

Real-Time Wireless Concept of Vehicle to Vehicle Charging System

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ABSTRACT

The electric vehicle is the automotive future that supports the program of utilizing renewable energy over depleting fossil fuel. The electric vehicle enables us to have a better environment free of CO₂ emission. The issue of electric vehicle applications is charging points, not as many as the conventional charging station. This study investigates the concept of the real-time wireless vehicle to the vehicle charging system. The concept is realized by simulating it with two line-follower robots acting as the vehicles move side by side, where vehicle 1 charges vehicle 2. The maximum transferred voltage is 5.20 volt, and the maximum current is 93.50 mA with a closed distance of 1 cm. This maximum transferred energy results in the fastest velocity of 210 RPM. The highest distance possible between these two robots are 3.5 cm, and the induction is more potent as the distance is shorter. This concept enables charging without the vehicle in a stationary position.

Keywords: Receiver, transmitter, vehicle to vehicle, wireless energy transfer

1. INTRODUCTION

The electric vehicle is the automotive future where the power comes from generated electricity rather than utilizing the depleting fossil fuel [1]-[14]. The electric vehicle has stormed the world with its advantages over a conventional vehicle. This technology's application is more environmentally friendly than fossil fuel consumption that leads to the greenhouse effect. This alternative technology is growing fast and becomes the modern transportation system [15][16]. The electric vehicle can be developed more to be an autonomous vehicle.

The electric vehicle comes as the product of various technology, including mechanical, chemical, electrical, electronics, and automotive engineering. These different technologies are utilized to create an electric vehicle and realize an effective and efficient vehicle for power/fuel consumption. The electric vehicle consists of an electric motor to drive and utilize the electrical energy deposited in batteries, a power converter to convert the electrical energy into mechanical energy, and energy source management. The electric vehicle designs include identifying the applied environment and determining the technical specifications, including estimating loads, considering the energy source, which is batteries, motors, and its parameters.

One of the electric vehicle's issues is the energy management system, including charging and discharging electric vehicle. The emerging technology is including vehicle to grid, smart grid, and vehicle to vehicle charging (V2V). V2V can be very useful since the charging can occur anywhere without having to come to the specific charging station concerning; currently, the charging stations of electric vehicles are not as many as the conventional fossil fuel charging stations (gas stations).

The V2V system can be developed more by adopting the wireless charging system, where the source vehicle charged the other vehicle without connected by a physical wire [17]-[40]. This wireless charging system is more promising and effective since it is not required to stop or be stationary. This paper discusses the concept of real-time wireless charging of vehicle-to-vehicle charging system. The wireless system allows the vehicle to keep moving, such as a bus or an automatic vehicle; therefore, this system does not interfere with an automatic vehicle's schedule system. The vehicle to vehicle charging in this study is simulated by using two mobile robots demonstrating the automatic vehicle. This study is the continuation of our studies published in [16]-[19], which are the fundamental of the wireless system, and [16] discusses the concept of the automatic vehicle.

2. METHODS

This study discusses the concept of V2V charging by adopting the wireless technology applied to two line-follower robots as simulating devices. The experimental test-bed is set by installing the transmitter devices on vehicle one as the charging device, and receiver coil to vehicle 2. Vehicle one moves side by side with vehicle 2, charging online and in real-time.

2.1. Wireless Energy Concept

Wireless energy is not a new thing in electricity transmitting and charging. First introduced by Nikola Tesla in 1890 and was able to power a lamp without any contacting physical devices. The most applied wireless energy transfer (WET) in the near field method using magnetic coupling coils. The mid-air gap between transmitter and receiver functions as the media to transfer the power from transmitter to receiver. This method, however, is highly affected by the distance of the transmitter and receiver. The early concept of WET used the AC voltage source with a constant amplitude. In this study, the source is changed into a DC voltage source to imitate the energy transfer from a battery in a vehicle to the battery at the other vehicle (the charged vehicle).

The magnetic coupling method applied in this study is given in Figure 1, where the circuit is divided into the transmitter (T) and receiver (R). Therefore, i_T , L_T , R_T , and C_T are current, inductor, resistance, and capacitor at the transmitter side, while i_R , L_R , R_R , and C_R are current, inductor, resistance, and capacitor at the receiver side. The load is positioned in the R_L , which is in this study in vehicle 2. The distance between transmitter and receiver is d , and M is the magnetic induction between them.

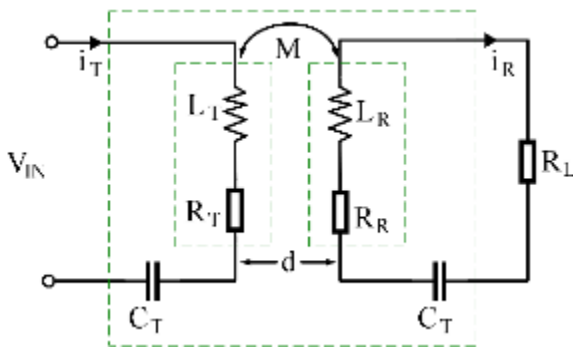


Figure 1 The model of the wireless energy concept adopted in this study.

The impedance presentation of magnetic induction in Figure 1 is given by

Figure 1 shows the energy coupling between the transmitter and receiver due to the inductor interception of a magnetic field produced by the transmitter. The coupling coefficient is calculated by

$$V_T = j\omega L_T i_T + j\omega M i_R, \quad (1)$$

and

$$V_R = j\omega M i_T + j\omega L_R i_R. \quad (2)$$

Figure 1 shows the energy coupling between the transmitter and receiver due to the inductor interception of a magnetic field produced by the transmitter. The coupling coefficient is calculated by

$$k = \frac{M}{\sqrt{L_T L_R}}. \quad (3)$$

The power coupling in the transmitter side is the product of magnetic induction (M) and the receiver current (i_R), and the power coupling on the receiver side occurs due to transmitter current (i_T) flowing in the transmitter, which is coupled by the mutual induction.

The magnetic induction in Figure 1 is positively affected by the distance between transmitter and receiver and given by

$$M = \frac{\mu_0 i_R}{2\pi d}. \quad (4)$$

where μ_0 is $4\pi \times 10^{-7} \text{ WbA}$, magnetic flux (Φ) is given Φ is the product of magnetic induction and coil's cross-sectional area, and the produced electrical power (P) is the product of voltage and current in the receiver.

2.2. Wireless Vehicle to Vehicle Charging

The wireless V2V charging concept adopts the possibility of using WET to charge the nearby electric vehicle. The advantage of wireless V2V is charging, and the charged vehicle does not need to stop. They can be driving side by side. This method is effective and applicable for an autonomous vehicle with a particular schedule.

The possibility of applying the wireless V2V concept is shown in the block diagram in Figure 2. Vehicle 1, having the transmitter coil, becomes the charging point for vehicle 2. The concept is that vehicle 1 emits the magnetic coupling to transfer the electricity to vehicle 2. The experimental design shows that vehicle 1 carries the transmitter coil, and vehicle 2 gets the receiver coil, as shown in Figure 3. The experimental setup and testbed are given in Figure 4. This setup is to prove the possibility of applying the wireless V2V concept.

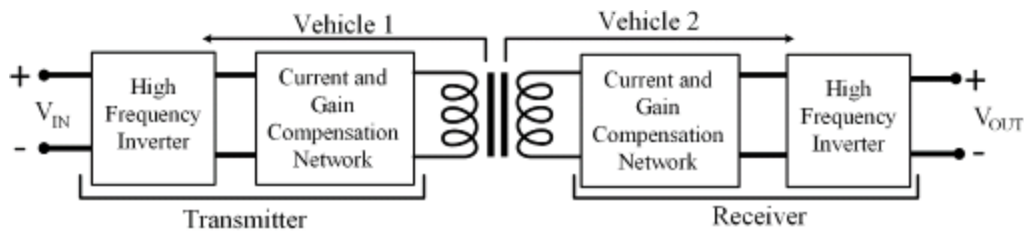


Figure 2 The wireless V2V charging concept2. The wireless V2V charging concept.

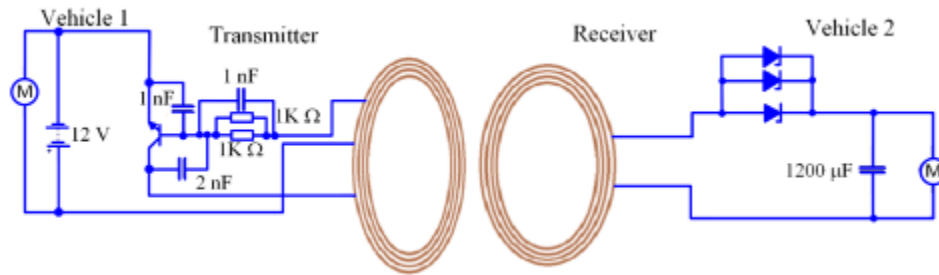


Figure 3 The electric circuit of both transmitter and receiver is installed on the experimental test-bed.

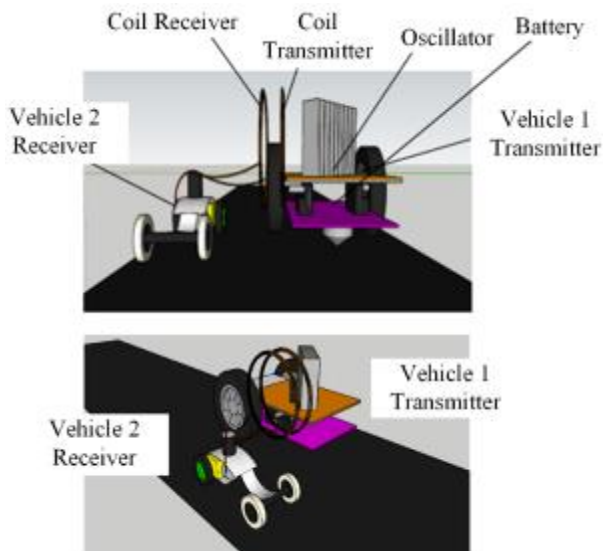


Figure 4 The transmitter and receiver vehicles considered in this study.

3. RESULT AND DISCUSSION

The wireless V2V charging concept is realized in Figure 5, where two line-follower robots act as the vehicles move side by side, where vehicle one charges vehicle 2. Wireless power transmission works by

utilizing the principle of electromagnetic resonance, which is that two copper coils resonate with the same frequency between the transmitter and receiver. The transmitter coil is connected to the battery, which moves the line follower robot as vehicle 1 to charge another line follower robot as vehicle 2. The electrical energy that comes from the battery makes the copper coil resonate at a particular frequency.

Furthermore, the space around the copper coil is filled with non-magnetic radiation. This condition creates a magnetic field that will transmit energy to the copper coil, so the coil connected to the receiver can resonate in the same frequency as the first copper coil (transmitter). So, the line follower robot at the transmitter and receiver parts can go hand in hand.

The complete experimental results of the wireless V2V charging concept are shown in Table 1, where dist is distance, V is voltage, P is power, and velocity is both vehicle 1 and 2 velocity. It is shown that the velocity of the robots is affected by the power transferred between robots. Figure 6 shows the transferred power and the velocity of the robots. Since the robots are moving simultaneously; therefore, the velocities are the same. Figure 7 shows the relationship between produce powered, the distance of Tx and Rx, and magnetic induction. Table 2 shows the magnetic induction (B), flux (Φ), and frequency (f) achieved by calculation.

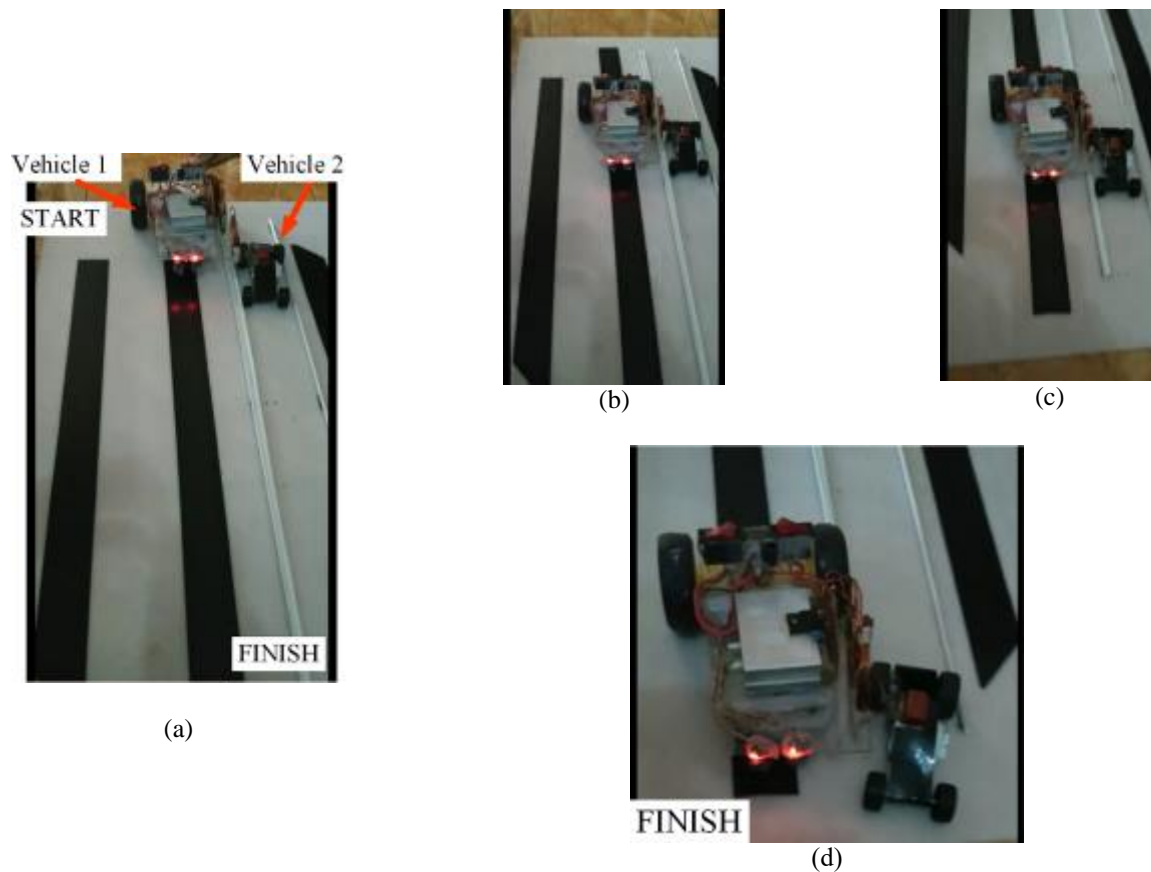


Figure 5 The experiment of wireless V2V concept

Tabel 1. The experimental result of the transferred power and velocity

Dist (cm)	V (V)	I (mA)	P (Watt)	Velocity (RPM)
1	5.20	93.50	0.48	210.00
	5.20	94.00	0.48	189.90
	5.10	94.00	0.47	188.50
1.5	4.30	73.70	0.31	179.50
	4.30	73.90	0.31	175.70
	4.20	73.20	0.30	175.60
2	3.20	61.70	0.19	130.40
	3.50	61.10	0.21	133.80
	3.40	61.90	0.21	133.00
2.5	2.50	50.50	0.12	72.00
	2.60	50.40	0.13	78.30
	2.50	51.20	0.12	74.50
3	1.80	41.40	0.07	63.70
	2.10	41.80	0.08	61.60
	2.00	41.50	0.08	64.00
3.5	1.30	32.80	0.04	37.20
	1.40	32.70	0.04	41.40
	1.50	32.20	0.04	37.00

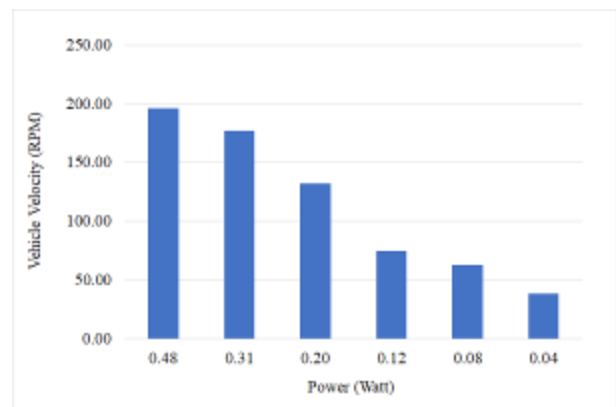


Figure 6 The transferred power VS the vehicle velocity.

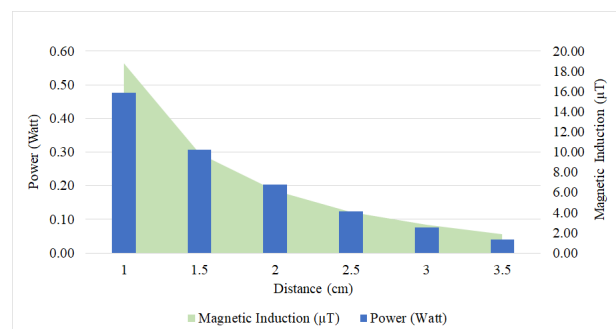


Figure 7 The relationship among produce powered, the distance of Tx and Rx, and magnetic induction.

The maximum transferred voltage is 5.20 volt, and the maximum current is 93.50 mA with a closed distance of 1 cm. This maximum transferred energy results in the fastest velocity of 210 RPM. The wireless V2V charging concept promises the advantages of charging without physical media and without the vehicles' necessity to be in a stationary position. This concept is realized by simulating it with two line-follower robots. This proposed method is effective at a certain point.

Tabel 2 The magnetic induction, flux, and frequency.

Dist (cm)	B (T)	Φ (Wb)	f (Hz)
1	18.7×10^{-7}	14.02×10^{-9}	10.45
	18.8×10^{-7}	14.10×10^{-9}	9.49
	18.8×10^{-7}	14.10×10^{-9}	9.42
1.5	9.82×10^{-7}	7.36×10^{-9}	8.97
	9.85×10^{-7}	7.38×10^{-9}	8.78
	9.76×10^{-7}	7.32×10^{-9}	8.78
2	6.17×10^{-7}	4.62×10^{-9}	6.52
	6.11×10^{-7}	4.58×10^{-9}	6.69
	6.19×10^{-7}	4.64×10^{-9}	6.65
2.5	4.04×10^{-7}	3.03×10^{-9}	3.6
	4.03×10^{-7}	3.02×10^{-9}	3.91
	4.09×10^{-7}	3.06×10^{-9}	3.72
3	2.76×10^{-7}	2.07×10^{-9}	3.18
	2.78×10^{-7}	2.08×10^{-9}	3.08
	2.76×10^{-7}	2.07×10^{-9}	3.2
3.5	1.87×10^{-7}	1.40×10^{-9}	1.86
	1.86×10^{-7}	1.39×10^{-9}	2.07
	1.84×10^{-7}	1.38×10^{-9}	1.85

4. CONCLUSION

This study discusses the wireless V2V charging concept by simulating two line-follower robots acting as the vehicles move side by side, where the vehicle 1 charges vehicle 2. The maximum transferred voltage is 5.20 volt, and the maximum current is 93.50 mA with a closed distance of 1 cm. This maximum transferred energy results in the fastest velocity of 210 RPM. The highest distance possible between these two robots are 3.5 cm, and the induction is more robust as the distance

is closer. This concept enables charging without the vehicle in a stationary position.

AUTHORS' CONTRIBUTIONS

All the authors share contributions in this manuscript. T. Dewi and P. Risma designed and directed the project; Y. Oktarina and M. Nawawi performed and supervised the experiments; T. Dewi, and Y. Oktarina conducted data analysis and wrote the article.

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