Time Synchronization Method for SOE Events of Fully Digitalized Systems in Nuclear Power Plants

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1. Introduction

In order to analyze prime causes of trouble after events and trips occur, SOE (Sequence of Events) system has been adopted in nuclear power plants to acquire the sequential information along where and when events or trips take place.

In this paper, we conceptually propose a time synchronization method of SOE events of fully digitalized systems under requirement that any data from safety systems to non-safety systems shall not be sent.

2. SOE System Structure

SOE system is divided into two parts. In Figure 1, time server has a role to sequence SOE events provided through data network from A, B system. A, B system generating SOE events provide time server with time information (for example, SOE event occurrence time, Local time when SOE event data are transmitted) required to synchronize SOE event occurrence time.

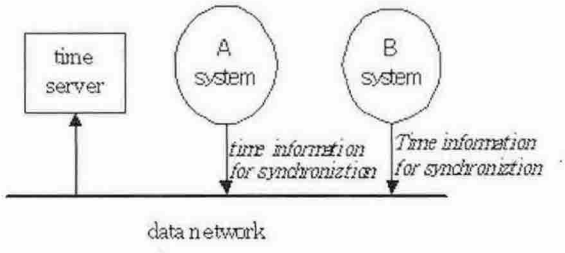

Figure 1. SOE system structure

SOE system has restraints below.

- The systems that need to synchronize times of SOE events have their own local clocks. They need not to receive information from time server to synchronize their own local clocks.
- To synchronize occurrence time of a SOE event, A system and B system must send time information to time server in one-directional way as in Figure 1.

In fact, SOE system has requirement that any data from safety systems to non-safety systems shall not be sent. The time server is a non-safety system and A system and B system are non-safety or safety systems.

3. Time Synchronization Concept

Elapsed time intervals until SOE events arrive at time server since SOE events have occurred can be divided into two as follows.

- $T_{(le,\ event)}$: Elapsed time since a SOE *event* has occurred in a local system.
- $T_{(dn,\ event)}$: Elapsed time of an *event* in data network

3.1 Time Synchronization Equation

Now, we can calculate synchronized time, $T_{(sync,\ event)}$ of a SOE event in time server :

$$T_{(sync,\ event)} = T_{(arrival,\ event)} - (T_{(le,\ event)} + T_{(dn,\ event)})$$

Equation (1)

In Figure 2, we can easily calculate $T_{(le,\ event)}$, $T_{(dn,\ event)}$ respectively :

$$T_{(le,\ event)} = T_{(local,\ event)} - T_{(occurrence,\ event)}$$

Equation (2)

$$T_{(dn,\ event)} = T_{(transmission,\ event)} + T_{(delay,\ event)}$$

Equation (3)

By replacing $T_{(le,\ event)}$, $T_{(dn,\ event)}$ with (2), (3) respectively, finally we can get $T_{(sync\ ,\ event)}$:

$$T_{(sync,\ event)} = T_{(arrival,\ event)} - [(T_{(local,\ event)} - T_{(occurrence,\ event)}) + (T_{(transmission,\ event)} + T_{(delay,\ event)})]$$

Equation (4)

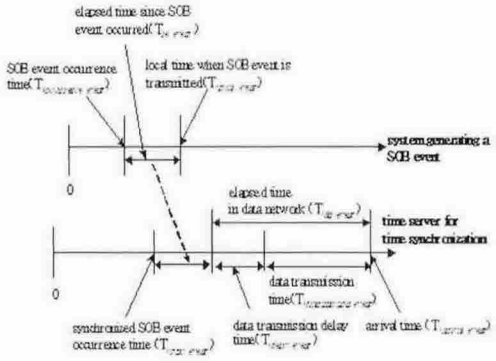

Figure 2. time synchronization conceptual diagram

3.2 Example

We suppose that A system is 5 ms later than B system and A system and B system have conditions below.

- Data transmission cycle

A system : 45 ms, B system : 50 ms

- Data occurrence time
  A system : 10 ms, B system : 10 ms
- Data transmission time
  A system : 5 ms, B system : 5 ms
- Data transmission delay time
  A system : 0.001 ms, B system : 0.004 ms
- Arrival time to Time Server
  A system : 1000 ms, B system : 1000 ms

By equation (4), we can calculate synchronized times $T_{(sync,\ SOE\ A\ event)}$, $T_{(sync,\ SOE\ B\ event)}$ in time server of SOE A event, SOE B event occurred in A system and B system.

- Synchronized time, $T_{(sync,\ SOE\ A\ event)}$ of $T_{(occurrence,\ SOE\ A\ event)}$ of SOE A event in time server

$$T_{(sync,\ SOE\ A\ event)} = 1000 - [(45-10) + (5+0.001)]$$
$$= 959.999 \text{ ms}$$

- Synchronized time, $T_{(sync,\ SOE\ B\ event)}$ of $T_{(occurrence,\ SOE\ B\ event)}$ of SOE B event in time server

$$T_{(sync,\ SOE\ B\ event)} = 1000 - [(50-10) + (5+0.004)]$$
$$= 954.996 \text{ ms}$$

Figure 3. shows that even though SOE A, B events occurs at the same time in their local clocks, $T_{(sync,\ SOE\ A\ event)}$, $T_{(sync,\ SOE\ B\ event)}$ of SOE A, B events in time server differ each other.

3.3 SOE Events Sequencing Process

When SOE events occur, SOE events sequencing process is as follows.

a. The system generating SOE events stores SOE Point ID, its occurrence time, and its state value in its own buffers.
b. Per data transmission cycle of each system to Time Server, they send SOE event messages to Time Server.
c. Time Server calculates $T_{(sync,\ event)}$ of each SOE event by Equation (4)
d. Time Server sorts SOE events by $T_{(sync,\ event)}$ (by ascending order) and stores SOE events into a file.
e. Upon operator demand, SOE report can be generated.

4. Conclusions

We proposed time synchronization method of SOE events in safety systems and non-safety systems that exist together. This method can be useful in the systems of nuclear power plants that are fully digitalized.

We explained time synchronization method theoretically. To practically apply this method to SOE events of the fully digitalized systems in nuclear power plants, we are going to perform the following tasks in the next stage.

- Testing and validating time synchronization method in real environments composed of hardware and software.
- Finding an estimated data transmission time and an estimated data transmission delay time.
- Analyzing accuracy of proposed time synchronization method.

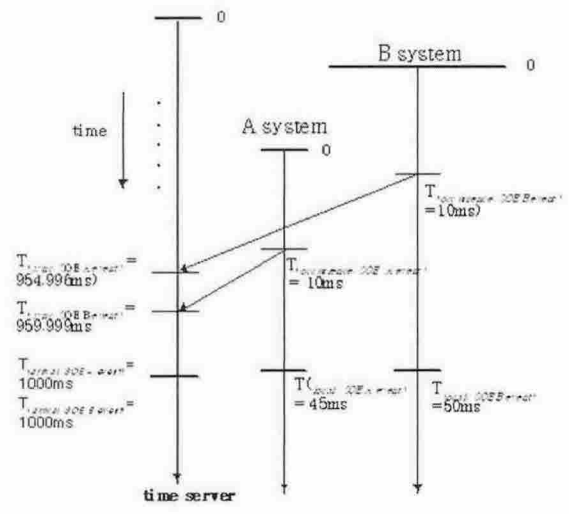

Figure 3. time synchronization diagram of $T_{(occurrence,\ SOE\ A\ event)}$, $T_{(occurrence,\ SOE\ B\ event)}$ in A, B systems

REFERENCES

[1] Byoung-chae Lee, Chong-son Chun, Kyong-ho Lee, A study for the Sequence of Events(SOE) system on the Nuclear Power Plant, Korea Atomic Energy Research Institute, 1996