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Numerical Simulation and Design of Power Fluctuation Controlling of Hybrid Energy Storage System Based on Modified Particle Swarm Optimization

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Abstract:
While intermittent renewable energy sources like wind and solar have high volatility, hybrid energy storage is crucial to microgrid power balancing and smoothing out renewable energy's power fluctuations. Microgrids are now a highly effective and adaptable new distribution power grid that can be seamlessly integrated with existing power systems thanks to the microgrid industry's recent rapid growth. The amount of power generated via renewable resources is rising. The generation of photovoltaic (PV) electricity may fluctuate due to changes in cloud cover and weather-related variations in light intensity. These can have a significant impact on a severe Microgrid voltage fluctuation problem in a system with a high PV penetration. However, the battery energy storage system (BESS) is a piece of technology that may be employed to reduce PV volatility and increase the Microgrid's adaptability. An enhanced particle swarm optimization (I-PSO) is created in this study. By maximizing both BESS active and reactive power, battery consumption may be improved, overcharging and discharge prevented, and voltage fluctuation is reduced.

***Keywords**: PSO, Micro-Grid, PV.*

I. INTRODUCTION

Growing fuel prices with rapid depletion of fossil fuel reserves and increasing concern for the environment across the globe have instigated the growth of renewable power systems. India was the first country in the world to start a new ministry for the development of non-conventional and renewable power in the form of the Ministry of New and Renewable Energy (MNRE) in the early 1980s. Since then, MNRE has actively formulated and implemented numerous power schemes by setting up separate independent research and development bodies for every renewable power generation sector. As of March 2020, India‟s renewable power capacity has reached about 134.7 GW, which was nearly 36.2 % of India‟s total power capacity, with wind contributing about 27.90% of the renewable power, as shown in Figure 1.

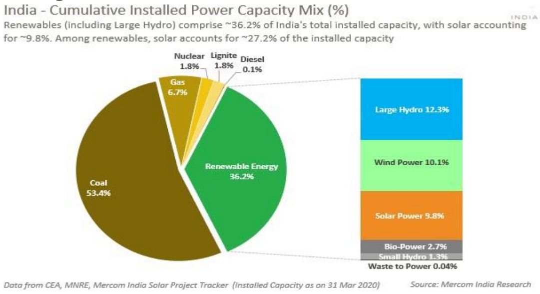

Fig 1: Comparison of Flexural Strength M45 & M50 in Replacement at 28 days

As per the National Action Plan for Climate Change released by the Govt. of India, India aspires to achieve about 40% of the country‟s power capacity from renewable sources by 2030. It includes establishing an additional 100 GW of solar power and 20 GW of wind power by 2022. These targets though achievable, do have many challenging hurdles along the way, as listed below:

- High change into bulletins of capital.
- The weak financial position of poorly run distribution companies
- Non-compliance of renewable portfolio obligation (RPO) targets.

- Uncertain policy regime
- Complicated law-making process for the power sector
- Challenges to the integration of renewable energy into the grid
- Inadequate transmission infrastructure, open access issues

II. RESEARCH MOTIVATION

Due to consistent technological advancement and declining prices, wind and solar are gaining a lot of importance among renewable power sources. Hybrid renewable systems are being discussed as a promising solution to balance the intermittency and unpredictability of renewable systems. Hybrid Renewable Energy Systems (HRES) integrate one or more renewable energy sources with or without storage options to form flexible and cost-effective power systems capable of operating as stand-alone or grid-connected systems. As wind and solar energy are complementary, wind-PV systems are most widely implemented and operated. However, such systems generating renewable power face many issues while being connected with the utility grid. The main points raised are:

- Intermittency in power is generated owing to the uncontrollable nature of energy sources like wind and solar.
- Unreliability of the system, which enforces stringent forecasting techniques and measures
- Fluctuations in power affecting grid stability and system integrity
- The mismatch between power availability and peak demand times
- Failure to evacuate the generated green power due to insufficient transmission and distribution infrastructure.

III. OBJECTIVES

In tune with the history and development of HRES, the main objective of this research work is to propose a suitable methodology to design a hybrid energy sources for a standalone and grid connected mode. This research also finds an optimal combination of energy and back up sources for a given standalone system. An attempt has also been made to interconnect the hybrid sources as distributed generation and as a micro-grid. Thus the objectives of the research work are:

i. To design a basic stand-alone PV-Wind-Battery based hybrid energy system with minimum cost and maximum reliability by obtaining the combination of PV panels, wind turbines, batteries, using single objective Particle Swarm Optimization (PSO) algorithm.
ii. To compare and analyze the techno-economical aspects of storage devices for a stand-alone hybrid energy system.
iii. The optimization of battery utilization and avoid overcharge and discharge

IV. METHODOLOGY

Here we proposed a new method that uses PSO-based technique organize of Microgrid to establish the optimal size of BESS with the least total cost of BESS. After 15 years of installation in a typical micro-network, the impact of BESS-specified costs on modern storage technology was investigated, minimized, or evaluate. The recommended optimal size of the BESS-based PSO method is compared with the optimal size of the BESS-based analysis method or conventional BESS size quoted from a typical Microgrid.

V. PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization (PSO) is a stochastic optimization technique. Created by Dr Kennedy and Dr It was Eberhart in 1995. Similar to the behaviour of a flock of birds, the algorithm mimics the pattern of a chicken in flight to find the best feeding path. Compared to a genetic algorithm (GA), a combined micro -algorithm has many advantages such as fewer parameters that need to be adjusted, higher computational efficiency, and higher conversion efficiency. PSOs have been widely used in various industries, such as enhancing automatic monitoring to detect ovarian cancer patient areas, improving global solar radiation estimates,and improving load balancing. [24]. One of the most common uses of a PSO is to determine the monitor‟s battery usage in car-powered applications. Another popular application is optimal energy management in hybrid noise systems. a PSO-based method for evaluating the SOC of a lithium-ion battery. This method uses a region model with the same circuit type to estimate the SOC of a LiFePO4 battery. Here we have focused on an electrochemical battery model based on the chemical structure of a lithium cobalt oxide (LCO) cathode and evaluation of SOC based on PSO.

VI. PSO ALGORITHM

In the global PSO algorithm used in this article, many solutions (called fragments) are suddenly launched at the size of the solution. These particles are then moved through the solution space under the most suitable conditions. Coordinating the best solution to the problem space with follow-up. This is called pbest, and it is the best place for a particle in the solution space. Similarly, a global

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best value called gbest is followed, which is the best location or solution the piece has achieved so far. At each step, the particle speed is updated depending on the pbest and gbest values until the parameters needed to improve or reach the end of the algorithm are met.

Step (1) Create a „population" of agents (particles) uniformly distributed over X Step (2) Start particle j = 1 in the particle heat.

Step (3) performs the objective function of particle jth in it iteration.

Step (4) find Pbest and Gbest for the jth particle of iteration. in the case ofjth fitness value

<best global fitness value

The program sets Pbest = f1 (xj) and saves the best overall cost(Pbest_CT) = f2 (xj).

Step (5) Increase the jth particle by 1. Then check if the condition isParticle jth + 1 6 NP, go back to step (3).

Step (6) Adjust i-thGbest = the best value of i-Pbest.

Step (7) adds 1 to iteration it. Then check if the condition isIterate it with + 1 6 NI, return to step (2) and updatebbNew position (xi + 1) and new speed (vi + 1) onNext iteration.

Step (8) If iteration ith + 1> number of iterations (NI), thenThe process ends and then optimizes the size and price of BESS

Step (1) Initialize energy production data from photovoltaic systems (PPV) and hydropower Generator (PHV), small hydropower generator (PMini).

Step (2) Set the total load requirement in the microgrill (PLoad).

Step (3) Calculate differentiated power (PD) between each generation and let. Step (4) Set the difference effect (PD) to be equal to the BESS effect(PBESS).

Step (5) Check the state of PBESS> 0 and perform the measurementFeatures. If PBESS 60 ends the process and there is noneBESS installation in the system

Step (6) after performing the lens function, check if the frequency of the microgridis within the frequency rangeAcceptable range. If the frequency of the microgrid is notMeet the conditions. The program adds PBESSReduce by 0.1 MW, then perform step (5) again. This step continues until the conditions are met.

Step (7) If the frequency of the microgrids meets the frequency condition, the process ends, and then the best size and price are selected.

PSO Flow Chart

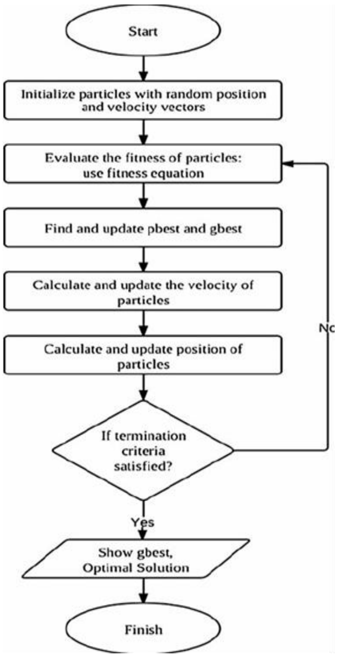

Fig 2: PSO Flowchart

VII. PROPOSED METHOD AND RESULTS

The plan considers the power fluctuations during the grid-connected operation of the microgrid and quantifies the economic benefits of hybrid energy storage. A multi-objective function to minimize the power fluctuations of the DC bus in the Microgrid and optimize the capacity ratio for each energy storage system in the hybrid energy storage system (HESS) is established. The enhanced particle swarm optimization (PSO) is used to solve the objective function, and the solution is used on the microgrid's experimental platform. Comparing current fluctuations from batteries and supercapacitors in HESS directly reflects the current distribution. Compared to the traditional hybrid energy storage management strategy, the optimized hybrid energy storage management strategy.

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This work proposes an energy storage system based on a hybrid energy storage system to smooth out wind and solar energy fluctuations. The main objective of the proposed method is to find the power and energy capacity of the hybrid energy storage system to minimize the total daily costs for all plans. The energy management strategy used in this work is designed as a two- level energy distribution scheme: the first level is responsible for setting the output power of the hybrid energy storage system, and the second level controls the current between the battery and the utility point connection.

A mathematical model is established for optimizing hybrid energy storage by taking the micro-lattice island model as a research object. A hybrid parallel particle swarm optimization algorithm is proposed for the control parameter problem of energy management strategy. In addition, the proposed method uses a piecewise adjustment function to describe battery life. The results obtained show that the hybrid energy storage system, which uses the proposed energy management strategy, can provide the best performance of the wind power system in terms of cost and service life.

Renewable energy sources such as wind and solar cells can be added to some buses to solve the voltage collapse in the electrical system caused by the increase in load. This option can reduce electricity generation costs and improve system efficiency and reliability. This article introduces an enhanced innovative technology using Particle Swarm Optimization (PSO) to select the best hourly trend for renewable energy

Renewable energy sources such as wind power and solar energy have strong volatility and intermittency. Hybrid energy storage plays an essential role in the flow balance of microbalances and the stable current fluctuations of renewable energy. With regard to the isolated mode of operation of the microgrid, such as wind power, photovoltaic systems, variable load, etc., a method for optimal allocation of hybrid energy storage capacity is proposed. A mathematical multi-objective optimization model is proposed based on the charging and discharging power and state of charge (SOC) of the energy storage medium with the lowest average annual cost of renewable energy and least fluctuations. A power correction strategy is designed for the situation where the remaining capacity of the energy storage medium is too low or too high. Finally, the rationality and efficiency of the proposed method are verified by MATLAB programming.

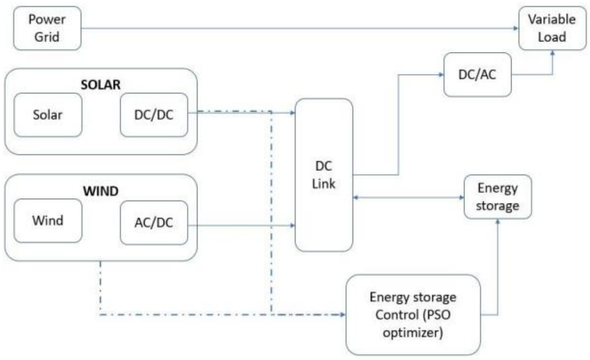

Fig 3: Block Diagram of Proposed System

A. PSO Optimization

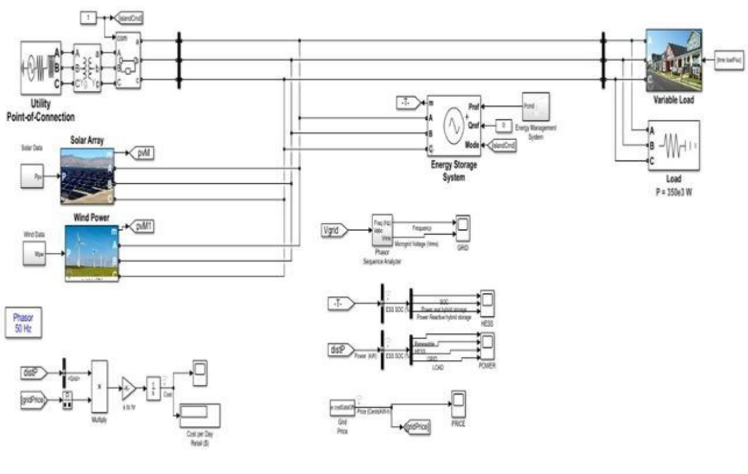

Fig 4: Proposed Simulink Model with Optimization

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The energy storage system makes it more stable on the time scale and the power scale. The Super-capacitor compensates for the high-frequency oscillating power, and the lithium battery pays for the low-frequency oscillating power. However, the coincidence of hybrid energy storage and emissions caused by the intermittent electricity production of wind and solar energy may cause the SOC to approach the limit, leading to insufficient charging and emission capacity available for the next time. Therefore, the power command value must be corrected. This section uses hybrid energy storage in island mode to stabilize wind power fluctuations as an example. The current distribution and correction structure of the composite energy storage system is shown in Fig4.

B. Grid-Connected Solar Array

This block model a grid-connected solar array using the Three-Phase Dynamic Load block. This system-level model does not contain any power electronics but is helpful for load flow, phasor, and hybrid phasor-EMT simulations. The input to this block is the power output of the grid-connected PV array, not irradiance.

For more detailed PV models, consider the PV Array block in the Renewable library. Consider using this PQ Model to perform load flow studies and switch to a more complex model when complete EMT studies are required.

TABLE I
SIMULINK PARAMETER FOR SOLAR SYSTEM

Nominal L-L Voltage (Vrms)[volt]	5000
Nominal Frequency [Hz]	60
Initial Power [W]	500e3

TABLE II
SIMULINK PARAMETER FOR GRID SYSTEM

Phase-to-phase voltage (Vrms) [volt]	(13800) *1.00243
The phase angle of phase A (degrees):	0.071468
Frequency (Hz):	50
3-phase short-circuit level at base voltage (VA)	250e6
Base voltage (Vrmsph-ph):	13.8e3

C. Power Allocation and Correction Strategy for Composite Energy Storage System

Different energy storage units in an energy storage system are responsible for high-frequency or low-frequency power fluctuations generated by renewable energy. Combined with the characteristics of the two types of energy storage units, the smooth control strategy can use Supercapacitor to suppress high-frequency part of the fluctuations in Pre f , and batteries to stabilize the low-frequency part of Pre f . When the output power of the renewable energy fluctuates greatly, the DC bus power of the Microgrid will not fluctuate greatly, and the Microgrid can operate reliably.

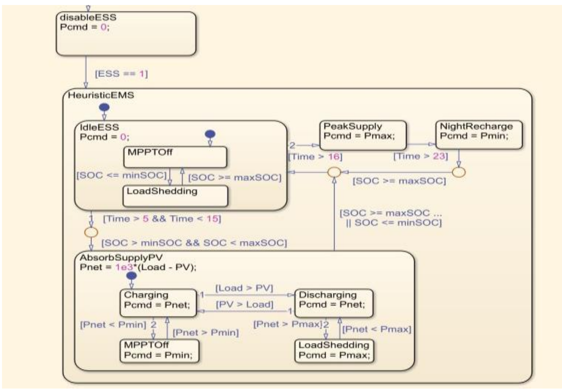

Fig 5. Energy Storage System Flow

This system is composed of a PV system, MPPT; boost converter, load scheduling, discharging a three-phase inverter/rectifier, a bidirectional DC/DC converter, and thyristor switches. The boost converter extracts maximum power from the PV panels and wind and sends it to the DC-link.

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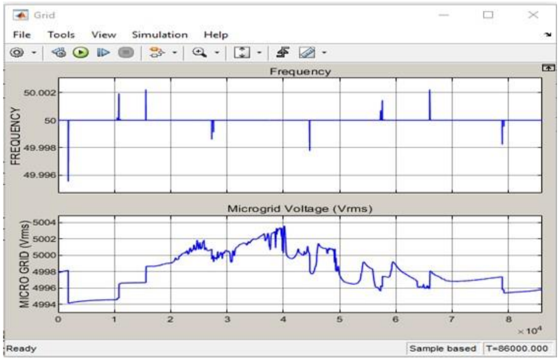

Fig 6. 50 Hz Frequency, Micro Grid Voltage (Vrms)

Fig 6 shown the Microgrid voltage at 50 Hz frequency.

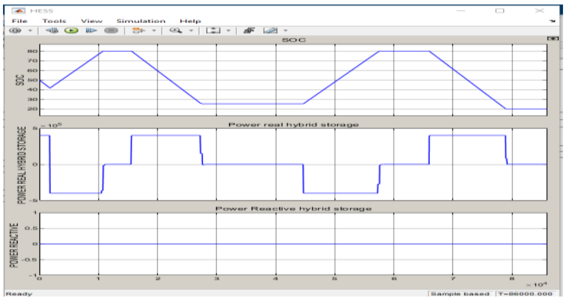

Fig 7. Energy Storage Performance

The device of converting electrical energy from power systems into a form that can be stored for converting back to electrical energy when needed.

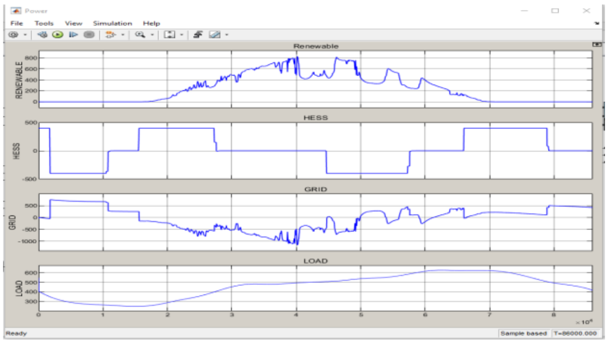

Fig 8. Renewable (PV), HESS, Grid, Load Voltage

Fig 8 shown the Renewable (PV), HESS, Grid, Load Voltage, A HESS consisting of batteries and supercapacitors is used to meet the highly fluctuating power demands. Due to the slow dynamics of the battery system, the reference currents are not tracked immediately hence affecting the DC grid voltage.

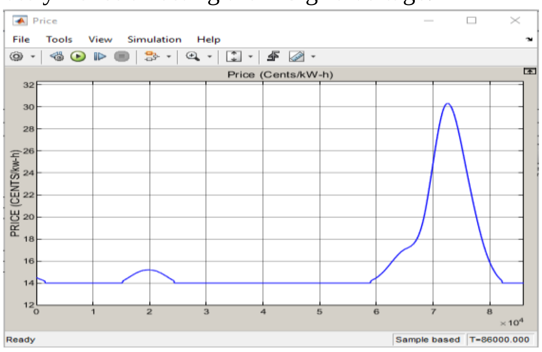

Fig 9. Price after Optimizer

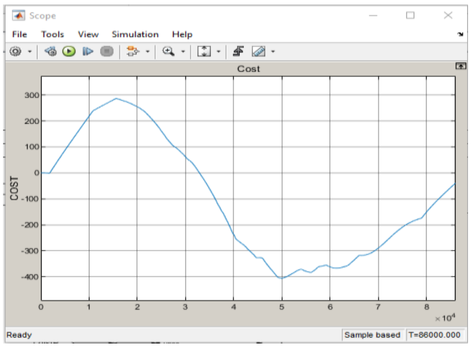

Fig10. Cost/day after Optimizer

D. Without Optimization

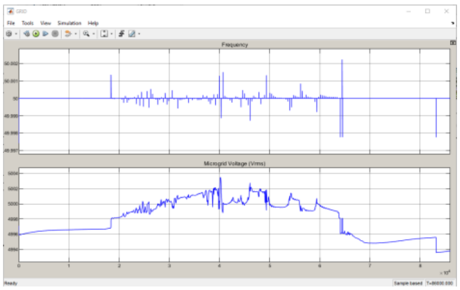

Fig11. Micro-Grid Voltage

Fig 11 shown the Microgrid voltage at 50hz frequency .

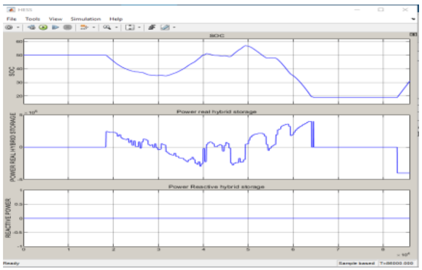

Fig12. Energy Storage Performance

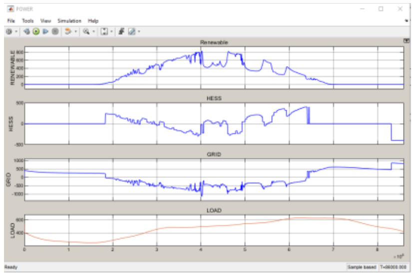

Fig13. Grids, HESS, Grid, and Load Voltage

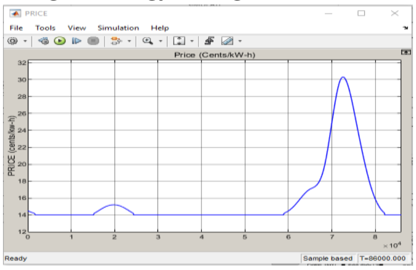

Fig14. Price after Optimizer

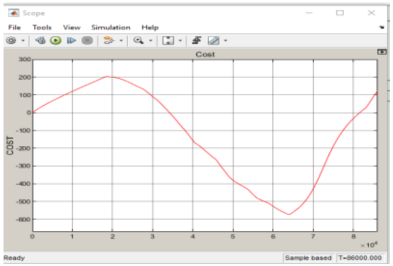

Fig 15: cost/day after the optimizer

The fig 15 shown the cost/day after the optimizer

VIII. CONCLUSION

In this we have tried to optimize the configuration of each unit‟s capacity for energy storage in the Microgrid system, in order to ensure that the planned energy storage capacity can meet the reasonable operation of the microgrid‟s control strategy, the power fluctuations during the grid- connected operation of the Microgrid are considered in the planning and the economic benefit of hybrid energy storage is quantified. A multi-objective function aiming at minimizing the power fluctuation on the DC bus in the Microgrid and optimizing the capacity ratio of each energy storage system in the hybrid energy storage system (HESS) is established.

The results demonstrate that the configuration's hybrid energy storage capacity can attenuate power variations on the DC bus, therefore reducing the fluctuation of the battery's high- frequency components, extending the battery's cycle life, and lowering the system's cost. In comparison to the configuration's standard hybrid energy storage capacity, the technique can save the costs, while also greatly improving the performance of renewable energy's power fluctuation modulation. Given economic and technical requirements, a mathematical model and solution algorithm for multi-objective optimization of microgrid's hybrid energy storage capacity is proposed. Current distribution and correction are realized based on a low-pass filtering algorithm and unclear control rules. Finally, the adaptive weighted particle swarm optimization algorithm is used to solve the mathematical model through MATLAB. Examples show that the proposed method can achieve a better economy and higher technical performance (Renewal, HESS, Grid, and Load Voltage).

A hybrid electricity generation system is a better and more efficient electricity generation solution than traditional energy. It has higher efficiency. It can be delivered to remote areas that the government cannot reach. So that electricity can be used where it is generated, thereby reducing transmission losses and costs. The cost can be reduced by increasing the output of the equipment. People must actively use unconventional energy. It is very safe for the environment because it does not generate emissions and hazardous waste like traditional energy sources. This is a cost-effective solution for electricity production. It only requires an initial investment. Its lifespan is also very long. All in all, it is a good, reliable and economical solution for electricity production.

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