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Comprehensive Assessment of Power Transfer Capability of Electromagnetically Coupled Wireless Power Transfer Systems

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Abstract—Magnetic coupling based Wireless Power Transfer (WPT) systems for charging no doubt have emerged as an eye catching alternative charging methodology in recent years. However, a rigorous assessment between magnetic coupling based traditional WPT system and magnetic resonant coupling based WPT system is essential in order to characterize and decide the best suited technology corresponding to their applicability. The effectiveness of both the technologies and their power transfer characteristics have been demonstrated in perception of consumed input power, delivered load power for different coupling coefficient over varying operating frequency and electric load condition. The theoretical and analytical study supported with the simulation and bench set up experiments has been carried out in order to disclose the viability of both the technologies in the device charging. In addition, an inclusive correlation between the performance parameters of the WPT systems has been established through the analysis and justification regarding the RIC-WPT system as an alternative viable solution in the charging field is outlined.

1. INTRODUCTION

Contactless transfer of electrical energy has been in use over last few decades for energizing electrical/electronic devices with a wide range of power requirements [1–4]. Based on flux linkage coupling phenomena, both inductive coupling (IC) and resonant inductive coupling (RIC) based wireless power transfer technologies have been practically developed and brought to the forefront for charging or powering the devices [5–7]. The inductive type contactless energy transfer technology prevails and gets more attention due to its suitability for various charging applications with power requirement over a wide range [8–11]. It has been found from the literature that charging efficiency in the case of inductive type is lower than traditional plug in socket charging. Due to the air-gap between the transmitting and receiving coils in the inductive charging, the prominent effects are large leakage inductance, low mutual coupling, and high resistive heating [12–14]. In addition, low frequency inductive charging leads to slow charging and higher heat generation. However, in order to keep up with consumer demands with the lowest level of compromise, the inductive charging in a new form with the same basic principle has been developed and known as resonant inductive coupling based wireless power transfer technology (RIC-WPT) [15–20]. Unlike traditional inductive charging, RIC-WPT operates at resonant frequency and a very small or almost null radiation from the nearby off-resonant objects. Although theoretical and numerical analysis in past reveals that RIC-WPT is more practical and efficient for mid-range air-gap compared to its counterpart traditional inductive coupling charging (IC-WPT) method, a detailed study is necessary in order to reveal the characteristics behaviour of both technologies. This necessitates the pursuit of methodical exploration to reveal the best suited wireless power transfer system and to

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decide the technology allied to their applicability. Thus, the electromagnetic circuit model analysis, practical demonstration, and experimental measurements have been carried out in order to disclose the viability of both the technologies in the powering or charging of devices. The reported work provides an in-depth analysis of both IC-WPT and RIC-WPT systems clearly focusing on the much-needed performance enhancement characteristics associated with frequency and load characteristics of input power, output load power for different coupling coefficients over varying operating frequency, electric load condition, and power transfer efficiency characteristics. A comprehensive comparative analysis based on the performance parameters has been put forward, and the rationalization regarding the preference of RIC-WPT system has been distinguished as an attainable solution in the charging field.

2. SYSTEM ARCHITECTURE

The WPT concept is based on inductive coupling (IC) and resonance inductive coupling (RIC). Fig. 1 demonstrates the common technique for an IC based WPT system.

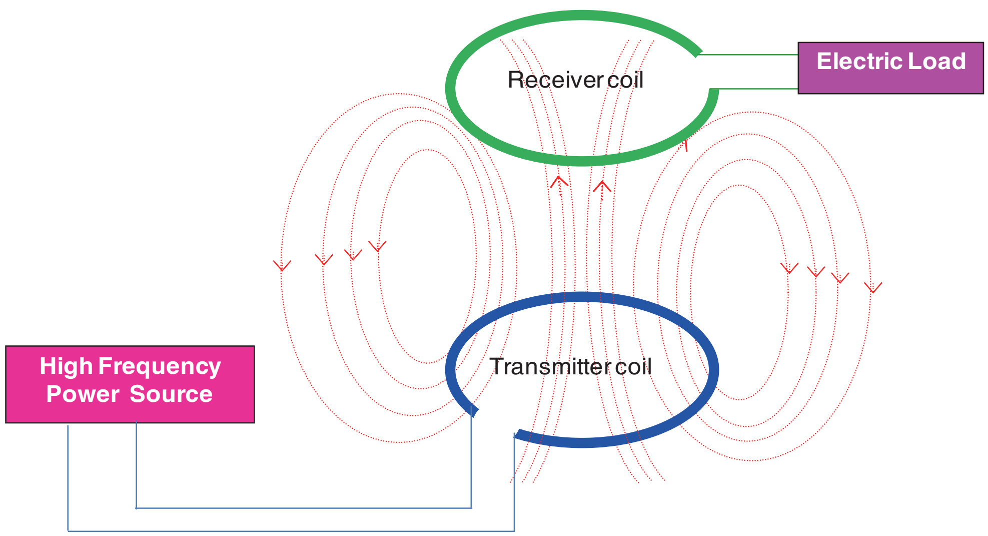

Figure 1. Schematic diagram of the inductive coupling based power system.

The IC method is based on a phenomenon known as electromagnetic induction. The inductive coupling based WPT system consists of three most important sections: the source side high frequency power based electronic circuits allied to excite the transmitter coil (L_t), the inductive flux link, and the allied receiver coil (L_r) with electric load of the system. When an alternating current is flowing through the transmitter coil at that time, both the coils are mutually electromagnetically coupled with each other, and the magnetic flux linkage enables voltage across the receiver coil that is fed to the electric load.

The resonant inductively coupled WPT system is illustrated in Fig. 2. At first glance, the resonant WPTS may give the impression awfully comparable to the general inductively coupled system; however, the key difference is in the power transfer mechanism. The resonant WPTS entails a non-radiative, directional, and near field coupled type power transfer approach. It works on the principle of magnetic resonance in order to make possible the power transmission between the magnetically coupled resonant coils in the midrange proximity. When the resonant coils are excited at their resonant frequency, their near fields will couple strongly, which enables the efficient wireless power transfer within a much shorter time than the characteristic decay time of the WPT system. This system assists very little in exchanging energy with non-resonant objects whereas exchange energy efficiently between the objects with the same resonant frequency. In consequence of being efficient, recently, the resonant inductively coupled WPT system has gathered momentum towards a viable solution for wireless battery charging. In the developed system, an RF resonant inductive link is allied with source side power electronics

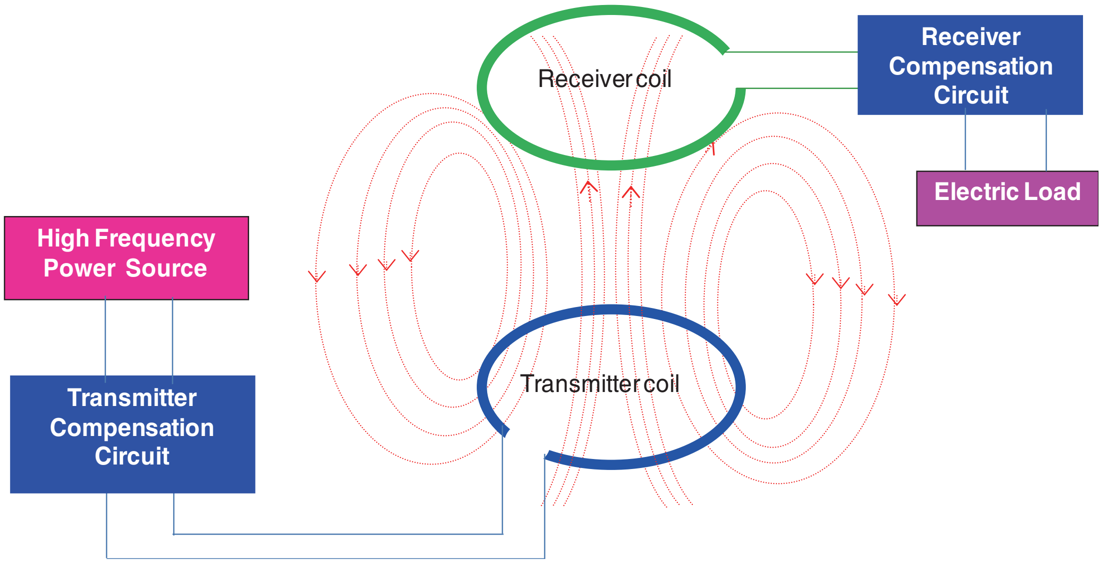

Figure 2. Schematic Diagram of the RIC based power transfer system.

circuitry and battery side of the devices. The transmitting coil is directly powered by an RF input power source connected through an external series resonant capacitor (high frequency source that is converted through a converter from the usual grid supply 220 VAC 50 Hz). The transmitting coil gets excited at certain resonant frequency of the WPT system. Similarly, coil at the receiver placed away from the transmitting coil is excited with the same frequency of operation as the transmitting coil. At resonance, both the coils are coupled with strong magnetic fields, which enable power transfer from transmitting to receiving coils at a faster rate over an adequately large distance. The ac output power across the receiving coil is processed before being supplied to the battery of electrical & electronic devices.

3. ELECTRICAL EQUIVALENT CIRCUIT MODELLING OF IC AND RIC POWER TRANSFER SYSTEM

3.1. IC Based Power Transfer Analysis

The electrical circuit of an inductive coupling is shown in Fig. 3. If L_t and L_r are the self-inductances, R_t and R_r are coil resistances, and M is mutual inductance of the coils, then evaluating the performance of the inductive link using an important parameter, i.e., the coupling coefficient (k) is given by [21]

$$k \triangleq \frac{M}{\sqrt{L_t L_r}} \tag{1}$$

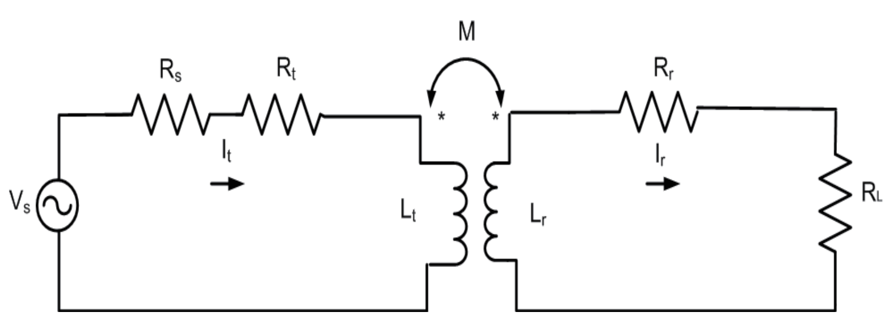

Figure 3. Derived circuit model of inductive coupling method.

If V_S is the input source voltage; ω is the angular frequency; Z_t and Z_r are the impedances of the transmitting and receiving parts, then the voltage equations in the transmitting and receiving parts will be

$$\begin{cases} V_s = I_t Z_t + j\omega M I_r \\ 0 = j\omega M I_t + I_r Z_r \end{cases} \tag{2}$$

where

$$Z_t = R_t + R_s + j\omega L_t \tag{3}$$
$$Z_r = R_r + R_L + j\omega L_r \tag{4}$$

The current in the transmitter (I_t) and receiver (I_r) parts can be derived as follows:

$$I_t = \frac{V_s Z_r}{Z_t Z_r + \omega^2 M^2} \tag{5}$$
$$I_r = -\frac{j\omega M V_s}{Z_t Z_r + \omega^2 M^2} \tag{6}$$

By (2)–(6), the complex power S_s delivered by the voltage source and quantities A_s and P_L can be calculated as

$$S_s = V_s I_t^* = \frac{|V_s|^2}{|Z_t Z_r + \omega^2 M^2|^2} Z_r^* \left(Z_t Z_r + \omega^2 M^2\right)$$
$$A_s = \frac{|V_s|^2 |Z_r|}{|Z_t Z_r + \omega^2 M^2|}$$

From the above relations, the reactive power can be calculated as

$$P_R = \mathrm{Im}g\,[S_s] = \frac{|V_s|^2 \left[\omega L_t (R_r + R_L)^2 - \omega^3 M^2 L_r + \omega^3 L_t L_r^2\right]}{|Z_t Z_r + \omega^2 M^2|^2}$$

Then at the receiver side, the power supplied to electric load can be obtained as:

$$P_L = \|I_r\|^2 R_L = \frac{V_s^2 \omega^2 M^2 R_L}{\|Z_t Z_r + \omega^2 M^2\|^2} \tag{7}$$

The total power transfer efficiency (the ratio of the received power delivered to electric load and the input real source power) of the inductively coupled wireless power transfer system can be calculated as follows:

$$\eta_i = \frac{\omega^2 M^2 R_L}{|Z_r|^2 R_e[Z_t] + \omega^2 M^2 R_e[Z_r]} \tag{8}$$

By putting the values of Z_t and Z_r, the efficiency can be expressed as

$$\eta_i = \frac{\omega^2 M^2 R_L}{\left[(R_r + R_L)^2 + \omega^2 L_r^2\right](R_t + R_s) + \omega^2 M^2 (R_r + R_L)} \tag{9}$$

The above efficiency can be expressed in terms of coupling coefficient (k) as well as quality factors (Q) of the coils. Q_t and Q_r are the quality factors of the transmitter and receiver coils, which can be defined as follows:

$$\begin{cases} Q_t = \dfrac{\omega L_t}{R_t'} \\ Q_r = \dfrac{\omega L_r}{R_r'} \end{cases} \tag{10}$$

where

$$\begin{cases} R_t' = R_t + R_s \\ R_r' = R_r + R_L \end{cases} \tag{11}$$

where R_S is the source resistance, R_t the effective series resistance of transmitter, and R_r the receiver coil resistance. Thus, the efficiency can be expressed as

$$\eta_{IC} = \frac{R_L}{R'_r}\left(\frac{k^2 Q_t Q_r}{1 + Q_r^2 + k^2 Q_t Q_r}\right) \tag{12}$$

It is apparent from the above equation the power transfer efficiency of the inductively coupled system can be enhanced by increasing the value of (k) and (Q) of the coils.

The power factor of an inductively coupled WPT can be calculated as follows:

$$\mathrm{Cos}\,(\phi) = \frac{\omega^2 M^2 R_L}{|Z_r|\,|Z_t Z_r + \omega^2 M^2|} \tag{13}$$

By putting the values of Z_t and Z_r, the power factor becomes

$$\mathrm{Cos}\,(\phi) = \frac{\omega^2 M^2 R_L}{\sqrt{(R'_r + \omega^2 L_r^2)\left[\omega^4 L_r^2 L_t^2 + \omega^2 L_r^2 R_t'^2 + \omega^2 L_t^2 R_r'^2 - 2\omega^4 M^2 L_r L_t + (\omega^2 M^2 + R'_t R'_r)^2\right]}} \tag{14}$$

The power factor is expressed in terms of quality factors of the coil and k as

$$\mathrm{Cos}\,(\phi) = \underbrace{\frac{R_L}{R'_r}}_{1}\underbrace{\frac{k^2 Q_t Q_r}{\sqrt{(1 + Q_r^2)\left(Q_t^2 Q_r^2 + Q_t^2 + Q_{r1}^2 - 2k^2 Q_t^2 Q_r^2 + (1 + k^2 Q_t Q_r)^2\right)}}}_{2} \tag{15}$$

The receiver efficiency is represented by the first term whereas the next term represents the inductive link power factor. It can be realized that at the transmitter side, active power is absorbed by the effective series resistance. The reactive power is absorbed by the coupled coils, and it becomes larger for lower value of coupling coefficient (k) restricting the power factor to be unity. The lower value of coupling coefficient as well as quality factor indicates the poor transfer efficiency of the WPT system. Therefore, inductively coupled WPT system is generally utilized for effective short-range power transmission.

3.2. Mathematical Analysis of RIC

The transmitting coil of the WPT system is powered by an input A.C. source. As shown in Fig. 4, the external capacitor (C_t) is connected in series with the transmitting coil (self-inductance (L_t) and self-resistance (R_t)) in order to make the circuit resonant. From the theoretical analysis, series resonant circuit generates maximum magnetic field at transmitter side as a large current passes through the transmitter coil. The generated magnetic field is linked with the resonant receiver coil. The magnetic flux linkage is categorized by coupling coefficient (k) along with mutual inductance (M) between the two coils. The power received wirelessly by the receiver coil is sent to the connected electric load (R_L).

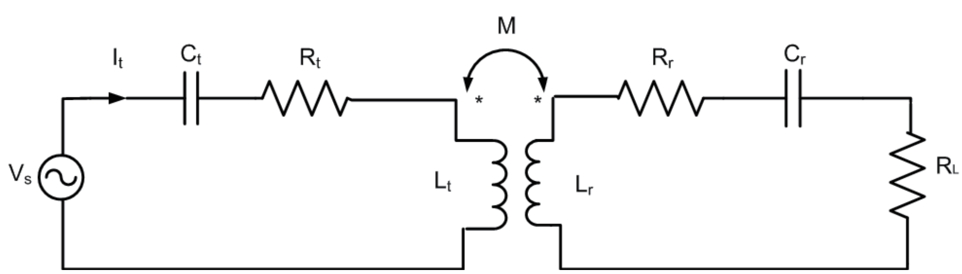

Figure 4. Equivalent circuit model of RIC method.

In the RIC-WPT system, the power transfer between two compensated mutually coupled coils is based on the principle of mutual induction. From the Faraday's law of electromagnetic induction [21], the voltage induced in the receiver coil due to the current (I_t) in the transmitting coil is

$$V_{ind} = j\omega M I_t \tag{16}$$

The open circuit voltage (V_{OC}) and short circuit current (I_{SC}) at the receiving coil are given by

$$\begin{cases} V_{OC} = j\omega M I_t \\ I_{SC} = \dfrac{j\omega M I_t}{j\omega L_r} \end{cases} \tag{17}$$

From maximum power transfer theorem, the capability of RIC-WPT system can be calculated as follows:

$$P_{\max} = \frac{|V_{OC}|\,|I_{SC}|}{2} \tag{18}$$

From the above equation, the maximum power transfer capability of this system is given by

$$P_{\max} = \frac{\omega I_t^2 M^2}{L_r} \tag{19}$$

From the analysis, it can be seen that the maximum power transfer capability of a RIC-WPT system under no load condition is influenced by the operating frequency (ω), mutual inductance (M) between the coils, and current (I_t) in the transmitting coil. Under load condition, when the resonant inductively coupled WPT system is connected to a resistive load, the impedance of the transmitting and receiving coils will be modified as follows:

$$\begin{cases} Z_t = R_t' + j\left(\omega L_t - \dfrac{1}{\omega C_t}\right) \\ Z_r = R_r' + j\left(\omega L_r - \dfrac{1}{\omega C_r}\right) \end{cases} \tag{20}$$

At resonance the transmitter and receiver impedances are

$$\begin{cases} Z_t = R_t' \\ Z_r = R_r' \end{cases} \tag{21}$$

The load power can be express as

$$P_L = |I_r|^2 R_L = \frac{V_s^2 \omega^2 M^2 R_L}{\|R_t' R_r' + \omega^2 M^2\|^2} \tag{22}$$

When both the coils are well compensated by external series capacitors, the PTE of RIC-WPT system can be calculated as follows:

$$\eta_{RIC} = \frac{R_L}{R_r'}\left(\frac{\omega^2 M^2}{\omega^2 M^2 + R_t' R_r'}\right) \tag{23}$$

In terms of quality factors, the efficiency can be rewritten as

$$\eta_{RIC} = \frac{R_L}{R_r'}\left(\frac{k^2 Q_t Q_r}{1 + k^2 Q_t Q_r}\right) \tag{24}$$

From Fig. 4 it can be seen that an external capacitor is inserted in series to both transmitting coil and receiving coil. Therefore, both the transmitting and receiving section impedances are shown in Equation (20). Here it is noticed that the series insertion of external capacitor modifies only the imaginary part of the impedances. In contrast, the PTE of IC-WPT system depends on both the real and imaginary parts of Z_r as well as the real part of Z_t. So it is obvious that the insertion of a capacitor to the transmitting coil in series has no impact on the power transfer efficiency. Rather, the efficiency will be affected and can be enhanced by connecting a capacitor with the receiver coil.

The power factor at the transmitter coil of an RIC-WPT system can be calculated as follows:

$$\begin{cases} \mathrm{Cos}\,(\phi)_{tr} = \dfrac{\omega^2 M^2 R_L}{\sqrt{(R_r'^2 + \omega^2 L_r^2)}\left[\omega^2 L_r^2 R_r'^2 + (\omega^2 M^2 + R_t' R_r')^2\right]} \\ \mathrm{Cos}\,(\phi)_{tr} = \dfrac{R_L}{R_r'} \dfrac{k^2 Q_t Q_r}{\sqrt{(1 + Q_r^2)\left(Q_r^2 + (1 + k^2 Q_t Q_r)^2\right)}} \end{cases} \tag{25}$$

Similarly, the power factor at the receiver coil of RIC-WPT system is expressed as

$$\begin{cases} \mathrm{Cos}\,(\phi)_{rr} = \dfrac{R_L}{R_r'} \dfrac{\omega^2 M^2}{\sqrt{\omega^2 L_t^2 R_t'^2 + \left(\omega^2 M^2 + R_t' R_r'\right)^2}} \\ \mathrm{Cos}\,(\phi)_{rr} = \dfrac{R_L}{R_r'} \dfrac{k^2 Q_t Q_r}{\sqrt{\left(Q_t^2 + \left(1 + k^2 Q_t Q_r\right)^2\right)}} \end{cases} \tag{26}$$

From (15) & (26), it can be noticed that RIC-WPT system entails better power factor than IC-WPT system, which is due to the absence of reactive power delivered by the source. Therefore, the resonant inductively coupled WPT system is usually regarded as an efficient WPT system meant for battery charging of electrical and electronic devices.

4. RESULTS AND DISCUSSION

In order to see the outcome of operating parameters on the performance of equivalent circuit models such as IC system and RIC system, a comparative analysis has been carried out. The values of the parameters used in theoretical calculation are listed in Table 1. To carry out the analysis the battery load is assumed as a resistive load.

Table 1. Values of parameters used for analysis.

Parameters	Symbol	Value
Input voltage (DC)	V_s	4.5 V
Transmitter coil	L_t	168 µH
Receiver coil	L_r	168 µH
Transmitter tuning capacitance	C_t	330 nF
Receiver tuning capacitance	C_r	330 nF
Primary coil ESR 192 mΩ	R_t	192 mΩ
Secondary coil ESR	R_r	192 mΩ
Operating frequency	f_0	20 kHz

The frequency characteristics of the power delivered to the load with respect to the physical separation gap between the coils for IC and RIC based wireless transmission system are revealed in Fig. 5. The frequency of operation region is flat for IC-WPT system while a sharp narrow region is observed for RIC-WPT system. It can be clearly observed that for a fixed operating frequency the power supplied to the load is maximum for each physical gap between the transmitter and receiver for RIC WPT system. It can be seen that for a fixed physical separation gap between the coils, there exists a frequency band for which power delivered to the load is maximum, and the operating frequency band moves to higher side with the increment in physical gap between the coils in the case of RIC WPT system whereas it is independent in IC based WPT system.

The dependencies of input power on the operating frequencies and the distance between the coils for IC and RIC models are depicted in Fig. 6. It is observed that with the increase in frequency of operation, the input power decreases in IC-WPT system. At certain frequency, the input power is seen to be maximum that is happening due to resonance phenomena which can effectively produce large magnetic flux to transmit large power in comparison to IC-WPT system. With the increase in separation gap of the coils the frequency of maximum input power region becomes narrow while it is self-determining in IC-WPT system.

The dependencies of power delivered to the load on the distance between both the coils and load resistances for both models are shown in Fig. 7. It has been observed that there exists an optimum

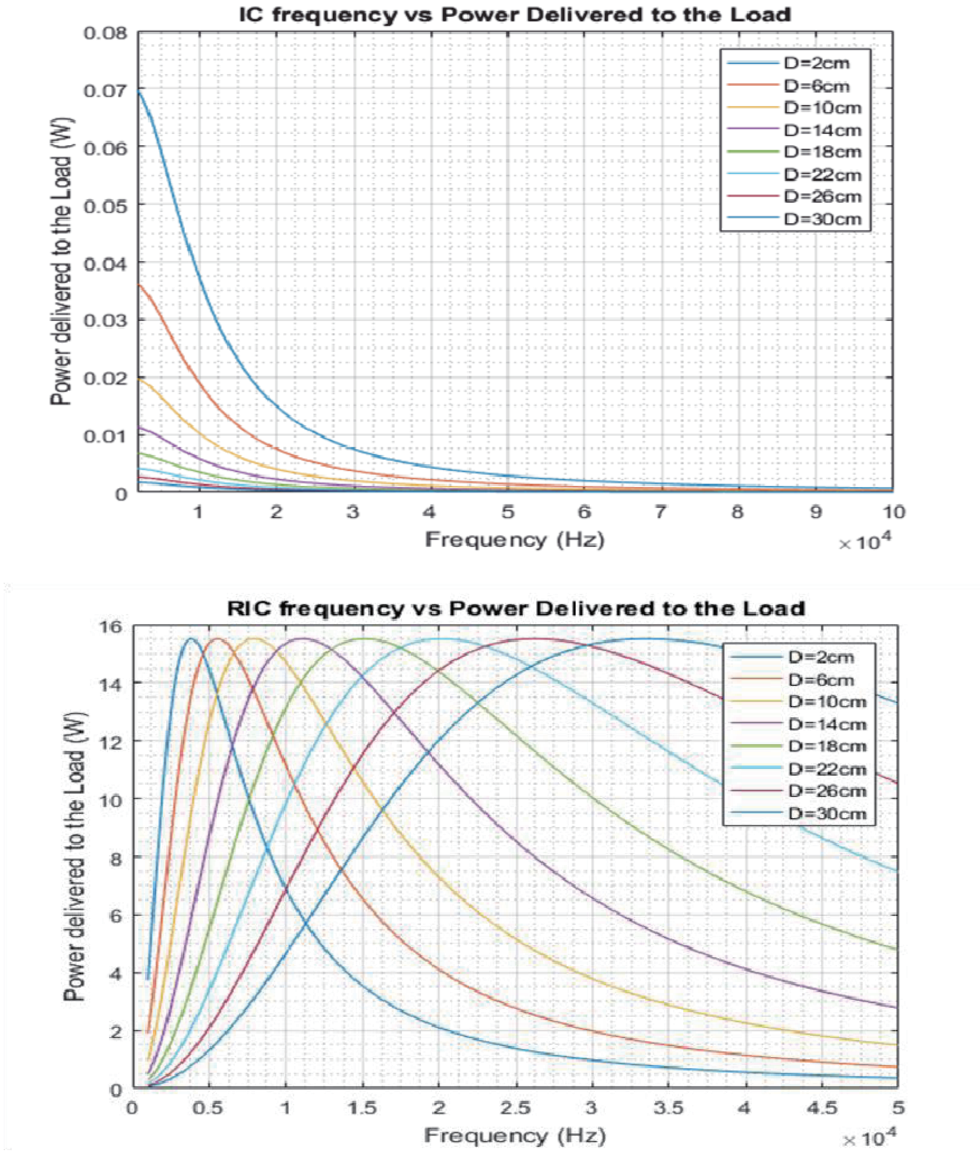

Figure 5. Frequency characteristics of the power delivered to the load for different physical separation gap between the coils for IC and RIC based WPT system.

distance corresponding to the load resistance for which maximum power transfer occurs. Again it is noticed that in RIC model when the load resistance is 10 Ohm, the power delivered to the load is 15 W for a fixed operating frequency. But in the case of IC at the same load resistance and frequency, the power delivered to the load is 0.052 W. From the analysis it can be observed that in the case of RIC, the power delivered to the load is maximum as compared to the IC model. For both the cases if the load resistance value 100 ohm, RIC model gives an optimum distance, but in the case of IC model it is very difficult to find out the optimum distance at which maximum input power occurs.

The frequency characteristics of efficiency for inductive coupling and resonant inductive based WPT systems are illustrated in Fig. 8. It has been observed that in RIC model when the distance is 10 cm and electric load 10 Ohm, the power transfer efficiency is 88% for a fixed operating frequency. But in the case of IC at the same load resistance and frequency, the power delivered to the load is 25%. From the analysis it can be observed that in the case of RIC the power transfer efficiency is maximum as compared to the IC model. For both the cases if the distance between the two coils is 2 cm, RIC model

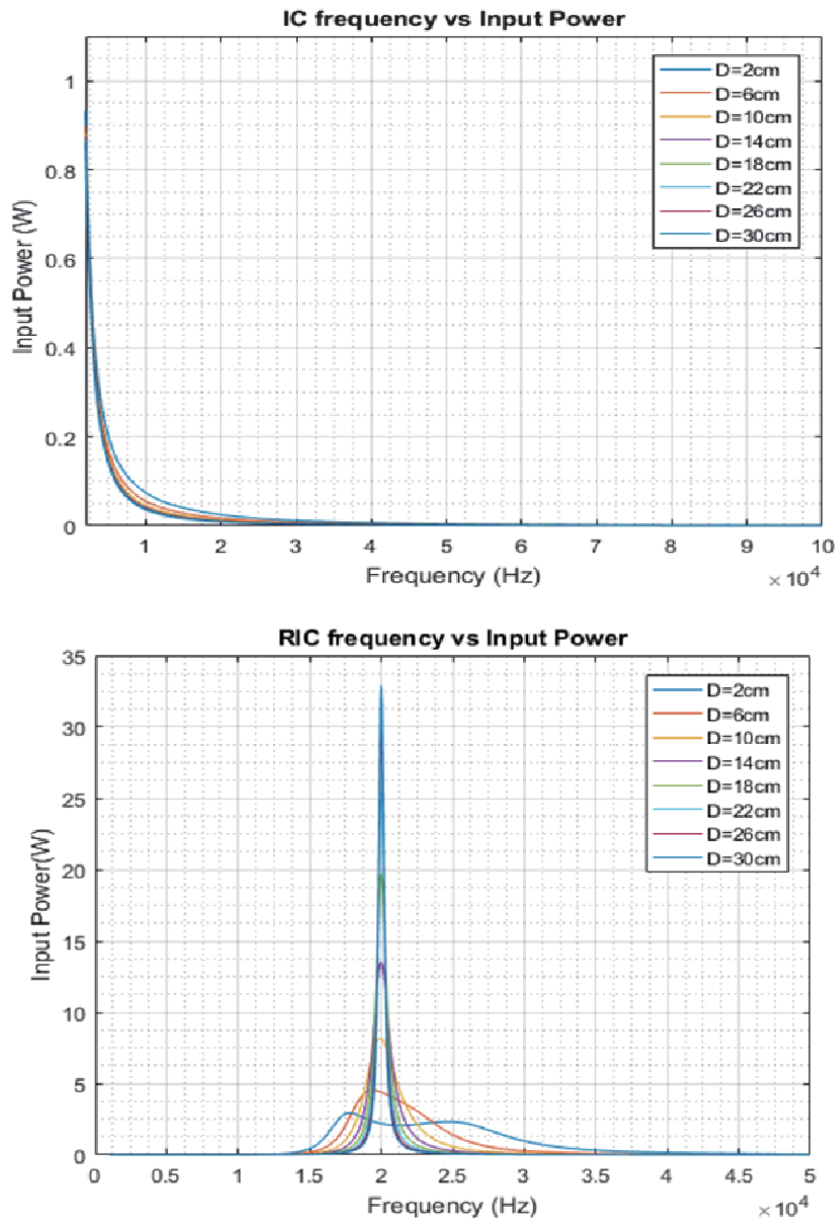

Figure 6. The dependencies of input power on the operating frequencies and the distance between both the coils for IC and RIC WPT system.

gives maximum efficiency (i.e., 90%) for a certain operating frequency, but in the case of IC model, it gives only 52% efficiency that is very low as compared to the RIC model. Therefore, it is indicated that the RIC based wireless power transfer system is relatively efficient compared to IC WPT system.

It can be seen from RIC model that there exist an optimum load resistance and the optimum load point shifts towards higher side with large separation gap. However in the case of IC-WPT, there is no variation in the input power with the variation of distance as well as electric load. It indicates that there is no effect of the receiver load which means that the maximum power is consumed in the transmitter. Without the receiver coil as there is input power, it is indicated that in IC based WPT system more electromagnetic radiation occurs. It is quite evident from the RIC-WPT characteristics that whenever the receiver coil is in the proximity of the transmitter coil, there is large input power across the transmitter coil, and there is very low power when there is no receiver load. It indicates that the resonant system works when the receiver load is there; otherwise, no power is radiated to the

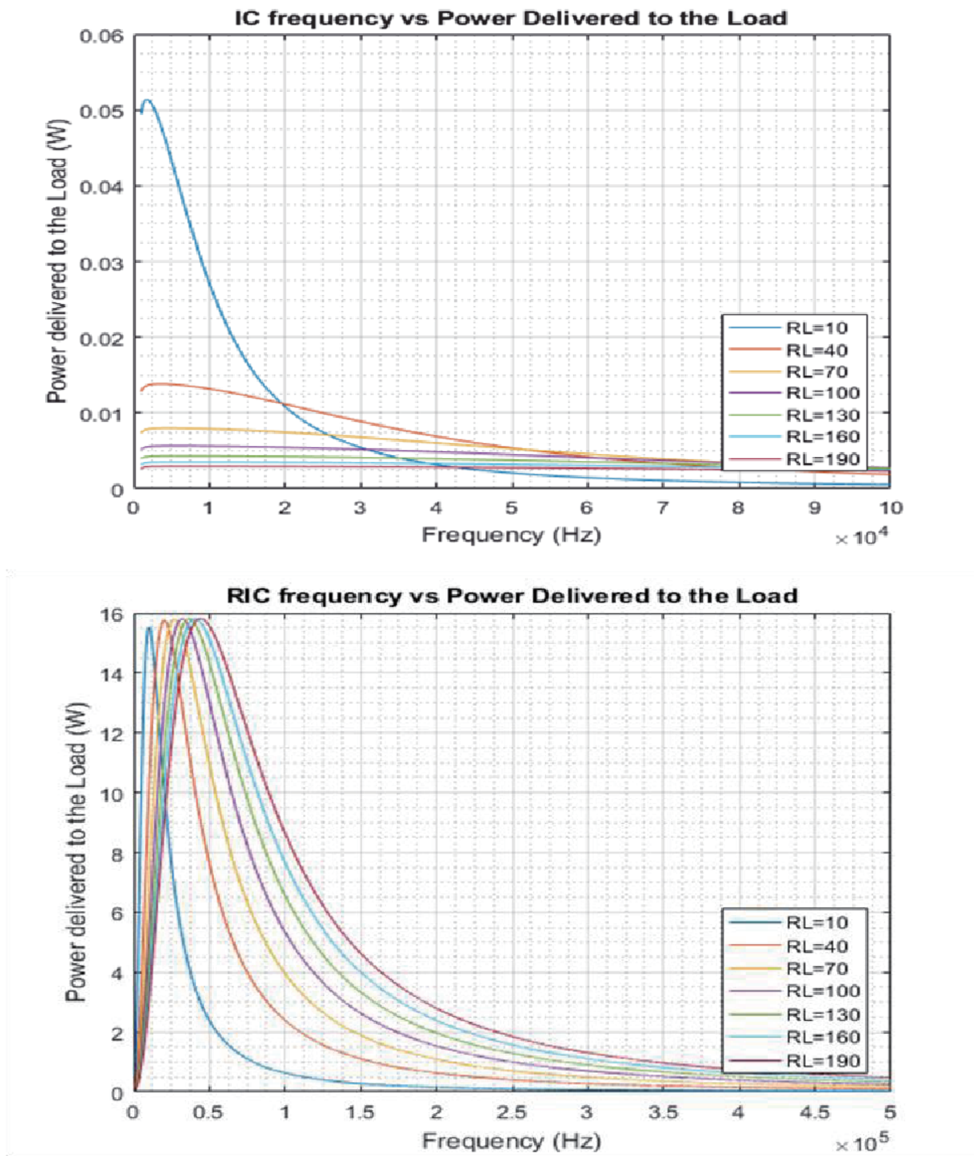

Figure 7. Dependence of power delivered to the load on the distance between both the coils and load resistances for IC and RIC WPT system.

medium. This analysis paves the way to pick up accordingly a suitable magnetically coupled system for maintaining maximum power transfer and minimizing the loss for charging of electric and electronic devices.

5. EXPERIMENTAL VALIDATION

The experimental frequency characteristics of power delivered to load for inductive coupling and resonant inductive based WPT systems are illustrated in Fig. 9. The measurement is taken for a certain gap and electrical load. Comparing the simulated and experimental results it is found that the relative error is approximately 1%. Simulated outcomes agree well with the obtained experimental results. The experimental frequency characteristics of efficiency of both WPT systems are illustrated in Fig. 10. It has been realized that RIC based wireless power transfer system is relatively efficient compared to IC WPT system. The close agreement between the simulated and experimental results demonstrates the effectiveness of the equivalent model used. Recreated results concur well with the acquired test results.

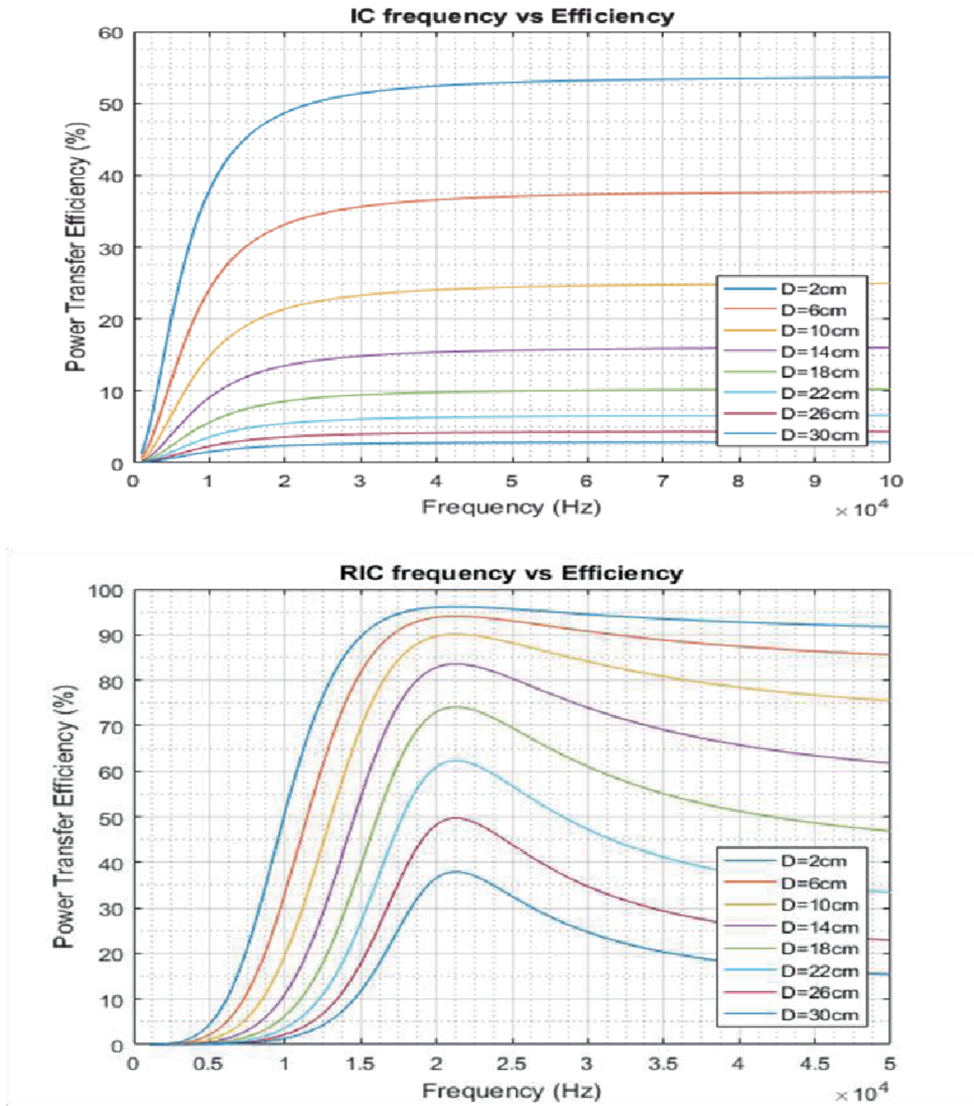

Figure 8. Power transfer efficiency characteristics for IC and RIC WPT system.

6. PRACTICAL DEMONSTRATION OF WIRELESS POWER TRANSFER WITH RESPECT TO RECEIVER LOAD

In order to investigate the outcomes of comparative analysis in between IC and RIC system, the experimental validation has been done. In the case of IC-WPT system, there is no variation in the input power with the variation of distance as well as electric load whether there is a receiver load or not. From the illustrated figure (Fig. 11), it can be seen that in the presence of receiver load the provided input voltage is 5.965 V at a certain distance between the two coils.

Again from Fig. 12, it is noticeable that there is the same input voltage (i.e., 6 V) with the absence of receiver load. Hence, in the case of IC-WPT, it is very difficult to find the optimum load resistance value. Therefore, it indicates that there is no effect of receiver load which means that maximum power is consumed in the transmitter coil.

In the case of RIC-WPT system, it can be observed that there is large input voltage (i.e., 1.004 V) across the transmitter coil when receiver load is present at a certain distance due to electromagnetic coupling; otherwise, very low input voltage (i.e., 493.9 mV) is consumed by the transmitter without receiver reducing the electromagnetic radiation, as shown in Figs. 13 and 14.

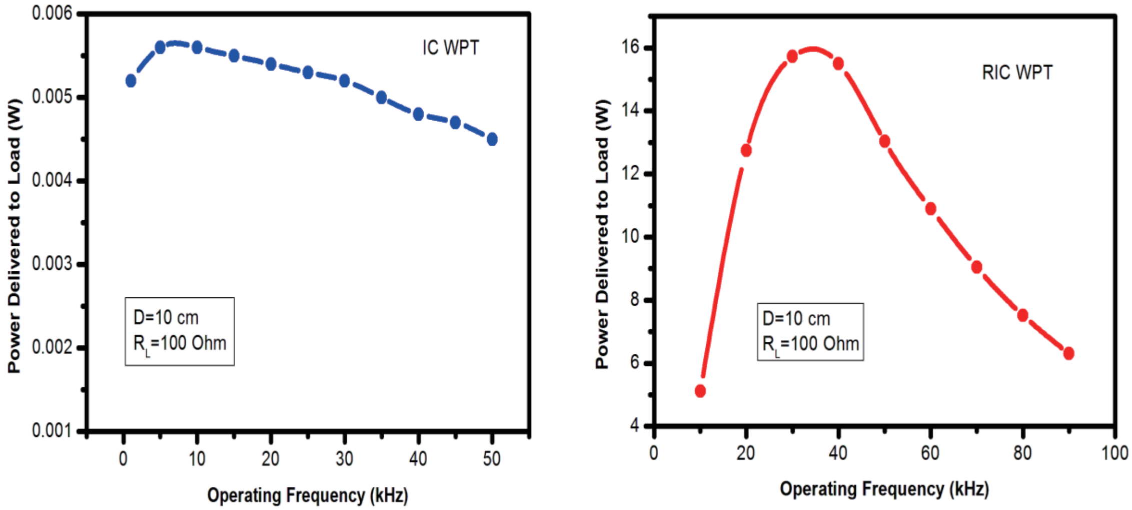

Figure 9. Experimental frequency characteristics of power delivered to load of IC and RIC WPT system.

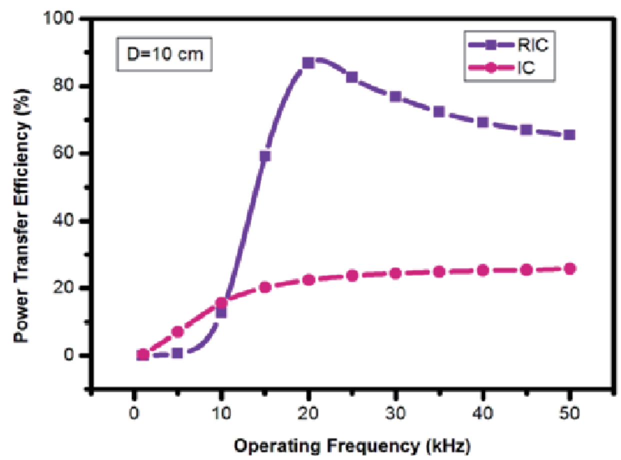

Figure 10. Experimental frequency characteristics of power transfer efficiency of IC and RIC WPT system.

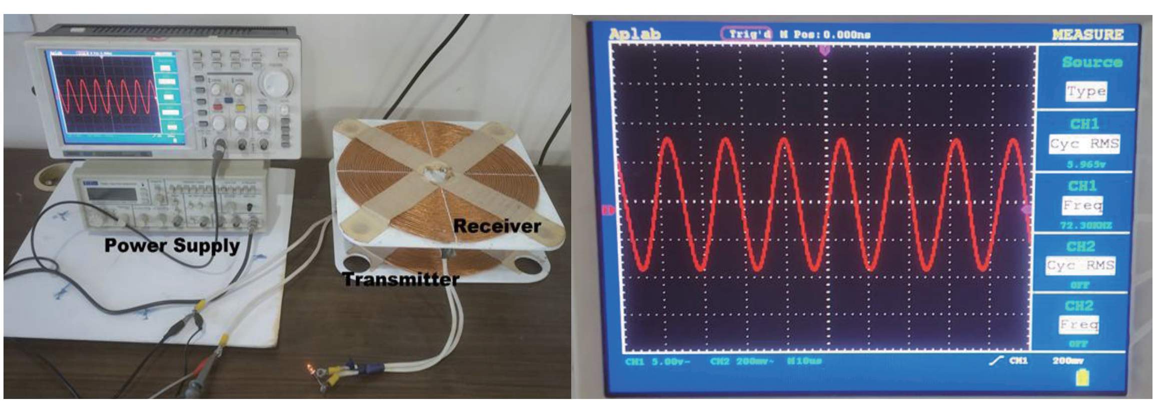

Figure 11. Experimental setup to measure the performance of IC-WPT system with receiver load.

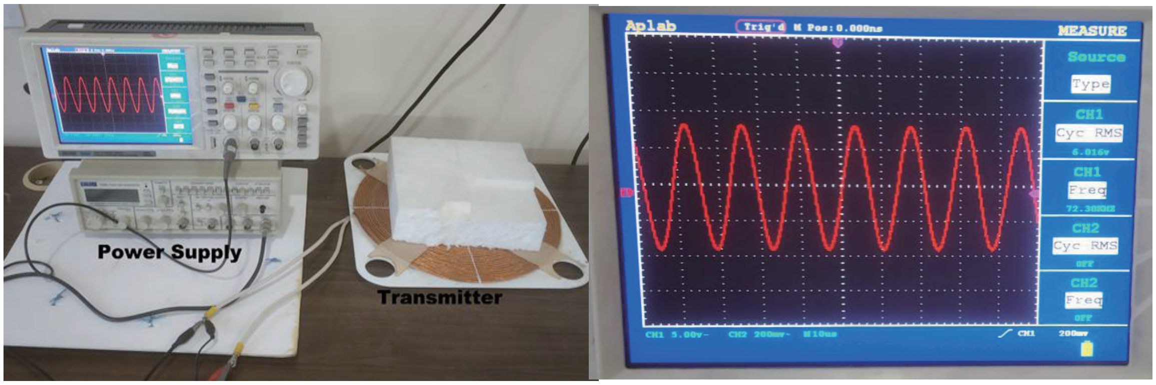

Figure 12. Experimental setup to measure performance of IC-WPT system without receiver load.

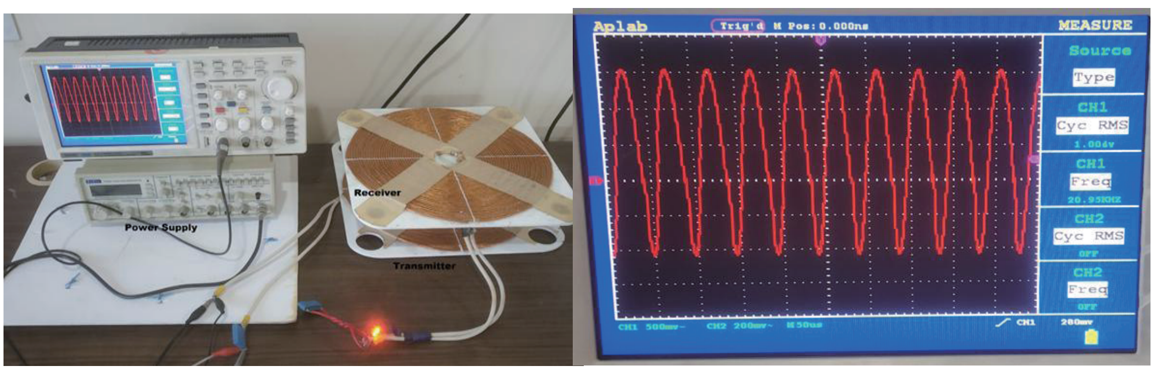

Figure 13. Experimental setup to measure the performance of RIC-WPT system with receiver load.

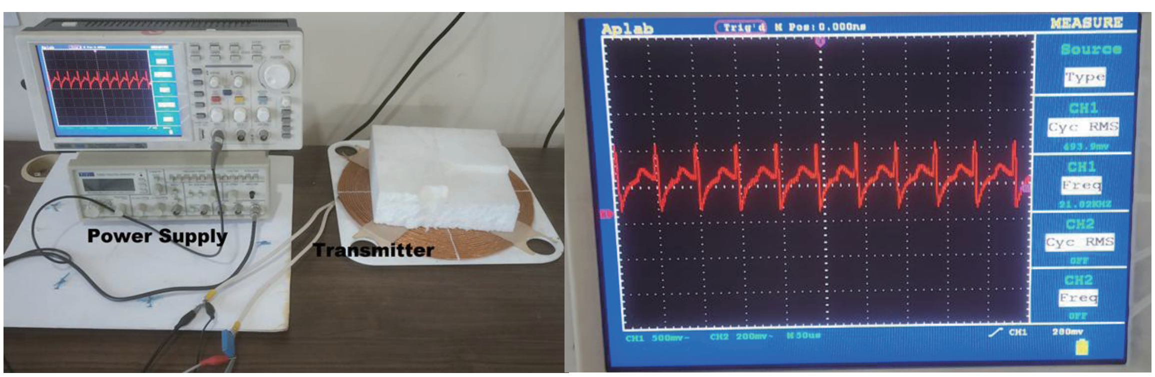

Figure 14. Experimental setup to measure performance of RIC-WPT system without receiver load.

From these investigations it can be perceived that the resonant system works when the receiver load is there; otherwise, no power is radiated to the medium. This analysis lays the way for selecting a suitable magnetically coupled system for maximising power transfer while minimising loss when charging electric vehicles with reduced electromagnetic radiation.

A comprehensive comparative analysis has been made based on the performance parameters to delineate the advantages of this work, as illustrated in Table 2. The rationalization regarding the preference of RIC-WPT system is distinguished as an attainable solution in wireless charging.

Table 2. Distinctiveness of IC and RIC WPT systems.

PARAMETERS	IC	RIC
Compensation	Primary and secondary compensation is not required.	Both primary and secondary compensation is required.
Distance	Distance between the two coils is independent on maximum power delivered to load	For a fixed distance between both the coils, there exists a frequency band for which power delivered to the load is maximum.
Load	Use lower value of load to achieve maximum efficiency.	Higher value of loads can be used to achieve maximum efficiency.
Input Power	Transmitter even consumed power without the receiver load	Transmitter does not consume power without the receiver load
Output Power	Frequency of operation region is flat.	Sharp narrow operating frequency band can be observed.
Efficiency	Efficient for very short range power transfer.	Efficient for mid range power transfer.

7. CONCLUSIONS

The comprehensive analysis and comparison of electrical power transferring abilities of IC and Resonant IC -WPT systems have been carried out. From the theoretical analysis and experimental investigation, it can be observed that for a fixed physical gap between the coils, there exists a particular frequency band for which power transfer to the load is maximum. The operational frequency band moves towards higher region with the increase in physical gap between the coils in the case of RIC WPT system whereas it is independent in IC based WPT system. For a certain frequency, the maximum input power is observed that is happening due to resonance phenomena which can effectively produce large magnetic flux to transmit large power in comparison to IC-WPT system. It has been observed that for a fixed load value the corresponding distance is fixed for which maximum power transfer occurs. RIC model is able to withstand large frequency fluctuations while maintaining high efficiency, but the IC model is not able to withstand large frequency fluctuations. The RIC model gives an optimum distance for each load (optimum distance point varies with the electrical load), but in the case of IC model there is no such point for each load (the optimum is independent of the electrical load). This analysis paves the way to pick up accordingly a suitable magnetically coupled system for maintaining maximum power transfer and minimizing the loss for charging electrical and electronic devices. The effectiveness of both the technologies and their power transfer characteristics have been demonstrated to disclose the viability of resonant inductively coupled wireless power transfer system as an alternative viable solution for EV charging.

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