
APPLICATION EXAMPLE

AC500 V3 - SEQUENCE OF EVENTS (SOE)



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2 Introduction

2.1 Scope of the document

A lot of Installations mainly in Buildings, Infrastructure and especially Power-generation- projects need the Sequence of Event (SoE) logging for effective root-cause analysis. SoE means the order of incoming events on IO in the control system must be registered in a way that they are in the same order (timestamped) as they physically have occurred.

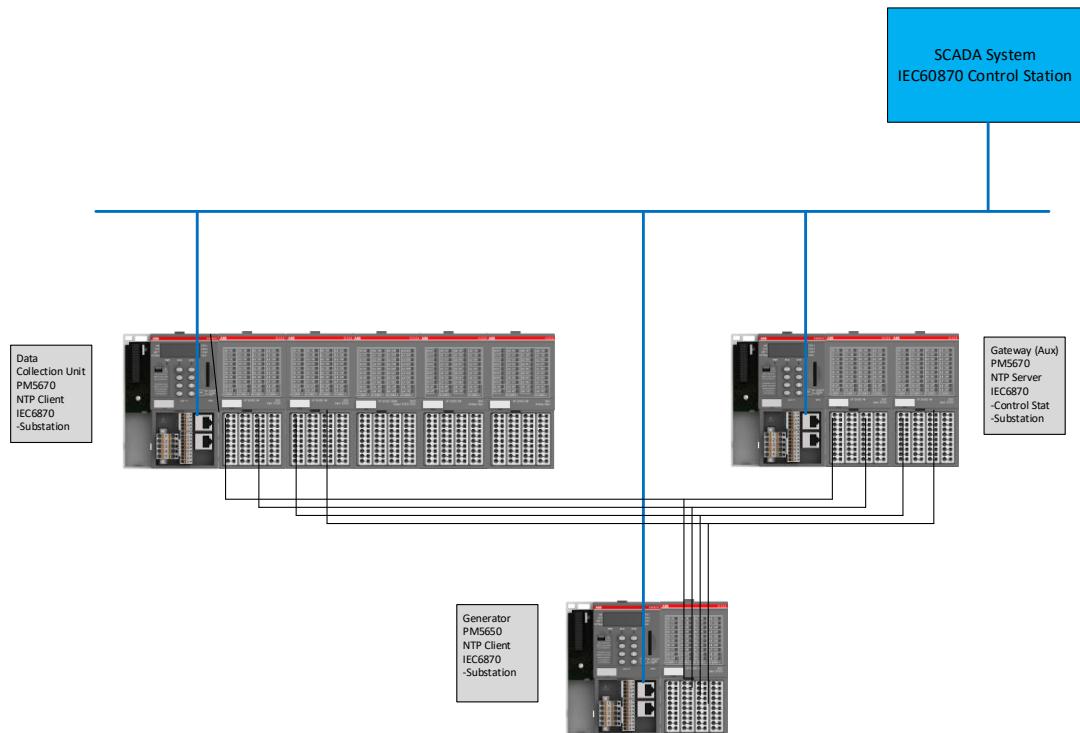
The following document shows how we can achieve this with AC500/S500 with an application program, as the S500 IO Modules don't have the functionality built-in to create a timestamp and transfer it with the event directly at the IO Channel.

2.2 Compatibility

The application example explained in this document have been used with the below engineering system versions. They should also work with other versions, nevertheless some small adaptations may be necessary, for future versions.

- AC500 V3 PLC
- Automation Builder 2.4.0 or newer

2.3 Overview



The configuration used for this example consists of three PLC systems:

Data Collection Unit detects changes on digital inputs (= events) and sends event telegrams with timestamps to the

Gateway which has two functions: 1. it detects changes on digital inputs and sends event telegrams with timestamps to SCADA System. 2. it receives telegrams with time stamps from the Data Collecting Unit and forwards them to the SCADA System.

The **Generator** creates test signals (=events) on its digital outputs.

3 Boundary Conditions

- Based to the fact that the IO channels have no timestamp, the system must be configured in a way that IO's come fast to the PLC Task and get their timestamp in this task.
- In addition to get an exact timestamp within one PLC we must ensure that we have the right timestamp independent of the PLC where the Event appear.
- Same time in all PLC's will be achieved with NTP synchronization. NTP (Network Time Protocol) means an accuracy of 1ms. In our example the Gateway PLC act as an NTP Server and the other PLC's have an NTP Client. In a plant AC500 can also be synchronized from a Time Server with NTP Protocol.
- In order to combine value and timestamp, we need a fast task to recognize change in IO and save the Time Stamp in a common structure.
- For same reason as above, we need the synchronization between IO Bus and fast application task to avoid a jitter.
- Time Stamp in our case consists of DT time Format and in addition the Milliseconds in a separate Value. This is necessary to transfer the Data via IEC60870 protocol, because the protocol need these two values. An own FB deliver this data.
- One AC500 V3 PLC act as a Gateway between SCADA/DCS/HMI and collect the Data from the Data Collection Units (AC500 V3 PLC) via IEC60870 Protocol. Gateway has for each Unit a dedicated Control Station and in each Unit is the Substation. Gateway PLC has also the opportunity with own local IO's.
- To transfer the Data to SCADA/DCS/HMI the Gateway is Substation. Inside of the Gateway PLC will be mapped from the Control Stations (for each Unit) to the Substation.

4 Realization

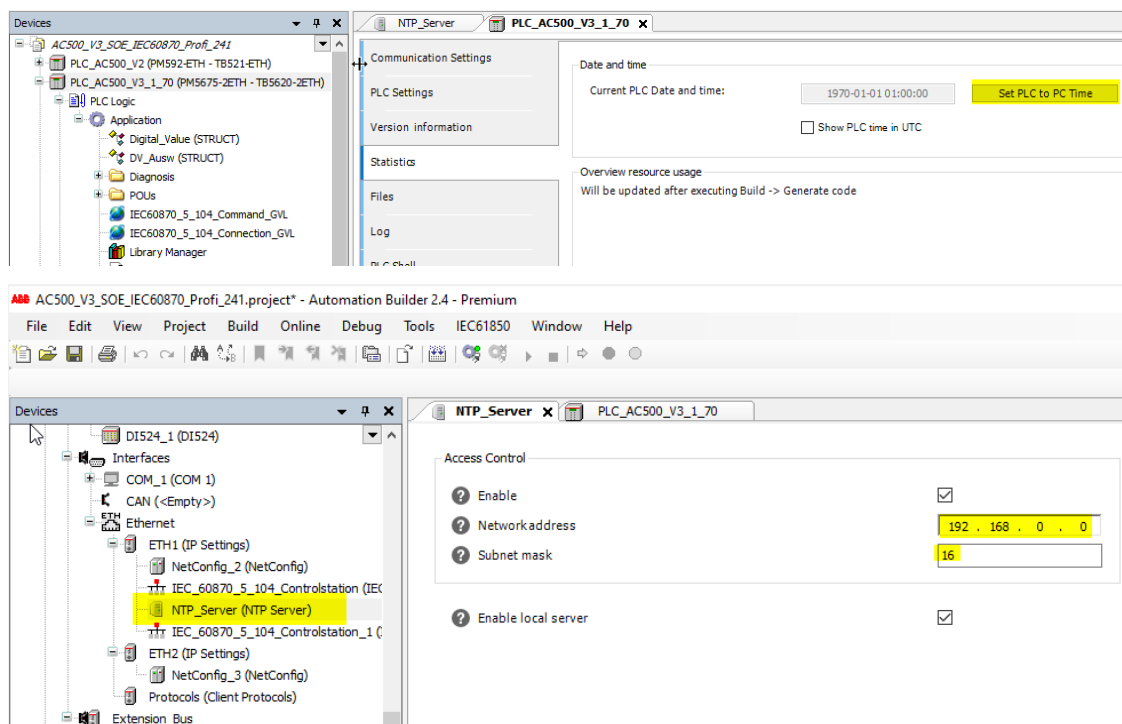
4.1 NTP

NTP protocol has an inbuilt drift correction, that means every time the Client get the time from the NTP Server he compares the time with the time at the server and calculate the deviation. This value will be used to correct the time at the Server also between the NTP requests.

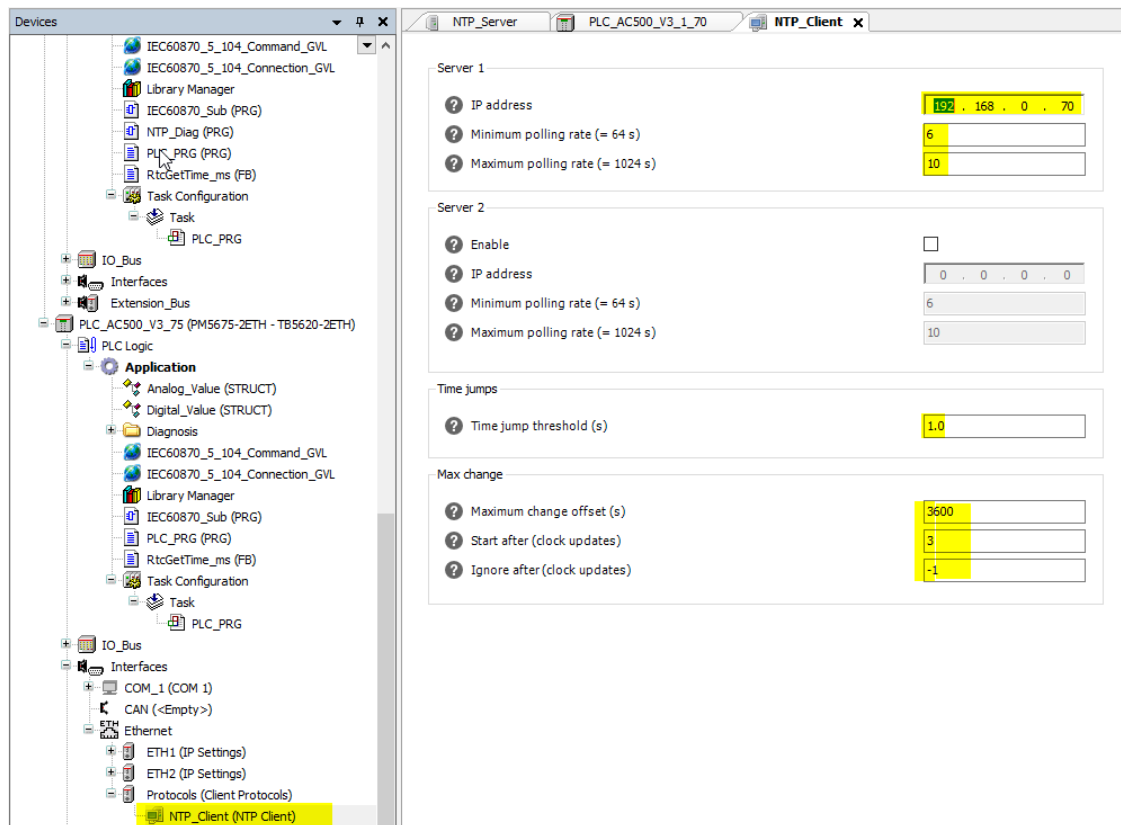
Depending on the deviations the NTP server can change the cycle for NTP requests within the window defined by minimum and maximum polling rate.

4.2 Time Synchronization

In this example the Gateway PLC will act as NTP Server. Time on Gateway will be set via Automation Builder.



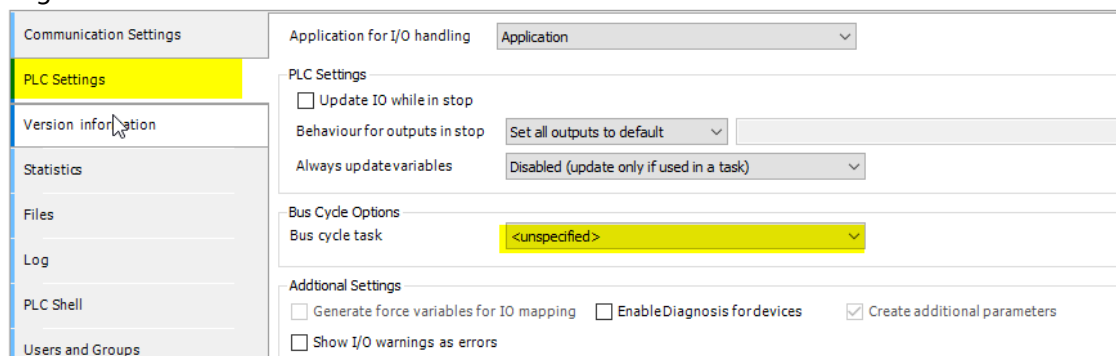
Data Collection Units by connecting as NTP Client to the NTP Server



- *Minimum Polling Rate* of 6 mean 2^6 sec = 64 sec (Default Value, mainly used for connections to Internet based NTP servers. Internet based servers very often do not accept shorter polling rates. For Local NTP Server polling rates can be faster, but please take in consideration that this increase the Load at PLC and Network)
- *Maximum Polling Rate* of 10 mean 2^{10} sec = 1024 sec (default value, see above)
- *Time Jump Threshold* of 1 mean change time in steps of max. 1 sec
- *Maximum change offset* of 3600s (1 hour) mean if Clock of PLC is more than 1 hour drifted, clock will not be synchronized
- *Ignore after (Clock Update)* of -1 means protocol is always active even if the max. offset is exceeded

4.3 Task and IO-Bus

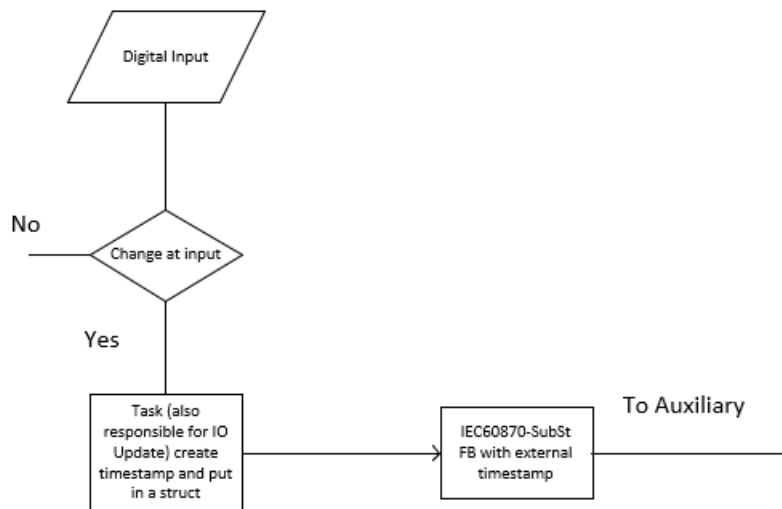
Important for exact Time Stamp is that IO Bus Cycle and the IEC task are synchronized. This is the case at AC500 V3. Relation between IO Bus and IEC Task will be configured in PLC Settings



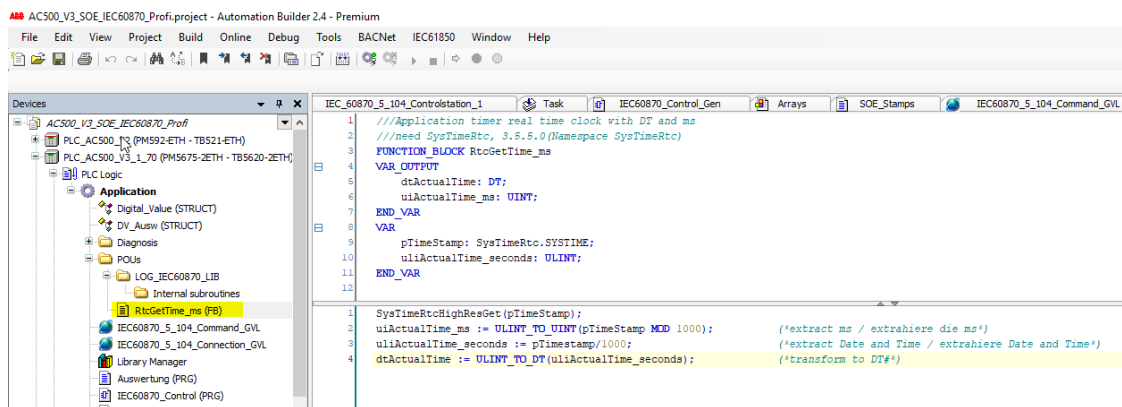
In our case we have only one IEC Task in the real time range. That mean IO Bus will synchronized with this Task. If more than one Task is there, then one (fastest) Task should be chosen.

4.4 Creating Time Stamp

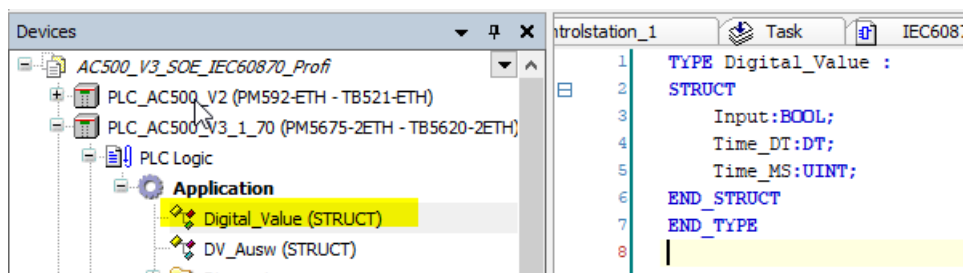
In Data Collection Units and Gateway PLC (Aux) incoming IO Signals get a timestamp with the help of an FB which deliver DT format and MS as two Variables. This is necessary to transfer the Values incl. timestamp.



FB to get the Time



Data Structure for Values



Sequence to save Values and Time

```

IEC_60870_5_104_Controlstation_1  Task  IEC60870_Control_Gen  Arrays  SOE_Stamps  IEC60870
1  PROGRAM PLC_PRG
2  VAR
3      Local_DI_0: ARRAY[0..19] OF Digital_Value;
4      Local_DI_1: ARRAY[0..19] OF Digital_Value;
5      Local_DI_2: ARRAY[0..19] OF Digital_Value;
6      Local_DI_3: ARRAY[0..19] OF Digital_Value;
7
8      IEC60870_Control();
9      IEC60870_Control_Gen();
10     Auswertung();
11     SOE_Stamps();
12     Gettime();
13
14 IF DI524_0_I0 <> Local_DI_0_Old THEN
15     Local_DI_0[n].Input      :=DI524_0_I0;
16     Local_DI_0[n].Time_DT    :=Gettime.dtActualTime;
17     Local_DI_0[n].Time_MS    :=gettime.uiActualTime_ms;
18     Local_DI_0_Old          :=DI524_0_I0;
19     n                       :=n+1;
20
21     IF n=20 THEN
22         n:=0;
23     END_IF
24 END_IF
25
26 END_PROGRAM

```

4.5 Use of IEC60870 to transfer Data to Gateway

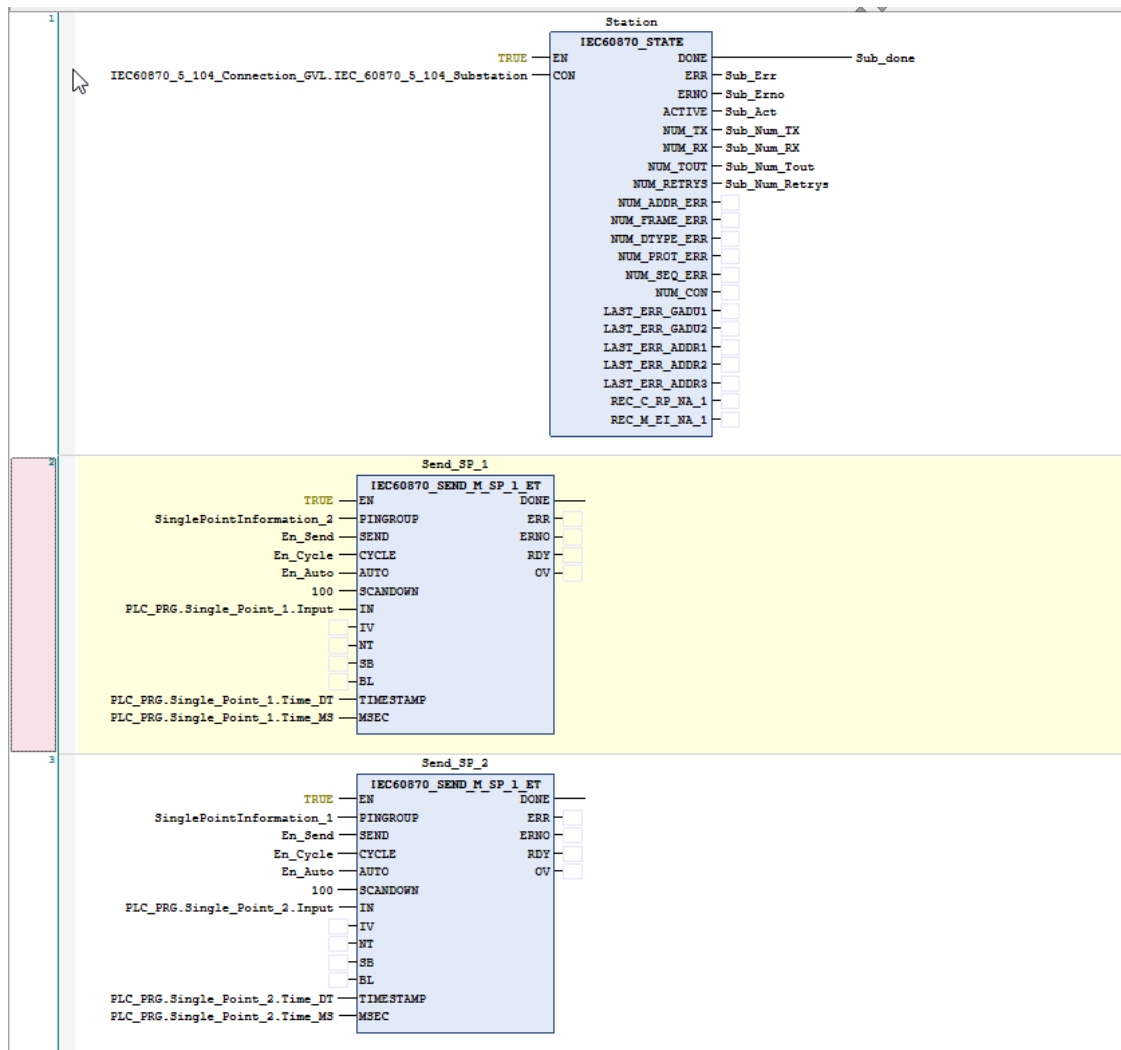
At each Data collection Unit an IEC60870 Substation is working to transfer the values incl. timestamps to the Gateway (Aux)

```

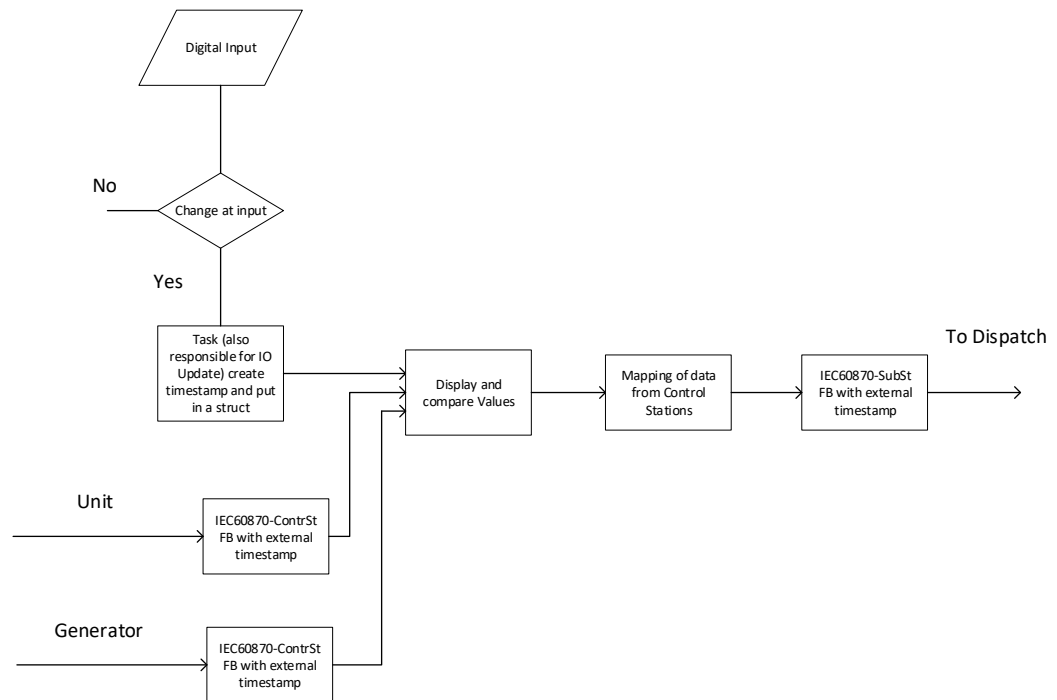
PROGRAM IEC60870_Sub
VAR
    Station:AC500_IEC60870_5_104.IEC60870_STATE;
    Sub_Act: BOOL;
    Sub_done: BOOL;
    Sub_Err: BOOL;
    Sub_Errno: WORD;
    Sub_Num_TX: DWORD;
    Sub_Num_RX: DWORD;
    Sub_Num_Tout: DWORD;
    Sub_Num_Retrys: DWORD;

    Send_SP_1:IEC60870_SEND_M_SP_1_ET;
    Send_SP_2:IEC60870_SEND_M_SP_1_ET;
    Send_SP_3:IEC60870_SEND_M_SP_1_ET;
    Send_SP_4:IEC60870_SEND_M_SP_1_ET;
    Send_ME_1:IEC60870_SEND_M_ME_1_ET;
    En_Send: BOOL;
    En_Cycle: BOOL;
    En_Auto: BOOL := true;
END_VAR

```

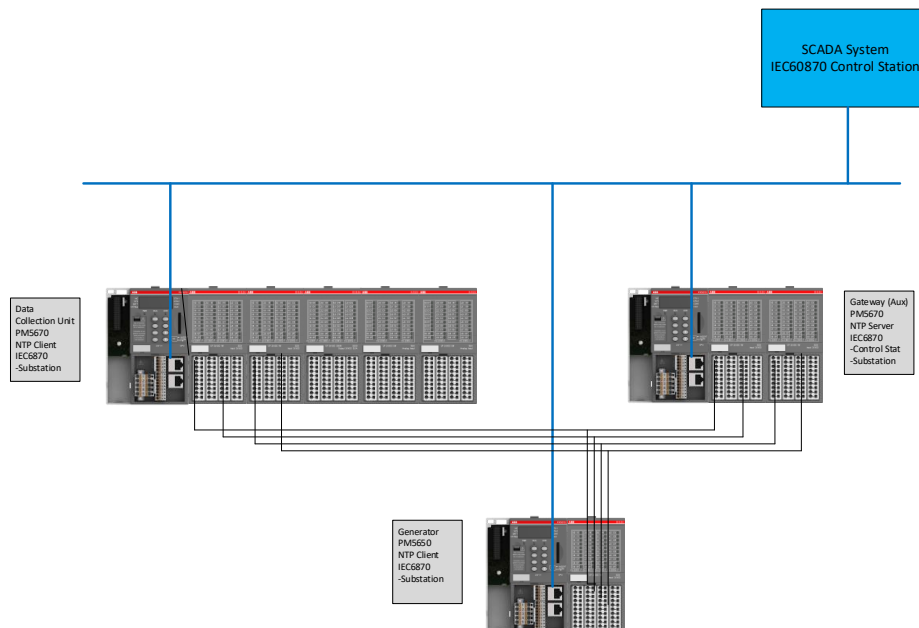


4.6 Transfer Data from Gateway to DCS

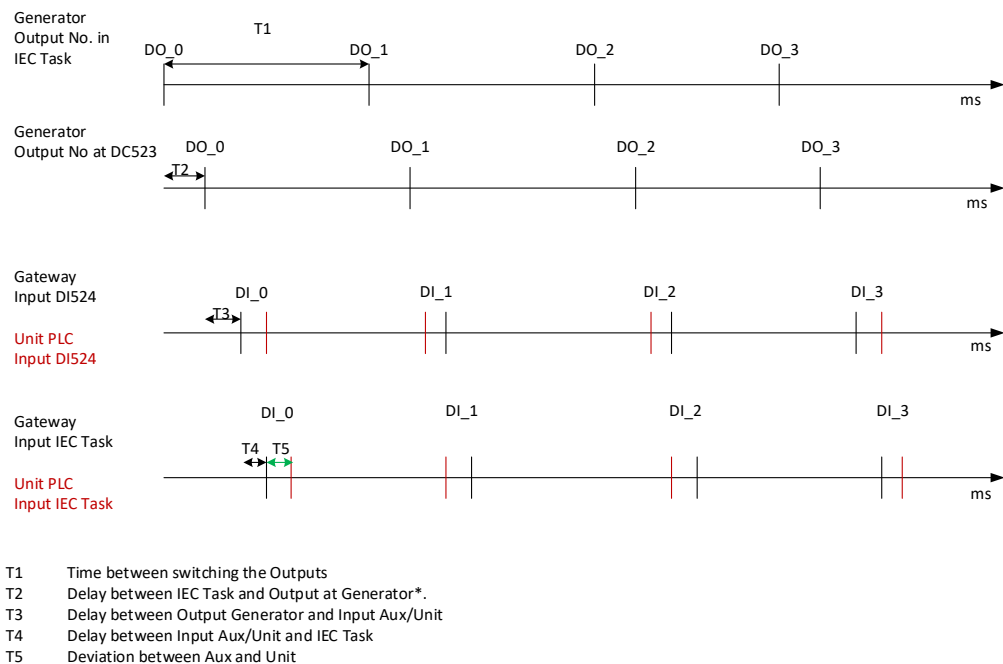


5 Results

5.1 Method



Generator switches 4 Outputs with a dedicated delay time between the Outputs. Gateway PLC (Aux) and Unit PLC get these signals on their Local IO's (DI524) parallel.



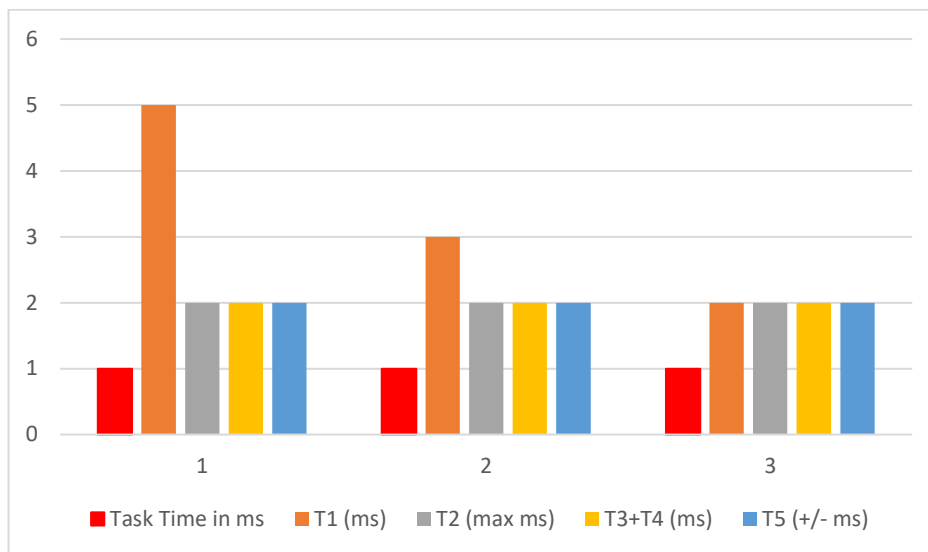
*T2 is half of the time measured between set Output at Generator in IEC Task and visible as input in IEC Task in Aux/Unit ($4\text{ms}/2 = 2\text{ms}$)

Example Project: AC500_V3_SOE_IEC60870_local

The Measurements are made with different Task times

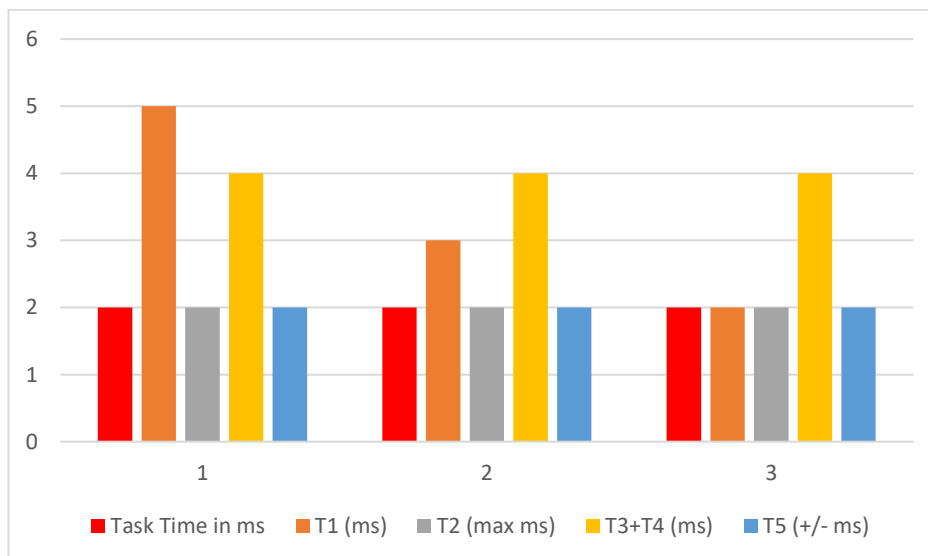
If not only the order of the events is necessary and the absolute time is important, a correction of the timestamp by subtracting the T3 and T4 from the created timestamp is possible.

5.2 Measurement with 1ms Task Time



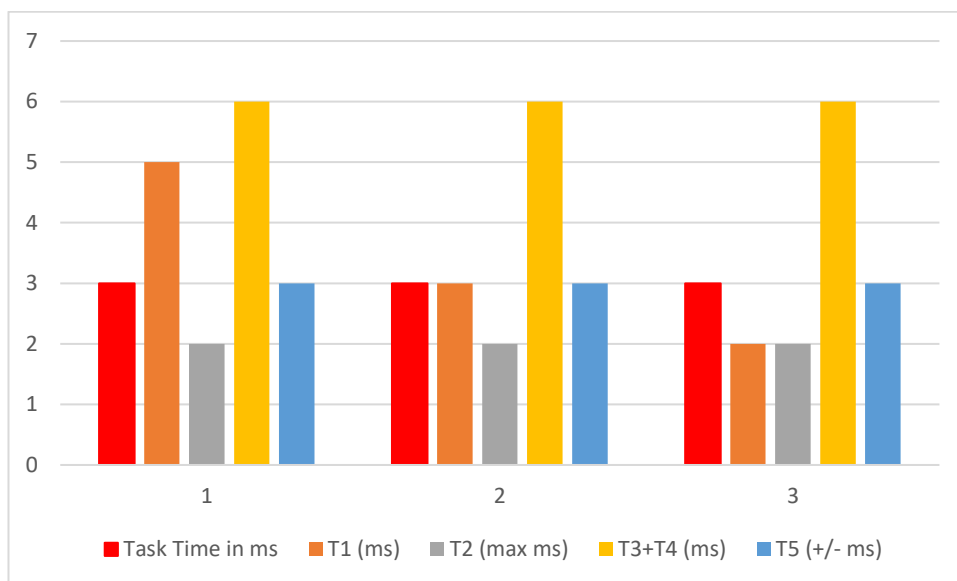
With Time differences of 5 and 3ms between the different Outputs/Inputs we have a clear SOE, with 2ms it's not sure to detect the right order.

5.3 Measurement with 2ms Task



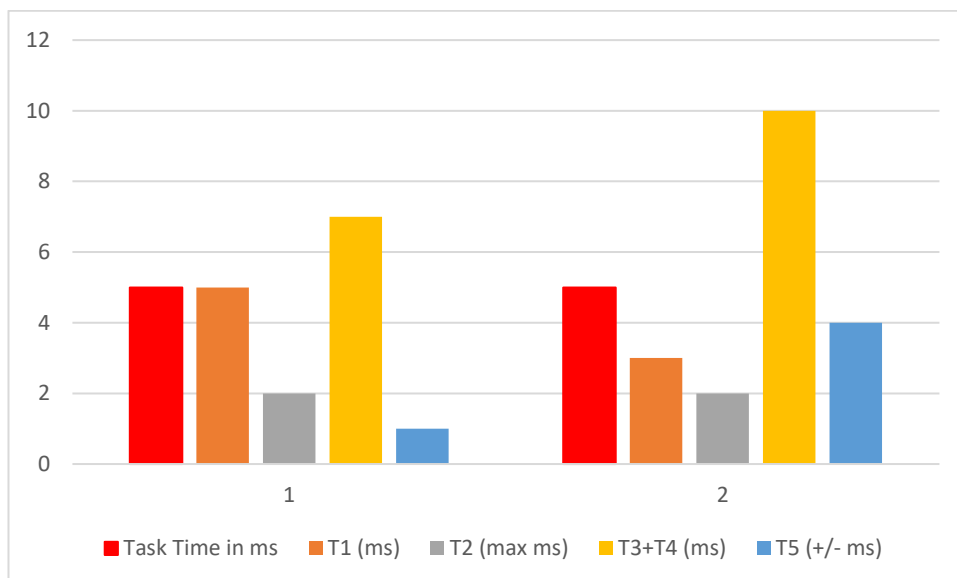
With Time differences of 5 and 3ms between the different Outputs/Inputs we have a clear SOE, with 2ms it's not sure to detect the right order.

5.4 Measurement with 3ms Task



With Time differences of 5ms between the different Outputs/Inputs we have a clear SOE, with 3ms it's sure to detect and with 2ms it's not possible to detect the right order.

5.5 Measurement with 5ms Task



With Time differences of 5ms between the different Outputs/Inputs we have a clear SOE, with 3ms it's not possible to detect the right order.

5.6 Caution



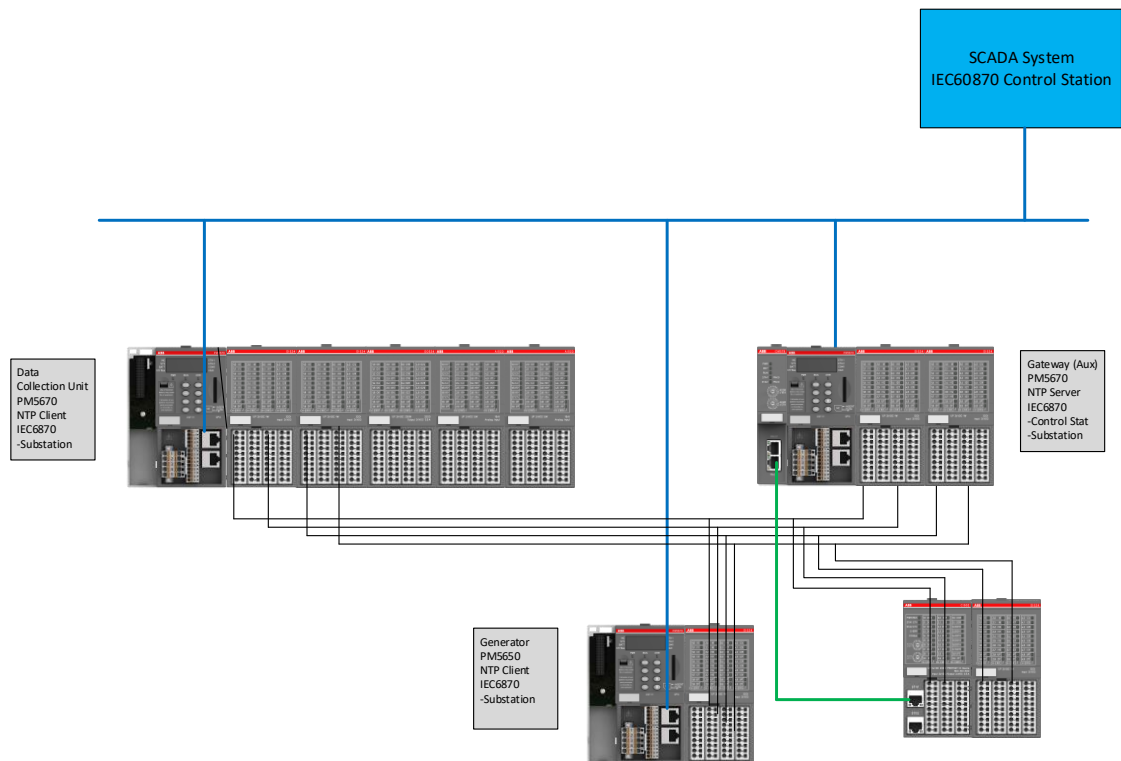
CAUTION!

The showed project is only an example and the results could be different depending on the complete application project.

Working with this applicative SOE need to have a fast task in your application. Please take care that this fit to your application.

6 Additional Measurement with PROFINET

Target is to get delay times from PROFINET IO's to Local IO's

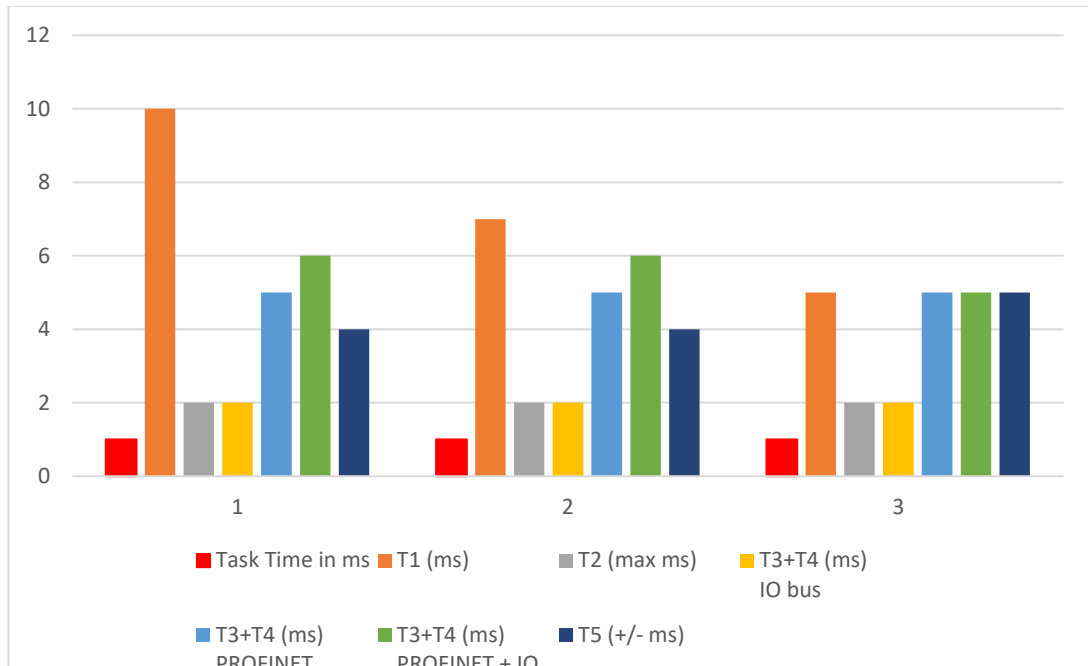


In addition to the local IO's here are some IO's via PROFINET connected.

Example Project: AC500_V3_SOE_IEC60870_Profi

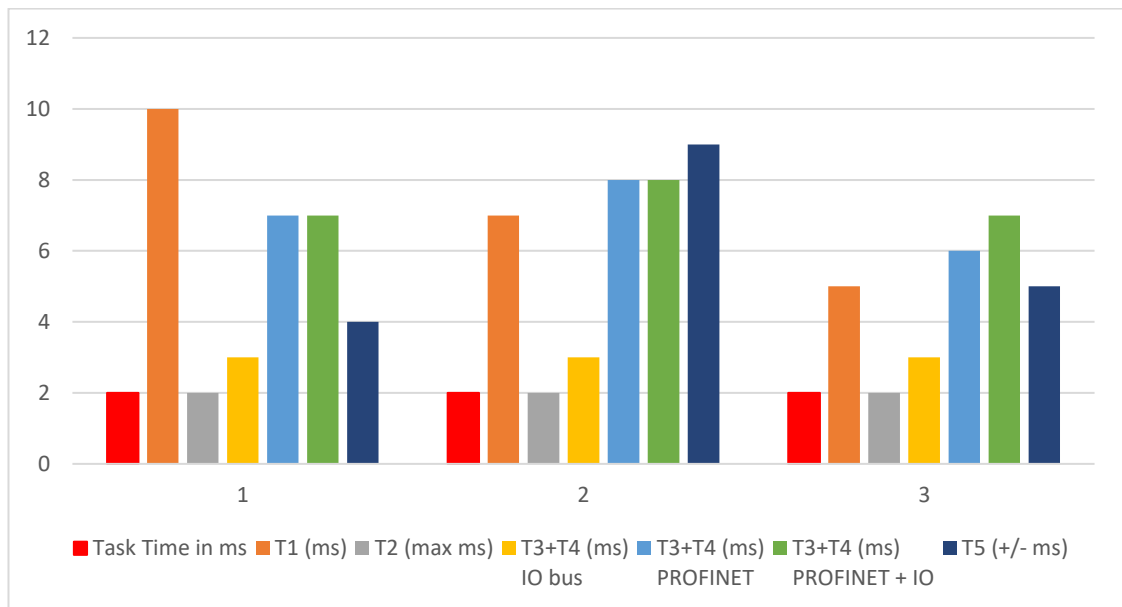
6.1 Measurements

6.1.1 Measurement with 1ms Task Time



With Time differences of 10 and 7ms between the different Outputs/Inputs we have a clear SOE, with 5ms it's not sure to detect the right order.

6.1.2 Measurement with 2ms Task Time



With Time differences of 10ms between the different Outputs/Inputs we have a clear SOE, with 7 and 5ms it's possible to detect the right order.

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