An Algorithm for GPS Synchronized Power System Controllers and Information Networks

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

Abstract – The paper discusses an algorithm for synchronization of energy information measurement systems using GPS. The algorithm computes a future moment of time used for synchronization of the measurement controllers in the information network. The results derived by prediction are sufficient for the synchronization and measurement of Power Energy Systems (PES) necessities.

Keywords - GPS time synchronization, energy information networks.

I. Introduction

There are many publications about the application of GPS for network synchronization, synchronization of energy 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 networks, 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, it may be used reception of GPS signals and synchronization from one point either, or distributed, differential synchronization [1,3].

[7] discusses the applicability of general GPS receivers for synchronization in one point of Energy Information Measurement Networks. The sources and the types of errors received in the determination of the time through GPS are analyzed. Based on the analysis, the rate of variation of the informative quantities in the system for telemeasurement, control and management is discussed. The admissible quantization time error and the admissible time error for registration are determined. Based on these, the paper proposes an algorithm for synchronization with general GPS receiver and time prediction. The time determination error obtained by a general GPS receiver is not greater than 60 ms and taking into account the variation rate of the informative quantities in the system for telemeasurement, control and management in the PES we may conclude that the precision of the described in [7] methods for determination of the unified time (synchronization) with GPS is sufficient for the PES necessities.

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II. Characteristics of The Synchronization Signals and Data From GPS

GPS receiver is able to transmit information about the coordinates and the time in a message every one second. This message is transmitted over standard interface RS232 with pre-defined data rate. For receiving the full information, minimum 10ms are necessary. The signal time diagram and the data packages, received by the GPS receiver are shown on Fig.1. Besides this, the received data is time delayed compared to the time reference 1PPS.The signal 1PPS is a time reference, transmitted every 1 second, and defines the received data validity.

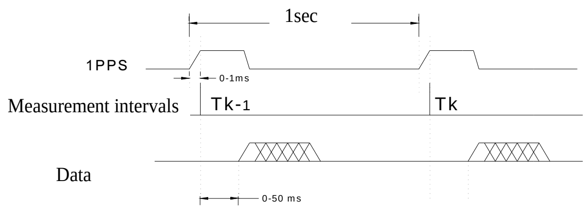

Fig.1

This signal has the following parameters:

- Rising time of the signal is approximately (20÷30) ns;
- The duration of the logical “1” of the impulse is approximately 200ms±1ms;
- Precision in self mode <130ns;
- Precision in hold mode <50ns.

The data is received for a time not greater than 50ms after this signal. This delay results in inaccuracy in determination of the time and it is comparative to the duration of the processes in PES and its influence must be removed. The time precision must be sufficient to be used for measurement of the values of the fast variance analog quantities. If they are measured and scanned by 10-bit ADC, the smallest conversion time is 36μs. Consequently the precision of the obtained time by GPS must be considered with the conversion time. For overcoming the data time delay of 10ms towards the reference time and the time adjustment of every measurement controller, it is necessary to use additional specialized communication controller included to the multi-computer system for control in real time (Fig.2).

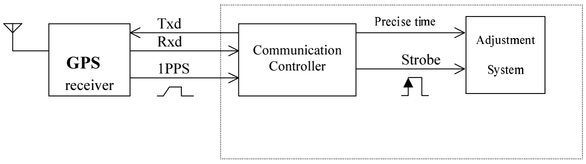

Fig.2

The functions of the communication controller of the system are widened with the algorithms for analysis and prediction of the real time. The prediction purpose is to obtain data every 1 second for the time from the GPS receiver and the computed prediction for the current second. The time calculation by the communication controller is based on the full data from the status message of the receiver. Data like: availability and number of the tracked satellites, Doppler frequency shift, a correction for the fraction part of the second (there is a time delay in the path from the satellite to the Earth), are necessary for authenticity of the computed time. The data for the fraction of the second is transmitted in 2 bytes in I/O message. The value formed from these bytes increases monotonically with rate dependant on every GPS receiver and the current data for correction from satellite. When this value becomes maximum it zeroes and start increasing again. The physical explanation in the increasing is that the value formed by this data is a liner increasing function with overloading constraint or ramp function *R(t)*. (Fig.3)

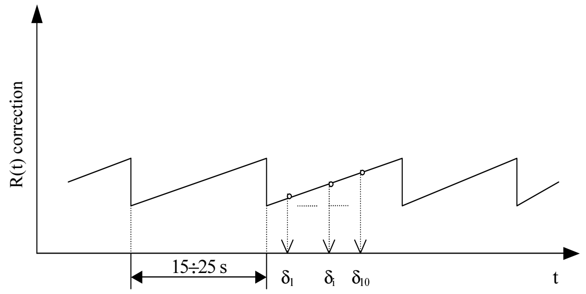

Fig.3

The time of variance form 0 to maximum value of this function is different for the different GPS receivers even though they are in one and the same point. This time varies from 15 to 25 s. Fig.4 shows the error variation, formed by the difference between the times obtained by the GPS receiver and stationary standard atom clock.

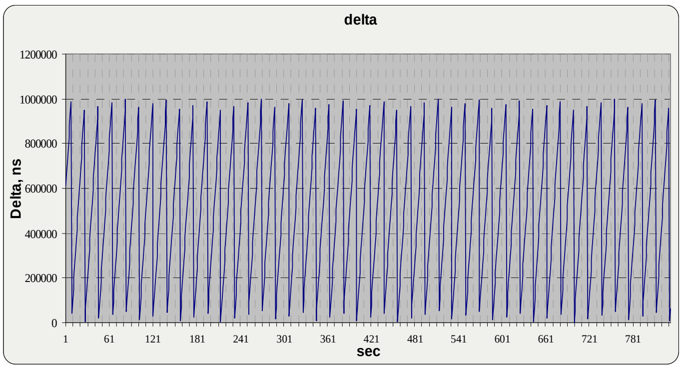

Fig.4

To be able to predict the time, the communication controller must carry out a synchronization signal toward the system that needs the precision time, based on the ramp function data. In the moment of transmitting the synchronization strobe impulse (Fig.5) it is transmitting the synchronized precise time.

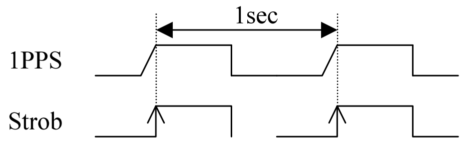

Fig.5

It is a value that is received by every controller by the GPS receiver with zero time of data processing.

Fig.6 shows the value variation derived by two bytes, carrying the information about the fraction part of the second.

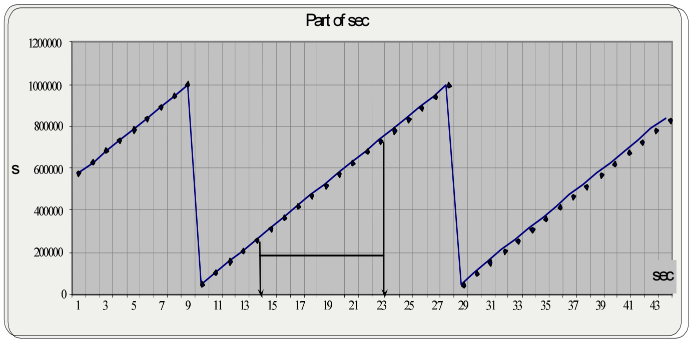

Fig.6

III. Time Prediction Algorithm by GPS Receiver Measurement

The paper proposes the following time prediction algorithm:

1. Scanning the moment from overloading to zero of the ramp function;
2. Searching 10 contiguous function values, where the last one has positive derivative (interval of constant increasing of the function);
3. Omitting the first and the last value;
4. Calculating the prediction correction based on the remaining 8 values:

$$\delta_{cp.} = \frac{1}{8}.\sum_{i=1}^{8} \delta_i \qquad (1)$$

5. Adding the computed prediction to the time data from the GPS receiver in the next moment;

The corrected data is transmitted to the synchronized system. The main system controller zeroes the internal free-running timer in the moment of receiving the precision time by the communication controller. The internal timer accumulates the time value automatically for 1 or more seconds. This time is necessary for the registration of the measured quantities for one period of comparison of the time. It is supposed that for a small period of time the internal quartz oscillator (the clock oscillator of the measurement controller) has minimal frequency deviation.

The predicted time, formed by δ_{cp}, changes only when the number of the tracked satellites by the GPS receiver is changed. In this case, the prediction controller makes a new measurement in an interval of 15 to 22 s to form a new δ_{cp}. During this interval, the time is transmitted with the old prediction. Fig.7 shows the program algorithm for synchronization.

IV. MEASUREMENT DATA

Fig.8 shows the deviation of the absolute error between the predicted and the real time obtained by the GPS receiver. The predicted time is computed following the previously described algorithm.

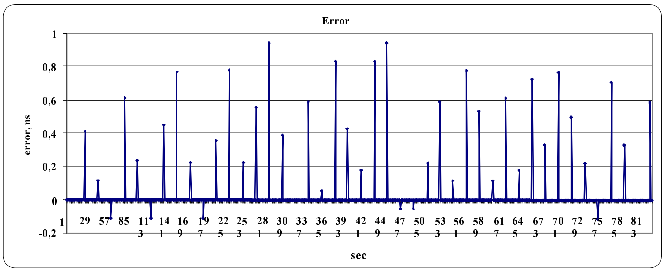

Fig.8

The root-mean square (RMS) error of the computed absolute error is not greater than 0.318ns. Fig.9 shows the absolute error deviation for the changing the number of the tracked satellites.

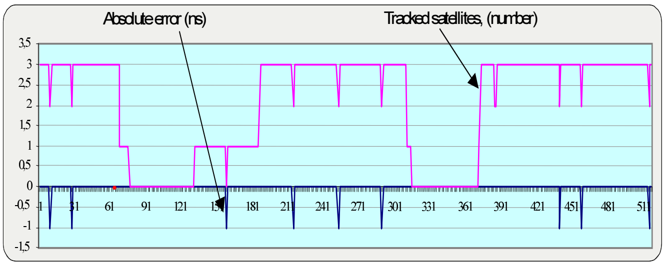

Fig.9

According to the measured data we may conclude that the time prediction algorithm works with sufficient error. The maximum deviation of the predicted results is not greater than 1ns and the RMS error is not greater than 0.318ns. When the number of the tracked satellites is changed the error is of the order of 1ns.

V. CONCLUSION

The application of general GPS receiver (without specialized built-in function for increasing the time precision) is real the synchronization of information measurement in the Systems in the Energy Systems the only drawback of the method is that the precision time data is delayed towards the time reference computed by the GPS receiver correlator. Consequently this signal 1PPS cannot be used for direct time correction of the separate measurement controller. The proposed algorithm removes this drawback by prediction of the time value in a future moment of appearing the signal 1PPS. In this way first data for the unified time is loaded in the measurement controllers and after receiving the reference signal they are actualized as real unified time. The measurement data for prediction error is satisfactory and the error value is not greater than 1ns, including the case of changing the number of the tracked satellites.

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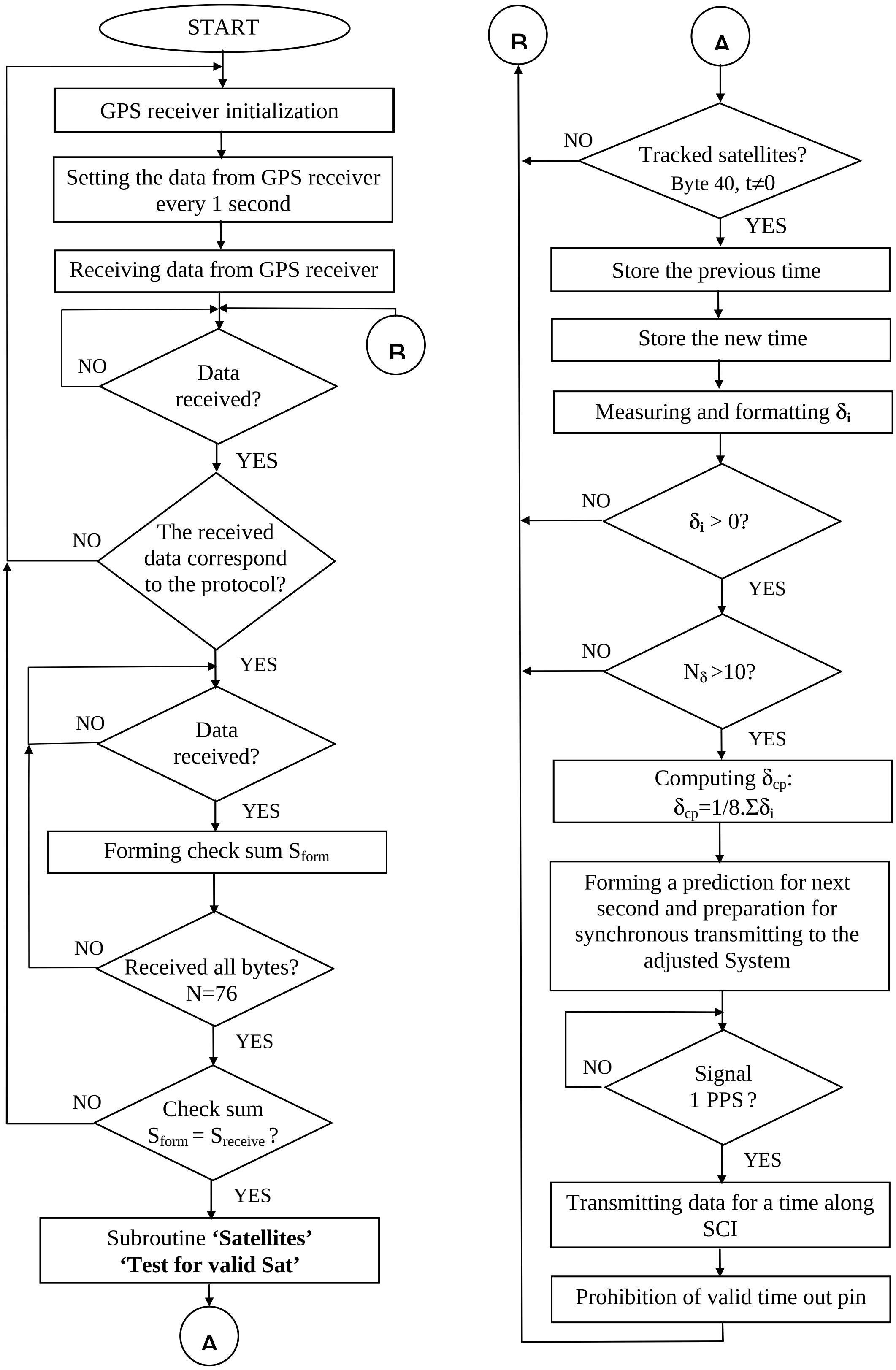
START
GPS receiver initialization
Setting the data from GPS receiver every 1 second
Receiving data from GPS receiver
Data received?
NO
YES
The received data correspond to the protocol?
NO
YES
Data received?
NO
YES
Forming check sum S_{form}
Received all bytes? N=76
NO
YES
Check sum $S_{form} = S_{receive}$?
NO
YES
Subroutine **'Satellites' 'Test for valid Sat'**
A
R
R
A
Tracked satellites? Byte 40, t≠0
NO
YES
Store the previous time
Store the new time
Measuring and formatting δ_i
$\delta_i > 0$?
NO
YES
$N_\delta > 10$?
NO
YES
Computing δ_{cp}: $\delta_{cp}=1/8.\Sigma\delta_i$
Forming a prediction for next second and preparation for synchronous transmitting to the adjusted System
Signal 1 PPS ?
NO
YES
Transmitting data for a time along SCI
Prohibition of valid time out pin
Fig.7