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A Review on Application of Solar Stirling Engine

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ABSTRACT: The Stirling solar dish system has proven to be the most effective way to use solar energy to produce electricity. The need to improve total performance and minimise errors and costs is becoming an essential concern for scientists due to the growing commercialization of this innovation. Study on modelling, thermodynamic efficiency analysis, simulation studies and techno-economic research of Stirling solar dish engines has gained momentum in recent years.For performance study of dish-Stirling systems, several parameters such as concentration ratio, absorber temperatures, high temperatures, freezing temperatures, regenerator efficacy, working fluid, dead volume and average working pressure values are usually considered. Researchers have found that thermal efficiency improves by increasing the concentration ratio and absorber temperature. For an absorber temperature of 850K and a concentration ratio of 1300, the optimum thermal efficiency recorded for the dish-Stirling device is 32 per cent. While loses from regenerators tend to decrease overall efficiency.Energy and energy consumption for the dish-Stirling system were stated to be 17% and 19%, respectively, in which the recipient experienced substantial losses. For the receiver, nevertheless, thermal efficiency as strong as 84 percent could be achieved. A review of results reveals that, with relatively higher results, dish-Stirling innovation could cost-effectively generate power than most other renewable energy systems. In addition, the integration of hybridization and thermal storage has arisen as an especially desirable choice for the device to run more continuously.

Keywords: Electricity, Environment, Renewable, Solar, Stirling dish, Photo voltaic, Temperature change.

INTRODUCTION

Increasing Energy requirements and rising environmental concerns have accelerated renewable energy study. One of the most promising sources of renewable energy for power generation is solar energy. This renewable technology decreases fossil fuel consumption and reduces environmental contaminants. In the world of clean energy production sources, concentrating solar power is among the most potential innovations. Four different types of CSP plants are used in the current situation: linear Fresnel reflectors, parabolic troughs, control towers, and dish systems from Stirling [1].The principle of using solar power in the Stirling engine was extended to the Stirling engines by integrating solar concentrators. Dish-Stirling systems first use concentrators and Stirling engines to transform thermal energy into mechanical energy, and then generators are used to transform mechanical to electrical energy. By transforming almost 30 percent of the sun's rays into electrical energy, Solar Stirling systems have shown the best performance while examining solar-based power generation systems.The Stirling dish technology is predicted to surpass the technologies of parabolic troughs by processing energy at a relatively low cost and high performance. These systems are modular and self-contained generators and can also be mounted in power plants varying from one kilowatt to 10 MW in capacity.

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Recent advances in architecture, optimization, and performance measurement are discussed in depth in this review report. The key goal is to include an analysis of the production and performance of Stirling solar-powered motors. With information on efficiency and simulation, the paper discusses the latest production status of receiver utilized directly in the solar Stirling systems. In particular, it studies the applications of Stirling solar dish systems in various fields, such as micro-cogeneration, hybridization and storage, power generation, off-grid electrification, solar power plants, processing of potable water and water pumping.

LITERATURE REVIEW

Applications of Solar Stirling Engine

The main applications andrecent works related to these applications are reviewed in this section:

Micro-cogeneration system

A micro-cogeneration device continuously produces electricity and usable heat, but the produced electrical output is below 5kW. A machine consisting of a Stirling engine for micro-cogeneration applications leads to greater self-sufficiency in achieving both heat and power demands. In addition, these programmes help to maximise the use of electricity supplies, increase energy efficiency and minimise carbon emissions. The residential sector is a significant use of these systems. Latest research and development on Stirling solar-powered engines has established possible application in the cogeneration sector via the introduction of small Stirling engines to improve performance.

Thermal and economic optimization of the micro-cogeneration method running on the solar-powered Stirling cycle engine has been carried out by an author. For maximisation of the annual valuation, eight decision variables were chosen in the research sample. The results suggest that the thermodynamic performance is in the range between 66.3 percent and 76.1 percent for the optimal device configuration[1].

Hybridization and storage

In the world of researches, the integration of the solar dish-Stirling engine with thermal energy storage or hybridisation with other forms of renewable energy is gaining prominence. In addition to that, hybridization facilitates the device to run more constantly. This systems also reduce reliance on solar energy supply. Latest research undertaken in the area of hybridization and storage when integrated with dish-Stirling systems has been reviewed [4].

In a 10kW parabolic dish-Stirling scheme, an author mixed both hybridization and thermal storage. The possibility of incorporating thermal storage to a dish-Stirling system was carried out by another author and the effect on levelized energy costs was subsequently studied (LCOE). In order to boost the structure's design, the engine and the thermal storage systems were mounted at the rear of the parabolic dish. The researchers noted that a dish-Stirling storage device would add benefit to the mechanism and results in a substantial decrease in LCOE[2].

Solar Stirling electric power generation system

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A thermal study of a solar-powered Stirling engine has been carried out by an author. The effect of the parabolic concentrator model parameter on the function of the Stirling engine has been investigated. Furthermore, the effect on the performance of dish-Stirling power systems of parameters such as total heat transfer coefficient and concentration ratio was also analysed[3].

A solar-powered dish-Stirling energy production device integrated with a high-temperature superconducting linear synchronous generator was proposed by another author. The researchers noted that the innovative nature of the device has the possibility of becoming a successful alternative in large-scale power generation systems for solar to electricity transformation[4].

Off-grid electrification

The solar dish Stirling system for standalone rural electrification was studied by an author. The assessment process of a dish-Stirling system was carried out by the researchers. For the solar-powered Stirling heat engine system, thermodynamic modelling was performed along with simulation experiments. In order to research the feasibility of the hybrid configuration, a research was chosen to construct a prototype of dish- Stirling with permanent magnet synchronous generator (PMSG) for the standalone method. In particular, a retrospective analysis was carried out to validate the findings, taking into account the results of the Eurodesk framework as a guide.It was decided that a variable speed mechanism for supplying an uncontrollable feed will be a reasonable alternative[5].

Solar Stirling power plants

A techno-economic study of 100 MW of dish-Stirling-based consolidated electricity solar thermal power plant technology was carried out by the author. In addition, three separate sites were evaluated for the factory. The technological efficiency of the dish-Stirling plant has been seen to be increased, although the economic performance of the plant declines as the plant works in the desert area.

The output of the standalone solar dish-Stirling system was investigated by another author. The researchers have studied the thermal efficiency of the dish collector, receivers' mechanism and Stirling motor.The outcomes of the research found that yearly electricity generation has the potential to increase by 19% simultaneously minimising levelized energy costs[6].

Potable water production

During the water distillation method, an author explored the likelihood of using heat lost from the cold chamber of the Stirling engine. A mathematical model accompanied by simulation based on actual weather inputs was introduced. In addition, the system's economic viability was also tested. As per the outcome of the analysis, this device was used to generate a large volume of water. The researchers, however, proposed improving the condenser system's architecture.

Water pumping

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A novel Stirling engine architecture has been created by an author wherein air is used as a working fluid. An integrated solar thermal water pump that can be coupled to the Stirling engine and further coupled to a rotary pump was also produced. Integrated solar thermal technology has been seen to be used for water pumping in remote or off-grid areas. It was established that any standalone pumping or standalone mechanical specifications like grinding, refining and compressing are protected by the markets for such systems[7].

CONCLUSION

In recent years, major progress has been made in improving the efficiency of solar-powered Stirling engines. This research article's key conclusions are as follows:

1. By increasing the temperature of the receiver gas to an optimal point of about 850K and the concentration ratio to 1300, the highest efficiency and power performance could be enhanced. Higher efficiency is also observed by Stirling engines working on helium as working fluid. For concentrator substances with a net conversion power of 97 percent, polymeric film non-metal reflectors are often seen as more suitable choice.
2. If the regenerator losses are considered, the total performance is decreased to 25 percent. Higher regenerator efficiency engines have higher thermal efficiency.
3. Thermal performance as strong as 40 per cent can be obtained using the multi-objective optimization technique.
4. A modern dual parabolic dish with an even distribution of heat flux could be a suitable alternative to a single parabolic dish.
5. It is noticed that when the absorber is fitted with a hot chamber, the efficiency of the dish Stirling system can be increased. The performance of a receiver can also be increased by the short aperture radius and the high value of receiver absorption. A modern structure of the cavity receiver fitted with a reflecting cone will attain an optical efficiency of close to 90%. The lack of radiation in the receiver is also particularly vulnerable to variations in wind levels.
6. The use of a micro-cogeneration device boosts energy savings and minimises both CO_2 emissions and energy costs. In hybridization and storage, for their recognition, economy and usability, immediate study is needed in the field of phase change materials. Further research is required, however, to enhance the concentrator's optical efficiency, which can be achieved by improving the concentrator part manufacturing method. In order to increase the system's efficiency, new approaches are also needed to minimise the receiver's energy and energy losses.

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