Paper ID:32

Designing and Comparing Microgrid System for Remote Islands of Western Bay of Bengal: Analyzed and Optimized by HOMER

Asikur Rahman[1], Jaber Rasul[1]
[1]Depertment of Mechanical Engineering, Rajshahi University of Engineering & Technology
E-mail: asikur919@gmail.com, raselruetme19@gmail.com,

Abstract

Electrical power supply in remote regions is difficult as those areas are far from the mainland and not directly connected to the mainland's national power grid. The southern border of Bangladesh is the Bay of Bengal which contains several remote islands in three directions east, north, and west. Electric power supply to those regions is very difficult. So, a hybrid power microgrid system developed using renewable energy sources can solve power supply and maintenance. In this paper, a comparison is made between several islands of the western Bay of Bengal to find the most economical and cost-effective hybrid energy microgrid system. The microgrid system is designed for 1300 houses, and 15 hotels each having 200 rooms,2 schools,1 clinic, 120 shops, and 1 mosque. HOMER software is used here for designing and analyzing architectures. In those systems, the average load(scaled) is 165.59 KWh/day and the peak load (scaled) is 32.62 KW. The load factor is considered 0.22 with an AC-type load. After analyzing the COE and NPC for each island, the best hybrid energy microgrid system is determined.

Keywords: microgrid, renewable energy, HOMER (Hybrid Optimization Model for Multiple Energy Resources), COE (Cost of Energy), NPC (Net Present Cost).

1. Introduction

Due to the high energy demand, non-renewable energy resources are being widely used for the production of electricity. Coal, fossil fuel, and oil are the most common sources of nonrenewable energy [1], [2]. Those are the main sources of global energy. The amount is nearly 70% to 80%[3] Near future the reserved coal under the deep ground will be finished [4]. If the consumption rate goes at the same rate coal, oil, and natural gas will not sustain more than respectively 122 years,42 years, and 60 years [5]. using nonrenewable energy for energy production mainly causes an emission of greenhouse gases (GHGs). Among them, carbon dioxide has a fluctuating concentration and its emissions increased up to 57.5% since 1990[3]. Now the earth is facing global warming and the climate is changing gradually [6]. In this situation, renewable green energy use for energy production like electricity can be an appropriate solution. It is accepted as an alternative to fossil fuels [7]. Solar energy, wind energy, Biomass, biogas, and hydroelectricity are the main resources of renewable energy and those are also available in Bangladesh [8]. Renewable energy can help to meet the electricity and energy demand. Renewable energy resources are environment-friendly because they are free from carbon emissions [9]. Bangladesh is a small country in South Asia having an area of 1,47,570 sq. km with 170 million inhabitants [10]. 32% area of the whole country is coastal zone and the population is approximately 35 million which is 29% of the total population [11]. coastal regions are segmented into several large and small islands. Western Bay of Bengal contains Ashar char, Andar char, Char Hare, Char Lakhsmi, Char Manika, Char Mantaz, Rangabali, Dublar char, Burir char, Pakhkhir char, Dimer char, Char Bagala. In the Northern Bay of Bengal Bhola Island, Ballar Char, Char Faizuddin, Char Gazi, Dal Char, Char Kukri Mukri, Char Nizam, Manpura Island, Hatiya, Swarna Dweep, Urirchar and in the Eastern Bay of Bengal St. Martin's Island, chhera island, Jaliadwip, Maheshkhali island, Sonadia island are most common [12], [13]. As the islands are separated from the mainland power generation and distribution are not traditionally possible [4]. Higher capital costs, maintenance, and supply problems, situated long distances from the mainland make it more difficult to supply electricity without traditional grid networks. So, a microgrid using a hybrid renewable energy system (HERS) could be a solution for remote areas [14]. Microgrids are the type of technology that helps to fulfill global energy demand and it consist of different elements like energy distributed systems, energy storage systems, and integrated loads [15]. HERS provides some benefits like cost analysis, levelized cost of energy (LCOE), and management. so, HERS can be considered as a suitable method for providing electric power by analyzing exclusive features like minimum cost of energy (COE), low emission with less harmfulness, and power supply with maintenance in a remote off-grid island [16]. For a hybrid energy model in a

remote area renewable energy resources could be used by implementing solar photovoltaics, wind turbines, biogas plants, hydrokinetic, tidal energy, and for maintenance batteries, converters, and generators [17]. A computer simulation software named HOMER is used for designing the best possible architecture for hybrid energy systems which include wind turbines, solar PV, generators, biogas plants, converters, and batteries [18]. A diesel generator can be used for backup power supply at night time. several studies have already done on hybrid power systems in a remote island of Bangladesh. However, finding the best island with having most economical and cost-effective hybrid power system in the region of the western Bay of Bangla has not been done so far. so, the main objective of this paper is to compare the minimum CEO and NPC for several islands of the western Bay of Bangla to determine the most economical and suitable region to implement a hybrid energy system and find the best possible architecture of hybrid energy power system for each region by HOMER optimizer.
This paper contains 6 parts. section 2 describes the required methodology and load calculation, section 3 describes the components used for hybrid energy and the proposed system architecture, and Section 4 describes the HOMER optimization results. Section 5 discusses the comparisons between those islands and result analysis with discussion part and section 6 covers the conclusion part.

2. Methodology and Electric load analysis

To design a micro-grid system for any region HOMER software is one of the best possible solutions. HOMER software uses resources from NASA Prediction of Worldwide Resource (POWER) or the National Renewable Energy Laboratory to calculate the characteristics of wind speed, solar radiation, and others. Fig. 1. shows the flow diagram of the proposed methodology to find the best possible architecture for each island.

2.1 Load Calculation

Lights, fans, and television are basic primary loads for a family. In a community, people live in a house that contains a domestic load. A community living on an island also has local shops, schools, clinics, mosques, and more importantly hotels for tourists. Usually, tourists visit those islands between November to March or sometime in April [19]. The load consumption during summer and winter will be different from winter. In this paper load consumption is calculated for 1300 houses,15 hotels each having 200 rooms,2 schools,1 clinic, 120 shops, and 1 mosque. This type of number is chosen by considering a permanent residual of locals and a growing industry of tourism. Table 1. Shows the required load consumption for a single house, single room of hotel,1 clinic,1 school,1 shop, and mosque. Usually, the average electric capacity for LED lights, fans, and television is respectively 30 W,40 W, and 80 W [4].

3. Components used for hybrid energy and the proposed system architecture

3.1 Potential Green energy sources and components

Due to its geographical location, the island of Western Bay of Bengal has a good source of solar energy and wind energy. Those are the main sources of green energy. Homer software used the geographical location to take information about solar radiation, annual clearness index, wind information, wind speed, and overall information about temperature from NASA (National Aeronautics and Space Administration). To use that energy solar PV cells and Wind turbines can be installed. For backup sources of energy batteries and diesel generators can be considered. To convert DC power to AC power a converter is needed. Those are the potential components required for the microgrid system.

3.2 Solar PV modules, Wind Turbine and Battery

In the Architecture Generic PV module is considered. Its capacity is 1KW. Generic 3KW wind turbine is being considered with a lifetime of 20 years. Hoppecke 8 OPzS storage battery is being used for the arrangement. Table 2 shows the technical details of the battery and technical details like capital cost, Replacement cost, O & M cost of PV solar modules [20] and shows the technical details of wind turbine [21].

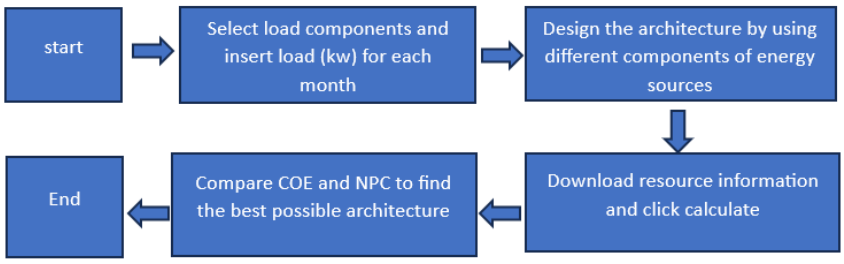


Fig.1. Flow diagram of methodology

Table. 1. Electric load calculation

Place	Appliance	Number	Capacity (Kw)	Operation Hours		Loads in (Kw)	Kwh Per Day	
				Summer	Winter		Summer	Winter
House	Light	3	30	6	9	.09	0.54	0.81
	Fan	3	40	18	2	.12	2.15	0.24
	TV	1	80	5	5	.08	0.4	0.4
	Total			29	16	.29	3.09	1.45
Shop	Light	2	30	8	10	.06	0.48	0.6
	Fan	2	40	14	2	.08	1.12	0.16
	Total			22	12	0.14	1.6	0.76
School	Light	30	30	3	5	0.9	2.7	4.5
	Fan	30	40	6	2	1.2	7.2	2.4
	Total			9	7	2.1	9.9	6.9
Clinic	Light	20	30	18	24	0.6	10.8	14.4
	Fan	30	40	24	2	1.2	28.8	2.4
	Fridge	3	75	24	24	.225	5.4	5.4
	Total			48	26	2.025	45	22.2
Hotel (Single Room)	Light	2	30	6	8	0.06	0.36	0.48
	Fan	1	40	10	2	0.04	0.4	0.08
	TV	1	80	4	4	0.08	0.32	0.32
	Total			20	14	0.18	1	0.88
Mosque or Temple	Light	10	30	1	2	0.3	0.3	0.6
	Fan	10	40	3	1	0.4	1.2	0.4
	Total			4	3	0.7	1.5	1
Total				132	78	5.435	62.09	33.19

Table. 2. Technical details of solar PV, battery and wind turbine

Description	PV	Battery	Wind Turbine
Capital Cost	$800	$87.5	$7500
Replacement Cost	$800	$75	$5625
O & M cost	$10/year	10$/year	125$/year
Lifetime	25 years	20	20
Derating factor	90%	N/A	N/A
Tracking system	NO	N/A	N/A
Rated Power	24	20	3 KW
Starting Wind Speed	43	53	4 m/s
Rated Wind Speed	3	11	13 m/s
cut-off Wind Speed	9	4	15 m/s
Nominal Voltage	998	2 volts	90
Nominal capacity	N/A	1.92 kWh	N/A
Minimum state of charge	N/A	86%	N/A
Maximum charge current	N/A	162 A	N/A

3.3 Power converter and Diesel generator

1 KW capacity Generic large, free converter is used in the architecture. Its technical details are capital cost $800, Replacement cost $600, O &M cost $5/year, efficiency 90%, Lifetime 15 years. For generator section 1KW Genset is being used with a specification of rated power 1KW, lifetime 15000h, minimum load ratio is 25%, fuel type diesel and capital cost $400 with a replacement cost of $300.O&M cost $0.25/hour, and fuel cost of $.24/L. [21]

3.4 System Architecture

A hybrid energy renewable system consists of different components like a wind turbine, solar PV panel, generator, electric load, boiler, Hydro plant, and converter. Fig. 2. shows the schematic architecture of a hybrid energy renewable system for this experiment.

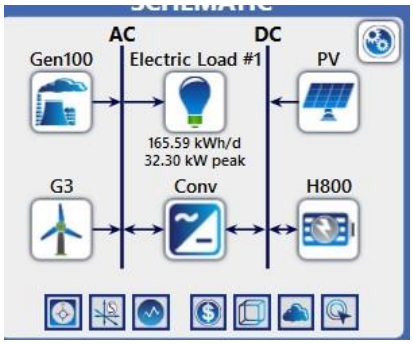


Fig.2. Complete hybrid energy renewable system

Architecture												Cost			
					PV (kW)	G3	Gen100 (kW)	H800 (#)	Conv (kW)	Efficiency1	Dispatch	NPC ($)	LCOE ($/kWh)	Operating cost ($/yr)	CAPEX ($)
					108	4		310	31.6	0	CC	$245,615	$0.315	$5,936	$168,880

Fig.3. Optimization result for Andar Char

Architecture												Cost			
					PV (kW)	G3	Gen100 (kW)	H800 (#)	Conv (kW)	Efficiency1	Dispatch	NPC ($)	LCOE ($/kWh)	Operating cost ($/yr)	CAPEX ($)
					91.4	3		360	27.3	0	CC	$225,661	$0.289	$5,934	$148,951

Fig.4. Optimization result for Char Kasem

Architecture												Cost			
					PV (kW)	G3	Gen100 (kW)	H800 (#)	Conv (kW)	Efficiency1	Dispatch	NPC ($)	LCOE ($/kWh)	Operating cost ($/yr)	CAPEX ($)
					97.6	3		320	27.8	0	CC	$223,567	$0.286	$5,631	$150,769

Fig.5. Optimization result for Char Mantaz

Architecture												Cost			
					PV (kW)	G3	Gen100 (kW)	H800 (#)	Conv (kW)	Efficiency1	Dispatch	NPC ($)	LCOE ($/kWh)	Operating cost ($/yr)	CAPEX ($)
					98.2	3		348	29.4	0	CC	$231,510	$0.296	$5,916	$155,029

Fig.6. Optimization result for Dublar Char

Architecture												Cost			
					PV (kW)	G3	Gen100 (kW)	H800 (#)	Conv (kW)	Efficiency1	Dispatch	NPC ($)	LCOE ($/kWh)	Operating cost ($/yr)	CAPEX ($)
					104	2		354	28.6	0	CC	$227,056	$0.291	$5,832	$151,663

Fig. 7. Optimization result for Nijhum Dwip

Architecture												Cost			
					PV (kW)	G3	Gen100 (kW)	H800 (#)	Conv (kW)	Efficiency1	Dispatch	NPC ($)	LCOE ($/kWh)	Operating cost ($/yr)	CAPEX ($)
					60.9	3	100	260	28.9	0	LF	$238,516	$0.305	$6,299	$157,086

Fig. 8. Optimization result for Nilgonj Dwip

Architecture												Cost			
					PV (kW)	G3	Gen100 (kW)	H800 (#)	Conv (kW)	Efficiency1	Dispatch	NPC ($)	LCOE ($/kWh)	Operating cost ($/yr)	CAPEX ($)
					91.4	3		360	27.3	0	CC	$225,661	$0.289	$5,934	$148,951

Fig. 9. Optimization result for Rangabali Dwip

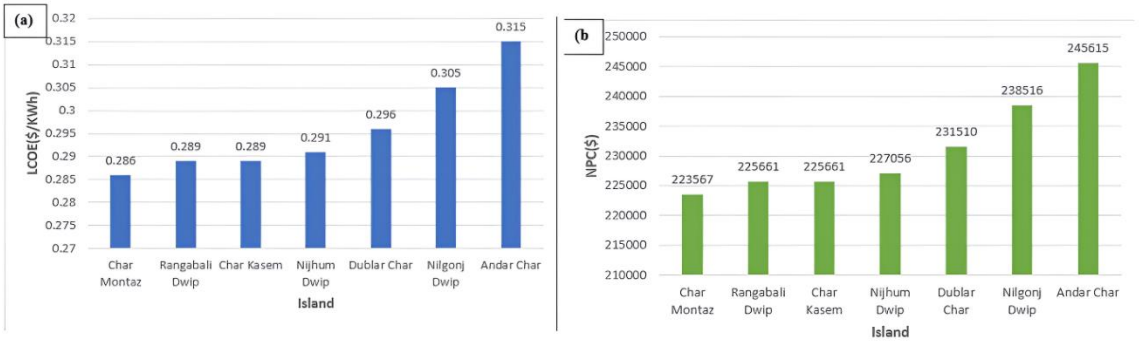


Fig. 10. Comparison of different islands (a)LCOE of different islands. (b) NPC of different islands

4. HOMER optimization results

About 14000 simulations were done by Homer software. After these thousands of simulations, HOMER software came up with an optimized solution to find out the best possible architecture for an island. Those architectures are selected by using different values of solar radiation, wind speed, temperature, and other parameters. The list of architecture is made by considering the descending order of lowest COE, NPC, and operating cost.

From Fig. 3. to Fig. 9. shows the HOMER optimization result of some islands situated in the western Bay of Bengal. Those islands are Andar char, char Kasem, Char Montaz, Dublar char, Nijhum Dwip, Nilgonj Dwip, and Rangabali Dwip respectively. Among those islands, Andar Char, Rangabali Dwip, Char Kasem, Nilgonj Dwip, and Char Montaz are situated in Patuakhali District. Dublar Char and Nijhum Dwip are situated in Bagerhat District and Noakhali District respectively. As those districts are located near sources of renewable energy have the same value and parameter

5. Result analysis

By using, the economical Optimization result of HOMER software, it shows that the Char Montaz has the lowest LCOE, NPC, and operating cost which are respectively 0.286 USD/KWh, 223567USD and 5631USD/yr. Andar Char has the highest LCOE of 0.315 USD/KWh, NPC of 245615 USD, and 5936 USD/year. For better understanding, Fig. 10(a) shows the comparison of LCOE of different islands of the western Bay of Bengal. And fig. 10(b) shows the NPC of different islands.

In the optimization result of HOMER software, the best architecture having the lowest NPC and LCOE contains Solar PV plates, Wind turbines, Hoppecke 8 OPzS storage battery, and a Generic large, free converter. Only Nilgonj Dwip contains diesel generators. Table 3 shows the kilowatt power generated by the generic flat-plate PV, Generic wind turbine, and string size of the battery of each island.

Optimized cost of energy is measured by equation (1) [22]

$$OCOE = \frac{(TAG \times COE) - (EXC \times SP)}{TAG} \quad (1)$$

Here,

OCOE represents the Optimized cost of energy. COE is the cost of energy optimized by HOMER software, TAG is the Total annual generation, EXC represents the excess electricity produced per year and SP is the selling price of per unit electricity.

From the table. 3. Mathematically it is clear that the island named Char Montaz has the lowest OCOE of 0.241(USD) and Andar char contains the highest OCOE of 0.270(USD) which is about 10% higher. On average about 300 quantities of battery are needed for every island and the capacity of the converter is between 27 KW to 31 KW. So most economical and suitable region to implement a hybrid energy system in the region of the western Bay of Bengel is Char Montaz and the second best is Rangabali Dwip which has about 2.03% higher OCOE than Char Montaz. The operating cost of every island is less than 6,000($/yr) but only Nilgonj Dwip has the highest operating cost of 6,299($/yr). The expensive place for implementing a hybrid energy microgrid system is Andar char as it has the highest OCOE and LCOE.

Table 3. Comparison of OCOE for different islands of the Western Bay of Bengal

Island	Total production by Generic Flat Plate PV(KWh/yr)	Total production by Generic wind turbine (KWh/yr)	Inverter capacity of Converter (KW)	Strings in parallel to Battery(strings)	Excess electricity (KWh/yr)	OCOE (USD)
Char Montaz	165,085	13,354	27.8	160	105,538	0.241
Rangabali Dwip	154,666	12,155	27.3	180	93,734	0.246
Char Kasem	154,597	12,155	27.3	180	93,665	0.246
Nijhum Dwip	166,967	9,429	28.6	177	103,029	0.247
Dublar Char	165,900	10,963	29.4	174	103,655	0.252
Nilgonj Dwip	103,081	12,155	28.9	130	43,958	0.267
Andar Char	174,019	13,772	31.6	115	114,873	0.270

6. conclusion

A hybrid energy micro-grid system is reliable, sustainable, and cost-effective for providing electricity to remote and isolated communities. HOMER software is used to design a hybrid energy micro-grid system. From several islands of western regions, Char Montaz shows the best possible economy with an OCOE of 0.241(USD) with 160 battery strings. power production by Flat plate PV contributes most to the system with the highest value of 174,019(KWh/yr) for Andar Char and the lowest value of 103,081(KWh/yr) for Nilgonj Dwip. The second highest energy contributor is the Generic wind turbine. And its production remains close to 12,000 kWh/yr. Those systems emit zero carbon. Diesel generator reduces the COE but that increases the emission and pollution.

7. References

[1] D. Jie, X. Xu, and F. Guo, "The future of coal supply in China based on non-fossil energy development and carbon price strategies," *Energy*, vol. 220, p. 119644, Apr. 2021, doi: 10.1016/j.energy.2020.119644.

[2] O. B. Awodumi and A. O. Adewuyi, "The role of non-renewable energy consumption in economic growth and carbon emission: Evidence from oil producing economies in Africa," *Energy Strategy Rev.*, vol. 27, p. 100434, Jan. 2020, doi: 10.1016/j.esr.2019.100434.

[3] A. Siddik and T. Islam, "CURRENT STATUS AND CORRELATION OF FOSSIL FUELS CONSUMPTION AND GREENHOUSE GAS EMISSIONS".

[4] S. Hasan, "Design and Comparative Feasibility Analysis of Optimized Hybrid Energy System for a Remote Island," in *2020 IEEE Bangalore Humanitarian Technology Conference (B-HTC)*, Vijiyapur, India: IEEE, Oct. 2020, pp. 1–6. doi: 10.1109/B-HTC50970.2020.9297947.

[5] N. Lior, "Energy resources and use: The present (2008) situation and possible sustainable paths to the future," *Energy*, vol. 35, no. 6, pp. 2631–2638, Jun. 2010, doi: 10.1016/j.energy.2009.06.049.

[6] T. M. Letcher, "Introduction With a Focus on Atmospheric Carbon Dioxide and Climate Change," in *Future Energy*, Elsevier, 2020, pp. 3–17. doi: 10.1016/B978-0-08-102886-5.00001-3.

[7] F. Dawood, G. Shafiullah, and M. Anda, "Stand-Alone Microgrid with 100% Renewable Energy: A Case Study with Hybrid Solar PV-Battery-Hydrogen," *Sustainability*, vol. 12, no. 5, p. 2047, Mar. 2020, doi: 10.3390/su12052047.

[8] M. R. A. Bhuiyan, H. Mamur, and J. Begum, "A brief review on renewable and sustainable energy resources in Bangladesh," *Clean. Eng. Technol.*, vol. 4, p. 100208, Oct. 2021, doi: 10.1016/j.clet.2021.100208.

[9] M. Nurunnabi, N. K. Roy, and M. A. Mahmud, "Investigating the environmental and socio-economic impacts of grid-tied photovoltaic and on-shore wind systems in Bangladesh," *IET Renew. Power Gener.*, vol. 12, no. 9, pp. 1082–1090, Jul. 2018, doi: 10.1049/iet-rpg.2017.0751.

[10] F. Bin Kashem and M. S. Arefin, "Feasibility analysis of grid connected mini hybrid energy system in coastal region of Chittagong, Bangladesh," in *2017 3rd International Conference on Electrical Information and Communication Technology (EICT)*, Khulna: IEEE, Dec. 2017, pp. 1–5. doi: 10.1109/EICT.2017.8275239.

[11] H. Ahmad, "Bangladesh Coastal Zone Management Status and Future Trends," vol. 22, no. 1, 2019.

[12] M. Hasan, D. K. A. Khan, N. R. Khan, and Z. Islam, "Sustainable Electricity Generation at the Coastal Areas and the Islands of Bangladesh Using Biomass Resource," vol. 2, no. 1.

[13] F. Rabbi, M. Sarker, Md. H. Ali, Md. O. Rahman, S. Zaman, and K. H. Suvo, "Techno-Economic Feasibility Analysis of Solar Wind-Based Hybrid Power System on the Islands of the Northern Bay of Bengal," in *2023 4th International Conference for Emerging Technology (INCET)*, Belgaum, India: IEEE, May 2023, pp. 1–5. doi: 10.1109/INCET57972.2023.10170379.
[14] D. Roy, "Modelling an off-grid hybrid renewable energy system to deliver electricity to a remote Indian island," *Energy Convers. Manag.*, vol. 281, p. 116839, 2023.
[15] D. T. Ton and M. A. Smith, "The U.S. Department of Energy's Microgrid Initiative," *Electr. J.*, vol. 25, no. 8, pp. 84–94, Oct. 2012, doi: 10.1016/j.tej.2012.09.013.
[16] S. Bahramara, M. P. Moghaddam, and M. R. Haghifam, "Optimal planning of hybrid renewable energy systems using HOMER: A review," *Renew. Sustain. Energy Rev.*, vol. 62, pp. 609–620, Sep. 2016, doi: 10.1016/j.rser.2016.05.039.
[17] S. K. Nandi and H. R. Ghosh, "A wind–PV-battery hybrid power system at Sitakunda in Bangladesh," *Energy Policy*, vol. 37, no. 9, pp. 3659–3664, Sep. 2009, doi: 10.1016/j.enpol.2009.04.039.
[18] C. S. Turchi, M. J. Wagner, and C. Boulevard, "WREF 2012: POWER TOWER REFERENCE PLANT FOR COST MODELING WITH THE SYSTEM ADVISOR MODEL (SAM)".
[19] M. Kamruzzaman, "Assessment of destination-specific factors of Bangladesh: A review of Saint Martin Island as an emerging tourist destination," *J Bus Stud*, vol. 39, no. 1, 2018, Accessed: Sep. 18, 2024. [Online]. Available: https://fbs-du.com/news_event/511561027502(Page%20113-125).pdf
[20] K. Foysal Haque, N. Saqib, and Md. S. Rahman, "An Optimized Stand-alone Green Hybrid Grid System for an Offshore Island, Saint Martin, Bangladesh," in *2019 International Conference on Energy and Power Engineering (ICEPE)*, Dhaka, Bangladesh: IEEE, Mar. 2019, pp. 1–5. doi: 10.1109/CEPE.2019.8726596.
[21] F. Diab, H. Lan, L. Zhang, and S. Ali, "An environmentally friendly factory in Egypt based on hybrid photovoltaic/wind/diesel/battery system," *J. Clean. Prod.*, vol. 112, pp. 3884–3894, Jan. 2016, doi: 10.1016/j.jclepro.2015.07.008.
[22] M. Ross, *Photovoltaics in cold climates*. Routledge, 2019.