2021

Optimal Onsite Microgrid Design for Net-Zero Energy Operation in Manufacturing Industry

Md Monirul Islam

Mostafizur Rahman
The University of Texas Rio Grande Valley, mostafizur.rahman@utrgv.edu

Farzin Heidari

Vinayaka Gude

Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 185 (2021) 81–90

Procedia Computer Science

www.elsevier.com/locate/procedia

Complex Adaptive Systems Conference Theme: Big Data, IoT, and AI for a Smarter Future
Malvern, Pennsylvania, June 16-18, 2021

Optimal Onsite Microgrid Design for Net-Zero Energy Operation in Manufacturing Industry

Md Monirul Islam[a*], Mostafizur Rahman[b], Farzin Heidari[a], Vinayaka Gude[c]

[a]*Department of Industrial Management and Technology, Texas A&M University-Kingsville, Kingsville, TX-78363, USA*
[b]*Department of Electrical and Computer Engineering, University of Texas Rio Grande Valley, Edinburg, TX-78539, USA*
[c]*Department of Mass Communication, Louisiana State University-Shreveport, LA-71115, USA*

Abstract

Developing an economic net-zero energy infrastructure for the manufacturing industry can play a critical role to achieve the goal of affordable, reliable, and sustainable clean energy paradigm for the next generation. However, it is quite challenging to develop such an infrastructure due to the uncertain demand of the manufacturing system, intermittent electricity generation from the renewable sources, time of use (TOU) pricing of electricity, and integrated operational planning for the long-term planning horizon. In this paper, a mixed-integer non-linear programming (MINLP) model is developed to economically design an onsite microgrid system considering the critical conditions and achieve a net-zero energy operation planning for the manufacturing industry. A linearization strategy is adopted to obtain the optimal design of the microgrid and the utilization of the resources. A numerical case study is conducted to evaluate the effectiveness of the model.

Keywords: manufacturing industry; onsite microgrid design; net-zero energy operation; MINLP; linearization.

1. Introduction

Due to the increase of global population and economic development, the demand for energy across the world is constantly rising over the last few decades. Based on the projection of the Energy Information Administration (EIA), the world energy consumption will grow by nearly 50% between 2018 and 2050 [1]. Along with the increasing energy demand, there has been a growing global concern of energy-resource scarcity and climate change. However, fossil fuels are still the main sources of energy and it is accounted for 84% of the world's primary energy consumption in 2019 [2]. Burning fossil fuel generates carbon emission which is the major concern for global warming and climate

1877-0509
10.1016/j.procs.2021.05.009

change. To address the environmental concerns, rapid depletion of the fossil fuel sources, and the increasing cost of energy, an accelerated global effort towards a reliable renewable energy system is adopted in recent years [3].

The result of the endeavor demonstrated the fastest growth of renewable power additions into different areas in last few years [4]. However, sustainable integration of the renewable sources is quite challenging, and it has been widely studied in different sectors such as the residential areas [5], commercial buildings [6] [7], critical sectors [8], agriculture [9], etc. Still, it is less investigated for the manufacturing industry which is the largest energy consumer of all the end-users in the United States, accounting for 32.6 quads, or one-third of the total energy demand [10]. Therefore, it is crucial to develop sustainable and clean energy infrastructure for this sector with enhanced reliability, reduced emission profile, and lower cost of energy.

To build such an infrastructure for the manufacturing industry, the majority of the researches focused on the optimal designing of the microgrid structure and efficient energy management of the renewable sources either in grid-connected [11] [12] [13] or islanded [14] [15] mode. In an islanded mode, zero-carbon energy infrastructure can be achieved. However, the structure is still under investigation due to the concern of reliability and economic feasibility. Besides, in a grid-connected microgrid structure, the manufacturing industry has the flexibility to purchase the shortage of energy when the demand is high compared to the generation from the onsite microgrid and sell the excess energy to the grid. This configuration allows minimizing the fluctuation that occurred due to the intermittency of the renewable sources. However, the existing configuration is incapable of eliminating the carbon emission from the manufacturing industry completely nor establishing a carbon-neutral energy system.

Considering the large energy demand of the manufacturing industry, power quality and reliability of the system, and current climate change, it is essential to develop an advanced energy infrastructure for the sector to slash the greenhouse gas (GHG) emissions dramatically, neutralize environmental impact, and reduce the energy cost significantly. The concept of net-zero energy infrastructure can play a crucial role to achieve the goal in the future. It can be seen as one of the most popular and effective tools [16] [17] in the trend of achieving the zero-emission world.

The net-zero energy infrastructure does not mean that the generation from the renewable sources is equal to the electricity demand of the manufacturing industry. Instead, it means that the total amount of energy consumed by the industry on an annual basis is equal to or less than the amount of generated energy from the renewable sources (solar, wind, etc.). Therefore, the manufacturing industry will get the opportunity to be connected to the conventional grid and share the power for improving the quality and reliability of the energy system while achieving the net-zero energy operation for the system.

To develop such an infrastructure economic and sustainable, several critical factors such as the amount and variation of the energy demand in the manufacturing industry, availability and stochasticity of the renewable sources, operational & maintenance cost for the components of the microgrid system (solar PV, wind turbine, and BESS), and the integration of the design variables of the microgrid and operational planning of the system must be considered. Besides, the time-based electricity prices and corresponding demand response should be integrated to achieve an optimal design of the microgrid system in the long run. In this paper, an MINLP model is developed to identify the economic design of the onsite microgrid system for achieving a net-zero energy infrastructure in the manufacturing industry considering the critical conditions. As the planning horizon of the study is split into small interval of time (3 hours), therefore, the fine-grained variations of the energy demand and stochasticity of the renewable sources (solar irradiance and wind speed) can be captured successfully in this model. A linearization strategy is adopted to effectively solve the problem and determine the optimal value of the design variables to build the onsite microgrid system.

Rest of the paper is organized as follows. Section II introduces the proposed method. The linearization strategy is described in Section III. The case study is developed in Section IV. Section V discusses the results and critical findings. Finally, Section VI concludes the paper with future directions.

Nomenclature

Parameters

m	index of the month in a year
t	index of the interval
Δt	duration of the discretized interval
T_m	total number of intervals in month m

i	discount rate
IC_{PV}	investment cost per unit capacity of solar PV ($/kW)
IC_{WT}	investment cost per unit capacity of wind turbine ($/kW)
IC_{BESS}	investment cost per unit capacity of BESS ($/kW)
OMC_{PV}	rate of yearly operation & maintenance cost for solar PV system ($/kW)
OMC_{WT}	rate of yearly operation & maintenance cost for wind turbine system ($/kW)
OMC_{BESS}	rate of yearly operation & maintenance cost for BESS ($/kW)
CC_{tm}	electricity consumption charging rate ($/kWh) at interval t of month m
DC_m	distribution charging rate ($/kW) in month m
TC	transmission cost of the electricity for the year
SB_{tm}	sold back benefit rate ($/kW) at interval t of month m
MCC_{max}	maximum number of charging-discharging cycles of the BESS
LT	lifetime of the microgrid
CR	rate of capital recovery
SOC_{min}	minimum allowable charge of BESS (10% of total capacity)
SOC_{max}	maximum allowable charge of BESS (90% of total capacity)
ChP_{eff}	charging efficiency of BESS
$DisP_{eff}$	discharging efficiency of BESS
Eff_{PV}	efficiency of solar system
Eff_{WT}	efficiency of solar system
PC	power coefficient of the wind turbine
d_{air}	density of air
IR_{avg}	average irradiance of solar energy (W/m^2)
IR_{tm}	irradiance of solar energy (W/m^2) at interval t of month m
V_{tm}	wind speed (m/s) at interval t of month m
V_{avg}	average wind speed (m/s)
MCC_{max}	maximum number of charging-discharging cycles of the BESS
$MT_{char/dischar}$	minimum time required to fully charge or discharge the BESS
RC_{PV}	rated capacity of solar PV
RC_{WT}	rated capacity of wind turbine
LN	Large number
Decision Variables	
PV_{size}	Size of the solar PV (m^2)
WT_{number}	Number of Wind Turbine
$BESS_{size}$	Size of the battery energy storage system (kW)
GP_{tm}	power purchased from grid at interval t of month m
SP_{tm}	Power sold back to the grid at interval t of month m
ChP_{tm}	Charging power at interval t of month m
$DisP_{tm}$	discharging power at interval t of month m
AV^1_{tm} and AV^2_{tm}	auxiliary binary variable
CV_{tm}	auxiliary continuous variable

2. Proposed Method

The goal of the formulation is to economically design an onsite microgrid system to meet the electricity demand of the manufacturing industry while obtaining a net-zero carbon-energy infrastructure for the facility. Therefore, the model objective is to minimize the total energy-related cost of the system consisted of the cost of grid energy, investment cost for the renewable sources, and their operations and maintenance cost.

The model is formulated as follows:

Minimize:

$$f(PV_{size}, WT_{number}, BESS_{size}, GP_{tm}, SP_{tm}, ChP_{tm}, DisP_{tm}) = YC_E + YC_{PV} + YC_{WT} + YC_{BESS} - B_{SE} \quad (1)$$

$$YC_E = \sum_{m=1}^{m=12} \sum_{t=1}^{T_m} GP_{tm} \times CC_{tm} \times \Delta t + \sum_{m=1}^{12} DC_m \times \max_t GP_{tm} + TC \times \max_{m \epsilon \{6,7,8,9\}} (\max_t GP_{tm}) \quad (2)$$

$$YC_{PV} = (IC_{PV} \times CR + OMC_{PV}) \times RC_{PV} \quad (3)$$

$$YC_{WT} = IC_{WT} \times RC_{WT} \times CR + RC_{WT} \times OMC_{WT} \quad (4)$$

$$YC_{BESS} = IC_{BESS} \times BESS_{size} \times (CR + OMC_{BESS}) \quad (5)$$

$$B_{SE} = \sum_{m=1}^{m=12} \sum_{t=1}^{T_m} SP_{tm} \times SB_{tm} \times \Delta t \quad (6)$$

Subject to:

$$GP_{tm} + PVP_{tm} + WTP_{tm} + DisP_{tm} = PDM_{tm} + SP_{tm} + ChP_{tm} \quad (7)$$

$$SOC_{min} \leq SOC_{tm} + ChP_{tm} \times ChP_{eff} \times \Delta t - DisP_{tm} \times DisP_{eff} \times \Delta t \leq SOC_{max} \quad (8)$$

$$ChP_{tm} \leq \frac{BESS_{size}}{MT_{char/dischar}} \quad (9)$$

$$DisP_{tm} \leq \frac{BESS_{size}}{MT_{char/dischar}} \quad (10)$$

$$\sum_{m=1}^{m=12} \sum_{t=1}^{T_m} \left(\frac{(ChP_{tm} + DisP_{tm}) \times \Delta t}{2 \times BESS_{size} \times (SOC_{max} - SOC_{min})}\right) \leq \frac{MCC_{max}}{LT} \quad (11)$$

$$YC_E + YC_{PV} + YC_{WT} + YC_{BESS} - B_{SE} \leq TC_{\acute{O}G} \quad (12)$$

$$ChP_{tm} \times DisP_{tm} = 0 \quad (13)$$

$$GP_{tm} \times SP_{tm} = 0 \quad (14)$$

$$\sum_{m=1}^{m=12} \sum_{t=1}^{T_m} GP_{tm} \times \Delta t = \sum_{m=1}^{m=12} \sum_{t=1}^{T_m} SP_{tm} \times \Delta t \quad (15)$$

The variables introduced in the formulation are related to the designing of the onsite microgrid and controlling the energy operation of the system. WT_{number}, PV_{size}, and $BESS_{size}$ are the decision variables for determining the capacity of wind turbine, solar PV, and BESS, respectively, while GP_{tm}, SP_{tm}, ChP_{tm}, and $DisP_{tm}$ are the decision variables for controlling the energy management of the system optimally.

The objective function (1) determines total energy-related cost: electricity billing cost due to the purchase of electricity from the grid, depreciation and operational & maintenance cost for the components (solar PV, wind turbine, and BESS) of the microgrid, and finally, the income due to the selling of excess electricity back to the grid.

Since the optimization problem reflects system operation over one year, the equivalent annual cost of each component has been obtained. The electricity billing cost in the objective function is calculated based on the three different terms shown in Equation (2): electricity consumption cost, distribution tariffs, and transmission utility tariffs. The electricity consumption cost is determined by the total energy consumed throughout the year and the rate of electricity at each period of the year. The distribution tariff is computed based on the highest demand of the power in the intervals during a billing cycle (i.e., month). The transmission utility tariff is determined based on the four-month (June, July, August, and September) coincident peak demand.

Annual depreciation and operation & maintenance costs for the solar PV are calculated by Equation (3). The total cost will depend on the initial investment cost for the unit capacity, capital recovery ($CR = \frac{i\times(1+i)^N}{(1+i)^N-1}$), unit operational & maintenance cost, and rated capacity of solar PV. The rated capacity of the solar PV ($RC_{PV} = \frac{PV_{size}\times IR_{avg}\times Eff_{PV}}{1000}$) can be computed by the size of the solar PV determined by the mathematical model, average solar irradiance in that particular area, and efficiency of the solar panel.

Similarly, the annual depreciation and operation & maintenance costs for the wind turbine and BESS are determined by Equation (4) and Equation (5), respectively. The rated capacity of the wind turbine ($RC_{WT} = \frac{\frac{1}{2}\times d_{air}\times\Pi\times R^2\times V_{ang}^3\times PC\times Eff_{WT}\times WT_{number}}{1000}$) depends on the number of wind turbines determined by the model, its radius, average wind speed, density of the air, power coefficient, and efficiency of the wind turbine. The sold back benefit is calculated by Equation (6) where the benefit depends on the amount of excess energy sold back to the grid at different intervals of the year and the corresponding rate of the sold back price during that interval.

The model involves nine different types of constraints. The first constraint (Equation (7)) represents the energy balance for the system which states that the rate of energy inflow is equal to the outflow. The power generated by the solar PV ($PVP_{tm} = \frac{PV_{size}\times IR_{tm}\times Eff_{PV}}{1000}$) and wind turbine ($RC_{WT} = \frac{\frac{1}{2}\times d_{air}\times\Pi\times R^2\times V_{tm}^3\times PC\times Eff_{WT}\times WT_{number}}{1000}$) at any particular period depend on their corresponding size and available renewable sources at that particular period. The second constraint (Equation (8)) bounds the state of charge of the BESS at any interval within the recommended limit. The maximum allowable charging and discharging rate are controlled by the third and fourth constraints (Equation (9) and Equation (10)). The fifth constraint (Equation (11)) restricts the total number of yearly charging /discharging cycles within the bounded limits. The sixth constraint (Equation (12)) ensures the economic feasibility of installing an onsite microgrid system. The seventh constraint (Equation (13)) will restrict the simultaneous charging and discharging while the eighth constraint (Equation (14)) will limit the simultaneous selling and purchasing opportunities. The final constraint (Equation (15)) will establish the net-zero energy framework for the system.

3. Linearization Strategy

The model formulated in the previous section is an MINLP problem. It has non-linearity in both objective function (max operator) and constraints (Equation (13) and Equation (14)). In this model, the variables related to the designing of the microgrid system are discrete while the control variables are continuous. It is quite challenging to solve such an MINLP problem due to the existence of multiple local minima. Moreover, the commercially available MINLP solvers are not able to find optimal solution for small-sized problem in reasonable computational time. Therefore, considering the dimensionality and complexity of the problem, the linearization strategy is adopted in this section to find an optimal solution at a reasonable computational time. The linearization strategy is described as follows.

The max operators used to calculate the electricity billing cost in the objective function are linearized by introducing new variables and the following conditions.

$$YC_E = \sum_{m=1}^{m=12} \sum_{t=1}^{T_m} GP_{tm} \times CC_{tm} \times \Delta t + \sum_{m=1}^{12} DC_m \times A_m + TC \times B \quad (16)$$

$$A_m \geq GP_{tm} \quad (17)$$

$$B \geq A_m, m \epsilon \{6,7,8,9\} \quad (18)$$

The product of the two continuous variables in Equation (13) is linearized by the following Equations.

$$ChP_{tm} \leq AV_{tm}^1 \times (\frac{BESS_{size}}{MT_{char/dischar}}) \quad (19)$$

$$ChP_{tm} \leq (1 - AV_{tm}^1) \times (\frac{BESS_{size}}{MT_{char/dischar}}) \quad (20)$$

$$CV_{tm} = AV_{tm}^1 \times BESS_{size} \quad (21)$$

$$CV_{tm} \leq LN \times AV_{tm}^1 \quad (22)$$

$$CV_{tm} \leq BESS_{size} - (1 - AV_{tm}^1) \times LN \quad (23)$$

$$CV_{tm} \geq 0 \quad (24)$$

Similarly, the constraint in Equation (14) is linearized by-

$$GP_{tm} \leq AV_{tm}^2 \times LN \quad (25)$$

$$SP_{tm} \leq (1 - AV_{tm}^2) \times LN \quad (26)$$

4. Case Study

Considering the stochasticity of the energy demand, weather pattern, and dimensional complexity, the temporal horizon selected for the case study is one year and the resolution is 3 hours. The power demand profile obtained from a real auto manufacturing facility is utilized as the power demand requirement for the study shown in Fig. 1.

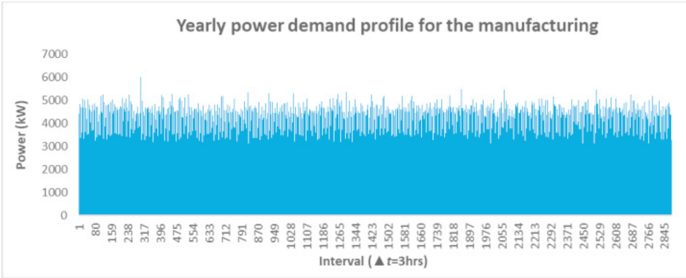

Fig. 1: Power demand profile of the manufacturing industry

Table 1. Electricity billing rate

Season	Period	Energy charge rate ($/kWh)	Distribution charge rate	Transmission charge rate	Metering charge
Summer	peak	0.15	3.5	2.23	63.07
	Off-peak	0.18			
Winter	peak	0.13	3.5		
	Off-peak	0.18			
Spring	peak	0.11	3.5		
	Off-peak	0.18			

Table 2. Sold back price rate

Season	Period	Sold back rate ($/kWh)
Summer	peak	0.05
	Off-peak	0.02
Winter	peak	0.05
	Off-peak	0.02
Spring	peak	0.05
	Off-peak	0.02

Yearly solar irradiance and wind speed profile are shown in Fig. 2. (a) and Fig. 2. (b), respectively. The efficiency for the solar PV is considered as 27% [18]. The parameters used to determine the wind turbine power generation are shown in Table 3. The charging/discharging efficiency for the BESS is 90% [19]. The maximum and minimum allowable state of charge for the BESS is set as 90% and 10%, respectively. The investment cost and operation & maintenance cost for the unit capacity of the solar PV, wind turbine, and BESS are listed in Table 4.

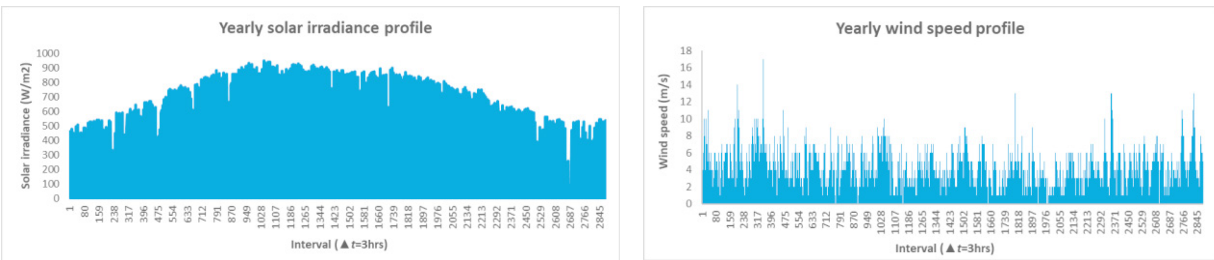

Fig. 2. (a) Yearly solar irradiance profile; (b) Yearly wind speed profile.

Table 3. Parameters used for wind turbine power generation[1]

Parameters	Value
Density of air (d_{air})	1.225 (kg/m3)
Power coefficient of the wind turbine (PC))	0.593
Efficiency of the wind turbine (Eff_{WT}))	40%

1. Wind Turbine Power Calculations, The Royal Academy of Engineering.

Table 4. Investment and operation & maintenance cost for the hybrid onsite generation system with BESS

Components of the System	Investment cost ($/kW)	Operation & maintenance cost ($/kW)
Solar PV[1]	2100	7.5
Wind Turbine[2]	2600	28
BESS[3]	150	1% of investment

1. U.S. Photovoltaic prices and cost breakdown, 2015. 2. Wind Technologies Market Report, 2016 3. Battery Energy Storage Market, 2016

5. Result Analysis:

The proposed model is coded in Jupyter Notebook platform containing GUROBI solver running on an Intel(R) Core (TM) i5 processor. The current model has a total of 23,056 mixed-integer decision variables and 43,210 constraints. The computational time required to solve the problem is 15,211 seconds. The design parameters and corresponding economic benefit of establishing the onsite microgrid system for achieving the net-zero energy infrastructure in the manufacturing industry are illustrated in Table 5.

Table 5. Design parameters and corresponding economic benefit of establishing the onsite microgrid system

Design Variables	Value
Area of Solar PV (PV_{size})	13,282 m^2
Number of Wind Turbine (WT_{number})	6
Size of the BESS ($BESS_{size}$)	3,507 kW
Yearly electricity cost without the onsite microgrid ($)	3,336,699.17
Yearly electricity cost with the microgrid while obtaining net-zero infrastructure ($)	3,056,972.09
Profit (%)	8.38%

It can be mentioned from the analysis that the yearly electricity cost after installing the onsite microgrid system is much lower than the electricity cost without the onsite microgrid system. About 8.8% of the total energy cost can be reduced by optimally designing the onsite microgrid system and effectively controlling the energy management plan.

As the energy demand of a manufacturing industry is more uncertain compared to the average variation of the renewable sources from year to year, the model is further investigated to identify the sensitivity of the energy demand on design parameters of the onsite microgrid and economic benefit of establishing the system. The energy demand variation is considered for the study is 5%. The design parameters and corresponding economic benefit of installing the onsite microgrid system considering the energy demand variation are presented in the Table 6.

Table 6. Design parameters and corresponding economic benefit of establishing onsite microgrid system considering the energy demand variation

Scenario	Low energy demand (5% reduced)	High energy demand (5% increased)
Area of Solar PV (PV_{size})	17,629 m^2	16,017
Number of Wind Turbine (WT_{number})	5	6
Size of the BESS ($BESS_{size}$)	3,102 kW	2811 kW
Yearly electricity cost without the onsite microgrid ($)	3,169,834	3,503,530
Yearly electricity cost with the microgrid while obtaining net-zero infrastructure ($)	2,907,384	3,187,310
Profit (%)	8.1%	9.02%

From the analysis, it can be seen that the design parameters of the onsite microgrid system (area of solar PV, number of wind turbine, and capacity of BESS) are quite sensitive with the variation of the energy demand. Therefore, it is required to determine the overall variation of the energy demand in the manufacturing industry and integrate the variation into the model to identify the optimal design and energy management of the microgrid system. Besides, it can be mentioned that the installation of the onsite microgrid for such a manufacturing industry is quite profitable regardless of the small variation of the energy demand. Particularly, the industry with higher energy demand has more opportunity to achieve a profitable and clean energy infrastructure though establishing such an microgrid architecture.

6. Conclusion and Future Works:

In this paper, an MINLP model is proposed to economically design an onsite microgrid system and optimally control the energy operation planning for achieving a net-zero infrastructure in the manufacturing industry. The proposed method will help to advance the decarbonization endeavor in the area of manufacturing industry. To avoid the complexity of the model, the reliability of the microgrid components (solar PV system, Wind turbine, and BESS) is not considered in this study. It is one of the major limitations of the study. Besides, the BESS degradation and power quality are not considered in this model. Therefore, the future research will focus on the integration of the reliability aspect of the microgrid components, power quality, and BESS degradation into the model to optimally design the microgrid system. In addition, the energy management of the infrastructure will be extended at the machine level to develop an optimal control strategy for effective load shifting and demand reduction according to the generation of the onsite microgrid system.

References

[1] Kahan, Ari (2020). "Today In Energy." *EIA*. https://www.eia.gov/todayinenergy/detail.php?id=42342#:~:text=Energy%20consumed%20in%20the%20buildings,to%20rising%20demand%20for%20energy

[2] Jackson, Robert B., Corinne Le Quéré, R. M. Andrew, Josep G. Canadell, Jan Ivar Korsbakken, Zhu Liu, Glen P. Peters, and Bo Zheng. (2018) "Global energy growth is outpacing decarbonization." *Environmental Research Letters*, ***13***(**12**), 120401.

[3] Gielen, Dolf, Francisco Boshell, Deger Saygin, Morgan D. Bazilian, Nicholas Wagner, and Ricardo Gorini. (2019) "The role of renewable energy in the global energy transformation." *Energy Strategy Reviews*, *24*, 38-50.

[4] Quadrelli, Roberta. (2020). "Where are we with renewable energy?" *International Energy Agency*. https://unece.org/fileadmin/DAM/energy/se/pp/gere/GERE.6_Oct.2019/1_StatusRE/1_R.Quadrelli_IEA_6thGERE.pdf

[5] Parhizi, Sina, Hossein Lotfi, Amin Khodaei, and Shay Bahramirad. (2015) "State of the art in research on microgrids: A review." *IEEE Access* 3, 890-925.

[6] Raza, Aamir, and Tahir Nadeem Malik. (2019) "Energy management in commercial building microgrids." *Journal of Renewable and Sustainable Energy*, ***11***(**1**), 015502.

[7] Jin, Xiaolong, Jianzhong Wu, Yunfei Mu, Mingshen Wang, Xiandong Xu, and Hongjie Jia. (2017) "Hierarchical microgrid energy management in an office building." *Applied Energy*, *208*, 480-494.

[8] Kumar, Arun, Ashu Verma, and Rajbans Talwar. 2020) "Optimal techno-economic sizing of a multi-generation microgrid system with reduced dependency on grid for critical health-care, educational and industrial facilities." *Energy,* 208: 118248.

[9] Ghasemi, Ahmad. (2018) "Coordination of pumped-storage unit and irrigation system with intermittent wind generation for intelligent energy management of an agricultural microgrid." *Energy*, *142*, 1-13.

[10] Liu, Yuning and McMillan, Colin (2020). 2018 Industrial Energy Data Book. *U.S. Department of Energy*. https://www.nrel.gov/docs/fy20osti/73901.pdf

[11] Islam, Md Monirul, and Zeyi Sun. (2019) "Onsite generation system sizing for manufacturing plant considering renewable sources towards sustainability." *Sustainable Energy Technologies and Assessments*, *32*, pp.1-18.

[12] Zhang, Yunchao, Md Monirul Islam, Zeyi Sun, Sijia Yang, Cihan Dagli, and Haoyi Xiong. (2018) "Optimal sizing and planning of onsite generation system for manufacturing in Critical Peaking Pricing demand response program." *International Journal of Production Economics*, *206*, 261-267.

[13] Islam, Md Monirul, Xiao Zhong, Haoyi Xiong, and Zeyi Sun. (2018) "Optimal scheduling of manufacturing and onsite generation systems in over-generation mitigation-oriented electricity demand response program." *Computers & Industrial Engineering*, *115*, 381-388.

[14] Roy, Tushar Kanti, and Md Apel Mahmud. (2017) "Dynamic stability analysis of hybrid islanded DC microgrids using a nonlinear backstepping approach." *IEEE Systems Journal*, ***12*****(4)**, 3120-3130.

[15] Marzband, Mousa, Fatemeh Azarinejadian, Mehdi Savaghebi, and Josep M. Guerrero. (2015) "An optimal energy management system for islanded microgrids based on multiperiod artificial bee colony combined with Markov chain." *IEEE Systems Journal*, ***11*****(3)**, 1712-1722.

[16] Voss, Karsten, Eike Musall, and Markus Lichtmeß. (2011) "From low-energy to Net Zero-Energy Buildings: status and perspectives." *Journal of Green building*, ***6*****(1)**, 46-57.

[17] Torcellini, Paul, Shanti Pless, Michael Deru, and Drury Crawley. (2006) "*Zero energy buildings: a critical look at the definition*." No. NREL/CP-550-39833., National Renewable Energy Lab (NREL), Golden, CO (United States).

[18] Hill, Cody, and Dongmei Chen. (2011) "Development of a real-time testing environment for battery energy storage systems in renewable energy applications." *2011 IEEE Power and Energy Society General Meeting*, 1-8. IEEE.

[19] Newnham, R. H., and W. G. A. Baldsing. (2004) "Advanced management strategies for remote-area power-supply systems." *Journal of Power Sources*, ***133*****(1)**, 141-146.