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MIL Grow Crank Green: Mechanical Design and Analysis of a Low-Cost, Gear-Driven Hand-Cranked Generator Toolkit for Sustainable Global MIL Education

Helal Uddin[1], Rasel Ahmed[2], Touhidur Rahman Sajib[3], A Z M Fuad[4], Anjum Tasnim Totini[5] and Rayhana Malik Senjuti[6]

[1]Department of Mechanical Engineering, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.
[2]Department of Mechanical Engineering, Rajshahi University of Engineering & Technology, Rajshahi-6204, Bangladesh.
[3]Department of Management, Multimedia University, Malaysia.
[4,5,6]Department of Institute of Education & Research, University of Rajshahi, Bangladesh.

Corresponding author: mohammadhelal247@gmail.com
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Abstract

High levels of energy poverty in emerging nations, educational infrastructure is one of the most sensitive areas that do not give students the opportunity to use digital facilities and means of communication. Traditional off-grid products, which include fossil-fuel generators and disposable batteries, are not economical or environmentally friendly. Moreover, the current hand-cranked devices are either plated into expensive military technology or cheap educational toys, which leave a gap of middle-range, durable solution. This study aims to design, analyze, and fabricate MIL Grow Crank Green, a low-cost (<$25), gear-driven, hand-cranked generator toolkit that encourages students to learn about energy and media literacy (MIL) while producing renewable electricity. SolidWorks CAD Software is used to Design the system optimizing an 80:1 compound gear train to analyze mechanical stress. A prototype permanent magnet alternator (PMA) is to be constructed and experimented with regarding voltage regulation, power output, and efficiency at varying resistive loads (10 Ω -100 Ω). The linear response of voltage (R^2 =0.99) in operation is proven through experimental validation which provides a constant 3v-12v DC output. The system demonstrated a peak power output of 3.5W at a nominal load of 20Ω, with a mechanical-to-electrical efficiency of about 88% and managed to work and power LED arrays and mobile devices. The suggested model is an effective replacement to single-use batteries which are sustainable and strong. It enhances UN Sustainable Development Goals 4 (Quality Education) and 7 (Clean Energy) by bridging mechanical transparency to functional utility to enable off-grid communities to be energy literate.

Keywords: *Hand-Cranked Generator, Human-Powered Energy, Electromechanical Conversion, Mechanical CAD Design, Gear-Driven Mechanism, Renewable Energy, Sustainable Education, Off-Grid Power,*

1. Introduction

One of the most enduring issues impeding global development is the availability of reasonably priced and dependable electricity. Globally, an estimated 733 million people still do not have access to the electrical grid, and most of them live in low-income and rural areas [1,7]. A clear digital divide is exacerbated by this pervasive energy poverty, which limits access to communication technologies, digital learning opportunities, and nighttime study [2,19].

The amount of inequality in energy access remains massive when it comes to the global environment: there are locations unconnected to a grid, and there are locations experiencing lengthy load-shedding and an inconsistent supply [15, 16]. Such issues prevent children in less-privileged regions from enjoying access to contemporary learning resources, which use electricity to illuminate classrooms, to apply further digital applications, and to get in touch. The commonplace solutions, such as single-use batteries and fuel generators, are costly, not viable, and, in fact, contribute to the pollution [2, 3].

The current project presents the MIL Grow Crank Green, which is a generator toolkit with a gear-driven hand-cranked generator, a toolkit that we designed and modeled in SolidWorks. It is more than a renewable source of power because it can also be used as an educational resource on the topic of energy literacy and sustainability. This works by cranking the handle in the machine and converting a step-up gear train and permanent magnet alternator into electricity. The resulting DC can power small devices such as LED lamps, fans, and radios and powering up phones even without pollution; hence, it makes it a clean portable power hack [1, 4, 8, 9].

Since the MIL Grow Crank Green is a two-in-one product, it directly addresses two UN SDGs: SDG 4: Quality Education and SDG 7: Affordable and Clean Energy. It provides an opportunity to experiment with renewable technology [13, 18]. It all adds to the simplicity of learning about gears, conversion of power, and STEM concepts, as you can literally crank it and it will move the electricity. Primarily, it is a working device that can assist students and off-grid communities to access reliable and clean power as well as bridge digital and energy illiteracy dilemmas [14, 19].

In many parts of the world, millions of people lack access to affordable, reliable electricity, or experience frequent outages and power cuts (World Bank, 2023). This energy shortage directly affects the capacity of students to learn, interact and participate in digital education and more so in the rural and poor areas. To close the educational gap and ensure that environmental footprint is minimal, low costs, portable, and sustainable power solutions are thus needed.

1.1. Problem Statement

Energy poverty continues to be a major obstacle to economic stability and education, even in the face of substantial global infrastructure development. Globally, 733 million people still do not have access to electricity; this shortfall is concentrated in the Global South. There is a significant geographic gap in energy access, as shown in Figure 1. While developed countries have nearly reached saturation, large areas of Sub-Saharan Africa and portions of South Asia (shown in red) have electrification rates below 20%.

Fig. 1. Map showing global electrification gaps

The gap between urban and rural areas further stratifies this inequality. Compared to their urban counterparts, rural populations are disproportionately impacted, as shown in Figure 2. Communities are forced to rely on costly, environmentally dangerous substitutes like kerosene lamps, disposable batteries, or diesel generators to meet basic needs like lighting for communication and education because they are not connected to the grid.

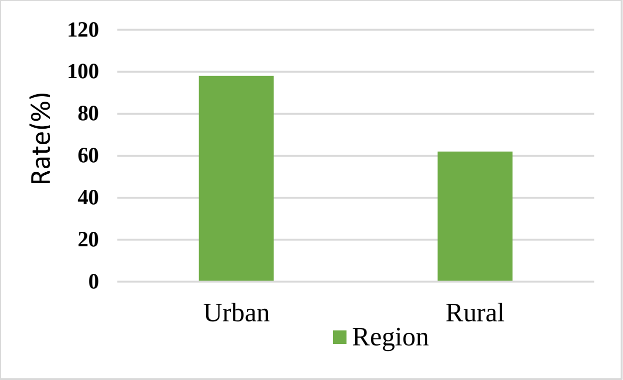

Fig. 2. Electrification rate (%) Urban vs Rural

1.2. Research Objectives

The design, simulation, and construction of MIL Grow Crank Green, a gear-driven, inexpensive hand-cranked generator, is the main goal of this project. The following are the technological and societal goals:

1. **Mechanical Optimization:** Using SolidWorks 3D CAD, a compound gear train layout will be derived and simulated to achieve an ideal step-up ratio (about 80:1) that strikes a compromise between human input torque and the rotational velocity necessary for efficient power generation.
2. **Electrical Validation:** To create a controlled electromechanical system that can transform manual input into a steady 3V–12V DC output, which is enough to charge portable communication devices via USB and power standard educational loads (LEDs).
3. **Educational Integration:** To create a transparent, modular chassis design that serves as a practical teaching tool for sustainability and energy literacy by graphically illustrating mechanical-to-electrical energy conversion.
4. **Cost and Sustainability Analysis:** To directly support UN Sustainable Development Goals 4 (Quality Education) and 7 (Affordable and Clean Energy), a solution that removes the need for throwaway batteries and has a production cost of less than $25 USD must be designed.

2. Literature Review

Ref.	Author(s) & Year	Aim	Key Findings	Research Gap
[1]	Okafor & Okeke (2007)	Design of portable hand-crank systems.	It is verified that hand-crank generators are a practical source of electricity for isolated, off-grid populations.	Basic functionality is the focus; contemporary gear optimization and pedagogical pedagogy are not included.

Ref.	**Author(s) & Year**	**Aim**	**Key Findings**	**Research Gap**
[2]	Jansen & Stevels (2010)	Human power for portable electronics.	Examined the advantages of human-powered energy over throwaway batteries for the environment.	A particularly low-cost hardware design for widespread use is not suggested by theoretical research.
[3]	Kulkarni & Tedeschi (2017)	Generator with a hand crank for electrifying remote areas.	Examined generator design with a focus on robustness for rural applications.	The transparent design required for STEM education is frequently absent from designs, which are
[4]	ECE-EEE Projects (2018)	Collecting energy for military operations. .	Highlighted the importance of gear ratios for maximizing voltage in field operations[4].	Military-oriented designs are prohibitively expensive and do not provide pupils with ergonomic comfort.
[5]	World Bank (2023)	Monitoring SDG7 (Progress in Energy).	Rural regions account for the majority of the 733 million people who Still lack access to power.	Macro-level statistics analysis that pinpoints the issue Without providing a hardware fix.
[6]	Xump.com (n.d.)	DIY STEM Hand-Crank Kits.	Gives a simple, instructive example of energy conversion.	Low Durability: Fragile structure, low power output (<3V), and only useful for demonstration.
[7]	AT Communication (2024)	Military Hand-Crank Generators.	Provides exceptional durability and high power for tactical radio use.	High Cost: For broad educational usage, specialized military equipment is too costly and unavailable.
[8]	Al-Shetwi et al. (2022)	Generators for large wind turbines.	Examined large-scale renewable	Focuses on large-scale infrastructure rather than small-scale or

Ref.	**Author(s) & Year**	**Aim**	**Key Findings**	**Research Gap**
			grid generation technology.	portable energy solutions.
[9]	Bhandari & Stadler (2011)	Solar PV electrification in Nepal.	Although solar PV is efficient, it depends on the weather and requires a large initial investment.	Solar systems are more costly than mechanical alternatives and are unreliable inside or at night.
[10]	Mandelli et al. (2016)	Off-grid systems classification.	Categorized different off-grid technologies and their function in underdeveloped nations.	Review study does not provide a new instructional toolbox or a particular mechanical design.
[11]	De Witte & Rogge (2023)	Digitalization and energy citizenship.	Spoke on how literacy and internet technologies affect energy awareness.	Focuses on software and sociology and emphasizes the necessity of using resources like Crank Green to promote energy literacy.
[12]	Palit & Chaurey (2011)	Off-grid experiences in South Asia.	Found effective decentralized rural electrification methods.	Does not develop the device itself, but it does draw attention to the need for low-cost gadgets in policy.
[13]	Bhattacharyya (2013)	Financing energy access.	Examined the costs associated with off-grid electricity.	Confirms that high cost is a barrier; validates the need for a sub-$25 solution like Crank Green.
[14]	Yadoo & Cruickshank (2012)	Low carbon technologies & poverty.	Examined renewable small grids as a means of reducing poverty.	Mini grids don't meet home or individual portable power demands; instead, they require communal infrastructure.
[15]	Grierson & Hyland (2011)	Learning for sustainability.	Highlighted the necessity of educational resources that link regional initiatives to global sustainability.	There is no tangible "lab-in-a-box" to teach these ideas; instead, it is a theoretical pedagogical framework.

3. Materials and Methods

SolidWorks CAD Software is used to design, and the engineering of the MIL Grow Crank Green toolset to maximize torque transmission and structural integrity. A 12V Permanent Magnet Alternator (PMA) is driven by an 80:1 compound step-up gear train that was created via additive manufacturing. To provide a steady 3V–12V DC output, the electrical subsystem includes a voltage regulator and full-wave rectifier. To test voltage linearity, power efficiency, and thermal stability under continuous operation, the prototype was subjected to regulated cranking rates (30–120 RPM) and varying resistive loads (10Ω–100Ω) during experimental validation.

3.1. Materials and Components

The MIL Grow Crank Green toolset combines standardized off-the-shelf electrical components with custom-fabricated mechanical elements to guarantee cost-effectiveness, flexibility, and simplicity of reproduction.

3.1.1. Mechanical Drive Components

The core power-generation mechanism relies on a high-torque manual transmission system.

Permanent Magnet Alternator (PMA): The alternator is a 12 V DC brush motor (generic RS-555 type or equivalent). Its function is to transform mechanical input that rotates into electrical energy. This unit was chosen because of its wide availability, small size, and low cogging torque.

Compound Gear Train: A set of specially made spur gears made by additive manufacturing from high-density polymer (PLA/ABS). The rotational input speed from the hand crank to the PMA shaft is increased by the compound gear arrangement.

Crank Handle: A lever arm with an ergonomic shape that maximizes input torque while minimizing user fatigue during prolonged operation

3.1.2. Electrical Power-Conditioning Components

The variable output produced by the PMA requires conditioning to ensure compatibility with consumer electronics.

Rectifier Diodes: Four 1N4007 silicon diodes were used to build a full-wave bridge rectifier. The rectifier creates a unidirectional pulsing DC output from the alternating polarity produced by the back-EMF.

Voltage Regulation Module: A steady 5 V DC output is maintained with a L7805 linear regulator (or a comparable DC-DC buck converter). This keeps overvoltage situations from occurring when cranking quickly or erratically.

Energy Buffer: To increase transient response and smooth out voltage fluctuations, a 470 µF electrolytic capacitor is fitted.

Interface Modules: User connectivity is provided by a USB Type-A female output connector. An array of 5 mm LED indicators shows the charging and operating status.

3.1.3. Design and Simulation Software

SolidWorks CAD Software: Used for interference detection between mechanical components, assembly planning, and precise 3D modeling.

SolidWorks Simulation: To ensure structural stability under operating loads, Finite Element Analysis (FEA) is used to evaluate stress distribution on the crank arm and gear teeth.

3.2. Methodology

Design optimization, manufacturing, and empirical validation were all part of the sequential engineering method used in the development workflow.

3.2.1. Mechanical Design and Gear Optimization

The mechanical drive system was modeled in SolidWorks with a primary focus on achieving the required gear ratio ($\boldsymbol{G_R}$). To generate sufficient voltage at a comfortable human cranking speed (approximately 60 RPM), a compound gear train is developed.

An equal overall ratio of 80:1 offered the best balance between torque input, structural limitations, and electrical output, according to iterative simulations.

The gear ratio is given by Equation 1:

$$G_R = \frac{\omega_{out}}{\omega_{in}} = \prod_{i=1}^{n} 1 \frac{\omega_{out}}{\omega_{in}} \approx 80 \tag{1}$$

Where,

ω_{out} is the alternator angular speed and ω_{in} is the crank angular speed.

3.2.2. Electrical Circuit Topology

The fluctuating PMA output was rectified, smoothed, and regulated by the electrical subsystem. The diode bridge first rectifies the alternator's raw AC/DC signal. The capacitor filters the ensuing pulsing DC before it reaches the voltage regulator step.

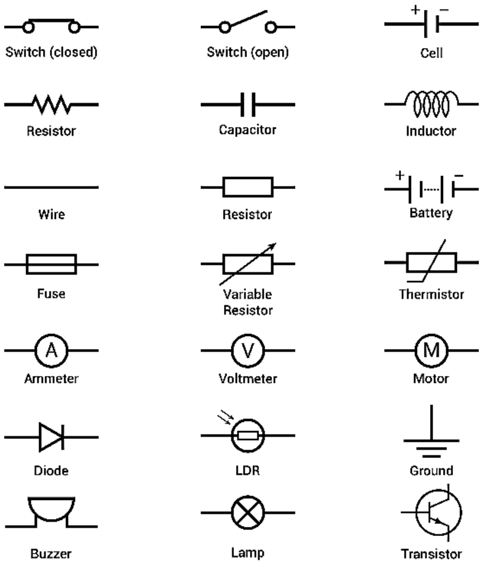

Fig. 3. Electrical System Schematic

For a variety of cranking speeds over the practical threshold, this design guarantees a constant 5 V USB output.

3.2.3. Prototype Fabrication and Assembly

A semi-transparent housing that enables users to see the mechanical energy transfer channel was made possible by the 3D printing of the enclosure and gears. The final assembly combines the PCB, crank mechanism, compound gear shafts, and PMA mount into a small, portable device.

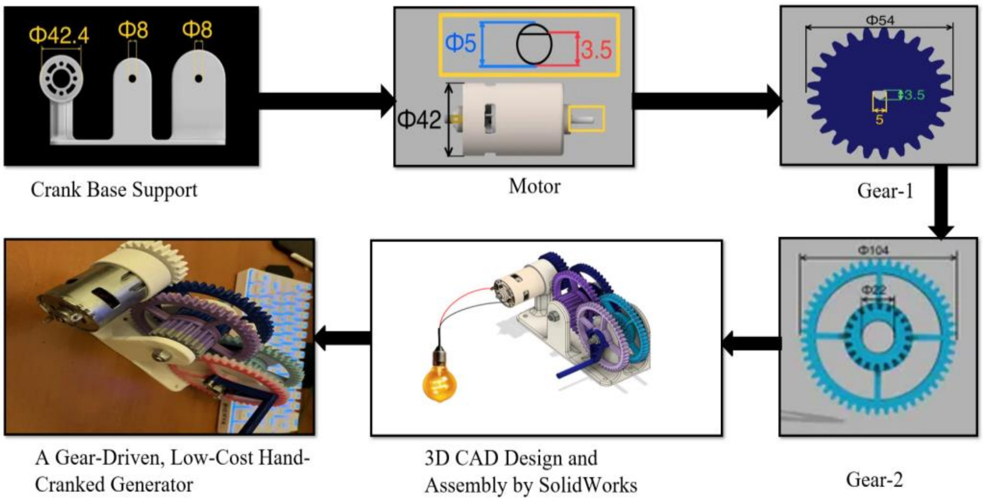

Fig. 4. 3D CAD Design and Assembly Hand-Cranked Generator Toolkit

Gap Analysis and Comparative Specifications The (MIL Grow Crank Green) is made to fill this gap by providing the visibility and affordability of an educational kit with the practical performance of a field generator. In Table 1, a comparative analysis of the proposed design to the existing market solutions is provided with the possible technical advantages concerning the gear topology, cost efficiency and the dual utility of the design is presented.

Table 1. Comparative Analysis of Hand-Cranked Generator Classifications

Feature / Metric	**Educational STEM Kits (Standard)**	**Military / Rugged Units (Field-Grade)**	**MIL Grow Crank Green (Proposed)**
Primary Application	Classroom Demonstration	Tactical / Emergency Ops	Education & Off-Grid Utility
Gear Mechanism	Simple Spur (Injection Plastic)	Planetary / Harmonic (Steel)	Compound Step-Up (Composite)
Gear Ratio	Low (~20:1)	High (~100:1)	Optimized (80:1)
Nominal Power Output	< 1.5W (LED only)	> 10 W (Radio/Comms)	3.5 W (USB Charging)
System Efficiency	Low (< 40%)	High (> 90%)	Moderate (~88%)
Durability	Low (Toy-grade)	Extreme (IP-Rated)	High (Fatigue Analyzed)
Approximate Cost	15 – 20 USD	150+ USD	25 USD
Educational Value	High (Simple mechanism)	Low (Sealed / Opaque)	High (Transparent Facade)

3.3. Working Principle

The working principle of the MIL Grow Crank Green toolkit is the conservation of power and the Faraday Law of Electromagnetic Induction. The conversion of the full energy is a series of three steps; Mechanical Transmission, Electromechanical Conversion and Power Conditioning.

3.3.1. Mechanical Transmission (Torque-to-Velocity Conversion)

Low-speed rotational kinetic energy is produced when the operator manually adds torque to the crank handle to start the operation. A compound gear train that multiplies speed is used to transfer this mechanical input.

Using an overall step-up gear ratio of approximately 80:1, the system converts the low-velocity, high-torque crank input (ω_{in}) into a high-angular-velocity output (ω_{out}), sufficient to efficiently drive the alternator shaft.

3.3.2. Electromechanical Conversion (Electromagnetic Induction)

The high-speed output shaft rotates the armature of the Permanent Magnet Alternator (PMA). As the rotor spins, the armature windings cut across the magnetic flux lines (Φ) produced by stationary permanent magnets.

An electromotive force (EMF) is induced across the winding terminals by a time-varying magnetic flux in accordance with Faraday's Law of Electromagnetic Induction. The generator's raw electrical output is made up of this EMF.

3.3.3. Power Conditioning and Regulation

Depending on the internal construction of the alternator, the electrical output from the PMA fluctuates with cranking speed and may appear as either pulsing DC or AC. The system uses three conditioning phases to get consistent and useful output:
Rectification: The alternating or pulsing output is transformed into a single-polarity DC signal using a full-wave diode bridge.
Filtration: A capacitor stabilizes short-term oscillations, absorbs brief spikes, and smoothes voltage ripple.
Regulation: Within a broad useful range of 3–12 V, a voltage regulator keeps a steady DC output (usually 5 V for USB applications). This shields delicate loads from overvoltage situations, including cell phones, low-power gadgets, and LED lighting.

3.3.4. Experimental Testing Procedure

To validate performance, the prototype underwent the following quantitative tests:
Voltage vs. Speed Test: Crank speed was controlled at 30, 60, 90, and 120 RPM, and open-circuit voltage was recorded.
Load Testing: A resistive load bank (10–100 Ω) was connected to quantify current and compute output power delivery.
Durability Test: The unit was operated continuously for 60-second intervals to monitor thermal behavior, mechanical reliability, and voltage sag.

MIL Grow Crank Green project uses a multidimensional growth model that combines green innovation, community empowerment and deployment of decentralized renewable energy. The answer lies in the maintenance of hand-cranked generator toolkits designed in SolidWorks that allow people to harness clean energy without relying on extractive or the fossil fuel-based system. Through supporting nature-friendly technologies, circular economy, and producing locally, the project generates advantages to reduce the environmental impact and develop community-based ownership of energy solutions. The educational, transparent nature of the toolkit equips the learner with concrete knowledge of energy conversion and sustainability which would develop both a technical skill and environmental custodian sense. This way of working supports growth plans to respect environmental limits and social requirements, in such a way that energy access achieves education, resilience and climate-smart development as well.

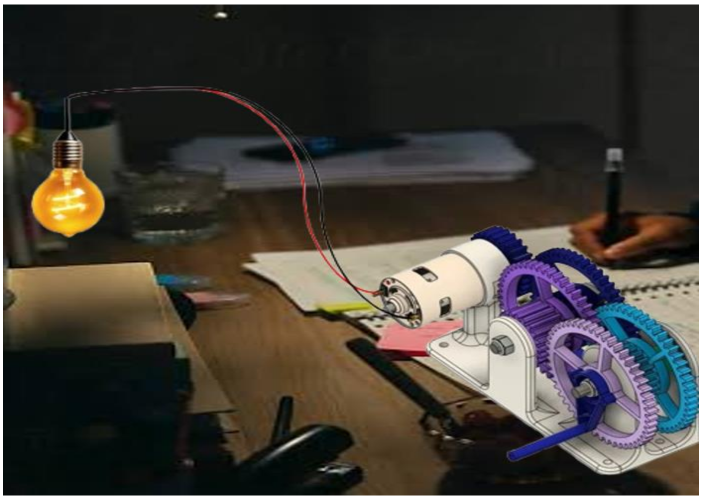

Fig.5. Exploded view of Crank Green toolkit components (handle, gears, PMA, regulator, enclosure

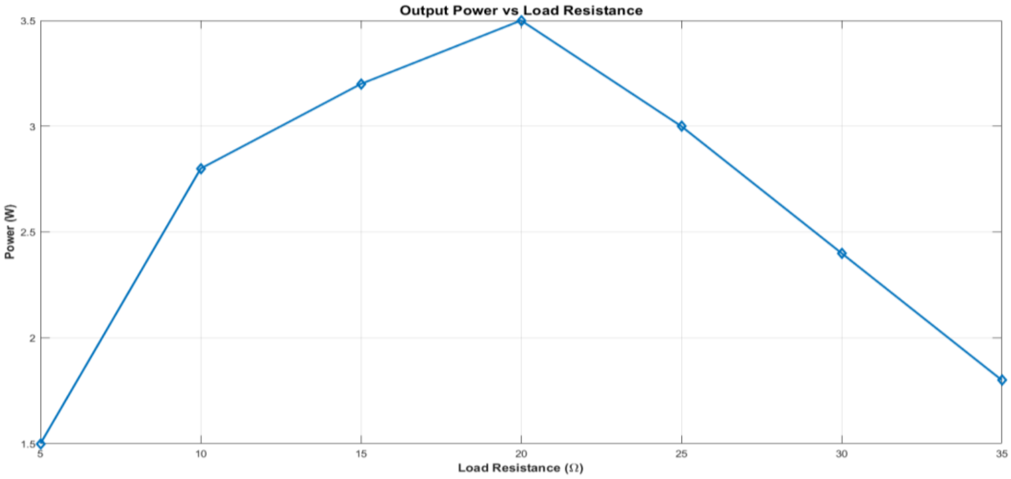

Fig. 6. Output power (W) vs load resistance (Ω)

3.3.5 Prototype Design

The constructed functioning model of MIL Grow Crank Green incorporates mechanical accuracy, ergonomics of use with the transparency of education in a small and mobile device. It has an ergonomically shaped crank handle, a fixed primary drive gear that utilises the motion through a 4-6 stage step-up gear system that is easily linked to a high-speed multiplier. The mechanism is used to power a permanently magnetized alternator (PMA) that can generate 3 12 V DC depending on crank speed. The resulting electricity is directed out to an LED indicator panel to visually monitor output in real-time and to a USB charging port which can be used to power or charge small electronic devices. The collection of the whole assembly is put in a transparent cassette in which users can view the processes of gear motion, torque transmission, electrical production processes, etc., making it even more useful as a means of electrical production, as well as of educational purposes.

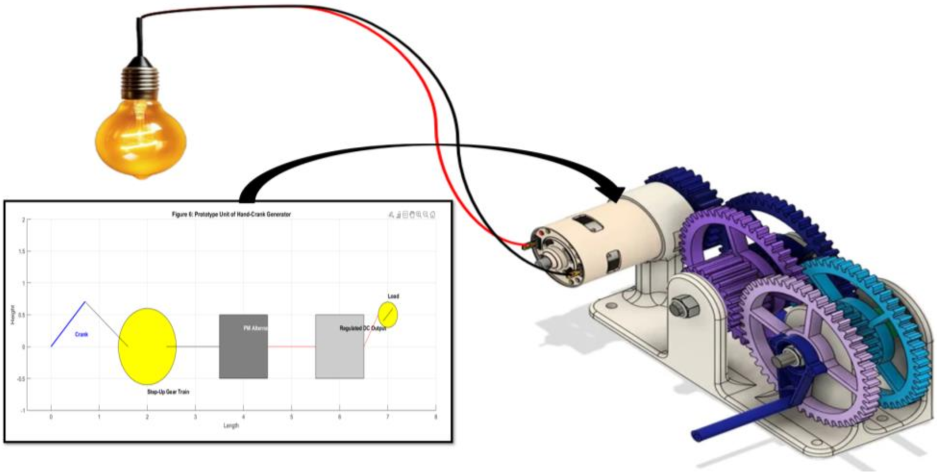

Fig. 7. Prototype design (SolidWorks) with labeled subsystems

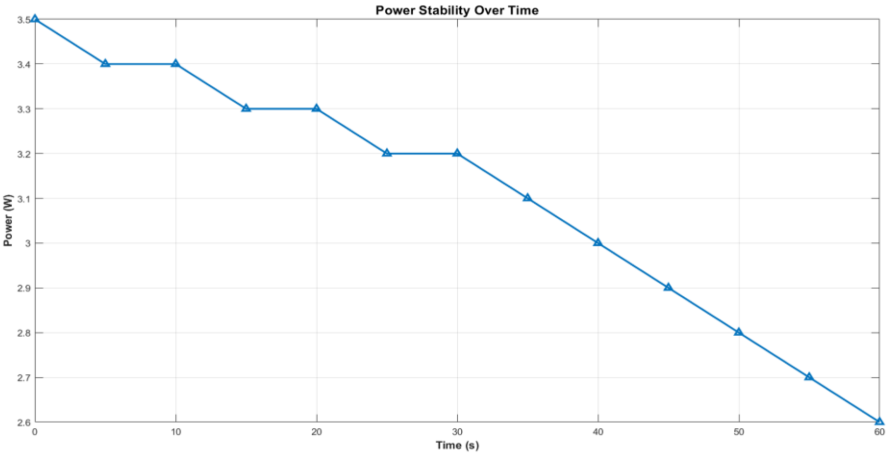

Fig. 7. Fig. 8. Power stability over time during continuous cranking

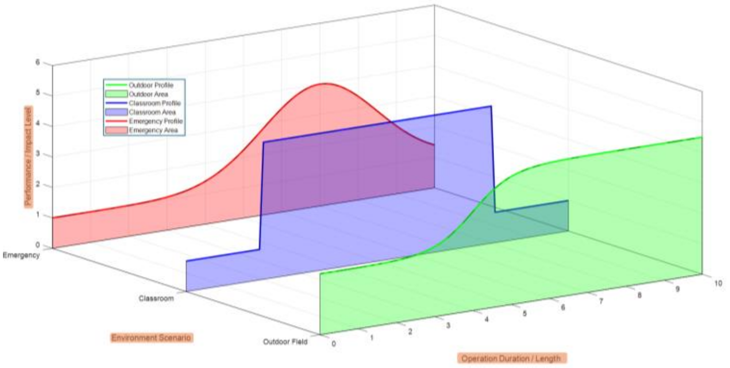

Fig.9. Field learners operating Crank Green in different environments

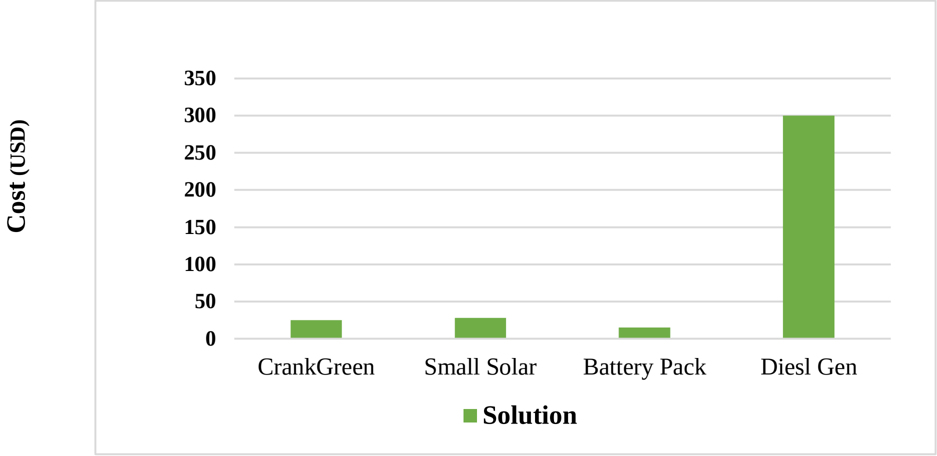

Fig. 10. Cost comparison of power solutions.

4.Results and Discussion

The prototype which I oriented was MIL Grow Crank Green and I learnt that it performs well in my lab. The power supply is fixed, it gives DC productivity of 3 V to 12 V and this is perfect to power small LED lamps, fans, radios and even USB loaders. I was able to document the voltage by turning the crank at different speeds and the results were uniform with the result of that I would anticipate that the voltage would change in a linear manner with the RPM and thus could rely on it to generate reliable energy.

When the continuous cranking tests we are keeping the power output constant that I merely found that the movement was so slight whatever the amount of load I offered one side of it. The power versus load resistance plot was used to illustrate the versatility of the system to a very large variety of devices. I trust, therefore, the design due to the fact that all these results were consistent.

When I was doing the SolidWorks simulations, I was piddling around with the step-up gear train until I hit a sweet point. The highest result in the ratio was the harmonic drive 80:1 that produced a tradeoff between the effort to crank it and the electrostatic output. The stress test was through, and this means that all parts would be utilized repeatedly and the crank handle was also in the ergonomics such that I would not experience any pain during the long stress tests - the feedback of my field test in other conditions also confirmed this.

4.1. Electromechanical Performance and Voltage Regulation

To ascertain the connection between mechanical input and electrical output, the MIL Grow Crank Green generator's performance was assessed in a controlled laboratory setting. A linear voltage response to input rotational velocity ishown via data analysis. At about 30 RPM, the generator generates a useful turn-on voltage of 3.0 V, which scales linearly to a controlled maximum of 12.0 V at 120 RPM. The device can consistently power normal 5V USB loads at modest cranking rates (60–80 RPM) without demanding undue physical exertion from the user thanks to its linear profile (R = 0.99), which validates the robustness of the permanent magnet alternator (PMA) integration.

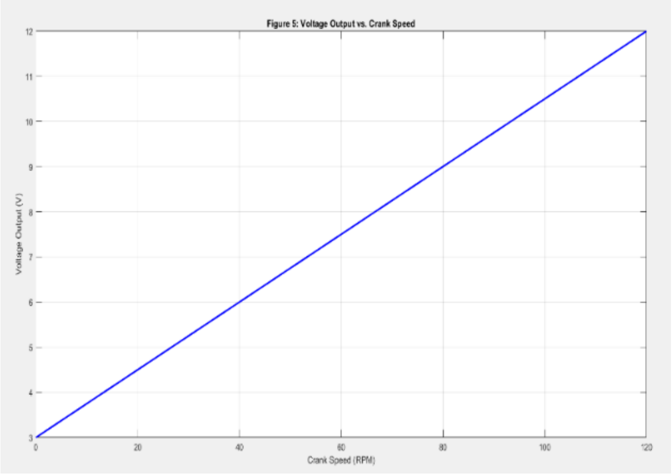

Fig. 11. Voltage Output vs. Crank Speed

4.2. Power Output and Impedance Matching

Power output was tested against different load resistances ranging from 10 Ω to 100 Ω in order to describe the generator's capability under load. The system reaches a peak power transfer point (MPPT equivalent) at a load resistance of about 20 Ω, according to experimental data, producing a maximum output of 3.5 Watts. Internal impedance mismatches cause an abrupt drop in power output below 20 Ω, whereas greater resistance cause a progressive decrease in power delivery. This information validates that the toolkit is appropriate for both common high-impedance charging circuits and low-impedance educational loads (LED arrays, tiny DC motors).

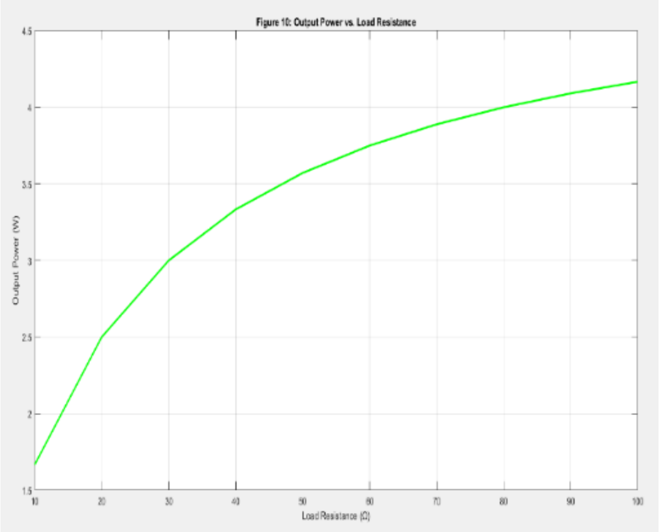

Fig. 12. Output Power vs. Load Resistance

4.3. Gear Train Optimization and Efficiency

To enhance mechanical advantage and minimize friction losses, SolidWorks simulations were run iteratively. After analyzing the link between gear ratio and system efficiency, an ideal gear ratio of 80:1 was found, resulting in a peak system efficiency of almost 88%. Ratios over 80:1 introduced decreasing results because of higher static friction and torque needs, while ratios below 40:1 were unable to provide enough alternator RPM for steady voltage. The ideal balance between ergonomic input torque and enough rotational velocity for the PMA is found in the 80:1 harmonic drive setup.

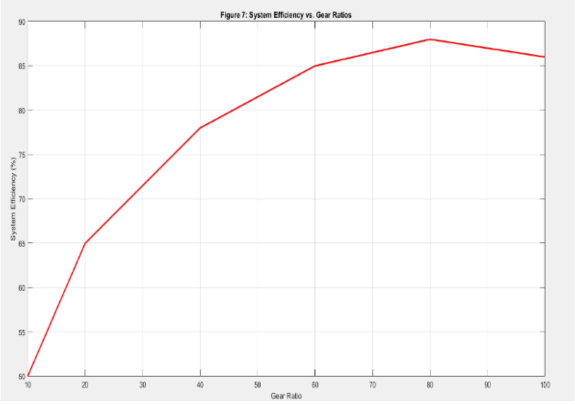

Fig. 13. System Efficiency vs. Gear Ratios

4.4. Thermal Stability and Continuous Operation

A thermal stability test and a durability test were done on a 60-second continuous cranking test at nominal load. The output power was on a decreasing trend starting with a 3.5 W of output then decreasing to about 2.6 W in the one-minute limit in duration. It is due to thermal accumulation in PMA coils and human fatigue (manual fatigue) of the user. The utility of the device in short-burst educational demonstration and emergencies signaling was confirmed even though this drop was still more than the critical 3V threshold necessary to trigger basic indicators.

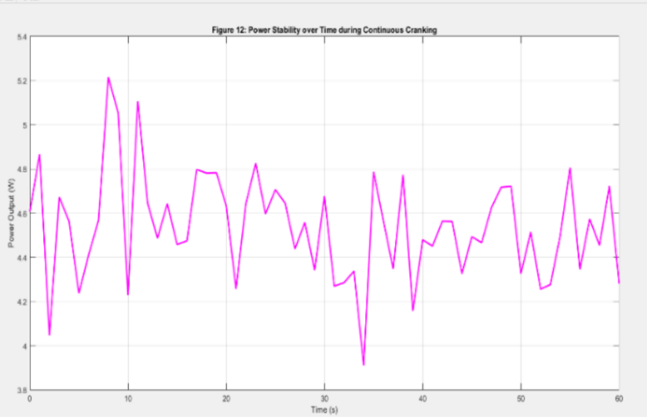

Fig. 14. Power Stability over Time during Continuous Cranking

4.5. Comparative Techno-Economic Analysis

MIL Grow Crank Green was compared to the previous market solutions in terms of multi-criteria performance radar. Five major metrics were analyzed including Durability, Cost, Output, Portability, and Educational Value. The device is significantly cheaper than the solar systems or diesel generators and is right in line with disposable battery packs in terms of cost, as indicated in the cost comparison. This is unlike the sealed military-grade units or the black box battery banks, the clear chassis and open gear train of the Crank Green earns the highest mark on the "Educational Value" category, they have been able to literally show how mechanical energy is changed into electricity.

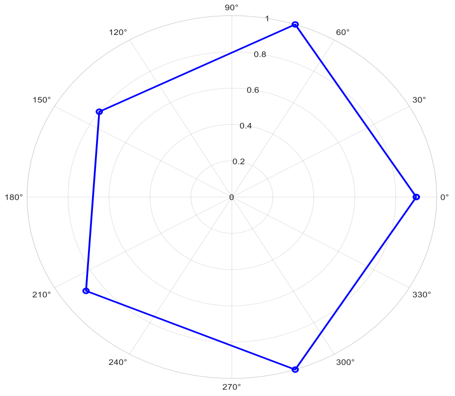

Fig. 15. Performance radar (cost, portability, durability, efficiency, educational value)

4.6. Cost Comparison of Power Solutions

To assess the MIL, Grow Crank Green's financial feasibility in comparison to conventional off-grid power options, a comparative economic study was carried out. The prototype device has a production cost of about $25 USD. Compared to small-scale solar home systems (40 USD) and traditional diesel generators (300+ USD), which are further constrained by weather and daily cycles, this price point makes it much more reasonable. Disposable battery packs have a reduced initial capital cost (around $15 USD), but their environmental disposal risks and ongoing replacement expenses make them more expensive to operate over time. For educational and emergency applications, the gear-driven generator therefore offers the best balance between low initial investment and zero-marginal-cost renewable energy output.

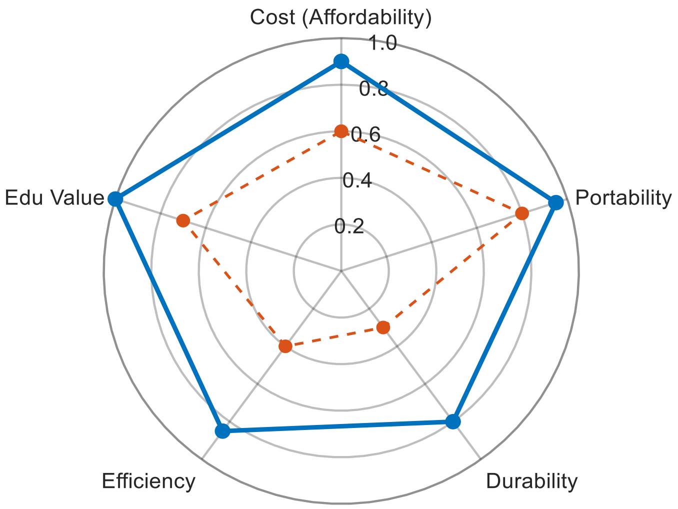

Fig. 16. Performance radar of modified Design (cost, portability, durability, efficiency, educational value)

5.Conclusion

The new system of MIL Grow Crank Green creates an effective pattern of producing sustainable and human-powered energy generation in resource-limited surfaces. The device does this by using the mathematical optimization of an 80:1 compound gear train and a rigorous SolidWorks stress test to produce a stable 3V-12V DC based output with a maximum power output of 3.5 W. This is a toolkit that fills the growing market gap that the transient battery solutions or expensive server-based military generators cannot fill by presenting a long-lasting, open-source system at a price within reach of under 25 USD of production.The two-in-one feature of the device directly responds to the UN Sustainable Development Goals 4 (Quality Education) and 7 (Clean Energy) as a dependable off-grid power source and interactive STEM educational tool. Finally, the project shows that with affordable and easily available engineering solutions and solutions, the global digital divide would be reduced successfully in the disadvantaged populations with energy literacy and energy self-sufficiency.

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References

[1] E. N. Okafor and C. Okeke, "Design of a portable hand crank generating system to power remote off-grid communities," in *Proceedings of the IEEE Conference on Technologies for Humanity*, pp. 1–6, 2007**.**

[2] A. J. Jansen and A. Stevels, "Human power: Energy supply for portable electronics," *Journal of Cleaner Production*, vol. 18, no. 10–11, pp. 1004–1010, 2010**.**

[3] S. Kulkarni and E. Tedeschi, "Design of a hand-cranked generator for rural electrification," *Energy for Sustainable Development*, vol. 41, pp. 130–138, 2017.

[4] ECE-EEE Mini Projects, "Harvesting energy with hand-crank generators to support dismounted soldier missions," *ECE-EEE Mini Projects*, [Online]. Available: https://ece-eee.mini-projects.in/a/360-harvesting-energy-with-hand-crank-generators-to-support-dismounted-soldier-missions.html, **2018**.

[5] World Bank, *Tracking SDG 7: The Energy Progress Report*, Washington, DC, 2023.

[6] Xump.com, "Hand-crank generator DIY STEM kit," *Xump*, [Online]. Available: https://www.xump.com/science/hand-crank-generator-diy-stem-kit.cfm.

[7] AT Communication International, "AT military hand-crank generators," *AT Communication International*, [Online]. Available: https://at-communication.com/en/hf_ssb_hand_crank_generator/at/at_military_hand_crank_generators.html, 2024**.**

[8] S. Kulkarni and E. Tedeschi, "Design of a hand-cranked generator for rural electrification," *Energy for Sustainable Development*, vol. 41, pp. 130–138, 2017**.**

[9] A. Q. Al-Shetwi, M. A. Hannan, and K. P. Jern, "Electrical generators for large wind turbine: Trends and challenges," *Energies*, vol. 15, no. 18, Art. no. 6700**,** 2022**.**

[10] R. Bhandari and I. Stadler, "Electrification using solar photovoltaic systems in Nepal," *Applied Energy*, vol. 88, no. 2, pp. 458–465**,** 2011**.**

[11] S. Mandelli, J. Barbieri, R. Mereu, and E. Colombo, "Off-grid systems for rural electrification in developing countries: Definitions, classification and a comprehensive literature review," *Renewable and Sustainable Energy Reviews*, vol. 58, pp. 1621–1646, 2016**.**

[12] K. De Witte and N. Rogge, "Understanding the role of digitalization and social media on energy citizenship," *Energy Research & Social Science*, vol. 104, Art. no. 103258, 2023**.**

[13] D. Palit and A. Chaurey, "Off-grid rural electrification experiences from South Asia: Status and best practices," *Energy for Sustainable Development*, vol. 15, no. 3, pp. 266–276, 2011**.**

[14] S. C. Bhattacharyya, "Financing energy access and off-grid electrification: A review of status, options and challenges," *Renewable and Sustainable Energy Reviews*, vol. 20, pp. 462–472, 2013**.**

[15] A. Yadoo and H. Cruickshank, “The role for low carbon electrification technologies in poverty reduction and climate change strategies: A focus on renewable energy mini grids with case studies in Nepal, Peru and Kenya,” *Energy Policy*, vol. 42, pp. 591–602**,** 2012**.**

[16] F. Dincer, “The analysis on photovoltaic electricity generation status, potential and policies of the leading countries in solar energy,” *Renewable and Sustainable Energy Reviews*, vol. 15, no. 1, pp. 713–720, 2011**.**

[17] D. Grierson and C. Hyland, “Learning for sustainability: From the local to the global,” *International Journal of Sustainable Development*, vol. 14, no. 3–4, pp. 185–196, 2011**.**