

User Experiences of Remote Data Evaluation

H.-J. HERRMANN, G. FLEISCHER
Siemens AG, Energy Automation, Germany
J. HAUSCHILD
50-Hertz-Transmission GmbH, Germany
hans-joachim.herrmann@siemens.com

KEYWORDS

Remote access, data evaluation, SAFIR, IEDs, fault and disturbance records, event logs, reporting, auto reclosing, power quality data

1 INTRODUCTION, SYSTEM OVERVIEW

One important feature of the digital technology of today is the immense storage of information. In locally installed IEDs, event logs as well as fault (disturbance) records are available for analysis. These IEDs are numerical protection and control relays and fault recorders. The Power quality meters deliver power quality information. All these data sources can be used for monitoring of the e.g. primary equipment, as all this data is available locally today. This paper shows how data from various sources, when integrated into an intelligent system, has real value for the user.

Siemens offers with SIMEAS SAFIR, an information system which gathers precise monitoring data, offers easy to-use web applications to asset managers, network control operators, protection experts and network planners. Due to the numerous measurements that SIMEAS SAFIR can collect in nearly real time, it can complement the picture provided to network operators by the SCADA system. Network analysis based on measurements neatly complements the calculations that rely more heavily on power system modelling.

The SIMEAS SAFIR system deals with 3 core functions:

- Disturbance and fault record analysis (fault analysis, fault location)
- Power quality (voltage dips & swells, frequency monitoring, measuring and recording)
- Condition monitoring (asset, transformer and circuit breaker monitoring)

The SIMEAS SAFIR system has been successfully installed in several utilities in Switzerland, Denmark and Germany. Typically the main utilisation of the system is its function dealing with faults and the analysis thereof, typically fault occurrences we use, the data is made available from remote sources to

- Collect, process and store transients records
- Use substation automation messages for analysis
- Display an event with the 'sequence of events' analysis
- Fault location
- Protection analysis
- Auto-reclosing analysis

Figure 1 gives a simplified overview of the principal system architecture. The system collects the relevant data from different locations and sources (i.e. substation computers). The data gathering and processing takes place in the main SIMEAS SAFIR server according installed applications (see the following chapters). The data collected is stored in a data bank. The processed results are visualised on different medium. The main medium being Web based (i.e. internet explorer) and exported into customized solutions.

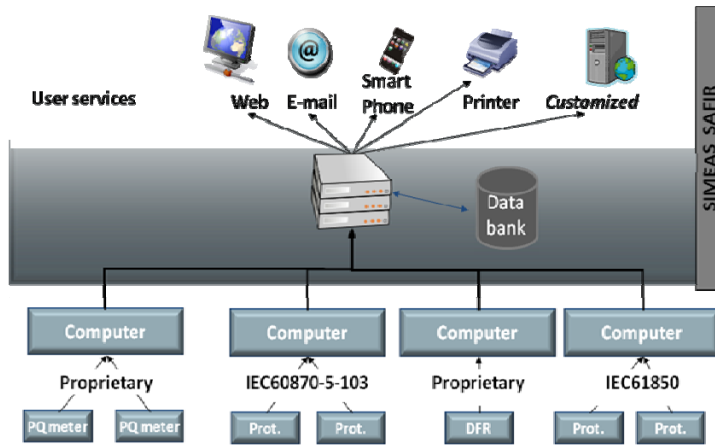


Figure 1: Basic architecture of SIMEAS SAFIR [1]

2 DISTURBANCE AND FAULT RECORD ANALYSIS

2.1 Motivation, Implemented System

After some experiences with propriety individual solutions for disturbances analysis, a German transmission utility made the decision to install the SIMEAS SAFIR system for a remote data evaluation system. The prime motivator for such a system was to have a common tool for different applications, different user scenarios and a support for quick decisions after a fault i.e. to support a decision whether to reclose a circuit breaker after it had tripped. The added value which SIMEAS SAFIR gave for the protection-system experts, was to have detailed standardised information for a analysis to allow weak points in the system to be found and then to optimize the system (e.g. auto reclosing dead time) as well as to analysis the primary equipment (i.e. inrush behaviour of transformers, transient behaviour of current transformers).

Furthermore, a further extension of the initial SIMEAS SAFIR system to include data from installed DFR's, PMU and PQ meters for a greater fault and situation awareness.

Figure 2 gives a principle overview of the implemented system and on the right side shows an overview of the transmission network. The data is collected from the main protection (MP) or back-up protection (BP) via the substation control system with the available communication infrastructure.

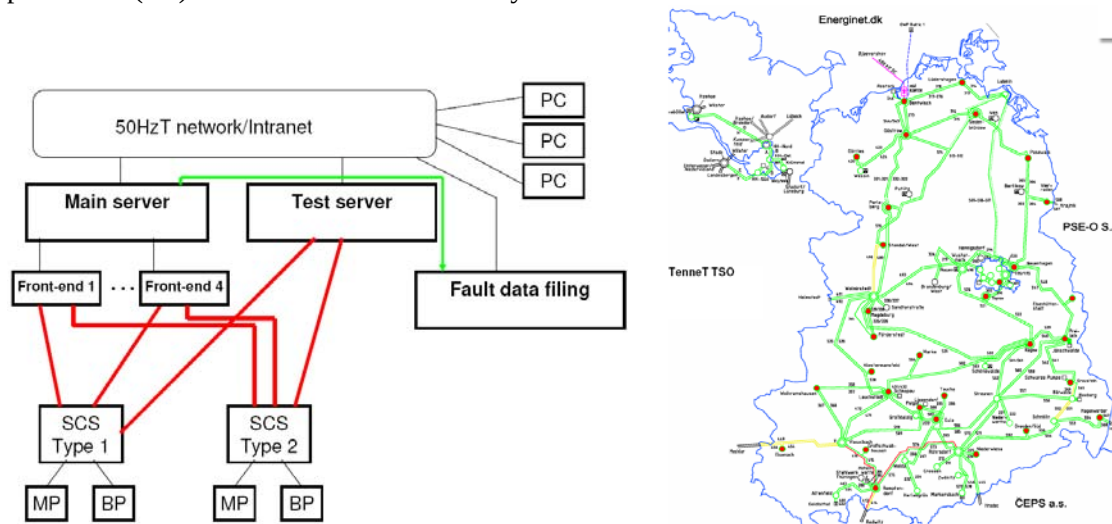


Figure 2: System structure of the remote system and network topology

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SIEMENS Fault analysis						
Events Records Auto-reclosings Inconsistencies SAS Messages						
Auto-reclosings						
Begin 2007/12/31 10:19:07 End 2011/01/10 10:19:07 OK						
136 auto-reclosing from 2007/12/31 10:19:07 to 2011/01/10 10:19:07						
Date and time	Equipment	Fault type	Autoreclosing type	Secondary arc detection	Suggestion to operator	
2008/02/22 22:16:17	We-Gus 424 (Line)	Single-phase	Unsuccessful	No	No manual reclosing advised	
2008/03/01 17:11:13	We-Gus 424 (Line)	Single-phase	Unsuccessful	No	No manual reclosing advised	
2008/06/18 04:44:52	Rag-Wol 532 (Line)	Single-phase	Unsuccessful	Yes	Manual reclosing advised	
2008/07/29 12:39:13	Roe-Hr 446 (Line)	Single-phase	Unsuccessful	No	No manual reclosing advised	
2009/09/19 19:53:58	Bae-Str 558 (Line)	Single-phase	Unsuccessful	Yes	Manual reclosing advised	
2009/06/14 20:28:41	Bae-Sm 552 (Line)	Single-phase	Unsuccessful	Yes	No manual reclosing advised	
2009/07/04 16:13:27	Re-Red 413 (Line)	Single-phase	Unsuccessful	No	No manual reclosing advised	
2009/09/03 10:08:28	Re-Red 414 (Line)	Single-phase	Unsuccessful	Yes	No manual reclosing advised	
2010/06/08 23:25:26	Roe-Sm 555 (Line)	Single-phase	Unsuccessful	Yes	Manual reclosing advised	
2010/07/12 15:28:41	Vib-Re-Goh 415 (Line)	Single-phase	Unsuccessful	No	No manual reclosing advised	
2010/07/21 04:40:41	Lub-Gus 512 (Line)	Single-phase	Unsuccessful	Yes	Manual reclosing advised	
2010/08/20 09:48:34	Rag-Ma 502 (Line)	Single-phase	Unsuccessful	Yes	Manual reclosing advised	

Figure 3: General visualisation of events (example Auto-reclosing)

According the administration of the system in a list form the actual events are visualized. In figure 3 showing an example for a fault analysis. The events are sorted in different subfolders. The user gets detailed information by clicking in the actual line. The next points present some experiences of the fault analysis.

2.2 Analysis of auto-reclosing

Single pole failures caused by lightning strikes are the main fault types in the transmission line systems. An auto-reclosure helps to clear this fault types and increases the availability of the transmission system. In the case of a fault the following questions are of interest: Where is the fault location (distance in kilometre) and between which transmission towers? Which phases are faulty? How is the reaction of the auto-reclosure? The following figure 4 shows an example of a successful fault clearance via auto-reclosing. It shows the relevant data. In the example it was a fault in phase L3 to ground. The auto-reclosing was successful and the figure shows detailed information to the auto-reclosure behaviour. This analysis tool is additional able to give some information regarding the light strike location. In the example the assumed distance to the line is 0,071 km. A click in the field “Location” shows in a graphical view (Transmission Grid map) the lightning strike location.

Overview

Fault measurement - Located short-circuit fault

Station	Röhrsdorf
Feeder	400kV Ltg Str 571
Line	Roe-Str 571
Type	L3-Ground
Distance	21.35 km from station Röhrsdorf (25.8 % of 82.81 km) between Mast 181 and Mast 180
Current	18.35 kA (through the fault) - fault resistance: 0.7 Ohm
Measurement window	0.046s [0.091 0.137]
Weight	87 %

Auto-reclosing

Line	Roe-Str 571
AR type	L3
Secondary arc behaviour	Burning time: 0.187 s [0.144 0.331], stable capacitive voltage: 0.733 s [0.482 1.215] (long >0.400 s)
Break time before reclosing	1.806s [0.159 1.965] (Streumen), 1.187s [0.152 1.339(v)] (Röhrsdorf)
Sequence	Successful autoreclosing
Suggestion for the operator	

Lightning strikes

Timestamp	Location	Current	Line	Tower 1	Tower 2	Distance from line
00:21:35.135	50.9696 13.0348	7,9 kA	Roe-Str 571	Mast 181	Mast 180	0,071 km
00:21:35.135	50.9696 13.0348	7,9 kA	Roe-Str 571	Mast 181	Mast 180	0,071 km

Figure 4: Example of a successful auto-reclosure

More effort – that means a detailed analysis - is necessary in the case of an unsuccessful auto-reclosure [5]. The possibility of the system will be illustrated on one example (see figure 5). The sys-

tem shows the basic information, like fault type, fault distance, fault current and gives at the bottom of figure 5 some information regarding the auto-reclosure. At this fault the auto-reclosure was unsuccessful. Important is the advice for the operators “No manual reclosing advised” because the system assumed a steady state fault condition. To find out this the voltage during the dead time is analysed [6]. As figure 6 shows, there is no resulting voltage in the faulty phase visible. The inspection of the overhead line showed a broken insulator and the line felled down from one side (see figure 7).

Overview

Fault measurement #1/2 - Located short-circuit fault

Station	Klostermansfeld
Feeder	400kV Ltg Wol 536
Line	Klm-Wol 536
Type	L3-Ground
Distance	1.48 km from station Klostermansfeld (1.2 % of 118.79 km) between Mast 99 and Mast 100
Current	9.99 kA L-G (at the measurement point), apparent fault resistance: 1.5 Ohm
Measurement window	0.052s [1.364 1.416]
Weight	96 %

Fault measurement #2/2 - Located short-circuit fault

Station	Lauchstädt
Feeder	400kV Ltg Klm 538
Line	Lau-Klm 538
Type	L3-Ground
Distance	38.77 km from station Lauchstädt (100.0 % of 38.77 km) after tower Portal Klm
Current	7.86 kA L-G (at the measurement point), apparent fault resistance: 2.6 Ohm
Measurement window	0.052s [1.364 1.416]
Weight	62 %

Auto-reclosing

Line	Klm-Wol 536
AR type	L3
Secondary arc behaviour	
Break time before reclosing	1.198s [0.158 1.356] (Klostermansfeld)
Sequence	Unsuccessful autoreclosing
Suggestion for the operator	No manual reclosing advised

Figure 5: Example of an unsuccessful auto-reclosure

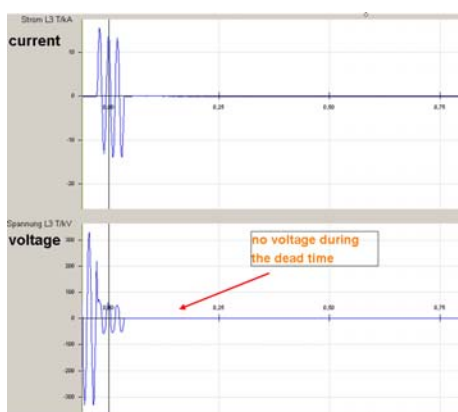


Figure 6: Detail of the fault record



Figure 7: Faulty overhead line

2.3 Further analysis and developments

The system is also able to show inconsistencies (see figure 8). One of the main reasons is wiring mistakes. The user gets a clear text indication of inconsistency and can send the maintenance crew to rectify the mistake. The example (figure 8) shows the standard display regarding the definition of the

measured and calculated zero sequence current. For that case the definition of the manufacturers must be considered.

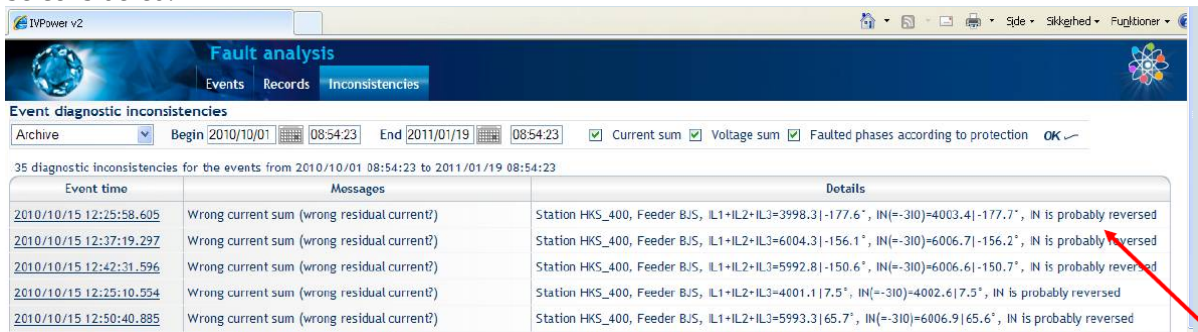


Figure 8: Example 1 of consistency check

Another kind of inconsistencies can be, if the installed protection devices react different on a fault type. A typical example is visualized in figure 9. The devices detected during the starting (pick-up) different fault types from the IEDs on different locations. For example in row 2 of the figure one device started with L1, L2, L3 and the other device in L3. By clicking on the event a detailed analysis can be executed by protection specialists.

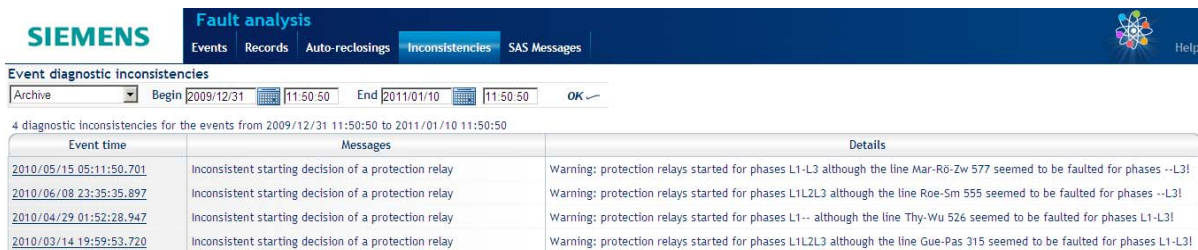


Figure 9: Example 2 of consistency check

During the application of this remote access system a lot of further useful experiences are accumulated. The additional possibilities described below:

- CT saturation can also be detected. In the event list general information is given that the current transformer is saturated. By clicking in this event the user gets detailed information. With the available fault record the degree of saturation can be analyzed. This gives a feedback regarding the quality of the current transformer or the current transformer selection.
- The SIMEAS SAFIR system can also detect inrush current at transformers. The system generates information that during switching on of the transformer an inrush current is detected. An analysis of fault record gives information of the highest magnitude of the inrush current and the inrush time constant.
- In Germany the distribution networks and 110-kV networks are mainly grounded by a Peterson coil (reactive grounding). So transient earth faults can also be detected using SIMEAS SAFIR. The main goal is that an earth fault extinct by this compensation method. In the event list the fault condition "Earth fault" is shown and an analysis of the record is possible.
- Detailed information of the faults: like fault duration, fault location, fault current, dead time of auto-reclosing and which device tripped.

Figure 10 shows for that case an example. The fault duration of a line to ground fault (here L2-G) was 69 ms. The fault distance is 10,39 km (between Mast 31 and Mast 32), the fault current on the measuring point is 8,14 kA. The dead time was 1,675 s.

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Event

Located phase-to-ground fault, Trip by prot., Succ. AR, U<, CB
Eula 220kV Ltg Ta 205
Total fault duration : 73 ms (from t=0,086 to 0,159 s)

2010/10/09

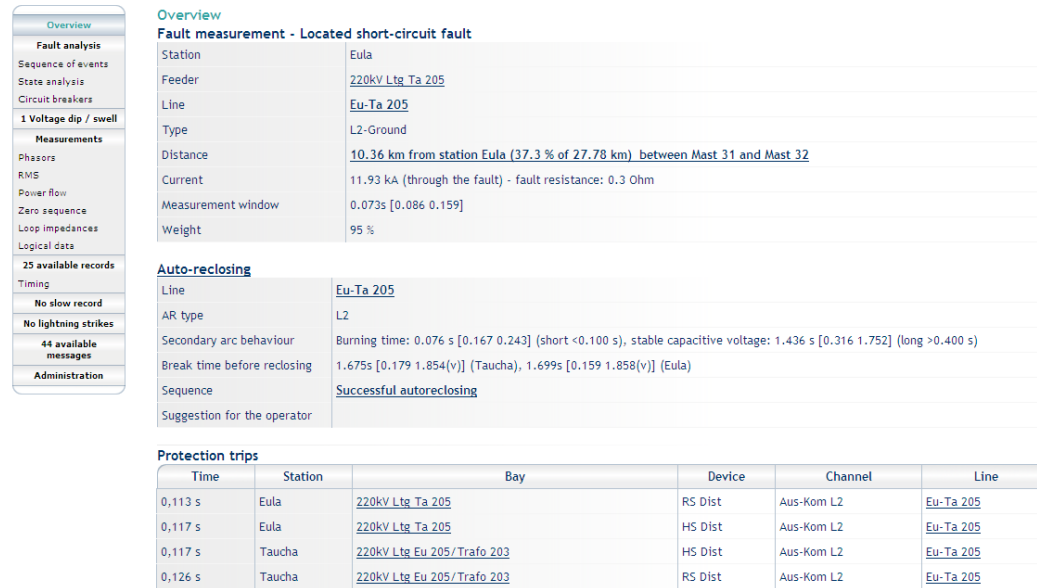


Figure 10: Detailed analysis of a fault

3 POWER QUALITY (VOLTAGE DIPS & SWELLS, FREQUENCY MONITORING, MEASURING AND RECORDING)

3.1 Wide Area monitoring

Installing PMU in the network to measure the phase angles at strategic points of the utilities interconnections with neighbouring utilities is an additional feature. The web based display (figure 11) of the phase angle and status can be called up by operational staff. Wide area monitoring with phasor data monitoring units have also been interfaced into the system, measuring the phase angles at strategic points. This simplified view helps the operators in monitoring the phase angles of the network. Furthermore, as it is web based the information can be monitored online within the company's network.



Figure 11: Phase angle monitoring at a single location and over the monitored network

3.2 Power dips and swells

The use of SIMEAS SAFIR to monitor abnormal signals and power quality levels i.e harmonics, unbalance etc especially at connection points to wind farms. These typical parameters are recorded and evaluated in the remote access system. The SIMEAS SAFIR supports the utility is the power qual-

ity monitoring at strategic points of the network (see figure 12) giving an overview of such a record for the voltage dips and swells in one system. Power quality monitoring, i.e. plots of PQ values and visualization of voltage dips and swells can be displayed on the Web pages. The system depends on the data source, provides both phase-to-ground and phase-to-phase voltage quality measurements.

3.3 Harmonics

The folder Harmonics (figure 13) is displayed with voltage and current harmonics. The data source is a Power meter which can give the SIMEAS SAFIR system near to real time data for monitoring

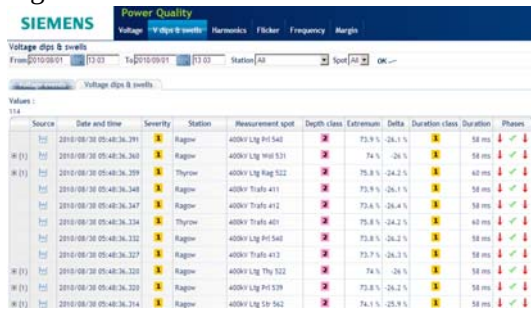


Figure 12: Record of power quality data

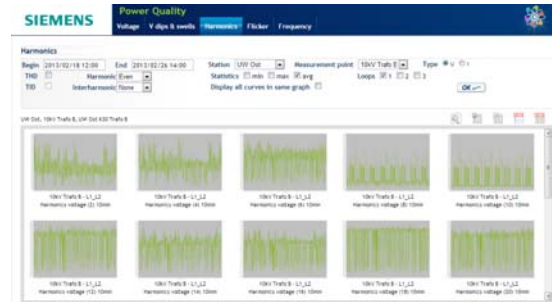


Figure 13: Harmonics

3.4 Frequency

The system can also display on-line the frequency, allowing the user, via the Web interface to select from the last 2 minutes or last week, using the selection of Station, trigger time, spot and type.

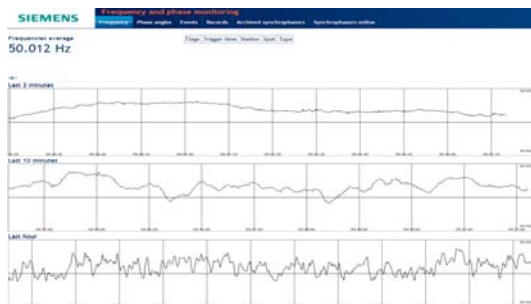
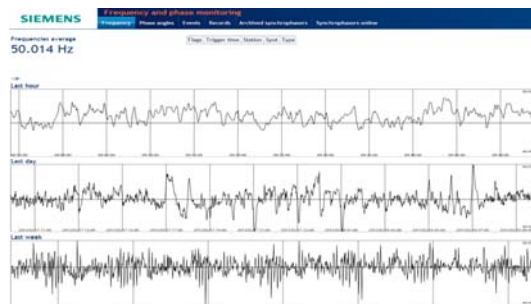


Figure 14: Frequency monitoring.



4 CONDITION MONITORING (ASSET, TRANSFORMER AND CIRCUIT BREAKER MONITORING)

To monitor the assets for a utility is important to prevent possible black-outs, the application to monitor the Circuit breakers is an important task. This information is already available to the SIMEAS SAFIR system within its data collection exercise. In the system a list abnormal operations of opening or closing of circuit breakers is displayed (figure 15). This allows the asset manager to react and to do take action after a closer inspection.

SIEMENS

Equipment

Circuit breaker events

Circuit breaker events list

Begin

2010/02/08 10:01:00

End

2013/02/18 10:01:00

Station

all

Bay

all

Circuit breaker

all

☒ Only abnormal events OK

50 circuit breaker events in which there are 50 abnormal events

42 circuit breaker opening events in which there are 42 abnormal events

8 circuit breaker closing events in which there are 8 abnormal events

Date time	Station	Bay	Circuit breaker	Type	Warnings	Records
2013/01/16 00:19:03.708	Niederviesa	220kV Ltg R0 226/Trafo 203	LS	Single phase opening	3	2
2012/12/25 01:30:11.913	Bentwisch	110kV Trafo 403	110kV Trafo 403	Multiple phase opening	1	1
2012/12/10 07:38:12.188	Hamburg/Ost	400kV Ltg Nor 962	LS	Multiple phase opening	1	2
2012/12/10 07:36:13.706	Hamburg/Ost	400kV Ltg Nor 961	LS	Multiple phase opening	22	2
2012/12/03 05:30:50.791	Hamburg/Nord	400kV Ltg Ost 962	LS	Single phase opening	1	1
2012/11/27 06:54:42.422	Güstrow	400kV Ltg Lub 512	LS	Single phase opening	4	2
2012/11/19 06:31:04.810	Lubmin	400kV Ltg Sow 509	LS	Multiple phase opening	1	2
2012/11/15 07:20:23.104	Stendal/West	400kV Ltg Sow 513	LS	Multiple phase opening	15	2
2012/11/15 07:20:21.513	Stendal/West	400kV Ltg Sow 513	LS	Single phase opening	4	2
2012/11/10 23:49:12.401	Niederviesa	220kV Ltg R0 225	LS	Single phase opening	1	2
2012/10/27 14:59:53.268	Weida	220kV Ltg Her 231	LS	Multiple phase closing	1	2

Figure 15: Circuit Breaker monitoring

5 CONCLUSION

The paper described a remote access system which is in service in different countries and utilities. The data is collected from different substation automation systems and evaluated in the remote access system. SIMEAS SAFIR has a distinct position in the toolbox of the TSOs due to its extensive possibilities of collecting field measurements – from high-speed synchrophasors to power quality data –, running advanced monitoring applications and adapting to the existing IT environment. It complements network control with applications that use additional data from disturbance recording, wide-area monitoring, power quality and generic monitoring systems.

Such a system is extremely useful for the daily operation of the network, for operational staff and technical experts alike. It gives clear operation instructions and general information regarding the fault and system conditions as described in this paper. Critical or interesting cases can be evaluated in detail and delivers additional information or data. To demonstrate the performance of the system different examples have been discussed. These are the successful or unsuccessful auto reclosing and further more. All these examples are illustrated with screen shots from the SIMEAS SAFIR system.

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