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Design of Hybrid Portable Underwater Turbine Hydro and Solar Energy Power Plants: Innovation to Use Underwater and Solar Current as Alternative Electricity in Dusun Dongol Sidoarjo

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ABSTRACT The need for electrical energy in Indonesia continues to increase every year. In line with the increase in the electrification ratio to 100% in 2050. Additionally, the need for electrical energy can reach seven times, namely 1,611 TWh. The purpose of this paper is to offer the concept of hybrid gadget configuration, modeling, renewable power sources, standards for optimization and manipulation strategies of hybrid gadgets, and software programs used for the main measure. For this reason, innovation is needed in terms of fulfilling electrical energy by utilizing the potential of renewable energy, one of which is water energy, which is 45,379 MW from a total resource of 75,091 MW. Therefore, innovations related to renewable energy have been created, namely the hybrid portable underwater turbine hydropower plant and solar energy. This power plant uses undersea currents as its driving force, which is hybridized with solar power to increase the production of electrical energy. This power plant has the advantage of having an underwater turbine design that is resistant to underwater flow and the direction of water flow to increase the working efficiency of the underwater turbine. From the test results, the underwater portable hydro turbine produces 950 W in a day. The solar panels produce 65.6 Watts a day. The total hybrid that can be produced is 1.02 kW per day. In the implementation, it can be loaded up to 900 (VA) such as lights, fans, TVs, etc. This hybrid power plant can be a solution to meet the electricity needs in the area around Dusun Dongol, Sidoarjo, through alternative electrical energy innovation.

INDEX TERMS Electrification, Turbine Hydro, Solar Energy, Renewable Energy.

I. INTRODUCTION

The need for electrical energy in Indonesia continues to increase every year. In line with the increase in the electrification ratio target to 100% by 2025, the electricity demand is projected to raise more than seven times to 1,611 TWh in 2050. To meet this electricity demand, the government has made a 35 GW program which has been confirmed in the Medium Term Development Plan document National (RPJMN) 2015 to 2019 [1]. When this program was launched, there was a slowdown in achievement due to economic and technical factors, such as the characteristics of each type of power plant project. These various factors into account, the additional power generation capacity during 2015 to 2019 is estimated to be only 12 GW, much lower than the initial target of 35 GW. Currently, the power plants that have COD (Commercial Operation Date) are only operating around 4% (± 1.5GW). Under these conditions, the implementation of the 35 GW program is expected to be achieved in 2025 - 2026 [1].

From the additional power generation capacity, in 2025, coal-fired power plants are estimated to still dominate, with a share reaching 58% or around 50 GW [1]. However, the existence of coal as a fuel for electricity generation is decreasing over time, and of course, it cannot be renewed. According to BPPT, in 2018, coal reserves will be exhausted within 68 years [1].

For this reason, innovations are needed in terms of the fulfillment of electrical energy in Indonesia continuously by utilizing the potential of renewable energy. One of which is hydro energy, which is 45,379 MW from a total resource of 75,091 MW [2][3]. This renewable energy is abundant energy in nature [6]. Therefore, these potential innovations related to renewable energy have been created, namely the Hybrid Portable Underwater Turbine Hydro and Solar Energy hybrid power plant. This power plant uses an undersea current as propulsion which is hybridized with solar power to increase the production of electrical energy [4][5][6].

In previous studies, when using solar cells and wind turbines, there were shortcomings where the placement was not proper so that it could not produce the expected power, especially in the wind turbine section [7]. In this study, the use of solar cells is very supportive of coping with optimal battery charging [8][9][10].

This power plant has the advantage that there is an Underwater turbine design that is resistant to underwater flow and a water flow direction to increase the work efficiency of the underwater turbine [6][3][11]. From the test results, the portable Underwater turbine hydro produces 1.02 kW a day [12]. Solar panels produce 65.6 Watts a day. The total hybrid that can be produced is 1.02 kW a day. In its implementation, it can supply loads of up to 1800 (VA) such as lamps, fans, TV, etc. This hybrid power plant can be a solution to help meet electricity needs in the area around Dusun Dongol, Sidoarjo, through alternative electrical energy innovations [13][14].

II. MATERIALS AND METHODS

A. MATERIALS AND EQUIPMENT

The tools and materials needed in the manufacture and testing of this hybrid power plant include:

1.) DIMENSIONS

The unit can be transported by a small pickup truck or SUV with a weigh-in at 215 pounds (98 kg). The wind turbine is 59 inches (1.5 m) in diameter; its tower is 149 inches (3.8 m) tall, extendable to a maximum height of 203 inches (5.2 m). The PV panel is 47 inches (1.2 m) wide, and the battery bank is 32 inches (0.8 m) wide.

2.) PV

A single 100-watt monocrystalline solar panel provides most of the power for this unit. Monocrystalline is slightly more expensive than the more common polycrystalline solar panels, but monocrystalline panels are more efficient. On a sunny day in a temperate zone, the panel can generate about 500 watt-hours of energy per day - even more in tropical climates. With the price of solar panels being so low, I'm surprised that they didn't use two or more panels in this system. (More on that later.)

3.) WIND

The wind turbine sweeps an area of 2732 square inches (1.76 square meters). It feeds a Freedom Permanent Magnet Generator (PMG) whose maximum output is 1600 watts. That sounds impressive until we look at the power curve for that generator. In order to generate 1600 watts, a wind speed of 22 m/s (50 mph) would be required. If the unit operates under those conditions, I hope that baby is anchored down with guy wires. In reality, at a hub height of only 173 inches (4.4 m), the typical wind speed is very low. In fact, most wind maps give the wind velocity at 33 feet (10 m) - more than twice the height of this tower. For the sake of argument, let's say the average wind speed is 3.6 m/s (8 mph). The maximum power in the wind, given the velocity and the area swept by the rotor, is about 50 watts. Most small wind turbines are about 30% efficient (at best), so in this scenario, the turbine will generate about 15 watts of power. If that's a steady wind, then the turbine would produce 360 watt-hours per day. (For a detailed analysis of small wind turbines, check out my article about rooftop wind turbines.)

4.) STORAGE

A pair of 12V, 115 Ah Everstart deep cycle marine batteries provides up to 2760 Wh of storage - adequate for emergency lighting and charging small electronics. While it could power a hot plate for a short time, I think a small camp stove with a propane cylinder would be a better source of heat for cooking. Based on my power calculations, it would take about three days to charge the batteries using renewable powerfully. Of course, the unit would arrive with fully charged batteries, so the PV and wind would need to top off the batteries rather than charge them from zero.

5.) INVERTER

An inexpensive Cen-Tech modified sine wave inverter turns the battery's DC output into AC power. It can deliver 1500 watts continuously and up to 3000 watts in short bursts. Unfortunately, these small inverters are only about 87% efficient.

6.) OUTPUT

According to the press release, this hybrid generator is capable of producing 1.5 kWh of energy per day. From my calculations, which are pretty generous as far as wind speed is concerned, it's likely to produce about half that amount.

7.) UNDERWATER TURBINE

Underwater Turbine is a turbine that has a working principle of converting the potential energy of underwater flow into mechanical energy, which is connected through a generator and the generator converting mechanical energy into electrical energy. This turbine uses a special design in water to make it durable (FIGURE 1) [15][16].

FIGURE 1. Underwater Turbine [11]

8.) GENERATOR DC

A DC generator is a dynamic electrical machine that converts mechanical energy into electrical energy, which generates DC / direct current. The DC generator only has one ring that is split in the middle, so it is called a commutator. The DC generator consists of two parts, namely the stator, namely the DC generator consisting of two parts, namely the stator, which is the stationary part of the DC engine, and the rotor, which is the rotating part of the DC engine [3]. The stator consists of a motor frame, stator winding, charcoal brush, bearing, and terminal box. In comparison, the rotor consists of a commutator, rotor winding, rotor fan, and rotor shaft [17][18] (FIGURE 2).

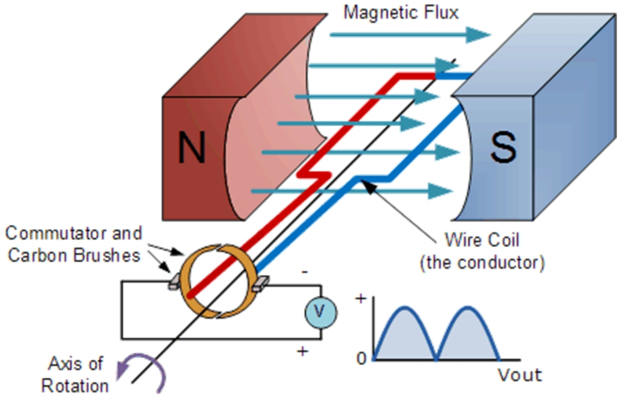

FIGURE 2. DC generator

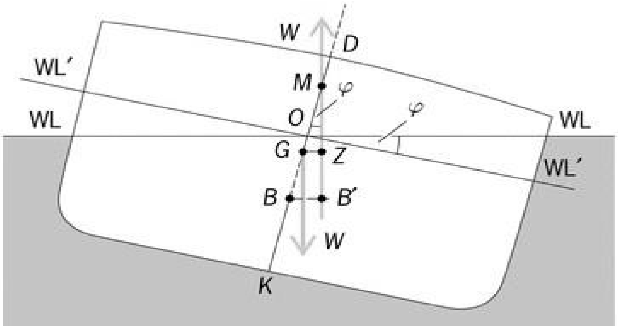

FIGURE 3. Basic symbols on a floating building [13]

9.) BUOYANCY

If a stationary object is completely submerged in a fluid or floats in such a way that only part of it is submerged, the resultant fluid force acting on the object is called the "buoyant force" [19]. A net upward force occurs because the pressure increases with depth, and the compressive forces acting from below are greater than the forces acting from above. The point through which the buoyancy force acts is called the center of buoyancy. For more details, it can be seen in FIGURE 3.

10.) WATER WHEEL

A waterwheel is a means to convert water energy into mechanical energy in the form of rotation on the wheel shaft [10]. The undershot water wheel works when the flowing water hits the blade wall which is located at the bottom of the waterwheel (FIGURE 4).

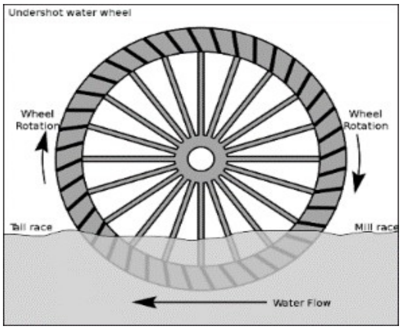

FIGURE 4. Undershot Waterwheel

This type is suitable for installation in shallow waters on a flat area. The advantages of construction are simpler, more economical, easy to move. The disadvantage of this type of turbine is that it has a small efficiency [3][5].

11.) MECHANICAL DESIGN

The design here has a function as a model and a reference in the form of installation and performance design (FIGURE 5).

FIGURE 5. Hybrid Powerplant Design

The design of this power plant was created using the Autocad 2007 application. This design was intended to facilitate the realization of this hybrid power plant.

12.) ELECTRICAL DESIGN

FIGURE 6 shows a working system or work scheme that can be divided into three main parts, namely the input, processing, and output parts. The input is the movement of the underwater flow and solar radiation by using underwater turbine processing and solar panels. The output consists of a charge and a battery.

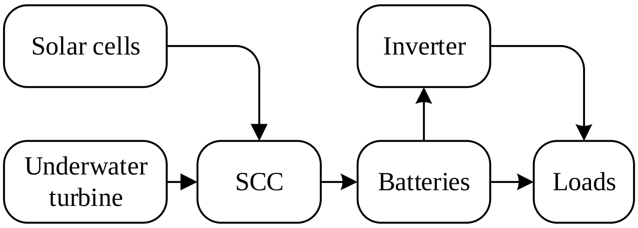

FIGURE 6. Working Principle

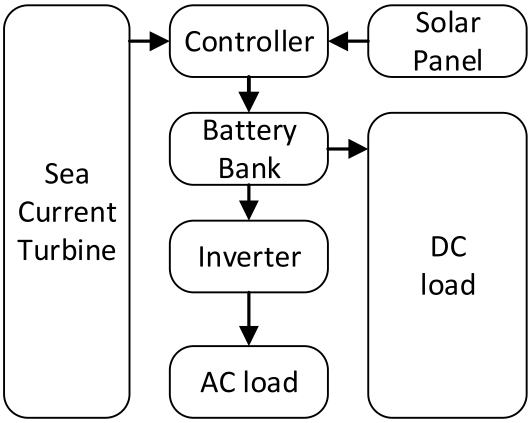

FIGURE 7. Flowchart Hybrid PV and Sea Current Turbine

The movement of the underwater flow from the river can drive the underwater turbines and make the generator work, and the solar radiation received by the solar panels can make the panels work (FIGURE 7). With the movement of underwater flow and the presence of solar radiation that is processed by solar panels, it can produce voltage and current. The voltage and current are charged to the battery. The electric power in the battery can be directly used to the lamp and can be used as household electricity through the on-grid inverter.

III. RESULTS

A. TESTING OF PORTABLE UNDERWATER TURBINE HYDRO PROTOTYPES.

This test was conducted to determine the power generated by the Portable Under Water Turbine Hydro prototype. This test was carried out in Mas River, Dongol Hamlet, Sidoarjo Regency (TABLE 1).

TABLE 1
RESULTS OF POWER TESTING ON THE PROTOTYPE OF PORTABLE UNDER WATER TURBINE HYDRO

No.	Power (Watt)		
	DC Canon Generator		DC 24 Volt Generator
	V = 1,330 m/s	V = 0,423 m/s	V = 0,423 m/s
1	1,2	0,8	2,98
2	1	0,93	2,79
3	1,34	1	3,89
4	1,25	0,78	3,85
5	1,34	0,9	3,99
Mean	1,226	0,882	3,5

From the results of the tests that have been carried out, a graph can be made, as shown in FIGURE 8. The test table explains that the Portable Under Water Turbine Hydro test in one cycle gets an average power of 3.5 watts. Then for one day, it gets a result of 950 W.

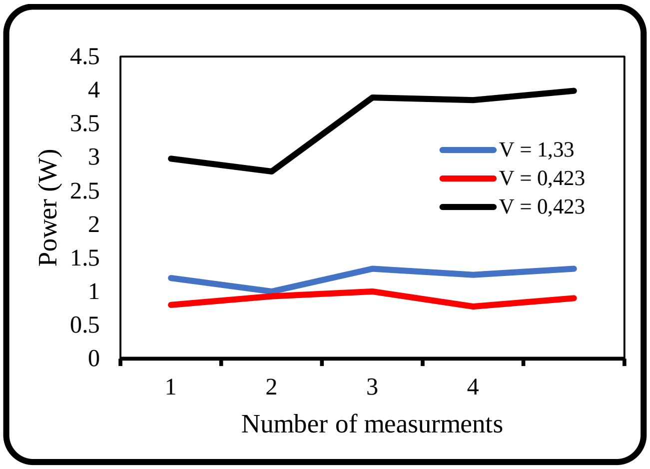

FIGURE 8. Underwater turbine test chart

B. SOLAR PANEL TESTING

This test is carried out with the aim of knowing the maximum power that can be taken by solar panels. This data can be seen in TABLE 2.

TABLE 2
SOLAR PANEL TESTING

Time (Hours)	Voltage (V)	Current (A)	Power (Watt)
9:00	19.79	0.44	8.7076
9:30	19.88	0.33	6.5604
10:00	19.75	0.35	6.9125
10:30	19.93	0.12	2.3916
11:00	19.44	0.3	5.832

Time (Hours)	Voltage (V)	Current (A)	Power (Watt)
11:30	19.53	0.128	2.49984
12:00	19.5	0.12	2.34
12:30	19.5	0.14	2.73
13:00	19.12	0.3	5.736
13:30	18.95	0.4	7.58
14:00	19.36	0.3	5.808
14:30	19.32	0.3	5.796
15:00	19.59	0.125	2.44875

From the results of the tests that have been carried out, a graph can be made, as shown in FIGURE 9.

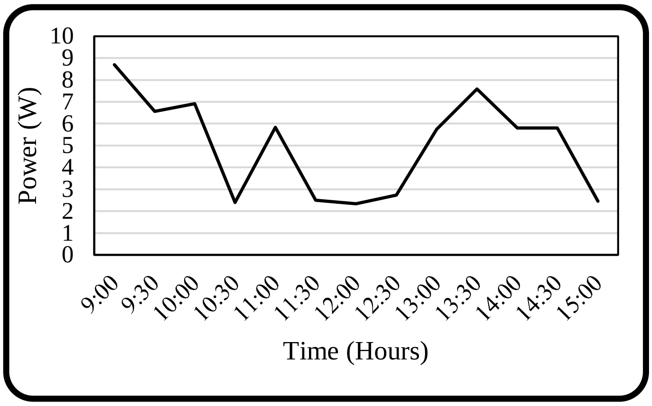

FIGURE 9. **Solar panel power test chart**

TABEL 2 pengujian tersebut menjelaskan, bahwa pengujian panel surya selama satu hari mendapatkan hasil sebesar 65,6 Watt.

C. HYBRID TESTING RESULTS

Hybrid test results get the following results shown in TABLE 3.

TABLE 3
Hybrid Power Calculation

No.	Information	Power
1.	Underwater Turbine	950 Watt
2.	Solar cell	65,6 Watt
3.	Hybrid	1,02 kW

IV. DISCUSSION

The test results on the Portable Under Water Turbine Hydro generate power up to 950 W in one day. The test results on the solar panels produce power reaching 65.6 watts a day. The amount of hybrid power between Portable Under Water Turbine Hydro and solar panels has the potential to reach 1.02 kW in one day.

In this study, a type of underwater turbine was used as a hydroelectric generator. This is because by using an underwater turbine, the turbine will not be affected by the high and low water levels. Additionally, it will increase the efficiency of the turbine itself. Unlike the floating turbine, which is complicated by the construction of a pontoon and a fairly complicated mooring system, this underwater turbine does not use mooring, but it is enough to put ballast on the lower side of the turbine itself. The load used can be iron, stone, coral, etc.

The reason that designers put solar and wind together is that they're complementary - sunny days tend to be calm, while cloudy days are often windy. Also, the turbine can generate power at night, assuming the wind is blowing. The utility-scale works well because large wind turbines are more efficient and reach higher velocity winds [20]. But small turbines on short towers produce so little energy that they're usually not worth the expense and complexity. Some designs cannot be scaled down effectively; this is one of them.

As you can see from the numbers, it would be more cost-effective to use extra solar panels and a larger storage system than to include a small wind turbine. For the cost of the permanent magnet generator (not even including the blades and the tower), another 100 W solar panel could have been added. Even on a cloudy day, I suspect that the PV panels would still generate more energy than the wind turbine.

One goal of this project was to show that one could produce an affordable emergency generator that uses only renewable energy. In this case, the students successfully built a functional prototype for about $1700. But the larger goal of a student design project is to learn real-world engineering skills. If I were designing a commercial version of this, I'd go with all solar and no wind turbine. But for a class project, it's important that the students learn the mechanical concepts associated with a wind turbine because those same concepts apply to other mechanical systems. When the field tests the unit under realistic conditions, I think they'll learn that some designs can be scaled up or down and still work effectively, while others - like small wind complementing solar - don't work out so well.

In previous studies, when using solar cells and wind turbines, there were shortcomings where the placement was not right so that it could not produce the expected power, especially in the wind turbine section. In this study, the use of solar cells is very supportive of coping with optimal battery charging. So in this study, try a hybrid combination with other models.

V. CONCLUSION

Hybrid strength technology gadget is the right and powerful answer for strength technology than nonrenewable power assets. It has more efficiency. It can offer to foreign places in which authorities are not able to reach. So that the strength may be made use of in which it generated on the way to reduce the transmission losses and cost. Cost discount may be completed via way of means of growing the manufacturing of the equipment. People ought to inspire to apply the renewable power assets now no longer best for the personal desirable however for the worldwide and surroundings desirable too. It is incredibly secure for the surroundings because it doesn't produce any emissions and dangerous waste products like traditional power assets. It is a cost-powerful answer for technology.

Test results on the Portable Under Water Turbine Hydro generate power up to 950 W in one day. The test results on the solar panel produce power reaching 65.6 watts a day. The amount of hybrid power between Portable Under Water Turbine Hydro and solar panels has the potential to reach 1.02 kW in one day. When Superstorm Sandy hit the east coast of the United States, power was out for weeks, and fuel supplies were severely limited. A few residents who had solar panels were letting their neighbors charge cell phones and other portable devices.

It is hoped that in the future, we can design models using Boost, Buck, and Buck-Boost converters and can make three hybrid generators.

REFERENCES

[1] S. Suharyati, H. P. Sadmoko, L. W. Jamludin, and I. P. Nurina, *Indonesai Energy Outlook 2019*. Jakarta: Secretariat General National Energy Council, 2019.
[2] S. Elschner, F. Breuer, H. Walter, M. Stemmle, and J. Bock, "HTS Components for High Voltage Resistive Current Limiters Based on a Magnetic Field Triggered Concept," *IEEE Trans. Appl. Supercond.*, vol. 17, no. 2, pp. 1772–1775, 2007.
[3] J. Chen, Q. Xu, and K. Wang, "Research and Application of Generator Protection Based on Fiber Optical Current Transformer," *IEEE Access*, vol. 8, pp. 172405–172411, 2020.
[4] W. S. Lee, Y. J. Hwang, J. Kim, S. Nam, Y. G. Park, and T. K. Ko, "Quench Protection for HTS Current Leads by Adding Connected HTS Bridges," *IEEE Trans. Appl. Supercond.*, vol. 24, no. 3, pp. 1–4, 2014.
[5] H. Wang and J. Shen, "Analysis of the Characteristics of Solar Cell Array Based on MATLAB/Simulink in Solar Unmanned Aerial Vehicle," *IEEE Access*, vol. 6, pp. 21195–21201, 2018.
[6] L. Fraas, J. Avery, L. Minkin, H. X. Huang, and P. Uppal, "Portable Concentrated Sunlight Power Supply Using 40% Efficient Solar Cells," *IEEE J. Photovoltaics*, vol. 1, no. 2, pp. 236–241, 2011.
[7] P. Chen, B. Wang, Y. Tian, and Y. Yang, "Finite-Time Stability of a Time-Delay Fractional-Order Hydraulic Turbine Regulating System," *IEEE Access*, vol. 7, pp. 82613–82623, 2019.
[8] A. Chikh and A. Chandra, "An Optimal Maximum Power Point Tracking Algorithm for PV Systems With Climatic Parameters Estimation," *IEEE Trans. Sustain. Energy*, vol. 6, no. 2, pp. 644–652, 2015.
[9] A. Díaz, R. Garrido, and J. J. Soto-Bernal, "A Filtered Sun Sensor for Solar Tracking in HCPV and CSP Systems," *IEEE Sens. J.*, vol. 19, no. 3, pp. 917–925, 2019.
[10] B. Li, C. Li, F. Guo, and Y. Xin, "Overcurrent Protection Coordination in a Power Distribution Network With the Active Superconductive Fault Current Limiter," *IEEE Trans. Appl. Supercond.*, vol. 24, no. 5, pp. 1–4, 2014.
[11] M. N. I. Khan, M. T. Iqbal, and M. Hinchey, "Submerged water current turbines," in *OCEANS 2008*, 2008, pp. 1–6.
[12] S. Ravikumar *et al.*, "Experimental Investigation of a Bidirectional Impulse Turbine for Oscillating Flows at Various Resistive Loads," *IEEE J. Ocean. Eng.*, vol. 46, no. 1, pp. 115–131, 2021.
[13] P. Orr *et al.*, "Distributed Photonic Instrumentation for Power System Protection and Control," *IEEE Trans. Instrum. Meas.*, vol. 64, no. 1, pp. 19–26, 2015.
[14] M. Tari, S. Nagano, H. Hasegawa, K. Tashiro, S. Murakami, and H. Shimada, "Development of a capacitance measuring robot for the water-cooled stator winding of turbine generators," *IEEE Trans. Energy Convers.*, vol. 14, no. 4, pp. 1366–1371, 1999.
[15] O. P. Malik and Y. Zeng, "Design of a robust adaptive controller for a water turbine governing system," *IEEE Trans. Energy Convers.*, vol. 10, no. 2, pp. 354–359, 1995.
[16] E. De Jaeger, N. Janssens, B. Malfliet, and F. Van De Meulebroeke, “Hydro turbine model for system dynamic studies,” *IEEE Trans. Power Syst.*, vol. 9, no. 4, pp. 1709–1715, 1994.
[17] K. Kobayashi, H. Matsuo, and Y. Sekine, "An excellent operating point tracker of the solar-cell power supply system," *IEEE Trans. Ind. Electron.*, vol. 53, no. 2, pp. 495–499, 2006.
[18] J. Zhu *et al.*, "Experimental Tests of Critical Current and AC Loss for a Self-Triggering High Temperature Superconducting Fault Current Limiter (SFCL) With Magneto-Biased Field," *IEEE Trans. Appl. Supercond.*, vol. 31, no. 8, pp. 1–4, 2021.
[19] A. G. Oh, D. W. Lee, and Y. Cho, "A continuous cell separator based on buoyant force in dissimilar density fluid flows," in *2010 IEEE 23rd International Conference on Micro Electro Mechanical Systems (MEMS)*, 2010, pp. 1023–1026.
[20] B.-C. Jeon, I.-H. Ji, Y.-H. Choi, S.-S. Kim, Y.-I. Choi, and M.-K. Han, "A new protection circuit for high-voltage current saturation of LEST," *IEEE Electron Device Lett.*, vol. 26, no. 3, pp. 191–193, 2005.