEEE and IEC Standards

The IEEE Standards are developed to address the implementation of the MGs and for secure and reliable power system [31]. Fig. 8 shows some IEEE standards and IEC standards related to MGs.

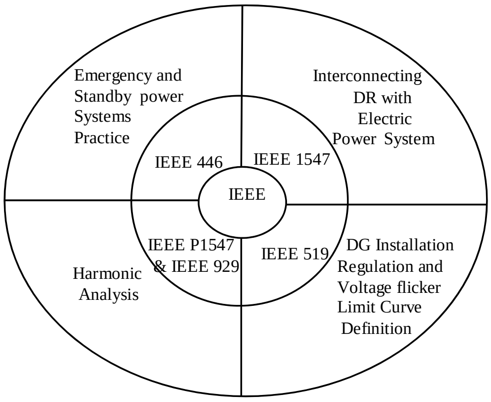

Fig. 8. IEEE Standards for MGs

IEEE 1547 provides the requirements for interconnecting distributed generation resources with the power grid. The complementary standards are designed for expanding and clarifying the initial standard and it is shown in the Fig. 9.

The article [30] presents standards commonly used for microgrid technology and practical tests of these standards before developing an industry microgrid standard. Standards of communication networks, Internet security, data and communications security, installation and protection of distributed generators and energy storage devices, electronic power interfaces of distributed energy resources, and interconnection of microgrids to electric power system are analyzed. The practical tests for the above standards are planned to perform at a low-voltage (380 V) AC microgrid test bed built by the Institute of Nuclear Energy Research, Taiwan. Microgrid configurations, installation of distributed generators and energy storage systems, operating conditions of the microgrid, microgrid energy management and control systems, and microgrid protection are mentioned in the proposed standard tests. The main contributions of this article are (i) to review and analyze common standards used for microgrids, (ii) to present research works from Taiwan to develop a microgrid standard for industry applications, and (iii) to propose practical tests of critical standards used for microgrids and how to perform these tests at a real-time low-voltage AC microgrid in Taiwan. This article presents standards commonly used for microgrid technology and practical tests of these standards before developing an industry microgrid standard.

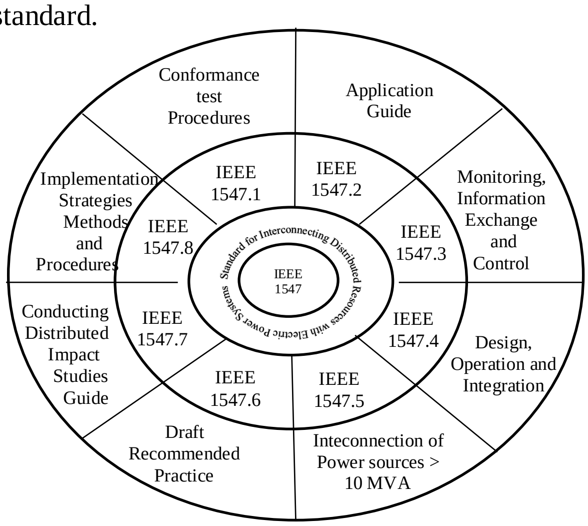

Fig. 9. IEEE 1547

The International Electrotechnical Commission is an international non-governmental, non-profit standard organization. International Standards for all the electrical and electronic related technologies are prepared and published by IEC [31]. The IEC TS 62257 gives the technical specifications and instructions for design, management and sizing for renewable energy and hybrid systems for Rural Electrification (Fig. 10).

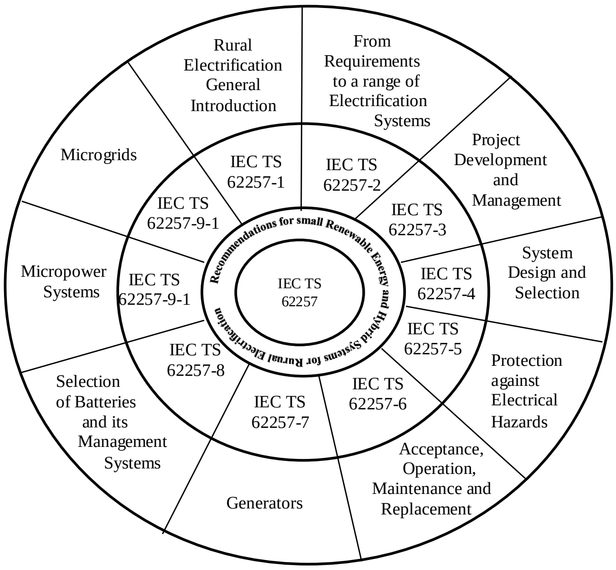

Fig. 10. IEC TS 62257

8. Conclusion

The paper investigated the aspects of microgrid such as:

1. Types of MG (AC MG, DC MG, Hybrid, Urban DG and Ceiling MG).
2. Different control mechanisms used in MG.
3. Need for earthing and earthing types.
4. Energy Management Issues.
5. Standards used in Microgrid such as IEEE and IEC.

Hence, this paper can be a ready reckoner for the realisation of MG. Further the following aspects can be challenged in future:

(i) Real time implementation of MG with stable operation via passivity based control.
(ii) Using five phase induction machine interfaced with Vienna rectifier for Wind energy conversion process.

References

1. Monesha, S., Ganesh Kumar, S., Rivera, M.: *Microgrid Energy Management and Control: Technical Review*. In: Proceedings of the IEEE International Conference on Automatica (ICA-ACCA), Curico, Chile, 19-21 Oct 2016, p. 1-7.

2. Monesha, S., Ganesh Kumar, S., Rivera, M.: *Methodologies of Energy Management and Control in Microgrid*. In: IEEE Latin America Transactions, Vol. 17, No.2, Sept. 2018, p. 2345-2353.

3. Stephen Bird, Chelsea Hotaling,: *Multi-stakeholder microgrids for resilience and sustainability.* In: Environmental Hazards and sustainability, Vol. 16, No. 2, 2017, p. 116-132.

4. Yiwei Ma, Jing Ji, Xianlun Tang,: *Triple-objective optimal sizing based on dynamic strategy for an islanded hybrid energy microgrid*. In: International Journal of Green Energy, Vol. 14, No. 3, 2017, p. 310-316.

5. Ahmed, R., Abul'Wafa,: *Energy Storage Sizing for Rooftop Grid-Connected PV System.* In: Electric Power Components and Systems, Vol. 45, No. 3, 2017, p.331-343.

6. Satish Kansal, Barjeev Tyagi, Kumar, V.,: *Cost–benefit analysis for optimal distributed generation placement in distribution systems.* In: International Journal of Ambient Energy, Vol. 38, No. 1, 2017, p. 45-54.

7. Barnam Jyoti Saharia, Munish Manas,: *Viability Analysis of Photovoltaic/Wind Hybrid Distributed Generation in an Isolated Community of Northeastern India.* In: Distributed Generation & Alternative Energy Journal, Vol. 32, No. 1, 2017, p. 49-80.

8. Kumaravel Sundaramoorthy,: *Development of the hard and soft constraints based optimization model for unit sizing of the hybrid renewable energy system designed for microgrid applications.* In: International Journal of Sustainable Energy, Vol. 36, No. 2, 2017, p. 192-208.

9. Hossein Ameli, Mohammad Taghi Ameli, Seyed Hossein Hosseinian,: *Multi-stage Frequency Control of a Microgrid in the Presence of Renewable Energy Units.* In: Electric Power Components and Systems, Vol. 45 No. 2, 2017, p. 159-170.

10. He, J., Liang, B., Li Y.W., Wang, C.: *Simultaneous Microgrid Voltage and Current Harmonics Compensation Using Coordinated Control of Dual-Interfacing Converters*. In: IEEE Transactions on Power Electronics, Vol. 32, No. 4, April 2017, p.2647-2660.

11. Chun –Xia Dou, Xiao- Gang An, Dong Yue,: *Multi-agent System Based Energy Management Strategies for Microgrid by using Renewable Energy Source and Load Forecasting*. In: Electric Power Components and Systems, Vol. 44, No. 18, 2016, p. 2059-2072.

12. Mahdian Dehkordi, N., Sadati, N.,Hamzeh, M.: *Robust backstepping control of an interlink converter in a hybrid AC/DC microgrid based on feedback linearisation method.* In: International Journal of Control, Vol.90, No. 9, 2017, p. 1990-2004.

13. Vigneysh, T., Kumarappan, N.: *Artificial Neural Network Based Droop-Control Technique for Accurate Power Sharing in an Islanded Microgrid*. In: International Journal of Computational Intelligence Systems, Vol. 9, No. 5, 2016, p. 827-838.

14. Gian Paolo Incremona, Michele Cucuzzella, Antonella Ferrara,: *Adaptive suboptimal second-order sliding mode control for microgrids.* In: International Journal of Control, Vol. 89, No. 9, 2016, p. 1849-1867.

15. Ganesh Kumar Srinivasan, Hosimin Thilagar Srinivasan,: *Passivity Based Control of Luo Converter*, In: Journal of Electrical Engineering, Vol. 3, 10 June 2015, p. 1-8.

16. Palizban, O., Kauhaniemi, K., Guerrero, J.M.: *Microgrids in active network management – Part I: Hierarchical control, energy storage, virtual power plants, and market participation.* In: Renewable and Sustainable Energy Reviews, Vol. 36, Aug 2014, p. 428-439.

17. Huang, P.H., Liu, P.C., Xiao, W., El Moursi, M.S.: *A Novel Droop-Based Average Voltage Sharing Control Strategy for DC Microgrid.*, In: IEEE Transactions On Smart Grid, Vol. 6, No. 3, May 2015, p. 1096-1106.

18. Parisio, A., Rikos, E., Glielmo, L.: *A Model Predictive Control Approach to Microgrid Operation Optimization.* In: IEEE Transactions On Control Systems Technology, Vol. 22, No. 5, Sept 2014, p. 1813-1827.

19. Manimuthu, Arunmozhi, Ramadoss Ramesh.: *Privacy and data security for grid-connected home area network using Internet of Things*. In: IET Networks 7.6, Vol. 7, No. 6, 2018, p. 445-452.

20. Nasirian, V., Shafiee, Q., Josep M. Guerrero, Frank L. Lewis, Ali Davoudi,: *Droop-Free Distributed Control for AC Microgrids.* In: IEEE Transactions on Power Electronics, Vol. 31, No. 2, Feb 2016, p. 1600-1617.

21. Rajesh, K.S., Dash, S.S., Ragam Rajagopal, Sridhar,R.: *A review on control of ac microgrid.* In: Renewable and Sustainable Energy Reviews, Vol. 71, May 2017, p. 814-819.

22. Yoldaş, Y., Önen, A., Muyeen, S.M., Athanasios V. Vasilakos, Alan, I.: *Enhancing smart grid with microgrids: Challenges and opportunities.* In: Renewable and Sustainable Energy Reviews, Vol. 72, May 2017, p. 205-214.

23. Han, H., Hou, X., Yang, J., Jifa Wu, Mei Su, Josep M. Guerrero,: *Review of Power Sharing Control Strategies for Islanding Operation of AC Microgrids.* In: IEEE Transactions on Smart Grid, Vol. 7, No. 1, Jan 2016, p. 200- 214.

24. Valencia, F., Sáez, D., Collado, J., Ávila, F., Marquez, A., Jairo J. Espinosa,: *Robust Energy Management*

System Based on Interval Fuzzy Models. In: IEEE Trans. On Control Systems Technology, Vol. 24, No. 1, Jan 2016, p. 140-157.

25. Wang, C., Yang, X., Wu, Z., Che, Y., Li Guo, Zhang, S., Liu, Y.: *A Highly Integrated and Reconfigurable Microgrid Testbed with Hybrid Distributed Energy Sources*. In: IEEE Transactions On Smart Grid, Vol. 7, No. 1, Jan 2016, p. 451-459.

26. Fu, Q., Nasiri, A., Solanki, A., B.-Ahmed, A., Weber, L., Bhavaraju, V.: *Microgrids: Architectures, Controls, Protection and Demonstration*. In: Electric Power Components and Systems, Vol. 43, No. 12, 2015, p. 1453–1465.

27. Nikos Hatziargyriou.: *Microgrids Architectures and Control,* IEEE press, Wiley, 2014.

28. Ahmed, M.N., Hojabri, M., Humada, A.M., Daniyal H.B., Frayyeh, H.F.: *An overview on microgrid control strategies*. In: International Journal of Engineering and Advanced Technology, Vol. 4, No. 5, 2015, p. 93-98.

29. Sechilariu, M., Locment, F.: *Urban DC Microgrid Intelligent Control and Power Flow Optmization,* Elsevier, 2016.

30. Duong Minh Bui, Keng-Yu Lien, Shi-Lin Chen, Xiao-Yan Cheng, Ming-Shan Lin,: *Standards Commonly Used for Microgrids—A Research Project to Develop an Industry Microgrid Standard in Taiwan*. In: Electric Power Components and Systems, Vol. 44, No. 19, 2016, p. 2143-2160.

31. Li Fusheng, Li Ruisheng, Fengquan, Z.: *Microgrid Technology and Engineering Application,* Elsevier, 2016.

32. Yu Wang, Mao, S., Mark Nelms, R.: *Online Algorithms for Optimal Energy Distribution in Mirogrids*, Springer, 2015.

33. David Wenzhong Gao, *Energy Storage for Sustainable Microgrid*, Elsevier, 2015.

34. Planas, E., Jon Andreu, Garate, J.I., de Algeria, I.M., Edorta, I.: *AC and DC technologies in microgrids: A review*. In: Renewable and Sustainable Energy Reviews, Vol. 43, March 2015, p. 726-749.

35. Unamuno, E., Barrena, J.A.: *Hybrid ac/dc microgrids-Part I: Review and classification of topologies*. In: Renewable and Sustainable Energy Reviews, Vol. 52, Dec 2015, p. 1251-1259.

36. Unamuno, E., Barrena, J.A.: *Hybrid ac/dc microgrids-Part II: Review and classification of control strategies*. In: Renewable and Sustainable Energy Reviews, Vol. 52, Dec 2015, p. 1123-1134.

37. Zhongwen Li, ChuanzhiZang, PengZeng, Haibin Yu, Hepeng Li,: *MAS Based Distributed Automatic Generation Control for Cyber-Physical Microgrid System*. In: IEEE/CAA Journal of Automatica Sinica, Vol. 3, No. 1, 10 Jan 2016, p. 78-89.

38. Meng, L., Sanseverino, E.R., Luna, A., Dragicevic, T., Juan C. Vasquez, Josep M. Guerrero,: *Microgrid supervisory controllers and energy management systems: A literature review*. In: Renewable and Sustainable Energy Reviews, Vol. 60, July 2016, p. 1263-1273.

39. Mehrasa, M., Pouresmaeil E., Catalao, J.P.S.: *A Multifunction Control Strategy for the Stable operation of DG units in Smart Grids*. In: IEEE Transactions on Smart Grid, Vol. 6, No. 2, March 2015, p. 598-607.

40. Pouresmaeil E., Shaker H.R., Mehrasa M., Shokridehaki M.A., Rodrigues E.M.G., Catalao J.P.S.: *Stability Analysis for Operation of DG Units in Smart Grids*. In: Proceedings of the IEEE 5th International Conference on Power Engineering, Energy and Electrical Drives, Riga, Latvia, 11-13 May 2015, p. 447-452.

41. Stimoniaris, D. Tsiamitros, D., Dialynas, E.: *Improved energy storage management and PV- Active power control infrastructure and strategies for microgrids*. In: IEEE Transactions on Power Systems, Vol. 31, No. 1, Jan 2016, p. 813-820.

42. Mehrasa, M., Pouresmaeil, E., Mehrjerdi, H., Bo Nørregaard Jørgensen, João P.S. Catalão,: *Control technique for enhancing the stable operation of distributed generation units within a microgrid*. In: Energy Conversion and Management, Vol. 97, June 2015, p. 362-373.

43. Olatomiwa, L., Mekhilef, S., Ismail, M.S., Moghavvemi, M.: *Energy management strategies in hybrid renewable energy systems: A review*. In: Renewable and Sustainable Energy Reviews, Vol. 62, Sept 2016, p. 821-835.

44. Ali Asghar Ghadimi, Hassan Rastegar,: *Control of a stand-alone microgrid with active management scheme*, In: Journal of Electrical Engineering, p. 1-8.

45. Nallusamy, S., Velayutham, D., Govindarajan, U., Parvathyshankar, D.: *Power quality improvement in a low-voltage DC ceiling grid powered system*. In: IET Power Electronics, Vol. 8, No. 10, Oct 2015, p. 1902-1911.

46. Ganesh Kumar, S., Hosimin Thilagar, S., Rivera, M.: *Cost Effective Control of a Partially Flat Boost Converter fed DC motor*. In: Proceedings of the IEEE International Conference on Automatica (ICA-ACCA), Oct 2016, p. 19-21.

47. Ganesh Kumar, S., Hosimin Thilagar, S.: *Load Torque Estimation and Passivity Based Control of Buck Converter*. In: The Mediterranean Journal of Measurement and Control, Vol. 9, No. 2, 2013, p. 51-57.

48. Ganesh Kumar, S., Hosimin Thilagar, S.: *Sensorless Load Torque Estimation and Passivity Based Control of Buck Converter Fed DC Motor*. In: The Scientific World Journal, No. 1, 2015, p. 0-15.

49. Ganesh Kumar, S., Hosimin Thilagar, S.: *Soft Sensing of Speed in Load Torque Estimation For Boost Converter fed DC motor*. In: Proceedings of the International level conference on IECON 2013 - The 39th Annual Conference of the IEEE Industrial Electronics Society, Austria, Nov 2013.

50. Arathy, R., Ganesh Kumar, S., Rivera, M.: 2016, I*nvestigation on Passivity Based Control for Electrical Applications*. In: Proceedings of the International level conference on IEEE CHILECON 2017, CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies, Chile, 18-20 Oct 2017.

51. Ganesh Kumar, S., Hosimin Thilagar, S.: *Comparative study of Proportional Integral and Passivity Based Control for buck converter*. In: Proceedings of the International level conference on SIMULTECH 2011, Portugal, 2011.