Time Synchronization of Power Protection Devices at the Chemistry Park Knapsack Hürth near Cologne, Germany

An easy and fast method of retrofitting power protection devices to a reliable time source.

To keep an electric power distribution network in operation, power utility companies have to maintain a large quantity of protection relays and power quality recorders. These assets are necessary to guarantee a smooth and reliable supply of electrical energy. When a power outage happens, parts of this network need to be shut down and the root cause of this failure needs to be found quickly. To ensure the proper function of the network, but also to assess an outage, the event recordings of the involved protection relays need to be analyzed.

An easy and accurate evaluation is only possible when all involved devices refer to the same time scale. Otherwise, the dependencies of specific reactions cannot be reproduced. To have the correct time at every connected protection relay, reliable time information needs to be distributed to every device of the protection network.

To improve the time synchronization of such devices, InfraServ Knapsack (ISK) and OMICRON Lab did setup the project described in this article. The power utility section of ISK is responsible for distributing electrical energy inside the chemistry park Knapsack Hürth near Cologne in Germany which is shown in Figure 1.

Figure 1 - The chemistry park Knapsack Hürth near Colon in Germany

Per year, 900 GWh of electrical energy are distributed via a 6kV- and a 20kV- medium voltage grid to the different chemical companies in the park. This is half of the energy consumption of the city of Cologne during one year.
The power grid is organized in 500 segments with approximate 2000 electrical measurement points, down to the 400 V low voltage level. The medium voltage grid is monitored, controlled and switched by a central control center. At a chemistry park, especially, the uninterrupted supply of electrical energy has highest priority. The chemical production processes cannot be stopped instantly. Their run-down needs to be controlled to avoid huge maintenance and cleaning effort for the involved machinery.

For this reason, ISK analyzes the root cause and impact of every power events, to continuously improve the protection system and inform the companies connected to the distribution grid. For such fault reports, the data from the control station, the protection relays and power quality recorders are analyzed. Therefore, it is important that the data of all components have exactly the same time base.

Only with an exact time synchronization the correct sequence of events during a fault at multiple parts of the power grid can be put together easily.

Different strategies and protocols for time synchronization

To analyze faults, most of the protection devices of ISK are synchronized to the GPS reference clock in the control center via the RTUs (Receiver Transmitter Unit) using the station protocol IEC-60870-103,-104.

The communication network infrastructure to the RTUs inside the different facilities can cause huge time variances. Additional components like power quality recorders are synchronized using the Network Time Protocol (NTP). NTP can also result in huge time variations, especially when the distribution path between NTP client and NTP server is passing many network switches. Figure 2 shows the time synchronization situation prior the retrofit done during the described project.

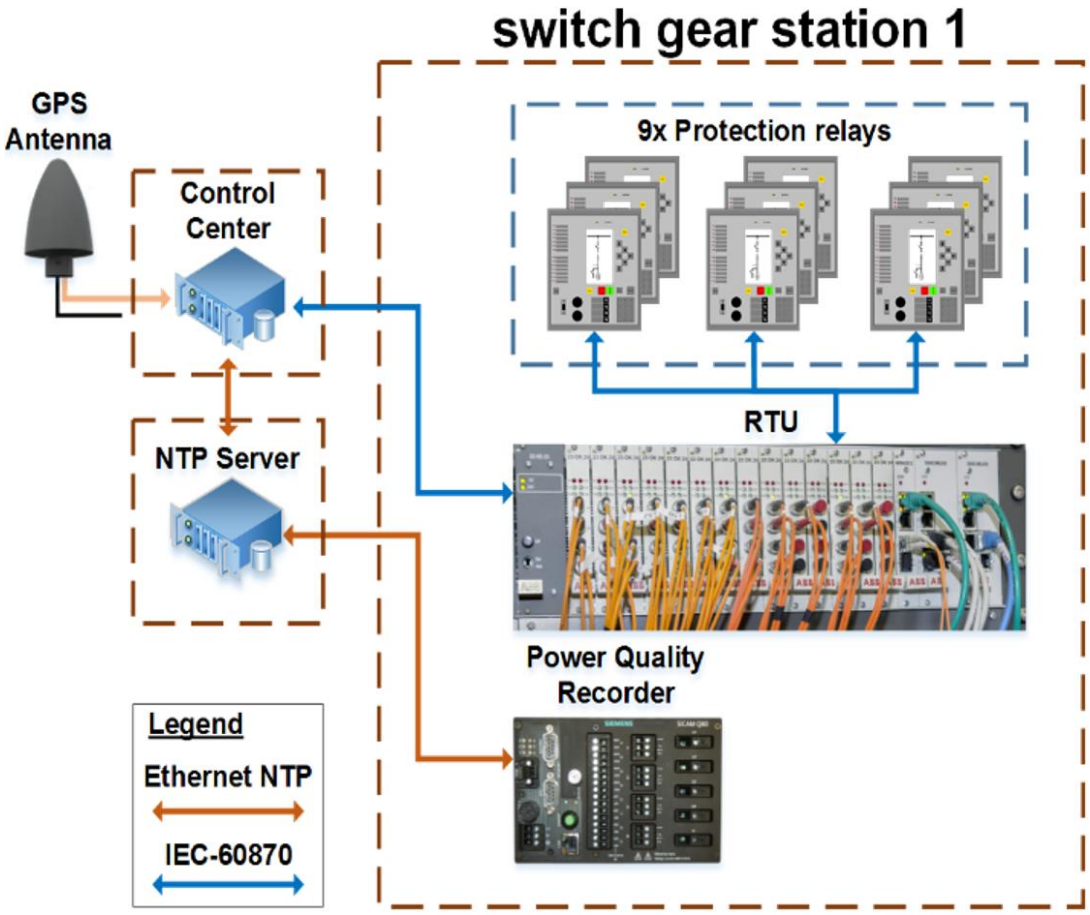

Figure 2 - Switch gear station before the retrofit

To improve the time synchronization of the already installed equipment, the backbone of the time synchronization needed to be changed from several sources to a Precision Time Protocol (PTP) network. To execute the steps for this transformation to a PTP backbone, the switch gear station 1 was chosen.

Retrofitting of switch gear station 1

First, the OMICRON Lab OTMC 100p, a GPS synchronized PTP Grandmaster clock, was installed on top of the building of switch gear station 1. The OTMC 100p was then connected to a PTP compliant Ethernet switch. This PTP-Switch communicates to two TICRO 100 PTP time converters. One TICRO 100 provides time synchronization to nine protection relays, while the second one provides time signals to a power quality recorder. The complete setup is shown in below.

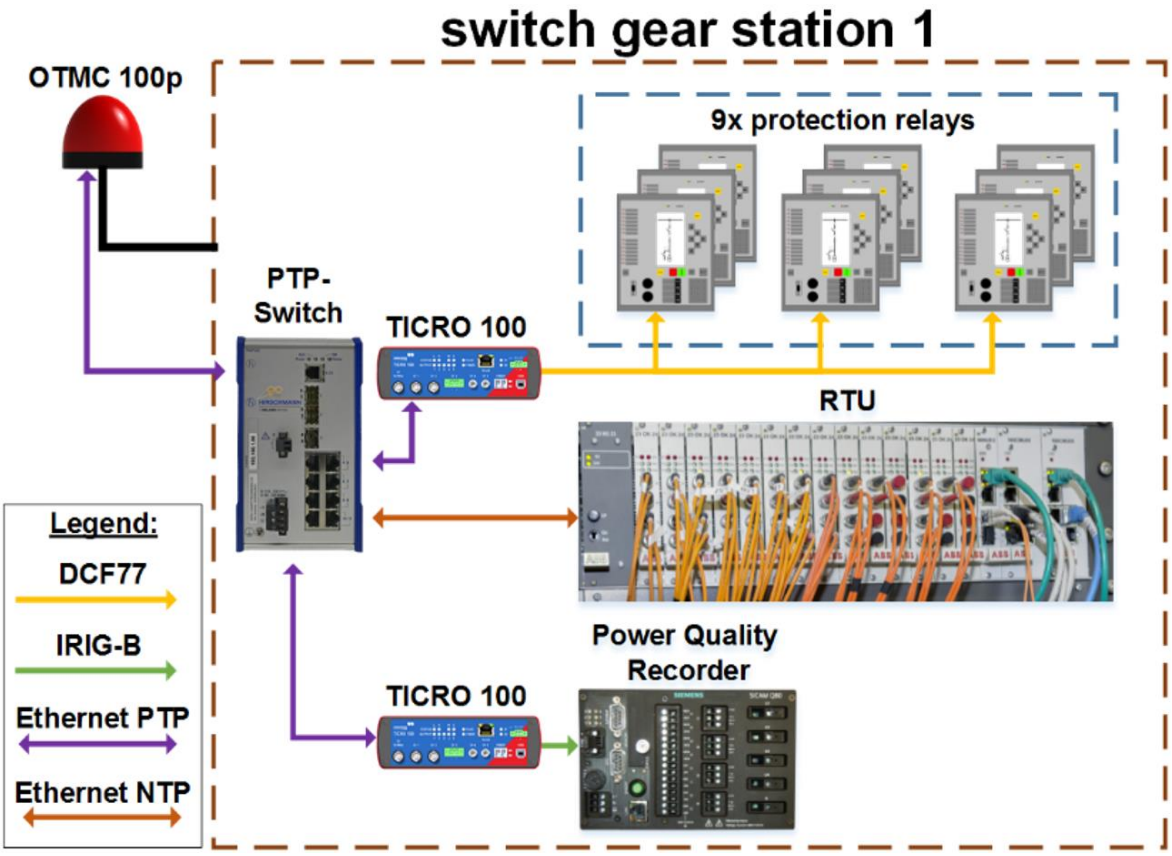

Figure 3 – Switch gear station after retrofit, locally PTP synchronized

The first TICRO 100 (on the top) connected to the protection relays, converts the time received via PTP to the DCF 77 telegram required for the synchronization of these protection relays.
The second TICRO 100 (on the bottom) is used to synchronize a power quality recorder using an IRIG-B time code.

The OTMC 100p acts as PTP Grandmaster clock and NTP time server at the same time so that the RTU (NTP-Client) (in the middle) can also be connected to the same time source over the network. Since there is only one switch between NTP-Server and NTP-Client, the synchronization is much more accurate than using the distant NTP-Server located in the control center.

In a PTP-Network, the propagation delays between the grand master clock (OTMC 100p) and the connected slave clocks (TICRO 100) are automatically compensated to achieve highest time accuracy, better than 1 µs compared to UTC at the Outputs of the TICRO 100. Using the timing products of OMICRON Lab, all required time codes like PTP, NTP, IRIG-B and DCF 77 can be generated to time synchronize the protection and control equipment with the highest possible accuracy.

Performance test of the time synchronization prior and after the retrofit

The effectiveness of time synchronization is best tested during a fault condition. To simulate such fault conditions, the OMICRON CMC 356 protection test set together with RelaySimTest software can be used. To test the synchronization quality, some protection relays in Station 1 were disconnected from the power grid. These relays were then connected to several CMCs, to simulate a protection event. These CMCs were time synchronized using the OTMC 100p, so the protection event was generated exactly at the same time for all involved relays. Afterwards the trigger times, inside the event recordings of the protection relays were analyzed. (see Figure 4 below)

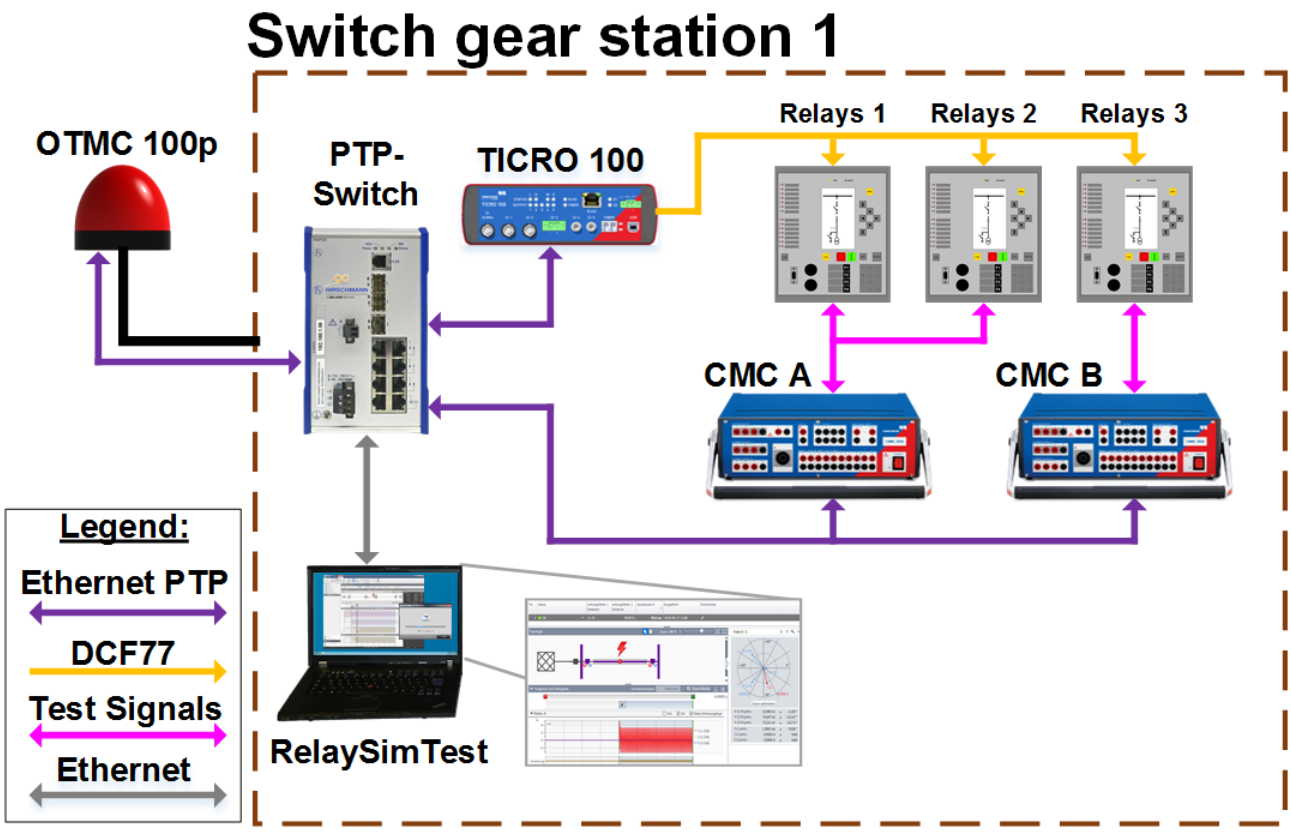

Figure 4 Test in Switch gear station 1 using RelaySimTest

The time difference between the protection relays synchronized via the RTU prior the retrofit (see Figure 2), was with a maximum difference of 16 ms to UTC - not too dramatic. All involved relays were connected via the same communication channel to the master clock inside the control center, so this result is explainable. Nevertheless it can be much better, since 16 ms deviation is already nearly one power cycle. (See Figure 6, Page 6)

To get more realistic results, protection relays located in different switch gear stations were included into the comparison tests. At the beginning of these tests, the second switch gear station 2 was not time synchronized via an OTMC 100p. The synchronization was established using the existing network from the control center (protocol IEC-60870-103). Both CMCs were time synchronized to GPS using two CMGPS 588 units, so the accuracy of the used CMCs was better than ±100 ns compared to UTC. (see Figure 5 below)

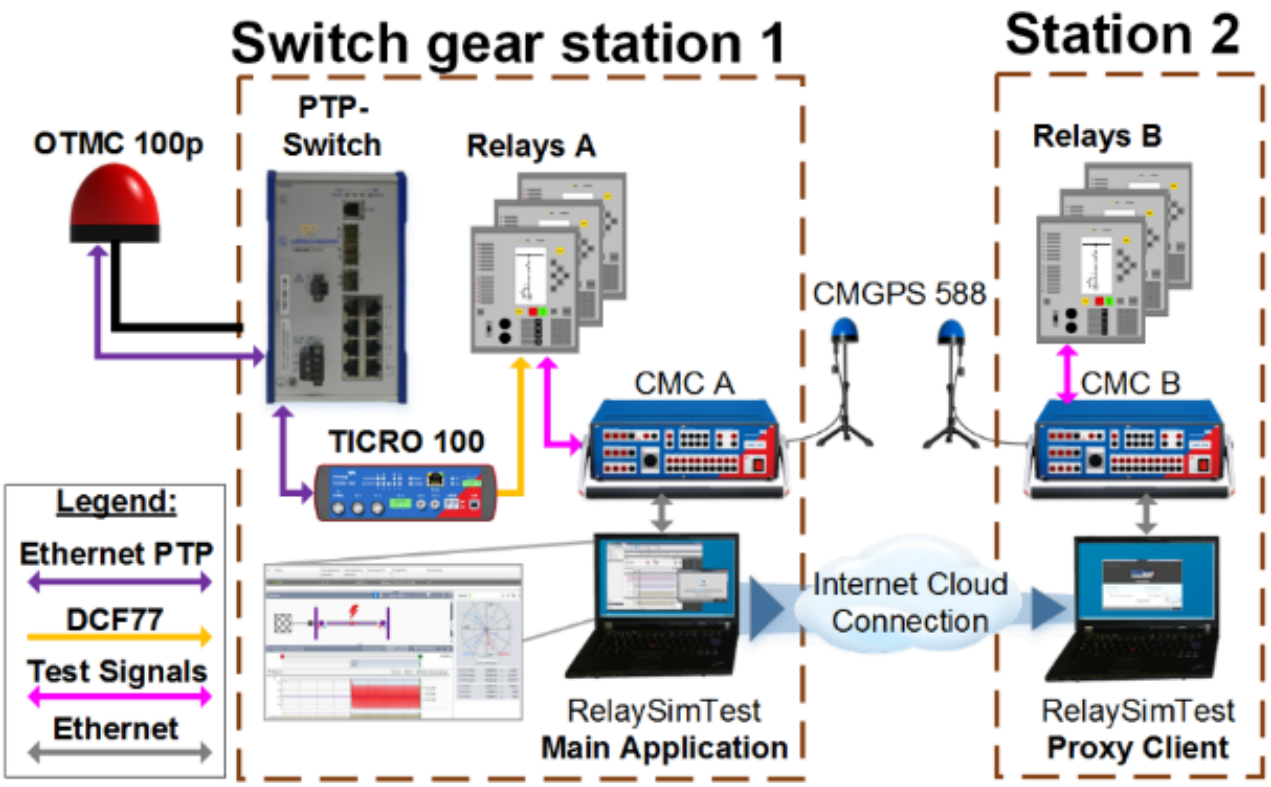

Figure 5 - Test in switch gear station 1 and station 2 using RelaySimTest

Both CMCs were controlled by the Main Application of RelaySimTest running on the Laptop controlling CMC A, placed in Station 1. The CMC B, in Station 2 was connected to the main application, using the RelaySimTest Proxy Client, via an Internet Cloud Connection. RelaySimTest can build up a distributed test setup including several CMCs at different locations. Therefore, it is a perfect tool to test the time synchronization quality of distributed protection systems. (See Figure 5)

After executing the test, an analysis of the event recordings of the involved protection relays in switch gear station 2 showed a huge time deviation of 115 ms up to 170 ms in comparison to station 1. Such time deviations represents 5 to 8.5 cycles of the line frequency of a 50 Hz power network. (See Figure 6, Page 6) Such deviations are dramatic since the comparison of the event recordings from both stations is practically impossible.

To verify the improvement of the time synchronization using the OTMC 100p, a temporary PTP network at switch gear station 2 was installed. For the next test, the same protection relays showed a time deviation of less than 1 ms. (see Figure 6, Page 6**Error! Reference source not found.**)

Results of the improved time synchronization using PTP components

Using the time synchronization via RTUs using the station protocol IEC-60870-103 or -104 makes analyzing of the event recordings nearly impossible. The performance of the time synchronization of the protection devices increases a lot, when a PTP network in combination with OMICRON Lab products is used. By using the TICRO 100 synchronized to a PTP network as a time source for the protection relays the time variation between the event recordings is reduced down to less than 1 ms as shown in Figure 6.

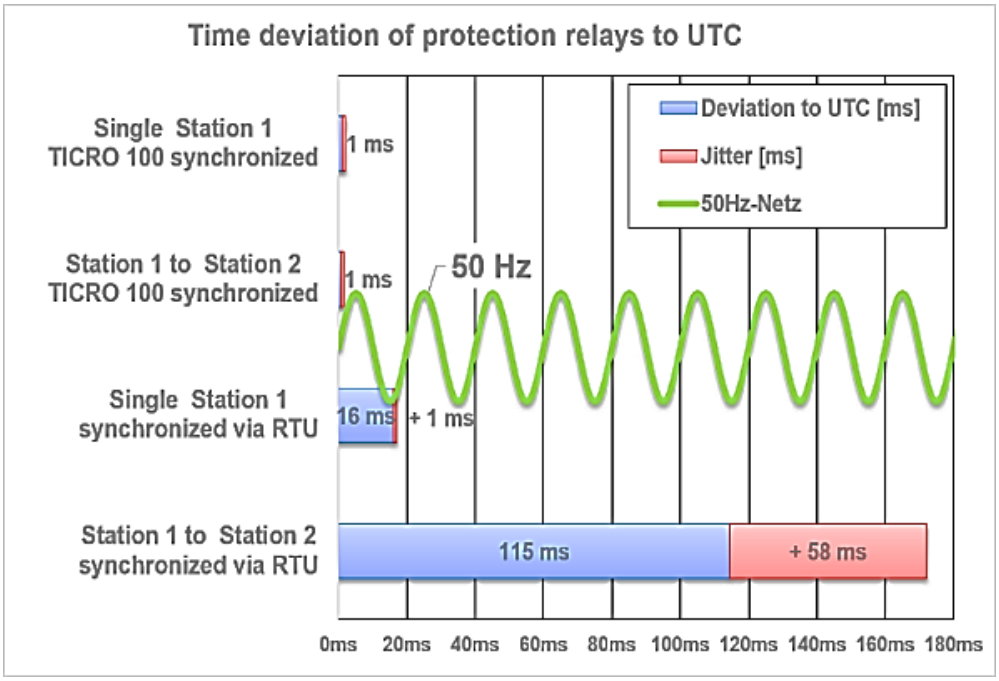

Figure 6 - Result of distributed measurement

In general accuracies better than 1 µs can be reached with PTP. However, the event time stamp resolution of the synchronized equipment is only 1 ms. For this reason 1 ms is also the maximum resolution that can be reached for the event time stamps.

The usage of PTP as time reference, makes analyzing of event recordings a lot easier for the protection engineers so that they can now fully concentrate on the fault analysis, and therefore, will identify fault reasons a lot faster. This pilot project shows a simple and cost effective way to retrofit already installed protection relays independently of the time synchronization method required by these devices.

OMICRON Lab supported this project for time synchronization of protection relays with the following services:

- Introduction to different time synchronization methods: DCF 77, IRIG-B, NTP and PTP
- Consulting service to select the right PTP components and time synchronization methods
- Support during planning and build-up of the PTP infrastructures
- On site assistance during test and implementation of the PTP system

For sure, time synchronization projects can be adapted to local needs and developed step by step. Feel free to contact us for further information

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