



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 7, July 2023

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.423

# Design and Simulation of Solar Photo Voltaic (PV Array) and Wind Turbine Hybrid Model

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**ABSTRACT:** The simulation of a solar-wind renewable system connected to a load aims to design a power generation system that efficiently utilizes solar and wind energy sources to meet the energy demand of a localized grid. This abstract provides an overview of the key aspects involved in this process. The first step involves determining the optimal sizing and configuration of the solar and wind components in the renewable system. Factors such as available space, solar irradiance, wind speed, and local climate conditions are taken into consideration. The selection of solar panels, wind turbines, inverters, batteries, and other components plays a crucial role in ensuring the system's performance. Factors such as efficiency, reliability, and component compatibility are carefully evaluated during the selection process. To monitor and control the operation of the renewable system, an energy management system (EMS) is developed. The EMS optimizes the energy flow between the solar panels, wind turbines, batteries, and nanogrid, with the aim of maximizing the utilization of renewable energy while meeting the load requirements. Simulation software is utilized to model and simulate the system's performance under various scenarios, enabling analysis, validation, and optimization. Optimization algorithms are then implemented to find the most optimal system configuration, control strategies, and dispatch algorithms.

**KEYWORDS:** Photovoltaic; Cost of Energy; Carbon Emission; Hybrid renewable energy system; Power management; Optimal sizing; wind energy; wind turbine..

## I. INTRODUCTION

The increasing global demand for clean and sustainable energy has led to a growing interest in renewable energy systems. Solar and wind energy are abundant and widely available sources. By carefully sizing and configuring the solar and wind components, taking into account factors like available space, climate conditions, and resource availability, an efficient and effective system can be achieved. Simulating the performance of the solar-wind renewable system using specialized software allows for a detailed analysis of its operation under various scenarios.

The optimization and simulation of a solar-wind renewable system connected to a nanogrid offers a sustainable and reliable solution for localized power generation. By harnessing the abundant solar and wind resources, optimizing system configurations, and integrating with a nanogrid, this approach contributes to reducing carbon emissions, promoting energy independence, and achieving a greener future.

Nanogrids are particularly suitable for residential communities, commercial buildings, or isolated locations with limited access to the main grid. They provide flexibility, control, and sustainability at a smaller scale, empowering consumers to actively participate in the energy transition and enhance energy resilience at the local level.

## II. CELLS, MODULES, PANELS AND ARRAYS

Photovoltaic cells are connected electrically in series and/or parallel circuits to produce higher voltages, currents and power levels. Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of PV systems. Photovoltaic panels include one or more PV modules assembled as a pre-wired, field-installable unit. A photovoltaic array is the complete power-generating unit, consisting of any number of PV modules and panels.

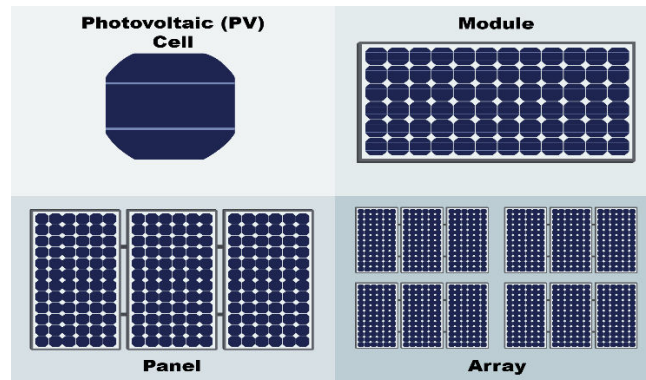


Fig.2 Photovoltaic cells, module, panel and array diagram.

The performance of PV modules and arrays are generally rated according to their maximum DC power output (watts) under Standard Test Conditions (STC). Standard Test Conditions are defined by a module (cell) operating temperature of 25°C (77°F), and incident solar irradiance level of 1000 W/m<sup>2</sup> and under Air Mass 1.5 spectral distribution.

**Test Conditions and Solar Panels**

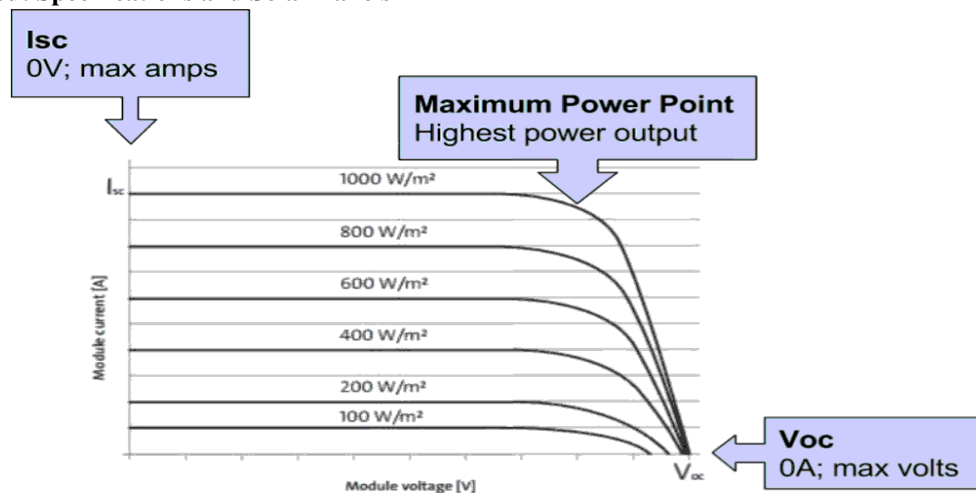
**Standard Test Conditions (STC)**

STC is the set of criteria that a solar panel is tested at. Since voltage and current change based on temperature and intensity of light, among other criteria, all solar panels are tested to the same standard test conditions. This includes the cells’ temperature of 25° (77°), light intensity of 1000 Watts per square meter, which is basically the sun at noon, and the atmospheric density of 1.5, or the sun’s angle directly perpendicular to the solar panel at 500 feet above sea level.

**Normal Operating Cell Temperature (NOCT)**

NOCT takes a more realist view of actual real world conditions, and gives you power ratings that you will likely actually see from your solar system. Instead of 1000 Watts per square meter, it uses 800 Watts per square meter, which is closer to a mostly sunny day with scattered clouds. It uses an air temperature of 20° (68°), not a solar cell temperature, and includes a 2.24MPH wind cooling the back of a ground mounted solar panel (more common in larger solar fields than a roof mounted residential array). These ratings will be lower than STC, but more realistic.

**Rated Output Specifications and Solar Panels**



Rated output for solar panels at different light intensities (W/m<sup>2</sup>). The “knee” of the curves is where the most power is produced, and the voltage & current is optimized.



**Open Circuit Voltage ( $V_{oc}$ )**

Open circuit voltage is how many volts the solar panel outputs with no load on it. If you just measure with a voltmeter across the plus and minus leads, you will read  $V_{oc}$ . Since the solar panel isn't connected to anything, there is no load on it, and it is producing no current.

**Short Circuit Current ( $I_{sc}$ )**

Short Circuit Current is how many amps (i.e. current) the solar panels are producing when not connected to a load but when the plus and minus of the panels wires are directly connected to each other. If you just measure with an ammeter across the plus and minus leads, you will read  $I_{sc}$ . This is the highest current the solar panels will produce under standard test conditions.

**Maximum Power Point ( $P_{max}$ )**

The  $P_{max}$  is the sweet spot of the solar panel power output, located at the "knee" of the curves in the graph above. It is where the combination of the volts and amps results in the highest wattage (Volts x Amps = Watts).

When you use a *Maximum Power Point Tracking (MPPT)* charge controller or inverter, this is the point that the *MPPT* electronics tries to keep the volts and amps at to maximize the power output. The wattage that a solar panel is listed as is the  $P_{max}$ , where,

$$P_{max} = V_{mpp} \times I_{mpp}$$

**Maximum Power Point Voltage ( $V_{mpp}$ )**

The  $V_{mpp}$  is the voltage when the power output is the greatest. It is the actual voltage you want to see when it is connected to the MPPT solar equipment (like an MPPT solar charge controller or a grid-tie inverter) under standard test conditions.

**Maximum Power Point Current ( $I_{mpp}$ )**

The  $I_{mpp}$  is the current (amps) when the power output is the greatest. It is the actual amperage you want to see when it is connected to the MPPT solar equipment under standard test conditions.

**Table I Solar Panel Nominal Voltage Cheat Sheet:**

<i>Nominal Voltage</i>	12V	20V	24V
<i>Number of Cells</i>	36	60	72
<i>Open Circuit Voltage (<math>V_{oc}</math>)</i>	22V	38V	46V
<i>Max Power Volts (<math>V_{mp}</math>)</i>	18V	31V	36V

**Table II PV Panel Specifications:**

PV Panel specification	Boost DC/DC converter specification	
PV model	1STH-215-P	L1 4 mH
Short circuit current ( $I_{sc}$ )	7.84 A	C1 100 $\mu$ F
Open circuit voltage ( $V_{oc}$ )	36.3 V	C2 100 $\mu$ F
Maximum Voltage ( $V_{mpp}$ )	29 V	Ro 20 $\Omega$
Maximum current ( $I_{mpp}$ )	7.35 A	
Maximum power ( $P_{mpp}$ )	213.15 W	
Number of cells in series (Ns)	60	
Temperature coefficient of $I_{sc}$	-0.36099%/ $^{\circ}$ C	
Temperature coefficient $V_{oc}$	0.102%/ $^{\circ}$ C	
Diode ideality factor (A)	0.98117	
Series resistance (Rs)	0.39383 $\Omega$	
Shunt resistance (Rsh)	313.3991 $\Omega$	

### III. MODELLING OF PV ARRAY

As mentioned above the components of the identified system are modelled using MATLAB/SIMULINK software tool.

#### 3.1 PV Module

A generalized PV model is built using Matlab Simulink to illustrate and verify the nonlinear I-V and P-V output characteristics of PV module. The behaviour of photovoltaic (PV) cells can be modelled with an equivalent circuit that includes a photocurrent source, a single diode junction, IGBT making BUCK BOOST CONVERTER, Inverter circuit and filter circuit for improving voltage obtained from the boost up circuit and a light load connected in parallel with the circuit. The Simulink model of PV module is shown in the Fig.1.

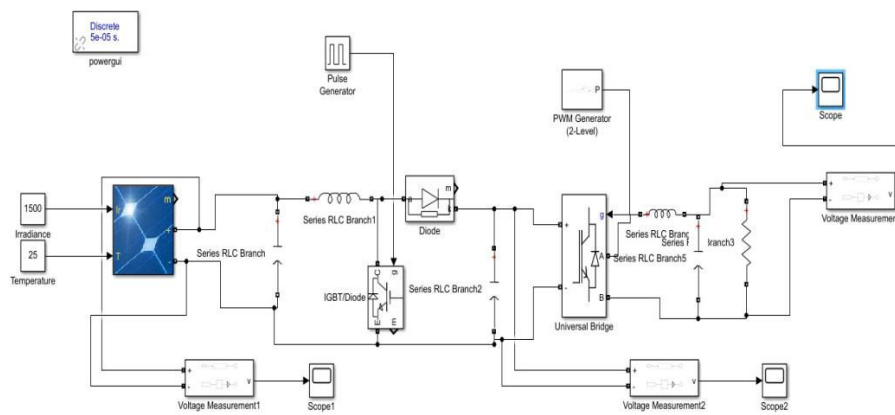


Fig. 3.1 Matlab Simulink model of PV array

#### 2.2 WT Module

Wind turbine is composed of a rotor, a generator, three-blades, and a drive train. In case of high wind speed, the generator output power is controlled by adjusting the pitch angle. Power is transmitted to the grid through power electronic interface. A wind turbine extracts kinetic energy from the wind blowing through the blades. The power developed by a wind turbine is given. The Simulink model of a wind turbine equation is shown in figure 2.

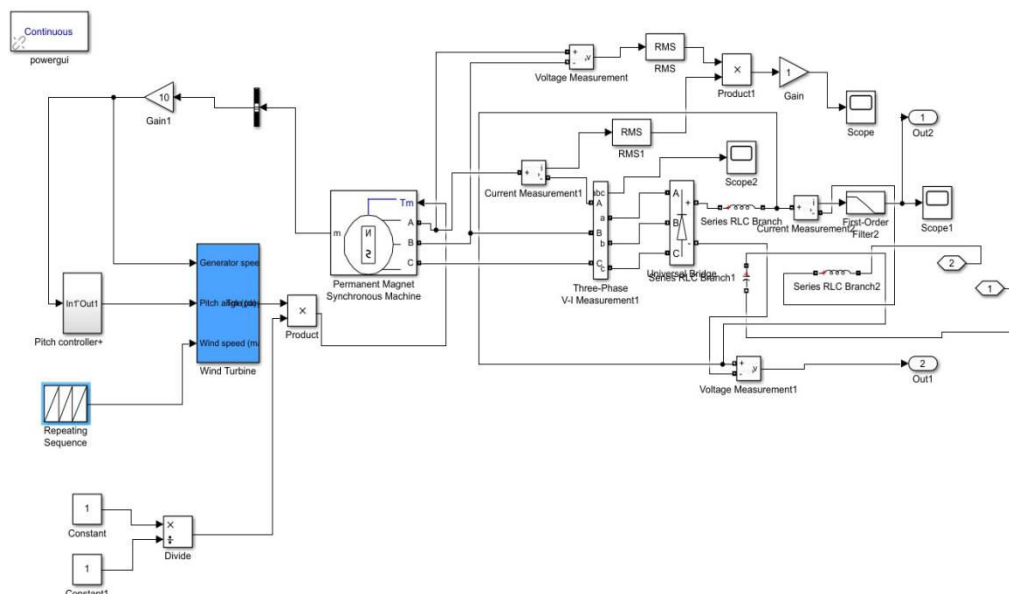


Fig. 3.2. MATLAB/ SIMULINK Model of Wind Turbine Block

### 2.3 Energy Storage Modules

The electricity demand fluctuates depending on the time of the day and the time of a year. Since the traditional power grid is not able to store up electricity, the mismatch between supply and demand is more likely observed. As the concept of Micro-grid is becoming more pervasive, a mixed power system makes the best use of the different types of local generation. Some forms of generations have large response time and others have little flexibility in operation. In addition, some forms of generations can start up very quickly to provide more or less energy quickly depending on the real-time load demand pattern. Provided these reasons clearly, the energy storage is beneficial in managing such a system. A desired form of energy storage is expected to provide the required power into the power system and store up sufficient energy at low electricity consumption. Two types of short-term storage are studied and modelled: Storage batteries, and Super-capacitor.

## IV. EXPERIMENTAL RESULTS

The simulation result of photovoltaic array and wind turbine modelled in MATLAB / SIMULINK is shown below.

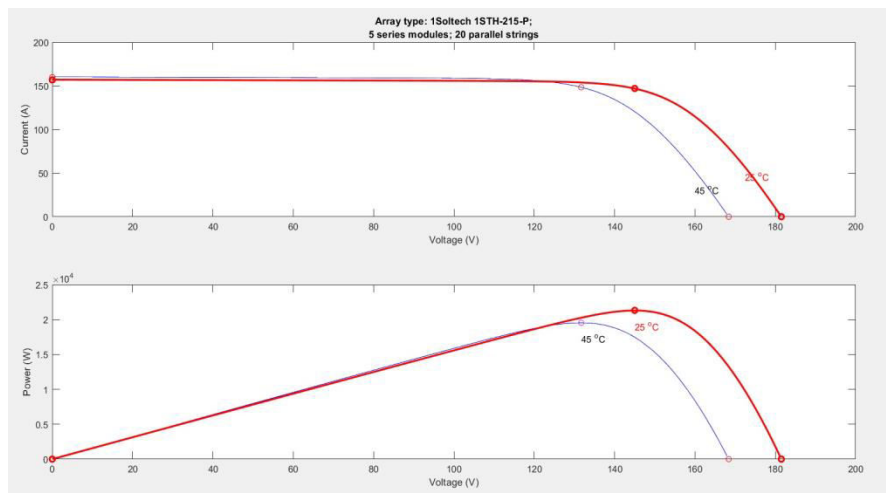


Fig. 4 Simulation results of I-V and P-V curves of PV array.

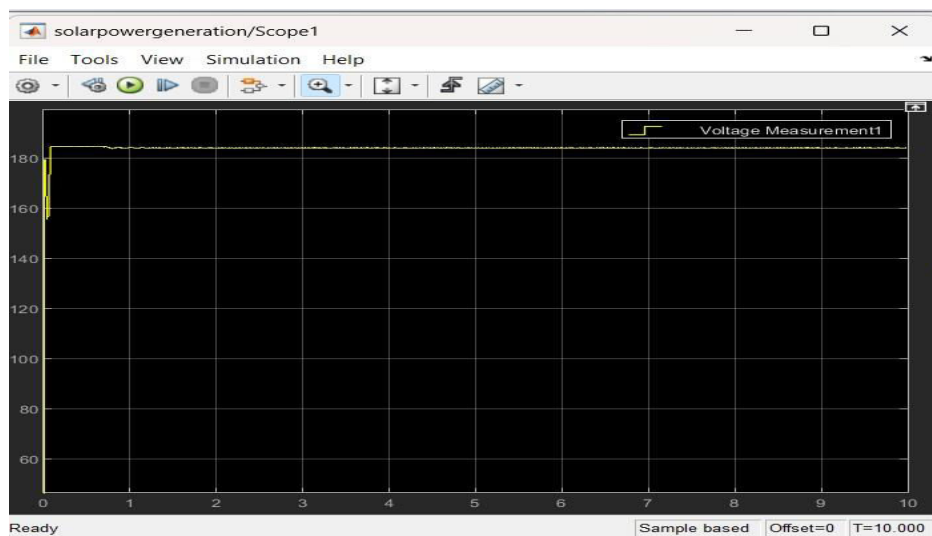


Fig 5 Voltage measurement obtained from the solar PV array

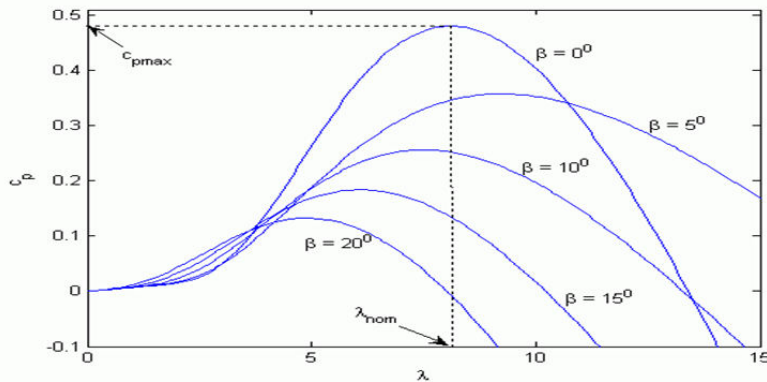


Fig.6 Simulation results of WT Power Curve

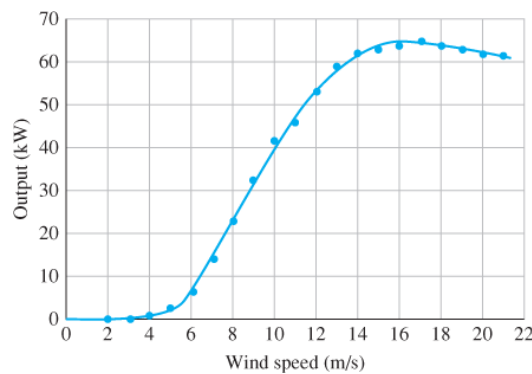


Fig. 7 Simulation results of Wind Turbine Power Curve

## V. CONCLUSION

The simulation of a solar-wind renewable system connected to a load is a complex and multidimensional process that involves careful consideration of numerous factors. By utilizing advanced techniques such as simulation software, optimization algorithms, and energy management systems, it is possible to design and develop highly efficient and reliable power generation systems that effectively utilize solar and wind energy sources to meet the energy demands of localized grids.

## REFERENCES

- [1] Inayat M, Sulaiman SA, Kurnia JC, Shahbaz M. Effect of various blended fuels on syngas quality and performance in catalytic co-gasification: a review. *Renew SustainEnergy Rev* 2019;105:252–67. <https://doi.org/10.1016/j.rser.2019.01.059>.
- [2] Kiwan S, Al-Gharibeh E. Jordan toward a 100% renewable electricity system. *Renew Energy* 2020;147:423–36. <https://doi.org/10.1016/j.renene.2019.09.004>.
- [3] Shivarama KK, Sathish KK. A review on hybrid renewable energy systems. *RenewSustain Energy Rev* 2015;52:907–16. <https://doi.org/10.1016/j.rser.2015.07.187>.
- [4] Kuang Y, Zhang Y, Zhou B, Li C, Cao Y, Li L, et al. A review of renewable energyutilization in islands. *Renew Sustain Energy Rev* 2016;59:504–13. <https://doi.org/10.1016/j.rser.2016.01.014>.
- [5] Tang R, Wu Z, Li X. Optimal operation of photovoltaic/battery/diesel/cold-ironinghybrid energy system for maritime application. *Energy* 2018;162:697–714. <https://doi.org/10.1016/j.energy.2018.08.048>.
- [6] Mofor L, Nuttall P, Newell A. Renewable energy options for shipping. *TechnologyBrief* 2015:60.
- [7] Ribeiro AED, Arouca MC, Coelho DM. Electric energy generation from small-scalesolar and wind power in Brazil: the influence of location, area and shape. *RenewEnergy* 2016;85:554–63. <https://doi.org/10.1016/j.renene.2015.06.071>.

- [8] Tang R, Lin Q, Zhou J, Zhang S, Lai J, Li X, et al. Suppression strategy of short-term and long-term environmental disturbances for maritime photovoltaic system. *Appl Energy* 2020;259:114183 <https://doi.org/10.1016/j.apenergy.2019.114183>.
- [9] Al-falahi MDA, Jayasinghe SDG, Enshaei H. A review on recent size optimization methodologies for standalone solar and wind hybrid renewable energy system. *Energy Convers Manage* 2017;143:252–74. <https://doi.org/10.1016/j.enconman.2017.04.019>.
- [10] Guney MS, Tepe Y. Classification and assessment of energy storage systems. *Renew Sustain Energy Rev* 2017;75:1187–97. <https://doi.org/10.1016/j.rser.2016.11.102>.
- [11] Ma T, Yang H, Lu L. Feasibility study and economic analysis of pumped hydro storage and battery storage for a renewable energy powered island. *Energy Convers Manage* 2014;79:387–97. <https://doi.org/10.1016/j.enconman.2013.12.047>.
- [12] Odou ODT, Bhandari R, Adamou R. Hybrid off-grid renewable power system for sustainable rural electrification in Benin. *Renew Energy* 2020;145:1266–79. <https://doi.org/10.1016/j.renene.2019.06.032>.
- [13] Ardizzon G, Cavazzini G, Pavesi G. A new generation of small hydro and pumped hydro power plants: advances and future challenges. *Renew Sustain Energy Rev* 2014;31:746–61. <https://doi.org/10.1016/j.rser.2013.12.043>.
- [14] Barbour E, Wilson IAG, Radcliffe J, Ding Y, Li Y. A review of pumped hydro energy storage development in significant international electricity markets. *Renew Sustain Energy Rev* 2016;61:421–32. <https://doi.org/10.1016/j.rser.2016.04.019>.
- [15] Aziz AS, Tajuddin MFN, Adzman MR, Azmi A, Ramli MAM. Optimization and sensitivity analysis of standalone hybrid energy systems for rural electrification: a case study of Iraq. *Renew Energy* 2019;138:775–92. <https://doi.org/10.1016/j.renene.2019.02.004>.
- [16] Arevalo P, Benavides D, Lata-Garcia J, Jurado F. Energy control and size optimization of a hybrid system (photovoltaic-hydrokinetic) using various storage technologies. *Sustain Cities Soc* 2020;52:101773 <https://doi.org/10.1016/j.scs.2019.101773>.
- [17] Muh E, Tabet F. Comparative analysis of hybrid renewable energy systems for off-grid applications in Southern Cameroon. *Renew Energy* 2019;135:41–54. <https://doi.org/10.1016/j.renene.2018.11.105>.
- [18] Ma T, Yang H, Lu L, Peng J. Pumped storage-based standalone photovoltaic power generation system: modeling and techno-economic optimization. *Appl Energy* 2015;137:649–59. <https://doi.org/10.1016/j.apenergy.2014.06.005>.
- [19] Ioakimidis CS, Genikomsakis KN. Integration of seawater pumped-storage in the energy system of the island of Sao Miguel (Azores). *Sustainability* 2018;10.
- [20] Ghasemi A, Enayatzade M. Optimal energy management of a renewable-based isolated microgrid with pumped-storage unit and demand response. *Renew Energy* 2018;123:460–74. <https://doi.org/10.1016/j.renene.2018.02.072>.
- [21] Kusakana K. Hybrid DG-PV with groundwater pumped hydro storage for sustainable energy supply in arid areas. *J Storage Mater* 2018;18:84–9. <https://doi.org/10.1016/j.est.2018.04.012>.
- [22] Guezgouz M, Jurasz J, Bekkouche B, Ma T, Javed MS, Kies A. Optimal hybrid pumped hydro-battery storage scheme for off-grid renewable energy systems. *Energy Convers Manage* 2019;199:112046 <https://doi.org/10.1016/j.enconman.2019.112046>.
- [23] Fodhil F, Hamidat A, Nadjemi O. Potential, optimization and sensitivity analysis of photovoltaic-diesel-battery hybrid energy system for rural electrification in Algeria. *Energy* 2019;169:613–24. <https://doi.org/10.1016/j.energy.2018.12.049>.
- [24] Ghaffari A, Askarzadeh A. Design optimization of a hybrid system subject to reliability level and renewable energy penetration. *Energy* 2020;193:116754 <https://doi.org/10.1016/j.energy.2019.116754>.
- [25] Stoppato A, Cavazzini G, Ardizzon G, Rossetti A. A PSO (particle swarm optimization)-based model for the optimal management of a small PV (Photovoltaic)-pumped hydro energy storage in a rural dry area. *Energy* 2014;76:168–74. <https://doi.org/10.1016/j.energy.2014.06.004>.
- [26] Energy Commission. Malaysia Energy Static Handbook 2018. Suruhanjaya Tenaga, 2018. [https://www.st.gov.my/contents/files/download/116/MES\\_2018\\_Handbook\\_FINAL.PDF](https://www.st.gov.my/contents/files/download/116/MES_2018_Handbook_FINAL.PDF).
- [27] Energy Commission. Toward world-class Energy sector Energy Malaysia. Suruhanjaya Tenaga, 2015. [https://www.st.gov.my/contents/files/download/112/Energy\\_Malaysia\\_18\\_\(Online\).pdf](https://www.st.gov.my/contents/files/download/112/Energy_Malaysia_18_(Online).pdf).
- [28] Jabatan Meteorologi Malaysia. Hourly Weather Data of Ipoh Station. 2018.
- [29] Kadier A, Kalil MS, Pudukudy M, Hasan HA, Mohamed A, Hamid AA. Pico hydropower (PHP) development in Malaysia: potential, present status, barriers and future perspectives. *Renew Sustain Energy Rev* 2018;81:2796–805. <https://doi.org/10.1016/j.rser.2017.06.084>.





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