Study of a New Time Transfer Method of Low Voltage Power Line

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Abstract—**Time transfer technology plays an important role in time science. With the development of communication, the time transfer technique has made significant evolving. The precision has got improved greatly and the application of the time and frequency has extended. The electric power network distribute widely, forming the general network for power energy transmitting and communication. The advantages of communication and time code transfer utilize the low voltage power line(LVPL) are: （1）the communication signal and power energy transmitting are using the same cable; (2) The devices are low in price and the techniques are applied widely. (3) The configuration of the device are simple, stable and convenient installment, and (4), persistent connection.**

This paper investigates the characteristic of the noise and attenuation of LVPL channel. To analyze the characteristic of signal transmitting in LVPL, the linear frequency modulation in spread spectrum communication is chosen according to the current techniques of the LVPL in data communication. A novelty method for LVPL time transfer is also presented. To demonstrate the performance of the new method, the experiments were conducted using two low voltage power lines with the lengths of 50 meters and 5 meters respectively, the results indicate that the corresponding time synchronization precision is less than 10 microseconds. The precision satisfy the general users and can be used to supply time synchronization service to scientific research, auto-control and power grid etc.

I. INTRODUCTION

With the rapid development of communication technology, the time transfer technique has made significant evolving. The precision has got improved greatly and the application of time has extended. At present, the time transfer techniques include long wave, shortwave, satellite, telephone and internet as well as the time transfer through TV signal. In recent years, time transfer by laser pulses and optical fiber, has become the focus of the newly research due to the development of communication.technology.

We have noticed that: the electric power network that distributes widely, is being used in communication applications, as a useable media, such as voice communication, data communication and internet network application. Low voltage power line as an existing media could be used in time transfering, time signal can be transmitted to some areas where other time service technology cannot arrive, for example, subways, underground constructions, the interior of large buildings, the surface of ocean, subaqueous vessel and so on. This paper investigates the characteristics of LVPL channel, and introduces how to transfer time through LVPL. To demonstrate the performance of the new method, the transfer experiments of time coding information were conducted using low voltage power lines under poor conditions and the results were analyzed.

II. CHARACTERTICS OF LVPL CHANNEL

A. *Characteristic of the Noise of LVPL Channel*

The noise and disturbance of LVPL channel is an important issue relating to quality and efficiency of the communication. Noise disturbance that mainly presents as randomicity, periodicity and time-viability, is the major obstacle in realizing the safe, reliable and high speed LVPL communication. The origins of LVPL noise are all kinds of electrical equipments, electromechanical products and the power line itself. The LVPL noise is not additive white gaussian noise, and its characteristic can probably change during a very short time. The LVPL noise falls into 5 categories in reference [1]: colored background noise, narrow band noise, periodic impulsive noise asynchronous to the mean frequency, periodic impulsive noise synchronous to the mean frequency, and asynchronous impulsive noise. The distribution of LPVL noise is closely related to the time, location, load and so on, but independent among noises. Generally speaking, the 5 categories can be put into two groups: background noise and impulsive noise. The previous two are background noise, and the others are impulsive noise, among which the asynchronous impulsive noise is independent from each other. Statistics in some literature show that the intensity of impulse disturbance can reach 40dBm at most [2], bringing about so deadly damage to the

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communication that the signals can not be recognized at the receive port.

B. *Characteristic of the Attenuation of Signals on LVPL*

Generally speaking, the greater the distance is, the greater the attenuation of the signals on LVPL will be, and the higher the frequency, the greater the attenuation. However, LVPL is a non-uniform distribution, the transfer line load on the LVPL network is very complicate and impedance of every node mismatches, for example, the impedance can change from 0.1Ω to 100Ω, ranging over 1000 time，in some parts it even appears so–called “impedance valley”, where signal is attenuated 80dB, as a result, the reflecting signal, standing wave and resonance etc may appear. The combination of all these complicated phenomonens, make the attenuation of signals more complicated.

It is referred in some literature that the attenuation characteristic of LVPL in radio frequency or higher frequency [3,4,5,6]. The result demonstrates that the load on the power network affects the attenuation of signals very much. Because the load changes via time, so the attenuation of signals changes via time on every given frequency spot. The attenuation of signals change can reach 20dB or higher. The different nodes in different building or the same building, or even the same node at the different time, the attenuation of signals difference is very great. Furthermore, the higher the frequency is, the greater the attenuation is, and the variety is not flat.

III. TIME TRANSFERRING METHOD ON LVPL

So far，spread spectrum and OFDM technology can be applied to overcome the uneven channel attenuation characteristic, great change of load and severe interference etc in power line carrier communications. The Electronic Industries Association suggest the Consumer Electronics Bus (CEBus) as the physical signal transmission standard in power line communications. The frequency range is probably from 50kHz to 500kHz. Chirp spread spectrum modulation is applied in CEBus. The chirp pulse signal can be described as follow.

$$s_1(t) = \mathrm{rect}(\frac{t}{T})\cos(\omega_0 t + \frac{1}{2}\mu t^2) \qquad (1)$$

and rectangle modulation function

$$\mathrm{rect}(\frac{t}{T}) = \begin{cases} 1 & \left|\frac{t}{T}\right| > 1/2 \\ 0 & \left|\frac{t}{T}\right| \le 1/2 \end{cases} \qquad (2)$$

Where ω_0 is work frequency,

B is chirp bandwidth,

T is rectangle modulation pulse timewidth,

μ is chirp slope，$\mu = 2\pi B/T$.

In CEBus, the frequency of the chirp pulse signal changes from 203kHz to 400kHz linearly in 19 periods, after then comes to 100kHz in 1 period , then become 203kHz again in 5 periods. The whole time is 100μs, which is called Unit Signal Time (UST). There will be different UST in different coding. When time signal is transferred through the LVPL, at first, the time information is coded, then the coded information is packed into data frame and sent to modem chip, finally the decoded time information reach receiver by anthoer modem chip. The modem chip offer the service of the data link layer and network service of physics layer, and are compatible with the CEBus standards. The chirp technology, which is similar to the CSMA/CD protocol, is applied in the modem chip.

The experiment is illustrated in figure 1. It is composed by a transmitter and a receiver, which are linked by the power line. The transmitter distributes the network address by MPU, codes the time information and packs the data which are modulated by modem chip. The modulated signal was sent to the coupling circuit and reaches the power line at last. The receiver gets parsing the network address and decoding after demodulate the signal on the power line, the time information is got.

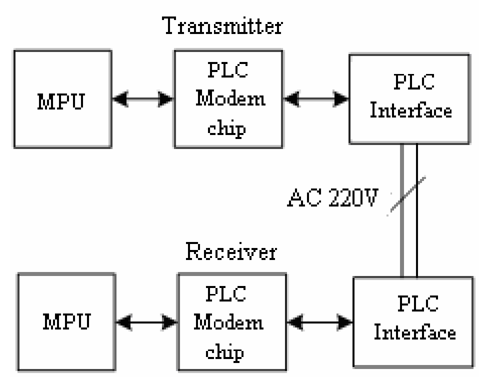

Fig.1. LVPL time transfer principle

IV. RESULT ANALYSIS

A. *Measurement of the time synchronization errors*

The time synchronization errors are usually measured by the time intervals counter, using the reference second pulse as the open signal and the measured second pulse as the close signal. When the measured second pulse lags the reference second pulse, the result showed on the time intervals counter is one second minus the absolute value of the time synchronization. The principium of the measurement is illustrated as figure 2.

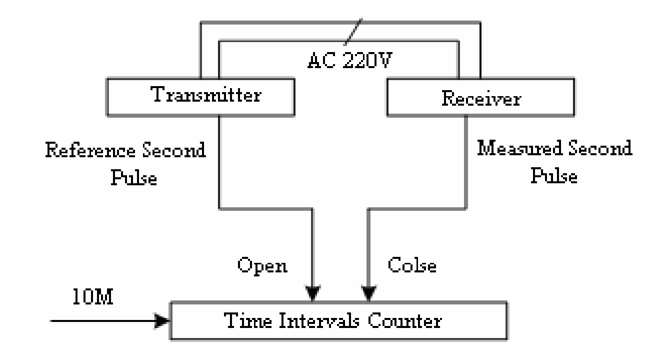

Fig.2. Time synchronization errors measurement principle

B. Analysis of the synchronization precision

The time signal is transferred through two low voltage power lines with the lengths of 50 meters and 5 meters. The time synchronization precision of the transmitter and the receiver is measured successively for an hour by a time interval counter., at each transfer distance 120 data were measured, The experimental data is as figure 4 and figure 5. Figure 4 is the synchronization result through the 5 meter-long power line. The measuring time is between 11am. and 12pm. And the maximum the synchronous error is 13.56ms , the average of the synchronous time transfer is 1.279ms ,and the standard variety is 6.124ms. Figure 5 is the synchronization result through the 50 meter-long power line. The time of the measurement is between 16pm and 17pm. And the maximum synchronous error is 14.42ms, the average of the synchronous time transfer is -3.237ms, and the standard variety is 3.801ms.

We deal with the data of the two different length power lines by deleting the outlier, and find no outlier in 5 meters LVPL synchronization result, and only a few outlier while the range is 50 meters. After deleting the outlier, According to figure 6, the max. of the synchronization error is 8.97ms, the average of the time transfer synchronization error is -3.243ms,and the standard variety is 2.85ms.

The time synchronization precision of the transmitter and the receiver is measured by manual work, so the measure intervals are not equal. Therefore Allen variety can not be used to describe the performance of the time transfer system. What we care about is not only the synchronization of the second signal, but also the transmission distance on the power line. As a rule, the instability of the time synchronization is presented by standard variety. From the figures we can noticed that the instability of the different distances is within 10ms, and the instability of the 50-meters' is better than the 5-meters'. It is probably because of different experiment time which shows that the power line is random and time-variable.

V. CONCLUSION

The low voltage power network is an open one with great attenuation, strong interferences, and complicated impedance variation when transferring signals .We still have to study on many technical problems if we want to transfer the time signals on the power line reliably and safely. In this paper, the chirp modulation technology is adopted to transfer and distribute time signal, the time synchronization instability is within 10ms, Also, we find in the experiment that the transmission on the LVPL is unstable. In order to improve the communication reliable and minish the error code rate in practical application, the transmission protocols and error codes are needed.

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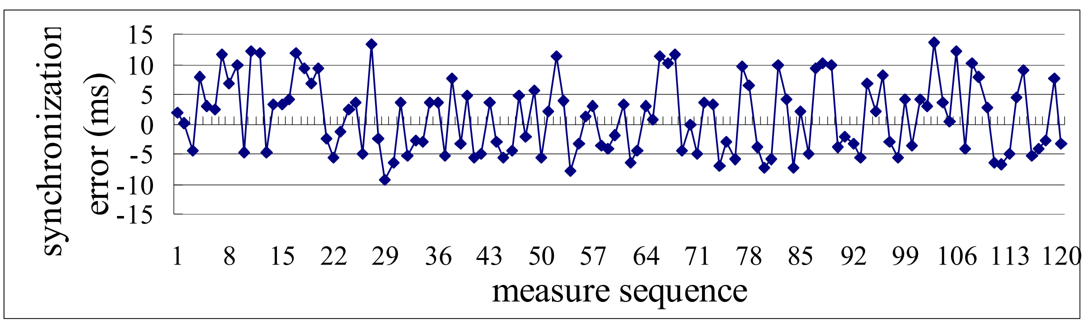

Fig.3. Time synchronization error when the distance is 5 meters

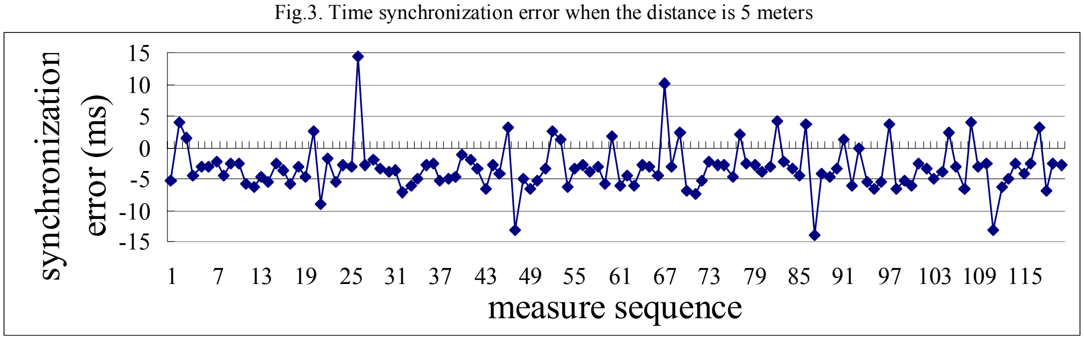

Fig.4. Time synchronization error when the distance is 50 meters

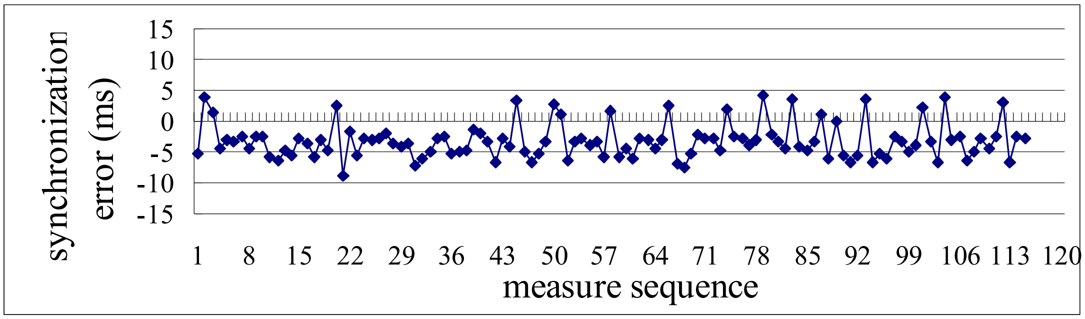

Fig.5. Time synchronization error after deleting the outlier when the distance is 50 meters