Application Analysis of GPS Used for Synchronization in Energy Information Networks

Ilia G. Iliev[1], Angel B. Colov[2], Rumen I. Arnaudov[3]

Abstract – **The work analyses the possibility of common GPS receivers' application for one point synchronization of the energy information measurement networks. The sources and types of errors derived in the time defining through GPS are investigated. The speed of variation of the informative quantities in the systems for telemeasurement, control and management analysis is made. An algorithm for synchronization with a common GPS receiver and time for seeing may be proposed on this base.**

Keywords – **GPS time synchronization, energy information networks.**

I. Introduction

There are many publications about GPS application in synchronization of data network, energy information networks, cellular communication networks (GSM, CDMA) etc. There are on the market many devices, for this purpose, working with determined time accuracy. There are also GPS receivers specially designed for uniform time synchronization with high accuracy for computer works, information-measurement system etc. Special algorithms for increasing the accuracy of the defined time are built-in their software (RIAM algorithms). The error is the order of dozens nanoseconds. This advantage is paid by the price. For synchronization purpose may be used receiving GPS signals and synchronization from one point either, or distributed, differential synchronization [1,3].

The work analyses the possibility of common GPS receivers application for one point synchronization of the energy information measurement networks. The sources and types of errors derived in the time defining through GPS, are investigated. The speed of variation of the informative quantities in the systems for telemeasurement, control and management analysis is made. The admissible error of quantization time is determined, from where the admissible time error for registration is computed. An algorithm for synchronization with a common GPS receiver and time for – seeing may be proposed on this base.

[1]Ilia Georgiev Iliev, Dept. of Radiotechnic in Faculty of Communications and Communication Technologies in TU – Sofia, E-mail: igiliev@vmei.acad.bg

[2]Angel Belchev Colov, Dept. of Radiotechnic in Faculty of Communications and Communication Technologies in TU – Sofia, E-mail: abc@vmei.acad.bg

[3]Rumen Ivanov Arnaudov, Dept. of Radiotechnic in Faculty of Communications and Communication Technologies in TU – Sofia, E-mail: ra@vmei.acad.bg

II. Common GPS Reciever Synchronization Error Analysis

All GPS satellites have internal atom clocks (cesium or rubidium frequency standard) on the board.

They are synchronized with the system time of GPS by the system control segment. The clock deviation is transmitted as a navigation message.

Transmitted data for the time of GPS is computed in relating to the zero time of the system (05.01.1980 00:00:00.0000h). It is intersecting that the system time of GPS is Universal Time Coordinated and the difference from synchronization is taken into account as a correction in the navigation message with accuracy of 90 ns.

In the common GPS receiver is generated the same pseudo-random sequence of C/A code (Gold code), transmitted by a satellite in the line of sight. This sequence is synchronized with the output clock signal, obtained every one second – 1PPS. The cross correlation function (CCF) between it and the received code (C/A) is computed in the receiver. The CCF has a maximum in a moment corresponding to the time difference Δt between the receiver and satellite clock signals. The spectrum of the received signal is unspread, by the recovered pseudo random sequence in the receiver. As a result is derived the navigation message. The receiver adjusts its own clock generator and synchronizes it with the given moment from the navigation message. Thus the signal 1PPS is synchronized with the data frame beginning of the navigation message. Because of many factors, the receiver clock generator has a time delay of reader of ms in relevance with the satellite generator. The receiver computes the difference between both clock signals in the following way:

$$dt' = \Delta t - (L/c + dDp + dI + dT) - dD + dC \;, \quad (1)$$

where Δt – time deviation between the receiver and satellite clock signals, L – geometric distance between satellite and GPS receiver antenna, c – light velocity, dDp – Doppler effect deviation, dI – time delay from the ionospheric propagation, dD – time delay in the receiver, dC deviation of the clock signals of the receiver in relevance of GPS time.

With a single GPS receiver, the time is obtained after accomplishing the necessary computations in formula (1). The time for accomplishing the complete cycle of computation in the initial starting of the receiver is of order of 10 minutes and depends on the type of the receiver and the manufacturer. The time synchronization is separated in the following way:

1. The receiver synchronizes its own clock signal 1PPS

with the first bit of the navigation message;

2. Multiple (from 6 to 15 times) times per a second is computed the cross correlation between the received and self generated pseudo random code and average the result;
3. The mean quantity is corrected with all the rest time delay corrections (formula (1));
4. Finding the mean quantity is doing again, but within the frame work of 13 minutes of the obtained time deviation between the receiver and the satellite cock generators;
5. It is corrected the clock signal 1PSS with the obtained deviation.

This method for synchronization is simple and does not require additional data, besides the data obtained by the GPS receiver.

The basic error sources in the synchronization, according to formula (1), and divided by the feature of its source are given in Table 1.

Table 1. Error per second

No	Error source (1s)	C/A code	P code
	Satellite Errors		
1.	Satellite atom clock	10 ns	10 ns
2.	Error in the satellite coordinates	15 ns	15 ns
	Propagation medium Errors		
3.	Ionospheric propagation Effects	15 ns	7.5 ns
4.	Tropospheric propagation Effects	3.0 ns	3.0 ns
5.	Multipath propagation Effects	10 ns	10 ns
	Receiver Errors		
6.	Error in the receiver antenna coordinates	33 ns	33 ns
7.	Time delay in the receiver hardware	5.0 ns	5.0 ns
8.	Time delay of the beginning of the software processing in the receiver	5.0 ns	5.0 ns
9.	Receiver noise	50.0 ns	5.0 ns
	Total error	65 ns	40 ns

The errors in setting the receiver and satellite coordinates and Doppler effect errors influence on the distance L computation. Besides, the time synchronization error depends on the inaccuracy of the receiver antenna coordinates and quantity of received and averaged data. For example, if the inaccuracy of the receiver position is of order 10 m, the mean error is about 40-65 ns for a period of 13 s. If a measurement is carried out for some days, the error decreases to some tenths of the nanosecond.

The synchronization error with P code receivers (military and other with special application) is less than using receiver that work with the C/A code. The reason for this, is that receivers with P code measure the signal time delay in two frequency band width and after a special processing decrease the ionospheric and tropospheric propagation error and the noise level in them is about 10 time less.

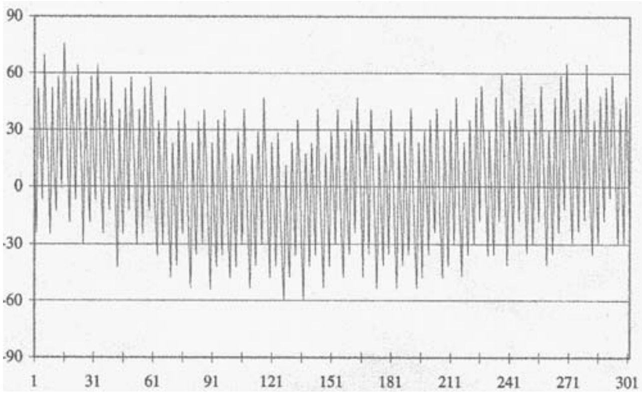

Fig. 1.

Fig. 1 shows the error obtained in the comparison between common GPS receiver and an atom clock.

It is obvious, that the time error obtained by the system is of order of 60-500 ns and depends on the work regime of the receiver. Easy built-in and implementation and easy support of the GPS receiver make it an unique device for providing exact uniform time, synchronized with the World Universe Time. In addition GPS requires less investment by the consumer for achieving the purpose in comparison with other synchronization methods.

III. Applicability of GPS in Telecontrol Power Electrical System Synchronization

A. *Processes and Necessity*

Fig. 2 shows some of the general system automatics in power electrical system (PES), in which the synchronization necessity (work in an uniform time) of the automatic control system (ACS) is of primary importance.

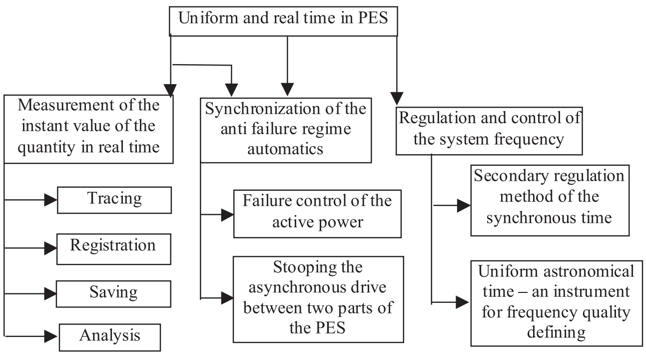

Fig. 2.

B. *Increasing the Stability of the Electrical Transmission Lines*

The accurate defining of the phase difference δ between the voltages of two PES parts (Fig. 3), connected by a distribution line W, may be done only in the uniform time of measurement in both parts.

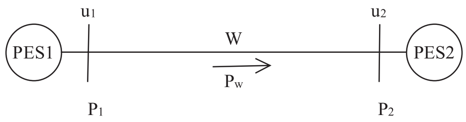

Fig. 3.

The value of the angle δ or its derivate may be used as direct criterion, describing the electrotransmission line stability. The active power in distribution line is:

$$P_w = (U_1 U_2 / X_s) \sin\delta \; , \tag{2}$$

where $X_\Sigma = X_1 + X_W + X_2$ is the sum reactance. At the phase $\delta = \pi/2$ [rad], maximum power P_W is carried and the electrotransmission line is on the border of the stability work. For ensuring the required static stability reserve, that must be not less than 20% in normal work, it is not allowed to carry power higher than the allowed Pa:

$$Pa = P\max/(1+k) \; . \tag{3}$$

k is the given reserve coefficient of static stability and it may be decreased in some cases. It is in limits of 0.05 – 0.2. The stable work is saved when the condition is true:

$$P_W < Pa \; . \tag{4}$$

The anti failure automatic for control of the active power, whose functions may be done by ACS, uses condition (4) on the base of the measured voltages and the angle δ.

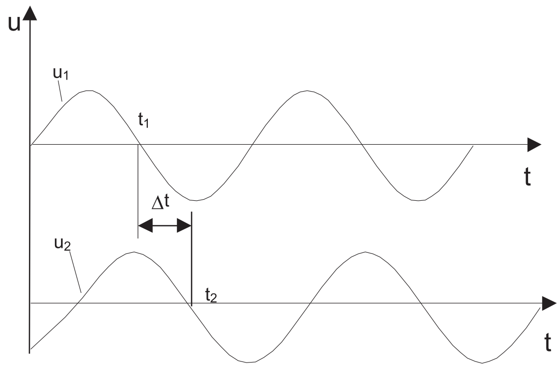

Fig. 4. u_1 and u_2 voltages and the phase difference

Consequently, the ACS may be used as an automation for stopping the asynchronous drive between the two parts. The asynchronous regime between two parallel working parts of PES characterizes with periodic three-phase deviating the phase of the voltage, the current and of the active power. The impedance is changing smoothly. The phase difference δ between the voltages U_1 and U_2 in a normal synchronous regime and constant angle velocity ω_n, is:

$$\delta = \arcsin\left(P_W \frac{X_\Sigma}{U_1 U_2}\right) . \tag{5}$$

In the asynchronous regime, the vectors of U_1 and U_2 are rotating with deferent frequencies $\omega_1 \neq \omega_2$. The angle δ is changing periodically from 0 to 2π [rad] with a slipping frequency $\omega_s = \omega_2 - \omega_1$. The deep degrading of the voltage, the flowing of big currents, commensurable with or bigger than the currents of short-circuit and the variation of the active power in asynchronous regime, are serious disturbances, dangerous for the equipment. The asynchronous regime limited to 2-3 cycles and its duration is not longer than 15 - 20 s. For this time the synchronous work must be recovered or the systems must be disconnected. The main indications of the asynchronous regime are the availability of ω_1 and ω_2 and the periodic variation of the angle δ. Based on this, ACS may be programmed in such way that the defensible object is disconnected and the asynchronous drive is stopped.

Another possible application of the uniform astronomic time in PES is for forming the difference:

$$\Delta t = t - t_a = \int_0^{ta} \frac{\Delta f}{f_n} dt \; , \tag{6}$$

where: t synchronous time – counting from the synchronous electrical clock; t astronomic time; Δf the system frequency deviation f from nominal value f_n.

The admissible difference between the synchronous and the astronomic time is ± 2 min. The electrical clocks, that count the synchronous time, are derived by a synchronous motor and the measured time depends on the frequency of the PES. It is an integral index for frequency deviation from the nominal and through it is made an accurate estimation for the frequency support. The value Δt_c may be used as an input value in the frequency regulators of rotating in the electric power-station.

C. *General Criteria*

Regardless of its functions, ACS are scanning and processing in real time many quantities with various features. In this case the electrical signals with industrial frequency are critical. Their registration and storing is made synchronous with the internal clock of the ACS.

The uniform time makes possible the comparison between the instant values of the electrical quantities of the remote energy objects. The values, transmitted through the communication channels, are connected with concrete time values and may be compared with the corresponding values, recorded in the same time in the other object recipient.

For fast developing processes (short-circuits) and for the most transient processes, typical time constant of the aperiodic component is 50 – 100 ms, and the order of the informative harmonics, necessary for analysis and control is maximum 15 (750 Hz for the 50 Hz frequency of the basic harmonic).

In the comparative analysis of fast developing failures at remote objects, without synchronization of the registration time of the quantities, the error may approach 100%. By the standard way of analog signal measurement- microcontroller with build-in 10 bit, 8-channel ADC, one cycle of conversion takes 26 clock times. For a typical clock frequency of the microcontroller of 2 MHz (clock generator 16 MHz), the necessary time for a sample is about 18μs. It is included the time for selection the measurement channel and the time for controlling the Sample/Hold, either.

The microcontroller clock generator guarantees the necessary stability and accuracy of the internal base time pulses. A difficulty is raised by the requirement for a synchronous work of set controllers, which are distributed irregularly on the PES area. Besides this, for guaranteeing reliability of the registered events, the error in giving the uniform time at the PES objects, must not be greater than the necessary time for scanning of the quantities instant values.

Usually the clock quartz generators have relative short-time instability of the order of 10^{-4} – 10^{-5}. Another important parameter – the long-term instability of the frequency depends on a row of parameters, schematics, constructive decision, operational environment, adjustment accuracy etc. The researches chow, that the quartz generators, used in the microcontrollers, have comparatively big relative long-term instability of the frequency. The main reasons are the accuracy of the initial adjustment and the different operation environment. So that it can not rely only on internal clock quartz generators for achieving the necessary accuracy in the measurement system (or control system) working in the uniform time.

IV. Conclusion

The accuracy of the described means for giving the uniform time (synchronization) with GPS is satisfactory for the PES needs. It is necessary to analyze the possibilities for creating an algorithm for processing and simplification of the informative package from GPS, so that it takes minimum time of the microcontoller for synchronization, without any lost of information about the controlled object condition.

The optimal variant is a combination of hardware and software mean for task distribution in ACS.

References

[1] Sangeeta Nagrare, M. R. Sivaraman, Synchronisation for WAAS over Indian Airspace using GPS, The Asian GPS Conference 29-30 October 2001, New Delhi.

[2] Pratap Misra, Brian P. Burke, Michael M. Pratt, GPS Performance in Navigation, Proceedings of the IEEE, Vol. 87, No. 1, January 1999

[3] Enge, P.K. Global positioning systems: signals, measurements, and performance, *International J. Wireless Information Networks* 1(2)

[4] John F. Hauer, Jeff E. Dagle, Pacific Northwest National Laboratory, White Paper on Review of Recent Reliability Issues and System Events, Transmission Reliability Program U.S. Department of Energy

[5] G. Gross (UIUC), A. Bose (WSU), C. DeMarco (UWM), M. Pai (UIUC), J. Thorp (Cornell U) and P. Varaiya (UCB) PSERC, White Paper on Real-Time Security Monitoring and Control of Power Systems, Transmission Reliability Program U.S. Department of Energy

[6] H. Quinot, H. Bourlès, T. Margotin, “Robust Coordinated AVR+PSS for damping large scale power systems ”, article accepted for publication in the IEEE PES Transaction