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Development and Construction of a Sustainable Sand-Based Power Generator: A Study on Reusability

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ABSTRACT:

Addressing the critical challenge of energy conservation in the contemporary context, this study presents an affordable and efficient approach to designing and producing a reusable sand power generation system. As global electricity demand escalates with ongoing development and modernization, it becomes imperative to meet this demand sustainably without adverse environmental effects. The key proposition is the utilization of reusable sand power generation, leveraging the ubiquity of sand worldwide.

The underlying principle of the sand power generation mechanism involves a straightforward technology that is not only cost-effective but also capable of catering to domestic (household) to medium power requirements. The process entails ordinary beach sand cascading onto the blades of a sand wheel placed in a main funnel. The resulting turbine rotation generates power, subsequently stored in a DC battery. The simplicity of the sand power generation concept lies in the conversion of potential energy to kinetic energy as sand descends from higher to lower altitudes. This kinetic energy is then transformed into circular motion and, ultimately, converted into electricity using a Mini DC generator.

It is important to note that while this sand power generation system is economical and efficient for standalone operations, it may not be cost-effective when an external power source is readily available for generating sufficient power levels. Consequently, there is a pressing need for an integrated design system and methodology to optimize the utilization of this concept. This project is implemented as a subsystem within existing industries, contributing to a more comprehensive and sustainable energy framework.

KEYWORDS: Sand Power, Renewable Energy, Power Generation, Portability.

Introduction

India's energy sector is primarily reliant on fossil fuels, particularly coal, contributing to approximately three-quarters of the total electricity generation in the fiscal year 2017-18. Despite this dominance, there is a notable governmental emphasis on bolstering investments in renewable energy. The 2018 National Electricity Plan, formulated by the Government of India, outlines a trajectory indicating that additional non-renewable power plants in the utility sector will be unnecessary until 2027. This strategic vision aligns with the ongoing construction of 50,025 MW coal-based power plants, alongside a goal to achieve a total installed renewable power capacity of 275,000 MW following the retirement of nearly 48,000 MW of aging coal-fired facilities.

Renewable energy sources currently constitute 14% of India's total installed capacity, with solar and wind contributing 2.5% and 8.8%, respectively. This underscores the nation's commitment to diversifying its energy mix, marking a shift toward a more sustainable and environmentally friendly power generation portfolio.

Throughout history, non-renewable energy sources have been pivotal to significant industrial advancements globally. However, as the demand for these finite resources escalates and their availability diminishes, it becomes imperative to acknowledge their limitations. Evidently, both governmental bodies and private sectors are increasingly recognizing the necessity of transitioning towards more sustainable and renewable energy sources.

In contrast to hydroelectric plants, sand-powered electric power plants offer distinct advantages, such as freedom from the need for fuel and avoidance of environmental pollution. Despite the prevalence of hydroelectric facilities, the sand-powered alternative is not constrained by specific water elevations, expanding its potential locations.

The primary goal of this endeavor is to design, develop, and test a reusable sand power generator. The overarching aim is to address human effort and energy challenges in rural areas by providing an economical and portable solution.

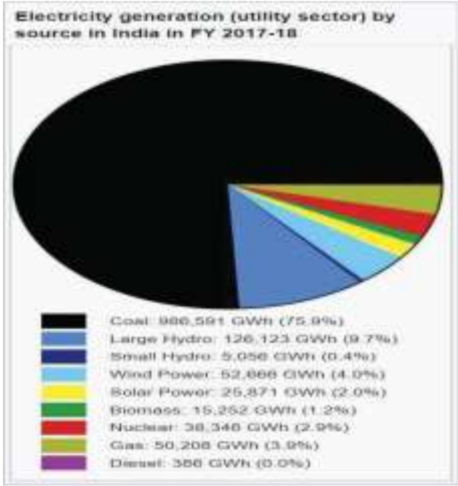
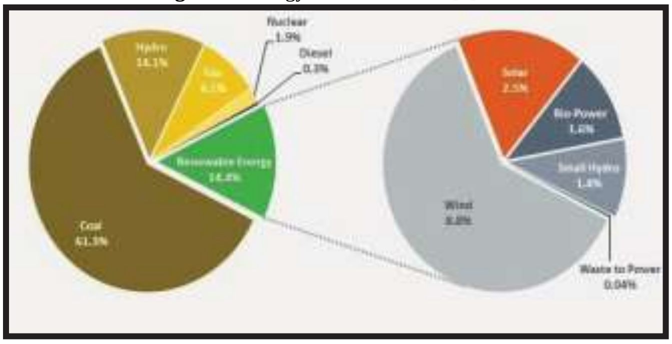


Figure 1: Electricity generation in India [2]

Figure 2: Energy sources in India [3]



LITERATURE REVIEW

In the contemporary era, individuals often take for granted the seamless availability of necessities by simply flipping a switch or pressing a button. Cell phones, computers, televisions, heated water, lights, and various other conveniences form the essential infrastructure of modern society. The electricity powering these systems is often overlooked until the moment it becomes unavailable. The intricate system enabling an immediate and consistent supply of conditioned power is commonly known as the grid.

Typically, the grid is sustained by government and/or private entities in developed countries, requiring substantial financial resources for establishment and ongoing support. Providing electricity as a service necessitates a significant investment. Surprisingly, in contrast to the developed world, nearly 80% of individuals residing in third-world countries lack access to electricity, totaling an estimated 1.5 billion people without this basic amenity. [4] Sand is an naturally-occurring granular substance consisting of finely divided rock and particles. Its classification is based on size, falling within a range finer than gravel and coarser than silt. Beach sand, characterized by its fine texture, exhibits a diverse color palette, ranging from pristine white to earthy brown, beige, tan, and subtle shades of grey. This versatile beach sand finds utility in an array of applications, contributing to the creation of inviting patios, vibrant volleyball courts, playful sandboxes, recreational playgrounds, and the establishment of picturesque faux beaches. Within our innovative method, sand assumes a pivotal role as the fundamental resource driving the rotation of the sand wheel, leading to the efficient generation of electricity. The composition of sand exhibits a rich diversity, contingent upon the distinct local rock sources and prevailing environmental conditions. In these inland continental settings and non-tropical coastal regions, the foremost component of sand emerges as silica, specifically in the form of quartz (silicon dioxide or SiO_2). This versatile approach harnesses the inherent properties of sand to contribute to sustainable and environmentally friendly electricity generation processes. The second most commonly found type of sand encompasses calcium carbonate, with aragonite serving as a notable example. This variant of sand has primarily evolved over the course of the past half billion years, with its creation attributed to the intricate processes involving various life forms, including coral and shellfish. Noteworthy is its prevalence as the primary sand type in regions where ecosystems have been shaped by the enduring presence of reefs for millions of years, as vividly exemplified in locales such as the Caribbean. This geological and biological interplay underscores the dynamic nature of sand formation and its intricate ties to the evolution of ecosystems over extended periods.[5]

The initial prototype that serves as the inspiration for our project utilizes a sophisticated sand conveyor system to facilitate the efficient reuse of sand. In this intricate process, ordinary sand is carefully placed into the primary funnel. Subsequently, it cascades onto the blades of a sand wheel, initiating the power generation process, with the generated power being stored in a DC battery. The resulting collision of sand creates a vigorous scattering effect, and this dispersed sand is methodically collected by a specially designed container with a small vent. The collected sand is then directed into conveyor boxes, each equipped with a DC motor that consumes a minimal amount of the power generated by the dynamo. These conveyor boxes play a crucial role in transporting the sand to a specific height, exceeding the funnel's stock point by one-third. From this elevated point, the sand makes its way back to the main funnel, initiating a cyclic process of sand reuse. This recycling continues for several months until the sand is reduced to minute particles.

This unique process stands out for its innovativeness and adaptability, as it can be scaled from meeting modest power requirements to accommodating extensive power needs. The system's simplicity and cost-effectiveness make it an ideal solution applicable to a spectrum of scenarios, from domestic (household) energy needs to large-scale and very large-scale power requirements. The culmination of these strategies and principles will be validated during the verification phase, ensuring the practicality and effectiveness of the finalized concepts.

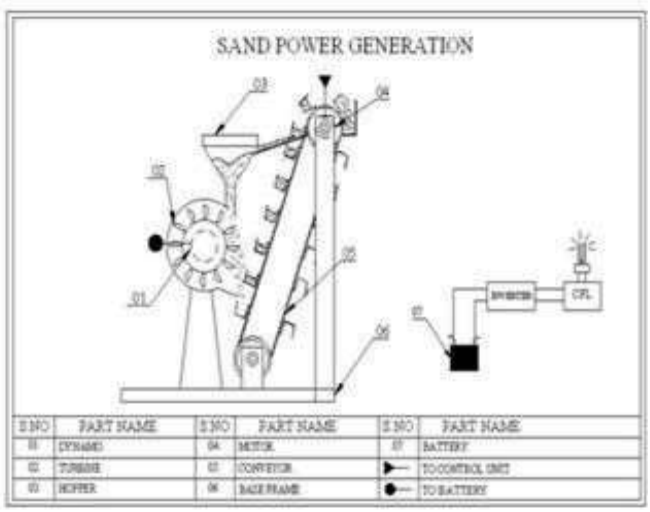


Figure 3 – Previous model for energy generation using sand [6]

DESIGN PROCEDURE

Working principal

The turbine, an essential component within our system, carries out a pivotal function with paramount significance:

Its primary objective is the conversion of energy, specifically transforming high-pressure energy into mechanical energy manifested as shaft rotation, thereby instigating the turning of the generator. This intricate process unfolds as a moving fluid engages with the turbine blades, inducing their motion and transference of rotational energy to the rotor. Early instances of turbines encompass iconic structures like windmills and waterwheels. It's noteworthy that gas, steam, and water turbines feature a protective casing surrounding the blades, a critical element in containing and managing the working fluid.

The operational concept of the Sand power generator is rooted in the ingenious conversion of potential energy stored in sand at an elevated position into kinetic energy by allowing the sand to descend. This kinetic energy, derived from the downward movement of the sand, is effectively utilized to set a rotor into motion, thereby generating electrical power. As the turbine's shaft undergoes rotation, the connected generator mirrors this rapid spinning, culminating in the generation of electricity.

In the intricate workings of the Sand power generator model, the passage of sand across the turbine initiates a dynamic spinning motion, propelling the rotation of the shaft and subsequently energizing the dynamo generator. This cyclic rotation of the dynamo, fuelled by the sand's movement, is instrumental in the continuous production of electricity. Drawing inspiration from the visual concept of a sand timer, our model envisions two substantial sand barrels or tubs positioned opposite each other, securely mounted on a robust frame composed of steel, wood, or preferably lightweight aluminium. This detailed framework embodies a holistic approach to harnessing the potential of sand to meet a diverse range of power requirements, ensuring adaptability and sustainability in various applications.

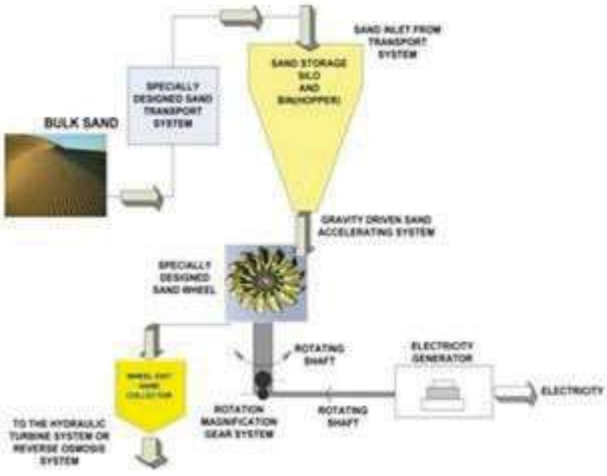


Figure: 4 Working Principle

The two containers will be linked by a plastic tube, and an electric motor (acting as the generator) or a permanent magnet alternator/rectifier, featuring a sand-wheel (a Pelton wheel), will be mounted on its driveshaft. An ideal choice for the tube is a piece of old drainpipe. The electric motor should be compact, capable of generating a usable voltage even at low RPM.

In its charged state, with 5-10 kg of sand in the upper barrel and the unit in a vertical position, it holds potential energy. Upon opening a valve/tap in the connecting pipe, the sand transitions from potential to kinetic energy, coursing across the Pelton wheel blades of the generator where it is converted into electric power. Given the fluid nature of sand flow, its substantial mass ensures that exit pressure is not contingent on the sand's height above it in the charge.

To recharge the unit, a 'simple' rotation of 180 degrees is required after first closing the valve/tap in the connecting pipe. This repositions the previously filled barrel at the top of the frame, poised to discharge across the generator once again. For ease of operation, the unit may incorporate a gearbox and crank handle, enabling a single person to rotate and recharge it. Alternatively, with three or four individuals available, manual rotation to the fully charged position can be accomplished within a few seconds. This flexible design allows for efficient and straightforward recharging, ensuring optimal functionality of the system.

Construction

Nestled within the confines of the sandbox is a precisely measured 1.5 kg of sand, neatly distributed to fill a volume of 1 liter. The design of the box exhibits ingenuity, allowing for the seamless and recurrent reuse of the sand. This thoughtful design not only emphasizes efficiency but also ensures that the quantity of sand remains consistently fixed, contributing to a sustainable and controlled sand utilization.

Prototype design

Within the sandbox, a well-thought-out two-chamber system is implemented. Chamber 1 serves as the receptacle where the sand gracefully descends, while Chamber 2 is designated for collecting the falling sand. Each chamber features a carefully integrated one-hopper and one-way flaps, strategically designed to ensure that once the sand is collected, it remains securely within Chamber 2. The flaps are configured in a manner that facilitates continuous sand flow, permitting the sand to exit only through the designated hopper opening.

To further fortify the containment of sand within the box, two glass panels are thoughtfully incorporated. These panels serve as a protective barrier, not only preventing the escape of sand from the box but also ensuring that the quantity of sand within remains consistent.

In addition, DC generators are positioned externally to the box, strategically placed to avoid the accumulation of sand on the shaft, which could lead to friction. This precautionary measure not only safeguards the generators from potential damage but also contributes to the overall efficiency and durability of the system.

Fig: 5: Solidworks Model Isometric View

Working of prototype

The sandbox undergoes a deliberate anticlockwise rotation, spanning approximately 180 degrees, orchestrating a well-coordinated sequence of actions. As this rotation unfolds, the sand that had previously found its place in Chamber 2 gracefully transitions to Chamber 1. The strategic placement of the sand in Chamber 1 sets the stage for its descent onto the turbine blades. These blades are intricately connected to a shaft, forming a vital link to a DC generator, thus commencing the generation of electrical voltages.

Upon reaching the zenith of the 180-degree rotation, the sand nestled in Chamber 1 attains a height of precisely 60 cm. In synchrony with this movement, Chamber '2' seamlessly assumes the position formerly occupied by Chamber '1'. This rotational shift sets the sand in motion, orchestrating a controlled descent aided by a precisely designed hopper. The ingenious design of the hopper concentrates the sand, guiding it through a reduced opening with a diameter of 1.8 cm. The sand then gracefully descends, meticulously collected in Chamber 2 as the flap maintains its open position, responding to the weight of the sand.

With the subsequent 180-degree rotation, a fascinating interplay of forces comes into play. The sand, now in Chamber 1, exerts force on the flap, compelling it to close in response to the sand's pressure. Simultaneously, the inclined structure towards the hopper facilitates the seamless descent of sand from the opening. This cyclic process unfolds with remarkable precision, setting the stage for a repetitive and self-sustaining cycle that showcases the innovative and ingenious nature of this sand power generation system.

Testing and Results

Selection of Number of Blades

In the process of determining the optimal number of blades, the data provided in the aforementioned table is based on specific parameters, including a sand volume of 1 litter (equivalent to 1.5 kg) and a nozzle diameter of 1.8 cm. According to the results, this configuration yields a noteworthy maximum output voltage of 5.10 volts, achieved within a duration of 16 seconds. This critical information aids in refining the selection criteria for the number of blades, ensuring an effective and efficient sand power generation system.

Table 1: Blade Numbers vs Output

Sr no.	Number of blades for the diameter of the turbine	Voltage	Time	Comment
1	10	5.16 v	15 sec	-
2	11	6.25 v	15 sec	Preferred
3	12	5.06 v	15 sec	-

Selection of Flow diameter

In the formulation of our prototype, a pivotal aspect requiring careful consideration is the selection of the nozzle diameter for the chamber. This choice holds significant importance as it directly dictates the time it takes for the sand to descend onto the rotor blade. To delve deeper into this aspect and facilitate a comprehensive exploration, two distinct sets of nozzle diameters—specifically 2.2 cm and 1.8 cm—have been identified for further experimentation. The detailed specifications and outcomes of these nozzle diameter variations are systematically documented in the table provided below, contributing valuable insights to the ongoing development and refinement of our sand power generation system.

Table 2: Output voltage for different nozzle diameter for 8 no. of blades

Diameter of flow for 1.5 kg of sand	" 11 " blade arrangements	Voltage	Time	Comment
2.8 cm	Larger diameter blade 16cm	3.5 V	10 sec	-
	Smaller diameter blade 14cm	3.86 V	10 sec	-
1.9cm	Larger diameter blade 16cm	5.02 V	21 sec	-
	Smaller diameter blade 14cm	6.10 V	21 sec	Preferred

Conclusion

The distinctive approach to electricity generation presented here harbors significant potential that can be fully realized through the implementation of a comprehensive action plan. Currently, this unconventional source remains largely untapped, primarily due to the underrecognition of its positive attributes and the absence of dedicated initiatives. However, envisioning the active deployment of this sand power generation process paints a picture of it surpassing traditional energy sources in the market, offering a sustainable solution without compromising the environment. The cyclic use of sand as a readily available raw material ensures a continuous supply chain without the challenges associated with constant procurement efforts.

The project's outlook is exceptionally promising, especially in the absence of comparable ongoing endeavors. Its inherent advantage of low maintenance costs positions it as an economically viable option for electricity production, promising more accessible rates compared to conventional sources. Furthermore, the project's eco-friendly profile opens up avenues for trading carbon credits, potentially yielding significant returns in esteemed platforms like the London Stock Exchange. The prevention of carbon emissions through the adoption of this energy source not only aligns with sustainable practices but also presents lucrative opportunities for environmental initiatives and investments. As the project gains traction, its positive impact on both energy generation and environmental conservation is poised to make a notable mark in the industry. It can be conclude from the above analysis that:-

1. Sand power generation offers a unique and untapped source of electricity with great potential if properly implemented.
2. With no ongoing projects, the bright prospects lie in its low maintenance costs and affordability compared to conventional energy sources.
3. Its green profile opens opportunities for carbon credit trading, ensuring environmental benefits and higher market value.

Future Scope

This innovative concept holds vast potential with several applications:

1. It can function as a mini power plant in basements, requiring designated space for installation.
2. When connected in series, human effort is needed to rotate all four boxes simultaneously. The incorporation of gears can effectively reduce the manual effort required for box rotation.

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