Wireless Mobile Charging System Using Inductive Coupling

Prajakta Kutwal[1], Ekta Kurkure[2], Dr. Hemlata Jadhav[3]

Department of Electronics and Telecommunication Engineering, Marathwada Mitra Mandal's College of Engineering, Pune - 411052

ABSTRACT
A wireless charging system that uses inductive coupling, a process based on electromagnetic induction, for wireless power transfer. The framework comprises of two fundamental components: a charging pad and a mobile device within a receiving coil. The charging pad contains a transmitting coil that creates an alternating magnetic field when connected to a power source. A mobile device with a receiving coil is placed in close proximity to the charging pad. The magnetic field generated by the charging pad induces an alternating current in the receiver coil, enabling wireless power transfer. The Ampere's law, Biot Savart's law and Faraday law are used to calculate the inductive coupling between the transmitter coil and the receiver coil. It discusses the main advantage of inductive-coupling based wireless charging.

Keywords: Wireless charging, Inductive coupling, mobile devices, power transfer efficiency, convenience.

INTRODUCTION
Increasing reliance on mobile devices such as smartphones, tablets and smart devices has led to an increased demand for efficient and convenient charging solutions. Conventional charging systems, while effective, have limitations such as requiring physical connection, restricting mobility, and damaging the cable. To solve these problems, wireless charging technology, which provides freedom of power transfer without energy, has emerged as a promising solution. One of the wireless charging technologies is inductive coupling, which uses electromagnetic fields to transfer power between the charging pad and the mobile device. Inductive coupling is based on the principle of electromagnetic induction, in which alternating current in a transmitting coil induces a direct current in a closed receiver coil. The objective of this presentation is to supply an outline of a remote portable charging framework utilizing inductive coupling, highlighting its importance and potential benefits. The framework comprises two essential components: a charging pad and a mobile device prepared with a receiving coil. When the portable gadget is put on or close the charging cushion, the inductive coupling instrument encourages the exchange of the electrical vitality. The biggest disadvantage of wired technology is the lack of mobility. The body is limited by the reach of the cables, while the wireless technology allows users to move easily and comfortable.

LITERATURE SURVEY
In [1] a utility-based collaborative charging (UBCC) procedure is presented for minimizing the charging taken a toll and maximizing the charging utility to explore the circle zone organize, and utilize a bunch of server MCs as well as two bunches of charging MCs, which collaboratively serve sensor nodes from one

area to another. But on one hand it includes a impediment as a few intrusions cannot be detected & corrected. In [2] It conveys a strategy that states a uncommon wireless-powered sensor arrange comprising of set of sensors fueled by the vitality exchanged from a Mobility Energy Station (MES) that can occasionally travel through a pre-planned way to charge the sensor utilizing develop an RF energy transfer-based equipment stage. The Nearest-Job Next with Pre-emption (NJNP) is the technique discussed in [3] Its methodological portrayal gives an analytical assessment of the on Demand Mobile Charging (DMC) issue beneath the discipline of NJNP. A basic but proficient Nearest-Job Next with Pre-emption (NJNP) discipline for the On-Demand Mobile Charging (DMC) issue which plans the charging of individual hubs concurring to their spatial and temporal properties.

BLOCK DIAGRAM OF THE PROPOSED WIRELESS CHARGING SYSTEM

As shown in Figure 1, the circuit is a transmitter circuit used to generate voltage wirelessly. The transmitter circuit consists of an AC power supply, a step-down transformer, a bridge rectifier, an N-Channel MOSFET, and a transmitter coil. The receiver circuit consists of a bridge rectifier, a capacitor, a voltage regulator, and a receiving coil. The transmitter is connected to the power source.

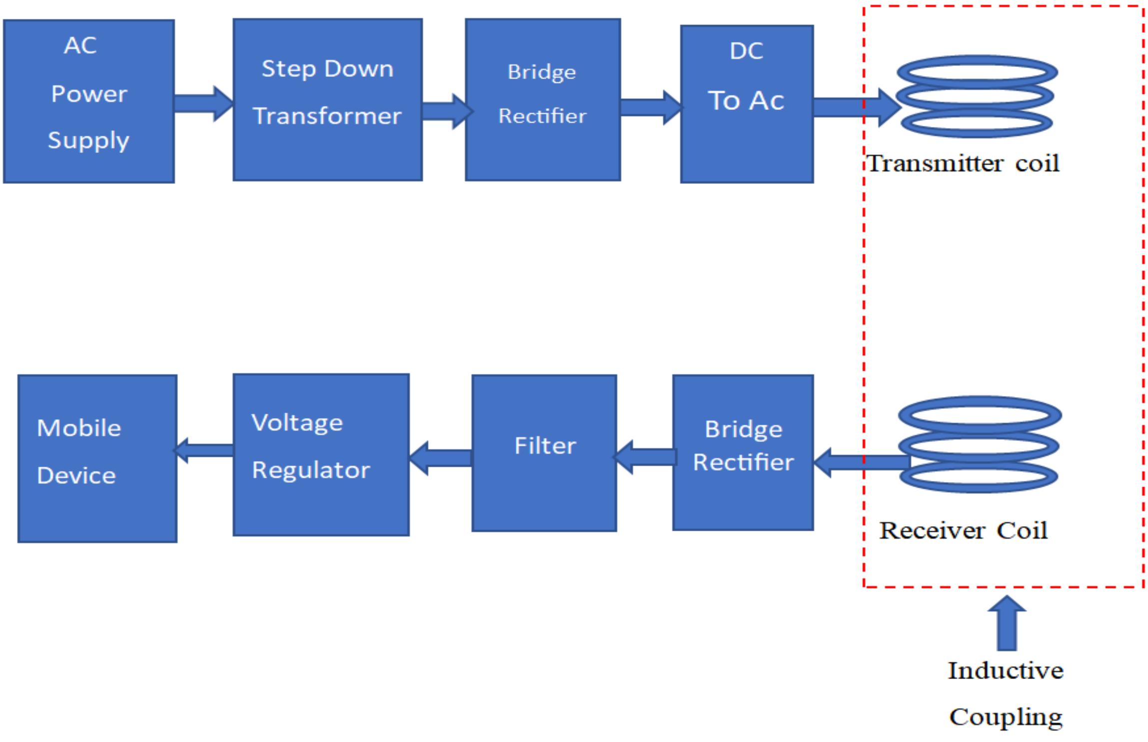

Figure 1. Block diagram of the proposed Wireless Charging System

When the power source is turned on, electric current flows through the coil, and according to Oersted's law, "any moving electric charge produces a magnetic field." The strength of the magnetic field depends on the number of coils present in the transmitter. An alternating magnetic field creates an electromotive force. This generates an alternating electric current in the receiver coil, which is converted to DC by a rectifier, and this voltage then charges the phone at DC.

CIRCUIT DIAGRAM OF PROPOSED WIRELESS CHARGING

In this simulation, the transmitter is used to control the connection. Here, when 230V input voltage is giv en, 4.7V output value is obtained as shown in Figure 2. From this we conclude that there is no fault in th e circuit. Figure 2, shows that the transmitter circuit is used to produce voltage wirelessly. The project mainly consists of a transmitter circuit and a receiver circuit. We will bring the receiver coil closer to the transmitter and the receiver coil will be induce by the transmitter coil hence the transmitter coil has already created a magnetic field in that available space. Figure 3, shows that the transmitter will be connected to the power source. A wireless mobile charging system typically consists of several key components:

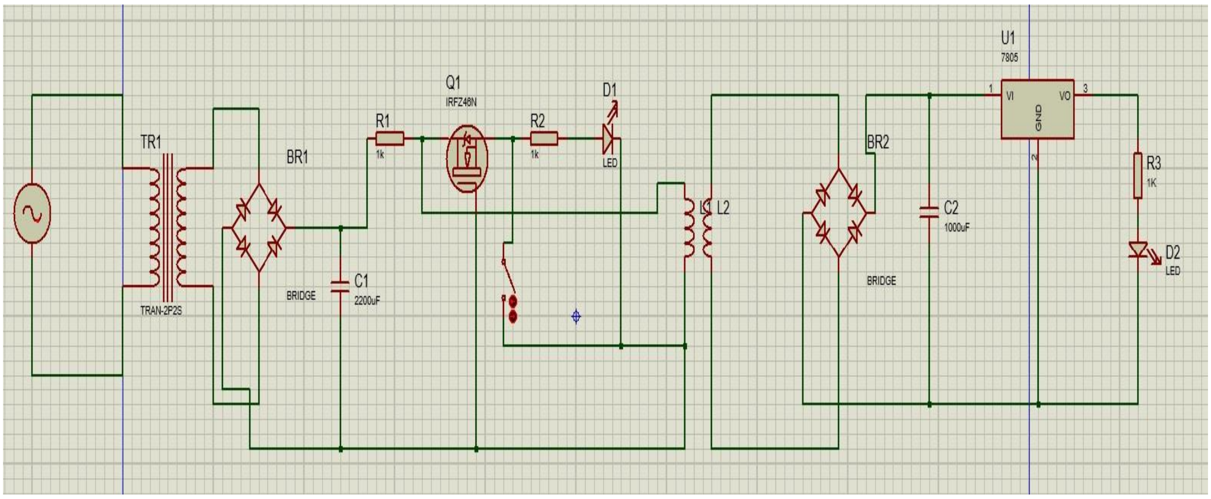

Figure 2. Circuit diagram of proposed Wireless Charging System

a step down transformer, a MOSFET, transmitter and receiver coils, a rectifier, a filter, and a regulator. Let's go through its working in the system: The step down transformer is used to convert the high voltage from the power source to a lower voltage suitable for charging mobile devices. The primary coil is connected to the power source, and the secondary coil is connected to the transmitter coil MOSFET is used as a switch to control the power transfer between the primary and secondary coils. When the MOSFET is turned on, it allows current to flow through the primary coil, creating a magnetic field. When it's turned off, the magnetic field collapses, inducing a voltage in the secondary coil.

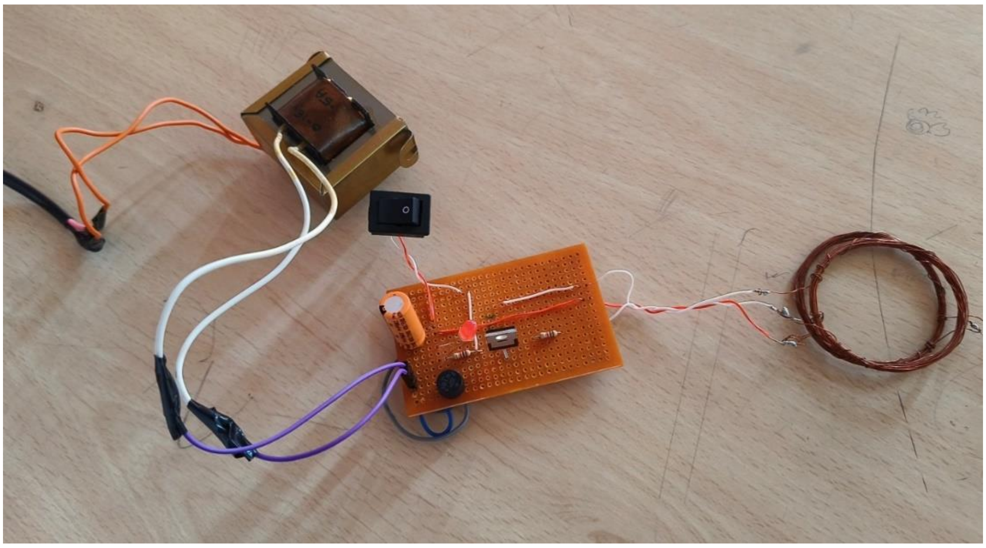

Figure 3. Transmitter Circuit

When the primary coil receives alternating current (AC) from the power source, it generates a magnetic field. Figure 4, shows this field induces an alternating current in the receiver coil, which is connected to the mobile device. The alternating current induced in the receiver coil is converted into direct current (DC) using a rectifier. The rectifier typically consists of diodes that allow current to flow in only one direction. This conversion ensures that the mobile device receives the appropriate DC power required for charging. The rectified current may still contain some ripple or high-frequency noise.

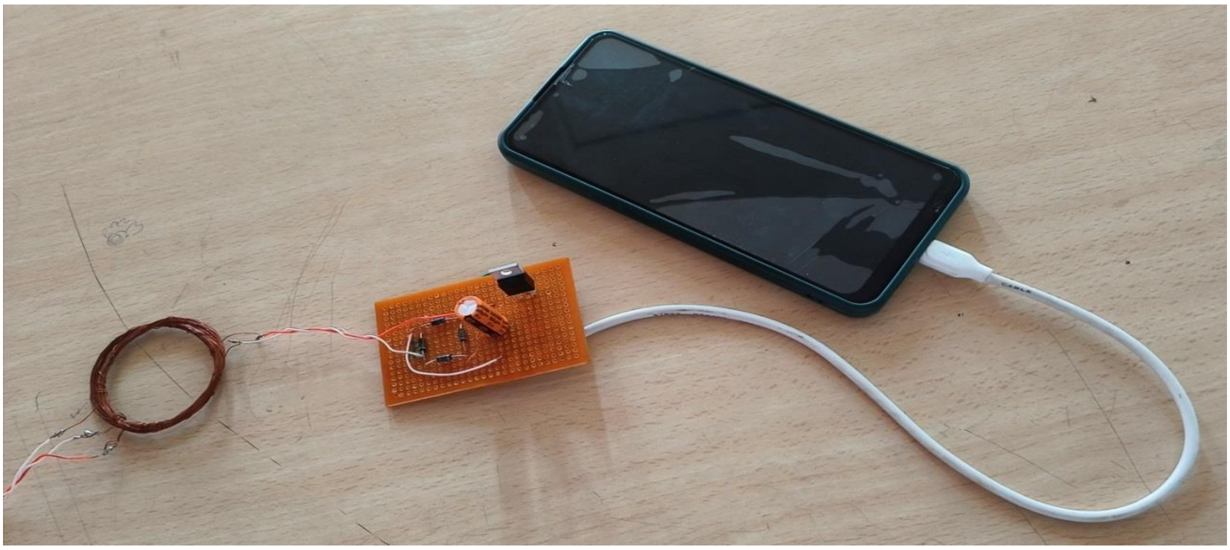

Figure 4. Receiver Circuit

To smoothen the DC output, a filter is employed. The filter consists of capacitors and inductors that attenuate the unwanted high-frequency components, resulting in a smoother DC. The filtered DC voltage may still have slight variations, which can be harmful to the mobile device. A voltage regulator is used to maintain a stable and constant output voltage. It adjusts the voltage to the desired level and provides a regulated output to charge the mobile device.

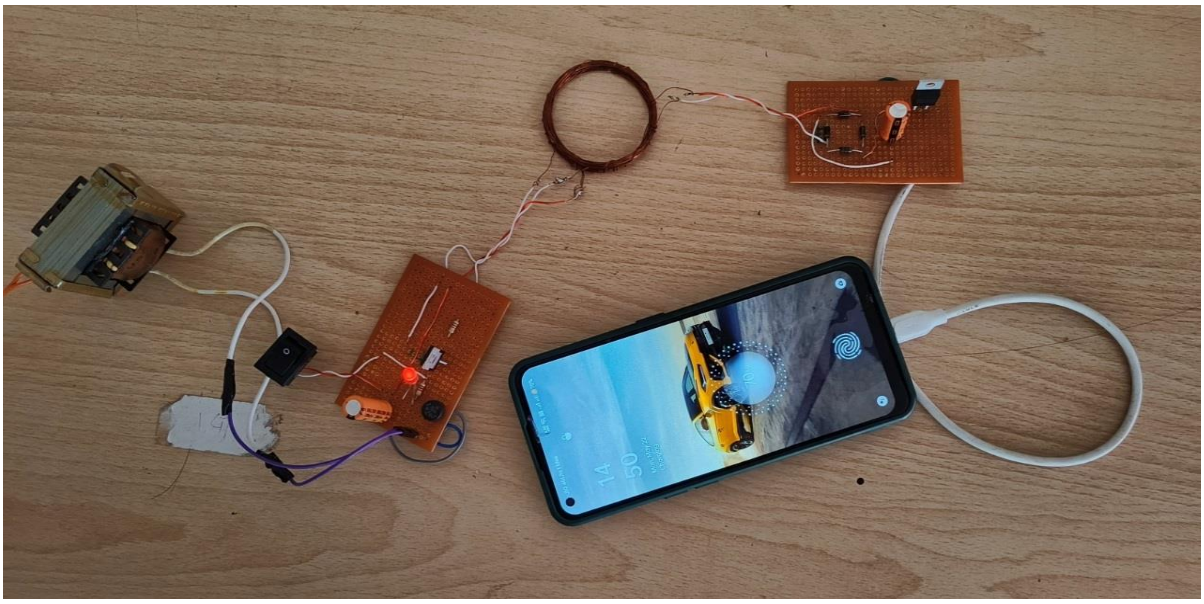

Figure 5. Charging Initiation

Overall, the working of a wireless mobile charging system involves the conversion of AC power from the primary coil to a lower voltage, the transfer of power via a magnetic field, rectification and filtering of the received power, and finally as shown in Figure 5, regulating the output voltage to charge the mobile device efficiently and safely.

HARDWARE SPECIFICATIONS

- **IRFZ44N MOSFET:** It has a voltage rating of 55V and a continuous drain current of 50A, making it suitable for high-power switching and amplification.
- **1N4007 DIODES:** 1N4007 diodes are commonly used rectifier diodes with a voltage rating of 1000V and a maximum forward current of 1A.
- **STEP DOWN TRASNFORMER:** This transformer is an 18-0-18 18V 5A step-down transformer. It gives the output of 18V, 0V, or ground and 18V. This transformer act as a step-down transformer reducing 230V AC to 18V AC. This transformer has a power rating of 5A.
- **VOLTAGE REGULATOR:** The 7805 voltage regulator is a popular linear regulator integrated circuit (IC) that provides a constant output voltage of +5 volts. The input voltage range for the 7805 is typically between 7 and 25 volts.
- **COPPER WIRE:** The copper wire used in the proposed system is of 25 gauge.

DESIGN CALCULATION

Designing a wireless charging system requires meticulous calculations to optimize its performance and usability. Detailed calculations of the proposed system is given below.

Details of Transmitting coil :

Radius of Transmitting coil (r) = 2.5 cm
Radius of the cross – section (a) = 0.0148 cm
Number of transmitting coil turns (N) = 30 turns
Coil wire gauge = 25 gauge
Diameter = 25 gauge
Width of the winding = 0.34 cm

Details of Receiving coil :

Radius of the receiving coil (r) = 2.5 cm
Radius of cross – section (a) = 0.0418 cm
Number of receiving coil turns (N) = 30 turns
Coil wire size = 25 gauge
Diameter = 5 cm

Theoretical Calculation

Inductance of the winding
Inductance of the transmitting coil =
$= N^2 \mu_0 r\{ \ln(8r/a) - 1.75 \}$
$= 30^2 \times 4\pi \times 10^{-7} \times 2.5 \{ \ln(8 \times 2.5 / 0.0148) - 1.75 \}$
$= 0.01543$ H

= 15.4 mH
Inductance of the receiving coil =
= $N^2\mu_0 r\{ \ln(8r/a) – 1.75$
= 30^2 x 4π x 10^{-7} x 2.5 { ln(8 x 2.5 / 0.0148) – 1.75 }
= 0.01543 H
= 15.4 mH
Resistance of the winding
Resistance of the winding (R) = ρl/A
Length of receiver coil (l) = Circumference of coil x N
= 2π x D x N
= 2 x 3.14 x 5 x 30
= 942 cm
Length of transmitter coil (l) = Circumference of coil x N
= 2π x D x N
= 2 x 3.14 x 5 x 30
= 942 cm
A = 2πr(r+h)
Where 'h' is width of the winding
'A' = 2 x 3.14 x 2.5 (2.5 + 0.34)
= 44.58 cm^2
'ρ' = Resistivity of Copper = 1.796 x 10^{-8}
Resistance of transmitter coil = (1.796 x 10^{-8} x 942) / 44.58
= 0.0000003795
= 3.795 x 10^{-7} Ω
Resistance of transmitter coil = 3.795 x 10^{-7} Ω
Resistance of receiver coil = (1.796 x 10^{-8} x 942) / 44.58
= 0.0000003795
= 3.795 x 10^{-7} Ω
Hence,
Resistance of transmitter coil = 3.795 x 10^{-7} Ω
Resistance of receiver coil = 3.795 x 10^{-7} Ω

RESULT

When the smartphone is placed on the charging pad, the charging process initiates automatically. However, when the smartphone is lifted or moved away from the charging pad, the charging process ceases. It should be noted that as the distance between the transmitter coil and receiver coil increases, the efficiency of the charging system diminishes.

The below table :

Table 1. Relation between Distance and Efficiency

Distance (cm)	Efficiency (%)
0	27.77
0.5	25.66
1	0.03

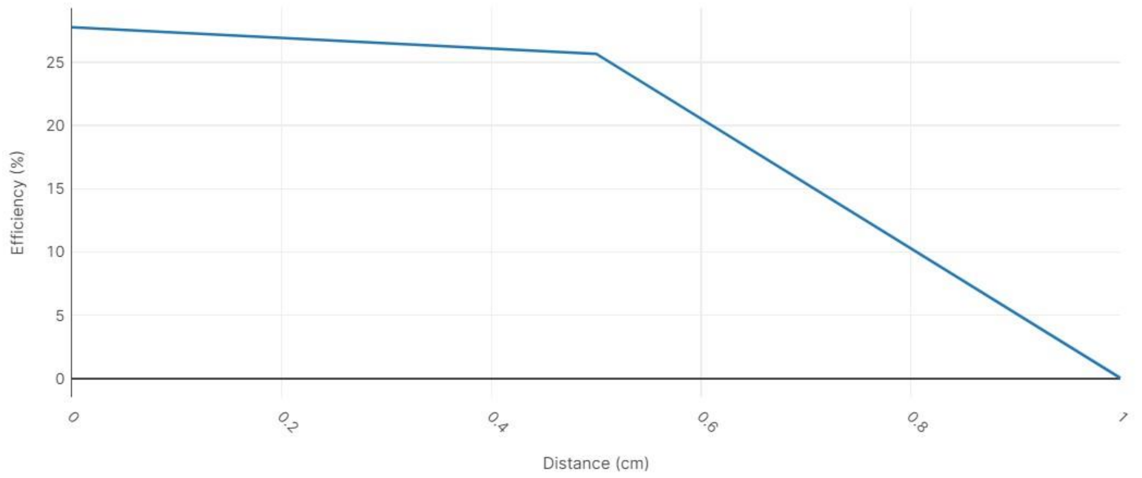

Figure 6. Relation between Distance against Efficiency

CONCLUSION

The primary objective of this work was to explore and realize the concept of a wireless mobile charging system utilizing inductive coupling technology. Extensive analysis was conducted to optimize each component of the system, leading to the design and successful implementation of a functional prototype. The system's operation was thoroughly examined, step by step, to identify areas for improvement and achieve optimal performance. Through careful consideration of various parameters, a robust system was developed, capable of wirelessly transferring power via inductive coupling. The system's functionality was described and showcased through practical demonstrations. It was demonstrated conclusively that inductive coupling serves as an effective method for wirelessly delivering power from a source coil to a load coil, ultimately enabling the charging of a mobile phone.This project represents a significant advancement in the realm of wireless charging technology. By successfully harnessing the principles of inductive coupling, it demonstrates the feasibility and potential of wirelessly charging mobile devices. The findings from this project lay the foundation for further advancements in wireless charging systems, leading to enhanced convenience and accessibility for users worldwide.

FUTURE SCOPE

Wireless charging holds great potential in expanding the scope and enhancing the mobility of IoT device users. Initially, the first-generation wireless chargers had limited functionality, allowing for charging only within a short distance of a few centimeters between the device and the charger. However, with advancements in technology, the latest chargers have extended this range to approximately 10 centimeters. Continual progress in wireless charging technology suggests that in the near future, it may be feasible to transmit power wirelessly across even greater distances, spanning several meters. Imagine restaurant tables equipped with wireless charging capabilities, enabling patrons to effortlessly recharge their smartphones and other smart devices while enjoying their meals. In office environments, furniture integrated with wireless charging capabilities could offer convenient power access, eliminating the need for cumbersome cables and chargers cluttering desks. Additionally, kitchen counters could be transformed into efficient power sources, wirelessly energizing coffee machines and other appliances. These emerging applications of wireless charging technology showcase its potential to enhance user convenience, declutter spaces, and provide seamless power access.

REFERENCES

1. W. Ouyang et al., "Utility-Aware Charging Scheduling for Multiple Mobile Chargers in Large-Scale Wireless Rechargeable Sensor Networks," in IEEE Transactions on Sustainable Computing, vol. 6, no. 4, pp. 679-690, 1 Oct.-Dec. 2021, doi:10.1109/TSUSC.2020.3003014.
2. F. Sangare, Y. Xiao, D. Niyato and Z. Han, "Mobile Charging in Wireless- Powered Sensor Networks: Optimal Optimal Scheduling and Experimental Implementation," in IEEE Transactions on Vehicular Technology, vol. 66, no. 8, pp. 7400-7410, Aug. 2017, doi: 10.1109/TVT.2017.2668990.
3. L. He, L. Kong, Y. Gu, J. Pan and T. Zhu, "Evaluating the On-Demand Mobile Charging in Wireless Sensor Networks," in IEEE Transactions on Mobile Computing, vol. vol. 14, no. 9, pp. 1861-1875, 1 Sept. 2015, doi: 10.1109/TMC.2014.2368557.