Journal of Engineering Technology and Applied Physics

Recent Progress in Floating Solar Photovoltaic Systems: A Review from Malaysia's Perspective

Siow Chun Lim[1,*], Mohammed M. F. Dawoud[1], Kwok Yew Hoe[2] and Wong Wai Yin[3]
[1]*Faculty of Engineering, Multimedia University, Persiaran Multimedia, 63100 Cyberjaya, Selangor, Malaysia.*
[2]*Cenergi SEA Berhad, Level 4, Block E, Dataran PHB Saujana Resort, Section U2, 40150 Shah Alam, Selangor, Malaysia.*
[3]*Fuel Cell Institute, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia.*
**Corresponding author*: clsiow@mmu.edu.my, *ORCiD*: 0000-0003-2353-0103
https://doi.org/10.33093/jetap.2024.6.1.1
Manuscript Received: 26 July 2023, Accepted: 6 August 2023, Published: 15 March 2024

***Abstract* — Floating solar photovoltaic (FPV) technology has been gaining popularity in various parts of the world to address the growing clean energy demand and land scarcity challenges posed by conventional solar PV installations. This paper presents a comprehensive review of the recent progress in FPV research and actual implementations, highlighting advancements, challenges, and future prospects in this dynamic and promising field in Malaysia.**

Keywords—Floating solar photovoltaic, Solar energy, Renewable energy, Environmental impact, Lightning protection

I. INTRODUCTION

Solar energy has been gaining momentum globally as one of the most prominent renewable energy sources due to its abundance in supply and maturing harvesting technology. There are two types of solar energy systems; on land and on water. On land, the installations usually are either solar farms or on rooftops of buildings. On water, a feasibly large surface area of lakes, rivers and seas are required. Previous studies show that, for standard office buildings, PV solar systems are preferred over solar thermal systems. In addition, a life cycle analysis was performed to analyse and evaluate the overall performance of an optimization system and a conventional system, and it showed a huge improvement for the optimization system [1].

According to Valančius and Mikučionienė, there is potential to use solar systems to renovate Soviet-style apartment buildings. Using the combination of PV solar and thermal solar systems to get the maximum benefits of electricity usage, the usage of different buildings in terms of space and capacity was compared by the aforementioned authors in [2].

Rabaia *et al.* found that after testing and an in-depth evaluation among numerous technologies, the technology of thin-film amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium gallium selenide (CIGS) has higher environmental performance compared to different technologies. In addition, massive metal smelters can be used to recycle thin-film photovoltaics (TFPVs). provided a table for solar system cells, and they are classified into three generations with their types. In addition, they compared the efficiency, advantage, and disadvantage of each type of the aforementioned technologies [3]. The subsequent section reviews recent progresses made in the field of FPV systems.

II. FLOATING SOLAR PV SYSTEMS

As aforementioned, the other type of solar energy which runs on water is FPV systems. As it is newly introduced and still in its infancy stage in Malaysia, there are no well-defined statistics on the contribution of total power generation from FPV in Malaysia. Floating solar systems can be found on different sites, like basins, lakes, and many other locations with water areas.

Studies show how the calculation has been done for the economic analysis of floating solar power plants (payback period). In addition, the various types of FPV systems and the advantages and disadvantages of each type are discussed. Finally, the advantages of floating over land PV solar systems are summarised in terms of efficiency, shadow effect, and saving land space [4].

According to Dörenkämper *et al.*, they found a mathematical relationship between the temperature and the output power of the PV panels. One of the analytical methods is to compute the irradiance-

Published by MMU PRESS. URL: https://journals.mmupress.com/index.php/jetap/index

weighted average temperature, this is a method for comparing the measured temperatures of the panels immediately. Calculating the heat loss coefficient is a different way of expressing the behaviour of different temperatures between the reference system and the floating structures, this coefficient is referred to as the U-value, and the greater this U-value, the less complicated it is for the module to expend its thermal energy [5].

Thi Thu Em Vo *et al.* discussed the advantages and disadvantages gathered from different studies of implementing FPV systems offshore. The advantages are, saving water from evaporation, especially in water bodies like dams or reservoirs, avoiding using land in crowded areas, and better efficiency compared with on-land PV systems due to the cooling effect on PV modules and cables. The disadvantages are that the configuration of the mooring and anchoring systems is not commercially available, installations pose challenges in positioning and lifting heavy structures, and seawater negatively impacts PV panels due to the algae and aquatic species attached to the floating systems, causing degradation and corrosion over the long term [6]. Figure 1 depicts a typical FPV system described in [6].

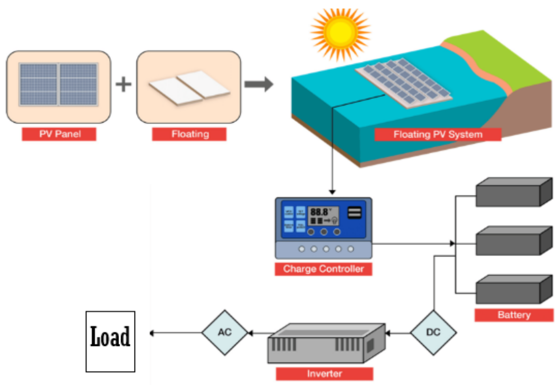

Fig. 1. A typical FPV modified from [6].

Solomin *et al.* reviewed different designs for hybrid FPV (HFPV) technologies these technologies include the combination of FPV and hydro, pumped hydro, wave energy converters, and more. HFPV systems are reliable and sustainable technologies that utilise the water-energy nexus to generate power with a low-carbon pathway. Island nations have huge potential to meet their energy demand by implementing HFPV using hydroelectric power plant (HPP) dams. In terms of power generation, the HFPV systems will be an alternative and efficient method compared with standard FPV systems [7].

Oliveira-Pinto and Stokkermans summarised some of the pros and cons of the FPV system and some of its limitations. The benefits include the utilisation of unused water bodies for power generation, no shading because of the open areas, reduced water evaporation and algae growth, availability of water for cleaning the PV modules, and simple construction. Using FPV systems on reservoirs can be advantageous due to existing infrastructure for grid connection, and typically during dry seasons, solar irradiation is high, resulting in higher power quality production. The cons and limitations are that the regulations for implementing this technology are unclear, the warranty, reliability, and lifetime of the PV modules under salt water and humid conditions are not guaranteed, the floating structure lifetime is typically 25 years, and there are no advancing simulation tools to simulate and assess the energy and efficiency of the FPV systems under the cooling effect of water [8].

Studies found that the presence of FPV systems has no effect on the albedo effect or global warming, this is an advantage compared with land-based PV (LBPV) systems due to the reduction of the local albedo effect. FPV systems contribute to saving water from evaporation, especially in reservoirs, as they secure the water resource. For one hectare of FPV systems, they save 15,000 m^3 annually. By utilising reservoirs and existing electrical infrastructure for grid connection, HFPV and HPP systems are cost-effective and produce more energy. No impact on zootechnical and fish equilibrium exists, and aquatic fauna and even birds are not bothered by the presence of floating structures [9].

Exley *et al.* found that solar irradiation and wind speed reduction in an average basin or lake can generate a non-linear and complex response, the direction of which depends on the design of the FPV system's array. FPV systems with small surface coverage had little influence on the system thermal structure test, whereas large surface coverage was a significant disruptor of the archetypal system thermal structure. While FPV affects lake thermal structure or light environment, a well-designed FPV system will be required to decrease the probability of hypolimnetic anoxia and maximise changes in marine ecosystems [10].

From field experience, Liu *et al.* reported some of the benefits and challenges of FPV systems. FPV systems have many potential advantages. It can be summarised as follows, there is no land use, and this is beneficial for countries with high populations and high energy demand. The low temperature of PV modules is due to evaporation. Water bodies are less dusty and therefore have negligible soiling effects because of dust particles. There have been mentions of difficulties encountered. Soiling effect due to bird droppings, in areas where the rain washes the bird droppings away, and in others where it does not, the panels must be operated and maintained regularly to ensure that the performance ratio (PR) is not impacted. Insulation faults cause the inverters to shut down, resulting in a significant loss of energy. Proper insulation of the electrical components, particularly the cables, is required during installation because the systems come into contact with water, which can conduct electricity on occasion [11].

A study conducted by Zahedi *et al.* on cleaning techniques for FPV systems initially applied these techniques to LBPV systems. It can be generally categorised as water-based and water-free approaches, each with different techniques. The water-based approach involves using chemical fluids, the temperature of the fluids is recommended to be the same as the PV panels' temperature to prevent electric shock. There are four techniques in this approach. First is the rainfall, where the PV panels are cleaned naturally, the effectiveness of this technique is different in heavy-rain areas than it is in light-rain areas. The second is manual cleaning, since natural assistance from rain and snow is not widespread in all regions, manual cleaning is suitable for removing soils from the PV panels with a simple piece of cloth and either a tucker pole or a PV-spin device. The third is self-cleaning, where high-pressure water sprinklers are placed between the PV panels, this technique is used for either cleaning or cooling down the temperature of the PV panels. Fourth is robotics, where robots are placed on the PV panels and start cleaning automatically, this is one of the most promising techniques to clean PV panels efficiently. The second approach is water-free, which reduces water consumption without involving any chemical fluids that could potentially pollute reservoirs and affect water quality. First is airflow, this technique relies on wind to clean and remove the soiling on the PV panels, which has the same issue as the rainfall technique in that it is not suitable for all regions. Second is self-cleaning, by using air conditioning systems, the air is cooled, filtered, and then forced onto the PV panels. This approach is valid for arid regions like the United Arab Emirates [12].

In a nutshell, advantages and drawbacks of FPV were discussed. The subsequent section will highlight FPV projects which were deployed globally.

III. GLOBAL FPV PROJECTS

The installed global capacity of FPV systems was 1.3 gigawatts-peak (GWP) at the end of 2018, and the systems are growing significantly as the studies of the systems get more mature. What makes the FPV system an attractive option for power generation is the positive environmental impact, and countries with high populations, instead of using land for the PV systems, can deploy large-scale FPV systems on nearby water bodies. China, for example, has installed a few large-scale FPV systems by 2018 and over 300 projects, the total installed capacity is 950 MWP and 73% of the total installed capacity, which makes it the market leader for FPV systems, followed by Japan in second place with 16%, and the Republic of Korea with 6% [13].

Singapore officially opened the first large-scale inland floating solar farm in July 2021, with a system size of 60 MWP using 122,000 solar panels and a power class of 490 WP from 210 Vertex dual-glass technology modules on the Tengeh reservoir. The project period is 25 years, and the total CO_2 saved over that period is 32 $kilotonnes$ (kt), equivalent to taking 7,000 cars off the road [14].

Rosa-Clot *et al.* conducted a study on existing FPV systems in Bolivar, South Australia. The FPV system is constructed for wastewater treatment using two construction methods. The first has a fixed tilt angle of 15°, a system size of 75 MWP, and an annual produced energy of 133,875 Megawatt-hours (MWh). Second is vertical axis tracking with a slope of 25°, a system size of 42.4 MWP, and an annual production energy of 89,464 MWh. They concluded the energy yield of vertical axis tracking is higher than a fixed tilted angle, with values of 2110 kWh/kWP and 1785 kWh/kWP, respectively. There are two other areas in South Australia that have been studied. The first area in Goolwa (Latitude 35°30'05" S, Longitude 138°46'54" E) and the second area at Lilydale (Latitude 37°45'29" S, Longitude 145°20'60" E) each have four basins. The total installed capacity in Goolwa is 9.313 MWP, and the annual energy produced is 16,391 MWh with a tilt angle of 15°. The total installed capacity in Lilydale is 8.467 MWP, and the annual energy produced is 13,971 MWh with a tilt angle of 15° [15].

Analysis has been conducted by Cazzaniga *et al.* in Pisa, Italy. The existing FPV system utilized area is 4,000 m^2 and 4 m deep, power class of the solar panel is 250 WP using 60 panels, with two reflectors for each panel, placed on the sides, the reflector angle is 60°, to increase the radiation and possibility of gaining up to 30% in energy [16].

Popa *et al.* studied the potential of developing an FPV system on the Lacul Morii reservoir in Bucharest, Romania. The utilised area is 8000 m^2, accounting for 0.32% of the total reservoir area, the installed system has a capacity of 1 MWP, and the annual produced power and CO_2 emissions saved are 1,114 MWh and 341 tCO_2, respectively. The benefits of this project are increased power generation and awareness of implementing the first FPV system in Romania [17].

The Tocantins-Araguaia basin region in Brazil has potential for PV systems because of the high solar irradiation. A case study (CS) was conducted on the HPP reservoirs to provide more power generation and meet the demand. The four case studies were conducted with different methodologies. CS one uses all the area for the FPV system, CS two covers 1% of the total flood area, CS three covers 5% of the total flood area, and CS four system size of the FPV system is the same as the capacity of a HPP, this approach is recommended by several studies. The annual power generated from CS one to four is 2,555.04 Terawatt-hour (TWh), 25.55 TWh, 127.75 TWh, and 25.04 TWh, respectively. The annual reduction in CO_2 emissions is estimated at 19.86 to 2024.30 $million$ tCO_2. The water saved from evaporation saves water during dry seasons [18].

Africa has a high solar irradiation of more than 2000 kWh/m^2. Gonzalez Sanchez *et al.* assessed the potential of FPV systems on existing hydropower reservoirs. This study is conducted on central, eastern, northern, southern, and west African power pools. The annual power generated from FPV systems on 146 hydropower plants covering all surface areas of the reservoirs is 5,293 TWh, equivalent to the power generated from the HPP by 50 times. Covering less than 1% of the reservoirs can double the installed power capacity of the hydropower plant and annually produce an additional 46.04 TWh. Due to the water saved from evaporation, the annual energy produced by HPP generation is increased, and the total annual saved water and produced energy are 743 $million\ m^3$ and 170.64 Gigawatt-hour (GWh) [19].

Micheli evaluated the potential of applying FPV systems to the reservoirs in Spain, where the total number of reservoirs and surface areas are 262 and 1,604 km^2, respectively. Occupying all the surface area, the total system size is 288 GWP at a 10° tilted angle. Covering 1% of the surface area of the reservoirs can generate 1.7% of Spain's energy demand and add 3 GW to the national PV capacity. If the FPV system's system size matches the capacity of the existing HPP, it has the potential to cover 12% of energy demand and up to 70% of the missing PV capacity in order to meet the renewable energy targets for 2030 [20].

A study was conducted on the potential of the FPV system on reservoirs in Karun, Iran. Using AutoCAD and PVsyst as design tools. The total area used is 100,000 m^2. The tilted angle and the row spacing are 20° and 70 cm, respectively. The system size is 18.65 MWP, due to the shading study findings, the tilted angle is reconsidered at 27.1° to maximise the solar irradiation and minimise the shading effect. The average amount of solar irradiation is 2,138 kWh/m^2. The energy injected into the grid is 16,758 $MWh/year$, this power can supply 2,260 houses. The equivalent saved CO_2 emissions are 13,349 $metric\ tonnes$ [21].

Mittal *et al.* investigated the feasibility of the potential use of FPV systems in two lakes in India, Kota Barrage and Kishore Sagar. The installed system size at Kota Barrage Lake is 1 MWP, the estimated utilised area is 10,000 m^2, daily solar irradiation is 6.07 kWh/m^2, the annual produced energy is 1,838 MWh, saved water is 37 $million\ litres$, the reduced CO_2 emissions are 1,733 t. Kishore Sagar Lake has a total area of 719,844 m^2, considering 20% of the area, the system size is 14 MWP, the utilised area is 143,969 m^2, daily solar irradiation is 6.14 kWh/m^2, the annual produced energy is 25,740 MWh, saved water is 545 $million\ litres$, the reduced CO_2 emissions are 23,990 t [22].

In April 2023, Indonesia has commissioned the operation of a 561 kW FPV on the island of Java. The plant is expected to generate 1.4 million kWh in a year and reduce CO_2 gas emissions by up to 1,304 tons [23]. Meanwhile, the biggest FPV plant in Vietnam, in the state of Binh Thuan, with a capacity of 47.5 MW, was completed back in June 2019 [24].

On the other hand, the development of FPV system has been rather slow in Malaysia. To the authors' knowledge, there is only one FPV system of significant scale which was deployed at Sepang, Selangor rated at 13MWp. Nevertheless, several large FPV projects were announced to be deployed at Sarawak, Melaka, Tioman and Perak in the near future.

IV. ADVANCING FPV IN MALAYSIA

Globally, the deployment of solar FPV system has taken place in an aggressive manner of late as presented in the previous sections. Yet, it is known that FPV can potentially impact the surrounding environment negatively. For instance, Hayibo and Pearce stated that the shrinkage of lakes has a negative impact on the ecosystem of marine life, the level of total dissolved solids (TDS) increases when the lake loses water, and at this level, fish species and Lahontan cutthroat trout struggle to survive. As a result, the migratory birds that hunt the Lahontan cutthroat trout will significantly decrease [25]. Hence, this aspect has to be taken seriously to ensure minimal impact on the marine life in Malaysia in any development of FPV projects in the near future.

Solar tracking system should also be considered to boost the output of the FPV in Malaysia. Dawoud and Lim have demonstrated that single-axis tracker can result in 15% improvement in terms of energy yield compared to conventional solar PV system on land in Malaysia [26]. It would be interesting to evaluate such advantage margin on water.

FPV is also exposed to the threats of lightning strike due to their installations on huge and flat-water surface area. This hazard is even more pronounced in Malaysia where lightning is significant threat in terms of life and infrastructure [27]. Hence, lightning risk assessment should be conducted to gauge the level of risk that the FPV in a given location is susceptible to [28, 29]. Only then, lightning protection system can be designed appropriately if necessary. A recent work presented by Sobolewski and Sobieska is worth referring to in order to design the required lighting protection system for FPV [30].

V. CONCLUSION

In this paper, recent progresses and developments in FPV systems were presented. Actual implementations of FPV in various parts of the world was deliberated. Potential technical and environmental challenges in advancing the deployment of solar FPV systems in Malaysia were identified.

REFERENCES

[1] P. Si, Y. Feng, Y. Lv, X. Rong, Y. Pan, X. Liu and J. Yan, "An Optimization Method Applied to Active Solar Energy Systems for Buildings in Cold Plateau Areas – The Case of Lhasa," *Appl. Energ.*, vol. 194, pp. 487–498, 2017.

[2] K. Valančius and R. Mikučionienė, "Solar Energy As A Tool of Renovating Soviet Type Multi Apartment Buildings," *Solar Energ.*, vol. 198, pp. 93–100, 2020.

[3] M. K. Rabaia, M. A. Abdelkareem, E. T. Sayed, K. Elsaid, K. J. Chae, T. Wilberforce and A. G. Olabi, "Environmental Impacts of Solar Energy Systems: A Review," *Sci. Total Environ.*, vol. 754, pp. 141989, 2021.

[4] A. Sahu, N. Yadav and K. Sudhakar, "Floating Photovoltaic Power Plant: A Review," *Renew. and Sustain. Energ. Rev.*, vol. 66, pp. 815–824, 2016.

[5] M. Dörenkämper, A. Wahed, A. Kumar, M. de Jong, J. Kroon and T. Reindl, "The Cooling Effect of Floating PV in Two Different Climate Zones: A Comparison of Field Test Data from

The Netherlands and Singapore," *Solar Energ.*, vol. 214, pp. 239–247, 2021.

[6] T. T. Vo, H. Ko, J. Huh and N. Park, "Overview of Possibilities of Solar Floating Photovoltaic Systems in The Offshore Industry," *Energies*, vol. 14, no. 21, pp. 6988, 2021.

[7] E. Solomin, E. Sirotkin, E. Cuce, S. P. Selvanathan and S. Kumarasamy, "Hybrid Floating Solar Plant Designs: A Review," *Energies*, vol. 14, no. 10, pp. 2751, 2021.

[8] S. Oliveira-Pinto and J. Stokkermans, "Assessment of the Potential of Different Floating Solar Technologies – Overview And Analysis of Different Case Studies," *Energ. Conver. and Manag.*, vol. 211, pp. 112747, 2020.

[9] P. Rosa-Clot, "FPV and Environmental Compatibility," *Floating PV Plants*, pp. 101–118, 2020.

[10] G. Exley, A. Armstrong, T. Page and I. D. Jones, "Floating Photovoltaics Could Mitigate Climate Change Impacts on Water Body Temperature and Stratification," *Solar Energ.*, vol. 219, pp. 24–33, 2021.

[11] H. Liu, V. Krishna, J. Lun Leung, T. Reindl and L. Zhao, "Field Experience and Performance Analysis of Floating PV Technologies in The Tropics," *Prog. Photovolt.: Res. and Appl.*, vol. 26, no. 12, pp. 957–967, 2018.

[12] R. Zahedi, P. Ranjbaran, G. B. Gharehpetian, F. Mohammadi and R. Ahmadiahangar, "Cleaning of Floating Photovoltaic Systems: A Critical Review on Approaches from Technical and Economic Perspectives," *Energies*, vol. 14, no. 7, pp. 2018, 2021.

[13] World Bank Group, ESMAP and SERIS, *Where Sun Meets Water: Floating Solar Handbook for Practitioners*, World Bank, Washington, DC, 2019.

[14] "*AP/Trina Solar*," Trina Solar, 09-Dec-2022. [Online]. Available: https://www.trinasolar.com.

[15] M. Rosa-Clot, G. M. Tina and S. Nizetic, "Floating Photovoltaic Plants and Wastewater Basins: An Australian Project," *Energ. Proc.*, vol. 134, pp. 664– 674, 2017.

[16] R. Cazzaniga, M. Cicu, M. Rosa-Clot, P. Rosa-Clot, G. M. Tina and C. Ventura, "Floating Photovoltaic Plants: Performance Analysis and Design Solutions," *Renew. and Sustain. Energ. Rev.*, vol. 81, pp. 1730–1741, 2018.

[17] B. Popa, L. I. Vuta, G. E. Dumitran, I. Picioroaga, M. Calin-Arhip and R. F. Porumb, "FPV for Sustainable Electricity Generation in A Large European City," *Sustainability*, vol. 14, no. 1, pp. 349, 2021.

[18] C. A. Moraes, G. F. Valadão, N. S. Renato, D. F. Botelho, A. C. Oliveira, C. C. Aleman and F. F. Cunha, "Floating Photovoltaic Plants As An Electricity Supply Option in The Tocantins-Araguaia Basin," *Renew. Energ.*, vol. 193, pp. 264–277, 2022.

[19] R. Gonzalez Sanchez, I. Kougias, M. Moner-Girona, F. Fahl and A. JägerWaldau, "Assessment of Floating Solar Photovoltaics Potential in Existing Hydropower Reservoirs in Africa," *Renew. Energ.*, vol. 169, pp. 687–699, 2021.

[20] L. Micheli, "Energy and Economic Assessment of Floating Photovoltaics in Spanish Reservoirs: Cost Competitiveness and The Role of Temperature," *Solar Energ.*, vol. 227, pp. 625–634, 2021.

[21] M. E. Shayan and J. Hojati, "Floating Solar Power Plants: A Way to Improve Environmental and Operational Flexibility," *Iranian J. Energ. and Environ.*, vol. 12, no. 4, pp. 337–348, 2021.

[22] D. Mittal, B. K. Saxena and K. V. Rao, "Floating Solar Photovoltaic Systems: An Overview and Their Feasibility at Kota in Rajasthan," in *Int. Conf. Circuit, Power and Comput. Technol.*, Kollam, India, pp. 1-7, 2017.

[23] E. Meza, "Indonesia's Largest Floating Solar Plant Goes Online," *PV Magazine*, https://www.pv-magazine.com/2023/04/13/indonesias-largest-floating-solar-plant-goes-online/ [Accessed July 23, 2023].

[24] M. I. Islam, M. S. Jadin, A. A. Mansur, N. A. M. Kamari, T. Jamal, M. S. Hossain Lipu, M. N. M. Azlan, M. R. Sarker and A. S. M. Shihavuddin, "Techno-Economic and Carbon Emission Assessment of A Large-Scale Floating Solar PV System for Sustainable Energy Generation in Support of Malaysia's Renewable Energy Roadmap," *Energies*, vol. 16, no. 10, pp. 4034, 2023.

[25] K. S. Hayibo and J. M. Pearce, "Foam-based Floatovoltaics: A Potential Solution to Disappearing Terminal Natural Lakes," *Renew. Energ.*, vol. 188, pp. 859– 872, 2022.

[26] B. M. Dawoud and S. C. Lim, "Performance Comparison of Fixed and Single Axis Tracker Photovoltaic System in Large Scale Solar Power Plants in Malaysia," *Indonesian J. Electr. Eng. and Comput. Sci*., 21(1), pp.10-17, 2021.

[27] M. Z. A. A. Kadir, S. C. Lim, J. Jasni, C. Gomes and I. H. Muluk, "The Adoption of IEC 62305 Standards for Lightning Protection System in Malaysia: A Success Story," in *12th Asia-Pacific Int. Conf. Lightning*, Langkawi, Malaysia, pp. 1-5, 2023.

[28] M. A. A. Fathi, S. C. Lim and I. L. C. Pay, "Development of A Template for the Risk Assessment for Lightning Protection System Design based on," in *34th Int. Conf. Lightning Protection*, Rzeszow, Poland, pp. 1-5, 2018.

[29] H. Abulaban and C.L. Siow, "Recent Progress on Lightning Risk Assessment and Its Applications in Malaysia," *Int. Rev. Electr. Eng.*, vol. 16, no. 1, pp. 41-49, 2021.

[30] K. Sobolewski and E. Sobieska, "Lightning Protection of Floating Photovoltaic Power Plants - Simulation Analysis of Sample Solutions," *Energies*, vol. 16, no. 10, pp. 4222, 2023.