Simulation and Verification Synchronous Transmission System of Wireless Power and Signal Based on FSK

Ning Wang, Qingxin Yang
Tianjin Key Laboratory of Advanced Electrical Engineering and Energy Technology,
Tianjin Polytechnic University, Tianjin 300387, China

Abstract
A method of digital signals transmission based on energy flow, aiming at solving message transmission in Wireless Power System (WPT) has been proposed. To realize the transmission of power and information simultaneously, the feature of the message is pouring into the energy wave without appending any auxiliary circuits but sharing the same inductor channel. At the receiver end, system could not only fetch the energy, but also the demodulate unit could recover signals according to the specific features. Through the actual test and simulation, it is basically in agreement with the theoretical one. Compared Frequency-shift keying (FSK) and Amplitude-shift keying modulation, while the SNR is 3dB, FSK is better for decreasing BER nearly 8%, and when the distance is fixed, take 40cm for example, the efficiency of the system is enhanced almost 12% when take FSK method.

Key words: Wireless Power Transfer, Power-signal Synchronous Transmission, Frequency-shift Keying.

1. INTRODUCTION
WPT could avoid the direct connection between general electronic instruments and grid, the limitations such as unstability and device movement can be overcome by this way(Duklu and Songcheol, 2014; Jaegue, Seungyong and Yangsu et al., 2014; Jesús, Juan and Andrés et al., 2009; Mickel, John and Grant et al., 2013; Murat and Philip, 2013; Thierry, Marc and Valérie et al., 2002). As a complement on the traditional power supply mode, it brings to high attention of the researchers all around the world. However, in certain case, such as implanted medical devices and rotating machinery in robot, the information also need to be transmitted during the power transfer without adding any channels to realize the communication function of data interaction between the two terminal of the system(Edward, John and Grant et al., 2007; Junji, Tae-Woong and Atsuo, 2000; Junji, Tae-Woong and Atsuo, 1999).

Aiming to solve the problems above mentioned, scholars at home and abroad proposed the voltage amplitude modulation, this method effects transmitted power significantly and can only be used in miniwatt situation; frequency modulation is restrict with carrier frequency strictly, though the signal can be transferred, the power transform efficiency is badly decrease; time-sharing can be applied in the WPT system to transfer information, and the losses for power is also pretty high; dual-band resonant circuit is too hard to design. The data is directly modulated on the power carrier by frequency shifting keying (FSK) in data transmission, but the data rate is low (Gürkan, Öğuz and Catherine, 2013). The detailed communication circuits are discussed, and the crosstalk interference between power and data is analyzed, but OOK is not applicable to high speed signal transmission(Wu, Zhao and Lin et al., 2015).

In this paper, a method to transmit power and signal simultaneously: the features of signal will be loaded in the power wave. The receiver could not only fetch energy but also restore the signals by demodulator. At last, through the actual test and simulation, it is basically in agreement with the theoretical one. However, the data transmission could reduce the system efficiency. The impact of the signal modulation on system efficiency is discussed. Compared Frequency-shift keying (FSK) and Amplitude-shift keying modulation, while the SNR is 3dB, FSK is better for decreasing BER nearly 8%, and when the distance is fixed, take 40cm for example, the efficiency of the system is enhanced almost 12% when take FSK method.

2. SYSTEM PRINCIPLE ANALYSIS
2.1. System Working Principle
As is shown in Figure 1, which is the block diagram of the system designed in the paper. The system is divided into two parts, and each of them contains energy modulation module, signal modulation and demodulation module.
2.2. Signal Modulation

In order to recover the signal transmitted, the information must be modulated. The signal is modulated on the carrier. 3 parameters of the carrier can be modulated independently, so there are 3 basic modulation system these basic modulation are ASK, FSK, PSK.

ASK (Amplitude Shift Keying) is also called Amplitude Keying. This method can produce the same output waveform. Since the output waveform of the amplitude shift keying is an intermitted sinusoidal waveform, it is sometimes called on-off-keying (OOK). The symbol waveforms of ASK is shown as Figure 2.

FSK (frequency shift keying) is frequency modulation. The symbols 1 and 0 of the binary frequency shift keying signal are respectively transmitted by two sinusoidal waves with different frequencies, and their amplitudes and initial phases remain unchanged. The symbol waveforms of FSK signal is shown as Figure 3.
Since the FSK show the stronger anti-fading ability compared with ASK, FSK modulation system is often used.

3. SYSTEM SIMULATION

The communication unit is consist of modulator and de modulator. In this paper, we mainly analysis information transmission in low-power WPT system. Signal 0 and 1 are transferred by different frequency which is according to the features, thus, the mixed flow contain the information features and power. In the demodulator, there are rectifier, low-pass filter and compare circuit.

System designed in this paper using SP topology (Wu, Zhao and Lin et al., 2015), we establish platform through Simulink, the system frame diagram is shown as Figure 4, system parameters is shown as table 1.

![Figure 3. Symbol waveforms of FSK](image)

**Figure 3. Symbol waveforms of FSK**

![Figure 4. System frame diagram](image)

**Figure 4. System frame diagram**
Table 1. System parameter

| Parameters                              | value  |
|-----------------------------------------|--------|
| Input voltage                           | 48V    |
| Compensation capacitor C1 and C2        | 0.27μF |
| Magnetizing inductor of coupled inductors L1 and L2 | 148μH |
| Leakage inductor of coupled inductors Lm | 8μH    |
| Power-wave frequency                    | 20.2kHz|
| Carrier frequency                       | 1.58MHz|
| Mutual inductor                         | 17μH   |
| Distance                                | 8cm    |
| Load in system                          | 15Ω    |

4. EXPERIMENTAL RESULTS ANALYSIS

4.1. Signal Transmission

The features of discontinuous signals can be poured into the energy wave generated by the inverter, which is controlled by the analogy switches. As is shown in Figure 5, the signal collected from the transmitter is 1010..., when 1 is transmitted, high-frequency can be loaded in the energy wave while 0 is transmitted, the high-frequency is shut down.

The receiver end fetch the mixed flow, the processed result is shown as fig6. We can clearly recover the transmitted signal 1010.... However, the designed system is high order and nonlinear, which could bring large time delay in the demodulator unit.

Figure 5. Mixed flow at transmitter
4.2. Quality of Signal Analysis

Firstly, we established simulation platform which is referring to document (Wu, Zhao and Lin et al., 2015), and calculate the Symbol error probability. The symbol error probability curves for ASK both experimentally and theoretically, as is shown in Figure 7.

![Figure 6. Signal in demodulator](image)

![Figure 7. Comparison of BER in ASK and FSK system](image)

we can draw a conclusion that the ASK can be used in WPT system to achieve the goal that the signal and power can be transferred through coupling mechanism. However the ASK could be influenced by the white noise easily.

Thus, FSK is used in our design. The symbol error probability for FSK and ASK is compared, the result is shown in Figure 8.
4.3. Systematic Efficiency Analysis

To evaluate principle between the distance of the coupling device and the system effiency, mutual inductance is used to simulate the distance. We compared the two modulation and draw a conclusion that, in system this paper designed, the power transfer effiency is better compared with the traditional one when the mutual inductance is the same.

5. CONCLUSIONS

This paper proposed a new way to transmit signal in WPT system. Take the energy wave as carrier, pour the signal features into the carrier to realize transfer power and information simultaneously. The receiver could not only receive energy but also recover the signals by demodulator. Compared Frequency-shift keying (FSK) and Amplitude-shift keying modulation, while the SNR is 3dB, FSK is better for decreasing BER nearly 8%, and when the distance is fixed, take 40cm for example, the effiency of the system is enhanced almost 12% when take FSK method.
ACKNOWLEDGEMENTS

This work was supported by The National Natural Science Foundation of China(51477117, 51607121).

REFERENCES

Duklu Ahn, Songcheol Hong (2014) “Wireless power transmission with self-regulated output voltage for biomedical implant”, IEEE Transaction on Industrial Electronics, 61(5), pp. 2225–2235.

Edward L. van Boheemen, John T. Boys, Grant A. Covic, et al.(2007) “Dual-tuning IPT systems for low bandwidth communications”, Proc. IEEE Conf. on Industrial Electronics and Application, pp. 586–591.

Gürkan Yılmaz, Oğuz Atasoy, Catherine Dehollain.(2013) “Wireless energy and data transfer for in-vivo epileptic focus localization”, IEEE Sensors Journal, 13(11), pp. 4172–4179.

Jaegue Shin, Seungyong Shin, Yangsu Kim, et al.(2014) “Design and implementation of shaped magnetic-resonance based wireless power transfer system for roadway-powered moving electric vehicles,” Transaction on Industrial Electronics, 61(3), pp. 1179–1192.

Jesús Sallán, Juan L. Villa, Andrés Llombart, et al.(2009)“Optimal design of ICPT systems applied to electric vehicle battery charge,” Transaction on Industrial Electronics, 56(6), pp. 2140–2149.

Junji Hirai, Tae-Woong Kim, Atsuo Kawamura (2000) “Study on intelligent battery charging using inductive transmission of power and information”, IEEE Transaction Power Electronics, 15(2), pp. 335–345.

Junji Hirai, Tae-Woong Kim, Atsuo Kawamura.(2000) “Integral motor with driver and wireless transmission of power and information for autonomous subspindle drive,” IEEE Transaction Power Electronics, 15(1), pp.13–20.

Junji Hirai, Tae-Woong Kim, Atsuo Kawamura (1999) “Study on crosstalk in inductive transmission of power and information,” IEEE Transaction on Industrial Electronics, 46(6), pp. 1174–1182.

Mickel Budhia, John T. Boys, Grant A. Covic, et al.(2013) “Development of a single-sided flux magnetic coupler for electric vehicle IPT charging systems”, IEEE Transaction Power Electronics, 60(1), pp. 318–328.

Murat Yilmaz, Philip T. Krein (2013) “Review of battery charger topologies, charging power levels, and infrastructure for plug-in electric and hybrid vehicles”, IEEE Transaction Power Electronics, 28(5), pp.2151–2169.

Thierry Bieler, Marc Perrottet, Valérie Nguyen, et al.(2002) “Contactless power and information transmission,” IEEE Transactions Industry Applications, 38(5), pp. 1266-1272.

Wu Jiande, Zhao Chongwen, Lin Zhengyu, et al.(2015 ) “Wireless Power and Data Transfer via a Common Inductive Link Using Frequency Division Multiplexing”, IEEE Trans on Industrial electronics, 62(12), pp.7810-7820.