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Research Article

Optimal Design of Barangay Rogongon Microgrid System

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Abstract: In this research, specifically an electrical distribution system design of the proposed microgrid in a remote barangay, Brgy. Rogongon, in Iligan City, is presented. Due to limited access and limited-service electrical utility grid, about 10 % of the Philippine household population at a development disadvantage. Through the project, potential sites for hydropower and solar PV installations as well as distribution pathways were identified using Geographic Information (GIS). Household surveys were conducted to obtain the 5 yr projected load demand and the results are presented in thematic maps. The electrical distribution system of the microgrid was designed and simulated using Just Another Electrical Distribution Network Software (JAED.NS). The system simulation showed an acceptable 5.94 % estimated total system loss which implies that the designed electrical distribution system is feasible.

Keywords: Electrical Distribution, JAED.NS Software, Remote Rural Area, Renewable Energy, Thematic Map.

1. INTRODUCTION

In the Philippines, over 2×10^6 households do not have electricity, with limited access and limited service of only 4 h to 6 h d^{-1} [1], putting them at a developmental. One of these areas is in Region X (Northern Mindanao) with 1 953 sitios remain unenergized [2]. These include sitios in Iligan City, particularly in Barangay Rogongon. The said barangay has the largest land area in the Iligan City with 35 555 ha and a population of 4 870 [3]. Despite having the largest area it appears to be having a very low population density [4] and is 27.5 km away from the city proper [5] and is not yet connected to the electrical utility grid of Iligan City. This fact of the problem lies due to the limited access, services, and the lack of utility grid electrical connection.

Lately, the idea of microgrid has gained recognition turning modern power system expert attentions from centralized power generation to the microgrid system designed in two-way configuration; can deliver excess power into the electric utility grid as well as taking power from the grid and can operate completely separated ("off-grid/islanded") from the utility grid. [6, 7].

Because of the microgrids' capability to address energy access challenges, it is gaining popularity especially in remote rural area regions where high Potential renewable energy sources are available. Renewable energy sources are now recognized globally as an important alternative option in supplying electrical loads of microgrids because of their lesser operating cost, unlike conventional energy. sources [8–10].

This study aims to optimally design the Barangay Rogongon Microgrid. Specifically, this would accomplish the following: determine the load demand profile of the selected sitios of Barangay Rogongon; develop a thematic map of load demand using Geographic Information System (GIS) and design the electrical distribution system using JAED.NS software.

2. MATERIALS AND METHODS

2.1 Study Area

Barangay Rogongon represents about 44 % of the total land area of Iligan City, Philippines. It is situated in the remotest part of Iligan and majority of the inhabitants in the barangay are Indigenous

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People (IP), specifically "Higaunons". Majority of the area still has no access to electricity from the present grid, which is a major hindrance to its economic development. The study area is composed of five selected sitios in the barangay (Figure 1) [11].

2.2 System Design and Simulation

The Microgrid Electrical Power System is composed of three parts as the Generation System, Transmission System, and the Distribution System. For the generation system, two renewable energy sources were considered, hydro and solar.

Through the Department of Science and Technology (DOST) – funded project of Mindanao State University – Iligan Institute of Technology (MSU-IIT) entitled "Techno-Economic Feasibility Study of a Microgrid in a Remote Community", potential sites for hydropower and solar PV installation were identified using GIS and Multi-Criteria Decision Making (MCDM) [11].

For the transmission system, the least-cost path from the identified sites to load centers was adapted from the GIS Spatial Analyst-based Transmission line routing [12]. Along with the transmission pathway, the hydropower site, solar-PV site, and households were mapped using Just Another Electrical Distribution Network Software (JAED.NS). Also, analytic processes like fault analysis and load flow were executed using the JAED.NS.

Household surveys were conducted to determine the 5 yr projected energy demand. With the survey data, an energy assessment [13] was carried out to determine the general patterns of electricity consumption and hence, management of electric load demand. Also, thematic maps using GIS were produced based on the energy demand per sitio.

In designing the electrical distribution system of the microgrid, the requirements and specifications of all components such as the solar PV system equipment, wires, poles, and transformers were determined.

After data preparation and system design determination, simulations were then carried out using the aforementioned electrical distribution software. The designed electrical distribution system of Barangay Rogongon, Iligan City, was modeled and necessary system adjustments were made. System load flow was carried out as well wherein the voltages, currents, and real and reactive power flows in the system under given load

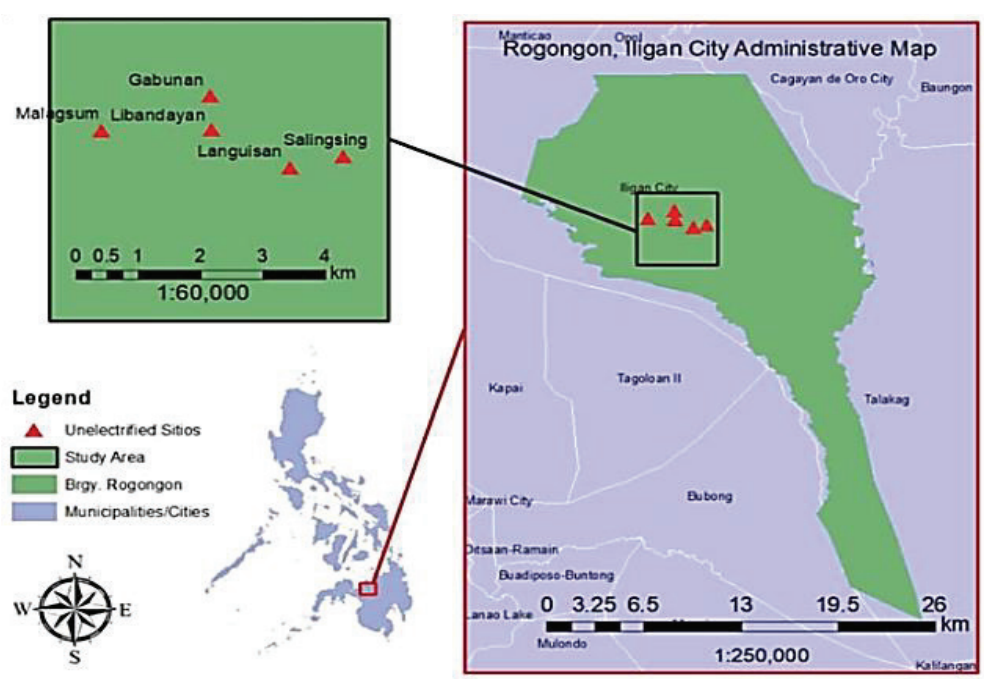


Fig. 1. Map of Barangay Rogongon, Iligan City (with the five selected sitios).

conditions were determined.

Fault analysis was also included which is an important consideration in any power system planning, protection equipment selection, and overall system reliability assessment. Different fault conditions were simulated and the values of short circuit currents were determined.

3. RESULTS AND DISCUSSION

3.1 Load Demand

Based on the conducted household surveys on the five sitios involved in the study, the load demand for the first five years is shown in Table 1 and Figure 2.

3.2 Thematic Map

From the data gathered during the conduct of household surveys, houses were geotagged and mapped using the ArcGIS platform. Figure 3 shows one of the thematic maps generated based on the identified households' load demand profile for the fifth year. As shown, Sitio Salingsing has the greatest demand while Sitio Malagsum shows the lowest.

3.3 Electrical Distribution System of Barangay Rogongon

Figure 4 shows the electrical distribution system of Barangay Rogongon overlaid in Google Earth, with hydro and solar as renewable sources of energy. Included as input data were parameters such as transformer profile, types, and size of distribution line wires, pole structure, and load audit of all five sitios.

3.4 Load Flow and Fault Analysis

The designed electrical distribution system consists of one substation transformer, one generator, six distribution transformers, 109 distribution poles, 12 secondary poles, and 45 households. Load flow analysis was performed as part of the simulation, wherein important data such as voltages, currents, and real and reactive power flows in the system under given load conditions were determined. Figure 5 shows the simulation results.

A feature of JAED.NS called net tracer was used to inspect line connections. As shown in Figure 5, there is no red mark on the wire lines and transformer. This indicates that the system is balanced and not overloaded. Furthermore, simulation results showed an acceptable 5.94 % estimated total system loss. Also, the voltage profile showed the line voltage at the downstream bus of Salingsing to be 12.725 kV. Voltage variation at this bus is 7.79 % which is within the 10 % tolerance on voltage as stipulated in the Philippine Distribution Code.

Figure 6 (a to d) shows the sub-transmission line load curve, distribution line load curve, underbuilt line load curve, and secondary service drop line load curve, respectively. A pattern can be seen in these four graphs wherein the line load curve fluctuates in the peak hour of the system. During these peak hours, consumers tend to use different appliances at the same time thus increasing the electrical demand per household. Other important information was derived from the simulation results such as the

Table 1. Load Demand Profile

Sitio Name	Max demand in Year 1 (VA)	Max demand in Year 2 (VA)	Max demand in Year 3 (VA)	Max demand in Year 4 (VA)	Max demand in Year 5 (VA)
Malagsum	1 504.67	1 518.79	1 518.79	1 518.79	1 518.79
Gabunan	12 888.85	14 342.38	16 384.23	16 869.14	16 869.14
Libandayan	3 710.52	4 884.49	5 936.10	7 044.28	7 044.28
Languisan	3 441.48	3 441.48	3 441.48	3 857.21	3 857.21
Salingsing	8 150.51	8 283.69	15 866.52	15 866.52	17 001.36
Unspecified Sitios	8 385.58	8 947.65	9 378.42	9 378.42	12 577.46

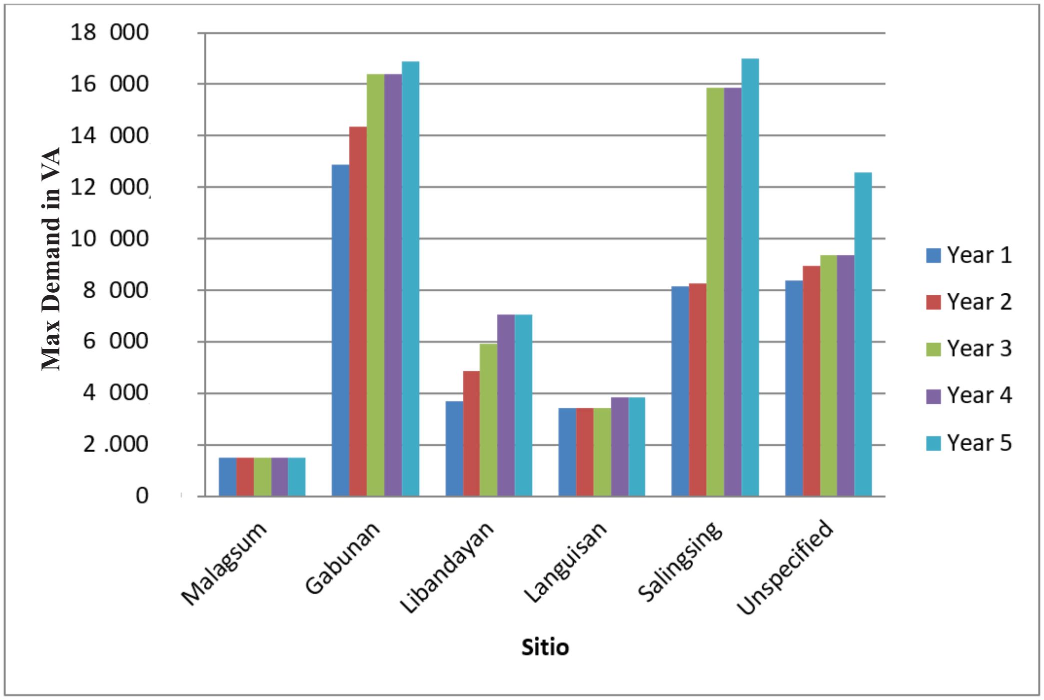
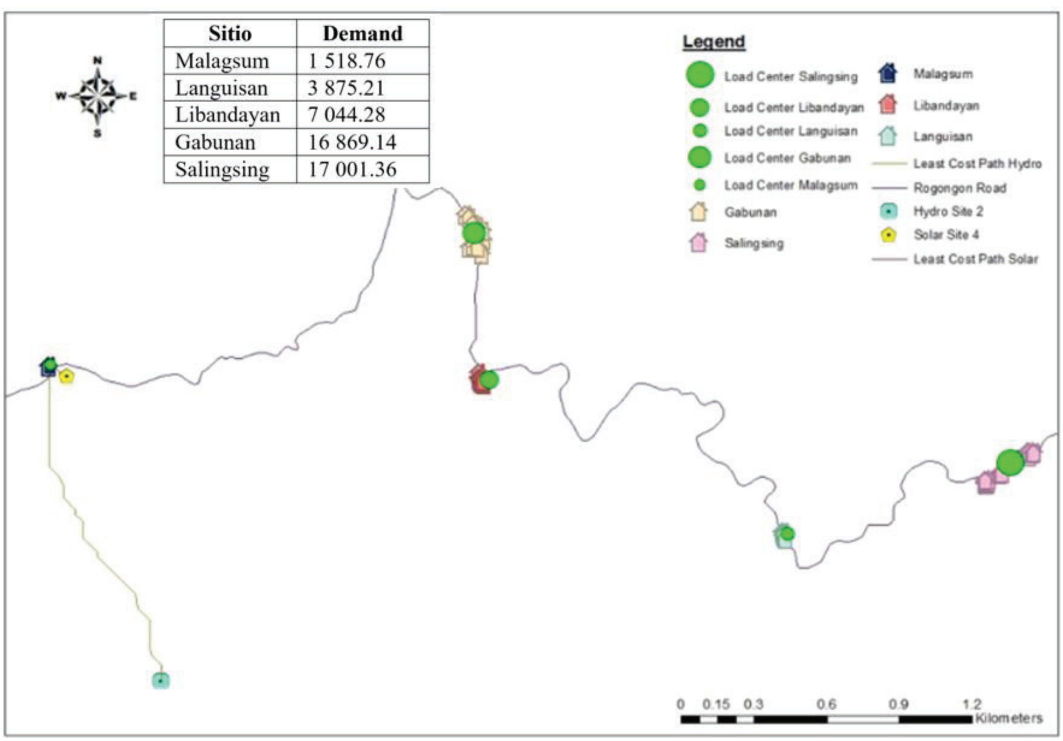


Fig. 2. Comparison of Load Demand Profile for 5 yr.



Sitio	Demand
Malagsum	1 518.76
Languisan	3 875.21
Libandayan	7 044.28
Gabunan	16 869.14
Salingsing	17 001.36

Fig. 3. Fhematic Map of Barangay Rogongon in Year 5.

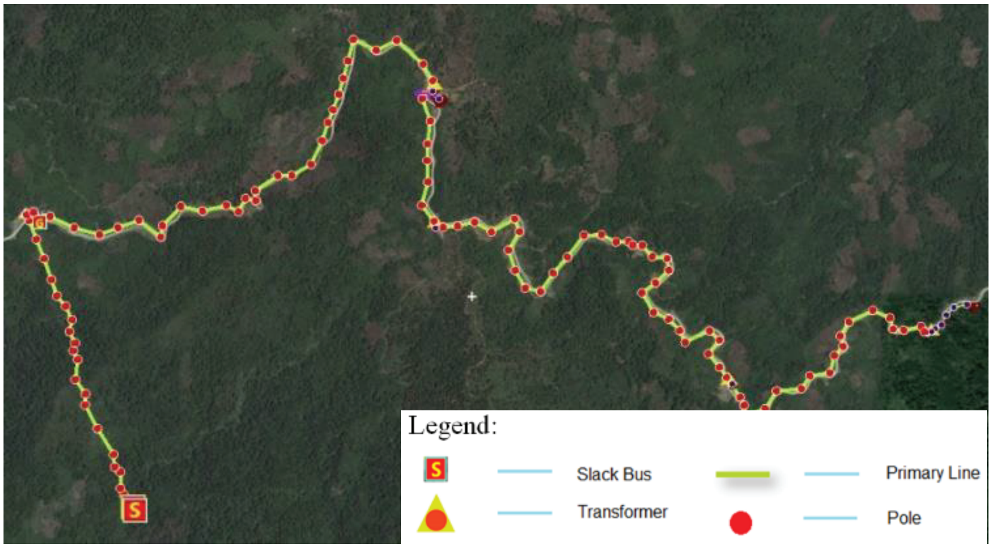


Fig. 4. Hydro and Solar Distribution System of Barangay Rogongon.

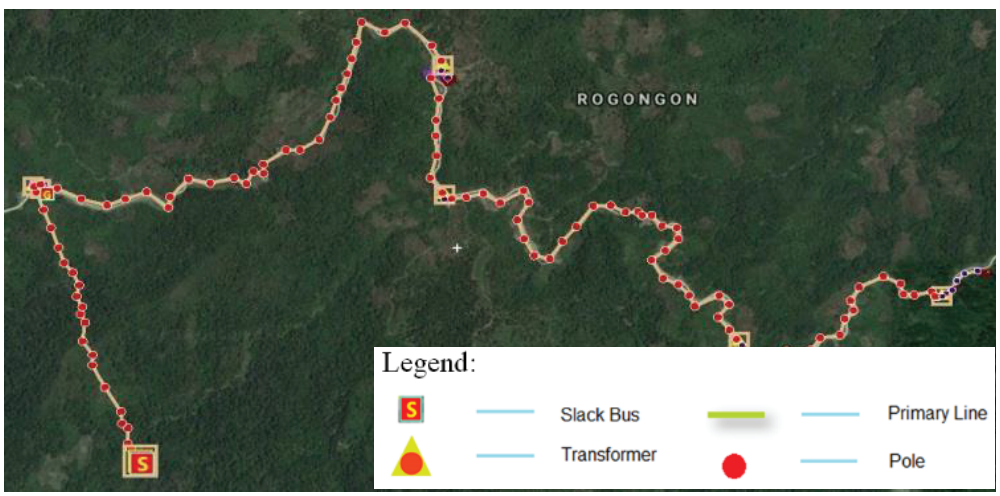
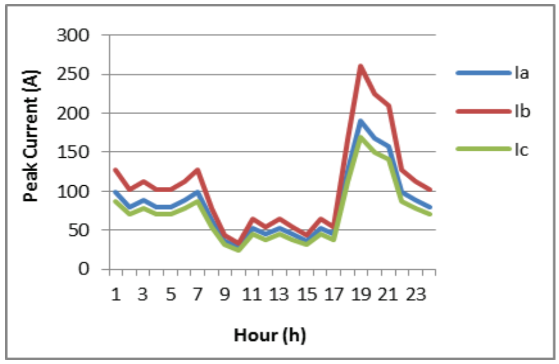


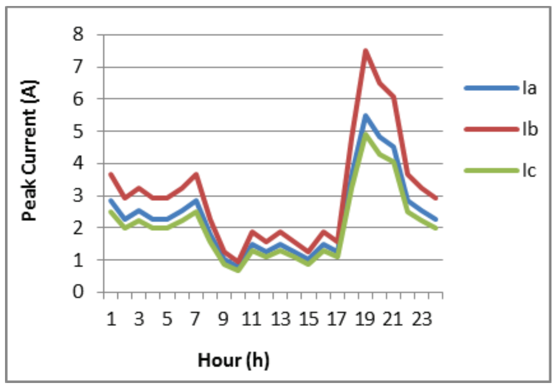
Fig. 5. Simulation Result for Hydro and Solar Distribution System of Brgy. Rogongon

Table 2: Voltage Profile of Rogongon Distribution System

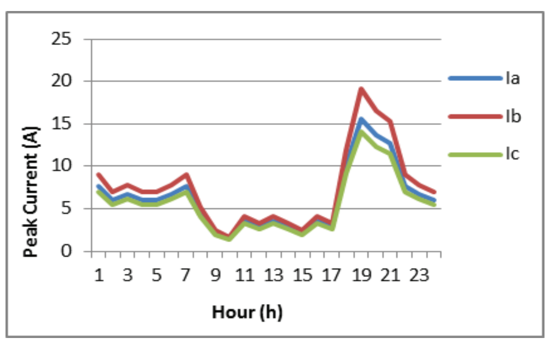
Bus Name	Line Voltage (kV)	Bs Name	Line Voltage (kV)
Reference	13.800	Libandayan	12.738
Malagsum	12.761	Languisan	12.729
Gabunan	12.741	Salingsing	12.725



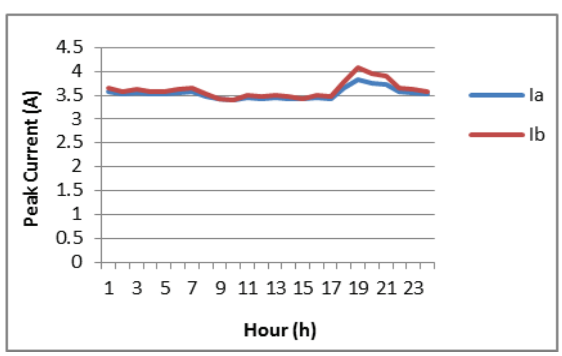
(a)



(b)



(c)



(d)

Fig. 6. Information derived from the simulation results showing: (a) Subtransmission Line Load Curve; (b) Distribution Line Load Curve; (c) Underbuilt Line Load Curve; and (d) Secondary Service Drop Line Load.

design for switch gears, setting of relays, and stability of system operation.

4. CONCLUSION

In this study, the 5 yr expected load demand of the five unelectrified sitios in Barangay Rogongon Iligan City were obtained and thematic maps were created using GIS. The electrical distribution system of the proposed Microgrid System was designed and simulated. After series of modifications, testing, and simulations, the distribution system resulted in an estimated 5.94 % total system loss. The system loss is well within acceptable range which implies that the designed electrical distribution system for Barangay Rogongon is feasible.

5. ACKNOWLEDGEMENTS

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6. CONFLICT OF INTEREST

The authors declare no conflict of interest.

7. REFERENCES

1. International Renewable Energy Agency, *Accelerating Renewable Energy Mini-Grid Deployment: A Study on the Philippines* [Online] from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Philippines_Renewable_Mini-Grids_2017.pdf (2017) [Accessed on 20 June 2019].
2. NEA. *National Electrification Administration,* [Online] from http://www.nea.gov.ph/index.php?option=com_phocadownload&view=sections (2017) [Accessed on 03 December 2018].
3. Philippine Statistics Office, *2010 Census of Population and Housing* [Online] from https://psa.gov.ph/content/population-iligan-city-was-recorded-323-thousand-results-2010-census-population-and-housing (2013) [Accessed on 01 May 2018].
4. Zamboanga. *Zambansa, Rogongon, Iligan City, Lanao del Norte, Philippines* [Online] from https://www.zamboanga.com/z/index.php?title=Rogongon,_Iligan_City,_Lanao_del_Norte,_Philippines (2017) [Accessed on 03 May 2018].
5. Iligan. *Iligan City Government, Iligan Barangays* [Online] from http://www.iligan.gov.ph/city-govt/iligan-barangays/ (2017) [Accessed on 01 May 2018]
6. H.E. Gelani., N. Mashood., D. Faizan, and H. Haseeb. Efficiency comparison of alternating current (AC) and direct current (DC) distribution system at residential level with load characterization and daily load variation. *Proceedings of the Pakistan Academy of Sciences: A. Physical and Computational Sciences* 54 (2): 111–118 (2017).
7. E. Yandri., R.H. Setyobudi., H. Susanto., K. Abdullah., Y.A. Nugroho., S.K. Wahono., F. Wijayanto, and Y. Nurdiansyah. Conceptualizing Indonesia's ICT-based energy security tracking system with detailed indicators from smart city extension. *E3S Web Conferences* 188(00007): 1–7 (2020). DOI: 10.1051/e3sconf/202018800007
8. A.U. Rehman., S. Zeb., H.U. Khan., S.S.U. Shah, and A. Ullah. *Design and operation of microgrid with renewable energy sources and energy storage system: A case study.* 2017 IEEE 3rd International Conference on Engineering Technologies and Social Sciences, (Thailand 2017). DOI: 10.1109/ICETSS.2017.8324151
9. K. Abdullah, A.S. Uyun, R. Soegeng, E.Suherman, H. Susanto, R.H. Setyobudi, J. Burlakovs, and Z. Vincēviča-Gaile. Renewable energy technologies for economic development. *E3S Web of Conference* 188(00016): 1–8 (2020). DOI:10.1051/e3sconf/202018800016
10. H. Hariyanto, D. Parenden, Z. Vincēviča-Gaile2, and P.G. Adinurani. Potential of new and renewable energy in Merauke regency as the future energy. *E3S Web of Conference* 190(00012):1–8 (2021). DOI: 10.1051/e3sconf/202019000012
11. D.A. Badang., C.F. Sarip, and A.P. Tahud. *Geographic Information System (GIS) and Multicriteria Decision Making (MCDM) for Optimal Selection of Hydropower Location in Rogongon, Iligan City.* 2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM),

(Baguio City, Philippines 2018). DOI: 10.1109/HNICEM.2018.8666266

12. J.V.S. Bondaug and R.V. Irosido. *Geographic Information System (GIS) Spatial Analyst-Based Electric Transmission Line Routing in Rogongon, Iligan City.* [Thesis BS]. Mindanao State University - Iligan Institute of Technology, Iligan City, Philippines (2017)
13. P. Mohanty., K.R. Sharma., M. Gujar, and M. Kolhe. *Solar photovoltaic system applications: A guidebook for off-grid electrification. Springer,* (2016). DOI: 10.1007/978-3-319-14663-8