VOL. 21, NO. 3, 2022, 13-22
https://elektrika.utm.my
ISSN 0128-4428

ELEKTRIKA
Journal of Electrical Engineering

A Review of Demand Side Management Strategies and Electricity Tariffs in Distributed Grids

Ahmed Tijjani Dahiru[1,2*], Chee Wei Tan[1], Sani Salisu[1,2], Kwan Yiew Lau[1], Chuen Ling Toh [4] and **Abba Lawan Bukar[1,5]**

[1]School of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.
[2]Department of Electrical/Electronics Technology, FCE (Technical) Bichi, Kano, Nigeria.
[3]Department of Electrical Engineering, Faculty of Engineering, Ahmadu Bello University Zaria, Nigeria.
[4]Department of Electrical and Electronic Engineering, Universiti Tenaga National Kajang, Malaysia.
[5]Department of Electrical Engineering, Faculty of Engineering, University of Maiduguri, Nigeria.

[*]Corresponding author: dahiru-1970@live.utm.my

Abstract: A major challenge in renewable energy planning and integration with existing systems is the management of intermittence of the renewable resources and customer demand uncertainties. In emerging distributed grids, state-of-the-art optimization techniques were used for cost and reliability objectives. In the existing literature, power dispatch and demand side management schemes were implemented for various techno-economic objectives. In renewable energy-based distributed grids, power dispatch is strategic to distributed grid operations. However, demand side management is preferred, as it allows more options for customer participation. Moreover, the demand side management can simply follow supplies. This paper investigates the functions of demand side management as it affects the planning and operations of renewable energy-based distributed grids. The traditional demand side management strategies were inflexible and affect customer comforts. The time-of-use methods on the other hand are utility-centered and do not allow customer participation. Hence, integration of demand side management with tariff regimes through hybridizations such as time-of-use based real-time pricing were conceptualized for improved economic performance, reliability enhancement, and mitigation of environmental implications.

Keywords: Demand side management, Distributed grids, Renewable energy, Tariff structures, Time-of-Use.

© 2022 Penerbit UTM Press. All rights reserved

Article History: received 9 February 2022; accepted 3 December 2022; published 22 December 2022.

1. INTRODUCTION

The main objectives in renewable energy (RE) based distributed systems are reliability, energy costs, supply availability, and emission control. Balancing the foregoing techno-economic objectives in distributed grid planning and operations requires defined energy management (EM) schemes at both sides of the meter. The foregoing are issues with EM schemes applied to the supply side (power dispatch) and demand side management in distributed grids (DG). Power dispatch in conventional grids (CG) is strategic to the system's operations. However, power dispatch in DGs may be more strategic due to the impacts of uncontrollable RE resources and diversified technologies involved as illustrated in Figure 1. Hence, reliability challenges are expected in DGs such that what may matter most to the systems' operations are the optimal implementations of demand side management (DSM). Moreover, the DSM is known to be flexible enough to be made to follow supplies in the event of irregular power dispatch.

The concept of DSM is focused on achieving the system's balanced operations as identified in reference [1]. Objectives of DSM implementations in DGs include energy cost reductions due to increasing demands and prevention of early failures due to overstretching demands. The DSM in a broader concept consists of demand response (DR) programmes and energy efficiency (EE) [2]. The DR is a utility-based designed programme for a short-term management of customer demands. The DR programmes provide opportunities for customers to participate in electric grid operations through shifting or reduction of electricity usage for time-based energy rates or financial incentives. Customers are attracted to respond to DR programmes through offerings such as time-of-use (TOU) pricing, critical peak pricing (CPP), real-time pricing (RTP), and critical-peak rebates (CPR) [2]. References [3], [4], and [5] highlighted the implementation of DSM in literature based on strategies which include shaving, valley filling, load levelling, and load shifting. Other strategies of the DSM are load levelling, load shifting, energy arbitrage, strategic load growth, strategic conservation, and flexible load scheduling as discussed in [6], [7], [8], and [9]. However, the foregoing strategies are not prominently applied in literature for DSM applications despite their flexibilities and suitability to RE-based DG system problems. Hence, this paper analyses literature implementations of DSM strategies as it applies to emerging DG frameworks with regards to the modern electricity tariff implementations. The paper contributes to the identification of the following points with regards to existing literature applications of DSM strategies in DG system developments and electricity usage.

- most of the traditional DSM strategies are designed to be suitable for CG applications.
- the DSM strategies implemented based on utility-initiated demand response (DR) programmes are utility-centred, hence customer comforts are mostly jeopardized.
- dump energies due to power generation curtailments are not as economical as it appears. The process incurs additional costs and power losses.

The paper hence recommends hybridization of the DSM strategies with electricity tariff methods such as reference [10], where TOU-based RTP was proposed and implemented.

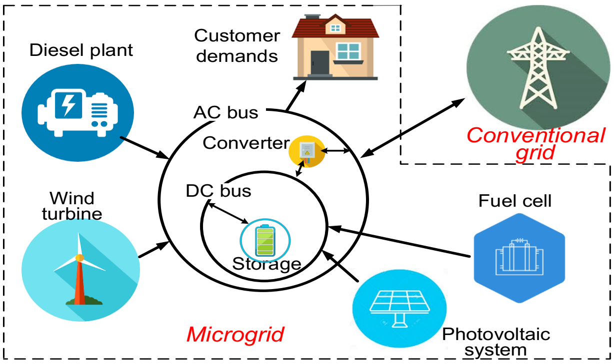

Figure 1. Multi-energy structure of a microgrid

2. DISTRIBUTED GRID TECHNOLOGIES

The CG is a vertically structured centralized system comprising of units such as generation, transmission, distribution, and retails [11]. Challenges affecting the performance of CGs include high costs of fuels and the effects of volatile oil markets [12], transmission losses [13], [14], carbon emissions [15], and high acquisition costs [16]. Maintaining such systems could be costly, in terms of economy and environment [14], [17]. Other challenges could be reliability due to human errors, natural disasters [18],[19], and transmission losses [20]. Part of the solution to the foregoing problems is to improve supply reliability through increased generation [21], [22]. It is viewed in reference [23] that the power grid's transmission losses can significantly be reduced by the adoption of modern DG structures, and the need for expansion of the existing structure can be eliminated [3]. The DGs are as well good for the support of RE integration [24], reducing carbon emissions [25], and ensuring minimizations in maintenance and fuel costs [26], and energy consumption costs [27].

Apart from the significant impacts of DGs in power systems' support for RE generation and integrations discussed in [28] and [29], the REs are good in the harvest of free, abundant and life resources. Photovoltaic (PV) cells, wind turbines (WT), and fuel cells (FC) are a few examples of RE components used as generators in emerging DG systems. The DG hierarchy shown in Figure 2 comprises microgrids and nanogrids as scaled-down systems, usually designed for convenience, costs, and logistics. There may be no definite topologies in a DG architecture. However, system capacity and energy demand requirements could be a basis for the classification of DGs for components and system sizes listed as follows:

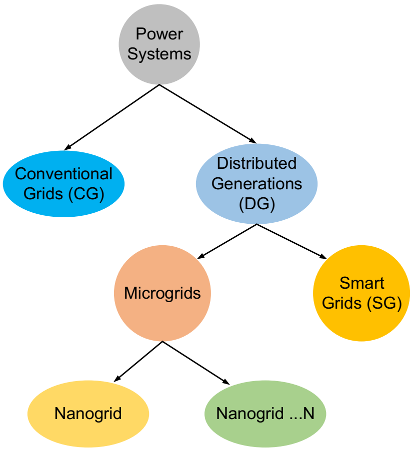

Figure 2. Decentralizations in a modern electrical power grid

- The Macrogrid System is a centralized system designed to serve customers within an extensively large area and large population. The architecture in macrogrid shown in Figure 3 has generation voltages (5 kV - 34.5 kV), transmission voltages (66 kV- 765 kV), and distribution voltages (120 V - 240 V single-phase, and 220 V - 420 V, 33 kV three-phase).

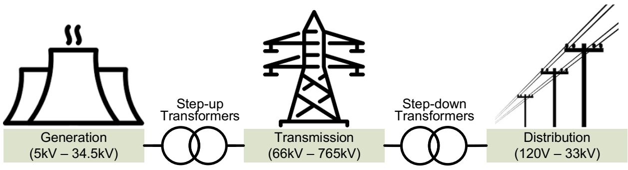

Figure 3. The basic structure of a macrogrid system

- The Minigrid System topology is smaller than the macrogrid in terms of generation capacities and consumer loads. Transmission networks are not part of this topology as the distance between generation and load centers is significantly close such that PDNs are adequate to facilitate power transfers. Generation capacity usually ranges between 1 kVA to 10 MVA [30], while operating on voltages (120 V - 220 V) [31].

- The microgrid illustrated in Figure 4, is an electrical entity of generators and loads operating either in isolated mode, in connection with other grids (macrogrids or minigrids), or a network of other microgrids. The microgrid topology may not have a definite size, however, The World Bank describes its operating voltages to be below 11 kV [32].

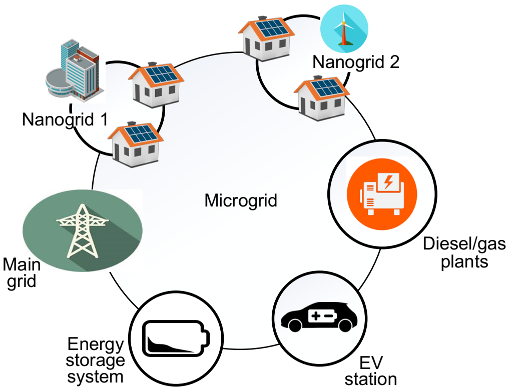

Figure 4. Typical structure of a microgrid

The nanogrid topology takes a general approach and design principles of microgrids but with much lower capacity. In similarities with the microgrids, the underlying philosophies about nanogrid concepts are economy (reduction in energy and operational costs, elimination of the cost of macrogrid extension), reliability (increased supply availability), environment (reduced rate of power generation-based emissions), and speed (the reduced time it may take to extend macrogrid services) [12], [33], [34] and [35].

3. DEMAND SIDE MANAGEMENT AND STRATEGIES

The main objective of power dispatch in a DG is the economic dispatch of generating components based on supply availability and demand response programmes. Whereas DSM's main objectives include cost-effective load scheduling based on demand response programmes at the customer end to achieve the following [36]:

- maintaining a load factor as close as possible to 1.0.
- maintaining a peak within the proper supply/demand margin.

By achieving the foregoing objectives, utilities could get adequate energy from participating generating units thereby maximizing profits and minimizing per kWh cost of energy. To that effect, traditional DSM strategies such as peak shaving, valley filling, load shifting, and energy arbitrage were implemented in [3] and [37]. Reference [38] categorizes DSM into the following three (3) activities upon which implementation strategies may be derived:

- Energy demand reduction programmes as an activity where demands are reduced through better and efficient processes such as smart energy buildings or the use of energy-efficient equipment.
- Load management programmes as an activity of changing load patterns through demand shifts and demand curtailment during peak periods and peak rates.
- Load growth and conservation programmes as an activity for change of load pattern through substitution or deferment of loads.

There are many strategies discussed in the literature for effective DSM implementations. Examples of such include a study prepared and presented in reference [3] to investigate a wide range of DSM strategies, with illustrations in Figure 5. The strategies are meant to be used in enabling customer participation in the management of DGs as one of the preferred characteristics of emerging modern power grids:

- Peak shaving, also known as peak clipping is a DSM strategy that considers cutting off a portion of loads at a time in peak hours of electricity demand without adverse effect to overall demand curves. Benefits of peak shaving are identified in [37], [39], [40], and [41] as a solution to varying daily electricity needs, clean energy production, and additional unpredictable loads such as electric vehicles (EV).

- Valley filling is implemented at periods of low demands concerning base loads. Higher levels of generations during such periods may comparatively be at a loss if demands are not raised due to unused (dump) energies. Valley fillings were used to stabilize the grid [42], achieve desired aggregate load profile [43], and flatten the demand profiles [44].

- Load levelling is applied to power distribution networks where large fluctuations of loads are experienced. Multiple benefits of energy storage were reviewed in [45]. Load levelling objectives were combined with objectives of optimal ESS and peak demand scheduling in [46]. The load levelling was also realized through integrations of EVs into SG systems, [47], and reducing energy cost and protection of consumer privacy were achieved [48].

- Load shifting strategy considers the transfer of loads from one appliance's demands to another based on the criticality or flexibility of loads and periods of supply availability. Load shifting discussed in the literature include investigations into potentials of peak shaving, valley filling and load reference [49], sizing and selection of ESS for a PV/Wind-powered DG distribution system [50], optimizing generator and loads sizing schemes in a standalone microgrid [51], investigating the benefits of DSM to both the utility and customer side of a DG [8], classifications of PV users based on pre-grids and post-grids terms [52], increase levels of self-reliance in terms of energy consumption for a heat pump coupled to PVs [53], and reduction of peak demand and reshaping of a load profile is proposed multi-objective optimization framework [54].

- Energy arbitrage is described as energy vending at the time of higher energy prices after a stored purchase at lower prices. Energy arbitrage is usually achieved using efficient storage systems that can either be BESS, pumped hydro, supercapacitor, compressed air, hydrogen storage, or flywheel [45]. Examples of energy arbitrage in the literature include reference [55] which considered reducing costs and improving the energy efficiency of generic model ESS. Mathematical modelling to determine the feasibility of investing in energy storage of vanadium redox battery [56], and bi-level energy storage arbitrage solution [57].

- Strategic conservation is a consumer-centered DSM strategy that usually originates from utility-based DR programmes, specific to change power usage patterns. Incentivized sales and usage reduction change load shapes in the programme. Reference [58] achieved strategic conservation by making efficient use of energy, and by reducing the amount of energy service. Reference [59] emphasized that demand forecast needs to be prepared for strategic conservation to be successful.

- Strategic load growth is a planned increase in energy sales ahead of valley filling strategies due to the utilization of smart power technologies such as EVs, automation, and industrial process heating. This strategy aims to increase the market share of loads that sometimes involve the addition of new customers. A lot has been mentioned of the strategic load growth in literature such as references [3], [4], [36], [59], [60], without any known research implementation being undertaken.

- Flexible load shape is a programme where customers receive incentives for load curtailments as a result of deterioration of reliability or quality of service. The DSM programme by the utility deviates from permanently sticking to a specific load shape, such that incentives attached to load growth and decay on the customer sides are applied interchangeably.

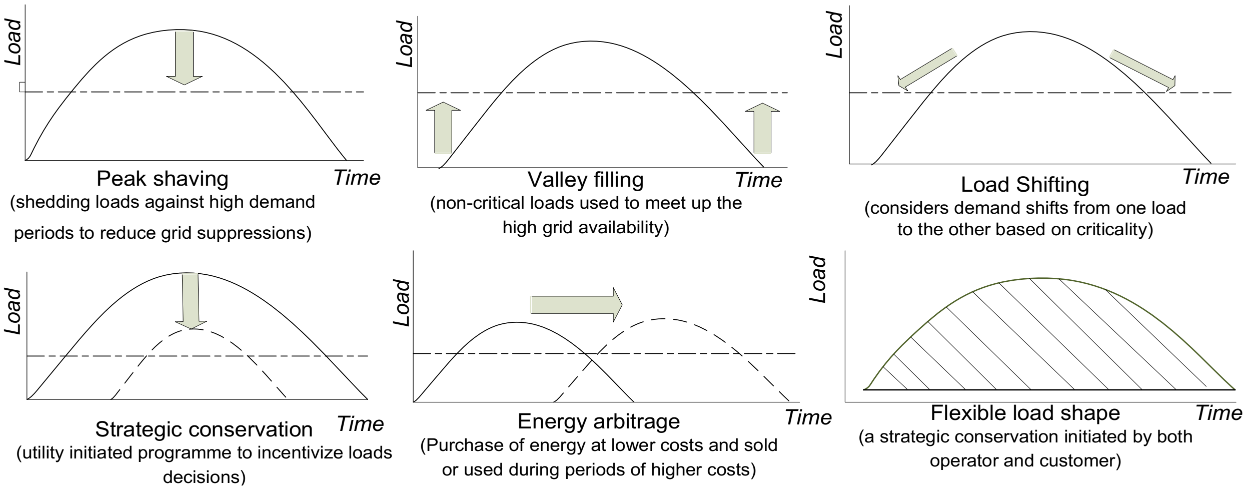

Figure 5. Graphical illustration of demand side management strategies for optimal load scheduling [3]

4. DEMAND RESPONSE AND ELECTRICITY TARIFFS

In an implementation of power dispatch, storage management, and the DSM schemes, optimization tools and methods are found to be mostly useful. Optimization as a concept is designed to minimize or maximize output parameters of a system by optimal selection of input parameters [61]. The main focus of optimizations in energy systems covers minimization of costs, reduction in energy consumptions, time resource management, maximization of profits, increased outputs, improved performance, and better efficiencies [62].

The DR as an aspect of DSM is described as a designed programme for short-term management of energy demands on the customer side of the electricity network. The DR provides the opportunity for customers to participate in electric grid operations through shifting or reduction of electricity usage for time-based rates or financial incentives. Customers are attracted to respond to DR programmes through offerings such as TOU pricing, CPP, RTP, and CPR, as briefly described:

- Standard tariffs, where billings are prepared based on monthly kWh consumed in addition to meter and equipment charges. The kWh electricity is the actual energy consumed by customers, whereas meter charges cover expenses incurred while installing and maintaining electricity meters.

- The TOU tariff structures are designed to persuade customers to shift loads away from peak demand periods. Demands in electricity usually increase based on seasonal factors, such as summer and winter seasons, where loads are highly rated for space comforts.

- The RTP is described as an ideal structure for electricity pricing where the true cost of electricity is reflected in rates that constantly change throughout the day on daily basis. RTP structure of electricity pricing is offered by utilities based on day-ahead, hour-by-hour real-time pricing. This tariff structure is viewed as an improvement over the TOU structure that attempts to capture the true cost of utility service.

Table 1 Critical analysis in DSM implementation methods in the literature

Ref	**Year**	**Problems/ Study Objectives**	**Implemented Algorithm(s)**	**Benchmarked Algorithms**	**Achievements**	**Shortcomings/Further Studies**
[81]	2016	Linear Programming	MILP-based battery sizing and operation in a microgrid.	PSO	The mixed-mode method employed was able to reduce the operating costs of the microgrid. The inclusion of a battery source in the microgrid reduced operating costs.	Higher SOC can reduce operating costs and lower battery capital costs. Higher SOC in batteries can reduce fuel-cell and main grid operating hours.
[82]	2017	Portfolio, placement, and optimal dispatch in a microgrid with multiple sources.	MILP	Distributed Energy Resource-Customer Adoption Model (DER-CAM)	The results of the power flow were compared between existing and proposed approaches and only small errors in the bus voltage magnitudes were noticed.	Larger microgrid modelling more nodes. Pursue integration of alternative linear power flow models.
[63]	2017	Optimal sizing of a DG and BESS.	FICO Xpress optimization tool on MILP	No benchmarks were reported.	Large penetration of PV generation and storage significantly reduces CO_2 emissions in the PDNs.	Ancillary services such as reactive power and voltage regulation at the PCC can improve feasibilities and additional incentives of the microgrid.
[83]	2017	Siting and sizing of energy storage for transmission grids	Novel economic and complex network-based metrics	IEEE-RTS96 was used to validate the work, but no benchmarked studies were considered.	Batteries indicate capabilities of energy storage that otherwise must be curtailed. Batteries reduced the rate of conventional power generation at the time of peak demands.	Siting shows no influence on optimization results. Investigations into the extent of battery enhancement are suggested.
[57]	2018	Minimizing annual revenue through energy storage arbitrage.	Mathematical equilibrium constraints re-casted into MILP.	The case study used the PJM 5-bus system. IEEE 118-bus was used for validation	Both load and wind levels jointly determine the potential of the system.	Multiple energy storage systems are recommended for increased arbitrage. The study did not consider system planning which includes sizing of the energy storage system.
[84]	2018	Coordination for generation and storage expansion under Primary Frequency Response	Of-the-Shelf solver-based MILP.	Comparisons were made between the traditional expansion model and the proposed formulations.	The proposed formulations were able to achieve both sizing and siting objectives. Mathematical formulations for generations and storage expansions.	The work concentrates on generation and storage unit failure and their contingencies. Other failures, such as line failures due to frequency do not need primary frequency response.
[85]	2018	Load forecasting to achieve low voltage community battery storage.	Neural Network (NN), Wavelet Neural Network (WNN), and ANFIS.	Case study location in Perth Solar City. No benchmarks were reported.	The mean absolute error in the forecast was less than 3%.	Factors such as battery cost and time of use (TOU) tariffs that determine the cost of energy were not considered.

5. CRITICAL ANALYSIS AND STUDY RECOMMENDATIONS

The use of RE resources in DG systems considering their resource dispersion, characteristics, and intermittence not only affects the protection and control architecture of the system but makes it more complex to predict due to size, operational characteristics, cost implications, and reliability. Apart from intermittent renewable resources, irregular customer demands contribute to uncertainties in DG performance. Moreover, the intermittent RE resources such as solar insolation and wind speeds affect DG systems' reliability that obliged alternative use of ESS from either a battery as suggested in [63], [64], supercapacitor suggested in [65], [66], hydrogen storage suggested in [67], flywheel suggested in [68], [69] and hydrostatic technologies suggested in [70].

The combination of two or more of the foregoing energy storage technologies in hybrid form also proved to be effective. Thus, coordinating such a multi-source and multi-technology DG system requires effective optimization techniques to achieve operational stability and reliability with minimized acquisition and running costs [71]. Reliability, stability, and economy are the main objectives to attain optimal DG system planning and operational design goals. It is emphasized in [72] that for desired values in system designs and operating policy variables to be attained (such as a complex DG system), identification and evaluation of desired goals and objectives are desired. The goals and underlying objectives can be achieved using optimization and simulation models. The desired values achieved by suitable optimization methods will lead to the highest levels of system performance and eliminate inferior options.

While appreciating the advantages of DSM over power dispatch in RE-based systems, reference [58] emphasizes better DSM implementations through flexible load management. In recent studies, traditional strategies such as peak shaving, valley filling, load shifting, and energy arbitrage were implemented, as exemplified in references [37], [73], [40], [74], and [75]. However, implementation of the foregoing strategies affects customer comforts and may not be consistent with the stochastic RE generation and customer demand patterns at all times. Hence, the case may lead to a high rate of dump energies and unmet demands. Moreover, energy curtailments may not be an optimal option as the process may incur additional losses and increased operational cost implications. Hence, optimal load management is appropriate in coordinating customer demands based on real-time supply availability.

In references [76], [77], [78], [79], and [80], conventional time-of-use (C_{TOU}) methods were considered in achieving load management schemes. Incidentally, the C_{TOU} are fixed and does not usually appear to reflect the DSM-based desired operational objectives. It can be recalled that, uncertain demand patterns hardly match RE resource distributions that periodically differ with the change in climatic conditions. This implies that, the inflexibilities of C_{TOU} may not be capable of enabling customer participation in optimal load management, where a close matching of stochastic RE generation and customer demands is the main goal. Methods such as RTP can be considered in implementation of load management due to the customer-oriented features. Moreover, C_{TOU} is utility-centred, and RTP emphasizes on energy price per unit generation for a given time step. Hybridization of C_{TOU} and RTP may enable customer's full participation, through application of actual energy consumption charges. The proposed hybridization is envisaged to enable flexible options for customers' decision on load scheduling. The benefits of load management expected to be achieved using the foregoing hybridization could be a multi-purpose strategy, with many DSM features such as the load shifting, peak shaving, energy arbitrage, strategic load growth and flexible load scheduling as highlighted in Table 1.

6. CONCLUSION

In RE systems, optimal planning and operation schemes are implemented using optimization techniques. The methods ensure economic selection and placement of the RE components based on locations' weather resources. The RE system operations cover power dispatch and demand side management schemes. The power dispatch is strategic to RE system operations. However, the RE resource intermittence and demand uncertainties render power dispatch complex and uneconomical. Hence, the DSM is preferred, as it simply follows supplies. The DSM also ensures customer participation in systems' operations and particularly the optimal load management. The DSM is implemented through DR programmes for energy cost and utility tariffs. However, implementation of the DSM strategies affects customer comforts and is not consistent with the stochastic RE resources and customer demands. Hence, the derivatives may be the high rate of dump energies and unmet demands. Energy curtailments may not be an optimal option as the process incurs losses and increased operational cost implications. The $\mathrm{C_{TOU}}$ methods were used in the implementation of load management schemes. The $\mathrm{C_{TOU}}$ are inflexible and do not appear to reflect the DSM-based desired operational objectives. Hence, an optimal DSM strategy is envisaged to be feasible through a customer-oriented $\mathrm{C_{TOU}}$, RTP or both.

ACKNOWLEDGMENT

The authors want to acknowledge the generosity of the management of Federal College of Education (Technical) Bichi, Kano State, Nigeria for the In-service programme offered to the first author through Tertiary Education Trust Fund (TETfund) intervention. All the authors acknowledge the funding provided by the UTMShine under the vote Q.J130000.2451.09G32, and the facility provided by Universiti Teknologi Malaysia (UTM).

REFERENCES

[1] R. Atia and N. Yamada, “Sizing and Analysis of Renewable Energy and Battery Systems in Residential Microgrids,” *IEEE Trans. Smart Grid*, vol. 7, no. 3, pp. 1204–1213, 2016, doi: 10.1109/TSG.2016.2519541.

[2] G. M. Masters, *Renewable and Efficient Electric Power Systems*, Second Ed. New Jersey: John Wiley & Sons, Inc., 2004.

[3] R. Debnath, D. Kumar, and D. K. Mohanta, “Effective demand side management (DSM) strategies for the deregulated market envioronments,” *2017 Conf. Emerg. Devices Smart Syst. ICEDSS 2017*, no. March, pp. 110–115, 2017, doi: 10.1109/ICEDSS.2017.8073668.

[4] C. . Eze, D. . Agwu, and L. O. Uzoechi, “A NEW PROPOSED DEMAND SIDE MANAGEMENT TECHNIQUE,” *Int. J. Eng. Sci. Emerg. Technol.*, vol. 8, no. 6, pp. 271–281, 2016.

[5] C. S. Ioakimidis, D. Thomas, P. Rycerski, and K. N. Genikomsakis, “Peak shaving and valley filling of power consumption profile in non-residential buildings using an electric vehicle parking lot,” *Energy*, vol. 148, pp. 148–158, 2018, doi: 10.1016/j.energy.2018.01.128.

[6] H. J. Jabir, “Impacts of Demand-Side Management on Electrical Power Systems : A Review,” pp. 1–19, 2018, doi: 10.3390/en11051050.

[7] G. Gaur, N. Mehta, R. Khanna, and S. Kaur, “Demand Side Management in a Smart Grid Environment,” 2017, pp. 227–231, doi: 10.1109/ICSGSC.2017.8038581.

[8] B. Lokeshgupta and S. Sivasubramani, “Multi-objective dynamic economic and emission dispatch with demand side management,” *Int. J. Electr. Power Energy Syst.*, vol. 97, no. October 2017, pp. 334–343, doi: 10.1016/j.ijepes.2017.11.020.

[9] A. S. Jacob, R. Banerjee, and P. C. Ghosh, “Sizing of hybrid energy storage system for a PV based microgrid through design space approach,” *Appl. Energy*, vol. 212, no. September 2017, pp. 640–653, 2018, doi: 10.1016/j.apenergy.2017.12.040.

[10] A. Tijjani, C. Wei, A. Lawan, and K. Yiew, “Energy cost reduction in residential nanogrid under constraints of renewable energy , customer demand fitness and binary battery operations,” *J. Energy Storage*, vol. 39, no. March, p. 102520, 2021, doi: 10.1016/j.est.2021.102520.

[11] K. Ma, S. Hu, J. Yang, C. Dou, and J. M. Guerrero, “Energy trading and pricing in microgrids with uncertain energy supply: A three-stage hierarchical game approach,” *Energies*, vol. 10, no. 5, 2017, doi: 10.3390/en10050670.

[12] D. Akinyele, “Techno-economic design and performance analysis of nanogrid systems for households in energy-poor villages,” *Sustain. Cities Soc.*, vol. 34, no. July, pp. 335–357, 2017, doi: 10.1016/j.scs.2017.07.004.

[13] E. K. Bawan, “Distributed Generation Impact on Power System Case study : Losses and Voltage Profile,” *Power Eng. Soc. Summer Meet. 2000. IEEE*, vol. 3, pp. 1645–1656, 2000.

[14] P. Raman, J. Murali, D. Sakthivadivel, and V. S. Vigneswaran, “Opportunities and challenges in setting up solar photo voltaic based micro grids for electrification in rural areas of India,” *Renew. Sustain. Energy Rev.*, vol. 16, no. 5, pp. 3320–3325, 2012, doi: 10.1016/j.rser.2012.02.065.

[15] I. Zenginis, J. S. Vardakas, C. Echave, M. Morató, J. Abadal, and C. V. Verikoukis, “Cooperation in microgrids through power exchange: An optimal sizing and operation approach,” *Appl. Energy*, vol. 203, no. April, pp. 972–981, 2017, doi: 10.1016/j.apenergy.2017.07.110.

[16] R. Palma-Behnke *et al.*, “A microgrid energy management system based on the rolling horizon strategy,” *IEEE Trans. Smart Grid*, vol. 4, no. 2, pp. 996–1006, 2013, doi: 10.1109/TSG.2012.2231440.

[17] C. Deckmyn, J. Van de Vyver, T. L. Vandoorn, B. Meersman, J. Desmet, and L. Vandevelde, “Day-ahead unit commitment model for microgrids,” *IET Gener. Transm. Distrib.*, vol. 11, no. 1, pp. 1–9, 2017, doi: 10.1049/iet-gtd.2016.0222.

[18] Y.-K. Chen, Y.-C. Wu, C.-C. Song, and Y.-S. Chen, “Design and Implementation of Energy Management System With Fuzzy Control for DC Microgrid Systems,” *IEEE Trans. Power Electron.*, vol. 28, no. 4, pp. 1563–1570, 2013, doi: 10.1109/TPEL.2012.2210446.

[19] F. R. Islam, K. Prakash, K. A. Mamun, A. Lallu, and H. R. Pota, “Aromatic Network: A Novel Structure for Power Distribution System,” *IEEE Access*, vol. 5, 2017, doi: 10.1109/ACCESS.2017.2767037.

[20] D. Burmester, R. Rayudu, W. Seah, and D. Akinyele, “A review of nanogrid topologies and technologies,” *Renew. Sustain. Energy Rev.*, vol. 67, pp. 760–775, 2017, doi: 10.1016/j.rser.2016.09.073.

[21] M. Moradian, F. M. Tabatabaei, and S. Moradian, “Modeling, Control & Fault Management of Microgrids,” *Smart Grid Renew. Energy*, vol. 04, no. February, pp. 99–112, 2013, doi: 10.4236/sgre.2013.41013.

[22] J. A. P. Lopes, N. Hatziargyriou, J. Mutale, P. Djapic, and N. Jenkins, “Integrating distributed generation into electric power systems: A review of drivers, challenges and opportunities,” *Electr. Power Syst. Res.*, vol. 77, no. 9, pp. 1189–1203, 2007, doi: 10.1016/j.epsr.2006.08.016.

[23] M. S. Mahmoud, S. Azher Hussain, and M. A. Abido, “Modeling and control of microgrid: An overview,” *J. Franklin Inst.*, vol. 351, no. 5, pp. 2822–2859, 2014, doi: 10.1016/j.jfranklin.2014.01.016.

[24] C. D. E. Olivares *et al.*, “Trends in Microgrid Control,” vol. 5, no. 4, pp. 1905–1919, 2014.

[25] S. Ganesan, S. Padmanaban, R. Varadarajan, U. Subramaniam, and L. Mihet-Popa, “Study and analysis of an intelligent microgrid energy management solution with distributed energy sources,” *Energies*, vol. 10, no. 9, 2017, doi: 10.3390/en10091419.

[26] A. Molderink, S. Member, V. Bakker, M. G. C. Bosman, J. L. Hurink, and G. J. M. Smit, “Management and Control of Domestic Smart Grid Technology,” vol. 1, no. 2, pp. 109–119, 2010.

[27] G. Hoogsteen *et al.*, “Balancing islanded residential

microgrids using demand side management," *2016 IEEE Power Energy Soc. Innov. Smart Grid Technol. Conf. ISGT 2016*, 2016, doi: 10.1109/ISGT.2016.7781167.

[28] O. Paper and D. Boer, "r vi ew On r Fo Re vi ew On ly," pp. 0–34, 2013, doi: 10.3837/tiis.0000.00.000.

[29] Y. Kuang *et al.*, "A review of renewable energy utilization in islands," *Renew. Sustain. Energy Rev.*, vol. 59, pp. 504–513, 2016, doi: 10.1016/j.rser.2016.01.014.

[30] IRENA, *Policies and regulations for renewable mini-grids*. 2018.

[31] J. U. B. E. S. M. A. Program and (ESMAP), "Mini-Grid Design Manual," Washington, D.C., 2000.

[32] N. Javaid, G. Hafeez, S. Iqbal, N. Alrajeh, M. S. Alabed, and M. Guizani, "Energy Efficient Integration of Renewable Energy Sources in the Smart Grid for Demand Side Management," *IEEE Access*, vol. PP, no. c, p. 1, 2018, doi: 10.1109/ACCESS.2018.2866461.

[33] M. Shahidehpour, Z. Li, W. Gong, S. Bahramirad, and M. Lopata, "A Hybrid ac\/dc Nanogrid: The keating hall installation at the Illinois Institute of Technology," *IEEE Electrif. Mag.*, vol. 5, no. 2, pp. 36–46, 2017, doi: 10.1109/MELE.2017.2685858.

[34] S. Moussa, M. J. Ben Ghorbal, and I. Slama-Belkhodja, "Bus voltage level choice for standalone residential DC nanogrid," *Sustain. Cities Soc.*, vol. 46, no. January, p. 101431, 2019, doi: 10.1016/j.scs.2019.101431.

[35] M. A. Cordova-Fajardo and E. S. Tututi, "Incorporating home appliances into a DC home nanogrid.," in *Journal of Physics: Conference Series*, 2019, vol. 1221, no. 1, doi: 10.1088/1742-6596/1221/1/012048.

[36] H. A. Attia, "Mathematical Formulation of the Demand Side Management (DSM) Problem and its Optimal Solution," in *14th International Middle East Power Systems Conference (MEPCON'10), Cairo University, Egypt,* 2010, no. December.

[37] C. Augusto, R. H. Almeida, S. Mandelli, and M. C. Brito, "Evaluation of potential of demand side management strategies in isolated microgrid," *2017 6th Int. Conf. Clean Electr. Power Renew. Energy Resour. Impact, ICCEP 2017*, pp. 359–361, 2017, doi: 10.1109/ICCEP.2017.8004840.

[38] S. Saini, "Demand-side management module," 2007.

[39] A. Molderink, V. Bakker, M. G. C. Bosman, J. L. Hurink, and G. J. M. Smit, "Management and Control of Domestic Smart Grid Technology," *IEEE Trans. Smart Grid*, vol. 1, no. 2, pp. 109–119, 2010, doi: 10.1109/TSG.2010.2055904.

[40] L. Martirano *et al.*, "Demand Side Management in Microgrids for Load Control in Nearly Zero Energy Buildings," *IEEE Trans. Ind. Appl.*, vol. 53, no. 3, pp. 1769–1779, 2017, doi: 10.1109/TIA.2017.2672918.

[41] A. Serpi, M. Porru, and A. Damiano, "An optimal power and energy management by hybrid energy storage systems in microgrids," *Energies*, vol. 10, no. 11, 2017, doi: 10.3390/en10111909.

[42] A. Nazarloo, M. R. Feyzi, M. Sabahi, and M. B. Bannae, "Improving Voltage Profile and Optimal Scheduling of Vehicle to Grid Energy based on a New Method," vol. 18, no. 1, pp. 81–88, 2018.

[43] B. Sun, Z. Huang, X. Tan, and D. H. K. Tsang, "Optimal Scheduling for Electric Vehicle Charging with Discrete Charging Levels in Distribution Grid," *IEEE Trans. Smart Grid*, vol. 9, no. 2, pp. 1–1, 2016, doi: 10.1109/TSG.2016.2558585.

[44] M. Liu, P. K. Phanivong, Y. Shi, and D. S. Callaway, "Decentralized Charging Control of Electric Vehicles in Residential Distribution Networks," *IEEE Trans. Control Syst. Technol.*, pp. 1–16, 2017, doi: 10.1109/TCST.2017.2771307.

[45] P. Nikolaidis and A. Poullikkas, "Cost metrics of electrical energy storage technologies in potential power system operations," *Sustain. Energy Technol. Assessments*, vol. 25, no. December 2017, pp. 43–59, 2018, doi: 10.1016/j.seta.2017.12.001.

[46] S. U. Agamah and L. Ekonomou, "Energy storage system scheduling for peak demand reduction using evolutionary combinatorial optimisation," *Sustain. Energy Technol. Assessments*, vol. 23, no. April, pp. 73–82, 2017, doi: 10.1016/j.seta.2017.08.003.

[47] A. O. David and I. Al-Anbagi, "EVs for frequency regulation: cost benefit analysis in a smart grid environment," *IET Electr. Syst. Transp.*, vol. 7, no. 4, pp. 310–317, 2017, doi: 10.1049/iet-est.2017.0007.

[48] J. X. Chin, T. Tinoco De Rubira, and G. Hug, "Privacy-Protecting Energy Management Unit Through Model-Distribution Predictive Control," *IEEE Trans. Smart Grid*, vol. 8, no. 6, pp. 3084–3093, 2017, doi: 10.1109/TSG.2017.2703158.

[49] F. Zhang, H. Zhao, and M. Hong, "Operation of networked microgrids in a distribution system," *CSEE J. Power Energy Syst.*, vol. 1, no. 4, pp. 12–21, 2015, doi: 10.17775/CSEEJPES.2015.00043.

[50] S. R. Sepulveda, Camilo, Canha Luciane, Sperandio Mauricio, "Methodology for ESS-type selection and optimal energy management in distribution system with DG considering reverse flow limitations and cost penalties," *IET Gener. Transm. Distrib.*, vol. 12, no. 5, pp. 1164-1170(6), 2018, doi: 10.1049/iet-gtd.2017.1027.

[51] U. Akram, M. Khalid, and S. Shafiq, "An Improved Optimal Sizing Methodology for Future Autonomous Residential Smart Power Systems," *IEEE Access*, vol. 6, 2018, doi: 10.1109/ACCESS.2018.2792451.

[52] I. Wittenberg and E. Matthies, "How do PV households use their PV system and how is this related to their energy use?," *Renew. Energy*, vol. 122, pp. 291–300, 2018, doi: 10.1016/j.renene.2018.01.091.

[53] J. Romaní, M. Belusko, A. Alemu, L. F. Cabeza, A. de Gracia, and F. Bruno, "Control concepts of a radiant wall working as thermal energy storage for peak load shifting of a heat pump coupled to a PV array," *Renew. Energy*, vol. 118, pp. 489–501, 2018, doi: 10.1016/j.renene.2017.11.036.

[54] M. Bastani, H. Damgacioglu, and N. Celik, "A δ-constraint multi-objective optimization framework for operation planning of smart grids," *Sustain. Cities Soc.*, vol. 38, no. December 2017, pp. 21–30, 2018, doi: 10.1016/j.scs.2017.12.006.

[55] M. B. C. Salles, M. J. Aziz, and W. W. Hogan,

"Potential arbitrage revenue of energy storage systems in PJM during 2014," *IEEE Power Energy Soc. Gen. Meet.*, vol. 2016-Novem, 2016, doi: 10.1109/PESGM.2016.7741114.

[56] T. Coronel, E. Buzarquis, and G. A. Blanco, "Analyzing feasibility of energy storage system for energy arbitrage."

[57] H. Cui, F. Li, X. Fang, H. Chen, and H. Wang, "Bi-Level Arbitrage Potential Evaluation for Grid-Scale Energy Storage Considering Wind Power and LMP Smoothing Effect," *IEEE Trans. Sustain. Energy*, vol. 9, no. 2, pp. 707–718, 2017, doi: 10.1109/TSTE.2017.2758378.

[58] I. Khan, "Energy - saving behaviour as a demand - side management strategy in the developing world : the case of Bangladesh," *Int. J. Energy Environ. Eng.*, no. 0123456789, 2019, doi: 10.1007/s40095-019-0302-3.

[59] A. Kumar, "Planning and implementation strategy of Demand Side Management in India," no. February, 2014, doi: 10.1109/ACES.2014.6808001.

[60] A. N. Al-enezi, "Demand side management (DSM) for efficient use of energy in the residential sector in Kuwait: analysis of options and priorities.," De Montfort University, Leicester, 2010.

[61] E. Insam, "Optimal Sizing of Stand-Alone Renewable Energy Systems for Electricity & Fresh Water Supply," Delft University of Technology, 2017.

[62] X.-S. Yang, "Introduction to Algorithms," *Nature-Inspired Optim. Algorithms*, pp. 1–21, 2014, doi: 10.1016/b978-0-12-416743-8.00001-4.

[63] I. Strnad and R. Prenc, "Optimal Sizing of Renewable Sources and Energy Storage in Low-Carbon Microgrid Nodes," *Electr. Eng.*, 2017, doi: 10.1007/s00202-017-0645-9.

[64] D. Metz and J. Tomé, "Use of battery storage systems for price arbitrage operations in the 15- and 60-min German intraday markets," *Electr. Power Syst. Res.*, vol. 160, pp. 27–36, 2018, doi: 10.1016/j.epsr.2018.01.020.

[65] Q. Zhang, W. Deng, and G. Li, "Stochastic Control of Predictive Power Management for Battery/Supercapacitor Hybrid Energy Storage Systems of Electric Vehicles," *IEEE Trans. Ind. Informatics*, vol. 3203, no. c, pp. 1–8, 2017, doi: 10.1109/TII.2017.2766095.

[66] M. Sellali, A. Betka, S. Abdedaim, and S. Ouchen, "Implementation of a Real-Time Energy Management Consisting of a Battery and a Supercapacitor," *5th Int. Conf. Electr. Eng.*, no. November, 2017.

[67] P. R. C. Mendes, M. Maestre, C. Bordons, and J. E. Normey-rico, "Binary Search Algorithm for Mixed Integer Optimization : Application to energy management in a microgrid," *Eur. Control Conf.*, pp. 2620–2625, 2016.

[68] A. Abazari, H. Monsef, and B. Wu, "Coordination strategies of distributed energy resources including FESS, DEG, FC and WTG in load frequency control (LFC) scheme of hybrid isolated micro-grid," *Int. J. Electr. Power Energy Syst.*, vol. 109, no. February, pp. 535–547, 2019, doi: 10.1016/j.ijepes.2019.02.029.

[69] W. Li, G. Zhang, L. Ai, G. Liu, Z. Gao, and H. Liu, "Characteristics Analysis at High Speed of Asynchronous Axial Magnetic Coupler for Superconducting Flywheel Energy Storage System," *IEEE Trans. Appl. Supercond.*, vol. 29, no. 5, pp. 1–5, 2019, doi: 10.1109/TASC.2019.2897827.

[70] J. Wang, G. Tang, and J. X. Huang, "Analysis and modelling of a novel hydrostatic energy conversion system for seabed cone penetration test rig," *Ocean Eng.*, vol. 169, no. April, pp. 177–186, 2018, doi: 10.1016/j.oceaneng.2018.09.035.

[71] B. Li, R. Roche, D. Paire, and A. Miraoui, "Sizing of a stand-alone microgrid considering electric power, cooling/heating, hydrogen loads and hydrogen storage degradation," *Appl. Energy*, vol. 205, no. September, pp. 1244–1259, 2017, doi: 10.1016/j.apenergy.2017.08.142.

[72] D. P. Loucks and E. van Beek, *Water resource systems planning and management: An introduction to methods, models, and applications*. 2017.

[73] M. A. Hossain, H. R. Pota, M. J. Hossain, and A. M. O. Haruni, "Active power management in a low-voltage islanded microgrid," *Int. J. Electr. Power Energy Syst.*, vol. 98, no. March 2017, pp. 36–47, 2018, doi: 10.1016/j.ijepes.2017.11.019.

[74] M. H. Yaghmaee, M. Moghaddassian, and A. Leon-Garcia, "Autonomous Two-Tier Cloud-Based Demand Side Management Approach with Microgrid," *IEEE Trans. Ind. Informatics*, vol. 13, no. 3, pp. 1109–1120, 2017, doi: 10.1109/TII.2016.2619070.

[75] E. Fernandez, M. J. Hossain, and M. S. H. Nizami, "Game-theoretic approach to demand-side energy management for a smart neighbourhood in Sydney incorporating renewable resources," *Appl. Energy*, vol. 232, no. October, pp. 245–257, 2018, doi: 10.1016/j.apenergy.2018.09.171.

[76] R. Pan, Z. Li, J. Cao, H. Zhang, and X. Xia, "Computers & Industrial Engineering Electrical load tracking scheduling of steel plants under time-of-use tariffs," *Comput. Ind. Eng.*, vol. 137, no. September, p. 106049, 2019, doi: 10.1016/j.cie.2019.106049.

[77] J. Liu and C. Zhong, "An economic evaluation of the coordination between electric vehicle storage and distributed renewable energy," *Energy*, vol. 186, p. 115821, 2019, doi: 10.1016/j.energy.2019.07.151.

[78] S. Rubaiee, S. Cinar, and M. B. Yildirim, "An Energy-Aware Multiobjective Optimization Framework to Minimize Total Tardiness and Energy Cost on a Single-Machine Nonpreemptive Scheduling," *IEEE Trans. Eng. Manag.*, vol. 66, no. 4, pp. 699–714, 2019, doi: 10.1109/TEM.2018.2846627.

[79] S. V. Oprea, A. Bâra, G. A. Ifrim, and L. Coroianu, "Computers & Industrial Engineering Day-ahead electricity consumption optimization algorithms for smart homes," *Comput. Ind. Eng.*, vol. 135, no. June, pp. 382–401, 2019, doi: 10.1016/j.cie.2019.06.023.

[80] S. Chen, Y. Liou, Y. Chen, and K. Wang, "Order Acceptance and Scheduling Problem with Carbon Emission Reduction and Electricity Tariffs on a Single Machine," pp. 1–16, doi: 10.3390/su11195432.

[81] S. Sukumar, H. Mokhlis, S. Mekhilef, K. Naidu, and

M. Karimi, “Mix-mode energy management strategy and battery sizing for economic operation of grid-tied microgrid,” *Energy*, vol. 118, pp. 1322–1333, 2017, doi: 10.1016/j.energy.2016.11.018.

[82] S. Mashayekh, M. Stadler, G. Cardoso, and M. Heleno, “A mixed integer linear programming approach for optimal DER portfolio, sizing, and placement in multi-energy microgrids,” *Appl. Energy*, vol. 187, pp. 154–168, 2017, doi: 10.1016/j.apenergy.2016.11.020.

[83] L. Fiorini, G. A. Pagani, P. Pelacchi, D. Poli, and M. Aiello, “Sizing and Siting of Large-Scale Batteries in Transmission Grids to Optimize the Use of Renewables,” *IEEE J. Emerg. Sel. Top. Circuits Syst.*, vol. 7, no. 2, pp. 285–294, 2017, doi: 10.1109/JETCAS.2017.2657795.

[84] C. R. Touretzky and M. Baldea, “With Energy Storage,” *J. Process Control*, vol. 33, no. 2, pp. 1824–1835, 2014, doi: 10.1016/j.jprocont.2014.04.015.

[85] P. Wolfs, K. Emami, Y. Lin, and E. Palmer, “Load forecasting for diurnal management of community battery systems,” *J. Mod. Power Syst. Clean Energy*, vol. 6, no. 2, pp. 215–222, 2018, doi: 10.1007/s40565-018-0392-6.