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Original Research Article

A STUDY OF SPRING MASS ELECTROMAGNETIC ENERGY HARVESTING SYSTEM EMBEDDED IN A MOBILE COVER

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Abstract:

Currently, smartphones have become a vital component of our daily lives, and the situation of running out of power, especially during an emergency, can be stressful and frustrating. To solve this problem, this research proposes an innovative smartphone cover that can produce power using the natural motion of the smartphone during daily operations. The concept revolves around electromagnetic induction, whereby a small magnet with a spring oscillates within copper wires to produce electric power whenever the smartphone is in motion.

Unlike conventional electric power systems that utilize only one motion direction, this system utilizes both vertical (up and down) and horizontal (side to side) motions. This increases the amount of electric power produced from simple operations such as walking or using the smartphone, the produced power is regulated by a boost converter to ensure it is safe for use during emergency charging. Although it is not meant to replace conventional charging systems, this smart phone cover is a feasible, portable, and environmentally friendly alternative with immense potential for future self-charging devices.

Keywords: *Motion Based Energy Harvesting, Electromagnetic Induction, Power Generating Mobile Cover, Sustainable Technology, Emergency Charging Solution*

Introduction:

In the modern technology age, smartphones have become a vital tool for communication, learning, financial transactions, navigation, and emergency response. However, the rapid draining of batteries has remained a challenge, especially during traveling, outdoor activities, and power failures. This paper proposes a motion-powered energy-harvesting mobile cover that harnesses the potential of everyday smartphone motion to produce electrical energy through the electromagnetic induction principle. By incorporating a magnet-coil system within the mobile cover, electrical energy can be produced through the vertical and horizontal motion of the smartphone.

The paper is founded on the principle of Faraday's Law of Electromagnetic Induction, which asserts that a magnetic flux change produces an electromotive force (EMF). In this research, the independent variable is the motion of the smartphone (intensity, frequency, and motion direction). The dependent variable is the quantity of electrical energy or voltage produced by the smartphone motion. As the motion intensity increases, the rate

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of magnetic flux change also increases, resulting in increased induced voltage.

The aim of this research is to investigate the potential of natural smartphone motion to produce adequate supplementary power for emergency purposes, thereby encouraging eco-friendly and self-sustaining mobile technology.

Limitations of Study:

1. **Limited Sample Size:-** The study is based on a small sample of 112 respondents, which may not necessarily represent the entire population of smartphone users.
2. **Non-Probability Sampling**:- Convenience sampling was adopted for the study, which is a limitation for the generalization of the study for a wider population.
3. **Self-Reported Response:-** The data is based on personal opinions of the respondents, which may include a certain amount of bias or error.
4. **Conceptual Evolution:-** User acceptance of the product was based on the concept rather than a fully developed prototype.
5. **Limited Technical Analysis:-** More emphasis is given to the study of user perception rather than experimental validation of the efficiency of power generation.

Review of Literature:

Energy harvesting through electromagnetic vibration systems has emerged as a significant area of research for the sustainable production of small-scale electrical power.

1. **According to study by Chiu et al. (2016),** 4.1 A study by Chiu et al. (2016) states that a spring-mass electromagnetic energy harvester attached to a vibrating body underwent additional numerical analysis. The study was designed with a cylindrical permanent magnet sandwiched between a coil and two helical springs. Vibrations caused the cylindrical magnet to travel sinusoidally between the coil, changing the magnetic flux and producing an electric current.

   Faraday's Law of Electromagnetic Induction, which postulates that the induced voltage in a coil is directly proportional to the change in the magnetic flux, is the cause of the occurrence. Put another way, the magnetic field varies as the magnet enters and exits the coil, and as a result an electric current is generated. The research investigation also took into account Lenz's Law, which states that the electric current generated has a force opposed to the direction of motion and causes electromagnetic damping.

   The authors concluded that the maximum electric current is reached when the natural frequency of the spring-mass system coincides with the frequency of external vibrations. This occurs when the system is in resonance, enabling it to operate at maximum efficiency.

   Since **Michael Faraday proposed his law of electromagnetic induction in 1831**, electromagnetic induction has remained one of the fundamental concepts of physics. According to Faraday's theory, an electromotive force (EMF) is created when the magnetic flux through a closed circuit changes. All contemporary electrical equipment, including transformers and generators, is still built on this idea. Lenz's Law, which states that the induced current always opposes the cause that produces it, is indicated by the negative sign in the

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mathematical expression of Faraday's Law, which states that the induced voltage is directly proportional to the rate of change of magnetic flux.

2. **According to the study by Härtel (2018)** further explored electromagnetic induction using both the electro-dynamic Weber model and the traditional Faraday-Lorentz model. The article explains how electromagnetic induction can be explained as a result of relative motion between electric charges, where the forces of induction are caused by shifting magnetic interactions. The study also discusses mutual induction and self-induction, both of which are directly relevant to the system with moving coils and magnets. The theoretical foundation of the suggested mobile phone cover system is amply demonstrated by the motion-based explanation of electromagnetic induction.
3. **According to the study by Patero (2023),** Additionally, Faraday's First and Second Laws of Electromagnetic Induction were validated experimentally. The study demonstrated that an induced EMF, which is proportionate to the rate of change of magnetic flux, is produced when the magnetic field surrounding a coil changes. Faraday's original theory was proven by the experimental data, which unmistakably demonstrated a linear relationship between the variation of magnetic flux and the induced voltage. The study also emphasized the use of electromagnetic induction in transformers and generators, where electrical energy is produced by mechanical motion in a magnetic field.The suggested design of the cell phone cover is directly impacted by this principle. In this design, the vertical and horizontal movements of the mobile phone during use cause a magnet mounted on a spring to move inside a copper coil. According to Faraday's Law, this causes the magnetic flux in the copper coil to fluctuate, which generates electricity.

Research Gap:

The current research on electromagnetic induction and energy harvesting technology has mainly concentrated on large-scale power generation, industrial systems, or small electronic sensor technologies. Very few research works have explored the concept of incorporating motion-based energy harvesting technology into daily life smartphone accessories. Moreover, past research has primarily concentrated on the efficiency of the technology, while the usability and needs for emergency use have received little attention. The relationship between battery-related emergency experiences and user willingness has also remained unexplored. The current research attempts to bridge the gap by considering both the usability and user willingness for a motion-based power-generating mobile cover.

Research Methodology:

1. **Objectives of the Study**
   i. To examine the frequency of battery-related problems faced by smartphone users during daily use and emergencies.
   ii. To assess users' awareness and acceptance of motion-based energy generation technology in mobile covers.
   iii. To evaluate the perceived usefulness of an energy-generating mobile cover in reducing battery anxiety and dependence on chargers or power banks.

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iv. To analyze users' willingness to adopt and pay for a power-generating mobile cover despite potential increase in device weight.

2. ***Hypothesis***

Ho1: There is no significant relationship between users' experience of battery-related emergencies and their willingness to use a power-generating mobile cover.

H1: There is a significant relationship between users' experience of battery-related emergencies and their willingness to use a power-generating mobile cover.

H02: The perceived usefulness of the energy-generating mobile cover does not significantly influence users' intention to adopt or recommend the product.

H2: The perceived usefulness of the energy-generating mobile cover significantly influences users' intention to adopt or recommend the product.

3. ***Research Design***

This research is ***experimental*** in nature since it entails the design, construction, and testing of a functional prototype of a motion-powered mobile cover. The current study was conducted as an applied, descriptive, and quantitative research study. It was based on a survey study aiming to analyze the issues associated with the battery of the smartphone and assess the acceptance of a motion-based power generating mobile cover. The concept is based on the principle of electromagnetic induction, which was first discovered by Michael Faraday. His pioneering work showed that mechanical motion can be converted to electrical energy, and this provides the scientific basis for the project. This research is also practical in nature. It is based on a real-world problem since it seeks to answer the question of how to charge mobile phones when power sources are not available. By targeting the problem of emergency charging, the project seeks to offer a practical solution to the problem.

4. ***Sampling Technique***

The sampling technique adopted for the present study is non-probability convenience sampling. The sampling unit is chosen based on their accessibility. The data was collected through an online survey of 112 users of smartphones.

Data Analysis and Interpretation:

Hypothesis 1 (User Acceptance and Need)

Null Hypothesis (H_0): There is no significant relationship between users' experience of battery-related emergencies and their willingness to use a power-generating mobile cover.

Alternative Hypothesis (H_1): There is a significant relationship between users' experience of battery- related emergencies and their willingness to use a power-generating mobile cover.

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Chi-Square Calculation Table:

Chi-Square Goodness-of-Fit Test					
Variable 1: Experience of Battery Emergency					
Responses	Observed Frequency	Expected Frequency	O - E	$(O-E)^2$	$(O-E)^2/E$
Yes	53	56	-3	9	0.160714
No	59	56	3	9	0.160714
Total	112				0.321429
df					1
α					0.05
$(\chi^2_{0.05,1})$					3.841

(Source: Primary data – Online Questionnaire)

Interpretation: The Chi-Square Goodness-of-Fit test was conducted to examine respondents' experience of battery-related emergencies. The calculated Chi-square value ($\chi^2 = 0.322$) was found to be lower than the critical table value (3.841) at the 0.05 level of significance with 1 degree of freedom. This indicates that there is no statistically significant difference between respondents who experienced battery emergencies and those who did not. Therefore, the null hypothesis was accepted and the alternative hypothesis was rejected.

The findings suggest that battery emergency experiences are relatively evenly distributed among respondents and do not show a significant variation within the sample population.

Variable 2: Willingness to Use Power-Generating Mobile Cover					
Response Category	Observed Frequency (O)	Expected Frequency (E)	O − E	$(O-E)^2$	$(O-E)^2 / E$
Very Interested	47	28	19	361	12.893
Interested	45	28	17	289	10.321
Not Sure	18	28	−10	100	3.571
Not Interested	2	28	−26	676	24.143
Total	112	112			50.928
df					3
α					0.05
$(\chi^2_{0.05,1})$					7.815
p-value					0.001

(Source: Primary data – Online Questionnaire)

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Interpretation:

The Chi-Square Goodness-of-Fit test was applied to examine respondents' willingness to use a power-generating mobile cover. The calculated Chi-square value ($\chi^2 = 50.928$) was found to be greater than the critical table value (7.815) at the 0.05 level of significance with 3 degrees of freedom. This result indicates a statistically significant difference among the willingness categories. Therefore, the null hypothesis was rejected and the alternative hypothesis was accepted.

The findings reveal that respondents demonstrate a strong preference and positive acceptance toward the adoption of a power-generating mobile cover, suggesting favorable user interest in the proposed innovation.

Hypothesis 2 (Perceived Usefulness and Adoption)

Null Hypothesis (H_{02}): The perceived usefulness of the energy-generating mobile cover does not significantly influence users' intention to adopt or recommend the product.

Alternative Hypothesis (H_{12}): The perceived usefulness of the energy-generating mobile cover significantly influences users' intention to adopt or recommend the product.

Chi-Square Calculation Table:

Response	**Observed Frequency (O)**	**Expected Frequency (E)**	**O − E**	**(O − E)²**	**(O − E)² / E**
Strongly Agree	24	22.4	1.6	2.56	0.114
Agree	45	22.4	22.6	510.76	22.803
Neutral	37	22.4	14.6	213.16	9.516
Disagree	6	22.4	−16.4	268.96	12.007
Strongly Disagree	0	22.4	−22.4	501.76	22.4
Total χ^2 df α ($\chi^2_{0.05,1}$) p-value					**66.84** **4** **0.05** **9.488** **0.001**

(Source: Primary data – Online Questionnaire)

Interpretation:

The Chi-Square Goodness-of-Fit test was conducted to examine respondents' opinions on whether a power-generating mobile cover can reduce battery anxiety. The calculated Chi-square value ($\chi^2 = 66.84$) exceeded the critical table value (9.488) at the 0.05 level of significance with 4 degrees of freedom. This indicates a statistically significant difference among response categories. Hence, the null hypothesis was rejected and the alternative hypothesis was accepted.

The findings suggest that respondents largely agree that the power-generating mobile cover can effectively reduce battery anxiety, reflecting positive user perception toward the proposed product.

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Recommended Conceptual Model and Its Functioning:

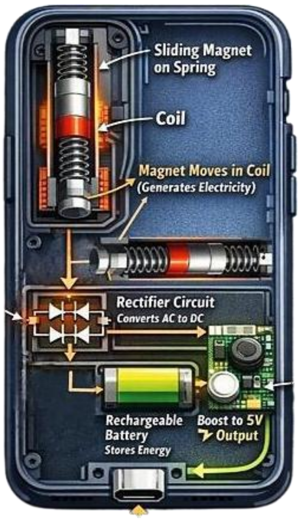

Figure 1

The motion-powered phone case is a protective phone cover designed to harness electrical energy from day-to-day movement. The device works on the basis of electromagnetic induction. A neodymium magnet is fixed inside the phone case. The magnet is connected to a copper coil. The magnet oscillates inside the copper coil whenever the phone is shaken, carried, or moved during day-to-day activities like walking. This oscillating motion creates an electromotive force according to Faraday's Law of Electromagnetic Induction, which was first discovered by Michael Faraday.

The current generated by the moving magnet is an alternating current. The alternating current is then rectified into direct current by the rectifier circuit. The voltage generated by the moving magnet is low, ranging from 0.5 to 2 volts. The current is temporarily stored in the rechargeable battery or supercapacitor.

A boost converter then follows, which increases the stored voltage up to a regulated 5 volts, which can be used for charging the phone, as it is the standard voltage for USB devices. This circuit ensures that the phone case can be used for emergency backup power without the need for an external electrical source, making it portable and efficient.

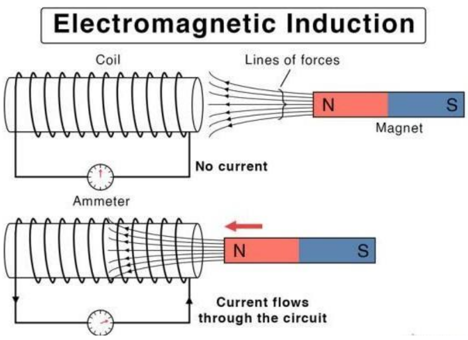

Figure 2

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This picture illustrates the concept of electromagnetic induction. As long as the magnet is just resting near the coil, nothing will happen because the magnetic field surrounding the wire is not changing, and therefore no electric current will be generated. But when the magnet approaches the coil, the magnetic field inside the coil will change. This will cause tiny electric charges (electrons) in the wire to move.

As the charges move, an electric current is generated, which can be measured by the ammeter.

In conclusion, the electric current can only be generated when the magnet is moving. It is the changing magnetic field, not the magnet itself, that produces the electric current.

Power Conservation:

Battery = 5000 mAh, 3.7 V

Energy for 10% charge = 18.5 × 0.10 = 1.85 Wh

Total energy = (5000 × 3.7) / 1000 = 18.5 Wh Wh

Generated power = 20 mW Boost efficiency ≈ 80% Usable power = 20 × 0.8 = 16 mW = 0.016 W

Daily motion = 8 hours

Energy/day = 0.016 × 8 = 0.128 Wh

Daily charge % = (0.128 / 18.5) × 100 ≈ 0.7%

≈ 0.5–1% per day

Energy for 10% charge = 18.5 × 0.10 = 1.85

Time for 10% charge

= 1.85 / 0.128 ≈ 14–15 days

Result:

Usable power ≈ 16 mW Energy/day ≈ 0.128 Wh Battery gain ≈ 0.5–1% daily 10% charge ≈ 2 weeks

Conclusion:

This study aims to examine the necessity and possibility of power generation-based mobile cover with respect to the solution of the frequently occurring issues of battery drainage of smartphones. The findings of the survey carried out in this study have confirmed the frequently occurring issues of low battery of smartphones. The issues of low battery of smartphones have been more common during travel and emergency situations. The present study has found a strong positive response of the participants with respect to the proposed power generation-based mobile cover. The participants of the study have expressed some concern with respect to the weight, price, and durability of the power generation-based mobile cover. The findings of the present study have confirmed the strong positive response of the participants with respect to the proposed power generation-based mobile cover.

Suggestions:

- The efficiency of the prototype can be improved by optimizing the number of turns of the coil and the strength of the magnet to increase the power output.
- Future research could be carried out to increase the capacity of the stored energy to provide backup in case of an emergency.

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- Power management circuits can be integrated to reduce the loss of energy during the rectification and boosting of the voltage.
- The design can be miniaturized to increase the portability and feasibility of the system.
- More tests with large numbers of users can be carried out to evaluate the feasibility of the system.

Future Scope:

The proposed concept of motion-based power-generating mobile cover has shown significant potential for development and application. Future research directions can be taken to improve the efficiency of the energy conversion process by optimizing the design of the coil, enhancing the magnetic field strength, and improving the mechanical motion systems. Other energy storage devices can also be included in the design, such as micro-batteries or super capacitors.

Future research directions can also be taken for the development of energy storage devices with light and durable materials for the comfort of users and the longevity of the device. Also, the proposed technology can be developed for the use of other micro-power requirements, such as the power requirements of wearable devices, sensors, and other low-energy electronic devices.

It is recommended that the proposed concept of the motion-based power-generating mobile cover be tested in the real fields with larger sample sizes to ensure the effectiveness of the proposed technology and its acceptance by the users. Also, future research directions can be taken for the development of smart accessories for the smart devices of the future, which can lead to the development of energy- autonomous consumer electronics.

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