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# Thermo-Economic Optimization of a Novel Supercritical $CO_2$ Brayton Cycle Integrated with Concentrated Solar Power for High-Efficiency Electricity

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**Abstract:** The basic idea of this presented research is to modernize the electricity generation system with high quality and provide development in the economical and thermal mechanical design of the Bratton cycle. This research includes an advanced study of economic and analytical studies to give an ideal superior operational quality and enlarge the energy storage space while reducing excess costs. We used in this research the technology of simulating thermal movement in addition to the benefit of economic analysis to study variables on operational capabilities and benefit from them. The lower cycle also has an important role in thermal balance and modern experience has confirmed that it is more efficient than the old system in developing solar systems to reduce costs and consumption of thermal pressure inside. The system.

**Keywords:** Electricity generation, solar energy, co2.

## Introduction:

CSP (Concentrated Solar Power) is one of the most widely used solar energy technologies today. Its advantages include high quality and efficiency, as well as being harmless to health and environmentally friendly (1). It contains lenses or mirrors that reflect and concentrate sunlight, modifying the solar heat and converting it into hot steam. This steam then drives electric motors to produce clean electricity (2), generating power during winter days and at night when sunlight is unavailable (3). Furthermore, research focuses on improving the performance of this technology to reduce unnecessary expenses while maximizing productivity through the integration of an advanced thermal fusion method – something we need today.

## Research Problem:

It also has minor problems that hinder us from performing our tasks more efficiently in generating electricity and storing energy at a low cost. Therefore, we strive to obtain an improved and developed operating system and seek to design Bratton cycle systems using supercritical CO2 as an additive gas to achieve the best possible productivity and provide greater energy storage capacity during critical periods.

## Research Significance:

It plays a key role in improving the performance of concentrated alternative energy (CSP) to reduce excess costs and provide optimal energy output by combining thermal storage methods to conserve and preserve energy.

## Lecture review

There are many studies have addressed this topic, including the following:

Ahmed and others (2024) confirmed by mixing the Brighton CO2 cycle with concentrated alternative energy to reduce dependence on fossil fuels, while highlighting the economic aspect and focusing on specific, reliable energy in emergency situations. This study also differs from previous ones by mixing renewable and non-renewable energy and reducing concerns about fuel corruption.

This research also provides us with a comprehensive analysis of the heat and energy in the system, in addition to the barometric improvement during operation

It also made a clear enhancement of the system by about 55.45% to about 55.65 megawatts and a decrease in fuel consumption - 10 to 15%, depending on energy sources from one region to another and from one season to another, highlighting the summer season as it is the only season that benefits most from reducing fuel expenditure by 14.58% to reduce various environmental impacts while ensuring active and effective energy guarantee, and it may be more effective applied in remote areas that lack water and fuel (4).

Also, Lu and other researchers (2023) proposed a system for providing solar fuel based on thermal fossil energy and the currently available concentrated CSP system, in addition to other economically effective systems. Previous research also has other future developments to reduce costs and break markets and enhance it based on this literary research and development prospects for using effective clean fuels and alternative energy (5).

As Fairuzi and other researchers (2023) showed us by highlighting the review of previous research on concentrated alternative energy to show us the risks, positives and steps of this subsequent research. This research also needs multiple studies, including a biometric study to reveal the basic aspects of concentrated alternative energy (CSP). It also depends on details of the events and steps of working on concentrated energy in the experiment, which makes it of high and high value for those with experience in this field and includes the following: (1) Understanding technological data in concentrated alternative energy. And studying the strengths and weaknesses of current technologies and providing us with a clearer vision (2) Reducing the existing risks surrounding the concentrated alternative energy system and reducing thermal storage costs (3) Introducing new systems that contain renewable and non-renewable cells and knowing their details (4) Providing new updated research such as the production of basic gases for an advanced study with multiple positives (6) The research of (2023) Alami et al. has shown us. It provided us with appropriate research, estimated at approximately 143 research papers dedicated to concentrated alternative energy (CSP).

While confirming the special factors, such as storage capacity and others, the following research also shows us the difficulties and risks facing this system, including thermal fluids, storage techniques, and others within the scope of operation

Finally, the review highlighted and compared various hybridization technologies of CSP with different renewable energy sources, including photovoltaics, wind, and geothermal energy. The leading country in CSP adoption, the leading concentrating technology, the most suitable ES technology, and the most efficient LCOE-based hybrid technology were identified. The data analyzed in this study are crucial for forecasting the future of CSP in the market and its contribution to mitigating global warming potential. [7]

A number of studies have shown that several engineers have attempted to establish a new software for s.co.2 for SPT systems with the aim of increasing the thermal expansion channels inside the tank [8][9]. Another study [10] integrated a steam Rankine cycle into the compression of s.co.2, where it was used as a lower cycle and heated by the exhausted s.co.2 from the upper cycle. [12][11] proposed a cascade system of alternative energy, as in organic Rankine regeneration through the movement and compression of s.co.2, where the hot molten salt reacts first to heat the s.co.2, then the Rankine cycle. Consequently, [14][13] proposed an updated external design for ss.co.2 connected directly to an alternative energy receiver with microchannels that work with s.co.2. [16][15] also used the s.co.2 cycle and organic Rankine cycle to compensate for the loss of moderately and low-temperature gas with a total gas pump and to amplify the gas difference using high-temperature gas for its source [18][17]. This process succeeded in expanding the thermal range of storage and reducing system costs for storage.

However, there is an incompatibility between the upper and lower cycles, which in turn negatively affects temperatures, efficiency, and performance quality [19][20]

**The added value of the study**:

The focus of this study is to promote progress in the development of a high-quality electricity generation system and to enhance the dynamics of the thermal-economic design of the Bratton cycle. It combines analytical and economic studies to achieve maximum operational capacity, maximize energy storage capacity, and minimize excess costs

**Materials and Methodology:**

This study also sheds light on a specific type of gas, which is (S.CO.2), as a basic developed system. It also has two basic components, an upper layer and a lower layer for pressure within the system. This high-temperature gas (S.CO.2) is also added to the lower layer coming out of the engine to the upper layer to determine the storage of the gas in an advanced and optimal way. It also has other features: reducing excess costs and preventing risks to the connections between the layers and the heat in them to provide the best possible performance for stability in general, and to develop this model of research to make us An advanced thermodynamic system that contains detailed systems for the contents of the new SPT cycle, where reflective mirrors circulate light and heat to the molten salt stores in the vaults at pressure s.co.2. A system was also established to study the movement of heat in the two layers to improve the energy system. The heat movement of the SPT system was also developed, which showed us a clear development in performance, heat transfer, storage, etc. Heat and pressure force have variables within the system's interior, which allows us to add appropriate modifications for the development of research and monitoring to know and verify the characteristics of the system. Experiments showed us the difference between the modern and old systems with the study of parameters and others. Successive studies also showed us that the developed system offers better performance characteristics than the old systems in terms of quality, accuracy, and cost reduction in energy systems. Alternative

**Results and Discussion**

Experiments with the new systems have shown a significant improvement compared to the old system in terms of cost and performance quality. The new system provides an optimal design for sequential cycles, as illustrated in Figure (1) for solar energy transmission using the s.co.2 cycle. The new design integrates the lower and upper cycles to enhance and develop solar energy. Pressure and temperature affect system quality; in the lower cycle, increased pressure leads to better thermal circulation performance, reduced heat consumption, and increased electricity generation.

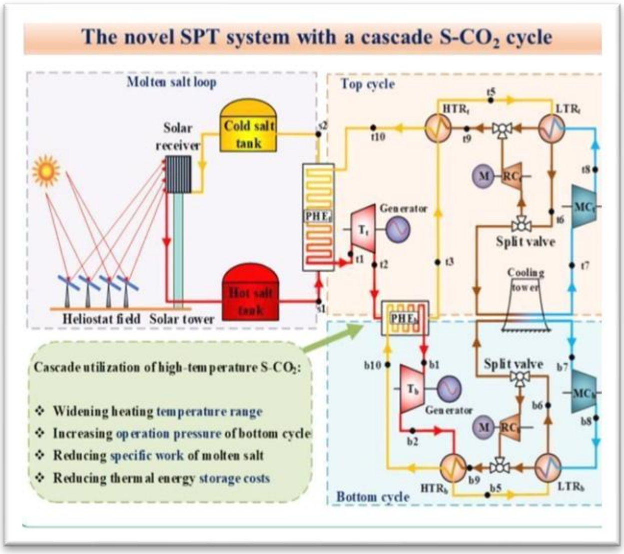


**Figure (1) shows the new SPT system with an S-CO2 cycle**

Figure (2) shows the effect of the parameters in the heat exchange area and operating pressure on the heat transfer capacity and the system in general, confirming that the modern system is more effective in these aspects.

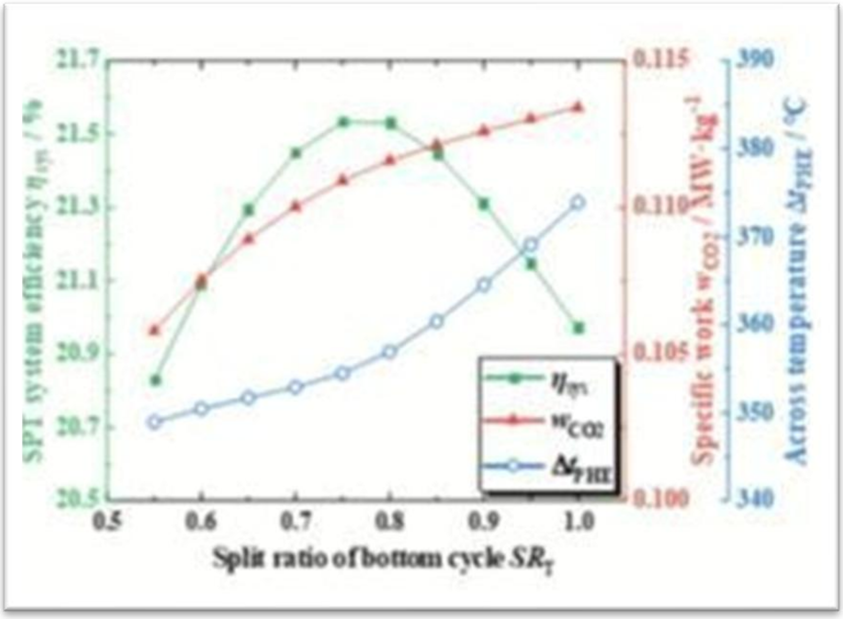


**Figure (2) Parameter Analysis**

As for the economic field, Figure (3) shows us, between start-up costs and capital costs, that the modern system has better production performance than the old one, and better cost performance on the other hand, as consumption decreases in the size and change of the system without reducing the quality of performance, and operational processes are controlled to reduce excess costs**.**

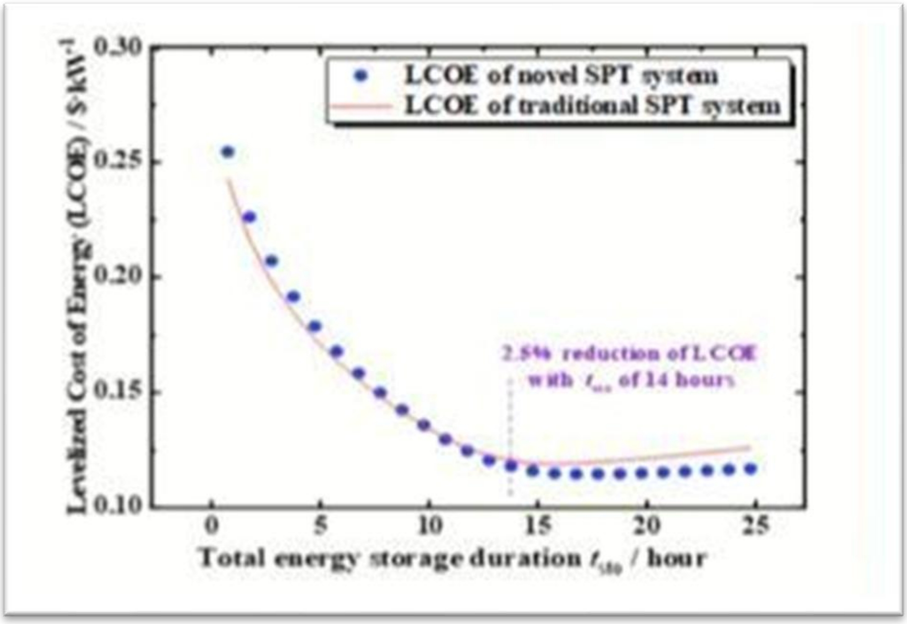


**Figure (3) Economic Comparison**

Figure (4) illustrates a tangible improvement in economic performance and efficiency, positively reflecting the ability to achieve better returns for each invested unit.

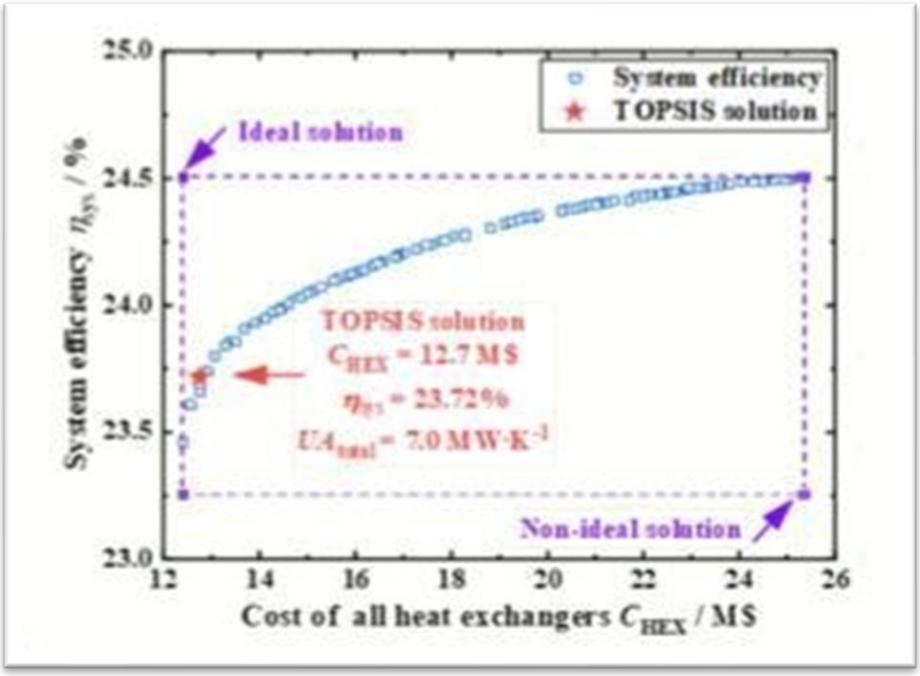


**Figure (4) shows the economic thermal optimization.**

Figure (5) shows the thermodynamic comparisons, indicating that the modern system provides a wider thermal distribution for storage while maintaining optimal thermal efficiency, resulting in smoother performance and thermal storage of solar energy, and a comprehensive and detailed development of both the upper and lower cycles.

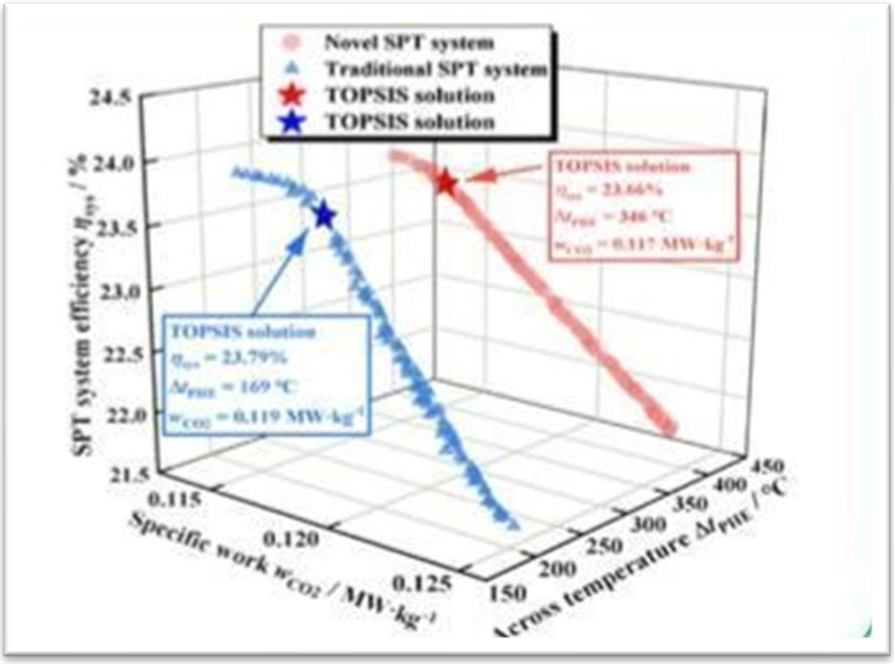


**Figure (5) Thermodynamic Comparison**

Through research and experiments, the reliability of the new SPT system has been demonstrated, increasing feasibility, production capacity, and optimal efficiency in use.

**Conclusion**

Based on all previous experiences, it has been confirmed to us that this system is the optimal system in the solar system through field experiments and through experimental use, and it is superior to its predecessors.

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