The International Journal of Engineering and Science (IJES)
|| Volume || 7 || Issue || 8 Ver. I|| Pages || PP 39-46 || 2018 ||
ISSN (e): 2319 – 1813 ISSN (p): 23-19 – 1805

Technological Analysis and Optimization Of Microgrids And Ders: A Comprehensive Review

T.Som, D.Thakur

Department of Electrical &Electronics, Delhi Technical Campus
Department of Electrical &Electronics, Delhi Technical Campus
Corresponding Author: T.Som

ABSTRACT

High demand for reliable power supply has become a vital issue in the current energy scenario. Consequently, many centralized power system has been shifted towards decentralized power generating systems or distributed generations, generally termed or called as microgrid power system. Moreover, the concerns towards global warming and depleting oil/gas reserves have made it inevitable to seek power from renewable energy resources. Consequently, different nonconventional and renewable distributed energy resources (DERs) have emerged as a new energy generating option with ample opportunities for developed and developing countries. Although the microgrid utilizing DERs as energy sources is a potential solution for reliable and clean power supply, it also faces a great deal of challenges regarding its design, operation, protection and energy pricing. This review discusses the current status of DERs integrated microgrid system. It provides the present research situations of different aspects of DER and microgrid technology, viz size, site, operation, control, protection and economy. In particular, the role of optimization of various factors affecting the microgrid-DERs system on the further developmental prospects of microgrid-DERs technology is emphasized.

KEYWORDS *- Carbon-tax, DERs, Energy, Microgrid, Optimization.*

Date of Submission: 20-07-2018 Date of acceptance: 04-08-2018

I. INTRODUCTION

Over last few eras, electric power generation has become immensely important in widening its scope over several aspects. With the current emphasis on delivering power more efficiently and effectively, the centralized services for delivery of electricity are orienting themselves towards the emerging technology of distributed energy resources (DERs), referred to alternatively as distributed generators (DG). DERs are located in proximity to the loads and efficiently distribute energy while incurring the smallest practicable amount of losses. The range of these types of decentralized or distributed energy resources found its application within different emerging power delivering technologies. As a result, the idea of microgrid has come into the forefront as an alternative and novel paradigm for electricity delivery, which integrates the power generators and consumers within close vicinity. Besides providing the desired demand of the integrated consumers, distributed energy resources within a microgrid system also includes various beneficial features. Besides providing the desired demand of the integrated consumers, distributed energy resources within a microgrid system also includes various beneficial features.

II. DISTRIBUTED ENERGY RESOURCES

With the mounting consciousness regarding need of reliable power conventional energy resources integrated to the centralized power delivery model are facing many problems which include environmental concern. Consequently these conventional electric power networks are changing on the road to DERs [1, 2]. Distribution generation technologies and several policy issues regarding future distributed generation are also coming up [3]. Studies on different types of dispersed or distributed energy resources (DERs) technologies in meeting different types of loads, such as commercial-sectors, residential complex have been made in the literature [4,5]. The authors of [4] model the growth of DER in the US commercial building sector using various projections of technology outreach. Differences of geopolitical and climatologically origin, as well as the economic potential for different building types are factored in to determine the optimal DER systems several building types and regions. Investments on small generator clusters [5], involving thermal and electrical residential systems has been discussed by Brahman et al. Adoption of such DERS and their operating flexibities have been dealt with considering thermal and electrical management. Reference [6] reviews alternative modeling approaches in place of the widely accepted DER-CAM model that the process by which new technologies are accepted by the society is well-represented by an S-shaped temporal pattern. The most popular explanation of this behavior is often given in terms of the epidemic model. This model is founded on the idea that the speed of usage is bottlenecked by the scarcity of available information on the new technology. The uses and benefits of the epidemic model [6] have also been mentioned. Jaffe. et al. [7] develop a framework for reconciling the ‗paradox' of slow technology diffusion regardless of its cost effectiveness. The analysis provides an understanding of the fact that the technology-diffusion processes relevant to DERs adoption are gradual, and focuses attention on the factors including those associated with market failures, unavailability insufficiency of information, hidden costs, high rates of discount, and client heterogeneity [7]. Proper usage of DERs can be apprehended depending on the power requirement corresponding to the installed size and capacity of distributed resources or generators.

Types and Size of DERs

Types and size selection is important as regards DERs are concerned. An idea of distributed generation of few kilowatts up to 50 MW has been presented by electric power research institute [8], while power requirement up to a range of 25 MW by natural gas as one of the DG unit is described by Gas Research Institute [9]. The flexibility in constructing DG units depending on different desired loads is one of the major advantages on the part of power generation. Preston and Rastler mentioned the development of DG units of a size from few kilowatts to over 100 MW [10]. The authors of [11] discuss the design of a restructured electric distribution network employing a large number of small-sized distributed energy resources (DERs), which are predicted to improve system reliability. Reference [12] analyzes modem technologies involving interfaces with various small scale generations and storage systems. A local dc distribution electricity grid equipped with both diode and IGBT bridge interface Converter has been dealt with. Different types of fuel cells are adopted as DERs by the authors of [13]. The different types of fuel cells are categorized according to their electrolyte. The operating characteristics of proton exchange membrane PEMFC, AFC, phosphoric acid PAFC, solid oxide SOFC, and DMFC have also been discussed.

~~DMFC have also been discussed.~~

A survey of manufacturer's engineering data has been made [14] in order to obtain a reliable relationship between the efficiency and installed capacity of combine heat and power (CHP) unit. Depending on the relationship Walla et.al [14] developed a model for predicting and calculating the production of energy from other DERs which is simultaneous operation with CHP. In order to automatic control the hydrogen-fuelled power generation system of a size of 80cm × 70cm × 120 cm single unit, a stack of A 1 kW class PEM fuel cell having a class of 1KW was fabricated [15] with an Aciplex-S™ membrane, which automatically controls. The reliability of the proposed PEM fuel cell DERs [15] having a dc/ac inverter to produces 220 VAC power have also been studied. The improvements of a solid oxide fuel cell (SOFC) as DERs over that of centralized generation has been discussed [16]. These include features like high overall efficiencies of about 80–90%, and proper utilization of waste heat. Wiemken.et al. [17] reviewed various advanced solar thermal electricity technologies along with new market approaches. In order to explore more renewable energy resources, authors in [18] studied an hybrid DERs model comprising solar and bio mass renewable energies. An interconnected model has been studied which gives efficient power transfer with respect to changes in power losses by solar power systems current injection in grid. Depending on various factors, such as position, temperature, locality, and types of load, suitable DERs technologies are adapted[19].

Utilization of Different DERs

Distributed energy resources find most of its application in remote regions but it is gaining fast popularity as back-up system to supply shortfall of power or partial loads in grid connect areas. On the basis of different government regulation, the power ratings of DG differ from country to country as shown [20]. The capacities of DG technologies in English and Welsh market have been presented by Cowell et.al [21], while the scenario according to Swedish legislation has been depicted elsewhere [22]. Usually, a set of DERs is used to address small markets which are expected to assume economic significance in the near future which will lead to further decentralization of the power delivery system. A change in the Brazilian electric energy system from highly centralized large generators to distributed infrastructures by inserting small capacity has been mentioned by Brazilian Electricity Regulatory Agency [23]. Amorium et al. presented brief features of a Portugese LV grid which supplies power to a local demand of about 200 KVA [24]. Gas turbines operating as a distributed generator (DG) technology have been portrayed by Vahidinasab et.al [25]. Micro-turbines used as distributed energy resources have been described by various authors elsewhere [26]. Combustion turbine operating as a DG and its performance has been studied by Yadav et al [27]. Hatziargyriou et.al analyzed [28] the problems and capacities of developing small hydro-turbine. To understand the problems related in using distributed sources like gas engine, combined heat power plant proper knowledge of the technology is important [29]. Both advantages and disadvantages of using CHP as distributed energy resources have been pointed out and discussed by Siddique et.al in literature [30] .Different combinations of distributed generators have been utilized with various facility outage costs along with/without an emission restriction [31]. Estimation for break-even costs of micro turbines and various facility outage costs depending on micro-turbine forced outage levels has been made. Authors in literature [31] also dealt with the installation of back-up energy storage system as DERs depending on the effects of varying the grid reliability and the capital costs of DG units.

Kribus. et al. dealt with the feasibility aspect of a solar power generator as DERs in a combined cycle configuration, driven by a high degree of solar energy concentration and dominant receiver with a high temperature. Advances in optical technologies for solar tower, improved effectiveness of air receivers and interface between solar and wind energy, were integrated into the solar power generator module as a new concept [32]. Hang. Et al. also studied the adopted Concentrating solar power (CSP) generation technology and developed certain control strategies to promote development of this technology. Utilization of wind power, solar power and hydro-storage system has been made by Kolkhop Village of Nepal [33] as a hybrid DERs system. Apart from delivering reliable power many distributed energy resources technology also have other advantages and disadvantages, such as small-CHP distributes local heat along with electric power. The operations of different DERs also include some positive effects to the environment.

Environmental Impact due to DERs

One of the main logic of DER use is their lesser impact on our beloved mother earth Works related to the carbon-dioxide emission and formulation of environmental impact reduction index has been developed by Barnhart et al. [34]. The role of carbon-dioxide emission, which is considered to be the primary reason behind global warming, is discussed in detail by Hadjipaschalis. et al. [35]. A challenge to reduce this emission between 50 to 80% by 2050 for each and every nation worldwide is the main notion which has been presented in this literature. With the focus on a greener and cleaner environment, power systems in Denmark observed a cut in greenhouse gas emission from 1975 to 2012 by utilizing DG technologies [36]. A reduction in emission between the existing systems has been compared by Hadley and Vandyke [37] with that of the installed distributed generators (DGs). Marin. et al. depicted utilization of proper DERs [38], which played a key role in reducing environmental pollution. In commitment to reduce green house gas (GHG) emission, installation of about 66.6% of total wind power generation in the world is made by European Union [39].. Adverse effects of bio-mass conversion power generating process have been presented by Mafakheri. et. al. Basic concepts and raw materials behind the combustion procedure of bio-mass have been defined and the compositions regarding the bio-fuels have been dealt in literature [40]. An Estimation and analysis of ammonia emitted from the natural sources, such as waste products along with other disposable miscellaneous product in bio-mass plant has been made in the literature [41] on the basis of both source strength estimates i.e. emission factors and source populations for the UK. Another revised study has been performed, which investigates the emission of various pollutants, such as total carbon ,e.g. organic/elemental carbons and poly-cyclic aromatic hydrocarbon [42] along with particulate matters. The authors conclude by declaring soy-biodiesel as an attractive alternative fuel for diesel generators both in terms of efficiency improvement and emissions [42]. Kemmoku. et al. depicted that the CO2 emissions decrease with increasing of the wind generating ratio from 100/0 to 0/100. Moreover the total CO2 emissions decrease as the natural energy ratio increases [43]. The literature also made a comparative study showing that total CO2 emissions of the PWD system are lower than those of the conventional diesel generator system.

However, different nonconventional and renewable sources are needed to be properly modeled for electric power generation as distributed generators (DG). These are generally made utilizing various design and control technologies.

Technical Aspects of DERs

The technical portions of the distributed generators or DERs are the key factors in forming a distributed generation network. The impacts in the network due to the variability of distributed generator (DG) sources are described by Leao et al. [44]. Kundur [45] presented a proper dynamic modeling of DG units by studying the impact in the network due to the presence of different generation units. The modeling of suitable generators on the basis of dynamic behaviors and some disturbances has been dealt by the authors Adoption of the procedures for synchronous and asynchronous machines collectively has been tired by the author [45] Little dynamic behavior of certain micro-sources have been developed [46] and described by Kariniotakis et al. The micro-generators include fuel cell, photovoltaic system and wind turbine, whose power interface models have been described [46]. Technical issues and active managerial issues have been discussed [47] for future development of different distribution systems. The authors of [47] dealt with embedded wind generation technology which are generally prone to a mal-function due to rise in voltage, in a rural distribution system. Connection of a micro-turbines as distributed generators to a low voltage grid, are presented in literature [48]. The main components of the designed micro-turbine along with the loads have been characterized and the some performances have been studied [48]. A topological study of the photo-voltaic module integrated converter (PV MIC) delivering a power range of about maximum 500 W has been studied in literature [49]. Different types of module integrated converter on the basis of different arrangements based on the dc link – DERs configurations has been discussed by Quan. et al. Different Photovoltaic (PV) power generation systems having different types of inverter circuits and the corresponding control schemes have been studied [50]. The authors dealt with the output power of solar module on the basis of PV arrays. It then involves an analytical procedure for understanding the performance characteristics of the module and array under the operating conditions representative of typical photovoltaic systems [50]. A maximum-power-point-tracking (MPPT) system comprised of a dc/dc converter with a high efficiency and a control unit employing a microcontroller has been proposed for application to wind-generator (WG) systems [51]. Koutroulis. et al. pointed the advantages of the proposed MPPT method, where without proper measurement of the wind speed or optimal power characteristic, a WG operates at a variable speed. In order to ensure the stability of the power obtained from variable-speed wind-energy-conversion systems (VS-WECS), a control approach using sliding mode has been proposed in [52]. A simulation for systems for conversion of wind energy was performed with the objective of design and performance assessment of a realistic integrated wind turbine system which includes a network of generators, transmission systems, controllers and power-electronic converters. A comprehensive review of different fuel cell technologies with their working principle, advantages, disadvantages with suitable applications in residential/grid-connected system, transportation, industries and commercial systems has been discussed [53]. Working principle of molten carbonate contained fuel cell technology has been focused in literature [54]. Studies on features like high temperature, thermal effluent, fuel-to-electricity efficiencies have been dealt by Bischoff. et al. The results allow significant cogeneration and/or integration with a heat engine cycle and efficiencies greater than 70% have been observed [54]. A cogeneration systems based on gasifier/gas turbine technologies has been modeled in literature [48]. A detailed full-load performance of the model has been studied. A design of circulating fluidized bed (CFB) biomass gasification has been made [55]. Though distributed energy resources are reliable and flexible power delivery system, but sometimes with varying load demand it may fail to deliver the required power. A provision for storage system then necessitate for no power interruption.

However, with growing power demand more number of distributed energy resources are required to deliver power. This gave rise to the concept of integrating different types of the distributed resources with or without main grid for reliable power supply. Microgrid power delivery system plays the vital role in integrating decentralized or distributed energy resources with existing electric power systems.

III. MICROGRID

To overcome the various challenges to power distribution in a conventional power delivery system, the idea of microgrid is assuming renewed significance as an alternative paradigm form delivery of electric power [56]. To overcome the power distribution difficulties in a conventional power delivery system, the idea of microgrid has arisen as a new electricity delivery system [56]. The authors of [57] discuss the islanded mode of microgrid operation, wherein during a disturbance, the microgrid is rendered immune to the disturbances in main grid and vice versa, thus making a decentralized power system more reliable. On the basis of load requirement the choice of micro-grid's operation is shown in Reference [58]. On the basis of different types of load, such as sensitive load, controllable load, peak load etc different operating strategies in microgrid has been assigned as mentioned in References [59]. The operational features of existing micro-grids vary based on the type and depth of penetration of the DER, characteristics of the load, constraints on power quality, and market participation strategies [59]. Design of micro-grids depending on user‘s operation on domestic level has been discussed by the authors in Reference [60]. Apart from providing effective and reliable power to the end users, few micro-sources integrated within the microgrid power system also finds its application in delivering heat simultaneously to users. This makes microgrid system much more advantageous over other traditional power delivery systems. The technology behind integration of generators and load within closed vicinity is the main feature of Microgrid.

Technical Issues of Microgrid

Technical aspects of microgrid, which includes the design, co-ordination and operation between generators and loads, plays vital role for effective power distribution. Kavousi-Fard. et al. [61] discuss certain advantages of microgrid power delivery system, viz. reduction in feeder losses, enhanced reliability of supplied power, and provision for enhancement of efficiency. In focus to technical issues of microgrid, electrical safety points during fault condition has been discussed in Reference [62]. Analysis of power system regarding small system stability has been made in Reference [63] On knowing the stability a priori can lead to a better design of microgrid power delivery system. The authors of [64] focused on keeping a specific voltage level during power delivery. It also mentioned a provision of back-up system during faults. The authors also identified the technological challenges which must be overcome, so that rapid percolation of technology within the power and energy sector can be ensured [64]. Moreira et al. proposed an integrated approach on the basis of the architecture for microgrid control [65]. The suggested framework is independent of platform, programming language and vendor. Based on the above features, the authors consider this framework as a ―ideal candidate‖ for effectively integrating to existing energy management systems and for distribution management systems (EMSs/DMSs).

While discussing backup energy storage system integrated with microgrid, the authors of [66] have taken into account life cycles and the effect on power losses of different energy storage systems (ESS). Authors of literature [67] proposed a new power delivery system which mainly deals with the integrating of distributed energy resources (DERs) to AC distribution network. In this regard, a multi-terminal voltage sourced converter (VSC) based DC system topology has been designed by Abbas. et al. The proposed topology integrates DC and AC networks at different voltage and power levels [67]. A focus has been made for the design of intentional island operation of microgrid during fault condition [68]. A control scheme is always an integral portion of any technically operating system. Likewise, operation of microgrid systems is infeasible without a controller.

Control Aspects of Microgrid

The control portion of DERs involves the control of interconnections between the DERs and consumers and their operational features viz, voltage levels, resulting in protections from damages. Two approaches in dealing with micro-grid's islanded operating mode [69] have been discussed by Shafiee et al. Considering the low voltage networks micro-generator shedding is employed [69] for better voltage control. A power quality compensator interfaced with the grid and using two inverters to control both the sensitive load voltages in microgrid and line current flowing between the micro-grids and utility system is mentioned in Reference [70]. The control and sensing of power network, depending on a typical distributed resource, are represented in Reference [71]. Control on feeder operation has been dealt by Laaksonen al for islanded microgrid operation [72]New protection schemes for both types of fault, i.e. internal fault and external fault have been introduced by introduced by Che et al. [73]. This method operates on the basis of abc to dq voltage transform, which again helps to detect and identify short circuit fault occurring inside or outside the microgrid. In context of protection, Laaksonen et.al [74] proposed a method for centralized controller microgrid. This operation restricts the current magnitude as well as provides a damping to oscillations. Modeling of converters in maintaining proper active and reactive power sources has been discussed in Reference [75]. Zubieta et al. [76] present a rational design approach for a controller for multi-bus microgrid system. Voltage and current loops to control the system dynamics at the micro-grid parent grid interface form an integral part of the arrangement proposed by these authors. A control mechanism to compensate load demand fluctuations have been proposed in Reference [77]. The microgrid presented in Reference [78] consists of several line-interactive uninterruptible power supply (UPS) systems connected in parallel. A control technique based on the droop method is adopted to avoid critical communications among the units of the UPS. This leads to a flexible microgrid that can operate in either grid-connected or islanded mode. A linearized (small-signal) analysis of the system stability is conducted in order to form the design basis of the main control parameters [78].

The authors of [79] discuss a power control strategy for a low-voltage microgrid, on the basis of frequency and voltage droop characteristics among the distributed generation (DG) units. The low frequency relative stability problem in parallel inverter based distributed generation (DG) units in micro-grids has been addressed by Mohamed, Y. et al. An adaptive decentralized droop controller of parallel inverter-based DG unit is presented [80] to preserve power sharing stability. The controller deals [80] with the drifting of power sharing to a new location as the demand-side power of each inverter changes under small signal stability. A control strategy that takes advantage of the controllability of inverters in operating a micro-grid and in delivering an acceptable power quality is examined and contrasted with both traditional power systems and with control of dc/dc power converters [81]. Experimental results are used to demonstrate the performance that is realiable with several sets of single-phase and three phase as well as linear and non-linear loads. A method based on potential theory for secondary-level and tertiary-level control of a microgrid, in both grid-connected as well as islanded modes has been introduced by Mehrizi-Sani et al [82]. In order to ensure high-quality output waveforms, authors dealt with design of controllers for different types of individual inverters in both grid-connected and islanding modes of microgrid [83]. Smooth mode transfers and precise sharing of current are achievable by the designed system level controls with control area network communication in a microgrid system employing multiple inverters.

The overall management of a microgrid system involving the technical operation, control and protection is generally expensive. Hence, the economic analysis in this regard is highly needed.

Economic Aspects of Microgrid

Youli. et.al made an economic analysis of microgrid power system by considering renewable resources like wind power, solar power and micro-hydro power at Kochi zone of Japan [84].Total annual cost of a microgrid having non conventional energy resources, in an Indian scenario have been dealt by Som et al using real valued cultural algorithm [85] On the basis of microgrid structure with multiple power generating systems like thermal supply, fuel gas, operating cost has been dealt by the authors in Reference [86]. Total annual cost of a microgrid system has been minimized by Bendo et.al considering the partial load efficiency of gas engine. Annual operational scheduling has been performed for the cost evaluation by mixed integer noon-linear programming [87]. Maximum benefit-to-cost ratio of a microgrid owner has been performed by Basu et al. [88] using Particle swarm optimization technique (PSO) technique. Through maximum benefit-to-cost ratio an optimal selection of size and separation of micro-generator is done. Economic evaluation of an inter-connected microgrid system with combined heat and power has been analyzed by the authors in Reference [89]. Neves et al. examined several cases at different regions of US. Micro-grids requirement towards the economics on the basis of combined heat power generation has been studied by the authors in Reference [90]. Various marketing strategies have been presented by the authors in A pricing structure has also been prepared in this regard by Panigrahi. et al. A linear programming technique has been adapted [91] and implemented for minimizing the total cost of delivering electricity in a microgrid by Zoka et al. A linear programming cost minimization model has been developed by Hawkes et al. for determining the unit commitment of a set of energy storage systems and DERs within a microgrid. To create a reliable, green and economical cost effective, reliable and environmentally friendly energy conversion and delivery system a set of energy resources working collaboratively has been dealt in literature [92]. The proposed model considers the expected time duration of microgrid autonomous operation, and restricting the flow of heat between microgrid participants. A typical case study network has been developed [93] considering a realistic market prices for power and distributed generators bids which reflect the realistic operational costs. An artificial immune system based algorithm has been implemented for the cases studied. Simulation results in literature [93] indicated an economically effective coordination of various distributed energy resources by the agent based control framework. Puglia et al. also aims to optimize the operation of the microgrid though optimal production of local distributed generators. A microgrid village has been designed with the distributed energy resources in literature [94]. The economic feasibility has been studied and evaluated by Effectiveness of microgrid power delivery system can be realized by proper utilization and operation of different types of distributed energy resources (DERs) within the microgrid power delivery system.

IV. MICROGRID AND DERS

Though DERs can be used separately outside a microgrid frame-work, but for simultaneous requirement of large and reliable power DERs are most suited under a microgrid operation.

Works regarding microgrid utilizing different DERs have been studied by the authors in Reference [95]. Cameron et al. [96] focused on the motives behind the existence of different distributed generation in various autonomous and non-autonomous microgrid power systems. The factors which drove the manufacturers and consequently the customers towards the production DG units and development of their service are mainly the search for better quality, higher reliability, superior control and price. Demand for de regulation or re-regulation in the electric utility industry is also a major issue in increasing growth of microgrid utilizing DERs. Certain benefits regarding the employment of DERs in micro-grids have also been depicted by the authors of [96]. The main advantages of using DERs in a microgrid are improved reliability, increased penetration of renewable sources vis-à-vis the economically and environmentally unsustainable non-renewable sources, dynamic islanding, and improved efficiencies of generation through utilization of waste heat. The task of managing a significant number of distributed generators with resources and control points with widely varying dynamic characteristics can overpower a grid. The authors of [97] review the existing microgrid test networks around the world (North America, Europe and Asia) and several distinct microgrid simulation networks present in the literature. This study is focused on the characteristics of the test systems and the control strategies available for the microgrid. Issues such as robustness of the control of local voltage and frequency, protection of the network and microgrid-connected equipment which are important to make a microgrid capable of to operate in parallel with the grid are discussed in this study. Finally, the study also discusses the requirement of the microgrid to facilitate demand-side management and resynchronization. [97].

V.CONCLUSION

With all the aspects of DERs and Microgrid discussed in the review paper, it has been inferred that although DERs and Microgrid both forms a superior energy delivery options in terms of delivering reliable and clean power, certain adjustments and optimizations between different parameters may result to an economically and technically more enhanced power delivery system. Moreover, the flexible and adaptive operational features of DERs and microgrid have also been emphasized in this review, through a study of their applications together, which result in improved outcomes for the Microgrid-DERs technology.

REFERENCES

[1]. Lew, D., Asano, M., Boemer, J., Ching, C., Focken, U., Hydzik, R., & Motley, A. (2017). The Power of Small: The Effects of Distributed Energy Resources on System Reliability. IEEE Power and Energy Magazine, 15(6), 50-60.

[2]. Clausen, Anders, "Agent-Based Integration of Complex and Heterogeneous Distributed Energy Resources in Virtual Power Plants." International Conference on Practical Applications of Agents and Multi-Agent Systems. Springer, Cham, 2017.

[3]. Hughes, Justin, Alejandro Dominguez-Garcia, and Kameshwar Poolla. "Coordinating Heterogeneous Distributed Energy Resources for Provision of Frequency Regulation Services." Proceedings of the 50th Hawaii International Conference on System Sciences. 2017.

[4]. Karl Magnus Maribu, Ryan M. Firestone, Chris Marnay, Afzal S. Siddiqui, "Distributed energy resources market diffusion model", International Journal of Energy Policy 35 (2007), 4471–4484.

[5]. Brahman, Faeze, Masoud Honarmand, and Shahram Jadid. "Optimal electrical and thermal energy management of a residential energy hub, integrating demand response and energy storage system." Energy and Buildings 90 (2015): 65-75.

[6]. Geroski, P.A., "Models of technology diffusion" Research Policy 29, pp. 603–625, 2000.

[7]. Jaffe, A.B., Stavins, R.N., "The energy paradox and the diffusion of conservation technology". Resource and Energy Economics 16, 91–122, 1994

[8]. Ellabban, Omar, Haitham Abu-Rub, and Frede Blaabjerg. "Renewable energy resources: Current status, future prospects and their enabling technology." Renewable and Sustainable Energy Reviews 39 (2014): 748-764.

[9]. Jentsch, Mareike, Tobias Trost, and Michael Sterner. "Optimal use of power-to-gas energy storage systems in an 85% renewable energy scenario." Energy Procedia 46 (2014): 254-261.

[10]. Luo, Xing, et al. "Overview of current development in electrical energy storage technologies and the application potential in power system operation." Applied Energy 137 (2015): 511-536.

[11]. Driesen, Johan, and FaridKatiraei. "Design for distributed energy resources." Power and Energy Magazine, IEEE 6.3 (2008): 30-40.

[12]. Brenna, Morris, Enrico Tironi, and Giovanni Ubezio. "Proposal of a local dc distribution network with distributed energy resources." Harmonics and Quality of Power, 11th International Conference on. IEEE, 2004.

[13]. Sharaf, Omar Z., and Mehmet F. Orhan. "An overview of fuel cell technology: Fundamentals and applications." Renewable and Sustainable Energy Reviews 32 (2014): 810-853..

[14]. Walla, Ch, and W. Schneeberger. "The optimal size for biogas plants." Biomass and bioenergy 32.6 (2008): 551-557.

[15]. Ceran, Bartosz, and Paul Anton Bernstein. "Application PEM fuel cells in distributed generation." Poznan University of Technology Academic Journals, Electrical Engineering (2014): 157-164.

[16]. Jiang, Zhenhua. "Agent-based control framework for distributed energy resources microgrids." Intelligent Agent Technology, 2006. IAT'06. IEEE/WIC/ACM International Conference on. IEEE, 2006.

[17]. Wiemken, E., et al. "Power characteristics of PV ensembles: experiences from the combined power production of 100 grid connected PV systems distributed over the area of Germany." Solar energ70.6 (2001): 513-518.

[18]. Som, T., and N. Chakraborty. "Evaluation of Different Hybrid Distributed Generators in a Microgrid—A Metaheuristic Approach." Distributed Generation and Alternative Energy Journal 29.4 (2014): 49-77.

[19]. Series, IET Renewable Energy. "Microgrids and active distribution networks." The Institution of Engineering and Technology (2009).

[20]. Ellabban, Omar, Haitham Abu-Rub, and Frede Blaabjerg. "Renewable energy resources: Current status, future prospects and their enabling technology." Renewable and Sustainable Energy Reviews 39 (2014): 748-764.

[21]. Cowell, Richard, et al. "Energy transitions, sub-national government and regime flexibility: How has devolution in the United Kingdom affected renewable energy development?." Energy Research & Social Science 23 (2017): 169-181.

[22]. R. Menges, K. Barsantny, Die Liberalisierung der Stromma¨rkte in Norwegen und Schweden; in: Zeitscltriftfu¨rEnergiewirtschaft, Vol. 21; Heft 1/1997; Energiewirtschaftliches Institute an der Universita¨tKo¨ ln, Germany, 1997, pp. 39–56.

[23]. Blarke MB, Lund H. ‗The Effectiveness of Storage and Relocation Options in Renewable Energy Systems', Renewable Energy 2008; 33(7):1499–507.

[24]. Amorim A, Cardoso AL, Oyarzabal J, Melo N. ‗Analysis of the connection of a microturbine to a low voltage grid', IntConf Future Power Syst 2005:1–5.

[25]. Vahidinasab, Vahid. "Optimal distributed energy resources planning in a competitive electricity market: Multiobjective optimization and probabilistic design." Renewable Energy 66 (2014): 354-363.

[26]. Mohammadi, Sirus, Soodabeh Soleymani, and Babak Mozafari. "Scenario-based stochastic operation management of microgrid including wind, photovoltaic, micro-turbine, fuel cell and energy storage devices." International Journal of Electrical Power & Energy Systems 54 (2014): 525-535.

[27]. Yadav, Alka, and Laxmi Srivastava. "Optimal placement of distributed generation: An overview and key issues." Power Signals Control and Computations (EPSCICON), 2014 International Conference on. IEEE, 2014.

[28]. Hatziargyriou N, Donnelly M, Papathanassiou S, Pecas Lopes JA, Takasaki M, Chao H, et al. CIGRE technical brochure on modeling new forms of generation and storage. CIGRE TF38.01.10 2000.

[29]. Carlos A. Hernandez-Aramburo, Tim C. Green,NicolasMugniot, "Fuel Consumption Minimization of a Microgrid", IEEE Transactions on Industry Applications, Vol. 41, No. 3, MAY/JUNE 2005,pp 673-681.

[30]. A. S. Siddiqui, C. Marnay, R. M. Firestone, and N. Zhou, "Distributed generation with heat recovery and storage," J. Energy Eng., vol. 133, no. 3, pp. 181–210, Sep. 2007.

[31]. Pipattanasomporn, Manisa, Michael Willingham, and Saifur Rahman. "Implications of onsite distributed generation for commercial/industrial facilities." Power Systems, IEEE Transactions on 20.1 (2005): 206-212.

[32]. Su, Wencong, Jianhui Wang, and Jaehyung Roh. "Stochastic energy scheduling in microgrids with intermittent renewable energy resources." IEEE Transactions on Smart Grid 5.4 (2014): 1876-1883.
[33]. Bhandari, Binayak, et al. "A novel off-grid hybrid power system comprised of solar photovoltaic, wind, and hydro energy sources." Applied Energy 133 (2014): 236-242.
[34]. Barnhart, Brad, et al. "Prioritizing conservation for the reduction of Gulf hypoxia using an environmental performance index." Ecological Indicators 66 (2016): 235-241.
[35]. Hadjipaschalis I, Kourtis G, Poullikkas A. Assessment of oxyfuel power generation technologies. Renewable and Sustainable Energy Reviews 2009; 13:2637–44.
[36]. Akhmat, Ghulam, et al. "The challenges of reducing greenhouse gas emissions and air pollution through energy sources: evidence from a panel of developed countries." Environmental Science and Pollution Research 21.12 (2014): 7425-7435.
[37]. Hadley SW, Van Dyke JW. Emissions benefits of distributed generation in the Texas market: United States. Dept. of Energy; 2005.
[38]. A. S. Siddiqui, C. Marnay, O. Bailey, and K. H. LaCommare, ―Optimal selection of on-site power generation with combined heat and power applications,‖Int. J. Distrib. Energy Res., vol. 1, no. 1, pp. 33–62, Jan.–Mar. 2005.
[39]. N. Hatziargyriou, A. Zervos, Wind power development in Europe, Proc. IEEE 89 (12) (2001) 1765–1782.
[40]. Mafakheri, Fereshteh, and Fuzhan Nasiri. "Modeling of biomass-to-energy supply chain operations: applications, challenges and research directions." Energy Policy 67 (2014): 116-126. 52 Nichols David K, Stevens John, Lasseter Robert. Validation of the CERTS MicroGrid concept The CEC/ CERTS MicroGridtestbed. IEEE Power EngSoc Gen Meet 2006:1–3.
[41]. Dragosits, U., J. Luk, and M. A. Sutton. "Ammonia emissions from UK non-agricultural sources in 2007: contribution to the National Atmospheric Emission Inventory." (2009).blends." Journal of hazardous materials 179.1-3 (2010): 237-243.
[42]. Tsai, Jen-Hsiung, et al. "PM, carbon, and PAH emissions from a diesel generator fuelled with soy-biodiesel blends." Journal of hazardous materials 179.1-3 (2010): 237-243.
[43]. Kemmoku, Yoshishige, et al. "Life cycle CO_2 emissions of a photovoltaic/wind/diesel generating system." Electrical Engineering in Japan 138.2 (2002): 14-23.

T.Som" Technological Analysis and Optimization Of Microgrids And Ders: A Comprehensive Review. "The International Journal of Engineering and Science (IJES) 7.8 (2018): 39-46