



PV-INTEGRATED WIRELESS POWER TRANSFER SYSTEM FOR HIGH-EFFICIENCY ELECTRIC VEHICLE CHARGING

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Abstract

Wireless power transfer (WPT) technology, which operates on the basis of electromagnetic resonance, has the potential to do away with the requirement for intricate wires. The basic concept behind WPT is the same as that of inductive power transfer (IPT), which has been studied for more than thirty years. WPT has grown rapidly recently. It now has a grid-load efficiency of over 90%, capable of delivering kilowatts over distances from millimeters to hundreds of millimeters. The automotive industry finds WPT particularly attractive for wireless charging of electric vehicles (EVs) when stationary and at the speed of the snow. This article provides an overview of WPT technology for EV wireless charging. Integrating WPTs with EVs can largely overcome the problems associated with duration, space, and cost. Additionally, the current work has depended on PV systems as input power to reduce power in the grid; battery technology is declining with the proliferation of EVs. These recent developments will motivate researchers to advance EV technology and WPT development. The PV system has been given superior current work better results compared to the grid source generator.

Keywords: magnetic resonance; wireless power transfer; inductive power transfer; electric vehicles

1. INTRODUCTION

Electric transport has long been a goal, driven by energy efficiency and environmental benefits. Electric locomotives are strategically placed and efficiently receive power from overhead lines. However, powering electric vehicles is a big challenge because of their speed. They rely on quality batteries to store energy, but their high cost and range prevent their widespread use. Government incentives play an important role in encouraging the sale of EVs, specifically EVs [1]. Another major downside to electric cars, besides the higher price, is the longer charging time. Fully charging an EV can take several hours, depending on the charger's power output. This takes much longer than refueling a gasoline car. Once the battery is depleted, the vehicle cannot be used until recharged. EV owners must be careful to charge their cars regularly to avoid power outages, which can be annoying [2]. Charging cables present a risk of falling off, and damaged ones can be dangerous, especially in severe weather. Plugging in during rain or snow also increases the potential for electric shock. Power Transfer via Wireless (WPT) technology eliminates these charging issues and is attractive to EV owners. WPT makes charging easy just park and walk over for stationary systems. Dynamic WPT also allows EVs to charge while driving and can reduce battery size by 20%. Despite

the high market demand, cost-effective implementation of WPT remains a challenge. However, a research team at MIT has shown that it is possible to deliver 60W of power over 2 meters using strongly coupled magnetic resonance, offering a promising step forward. [3] [4]. Scientists were surprised by the unprecedented results, which led to the advance of WPT. Extensive research followed, looking for new districts, policy reviews, and control mechanisms. Domino-repeater-like mechanisms were also explored to direct energy transfer. Although wind coils and MHz frequencies are commonly used to improve the efficiency of energy transmission, they pose challenges for EV charging. Kilowatt power conversion at MHz frequency is inefficient in current power electronics. Also, air inner coils are susceptible to ferromagnetic elements in the vicinity. [5] [6].

The air inside a coil's magnetism reaches the vehicle's chassis when it is attached, altering its characteristics and increasing eddy current losses. To overcome this a ferrite material directs magnetic flux energy in coil construction, and an aluminum plate acts as a shield, providing handy EV charging but at a frequency of less than 100 kHz. WPT using ferrite is similar to well-established inductive power transfer (IPT) technologies. The foundation of WPT is immediate-field, non-radiation electromagnetic principles and is essentially the same as the

conventional IPT function, which relies on magnetic field coupling between coils [7] [8]. IPT systems have a wide range of applications, from underwater vehicles to mining systems, from factory wireless robots to electric vehicle charging. Due to technological advances, the importance of EV charging and power transmission distances at the kilowatt level has increased dramatically from millimeters to hundreds of millimeters [9].

Auckland University researchers spent fifteen years exploring inductive power supply for mobile products, culminating in successfully creating EV static charging pads. Measuring 766mm x 578mm, these pads can deliver 5kW of power with 90% greater efficiency at distances of up to 200mm and 250 mm, respectively. m, 150 mm [10].

Perspectives in the On Line Electronic Vehicle (OLEV) scheme at KAIST also contribute to WPT design development. Developed in three generations, the Olevi system achieved impressive results with 73% efficiency for SUVs and 83% for buses, delivering 20 kW and 60 kW, respectively, with a maximum range vertically of 160 mm and asymmetrical sides of 200 mm [11]. From a performance perspective, WPT for electric vehicles shows promise for both static and dynamic charging conditions. However, there are better business models, the establishment of industry standards, and cost reductions before greater commercial adoption [12]. The conclusion is that the current work begins with the precise transfer of power wirelessly from the normal source to charge the battery of a car by some converter by high frequency, and the second circuit is compared with the normal wireless transfer method, which is also a wireless method. Still, the supply source is the PV system [13]. The circuit is the content of the single AC source inserted into the AC-DC converter and out of voltage into a high single-phase inverter frequency. The ferrite coil works the resonance to transfer the power in the car's second part of the stand coil to charge the battery. The second design circuit uses the PV system to replace the single-phase source to reduce the power charging in the battery.

Despite the growing body of literature on WPT systems for EV charging, most existing studies rely on conventional AC grid sources as the primary power supply, which limits their sustainability and increases dependency on non-renewable energy infrastructure. The present work addresses this gap by proposing and evaluating a PV-integrated WPT system in which the solar array directly replaces the grid source. The main contributions of this study can be summarized as follows: first, a complete simulation model of a PV-fed WPT charging system is developed and validated; second, a comparative evaluation between grid-sourced and PV-sourced WPT systems is performed under identical operating conditions; and third, the impact of the PV integration on charging power and harmonic distortion is quantified, demonstrating clear

advantages in both power delivery and waveform quality.

2. METHODOLOGY OF PRINCIPLE CURRENT WORK

with a quick overview of the wireless power transmission mechanism, the primary distinction from a wireless charging device and a traditional driver or cable charger is that the transformer is swapped out with the straightforward regular of coils [14]. As seen in Fig. 1, the coil and substitution grid are displayed separately.

$$S_{12} = -V_{12}\dot{I}_2^* = -jwMI_1\dot{I}_2^* \quad (1)$$

$$= wMI_1I_2 \sin \theta_{12} - jwMI_1I_2 \cos \theta_{12}$$

$$S_{21} = -V_{21}\dot{I}_1^* = -jwMI_2\dot{I}_1^* \quad (2)$$

$$= wMI_1I_2 \sin \theta_{12} - jwMI_1I_2 \cos \theta_{12}$$

Where; (L_1) is the self-inductance of the main section's transmission wire of coil, (L_2) is the self-inductance of the receiver's wire of coil, and I_1 and I_2 represent the currents flowing between these two coils, respectively [15]. Regardless whereas V_{21} denotes the voltage produced in the main wire of a coil by the current flowing in the second side wire of a coil as a result of coupled or reciprocated current, which is located (V_{12}) is the voltage produced by the current in a coil's primary wire in the secondary coil across the primary and secondary coils [16]. The apparent power entering (L_1) and (L_2) is thus shown by S_1 and S_2 . The transformer's expected power source is represented by S_3 and S_4 . The apparent power transferred between the two coils is seen in S_{12} and S_{21} . The financial compensation systems precise structure is unknown, and its features will be examined in the future. From this, we can compute a simpler equation for the dynamic energy exchanged from L_1 to L_2 if we ignore Magnetic losses and coil resistance.

Here, I_1 and I_2 stand for the RMS values, while (θ_{12}) shows I_1 and (w) phase difference. The following is a mathematical expression for the active force from the primary stage to the secondary stage [17], [18]:

$$P_{12} = wMI_1I_2 \sin \theta_{12} \quad (3)$$

The system shown in There are two ways to convey active power in Fig. 2. The power to be transmitted from there is taken into consideration in the subsequent analysis. L_1 through L_2 . The highest power may be transmitted from L_1 to L_2 if $\theta_{12} = \pi/2$ and I_1 leads I_2 with a 90-degree phase shift. Does the two-coil method absorb the entire power;

$$S = S_1 + S_2 \quad (4)$$

$$= j(wL_1I_1 + wMI_2)I_1 + j(wL_2I_2 + wMI_1)I_2 \quad (5)$$

$$= jw(L_1I_1^2 + L_2I_2^2 + 2MI_1I_2 \cos \theta_{12})$$

Thus, it is the total active power of the system with two coils.

$$Q = w(2MI_1I_2 \cos \theta_{12} + L_2I_2^2 + L_1I_1^2) \quad (6)$$

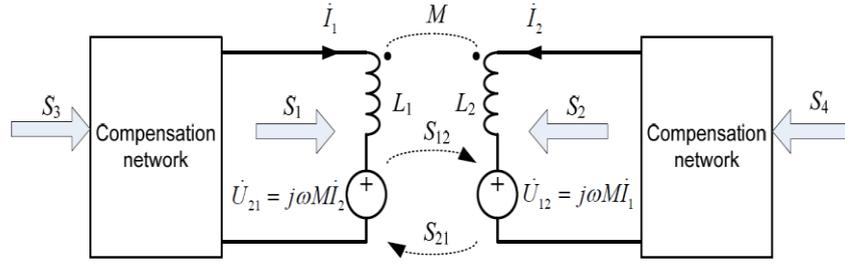


Fig. 1. A wireless transfer system with two coils in general

In a typical transformer, the active power is the magnetization power. A strong magnetic field causes significant energy loss in the copper expansion and core. To increase the efficiency of the transformer, it is necessary to increase the ratio of active power to reactive power [19], [20]. They are available through:

$$\begin{aligned} (\theta_{12}) &= \frac{|P_{12}|}{|Q|} \\ &= \frac{wMI_1I_2 \sin \theta_{12}}{\sqrt{wL_1I_1^2 + wL_2I_2^2 + 2wMI_1I_2 \cos \theta_{12}}} \\ &= \frac{k\sqrt{1 - \cos^2 \theta_{12}}}{\sqrt{\frac{L_1}{L_2} \frac{I_1}{I_2} + \sqrt{\frac{L_2}{L_1} \frac{I_2}{I_1}} + 2K \cos \theta_{12}}} \\ &= \frac{k\sqrt{1 - \cos^2 \theta_{12}}}{x + \frac{1}{x} + 2k \cos \theta_{12}} \end{aligned} \quad (7)$$

Where: $\frac{\pi}{2} < \theta_{12} < \pi$, $x = \sqrt{\frac{L_1}{L_2} \frac{I_1}{I_2}} > 0$, k is the L_1 and L_2 coupling factor.

The following equation must be solved in order to determine the greatest value for $f(\theta_{12})$.

$$\frac{\partial}{\partial \theta_{12}} f(\theta_{12}) = 0, \frac{\partial^2}{\partial^2 \theta_{12}} f(\theta_{12}) < 0 \quad (8)$$

The answers of the substitution are:

$$\begin{aligned} \cos \theta_{12} &= -\frac{2k}{x + \frac{1}{x}} \\ \sin \theta_{12} &= \sqrt{1 - \frac{4k^2}{\left(x + \frac{1}{x}\right)^2}} \end{aligned} \quad (9)$$

$$S = jwL_1I_1^2 + wMI_1I_2 \quad (10)$$

$$\begin{aligned} V_{12} &= I_2(R_2 + R_{Le}) = wMI_1 \\ &= wk\sqrt{L_1L_2}I_1 \end{aligned} \quad (11)$$

$$\eta = \frac{I_2^2 R_{Le}}{I_1^2 R_1 + I_2^2 R_2 + I_2^2 R_{Le}} \quad (12)$$

$$= \frac{(R_2 + R_{Le})^2}{K^2 Q_1 Q_2 R_2} + R_2 + R_{Le}$$

$$\eta(b) = \frac{1}{b + \frac{1}{b} + 2 + \frac{1}{K^2 Q_1 Q_2} + \frac{1}{b} + 1} \quad (13)$$

$$\frac{\partial}{\partial b} \eta(b) = 0, \frac{\partial^2}{\partial^2 b} \eta(b) < 0 \quad (14)$$

The maximum efficiency

$$\lambda_{max} = \frac{K^2 Q_1 Q_2}{(1 + \sqrt{1 + K^2 Q_1 Q_2})^2} \quad (15)$$

is achieved at

$$a_{\eta max} = \sqrt{1 + K^2 Q_1 Q_2} \quad (16)$$

It also yields highest efficiency. Multiple payment lines. Consequences are similar and consistent with the above results. Analysis: It doesn't show a specific payroll here. It has to be that way it is considered as a means of assessing the general performance of the coil and calculating the maximum efficiency of the power transfer. Batteries are common in EV wireless charging applications which are linked to the wire coil using four diodes to became a bridge rectifier. Serval of them are Time, it takes a force of action. The response is provided. Coil or compensating increases, like unit-powered instruments can provide power. It could be a battery. (Rb) is equal to U_b/I_b , where U_b & I_b stand for battery voltage and current, respectively, which are the opposite of resistance. If a battery is present linked directly to the reformer in the chain-to-chain as compensation, there may be equal ac component resistance It is calculated using $R_{ac} = 8/\pi^2 \cdot R_b$. In order to transform the batteries into a resistive load, they must be charged. various battery interconnection options, such as in parallel, series, or DC/dc commutator compensation, have various equations. most of the time. It is possible to acquire the corresponding R(ac). Particular equivalents The primary was not challenged in writing. Calculating equivalent AC resistances in the equation above. It is also possible to connect the rectifier to the battery. Pairing occurs between two coils that are around 0.2 apart for stationary EV wireless charging. If both are sent the quality factor of the receiver coils is 300 [21], [22].

3. DESIGN OF CIRCUIT

Fig .2 obtained the current design, so the parts necessary to build from AC-supply 325v 50Hz are the AC-DC rectifier, single-phase inverter mutual inductance, and the last-stage Vehicle Rectifier. Each one has a charged battery on the side of the car. Fig. 3 shows the PV system supplies the current - design circuit also, has the single-phase inverter and mutual inductance, and Vehicle Rectifier which in the end charges the battery on the car. Table.1 shows the characteristics of the PV panels has been used in the current work [14]. In building the simulation model, the resistance of each coil winding was included to account for copper losses, since this has a direct effect on how much power reaches the load. The ferrite core was modelled using its permeability

value to represent the flux guidance behaviour, which is the standard approach for this type of study. Other secondary effects such as the capacitance between winding turns and the variation of core losses with frequency were not modelled as individual components. These were left out because they have a minor influence on the overall comparison between the grid-fed and PV-fed systems, and the conclusions drawn from the results remain valid under these modelling assumptions.

4. RESULTS

Fig. 4 shows the DC link with the PV system connected with the current design work, which

responds well to the voltage and current delivered in the single-phase inverter. The voltage is stable at 0.04s and equals 267.7V. The current 20A is stable at 0.02s. Fig. 5 shows the DC link without a PV system. The voltage and current wave content oscillate until stable Fig. 6 shows the voltage and current in the primary winding for mutual inductance. The Square wave voltage equals 267.5V, and the sine wave current equals Peak-peak 32A. The high frequency equals 30Khz. Fig. 7 shows the voltage and current without a PV system doesn't stabilize the waveform from 0.0914s voltage decreases the opposite voltage in Fig. 6. Fig. 8 shows the voltage and current in the secondary winding for mutual inductance with the System. The square

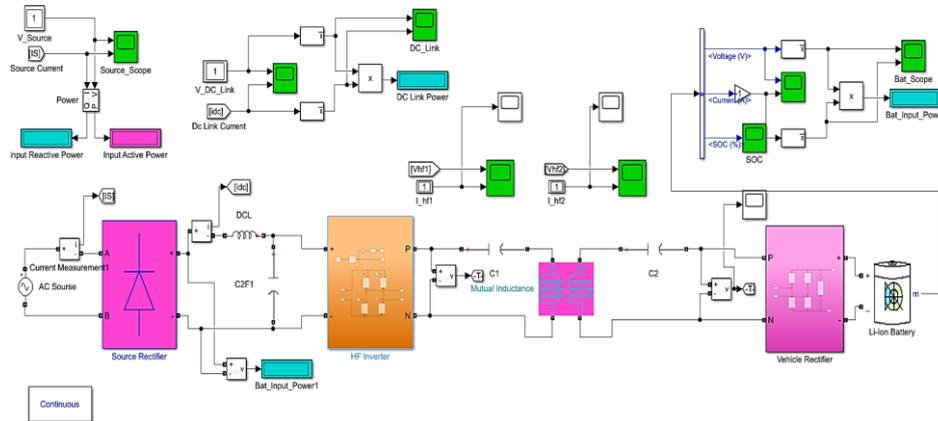


Fig. 2. The AC supply source delivers the circuit without the PV system to charge the car's battery

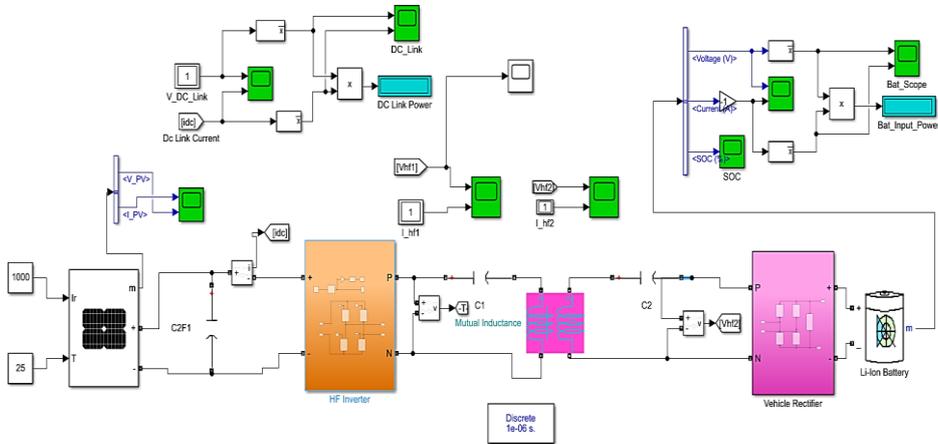


Fig. 3. The AC supply source delivers the circuit with the PV system to charge the battery on the car

Table 1. Shows the characteristics of the PV panel

Electrical Information at STC	ZT275P
Power max of Panel (Pmax)	275 Wp
Max. Voltage (Vmpp)	30.8 V
Max. Current (Imp)	8.93 A
Voltage at the open Circuit (Voc)	36.96 V
Current at the open Circuit (Isc)	9.56 A
Range temperature	-40~85 °C
Coefficient of the temperature	-0.41 %/°C
Coefficient of the temperature for Voc	-0.34 %/°C
Coefficient of the temperature for Isc	0.049 %/°C

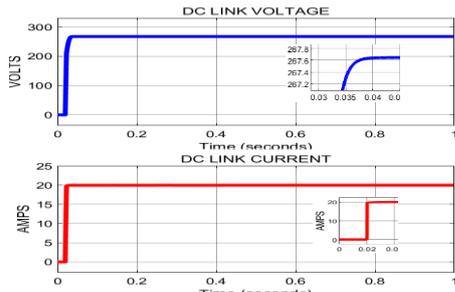


Fig. 4. The DC link voltage and current with the PV system

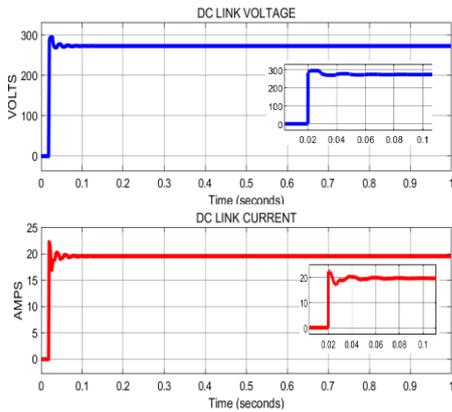


Fig. 5. The DC link voltage and current without the PV system

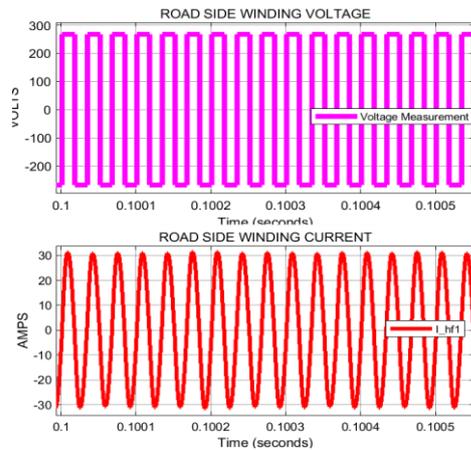


Fig. 6. Shows the voltage and current in the primary winding for mutual inductance with the PV system

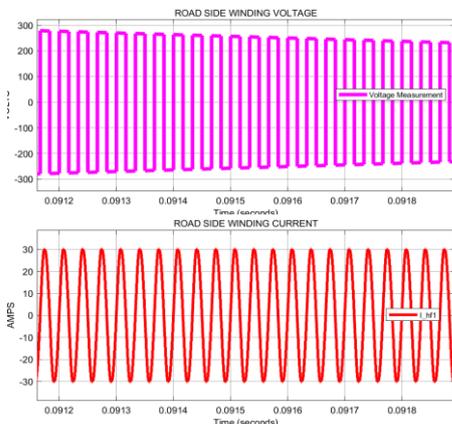


Fig.7. Shows the voltage and current in the primary winding for mutual inductance without the PV system

wave voltage equals 390V and - the sinewave current equals Peak-peak 19.5A, The high frequency equals 4Khz. Fig. 9 shows the voltage and current in the secondary winding for mutual inductance without the System.

Fig. 10 shows that the total harmonic distortion of the vehicle side winding with the PV system is 3.77%. This means the wave of current converts from the inverter to pass in the load according to the IEEE standard. Fig. 11 shows that the total harmonic distortion of the vehicle side winding with the PV system is 6.02%.

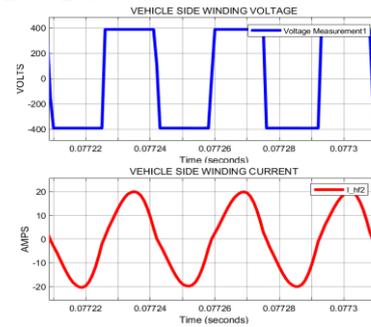


Fig. 8. Shows the voltage and current in the secondary winding for mutual inductance with the PV system

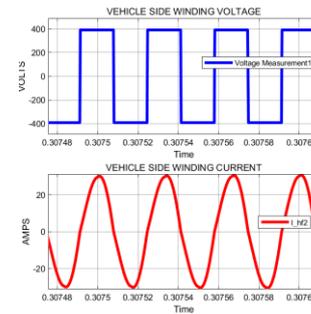


Fig.9. Shows the voltage and current in the secondary winding for mutual inductance without the PV system

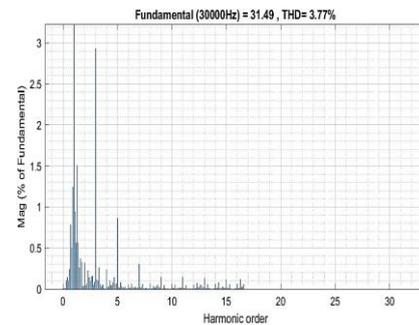


Fig. 10. Shows the total harmonic distortion of the vehicle side winding with the PV system

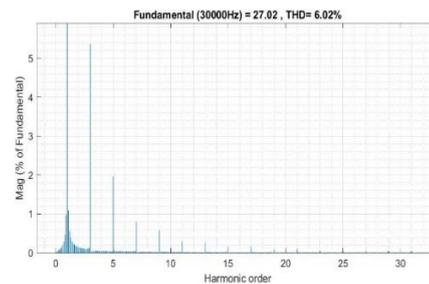


Fig. 11. Shows the total harmonic distortion of the vehicle side winding without a PV System

Fig. 12 shows the charging voltage and current on the car's battery. Voltage equals 390V current, and the power of charging the car's battery equals 4680w, approximately 12A without the PV system at the same input power. Fig. 13 shows the voltage and current of battery storage have been improving power charging with the PV system to become 5021W.

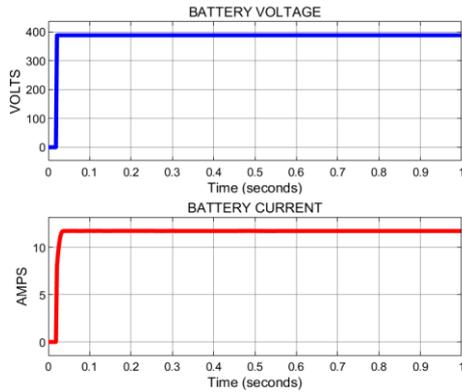


Fig. 12. The voltage and current charging a battery of a car from the system with the PV system

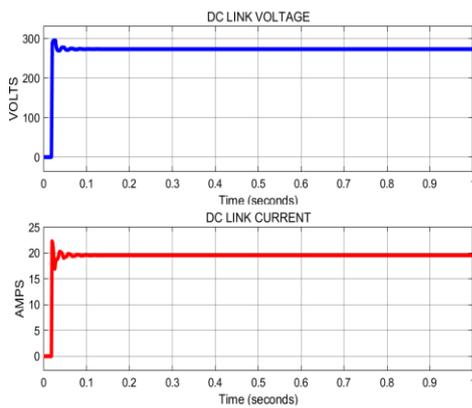


Fig. 13. The voltage and current charging a battery of a car from the system without the PV system

The efficiency of both systems was worked out from the same input power of 5335W. The grid system sent 4680W to the battery, so its efficiency came to 87.7%. With the PV system connected, the battery received 5021W, pushing the efficiency to 94.1%. Beyond the numbers, this tells us that the PV source does not just cut down grid usage, it actually moves power to the battery with less waste. Fig. 14 puts all three performance measures side by side so the difference between the two systems can be seen at a glance.

5. CONCLUSION

The results show that the EV WPT technology with PV system has an increase in the charging power of PV system equal to 5021 W or 7% more than the power without PV system equal to 4680 W and the results of THD equal to 3.77% with the PV system and equal to 6.02% without the PV system are shown. The results also provide an indication that there are possibilities of improving energy efficiency and reducing generation and transmission losses by using renewable energy which could make wireless power transmission for electric vehicles a desirable option in particular scenarios.

One limitation in this study is that the coils were kept in perfect alignment during all simulation runs. In real life, when a driver parks the car over the charging pad, some degree of lateral or angular offset is almost always present, and this kind of misalignment reduces the coupling between the coils and affects how much power is actually delivered to the battery. This was not part of the current study, but it will be considered in future work where different offset conditions will be tested and ways to compensate for them will be explored.

Taking everything into account, the study shows that replacing the grid source with a PV system in a WPT charging setup gives better results in terms of both delivered power and waveform quality, making it a worthwhile approach for sustainable EV charging."

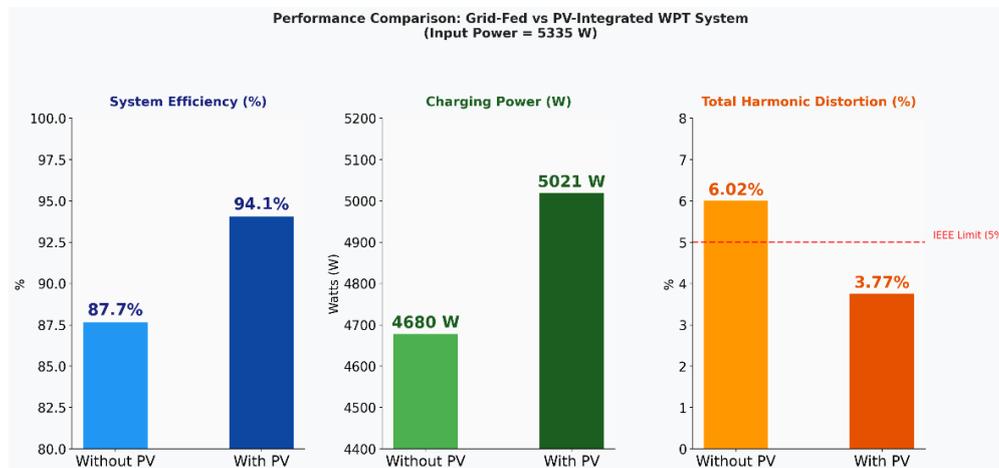


Fig. 14. Performance comparison between grid-fed and PV-integrated WPT systems showing efficiency, charging power, and THD at input power of 5335W

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