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Design of a Spring Powered Energy Generator for Low-Cost Applications: An Eco Spring Model

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Abstract: The increasing demand for sustainable and portable energy systems has encouraged the development of alternative methods of power generation that do not rely on fossil fuels or environmental conditions such as sunlight and wind. This paper presents the design and development of a spring powered energy generator, a compact mechanical system capable of converting stored elastic potential energy into usable electrical energy. The spring stores mechanical energy during winding and releases it gradually in the form of rotational motion, which is transmitted through gears. The fabricated prototype was designed with emphasis on portability, simplicity, reliability, and low-cost operation for small-scale energy applications.

This system of design demonstrates the practical implementation of renewable mechanical energy storage and conversion principles, without dependence on fuel-based energy sources. Design calculations, fabrication procedures, material selection, assembly processes, and performance evaluation were carried out to analyse the operational characteristics of the developed model. The study shows that the spring-based systems can provide useful low-power electrical output for emergency lighting, educational demonstrations, and portable energy applications. This research also highlights the importance of gear optimization, rotational stability, and friction reduction in improving system efficiency.

Keywords: Spring powered generator, Mechanical energy storage, Renewable energy, Torsion spring, Energy conversion.

I. INTRODUCTION

Energy plays a major role in industrial development, transportation, communication, and daily human activities. The continuous increase in electricity demand has created serious concerns regarding depletion of fossil fuels and environmental pollution. Conventional electricity generation methods such as thermal power plants, diesel generators, and gas turbine systems contribute significantly to greenhouse gas emissions and environmental degradation. Although renewable energy systems such as solar and wind power offer cleaner alternatives, their operation depends heavily on climatic conditions and geographical availability. Mechanical energy storage systems provide an alternative approach for generating electrical power without dependence on weather conditions. Among such systems, spring-based mechanisms are widely recognized for their ability to store and release energy repeatedly through elastic deformation. Traditional spring mechanisms have been used in clocks, toys, and mechanical devices for decades. Recent advancements in compact generators and energy conversion systems have created opportunities to utilize spring mechanisms for small-scale renewable energy applications.

This Spring powered energy generator (SPEG) operates on the principle of storing elastic potential energy within a torsion spring and converting it into rotational kinetic energy during controlled unwinding. The generated rotational motion is transmitted through a gear train and flywheel arrangement to drive a permanent magnet DC generator for electricity production. The present study focuses on the design, fabrication, and testing of a compact spring-powered energy generator suitable for low-power applications. This research demonstrates how stored mechanical energy can be converted into useful electrical energy using a simple and reusable mechanism.

II. LITERATURE REVIEW

Mechanical energy storage and spring-based energy conversion systems have gained increasing attention in renewable energy research. Several researchers have explored the potential of elastic energy storage mechanisms for portable and low-power applications. Wang and Chen (2018) investigated mechanical energy harvesting through spring-driven systems and observed that spring stiffness, material damping, and gear ratio significantly influence energy transfer efficiency. Their research highlighted the importance of optimizing torsional spring characteristics to improve power output and durability. Chatterjee and Gupta (2020) developed a hybrid spring and flywheel energy storage system to improve rotational stability and energy delivery duration. Their findings indicated that integrating flywheel systems with spring mechanisms improves torque stability and reduces fluctuations in power transmission.

Kumar and Iyer (2021) analysed mechanical energy recovery systems using elastic potential energy for low-power electrical applications. Their work demonstrated that spring-driven systems are suitable for powering sensors, LED loads, and portable devices in off-grid conditions. Okafor and Adebayo (2020) designed a spring-powered floor pad system capable of generating electricity from human footsteps. The research confirmed the feasibility of spring-based mechanical energy harvesting for urban and public infrastructure applications. Kim et al. (2021) proposed a three-dimensional spring-based piezoelectric energy generator for wearable electronics and vibration energy harvesting applications. The study showed that compact spring systems can achieve efficient energy conversion in micro-scale applications. Smith and Patel (2022) examined portable mechanical generators for off-grid energy applications and emphasized the importance of lightweight structures, corrosion resistance, and efficient gear systems for improving operational reliability.

Earlier research articles and patents related to spring-powered electric generators also demonstrated the practical implementation of mechanical energy storage systems for compact and emergency power generation. The overall literature indicates that spring-based energy systems provide a promising renewable energy solution for low-power applications. However, improvements in energy transfer efficiency, rotational stability, and friction reduction remain essential for enhancing practical performance.

III. METHODS AND MATERIALS

The primary objective of this modified approach is to design a compact spring-based energy generator that converts mechanical energy to produce electricity, offering a sustainable and eco-friendly energy solution. This initiative aims to create a functional model or prototype which efficiently converts the torque generated by a spring mechanism into electrical energy, showcasing a practical application of mechanical energy conversion principles. A key goal is to fabricate a working model demonstrates the feasibility of this technology and also highlights its potential for self-sustained operation through mechanical energy recovery, eliminating the need for external fuel sources or power inputs.

Furthermore, this design thoroughly analyze the system's performance, evaluating critical metrics such as torque output, energy conversion efficiency, and overall system reliability. By achieving these objectives, the setup intends to contribute to the advancement of renewable energy technologies, providing a portable, emission-free power generation solution suitable for short-term needs, and also laying the groundwork for future innovations in mechanical energy systems. This comprehensive design ensures that the generator is a proof-of-concept and a viable step towards addressing global energy challenges, reducing dependence on fossil fuels, and promoting environmental sustainability. The power flow diagram of the design is shown in Figure 1.

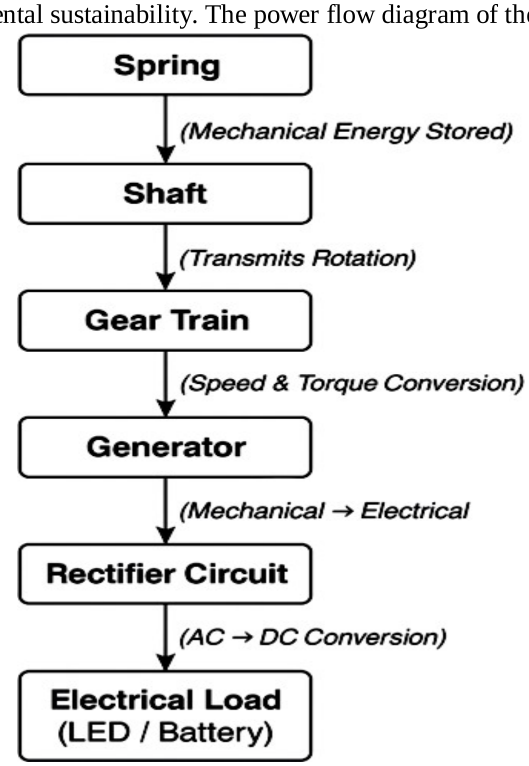

Fig. 1 Power Flow diagram of the system

The design of the spring power energy generator was guided by a thoughtful selection of engineering parameters, each contributing to the system's overall efficiency, reliability, and suitability for small-scale energy applications. One of the foundational considerations was spring selection, which determines the amount of mechanical energy that can be stored and subsequently released. The spring's stiffness constant (denoted as k) and its material properties such as elasticity, fatigue resistance, and tensile strength play a crucial role in optimizing the torque output and ensuring consistent energy delivery over repeated cycles of use.

IV. EXPERIMENTAL SETUP

The final design of the system was developed, including the spring mechanism, gear train, flywheel, and generator. A torsion spring was chosen as the primary energy storage element due to its ability to store significant mechanical energy when wound. The gear system was designed to increase the rotational speed from the spring to the generator, ensuring effective power generation. Mild steel was chosen for the frame due to its strength and durability. High carbon steel was used for the spring because of its high elasticity and fatigue resistance. EN8 steel was selected for shafts to provide good strength and machinability, while aluminium was used for the flywheel to ensure lightweight and smooth rotational motion. The fabrication process was carried out in authorized workshop tools and machines. The base frame was constructed by cutting and welding mild steel sections. Shafts were machined using a CNC lathe to achieve accurate dimensions. The spring housing was fabricated to securely hold the spring and ensure safe operation. Gears were assembled and aligned properly to ensure smooth transmission of motion.

The choice of generator type is equally important. A permanent magnet DC generator was selected for its high efficiency and reliability in converting mechanical rotation into electrical energy. These generators are known for their compact design, low maintenance needs, and ability to produce consistent voltage output, making them ideal for small-scale applications. Finally, the load characteristics were carefully defined to align with the generator's capabilities. The SPEG is designed to power low-voltage devices such as LED arrays or to charge small batteries within the 5–12V DC range. This makes it particularly useful in off-grid scenarios, emergency lighting, or educational demonstrations where compact and renewable energy solutions are needed. The Figure 2 shows the block diagram of this developed spring power generated system.

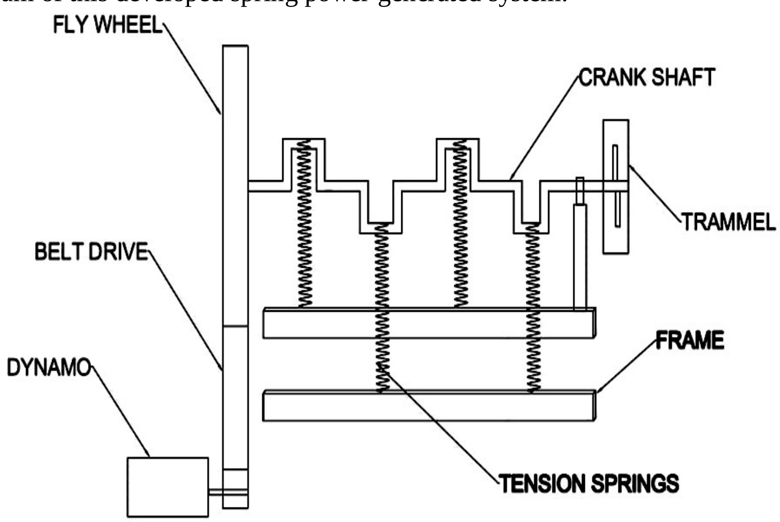

Fig. 2 Block diagram of the Setup

The base frame forms the structural backbone of the SPEG. Mild steel angle sections measuring 25 X 25 mm were cut to the required lengths using a power hacksaw. These sections were joined using arc welding to form a rigid rectangular frame. Welded joints were ground smoothly using a bench grinder to remove spatter and ensure a clean finish. Mounting holes were drilled at precise locations to accommodate shafts, bearings, and the generator. The entire frame was coated with anti-rust primer followed by a black enamel finish to enhance durability and aesthetics. A cylindrical steel casing with a diameter of 60 mm and a length of 100 mm was fabricated to house the helical torsion spring. The spring was anchored securely inside the casing using a locking pin and connected to the primary shaft. This housing provided safety and stability during winding and energy release. Lubrication oil was applied inside the casing to minimize friction and wear, ensuring smooth operation. The Figure 3 shows the fabricated design/model of the spring power generation system.

This system operates through a sequence of three fundamental stages that enables it to convert mechanical energy into electrical power. The first stage is the energy storage stage, during which the spring is wound either manually or with the help of a motorized mechanism. This winding action causes the spring to undergo elastic deformation, effectively storing potential energy within its coils. Once the spring is fully wound, the system transitions into the energy release stage. In this phase, the stored potential energy is gradually released as the spring begins to unwind. This unwinding motion generates torque, which is transferred to the output shaft, initiating rotational movement. Finally, the process enters the energy conversion stage, where the rotating output shaft drives a gear train that is mechanically linked to a DC generator. As the shaft turns, the generator converts the mechanical energy into electrical energy. This electricity can then be stored in batteries or used immediately to power small electrical loads, making the spring power energy generator a compact and efficient solution for low-power energy needs.

Fig. 3 Fabricated model of Spring powered energy generation system

The Spring Power Energy Generator operates on the principle of converting mechanical potential energy into kinetic energy, which is then transformed into electrical energy through electromagnetic induction. The process begins with energy storage, where the spring is manually wound using a handle attached to the primary shaft. This action stores mechanical energy as potential energy within the spring coils. The spring unwinds, converting the stored potential energy into rotational kinetic energy. This torque is transmitted to the gear train, which amplifies the rotational speed at a ratio of 1:8. The increased speed is then transferred to the flywheel and generator shaft. The DC generator utilizes Faraday's Law of Electromagnetic Induction to convert the mechanical energy into electrical energy. The resulting current flows through the rectifier circuit and powers the connected load. The LED indicator lights up, and the multimeter displays the output voltage and current. The duration of power generation depends on the spring's energy capacity and the resistance of the connected load.

V. RESULTS AND DISCUSSIONS

The Spring Power Energy Generator was successfully assembled and tested, confirming its ability to convert mechanical spring energy into electrical power. The system demonstrated stable output and high efficiency, averaging around 89%. Its compact, low-cost design makes it ideal for small-scale, off-grid applications. Safety and maintenance protocols ensured reliable operation. Though limited in energy capacity, it's reusable and independent of external sources. Overall, the prototype validates spring-based energy generation for low-power needs. The successful assembly and testing of the spring power energy generator demonstrate the practical feasibility of converting stored mechanical energy into electrical energy using a compact and low-cost system. The experimental results confirmed stable voltage and current output for short durations, validating the effectiveness of the spring–gear–flywheel mechanism in achieving controlled energy transfer. The system achieved an efficiency of approximately 85–90%, which is notably high for a mechanically driven prototype, indicating effective design, proper alignment, and reduced mechanical losses.

The system offers numerous advantages. Its compact and lightweight design makes it highly portable. It operates independently of sunlight, wind, or fuel, making it versatile for various environments. The generator produces consistent power for small loads and features a simple, low-cost construction. It is reusable through manual rewinding of the spring. Further innovation can focus on modular multi-spring configurations, where multiple springs operate in parallel or sequentially to increase output duration and power capacity.

Incorporating energy storage systems such as super capacitors or rechargeable batteries can store the generated electricity for later use, improving usability. Additionally, optimizing the system using smart control circuits can regulate output voltage and improve overall efficiency. Despite its benefits, the system has certain limitations that its energy storage capacity is limited, making it suitable only for short-duration applications. Manual effort is required to wind the spring, and the efficiency depends heavily on precise gear alignment and proper lubrication. The system is not scalable for high-power demands.

VI. CONCLUSIONS

In conclusion, the current prototype is best suitable for medium and low power or continuous power generation. It serves as a strong concept for spring-based mechanical energy systems. This concept lays a solid foundation for further innovation in alternative energy technologies and demonstrates the untapped potential of mechanical energy storage systems in modern engineering. However, despite of these results, the system exhibits a kind critical limitations which restrict its real-world applicability. The most significant limitation is the low energy storage capacity of the spring, results in short-duration power output. Additionally, the system relies on manual winding, making it impractical for large-scale energy generation. Mechanical losses due to friction, wear, and gear inefficiencies, although minimized, still affect long-term performance. Furthermore, the current design lacks scalability, as increasing power output would require disproportionately larger springs and structural components, leading to complexity and safety concerns.

To overcome these limitations, several improvements can be implemented in future developments. The integration of automatic or hybrid winding mechanisms, such as small electric motors powered by renewable sources (solar or wind), can eliminate manual effort and enable continuous operation. The use of advanced materials, such as high-strength alloy or composite springs, can significantly enhance energy density and fatigue life. Additionally, replacing conventional gear systems with low-friction or magnetic transmission systems can also reduce energy losses and improve the efficiency of the design.

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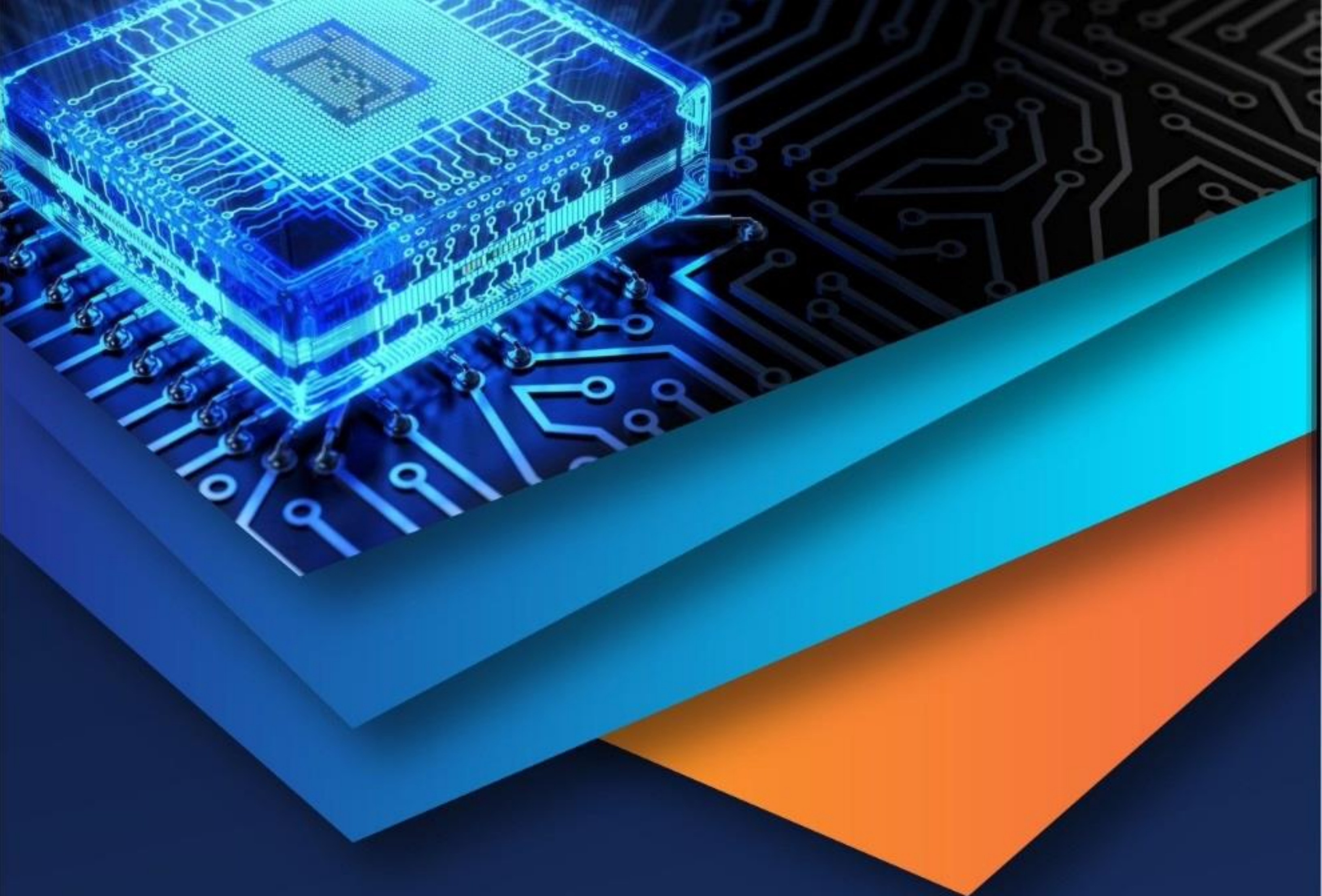

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