Design, Analysis and Application of Dynamic Wireless Power Transfer Technique at High Switching Frequency for a Electric Vehicle Battery Chargers

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Abstract--- *Wireless charging of Electric Vehicles (EVs) is made possible by Inductively Coupled Power Transfer (ICPT) system. This presents user convenience and safety issues are avoided. Battery charging applications, industrial loading machines, office appliances and medical sciences are the important applications of ICPT. For electric vehicle's charging, ICPT system can be used successfully with some power transmission distance limitations. Overall circuit's efficiency is reduced by this. In order to compute overall ICPT system's optimum circuit parameter values, in Mat lab software, developed a mathematical model based simulation. Maximum efficiency is achieved by proposed design.*

Keywords--- *ICPT, EVC, WPT, MPPT, MATLAB.*

I. INTRODUCTION

In applications and industries, major advancements can be delivered by the ability of wireless power. Unreliable as well failure prone contacting and physical connectors forms base for this applications and industries. In 1980s, Nikola Tesla demonstrated the Wireless Power transfer for the first time. But, lase decade, there is huge advancements in technology that offers tangible and real benefits for applications in real world. In Consumer Electronics market, there is a huge usage of resonant wireless power technology based applications. For charging of millions of everyday devices, new levels of convenience is delivered by wireless charging.

Across an air gap, without connectors, energy transmission to an electrical load from power source involves IPT or Wireless) Inductive Power Transfer. Receiver and transmitter coil is involved in wireless power system basis. In order to generate magnetic field, alternating current is used for energizing transmitter coil. In receiver coil, current is induced by this.

Energy transmission to a receiver from transmitter using an magnetic field which is oscillating is involved in wireless power basics. In order to accomplish this, transmitter is added with a specially designed electronics, which converts, power source's Direct Current (DC) into an Alternating Current (AC) at high frequency. In transmitter,

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Magnetic field is generated by energizing a copper coil by using alternating current. If receiver coil is placed near to this transmitter coil, an alternating current is induced by this filed in receiver coil. Usable power s obtained by converting this alternating current into direct current by a receiver device electronics.

In a cordless way, energy migration is realized incredibly by wireless power transfer (WPT) which is an epoch-making method. In applications like, unmanned aerial vehicles (UAVs), electric vehicles (EVs), solar-powered satellites, integrated circuits, implanted medical devices and portable electronic devices, energy utilization pattern can be changed by this. For energizing electric-driven devices, ideal technical solution is given by WPT technique due to its position-free and movability and flexibility characteristics, in and around specific regions.

There are two major problems in battery-powered devices. Popularization of battery-powered devices is limited by these problems. They are high initial cost and reduced battery life. So, WPT methods are more important. For example, in EVs, automobile manufacturers mention running speed of a product is 120 km per charge. But, in actual case, 100 km only used by drivers. Driving range can be increased to about 400 km by increasing number of installed batteries in EV. This requires high initial cost. General public cannot afford this.

A new energization method called WPT is attracting more attentions, as an alternative for energy storage methods. Batteries, technical bottlenecks are bypassed by this. In air, from electromagnetic field, wireless power can be harnessed by battery-powered devices via usage of WPT methods. In moving state, batteries of battery-powered devices can be charged. Problems of high initial cost and reduced battery life can be solved by this new charging method with huge number of batteries.

II. LITERATURE SURVEY

In 2019, Zhen Zhang, Various technical challenges are faced by battery-powered devices applications due to heavy weight, high cost and low power density limitations. For electric-driven devices, new way of energy acquisition is offered by wireless power transfer (WPT) by using new energization pattern. With classical applications, meta materials, technical challenges, working mechanisms, WPT method is presented by this paper. Current research topics in this area with its developments in future are also elaborated by this paper. In our daily life, renewable energy application and importance are shown by this paper.

In 2018, J. Choi, D. Tsukiyama, Y. Tsuruda, and J. M. R. Davila ,_ For wireless transfer (WPT), an enhancement mode gallium nitride (eGaN) device used for implementing high-power resonant inverter with magnetic resonant coupling (MRC) coils. Coils are operating at 13.56 MHz. Class Φ_2 inverter forms the base for this power inverter which drives transmitting coil. It has a fast transient response and uses low switch-voltage stress based single-switch topology. In a low-inductance package, recently available eGaN device are used for implementation. At 10 s of MHz switching frequency, it can be operated.

In a WPT, inverter experimental set up is presented by this paper. Over various operating conditions and distances, system performance is characterized in this work. with eGaN FET, class Φ_2 inverter performance is evaluated before the usage of MCR coils. With 95% of efficiency, it is able to deliver 1.3-kW output to a 50-Ω load while applying 280-V as input voltage. In order to deliver power to 270-mm distance, with a diameter of 300 mm, four open type coils are added in WPT operation. Over 270-mm distance among coils, around 87% of efficiency in delivering 823-W output power by class Φ_2 inverter with MRC coil is achieved.

Jian Zhang **,**Xinmei Yuan **,**Chuang Wang **,**Yang He stated that, wireless power transfer (WPT) is attracting more important due to consumer electronics and electric vehicle development (2017). For WPT, magnetic resonant coupling is used as a more attractive and effective technology. For magnetic resonant coupling, two-coil structure is most commonly utilized. Three-coil structure can be used to enhance the efficiency of system energy, as reported recently. Based on circuit theory, this work compares, two and three coil structure.

Between two structures, difference in energy efficiency can be analyzed comprehensively by proposing simplified model of three and two coil structure. Higher energy efficiency can be obtained by three coil structure when compared to two coil structure with simplified model, as indicated by the analysis. By using three coil system's proper design, within load's wide range, high energy efficiency can be achieved by WPT, as shown by analysis. Field emission and current stress produced by misalignment can be reduced by using three coil system. By using results of experimentation and simulation, confirmed the theoretical analysis.

In 2017,T. D. Yeo, D. Kwon, S. T. Khang, and J. W. Yu, For mobile device's wireless charging and closed-loop wireless power charging, maximum efficiency tracking control method is proposed by this paper. With high efficiency and output voltage, wireless charging systems has to be operated. Load condition and coupling coefficient defines the efficiency and output voltage of an open-loop system. Against load variations and coupling, stable output voltage is produced by closed-loop WPC system. Closed loop systems are studied by various researchers. Degradation of efficiency is a major drawback of existing methods. High efficiency which is possible can be achieved by maximum efficiency tracking scheme which is proposed in this paper.

High efficiency and stable output voltage requirements are satisfied by the proposed WPC system. Via Bluetooth, based on receiver's received data, transmitter current is computed by proposed control method. Loosely coupled series-series resonant coils, at 6.78 MHz, implemented a proposed WPC system for validation. While giving stable output voltage, high efficiency is produced by proposed system as verified.

In 2016, Qiu, C, The remote correspondence innovations has been found in all parts of our social and monetary life. Nonetheless, the exploration on the remote power transmission (WPT) has not been settled generally. A solid main thrust for the WPT advances originates from the shopper gadgets and the commercialization of electric vehicles (EV) as of late. WPT gives a basic, bound together and safe intends to energize the battery. With a broad reconciliation of this strategy, the implicit battery size can be limited to lessen framework volume and cost. Subsequent to playing out a far reaching audit of the close field WPT advances, three significant issues including precarious attractive coupling, unbendable framework engineering and helpless power transmission are recognized as the snags in expanding the WPT system into the dynamic application. Studied magnetic coupler design for giving power transmission in magnetic coupling. For subsequent design basics, finite element analysis (FEA) and circuit theory are combined to model circuit theory ability. A near report is then directed to assess a large portion of the plan contemplations for attractive couplers. An ideal structure technique is at long last presented. A 30×30cm single layer compound winding transmitter is proposed for charging the convenient gadgets. The uniform attractive coupling is focused on with the end goal that the power transmission is less delicate to the overall situation of the collector.

More flexible system structure is provided by a system having various modular receiver and transmitter. Studied about, magnetic field interaction between adjacent modular. Identified the flux cancellation phenomenon. Conducted a system configuration comparison. FEA is used for computing power transfer and magnetic coupling capability of two system topologies under six various configurations. Two configurations with high power transfer ability and stable magnetic coupling are selected. Proposed a new control method for avoiding power transfer sensitivity to load variations and magnetic coupling. Circuit analysis is used for deriving load-independent operation modes of various compensation methods. For stable magnetic coupling, select any one of the above mentioned modular transmitter topology. This ensures load-independent characteristic extension in dynamic situations. This also satisfies, free-positioning and load-independent features. For wireless LED lighting system, tentatively constructed an experimental prototype. During change in load and movement of receiver away from transmitter, stable output voltage is maintained by this. It eliminates the communication requirement on secondary and primary side. This is because of decoupled control.

In 2015, J. Dai and D. C. Ludois , Wireless power transfer (WPT) can be done using two methods. They are capacitive power transfer (CPT) and Inductive power transfer (IPT). For gap distances, various power levels, most commonly preferred one is IPT. For small gap distance power transfer application, CPT is preferred due to the limitation of voltage produced. In kilowatt power level applications, CPT is viable.

For small gap applications, comparison of CPT and IPT are given by this paper. It also summarizes the practical and theoretical limitations of these methods. With respect to efficiency, operating frequency, gap distance, power level, and other parameters, these two methods are compared. Theoretical physical limitation of CPT and IPT are used for analyzing limitation of coupler volumetric power in small gap. It also presents the guidelines for selecting CPT or IPT. Hao Hao **,**Grant A. Covic **,** John T. Boys developed a inductive power transfer (IPT) system with High-power in 2014. It operates at 100kW power levels. High-power electronic components are used by existing high-power IPT power supplies, which makes it more expensive and for one power level, they are designed. In a cost effective manner, high power of output is achieved by a parallel IPT power supply topology which is presented in this paper. Uneven sharing of power because of component tolerance are minimized by this parallel topology. For parallelization, additional reactive components are not required by this. In case of electronic shut down of faulty parallel unit, it can be operated continuously. System's reliability and availability can be enhanced by this. In parallel, identical modules can be connected for achieving more flexible output power. In parallel, three 2 kW power supplies can be connected in order to construct a 6 kW parallel power supply.

III. PROPOSED MODULE

3.1 PROPOSED TOPOLOGY & ITS PRINCIPLE

- Increase of coil's power transmission distance is a major objective of this system. In this project, ICPT system is presented with its design parameter optimization. Maximum efficiency is achieved by this system as demonstrated by the results of simulation.

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3.1.1. EXISTING SYSTEM DRAWBACKS

The available system exhibits drawbacks such as

- Less transmission distance.
- Less power transmission.
- Switching frequency (20khz).
- System Performance Reduced.
- Less Efficiency.

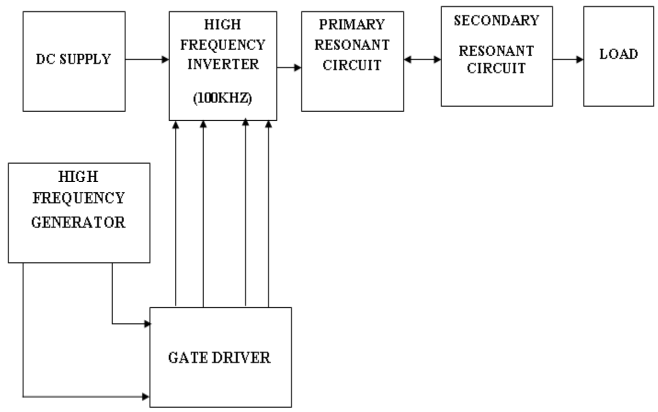

Figure3.1: Proposed System's block diagram

3.2 DESCRIPTION OF PROPOSED SYSTEM's BLOCK DIAGRAM

- With high reliability and accuracy, stable operation is ensured by proposed solution.
- With respect to angle, switching frequency, distance proposed control solution's effectiveness is verified by results of simulation.
- For EV's wireless charging, most successful technique corresponds to Inductively coupled power transfer (ICPT).
- For analysis, used coil dimension and ICPT system parameters optimization. Power transmission to larger distance and high efficiency is achieved by this.

3.2.1 PROPOSED SYSTEM ADVANTAGES

- Increased transmission distance.
- Increased power transmission.
- Switching frequency too high (100khz).
- System Performance improved.
- Overall Efficiency of the system improved.

IV. SIMULATION RESULTS

4.1About MATLAB

MATLAB R2011a is a software of user friendly. Project simulation can be done using this. For programming, visualization, numerical computation, it is used as interactive environment and it is high level language. It possible to create applications and models, develop an algorithm, analyze a data using MATLAB. Various mechanisms can be explored by in-built math functions, tools and languages. When compared with conventional programming languages including C/C++ or Java™ and spreadsheets, solution is attained in a fast way. In computational biology, computational finance, measurement and test, control systems, video and image processing, signal processing, and in array of applications, MATLAB is used.

In academia and industry, MATLAB is used by billions of scientist and engineers. It is a language used for technical computing. Multi domain dynamic systems can be analyzed, simulated, modelled using a programming language tool called Simulink. It is data flow graphical programming language. A graphical block diagramming tool, is a basic primary interface of it. Block libraries are set up by this which may be customized. With remaining environment of MATLAB, stronger integration is provided by this. Scripted or MATLAB is run by it. For Model based design and multi domain simulation, in digital signal processing and control theory, Simulink is more frequently used.

4.1.1 SIMULINK

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For dynamic system simulation and modelling, solvers, customizable block libraries and graphical editors are yielded by Simulink. With MATLAB®, Simulink can be combined. Various MATLAB algorithms can be incorporated into model by this combination. For more analysis, results of simulation can be exported to MATLAB. Figure 4.1 shows the Simulation Diagram of PMSG based Current Control Structure with MATRIX Converter & SVPWM.

4.2. Proposed Method's simulation Diagram

With transmitter and receiver unit, Wireless Power Transfer System's simulation diagram is shown by figure 4.1.

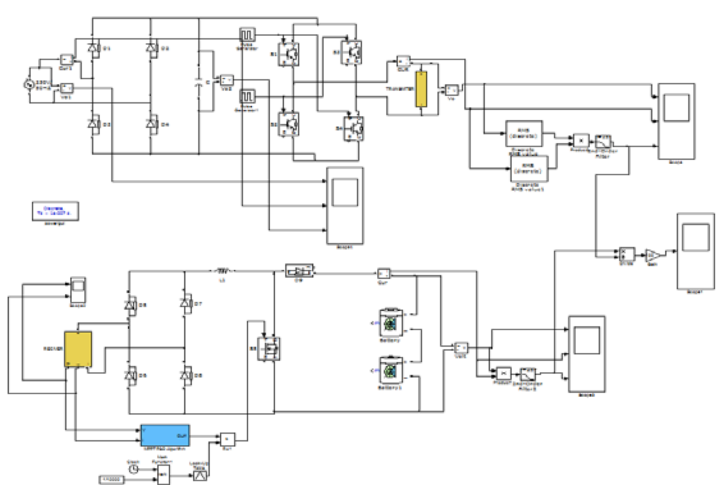

Figure 4.1: Simulation Diagram of Wireless Power Transfer System including Transmitter & Receiver Unit

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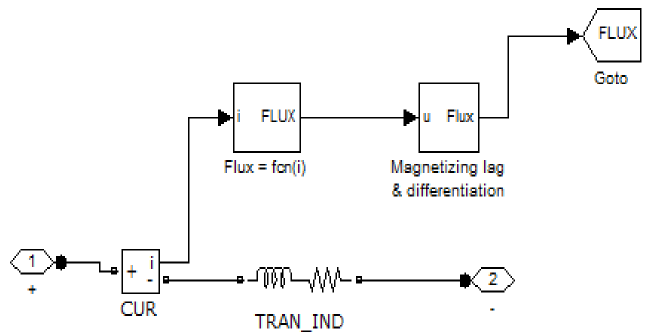

Figure 4.2: Transmission Section Flux Estimation's simulation diagram

For WPT systems, more important index of performance corresponds to capability of transmitted power. Associated control method, power-electronic inverters topology and switching component limits the power level due operation in high frequency range.

In MHz frequency band, capability of output power can be enhanced by using enhanced gallium nitride (eGaN) device in switching component.

IPT has high power. It is a major advantage of IPT, when compared with laser energy transmission, microwave, acoustic and photovoltaic transmission. It can be used for applications of long distance transmission. At 100 kHz frequency, up to 2.5m power can be delivered by output of simulation.

With respect to energy security, misalignment, distance, power and efficiency, summarized, WPT system's major technical problems.

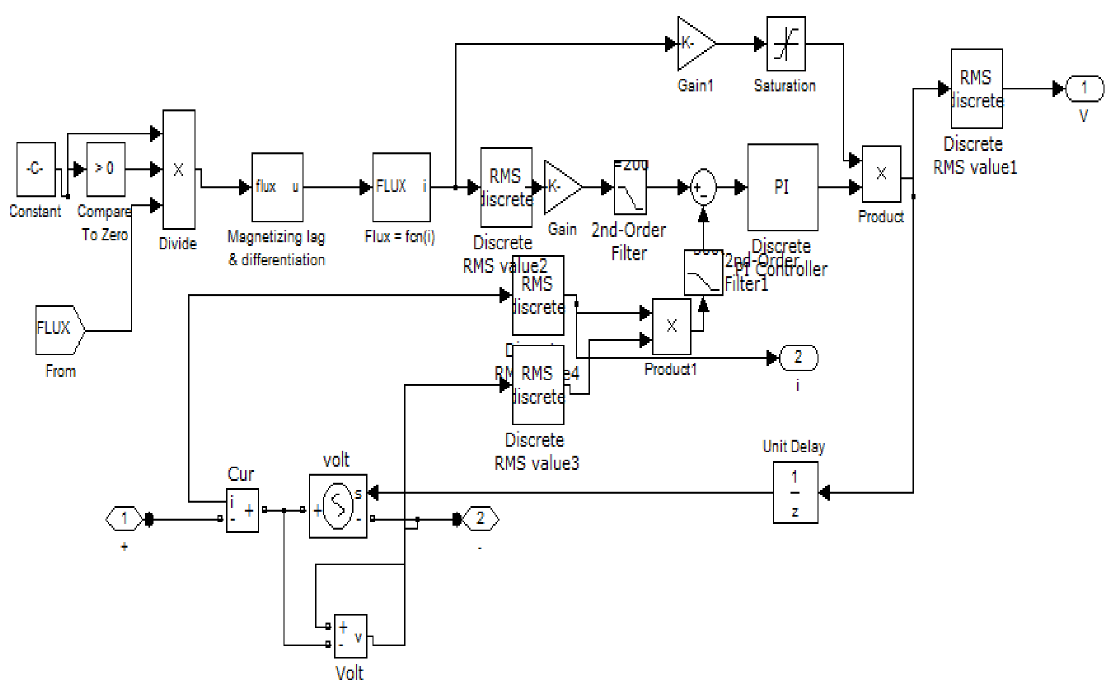

Figure 4.3: Simulation Diagram of Receiver Section Flux Estimation

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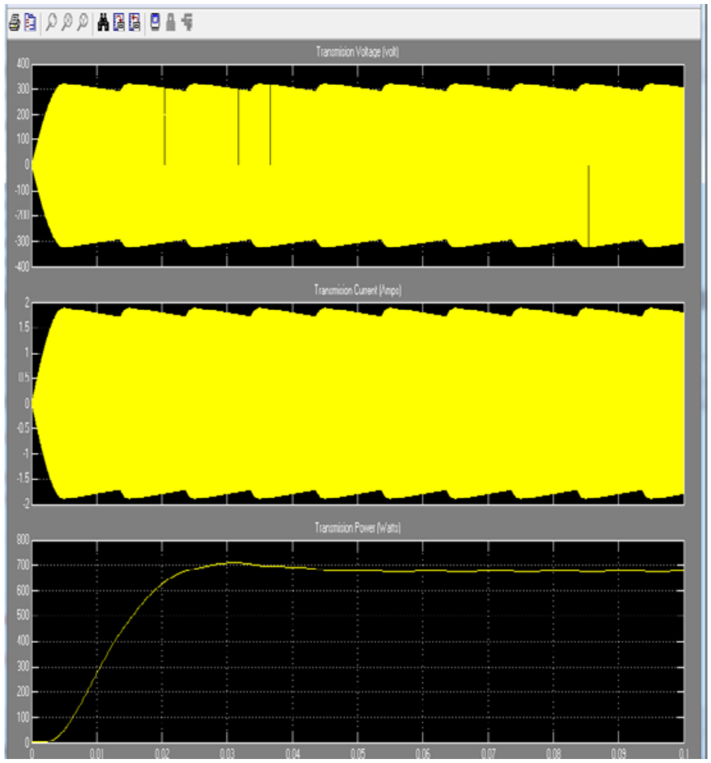

Figure 4.4: Output Waveform of Transmission Voltage /Current/Power

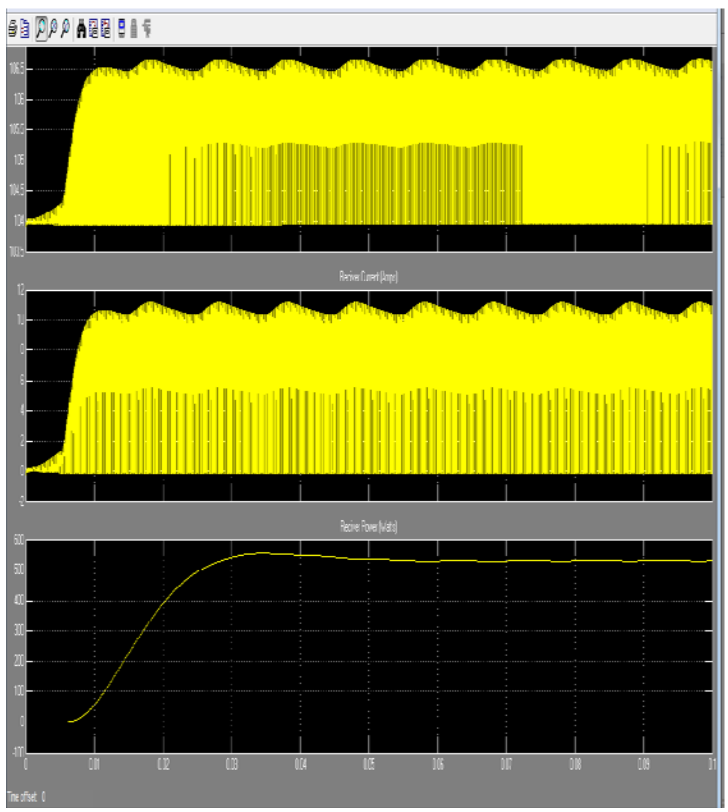

Figure 4.5: Output Waveform of Receiving Voltage /Current/Power

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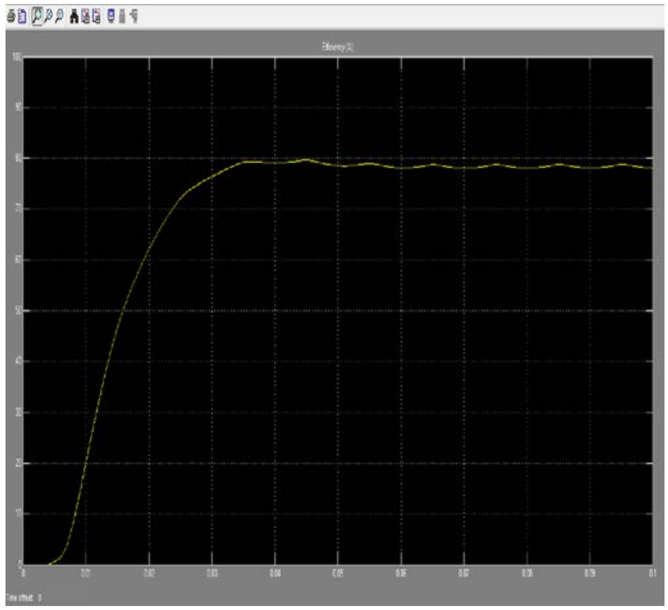
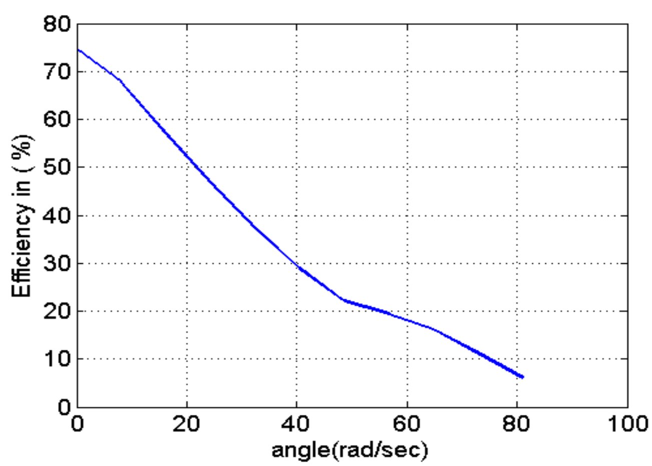


Figure 4.6: Output Waveform of WPT System Efficiency

Distance = 5cm,Switching frequency = 100 Khz

Load resistance = 4 ohm.Angle is varied from 0 to 82 degree.



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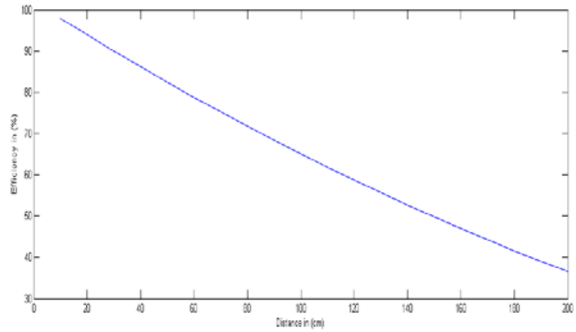
Angle = 0 degree, Switching frequency = 100 Khz

Load resistance = 4ohm,Distance is varied from 0 to 42 cm



Angle = 0 degree, Switching frequency = 100 Khz

Distance = 5 cm, Load resistance value is varied from 3.5 ohm to 8ohm.

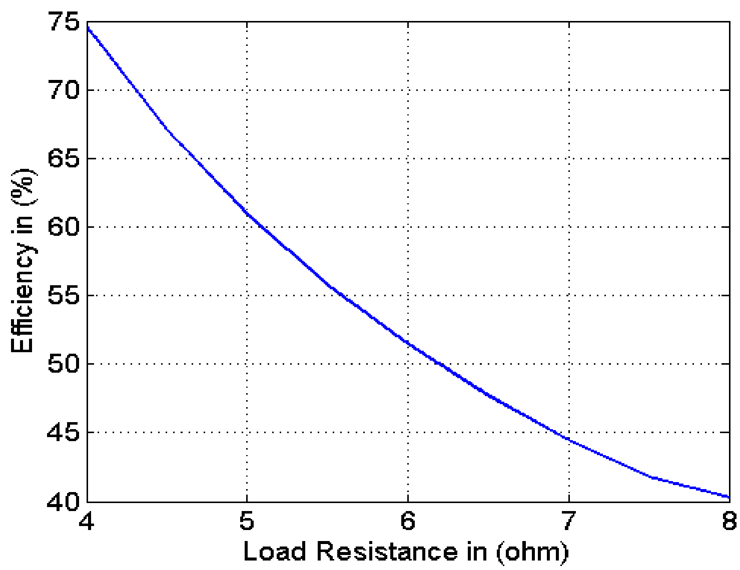


Figure 4.7: Output Waveform of WPT System (a) Efficiency vs Angle

(b) Efficiency vs Distance (c) Efficiency vs Load Resistance

Table 1: Efficiency vs Angle

Sl.no	Efficiency(%)	Angle(degree)
1	90	0
2	70	10
3	50	20
4	40	30
5	20	60

Table 2: Efficiency vs Distance

Sl.no	Efficiency(%)	Distance(cm)
1	90	15
2	80	30
3	70	60
4	60	100
5	50	140

Table 3: Efficiency vs Load Resistance

Sl.no	Efficiency(%)	Load resistance (ohm)
1	75	4
2	60	5
3	52	6
4	45	7
5	40	8

V. CONCLUSION

Design and implementation of Wireless Power Transfer (WPT) system using Inductively Coupled Power Transfer (ICPT) is a major aim of this project. System is designed as well as simulated. For optimization, entire system is analyzed systematically. With respect to power-transfer efficiency, significant enhancement is achieved by a proposed system, as shown by the results of simulation. From a source coil, power can be delivered wirelessly by using inductively coupled power transfer to a load as described and simulated.

From a source coil, power can be delivered wirelessly in a robust manner by using this mechanism. With respect to energy security, misalignment, distance, power, efficiency, summarized the WPT system's key issue in technical. Also discussed about applications like portable electronics, biomedical implants, and EVs. With angle control and power transfer distance, for power transfer efficiency, it presented as graphical and numerical data.

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