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Energy Harvesting and Efficiency of Floating Solar Panels

Abdul Hadi Abd.Wahab[1], Farahiyah Mustafa[1]*

[1] Department of Electrical Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, 84600, Pagoh, Johor, MALAYSIA

*Corresponding Author: farahiyah@uthm.edu.my
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Abstract

Floating solar panels are an innovative renewable energy technology designed to optimise energy generation by addressing the limitations of traditional ground-mounted solar installations. Key components include managing to shade using a 775 DC motor by cutting creepers away from solar panels and running loads. This project developed a prototype floating solar panel system with a high-density polyethene (HDPE) platform and photovoltaic (PV) panels. The system was evaluated under various environmental conditions, demonstrating effective thermal management, stable power output, and reliable operation. Floating PV systems showed improved cooling efficiency and consistent performance compared to ground-mounted systems, especially during peak sunlight hours.

1. Introduction

The availability of electricity has significantly driven countries' growth and economic development. Renewable energy sources have become crucial to meet future energy demands while adhering to environmental regulations. Solar power is a sustainable and scalable technology, with photovoltaic (PV) systems being the optimal way to harness this energy [1]. Notably, almost 44% of the world's population lives near coastlines and rivers, prompting the exploration of new energy sources such as "Floating Solar" or large-scale "Solar Islands" [2]. These systems, installed on water surfaces, present logistical, environmental, and technical challenges. They require careful design to ensure stability and efficiency, considering factors like wind loads, wave action, and water level variations. Key components include corrosion-resistant solar panels mounted on buoyant floaters, stabilised by anchors and mooring lines, and an electrical system comprising cables, transformers, and inverters to convert solar radiation into usable electricity.

Floating solar panels address the land use and environmental concerns associated with traditional solar power facilities, offering benefits like enhanced efficiency and durability of PV modules, water preservation, algae management, and support for aquatic habitats. However, they face challenges like shading effects from creeping vegetation and dynamic water-based elements, which can significantly reduce their efficiency and cause overheating and damage to solar cells. Unlike land-based arrays, floating panels must manage shading from water debris, ripples, and aquatic growth, necessitating a nuanced approach to maintain optimal energy production. Regulating shading in floating solar systems requires understanding the marine environment's impact on panel exposure and ensuring that creeping growth is controlled to prevent efficiency loss.

This project aims to develop an innovative floating solar panel system, focusing on design, installation, and maintenance solutions. Objectives include exploring new floating structures, mooring concepts, and electrical connections, evaluating the cooling effect on panel performance, and providing solutions to inhibit the growth of creepers. By mitigating heat and dust accumulation, these panels not only augment the longevity of solar cells but also provide ancillary benefits such as water preservation, algae management, and the fostering of aquatic habitats.

The project features a 50 W solar panel as the primary power source, a 12V battery bank for energy storage, a 12V DC LED bulb and a 775 DC motor as the primary load. Designed to float on water, the system's adaptability allows testing under various conditions, showcasing its potential in diverse floating environments. The selection procedure for optimal installation sites considers water depth, environmental impact, distance from infrastructure, and solar exposure. This project aims to develop a floating solar panel system that maximises energy efficiency and durability while addressing environmental and logistical challenges.

2. Literature Review

The increasing demand for renewable energy has led to significant advancements in PV systems, especially in regions with high solar irradiance, like Malaysia. This lecture review explores various installation methods, including ground-mounted, rooftop, and floating solar panels, and their advantages and challenges. It comprehensively explains current and future PV systems, particularly floating technology. A PV system uses solar energy to generate electricity, which an inverter converts into alternating current (AC). This system is used in various applications, such as computers and cell phones, and promotes an environmentally responsible and productive energy environment [3]. Three primary PV installation methods have emerged in Malaysia: ground-mounted, rooftop, and floating solar panels. Ground-mounted panels are positioned on metal frames or poles, maximising sun exposure but requiring more land and more costly installation [4]. Rooftop solar panels minimise cooling loads, conserve space, and prevent shade from neighbouring structures, but heat accumulation may diminish their efficiency. Floating solar panels are installed on platforms over bodies of water, providing advantages like decreased water evaporation and algal growth while cooling the panels. However, installation becomes more costly and complicated due to the need for large, stable water bodies and panels' resistance to natural influences. Examples of these installations include the Kelantan-based Tok Uban Lake Floating Solar Farm. For example, Fig 1 (a) the solar farm at Sungai Siput, Perak and Fig 1 (b) Tok Uban Lake Floating Solar Farm, Kelantan.


(a) (b)

Fig. 1 (a) Solar farm at Sungai Siput, Perak [3] (b) Tok Uban Lake Floating Solar Farm, Kelantan. [4]

The reviewed articles comprehensively analyse floating solar panel technology, highlighting its numerous benefits and promising future applications worldwide. As E. Solomin et al. [5] mentioned, designs with hybrid floating solar plants offer higher energy yields, better land usage, lower water use, and more efficient capacity utilisation. M. Wagh et al. [6] highlight the benefits of floating solar systems. The installation patterns across the globe show a consistent demand for and investment in renewable energy sources. Additionally, Ziar [7] highlights the enormous potential for floating PV systems to boost energy output worldwide, highlighting their significance at a time when the demand for renewable electricity was reportedly up 90 % last year. Specifically, reports reveal that it is possible to surpass the capacity of a single hydropower plant by 100 % or more through the construction of floating solar panels, demonstrating significant growth potential when combined with hydropower facilities. There are currently some floating photovoltaic (FPV) projects in India, and the development of FPV technology is a step forward for solar energy, as described by Badhoutiya [8]. The report also emphasises how solar power will become omnipresent, highlighting the undersea link of FPV. M. A. S. Jamalludin et al. [9] focus on Southeast Asia, particularly Malaysia, where hexagon-shaped floating solar panels have a significant advantage over round-shaped installations regarding energy yield, creating room for creative design possibilities. The benefits of FPV technology, including increased efficiency, a lower rate of water evaporation, higher-quality water, and land savings, are also discussed by E. Yousuf et al. [10]. These studies shed light on the rapidly evolving technology and its numerous geographical applications. C. Gamarra and J. Ronk [11] discuss these problems, emphasising the benefits and viability of floating solar technology, particularly in Texas. For water-stressed areas, emphasis is placed on energy production, evaporation reduction, and water conservation. Additionally, M. Elshafei et al. [12] discuss the potential widespread application of floating solar panels over Egypt's Lake Nasser to produce affordable green energy and conserve massive amounts of freshwater. Furthermore, several significant factors, such as wave drift, currents, total loads, and dynamic load incorporation, are listed in the paragraph on preliminary mooring design for Floating Solar Photovoltaic (FSPV) arrays [13]. These case studies and practical evaluations partially disclose the environmental factors and technical challenges of installing floating solar panels.

3. Methodology

Floating solar panels use photovoltaic cells to convert solar energy into DC electricity, which is then connected to a buoyant floating framework with mooring system support. The DC electricity is then sent into batteries using a solar charge controller, providing the load with DC power. Fig 2 illustrates a block diagram converting solar energy into electricity and distributing it throughout the broader electrical grid. It also addresses environmental, monitoring, and control aspects for sustainability and optimal performance.

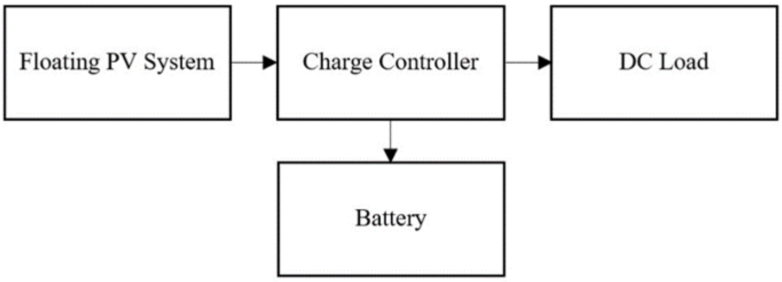


Fig 2 System block diagram.

Fig 3 shows the flowchart of a solar power system first fed by solar PV panels, which a charger controller regulates. The system incessantly loops back to the PV input if the produced power is unavailable. As soon as power is available, it powers a DC load and charges the battery at the same time. The procedure ends after successfully distributing the available energy, guaranteeing efficient battery charging and DC load powering management.

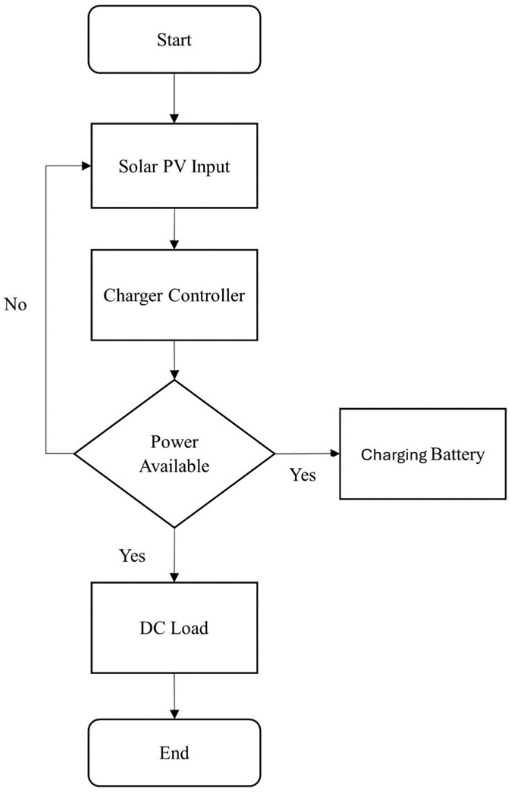


Fig 3 Flowchart system.

4. Results and Discussions

The project results have been analysed and evaluated through a series of experiments. These experiments focused on testing the functions and improvements of the floating PV system. Innovations like using a 775 DC motor to control climbing plants were emphasised to prevent shading, which can disrupt the system's performance. Tests were conducted under floating conditions and on land to compare the results. This allowed the assessment of the system's reliability in different situations, considering temperature and performance from various angles. Overall, the results show that this floating PV system can generate energy effectively while addressing the problem of climbing plants.

4.1 Actual Prototype

A floating PV prototype is built to test and gather data on renewable energy challenges. The prototype uses an HDPE platform with 8 HDPE support PVs mounted on a metal frame with an adjustable tilt angle for maximum sunlight exposure. It also has an MPPT solar charge controller, a battery, a 775 DC motor, and a 12V DC LED bulb for load testing. The system simulates real-world conditions and uses a lawnmower-like motor to cut creeping plants. Fig 4 shows the prototype floating solar panel.

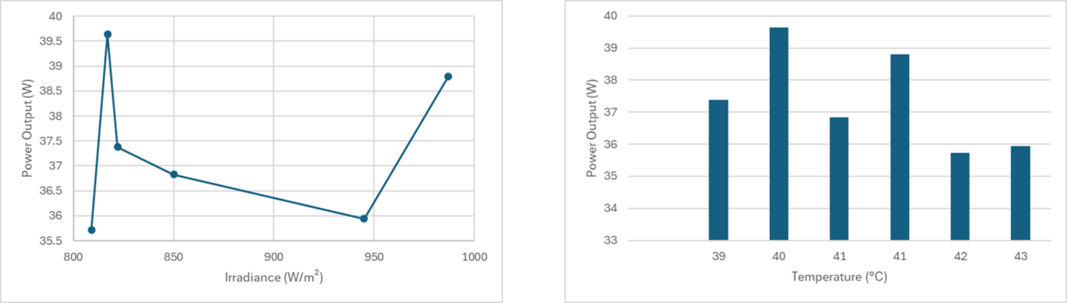
Fig 4 The prototype floating solar panel.

4.2 Load 775 DC Motor

The 775 DC motor load analysis for both floating and ground-mounted PV systems, evaluated at a 5° tilt angle, reveals robust performance under varying environmental conditions. The floating PV system, operating within an irradiance range of 809 W/m^2 to 987 W/m^2 and temperatures between 39°C and 43°C, shows stable power delivery. The solar charge controller maintains a voltage between 13.18 V and 13.91 V and a current of 1.2 A to 1.3 A, while the battery operates with a voltage of 13.18 V to 13.62 V and a current of 1.1 A to 1.4 A, producing a power output of 14.52 W to 19.05 W. The 775 motor runs with a voltage of 13.23 V to 13.67 V, a current of 2.7 A to 2.9 A, and generates power ranging from 35.72 W to 39.64 W. The system demonstrates a strong correlation between higher irradiance and increased power output, with effective thermal management minimising performance loss despite high temperatures. Table 1 shows the measured results of 775 DC motors for floating PVs. Fig 5 (a) shows the generated output power for the DC motor with different irradiance for floating PVs, and Fig 5 (b) shows the power output of the floating PV 775 DC motor at different temperatures.

Table 1 measured the results of 775 DC motors for floating PVs

No	Tilted Angle (°)	Irradiance (W/m^2)	Temperature (°C)	Solar Charger Controller		Battery Reading			775 Motor		
				Voltage (V)	Current (A)	Voltage (V)	Current (A)	Power Output (W)	Voltage (V)	Current (A)	Power Output (W)
1	5	987	41	13.67	1.3	13.36	1.2	15.91	13.38	2.9	38.8
2	5	945	43	13.52	1.2	13.27	1.2	15.92	13.31	2.7	35.94
3	5	850	41	13.91	1.3	13.62	1.2	16.34	13.64	2.7	36.83
4	5	822	39	13.42	1.2	13.21	1.1	14.52	13.35	2.8	37.38
5	5	817	40	13.90	1.3	13.61	1.4	19.05	13.67	2.9	39.64
6	5	809	42	13.18	1.2	13.18	1.3	17.13	13.23	2.7	35.72



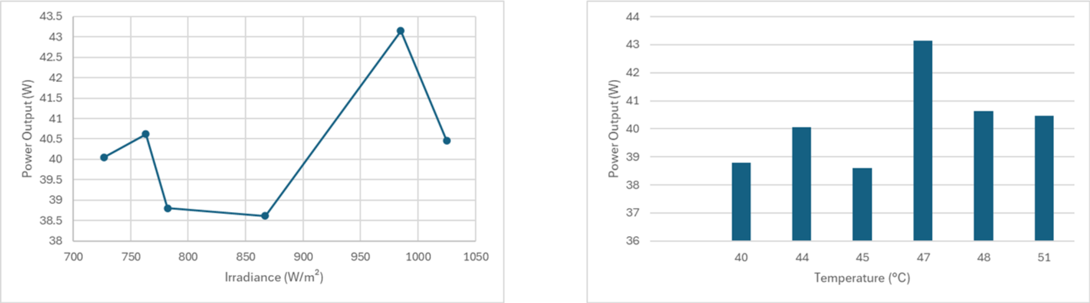
(a) (b)

Fig 5 (a) Generated and (b) Power output for 775 DC motor floating PV at different irradiance and temperature.

In contrast, the ground-mounted PV system, experiencing irradiance levels from 727 W/m^2 to 1025 W/m^2 and temperatures between 40°C and 51°C, also maintains efficient operation. The solar charge controller outputs a steady voltage of 13.45 V to 14.15 V and a current of 1.2 A to 1.4 A, while the battery shows consistent performance with a voltage of 13.32 V to 13.93 V, a current of 1.1 A to 1.4 A, and power output between 14.86 W and 19.5 W. The 775 motors in this setup operate with a voltage of 13.35 V to 13.95 V, a current of 2.8 A to 3.1 A, and a power output of 38.61 W to 43.15 W. Despite higher temperatures, the ground-mounted system effectively manages thermal conditions and maintains reliable energy conversion, with increased irradiance leading to higher power production. Table 2 shows the measured results of 775 DC motors for ground-mounted PVs. Fig 6 (a) shows the generated output power for the DC motor with different irradiance for ground-mounted PVs, and Fig 6 (b) shows the power output of the ground-mounted PV 775 DC motor at different temperatures.

Table 2 Measured results of 775 DC motors for ground-mounted PVs

No	Tilted Angle (°)	Irradiance (W/m^2)	Temperature (°C)	Solar Charger Controller		Battery Reading			775 Motor		
				Voltage (V)	Current (A)	Voltage (V)	Current (A)	Power Output (W)	Voltage (V)	Current (A)	Power Output (W)
1	5	1025	51	14.15	1.3	13.93	1.4	19.5	13.95	2.9	40.46
2	5	985	47	14.12	1.2	13.92	1.3	18.1	13.92	3.1	43.15
3	5	867	45	14.01	1.2	13.83	1.4	19.36	13.79	2.8	38.61
4	5	782	40	14.05	1.3	13.72	1.1	15.09	13.38	2.9	38.8
5	5	763	48	13.61	1.2	13.51	1.1	14.86	13.52	3.0	40.62
6	5	727	44	13.45	1.4	13.32	1.3	17.32	13.35	3.0	40.05



(a) (b)

Fig 6 (a) Generated and (b) Power output for 775 DC motor for ground-mounted PV at different irradiance and temperatures.

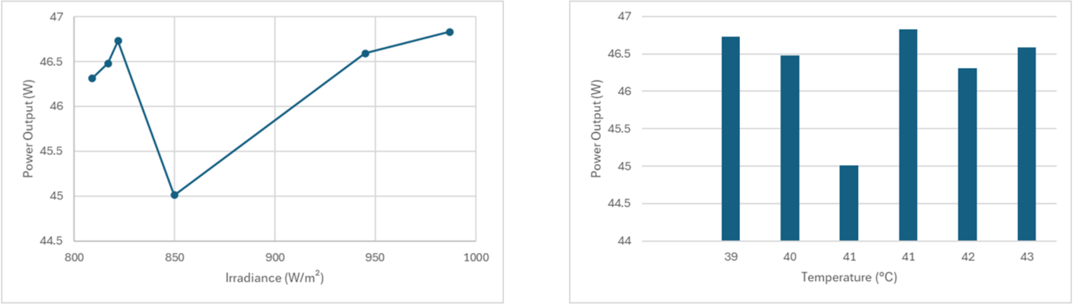
Comparatively, both systems exhibit strong performance and good thermal management, with ground-mounted panels producing slightly more power, especially in high-temperature and high-irradiance conditions. However, the floating panels offer consistent power output and reliability. Optimisation through tilt angle adjustments and improved cooling mechanisms could enhance performance, particularly in managing heat and maximising solar energy absorption. Overall, the data underscores the efficiency and reliability of both PV systems in different environmental conditions, with each system showcasing its strengths in power generation and thermal management.

4.3 Combined load

The analysis of the combined load involving the 775 DC motor and the 12V DC LED bulb demonstrates the reliability and sustainability of the energy storage and distribution system. The system handles higher electrical demands for floating PVs at a 5° tilt angle, maintaining steady voltage 13.18V-13.91V and current 1.2A-1.3A from the solar charge controller. The battery performance remains consistent with voltage 13.18V-13.62V and current 1.1A-1.4A, even as sunlight intensity ranges from 809 W/m^2 to 987 W/m^2 and temperatures from 39°C to 43°C. The combined load produces a voltage between 13.23V and 13.67V, drawing 3.3A to 3.5A and outputting 45.01W to 46.83W, indicating effective thermal management and system reliability. Table 3 shows the measured results of the combined load for floating PVs. Fig 7 (a) shows the generated output power for combined load different irradiance for floating PVs, and Fig 7 (b) shows the power output floating PV combined load at different temperatures.

Table 3 Measured results of combined load for floating PVs.

No	Tilted Angle (°)	Irradiance (W/m^2)	Temperature (°C)	Solar Charger Controller		Battery Reading			Both On		
				Voltage (V)	Current (A)	Voltage (V)	Current (A)	Power Output (W)	Voltage (V)	Current (A)	Power Output (W)
1	5	987	41	13.67	1.3	13.36	1.2	15.91	13.38	3.5	46.83
2	5	945	43	13.52	1.2	13.27	1.2	15.92	13.31	3.5	46.59
3	5	850	41	13.91	1.3	13.62	1.2	16.34	13.64	3.3	45.01
4	5	822	39	13.42	1.2	13.21	1.1	14.52	13.35	3.5	46.73
5	5	817	40	13.90	1.3	13.61	1.4	19.05	13.67	3.4	46.48
6	5	809	42	13.18	1.2	13.18	1.3	17.13	13.23	3.5	46.31



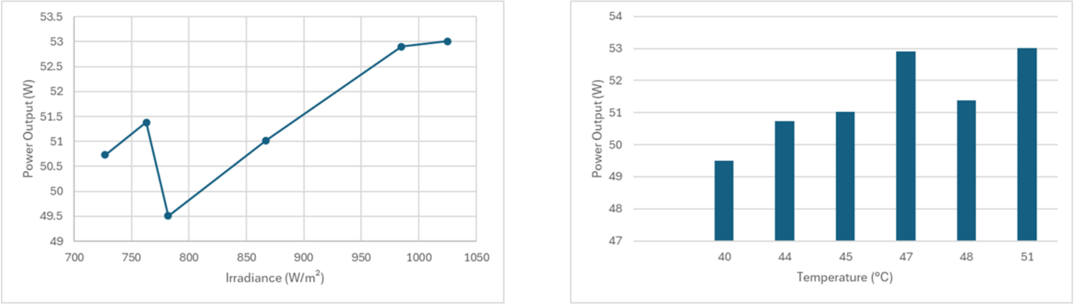
(a) (b)

Fig 7 (a) Generated and (b) Power output for combined load for floating PV at different irradiance and temperature.

For ground-mounted PVs at a 5° tilt angle, the system performs efficiently under irradiance levels of 727 W/m^2 to 1025 W/m^2 and temperatures between 40°C and 51°C. The solar charge controller maintains a steady voltage output of 13.45V to 14.15V and a current between 1.2A and 1.4A, while the battery consistently delivers power outputs ranging from 14.86W to 19.5W. When powering the 12V DC LED bulb and the 775 DC motor, the system draws 3.7A to 3.8A and produces 49.51W to 53.01W. This demonstrates the system's ability to meet increased power demands without significant performance loss and highlights its energy storage and conversion efficiency. Table 4 shows the measured results of the combined load for ground-mounted PVs. Fig 8 (a) shows the generated output power for combined load different irradiance for ground-mounted PVs, and Fig 8 (b) shows the power output ground-mounted PV combined load at different temperatures.

Table 4 Measured results of combined load for ground-mounted PVs

No	Tilted Angle (°)	Irradiance (W/m^2)	Temperature (°C)	Solar Charger Controller		Battery Reading			Both On		
				Voltage (V)	Current (A)	Voltage (V)	Current (A)	Power Output (W)	Voltage (V)	Current (A)	Power Output (W)
1	5	1025	51	14.15	1.3	13.93	1.4	19.5	13.95	3.8	53.01
2	5	985	47	14.12	1.2	13.92	1.3	18.1	13.92	3.8	52.9
3	5	867	45	14.01	1.2	13.83	1.4	19.36	13.79	3.7	51.02
4	5	782	40	14.05	1.3	13.72	1.1	15.09	13.38	3.7	49.51
5	5	763	48	13.61	1.2	13.51	1.1	14.86	13.52	3.8	51.38
6	5	727	44	13.45	1.4	13.32	1.3	17.32	13.35	3.8	50.73



(a) (b)

Fig 8 (a) Generated and (b) Power output for combined load for ground-mounted PV at different irradiance and temperatures.

Both floating and ground-mounted PV systems exhibit reliable performance under varying conditions, demonstrating good thermal management and the capacity to handle multiple loads. Despite fluctuations in temperature and sunlight intensity, the stability in voltage and current outputs underscores the systems' practicality and efficiency in renewable energy production. This makes them viable options for sustainable energy solutions, capable of maintaining consistent and sufficient electricity supply to various loads simultaneously.

4.4 Solution Inhibit the Growth of Creepers

The 775 DC motor is an innovative solution for preventing creeping plants from obstructing floating PV systems. Its high torque and durability ensure efficient and structural integrity. The motor operates reliably in various environmental conditions, making it suitable for fluctuating water bodies. Solar panels are activated periodically to reduce excessive plant growth, reduce manual intervention, and ensure optimal efficiency. The adaptability of the 775 DC motor to different power sources, including solar energy generated by PV panels, increases the solution's sustainability and survivability. The motor prevents fast and invasive creeping plants, increasing the efficiency of energy production. Fig 9 shows the DC 775 motor mounted at floating PV.

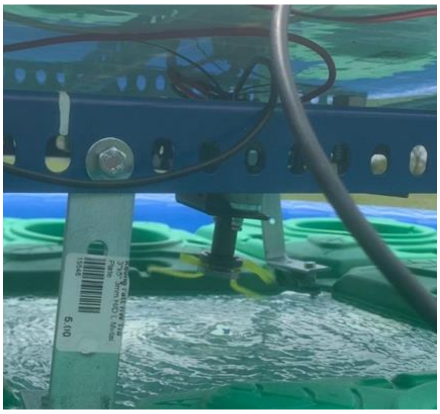


Fig 9 The DC 775 motor.

5. Conclusion

The project aimed to design a floating solar panel system that generates energy efficiently while reducing shading from climbing plants. A prototype was created and tested, demonstrating the feasibility and efficiency of such systems. Key performance features included excellent thermal control, consistent performance in various weather conditions, and adaptability to different water bodies. Floating PV systems offer a reliable and efficient alternative for renewable energy production, addressing land shortage issues and improving energy production efficiency. Future recommendations include modern cooling solutions, dynamically adjusting panel tilt angles based on real-time sun position data, better plant shading management systems, environmental tests on water bodies, exploring hybrid systems combining floating PV with other renewable energy sources, research and development on new materials and design improvements, and collaboration between engineers and environmental scientists to develop eco-friendly and sustainable techniques.

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References

[1] Mohd, Firdaus Muhammad-Sukki, Siti Hawa Abu-Bakar, and Nazmi Sellami, “Potential of floating solar technology in Malaysia,” ResearchGate, Sep. 2019. https://www.researchgate.net/publication/334130053_Potential_of_floating_solar_technology_in_Malaysia.

[2] H. U. Akole and P. S. Jadhav, "Floating Solar Plant," 2018 3rd International Conference for Convergence in Technology (I2CT), Pune, India, 2018, pp. 1- 4, doi: 10.1109/I2CT.2018.8529479.

[3] “Photovoltaic system - Energy Education,” Energyeducation.ca, 2020. https://energyeducation.ca/encyclopedia/Photovoltaic_system

[4] Solarvest Holdings Berhad, “Solar Farms in Malaysia - What are the Benefits/Disadvantages? | Solarvest,” Solarvest Holdings Berhad, Sep. 21, 2018. https://solarvest.my/2018/09/21/solar-farms-malaysia/

[5] E. Solomin, E. Sirotkin, E. Cuce, S. P. Selvanathan, and S. Kumarasamy, “Hybrid Floating Solar Plant Designs: A Review,” Energies, vol. 14, no. 10, p. 2751, May 2021, doi https://doi.org/10.3390/en14102751.

[6] M. Wagh, P. Desai, and Sujay, “A Review on Floating Solar Photovoltaic Power Plants A Review on Floating Solar Photovoltaic Power Plants,” International Journal of Scientific & Engineering Research, vol. 8, no. 6, 2017.

[7] Hesan Ziar, “Floating Solar Stations,” ResearchGate, Jun. 03, 2021. https://www.researchgate.net/publication/352172929_Floating_Solar_Station s

[8] Badhoutiya, “Advancements in PV Technology- Floating Photovoltaics,” 2023 5th International Conference on Smart Systems and Inventive Technology (ICSSIT), Jan. 2023, doi: https://doi.org/10.1109/icssit55814.2023.10060971.

[9] M. A. S. Jamalludin et al., “Potential of floating solar technology in Malaysia,” International Journal of Power Electronics and Drive Systems (IJPEDS), vol. 10, no. 3, p. 1638, Sep. 2019, doi: https://doi.org/10.11591/ijpeds.v10.i3.pp1638-1644.

[10] E. Yousuf, M. Khokhar, M. Zahid, and J. Kim, “A Review on Floating Photovoltaic Technology (FPVT),”doi: https://doi.org/10.21218/CPR.2020.8.3.067.

[11] C. Gamarra and J. Ronk, “Floating Solar: An Emerging Opportunity at the Energy-Water Nexus,” ResearchGate,Mar.25,2019.https://www.researchgate.net/publication/333387978_Floating_Solar_An_Em erging_Opportunity_at_the_Energy-Water_Nexus

[12] M. Elshafei et al., “Study of Massive Floating Solar Panels over Lake Nasser,” Journal of Energy, vol. 2021, pp. 1–17, Apr. 2021, doi: https://doi.org/10.1155/2021/6674091.

[13] R. Kanotra and R. Shankar, “Floating Solar Photovoltaic Mooring System Design and Analysis,” OCEANS 2022 - Chennai, Feb. 2022, doi: https://doi.org/10.1109/oceanschennai45887.2022.9775352.