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A Future Home Power System with Contactless Power Transmission Technologies

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Abstract

The traditional home power system is not suitable for the current complex household appliances for its low efficiency, which need a new power system. In this paper, a future home power system with contactless power transmission (CPT) technologies is proposed. Besides, with the consideration of using renewable power, a solar power hybrid generation system is integrated in the future power system. In addition, the distributed power system is introduced to the future power system instead of traditional centralized power method. The distributed power system is more stable and efficient. On the other hand, thanks to the CPT technologies, household appliances will be more safe and friendly by using CPT systems than before by eliminating cords and plugs. A simulation by PSIM DEMO version of the proposed future power system shows that the proposed concept is feasible. Furthermore, a CPT prototype has been fabricated to analyze the circuit characteristics of the CPT system. A novel concept of home power system is proposed, elaborated in detail and simulated by computer software.

Keywords*: CPT, renewable power, distributed power system, simulation*

1. Introduction

With the development of electronic technologies, the household electronic appliances are more and complex than before. Thus, the designing of power system has been sophisticated. The current home power system is not fit for many new electronic products, because it is inefficient and unsafe. So many power converters like AC/DC, DC/DC, AC/AC, and DC/AC are added before these electronic appliances to transfer power energy by different ways. Although by using high frequencies magnetic technologies, these power converter's volume and weight are decreasing, and power transferring efficiency is higher than linear power, which used power transistor to regular energy in linear area. However, those power converters almost work in pulse width modulation (PWM) mode which introduces serious electro-magnetic interference (EMI) and electro-magnetic compatibility (EMC) problems [1]. As a result, the utility power system has been polluted by harmonic current occurred by those power converters. Therefore, efforts should been make to filter this harmonic current by using a large amount of active filter or passive filter, which increases cost of utility power system [2, 3]. Furthermore, the serious problems of environment pollution and energy depletion call for a green power system.

Among the alternative energy sources, the solar energy generation is recognized as a clean and inexhaustible energy source. In this paper, a solar power hybrid home generation system is proposed. The structure of the proposed power system is distributing system, which is more stable and energy saving than traditional power system [4-6]. In addition, the household electronic appliances are power by the contactless power transmission (CPT) systems [7-10]. Not relying on the wires and plugs, the CPT system realizes electric power transmission by ways of electro-magnetic induction, radio frequency technology, electro-magnetic resonances, and microwave technology [11-13].

CPT system can transfer energy from power supply to load without directly contactless, the gap between the power supplies to the power consumer varies from several millimeters to ten more meters, and the power transferring is varied from several mW to more than 10kW. Such energy transfer has high security for children at home because no direct contact with eclectic and, it is also comfortable for user because of no plugs and cords.

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This paper is organized as following. In part 2, the concept of the proposed future home power system is expressed and discussed. Then, the detailed features of CPT system is analyzing in part 3. Finally, a simulation of proposed system is given, and some experiment results verify the feasibility of this system.

2. Proposed Power System

2.1. Traditional Power System

Figure 1 shows the traditional home power system. It is a centralized power system, in which the power flows on a bus line, then a variety of converters transform power to different forms to then to feed the loads.

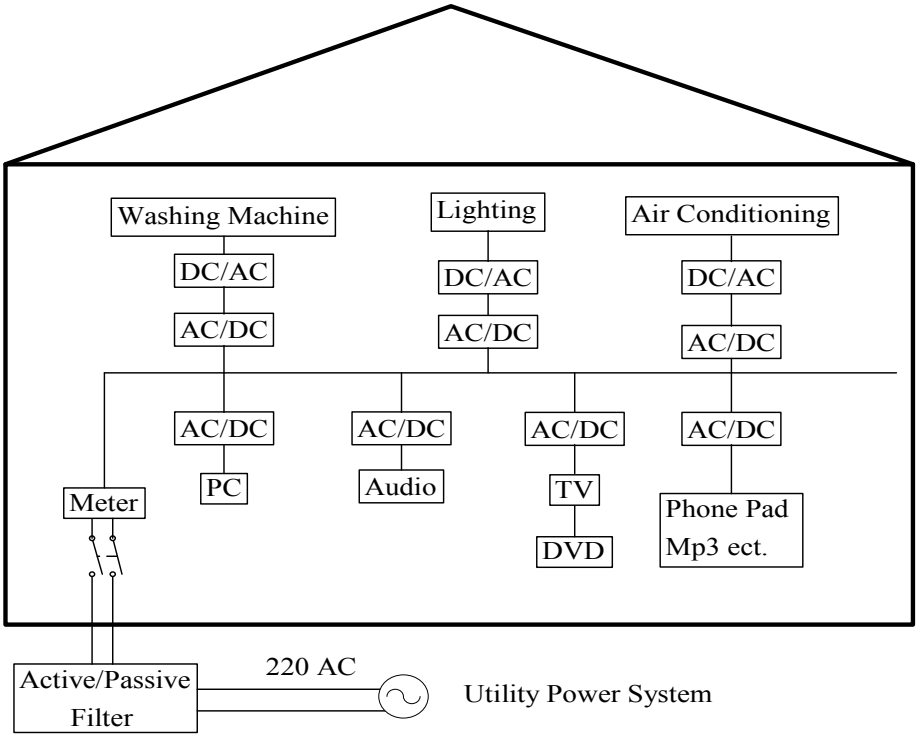
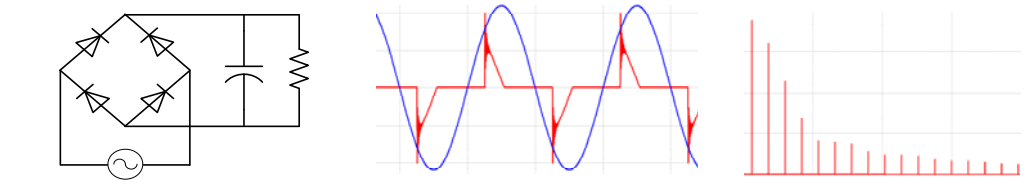


Figure 1. Traditional Home Power Supply System

With the advances of technologies, the age of incandescent has gone, and currently so many complex loads existed at every home. For example, washing machines and air conditions need a very high frequency ac current source to drive its motors; fluorescent lamps need a ballast which rectified the ac current to dc first, then invert it to a high frequency ac current at the frequency at 30 to 80kHz then to ignite lamps; the consumer electronics with growing amounts need a dc voltage to charge its battery. Therefore there are so many power convertors like AC/DC and DC/AC and all kinds of charger for consumer electronics in our home, which make the power system, become complicated and unstable. On the other hand, with the increasing of household appliances, the cords and plugs will be a great quantity which make rooms be disorderly and the plugs is unsafe for children.

Besides, many rectifiers are used to transfer the ac voltage sources to a dc voltage sources in a traditional power system. A very important rectifier-configuration for household appliances is the diode bridge rectifier. The circuits and waveforms of this rectifier are shown in Figure 2.



(a) Diode bridge rectifier (b) Waveforms (c) FFT of line current

Figure 2. Diode Bridge Rectifier

The discontinuous load current pulses cause pulsating line current as shown in Figure 2(b). The ripple in the capacitor voltage will be reduced with higher capacitance value, but which will cause narrow current pulses. Looking at Figure 2(c) which is the FFT (fast Fourier transform) formation of line current, the input current includes plenty of harmonics. Severe harmonic distortion of the current wave makes low PF and the line power factor (PF) can be define as:

$$PF = \frac{\text{Average power}}{\text{Supply rms voltage} \times \text{supply rms current}} = \frac{P_1}{V_s\sqrt{I_{s1}^2 + \sum_{n=1,2,3,\ldots}^{\infty} I_n^2}} \quad (1)$$

2.2. Proposed Power System

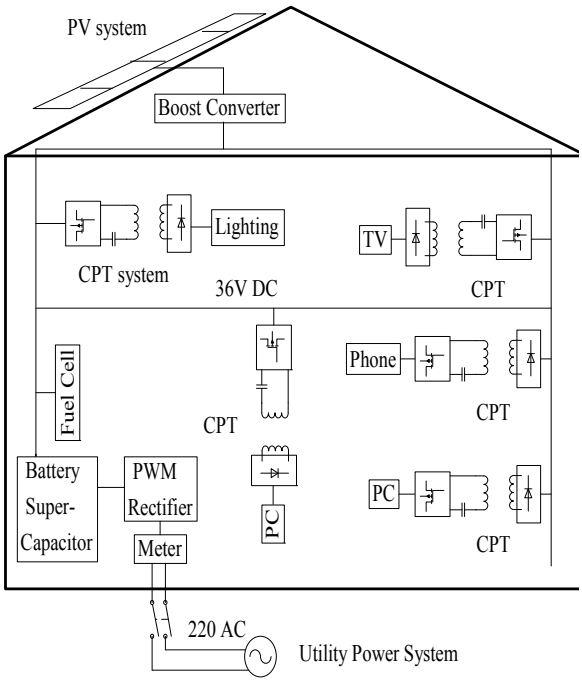
The proposed power system is shown in Figure 3. The highlight of this system is that a solar hybrid power system is included; the distributed power system is adopted; and the CPT system which acts as a resonant dc/dc converter is adapted to supply all kinds of household appliances.

In a normal solar power hybrid system, a boost type DC/DC converter is used to setup the input voltage. Then, an inverter is used to convert dc to 60 or 50Hz ac voltage to interface with power utility. At last the ac power is converted back to dc again by rectifiers to be interfaced with various household appliances. In a distributed power system, however, the solar energy is directly transferred to an energy tank consisting of super capacitors or batteries by a boost DC/DC converter. Afterwards the CPT systems acting as DC/DC converter transmit energy to all kinds of appliances with the contactless method. It is mention to note that the bus line voltage is 36V dc, which is safe for people, and no cords and plugs in our home, which make rooms be clean.

Distributed power system as shown in Figure 4, is been widely used for server and telecom power systems. In a distributed power system, power is processed by two stages. First stage converts ac input to 36V intermediate dc bus. This dc voltage is then distributed to the load side.

Many advantages of distributed power system prompted its use in these applications. First, with fast dropping on supply voltage of digital system, it is not realistic to deliver the power with such low voltage. Second, since the second stage (load converter) is placed very close to the load. The impact of parasitic is minimized. This converter can have very fast transient response to provide the fast current slew rate to the load. Third, for a distributed power system; front-end converter is independent of the load requirement. Each load converter is also independent to other load. This provides significant benefit for the fast changing system requirement. In the proposed distributed power system, the CPT system is used to act as the second power stage which performs the function of DC/DC conversion. Compared to the traditional DC/DC converter, CPT is a resonant converter which has the advantage of high frequency and high efficiency.

There is one thing worth to mention that in the proposed power system, the PWM rectifier is used. Compared to diode bridge-rectifier, it has the advantages of power flowing in two ways, unity power factor and low harmonic current in primary side [14-17].



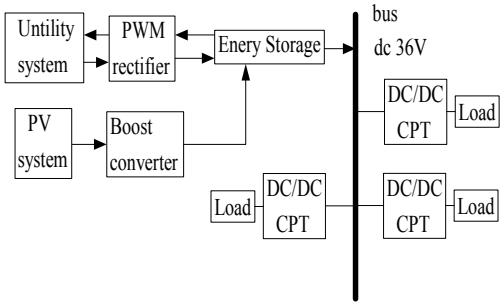


Figure 4. Distributed Power System for Home Power System

Figure 3. Future Home Power System

3. Structure of CPT System

A typical structure of the CPT system is shown in Figure 5, in which the contactless transformer is an essential element [18]. The primary coils of the contactless transformer transmit energy to the coils of secondary sides. It is note that there is a large gap between primary coils and secondary coils than traditional transformers.

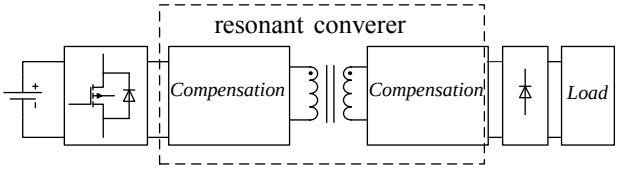


Figure 5. Schematic of the CPT System

Seen form Figure 5, the CPT system consists of a high frequency plus generator and a compensated net in series both on the primary and the secondary side, which acts as a resonant converter. Through the contactless transformer, the induced power of the secondary side is rectified to provide the load. Because of a large air gap existed between the primary coil and the secondary pick-up coil, the mutual coupling inductance within CPT systems is generally weak. As a result, the power efficiency transferred to the secondary side is relatively low. So a resonant tank circuits should be added into both the primary and secondary parts. Normally, the compensated net includes the *PP*, *PS*, *SP* and *SS*.

4. Simulations

Figure 6 shows the main circuit of the future home power system by using the simulation tool of PSIM DEMON version. The solar cell output voltage is boosted to constant 36VDC, and the energy is transferred to a super capacitor, which connected to the dc bus. In addition, a PWM rectifier is connected between the utility power system and the energy tank.

The PWM rectifier is a two way power flowing converter, so the home powering system can not only acquire energy from utility power system but also feeds back the solar energy to the utility power system.

Figure 7 shows the main waveforms of the future home power system. In Figure 7(a), the current and voltage waveforms of PMW rectifier are shown, which mean that the power factor of this system is almost at unity.

Figure 7(b) shows the features of the CPT system, the left is the primary side current, secondary side current, and the output dc voltage waveforms of this system. The right shows that the current of the contactless transformer, which mean that the CPT works as a resonant converter.

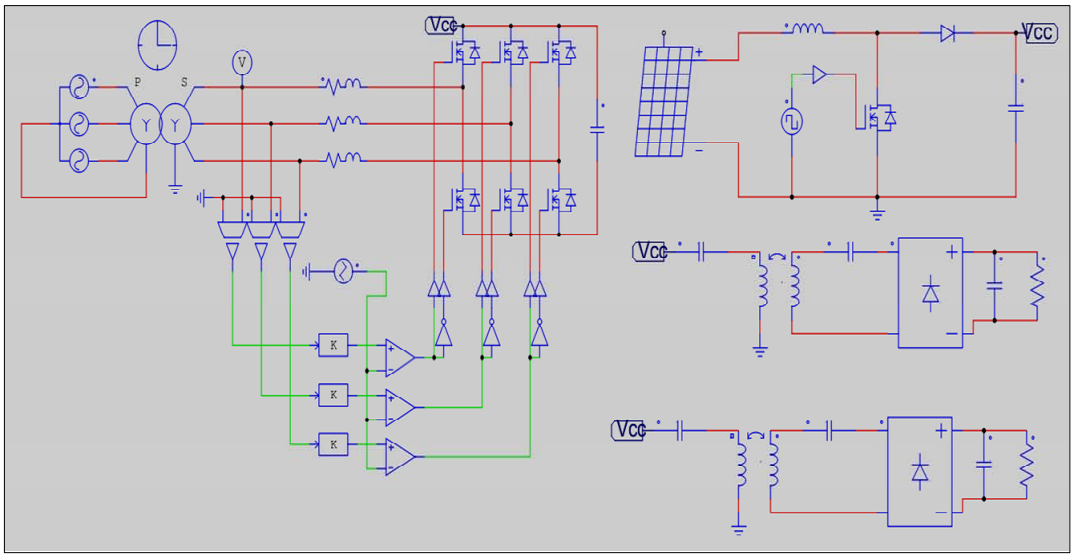
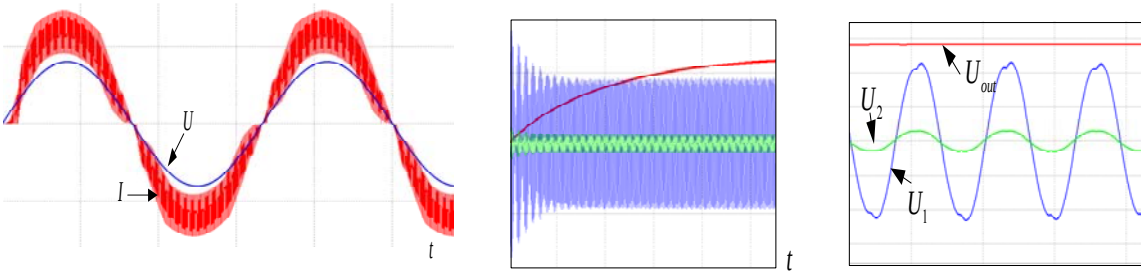


Figure 6. Model of Future Home Power System



(a) Waveforms of PWM rectifier

(b) Waveforms of CPT system

Figure 7. Waveforms of Future Home Power System

5. Experimental Results

Experimental results of a CPT prototype are used to verify the feasibility of this system. Table 1 shows the specifications and measured parameters of the CPT system. Figure 8 shows the experiment waveforms of CPT system, which is nearly corresponding with the simulation results.

Table 1. Parameters of Prototype Circuit

Parameters	Results
Input Voltage	12 V
Output Voltage	4.2V
Distance	5mm
Load	10.5Ω
Primary Coil Self-inductance	120μH
Secondary Coil self-inductance	10.8μH
Mutual Inductance	15.1μH
Primary Capacitor	333nF
Secondary Capacitor	370nF
Resonant Frequency	79.5kHz

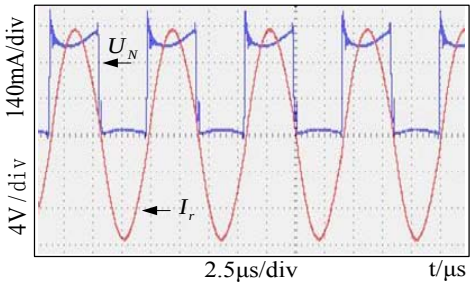


Figure 8. Experiment Waveforms of CPT System

6. Conclusion

In this paper, a future home power system is proposed. Compared with the traditional power system, the proposed system is green and efficient. Besides, it is safe and comfortable for user by using contactless power transmission technologies. The distributed power concept is introduced to future power system, and the characteristics and advantages of this method are explained in detail. On the other hand, characteristic analysis of the CPT systems is presented. Then, a simulation of the future home power system by PSIM DEMON VERSION is presented, which shows the main features of the proposed power system. Finally, some experiment results of the proposed power system validate the concept and feasibility of proposed future home power system.

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