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A study of pulse shape suitable for power packet dispatching on power transmission line

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Abstract—Power packet dispatching system is proposed as one of the advanced power distribution systems, which is suitable for smart energy management. In the system, electric power is delivered by a packetized voltage formed as pulses. In this paper, the pulse shape suitable for power packet delivery is investigated. Here, two types of pulse waveforms are adopted, i.e., rectangular and gaussian. In the paper, we investigate the pulse distortion and propagation loss through power transmission line for these shapes. As results, it is found that the gaussian pulse can suppress more than the rectangular one.

1. Introduction

Recently, advance power distribution systems are proposed, which utilize gathered information for more effective power management. Highly developed Information and Communications Technologies (ICTs) are essential to realize these system, which realize the large information gathering, networked control, pattern analysis for consumers, etc. In addition, new wide-band gap power devices such as SiC and GaN which can manage high-power and reduce power loss starts to be produced. These power devices have a potential to realize significantly lower switching power loss, higher frequency switching, and higher power capacity with compared to Si devices. It is also undoubtedly essential to adopt these devices and to develop technologies for exhibiting their performance sufficiently in power management.

As one of the advanced power distribution systems, a power packet dispatching system has been proposed [1]. The concept was proposed in 1998 [2]. Recently developed ICT and wide-band gap power devices allow us to extend the concept and development for more practical use. In the power packet dispatching system, electric power is delivered as a pulse with information bits, i.e., a packetized form. The proposed power packet consists of a header, a payload, and a footer. Figure 1 shows the configuration of the power packet. The payload carries the power, which means electric current exists in the duration of payload. As an information tag, the header and footer are attached to the payload as the voltage waveform physically. The header includes the start signal, the address of source and load. The footer includes the mark to notify the end of packet.

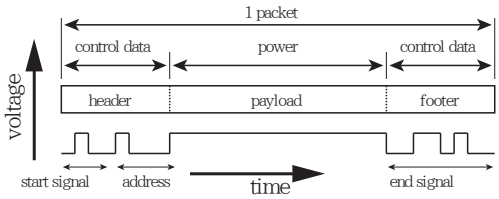

Figure 1: Structure of power packet.

In this paper, the pulse shape suitable for power delivery as a payload in a power packet is investigated. The propagation characteristics of power transmission line depends on the frequency [3, 4]. The power packet dispatching is proposed with a band of several hundred kHz to several MHz. Obviously, it is desired to suppress power loss in the power line. The pulse distortion should be also suppressed to prevent the damage to the apparatuses. The spectrum should be limited to prevent the interference. Therefore, the suitable pulse shape for power delivery should be selected. Here, we focus on the *rectangular* and *Gaussian* pulse shapes. The pulse shape in the prototype of power packet dispatching system is rectangular [1]. It is because the waveform of power packet has been obtained by the ON/OFF switching of connected dc power source. As is well known, the rectangular shape includes higher harmonic spectrum. On the other hand, the spectrum of Gaussian pulse is limited. Here, the pulse distortion and propagation loss for these pulse shapes are investigated numerically and experimentally.

2. Evaluation of pulse distortion and propagation loss on a power line

Figure 2 shows the schematic diagram of the system investigated here. This system consists of a pulse power source, a load, and an electrical cable with two wires. The

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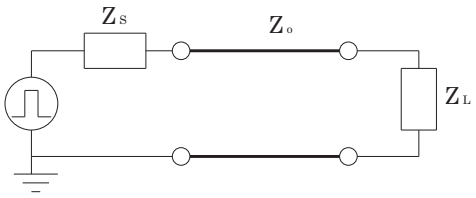

Figure 2: Schematic diagram of investigated system.

quantities Z_s, Z_0 and Z_L indicate the internal impedance of the source, the characteristic impedance of the line, and the impedance of load, respectively. As a power line, we adopt a 20 m VVF (Vinyl insulation, Vinyl sheath, Flat) electrical cable which is widely used for indoor power lines in Japan. Here, the channel model of this cable proposed in [3] is adopted, and the resistive load is used. We set $Z_s = Z_L = 50$ Ω. The quantity Z_0 is not the same with Z_s or Z_L, so that this system contains the impedance mismatching which causes the reflection of voltage or current.

Here, the switching frequency is set at 1 MHz, duty ratio $D = 0.5$. Figure 3 shows the waveforms at source and load for each pulse shape obtained by numerical simulations. The results show that Gaussian pulse can suppress the pulse distortion rather than rectangular one.

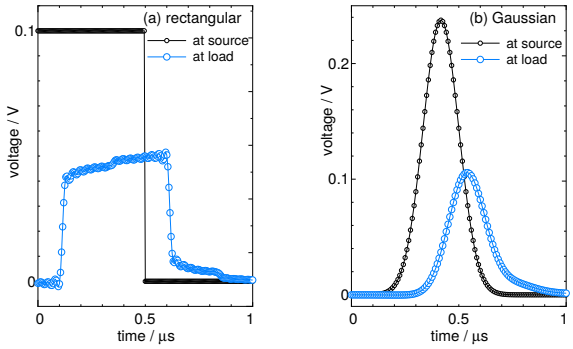

Figure 3: Voltage waveforms at power sources and load.

The efficiency of power delivery via a power line for each pulse shape is also evaluated. High efficiency implies low power loss. Note that, in this study, the switching loss is ignored. Figure 4 shows the efficiencies obtained by numerical simulations. In the figure, the one for sinusoidal wave, i.e. ac power delivery, is also depicted. From the results, it is found that the appropriate shape depends on frequency. Lower than 1 MHz, from the efficiency point of view, the Gaussian pulse is a bit better or almost the same with the rectangular pulse.

3. Conclusion and discussion

In this study, a suitable pulse shape for power delivery in power packet dispatching system was investigated. We evaluated the pulse distortion and power loss for the rectangular and Gaussian pulse shapes. The results show that

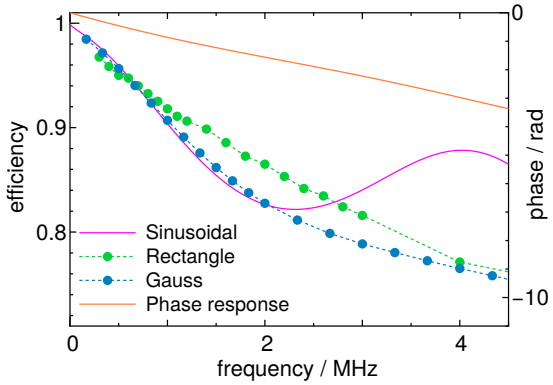

Figure 4: Efficiency of power delivery via VVF cable for each pulse shape.

the Gaussian shape can suppress the pulse distortion. As for the power loss in the power line, lower than 1 MHz, the Gaussian shape is a bit better than the rectangular one. From the viewpoint of interference noise, the Gaussian shape is better because its spectrum is limited.

Acknowledgments

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