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# Feasibility Study of Hybrid Renewable Energy System Design for a Typical High-Rise Building in Malaysia

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## Abstract

This article presents the Hybrid Renewable Energy System project plan (HRES) representation for high rise building in Malaysia. A building has been for this study since it signifies a distinctive load profile for many high-rise buildings in Malaysia. A techno-economic investigation has been performed to establish the possibility of PV, and battery system installation to reduce network dependence. The methodology started with information collection of load summary and solar resources at the selected location. Then, HOMER software was used by the analysis of hybrid financial and technological analysis configurations. Sensitivity examination was conducted to analyze system presentation under load and grid price changes. Results of analyses includes net present cost (NPC), energy cost (COE) and environmental pollution (CO2). This feasibility findings shows that the grid-only communication has the most promising results with the lowest NPC, preceded by the PV and battery grid system.

**Keywords:** Renewable Energy System, Solar PV, HOMER, Techno-economic Analysis, High Rise Building

## 1 Introduction

Conventional power generation from fossil fuel such as diesel, coal and natural gas releases significant amount of greenhouse gasses such as $CO_2$ that has negative impact towards the environment. Over the last decade, the usage




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of renewable energy sources such as battery storage, wind and limited geothermal energy sources has been growing. The global energy mix in 2016 comprises of fossil fuel (79.5%), modern renewable energy (10.4%), traditional biomass (7.8%) and nuclear energy (2.2%) [1]. Renewable energy contributed to 2,195 GWh of global energy capacity and has shown strong growth with 5.4% increment since 2005. Renewable energy technologies offer opportunity to provide electricity to remote areas and mitigating diesel fuel consumption.

Multiple renewable energy generation and fossil fuel are used to increase system reliability and efficiency in a HRES. However, feasibility study is desired to assess the possible of renewable energy installation to increase efficiency and minimizing power losses. Many researcher has conducted work in HRES design. For example, Ashish Shrestha et al. assesses factors such as energy cost and dynamic load demand for hybrid installation of renewable energy for a remote village in Nepal[2]. The off-grid hybrid energy system for standard remote villages is advocated by Ali Saleh Aziz et al in Iraq [3]. The results show hybrid PV, hydro, diesel and battery system has the most promising results with lowest NPC. Meanwhile, Weiping Zhang et al. perform assessment and size optimization of solar, wind and hydrogen system in Iran to increase reliability and efficiency [4][5]. M. R. B Khan perform HRES assessments for a South China Sea resort island [6], [7]. The proposed system of PV, hydro, diesel and renewables aims to reduce the burden of the island on diesel fuel. Furthermore, A. Can Duman et al. considers a hybrid PV, wind and fuel cell system to meet energy demand for off-grid location in Turkey [8]. Two load scenarios has been assessed such as during regular and seasonal period and battery storage system has lower cost compared to hydrogen system. EvangelosKalamaras has perform techno-economic analysis for an off-grid Greek island [9]. The PV, wind, hydrogen and battery materials are capable of to satisfy the load demand of the island. In [7], the author proposed PV system to alleviate grid dependence for a university premises in Malaysia [10]. The arrangement able to reduce energy import from the grid with installation of 50 kWp PV system with battery storage. Z. Othman et al. proposes hybrid PV system with several optimization techniques to establish the maximum charging time [11]. T. The experiment was done out with M. N.T Mansur et al. to minimize usage of electricity in a university building by incorporating PV system [12]. M. Kumar et al. analyses wind speed to determine the optimal wind generation and location for a location in Pakistan [13][14].

## 2 Methodology

In HRES design, optimal configuration is crucial to achieve higher efficiency. Therefore, the following framework as shown in Figure 1 are used. The project started with site assortment. The site chosen for this work is a one building condominium in Taman Putra, Gombak, Selangor, Malaysia. The building selected as it symbolizes distinctive condominium in Malaysia. Then, load profile of the building is calculated. Next, renewable resource assessment conducted where availability of solar throughout the year acquired from NASA POWER database. The system apparatus such as type of PV modules, and battery system is chosen followed by technical and economic analysis. In technical and economic analysis, the performance of hybrid configuration and its economics are simulated in HOMER. Finally, sensitivity study performed to simulate the system performance under variable changes such as load development and energy price.

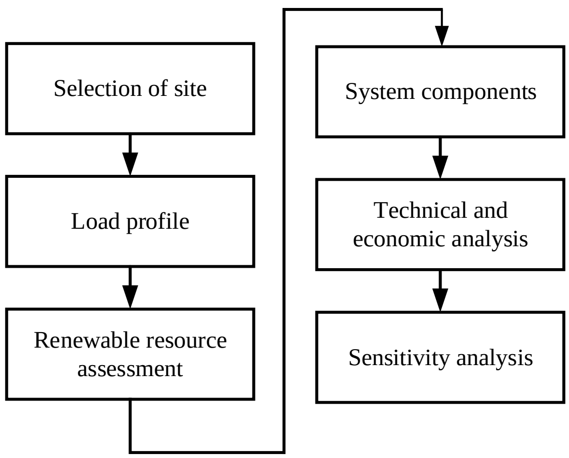


**Figure 1:** HRES optimal configuration framework

### *2.1 Load Profile Estimation*

The load profile for the building determined based on survey and calculations. **Error! Reference source not found.**Table 1 shows the load type and consumption at the condominium.

**Table 1**: Total load power for Putra Villa Condominium

| Type of Load | Power (W) |
|---|---|
| 416 unit houses | 7,841,600 |
| 1 Cafeteria | 2,100 |
| 1 Swimming Pool | 600 |
| 1 Badminton Court | 800 |
| 1 gymnasium | 7,750 |
| Floor lamp | 18,400 |

There are 416 units houses total. One-unit house has total power of 18,850 W, one cafeteria uses 2,100 W, one swimming pool use 600 W, one badminton court uses 800 W, one 1 gymnasium uses 7,750 W and the floor uses up to 18,400 W. The estimated load usage is 86,727.040 kWh/day. Figure 2 shows the estimated daily profile load for condominium.

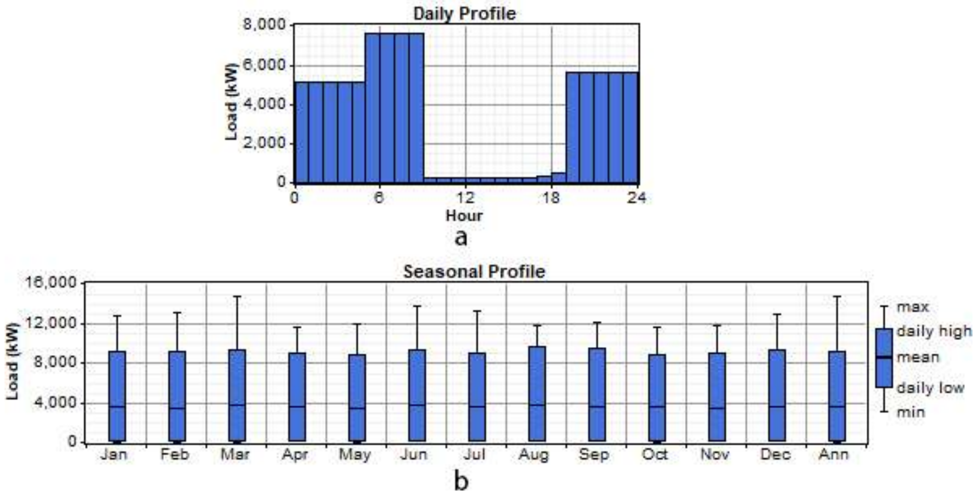


**Figure 2**: a) Daily Profile Load b) seasonal load profile

### *2.2 Renewable Resource Assessment*

Prior to HRES design, renewable energy resource assessment needs to be conducted to maximize power generation. solar radiation information was gathered in this study to determine the annual potential PV generation. Fig 3 shows solar radiation profile of the location. The average solar emission at the location is 3.2 KWh/m2/day with a 0.5 consistency index.

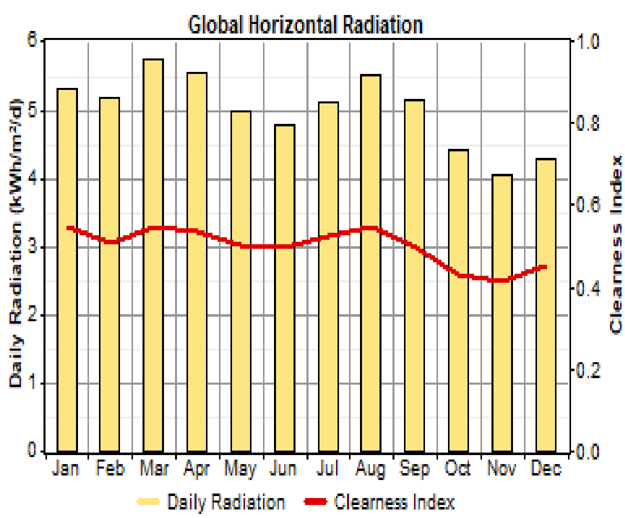


**Figure 3:** Solar radiation profile

### 2.3 HRES Design

In this work, PV, battery and grid were simulated to determine optimal hybrid configurations. The HRES modeled in HOMER is shown in Figure 4. Table **2** shows the system components of the hybrid scheme consists of PV, Inverter and Storage network for storage. The load profile has 9.9MWh/d with 1,677 kW peak.

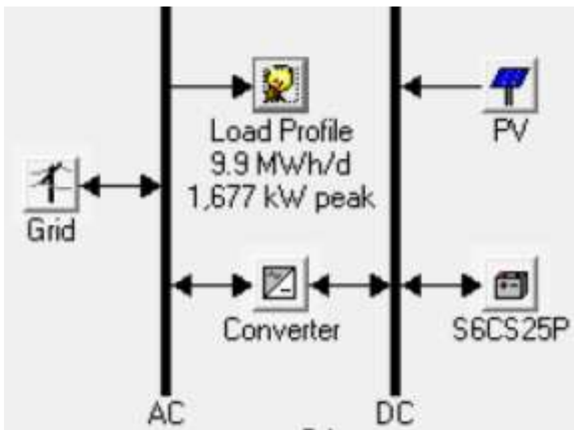


**Figure 4:** Schematic Diagram for HRES Design

**Table 2:** System components

| No | Elements | Specifications |
|---|---|---|
| 1 | PV System | |
| | Model | Peimar SG310MBF |
| | Size considered (kW) | 0,1,2,3,4,5 |
| | Capital cost ($/W) | 3.64 |
| | Replacement cost ($/W) | 3.64 |
| | Operation and maintenance cost ($/year) | 329 |
| | Lifetime (Years) | 25 |
| 2 | Inverter | |
| | Size considered (kW) | 0,1,2,3,4,5 |
| | Capital cost ($/W) | 1.05 |
| | Replacement cost ($/W) | 1.05 |
| | Operation and maintenance cost ($) | 10,500 |
| 3 | Batteries | |
| | Model | Generic Li-Ion |
| | Batteries per string | 83 |
| | Sizes considered | 0,1,2,3,4,5 |
| | Capital cost ($/battery) | 1,200 |
| | Replacement cost ($/battery) | 1,200 |
| | Operation and maintenance cost ($/year) | 10 |

## 3 Experimental Results

### *3.1 Technical and Economics Analysis*

As shown in Table 3, the most finest configuration is grid only arrangement followed by application for PV-grid, battery-grid and PV-battery-grid. Based on several key components, such as Net Present Cost, Operating Cost, Environmental impacts and energy mix, the best configurations are selected. Cycle charging (CC) is the best policy instrument for all systems, where surplus power can be used to remove the battery storage. Optimal PV system size is 50 kW for the installation. The lowest NPC and COE is the grid only configuration followed by PV-grid, PV-battery-grid and battery-grid. Since there is supposed to be no investment alongside operation and maintenance cost. The grid connected system does not have initial capital whereas basic fundamental for PV-grid, battery-grid and PV-battery-grid is $198,944, $95,896 and $249,452 respectively. The PV-battery-grid scheme has the maximum initial investment since it has two primary parts such as PV and battery storage arrangement. Although, PV-battery-grid scheme has higher NPC contrasted to PV-grid system, the renewable fraction is 3 % for both systems.

**Table 3:** Optimal hybrid system configurations list

| Rank | PV (kW) | Battery | Conv. (kW) | Grid (kW) | Dispatch Strategy | Initial capital ($) | NPC ($) | COE ($/kWh) | RF |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 1000 | CC | 0 | 4,615,567 | 0.100 | 0.00 |
| 2 | 50 | 0 | 50 | 1000 | CC | 198,944 | 4,754,795 | 0.103 | 0.03 |
| 3 | 0 | 83 | 50 | 1000 | CC | 95,896 | 4,810,383 | 0.104 | 0.00 |
| 4 | 50 | 83 | 50 | 1000 | CC | 249,452 | 4,858,099 | 0.105 | 0.03 |

Figure 5 shows the system NPC breakdown for the HRES system. The maximum NPC is from the grid followed by PV, battery and converter.

**Error! Reference source not found.** show electrical produced by grid only where the total kilowatts per year is 4,109 kWh/year. Since the load totally used only based on grid, the total load consumption is also 4,109 kWh/year. Figure 6 show average annual of electrical produced for all configurations. The PV system in PV-grid and PV-battery-grid has contributes only 3% of the total energy required with low generation in monsoon seasons such as January February, November and December.

Solar produce 42.3% (2,824 kWh/year) while grid purchases is 57.7% (3,849 kWh/year). The total kilowatts per year is 6,673 kWh/year. Total load consumption in this design is 6,185 kWh/y. 33.6% of them is grid sales (2,076 kWh/y) while the other 66.4% is the primary load (4,109 kWh/y).

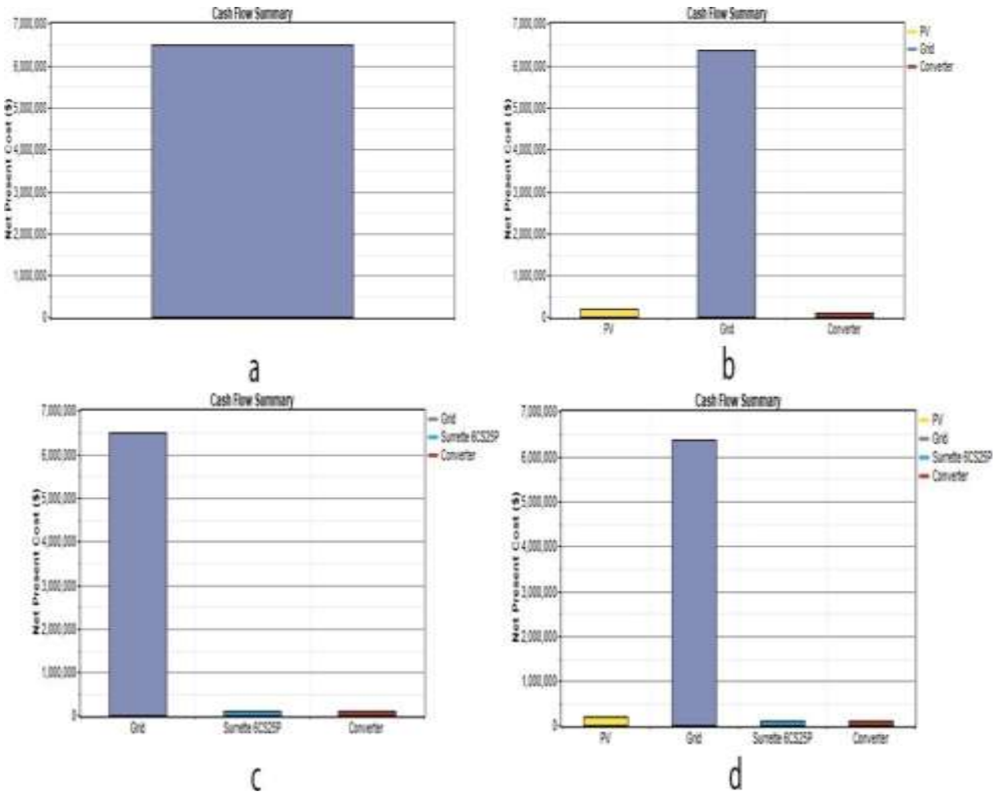


**Figure 5:** Cash Flow summary a) grid only b) PV-grid c) battery-grid d) PV-battery-grid

Table **4** show emission result where grid only system releases 2,247,437 kg/year of $CO_2$ similar to battery-grid (2,247,437 kg/year) followed by PV-battery-grid (2,202,38 9 kg/year) and PV-grid (2,201,619 kg/year).The results indicates addition of PV system reduces the $CO_2$ emissions. On the other hand, hybrid configurations with battery storage system have higher $CO_2$ emissions compared to non-battery system. Although, the most economical arrangement is to retain the current network associated arrangement for the building. However, PV-battery system shows promising results in higher renewable energy penetration with less $CO_2$ emission.

**Table 4:** Emissions

| Emission | Grid only (kg/year) | PV-grid (kg/year) | Battery-grid (kg/year) | PV-battery-grid (kg/year) |
|---|---|---|---|---|
| Carbon Dioxide | 2,247,437 | 2,201,619 | 2,247,275 | 2,202,389 |
| Carbon Monoxide | 0 | 0 | 0 | 0 |
| Unburned Hydrocarbons | 0 | 0 | 0 | 0 |
| Particulate Matter | 0 | 0 | 0 | 0 |
| Sulfur Dioxide | 9,744 | 9,545 | 9,743 | 9,548 |
| Nitrogen Oxides | 4,765 | 4,668 | 4,765 | 4,670 |

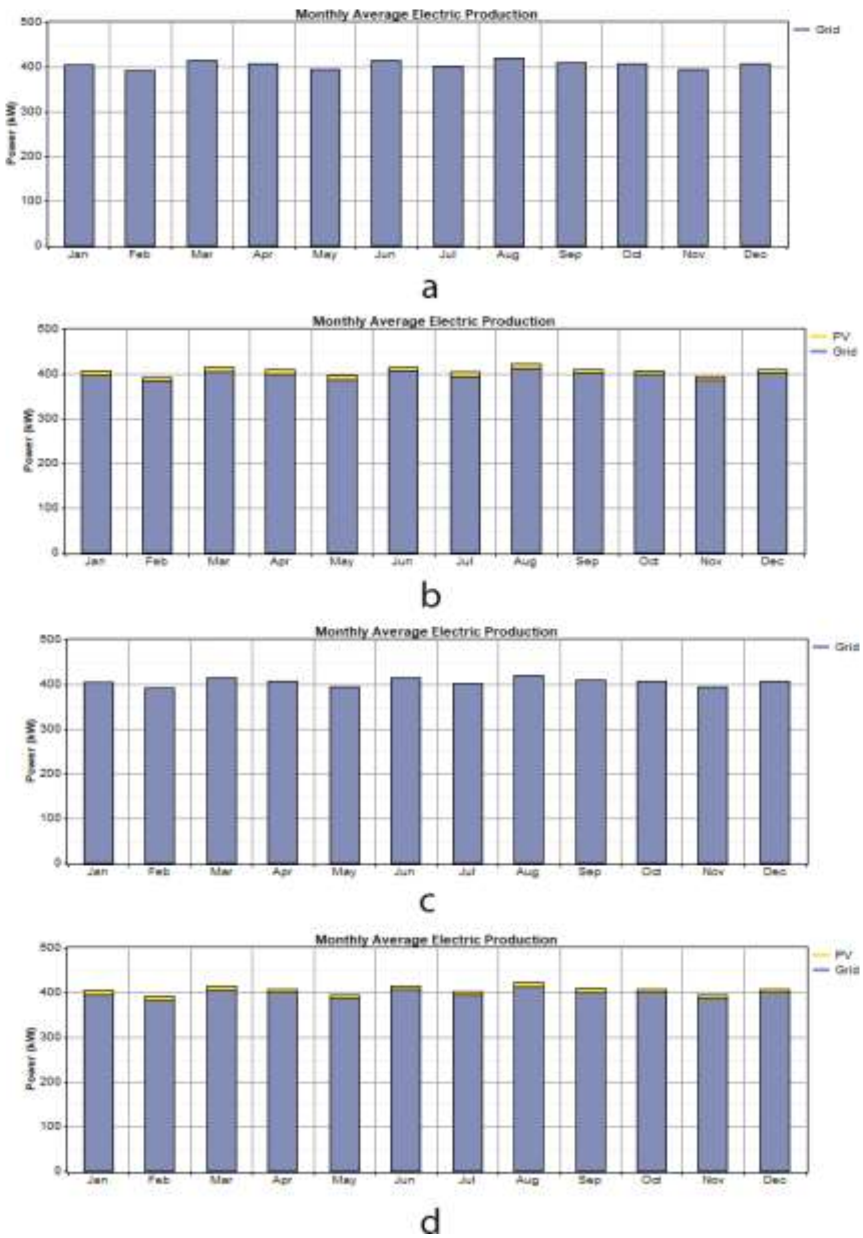


**Figure 6:** Electrical production a) grid only b) PV-grid c) battery-grid d) PV-battery-grid

### *3.2 Sensitivity Analysis*

Figure 7 shows the sensitivity analysis of the total NPC and net grid purchases. As the load outline grows in the prospect, the arrangement

NPC will rise along with energy import from the grid. To reduce the energy import, the PV system size needs to be increased.

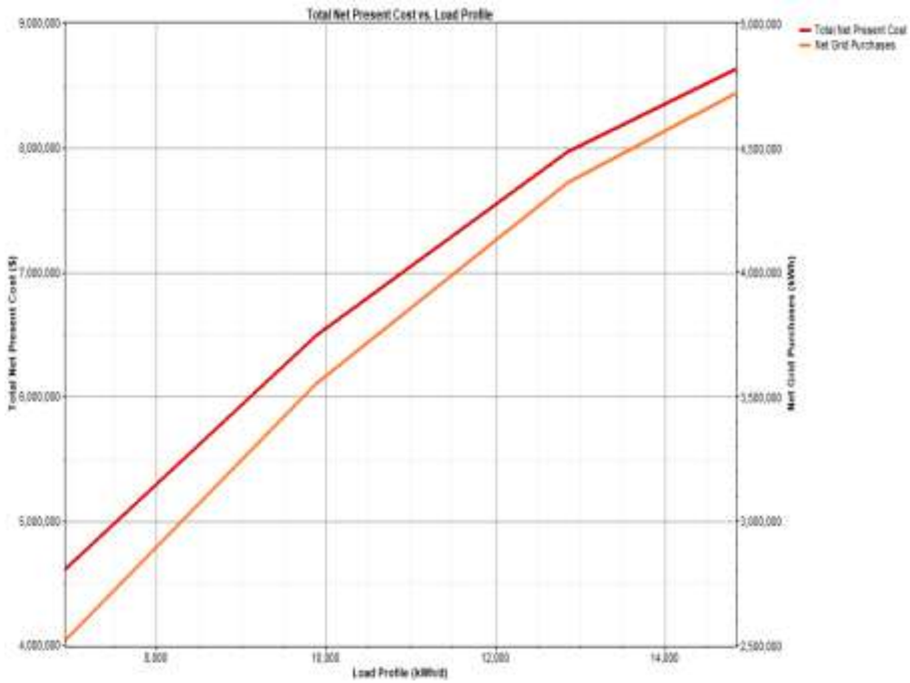


**Figure 7:** Sensitivity analysis total NPC vs net grid purchases.

## 4 Conclusion

The hybrid PV-battery is the best HRES pattern for the building. The scheme has smaller NPC compared to battery- system and PV-battery-grid system. Moreover, the scheme capable to reduce energy import from the grid as well as minimizing $CO_2$ emission lower than grid only, battery-grid and PV-battery-grid system.

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## References

[1]Niveditha Sivadanam, Bhookya Nagu, Maheswarapu Sydulu,"Inertial Response and Frequency Control in Electric Vehicles Integrated Renewable and Non-renewable Power System", journal of green engineering, Vol.10 no.11 pp.10981-10993,2020.
[2]A. Shrestha . "Assessment of electricity excess in an isolated hybrid energy system: A case study of a Dangiwada village in rural Nepal", Energy Procedia, Vol. 160, pp. 76–83, 2019.
[3]A. S. Aziz, M. F. N. Tajuddin, M. R. Adzman, A. Azmi, and M. A. M. Ramli. "Optimization and sensitivity analysis of standalone hybrid energy systems for rural electrification: A case study of Iraq", Renew. Energy, Vol. 138, pp. 775–792, 2019.
[4]W. Zhang, A. Maleki, M. A. Rosen, and J. Liu. "Sizing a stand-alone solar-wind-hydrogen energy system using weather forecasting and a hybrid search optimization algorithm", Energy Convers. Manag., Vol. 180, pp. 609–621, 2019.
[5] G.Supriya P.Sasikumar, V.Pavithra, M.Rahilabarvin,"Smart Home Emergy Management System Including Renewable Energy Based On Zigbee And Arm9 Microcontroller", International Journal Of Innovations In Scientific And Engineering Research (IJISER),Vol.4,No.2,Pp.71-77,2017..
[6]M. Khan, R. Jidin, J. Pasupuleti, and S. A. Shaaya. "Micro-hydropower potential assessment and generation volatility due to seasonal climate," IEEE International Conference on Power and Energy (PECon), pp. 371–376, 2014.
[7]M. R. B. Khan, R. Jidin, and J. Pasupuleti. "Energy audit data for a resort island in the South China Sea", Data Br., Vol. 6, pp. 489–491, 2016.
[8]A. C. Duman and Ö. Güler. "Techno-economic analysis of off-grid PV/wind/fuel cell hybrid system combinations with a comparison of regularly and seasonally occupied households", Sustain. Cities Soc., Vol. 42, pp. 107–126, 2018.
[9]E. Kalamaras, M. Belekoukia, Z. Lin, B. Xu, H. Wang, and J. Xuan. "Techno-economic Assessment of a Hybrid Off-grid DC System for Combined Heat and Power Generation in Remote Islands" , Energy Procedia, Vol. 158, pp. 6315–6320, 2019.
[10]M. Reyasudin Basir Khan, J. Pasupuleti, J. Al-Fattah, and M. Tahmasebi. "Optimal grid-connected PV system for a campus microgrid," Indonesian Journal of Electrical Engineering and Computer Sciense, Vol. 12, no. 3, pp. 899-906, 2018.
[11]Z. Othman, S. I. Sulaiman, I. Musirin, A. M. Omar, and S. Shaari. "Hybrid stand-alone photovoltaic systems sizing optimization based on

load profile," Bull. Electr. Eng. Informatics, Vol. 7, no. 2, pp. 153–160, 2018.

[12]T. M. N. T. Mansur, N. H. Baharudin, and R. Ali. "A comparative study for different sizing of solar PV system under net energy metering scheme at university buildings," Bull. Electr. Eng. Informatics, Vol. 7, no. 3, pp. 450–457, 2018.

[13]M. Kumar, B. Das, P. Nallagownden, I. Elamvazuthi, and S. A. Khan. "Optimal configuration of wind farms in radial distribution system using particle swarm optimization technique," Bull. Electr. Eng. Informatics, Vol. 7, no. 2, pp. 286–293, 2018.

[14] Haroun A. Elsheekh and Zainab M. Abdel Rahman Emad A. Ahmed, Ahmed Ghitas,"Solar radiation determination for solar energy applications; case study for two different sites in Egypt",International Research Journal of Multidisciplinary Science & Technology (IRJMRS),Vol.3,no.1,pp.1-5,2018.

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