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Incremental implementation of a utility-wide protection information system

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Introduction

Accurate, consistent and dependable information is the basis for an efficient operational system and becomes crucial to making the right decisions in the event of a power system fault. A Protection Data Management System (PDMS) provides all concerned departments of the utility easy access to accurate and reliable information gathered by protection related devices, to aid faster and easier finding and solving of problems. [1]

This paper briefly describes the changes made in the last years and focuses on a practical usage of a utility-wide monitoring application using some functions available in modern numerical devices.

New technical facilities

The big advances made in the microelectronics as well as communication fields have enabled new functions in protection relays to be developed, as well as new software applications which use these functions and combine them with advances made in communication. Some functions, which are now available in modern protection related devices are:

- Disturbance recording facilities with sufficiently high sampling rate for fault analysis
- Low sampling rate, but round the clock recordings of calculated signals like power, harmonics, frequency deviation and other derived signals for power quality applications.
- GPS synchronisation
- Online phase measurements of voltages and currents to build up online stability information systems for operation

To cope with future functional extensions as well as the increase in communication bandwidth in a standardized way, the use of flexible communication protocols is required. The new 'IEC61850 protocol for communications and systems in substations' guarantees this flexibility by design. The introduction of this protocol will simplify and speed up the implementation of comprehensive monitoring applications. [2]

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Changes in electricity market

Quality of service has become more and more important especially in markets which are being liberalized. End-customers are more and more susceptible to poor power quality, because of their increasing reliance on microelectronics and computer technology. After an outage, end-customer's patience and trust is put to the test. If the utility is able to provide clear statements about the reason for the outage and reliable prediction of how long the interruption will persist, the end-customer's loyalty will continue.

To provide high quality information, monitoring applications are necessary. In the same way, the importance of logging functions has increased, because more and more power supply contracts contain penalties.

Therefore there is an increasing need for faster, predictable fault restoration, better and faster information and monitoring applications, which are providing detailed logging.

Structure for an utility wide Protection Data Management System (PDMS)

An information system, which deals with dynamic information generated in different substations, has to execute the following main steps:

- Data collection
- Data communication
- Data archiving and applying algorithms to generate information
- Information hosting for different user-groups

The initial collection of field data is done in numerical devices deployed for protection, monitoring or control. To benefit from this data at any time, remote access has to be established, which means sufficient communication facilities are a prerequisite, enabling data and information flow from the devices to the different user groups. Information generated from the collected data has to be presented in the way user-groups are used to.

Depending on the amount of the generated raw data and the storage and calculation capacity of the used devices, it might be advisable to install data concentrators in the stations. This increases application speed, minimizes communication bandwidth and enables an economical use of storage capacity. [3]

Protection Data Management System (PDMS) at Elektra Basel Land in Switzerland

The utility Elektra Basel Land was founded more than 100 years ago and provides in the meantime more than 500 MWh per year to end-customers and mainly medium-sized enterprises. The distribution network is sourced from two 220 kV stations, whereby a 50 kV network covers most of the grid area, see Fig. 1

EBL uses relays with distance and also differential line protection functions. Most end-customers are located in network areas, which are operated as open rings. This allows feeding most customers from an alternative feeder by moving the open point in the ring they are connected to.

Fig. 2 shows a part of the network fed by one 30 kV feeder in UW Sissach (Ⓐ in Fig. 2). The breakers located at Sonnengasse (Ⓑ in Fig. 2) and Känerkinden (Ⓒ in Fig. 2) are normally open. If the operator moves these open points in the direction to UW Sissach, parts of the network will be fed from other feeders than UW Sissach via the two mentioned breakers.

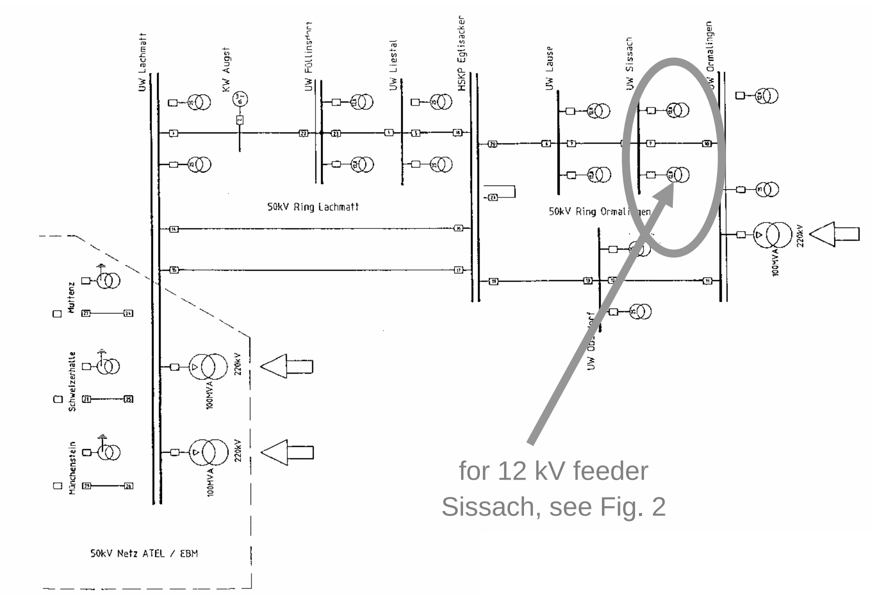

Fig. 1 50 kV Network of EBL two substations are fed with 220 kV

Workflow after a line trips

In the case of a fault (without autoreclosure) occurring in the network, the operator is informed about the line trip by the SCADA system. He immediately alarms the field engineers and sends them sequentially to hand-operated breakers. As soon as the breaker has been operated the operator switches on the power by way of trial. Breaker operation and re-powering is repeated until the faulty line segment is located between two neighbouring breakers, which remain open until the line is repaired.

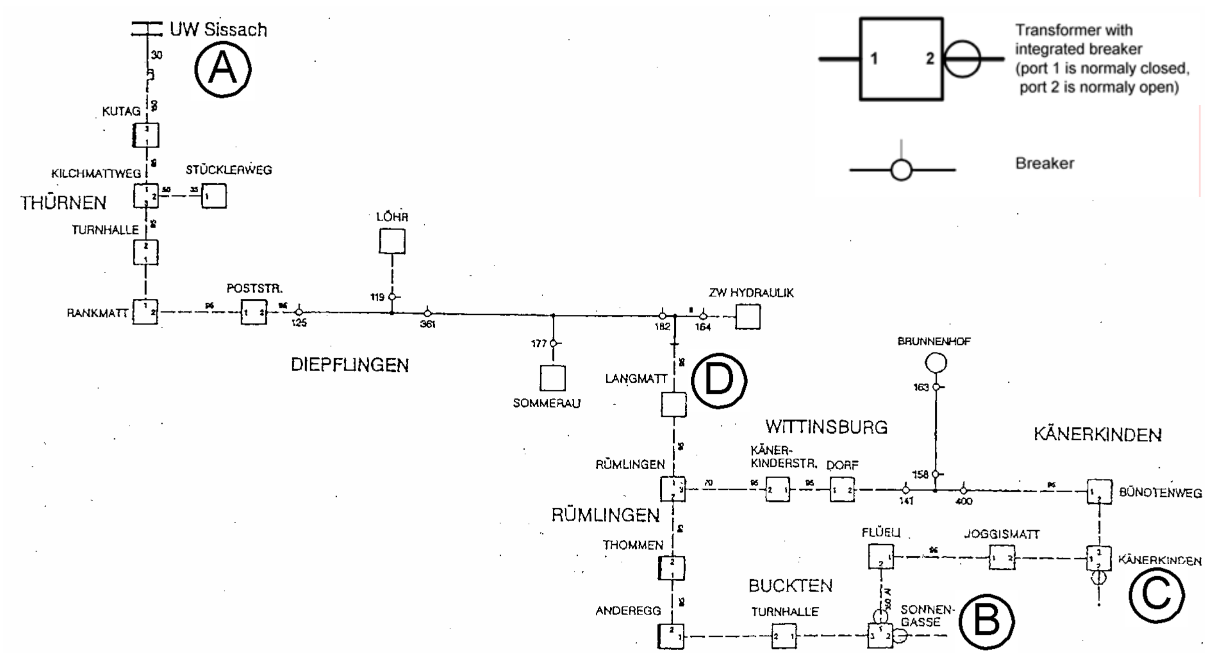

Fig. 2 Example of one tapped line with around 30 breakers

The strategy of switching actions is intended for the following two issues. First find and isolate a line segment as small as possible wherein the faulty line segment is located. Second bring back the power for as many customers as possible as quickly as possible, by moving the open point in the ring structure.

Operation of the network without PDMS

Because the software solution installed today influences the workflow of operation and protection departments, it is necessary to reflect relevant processes in the way they had been performed before PDMS was installed.

Supposing a fault occurred in the area drawn in Fig. 2, the protection relay in UW Sissach would trip and all customers in the drawn area would suffer an outage. Without PDMS the operator didn't know where the fault was located inside the affected area and he therefore initiated switching activities from the middle, Langmatt for instance (Ⓓ in Fig. 2). The breaker in Langmatt was opened and in case re-powering from UW Sissach was successful for the left area (left according to Fig. 2) one line section after the other was added to the re-powered section at the right-hand side (lower right according to Fig. 2) of Langmatt.

The area containing the faulty line segment was narrowed down step-by-step to the smallest possible segment located between two neighbouring breakers. This meant, field personnel spent a lot of time with switching activities. As a result, a lot of customers were affected by repetitive shutdowns, because the operator tried several times to re-power the part of the network still containing the fault. Especially firms working in the robotic field can be severely affected when several power ups and downs occur in a short time span.

Calls from customers and observations made by the field engineers were very important to narrow down the fault location. If it wasn't possible to locate the fault or network behaviour remained unclear, the protection engineers were required to do an analysis. They went to the substations to upload the disturbance records and support the operator with more precise fault location information after they had finalized manual record analysis.

Installation of the first PDMS system in 1999

The utility EBL in Switzerland installed the Protection Data Management System (PDMS) first in 1999 in order to make available remote access to all protection relays from a central computer located in the protection engineer's office. Furthermore, the software was to provide fault location facilities for the operators around the clock.

In this way the job of driving from one substation to another collecting all data manually should be made redundant and the use of PDMS should reduce duration of outages.

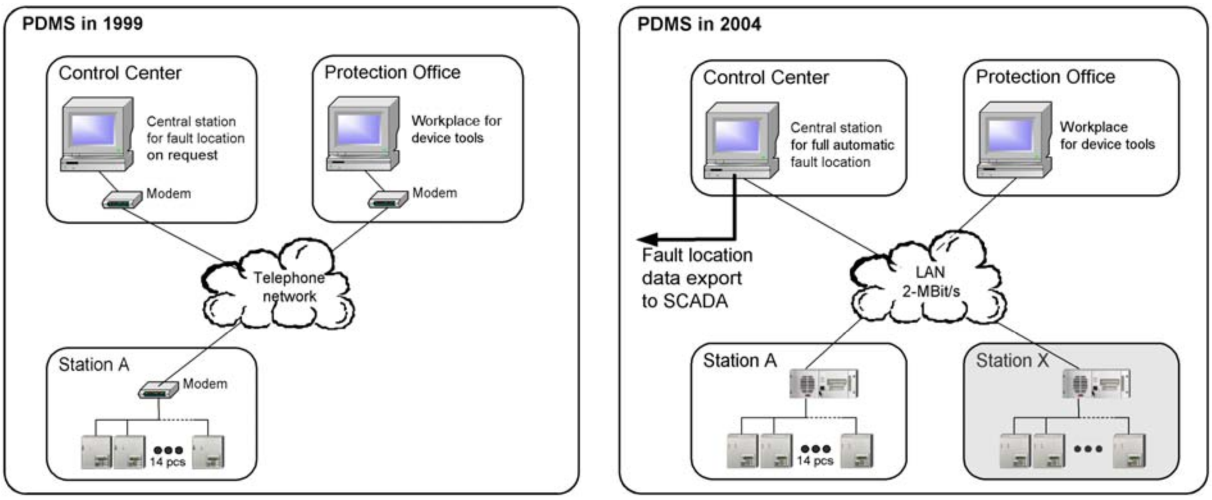

Fig. 3 Left: Structure of PDMS system in 1999
Right: Structure of PDMS system in 2004 with full automatic fault location facility and further extensions described below

Because the project was driven from the protection department it was a basic requirement to avoid any interference to the SCADA system. With respect to the communication, this meant that a separate communication network for the protection relays had to be used.

EBL started the installation of PDMS in 1999 with 14 distance protection relays located in one substation shown in Fig. 3.

PDMS system in operation

After some months, EBL used PDMS as follows: In case the SCADA system or a customer alarmed the operator that an area was without power, the operator manually initiated the upload of all disturbance records for automatic fault location at the PDMS system. Printouts were automatically generated containing the waveforms and even more important, a short textual report shown in Fig. 4

```
Automatic Expert Evaluation    FLT3.0/0

LINE:
Line name      = FL Kutag
Line length    = 1.0 km (standardized)

Station:
Station name   = ORM H25 Sissach
Event date and time  = 07-Oct-2003  17:41:32.100

Fault Location:
Fault type     = R - S
Distance to fault    = 0.88 km
```

Fig. 4 Short report generated by PDMS system

The line and station names in the short report reference one impedance-sheet or as an exception a few sheets prepared in a folder. An example of an impedance-sheet is shown in Fig. 5. Using line-impedance-graphs EBL is also able to make fault location for tapped lines.

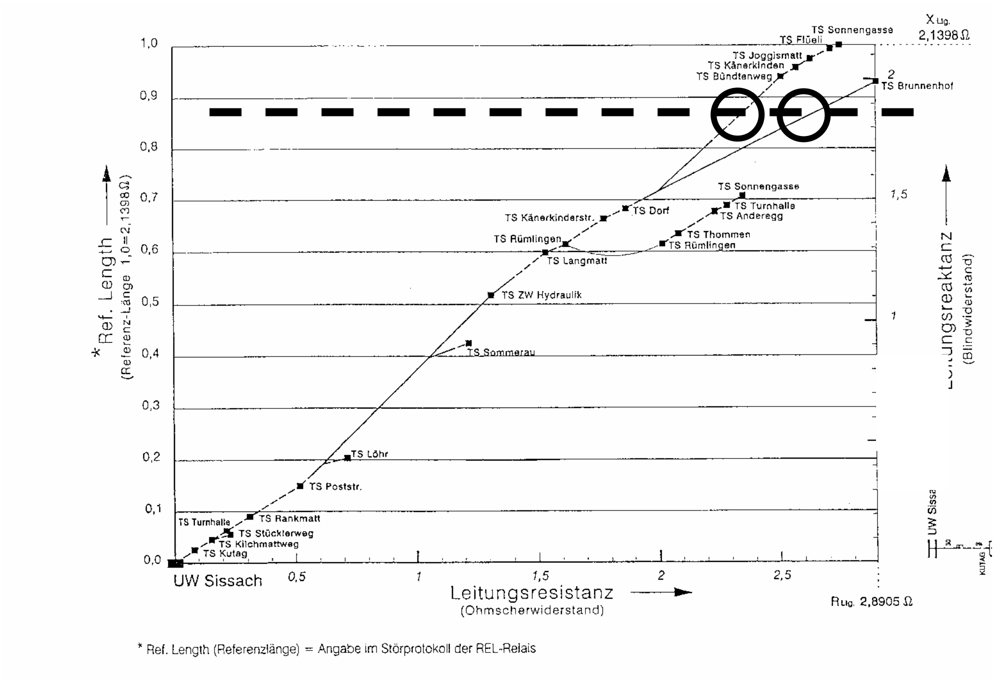

Fig. 5 An example of a line impedance graph. The operator drew the dashed line according to the "short report" generated by PDMS shown in Fig. 4. The circles mark possible fault locations.

Using the fault distance given in the short report, the operator draws a line on the line impedance graph to get all possible fault locations. With this information the opening and closing strategy for the different possible breakers is much more obvious than it was before PDMS was installed. Now the field engineers are usually sent to breakers which are very close to the line fault. Therefore outage times have been reduced noticeably, and even more important, the number of unsuccessful switching activities has been minimized.

PDMS also makes a daily routine check. Considering a quiet operation shift, which means the operator isn't woken up by the SCADA system or by emergency calls from end-customers, PDMS calls all substations automatically in the morning shortly before the morning shift and uploads all disturbance records to run fault location algorithms. In case disturbance records are available in the relays and the algorithms detect line faults, the short reports describing the location and kind of fault are printed as a consequence. A line fault which can be cleared by means of the autoreclosure function, e.g. a tree causing a short interruption, does not require the operator's intervention and he will not be alerted. The autoreclosure function is enabled in most of the line protection relays at EBL. Having a look at the hardcopies printed by PDMS, the operator of the new shift is prepared for possible weak areas in the network and can initiate pinpointed field inspections to reduce the probability of outages during the next day.

Action chronology after a fault using PDMS

On October 7th 2003 the winter set in surprisingly early in the eastern part of Switzerland. Heavy and wet snowfall caused whole trees to fall, because they were still in leaf. In the following night several power interruptions occurred. The chronology of one fault is described and shows that the PDMS system enables a straight forward switching strategy for the operator, and that the time needed for uploading the files and for automatic fault location is negligible compared with the travel time of the field engineers. Because of the reduced number of switching activities the outage time is kept at a minimum.

Table I: Chronology after a fault in the network occurred at October 7th 2003, 5:42 pm

Time delta	Incident	Action of operator
0:00	**271 customers are without power** SCADA alarm: Line trip	
0:03		**The operator alarms two field engineers** and sends them to the affected area
0:06		The operator initiates disturbance record upload and automatic evaluation for affected feeder at "Protection Data Management System", PDMS.
0:09	PDMS prints out the short fault reports and the waveforms (Fig. 4)	The operator uses the impedance graph for the affected feeder and gets the possible fault locations (Fig. 5)
0:13		The operator communicates the switching sequence to the field engineers
0:33	The field engineers arrive at breakers for opening respectively closing actions	Keep in touch with field engineers and place further switching commands
0:40	**Power is back for 270 customers** The affected line section is isolated. Power is switched on in all "healthy" branches.	
0:58	The field engineers arrive at the fault location. (A tree had fallen onto the line)	
1:36	The tree is cut down, the line repaired	The operator sends last switching order to field engineers
1:22	**Power is back for all customers**	

PDMS system extension

When the existing SCADA system was to be replacement and extensions to internal communication equipment were to be made, a tighter integration of some PDMS functions was discussed. An internal investigation at EBL showed that some operators had not used the PDMS system for more than one year. On the one hand, this was caused by statistical reasons: Nine operators are working in operation and managing approximately 30 faults per year, whereby most faults occur in smaller time-frames and are caused by bad weather conditions. On the other hand some operators haven't had the courage to use an additional software system in addition to their well-known SCADA, especially in the nerve-racking situation when line faults occur in the network.

Therefore EBL asked for PDMS extensions fulfilling the following requirements:

- PDMS shall use the new fibre optic communication network instead of the dial-up modems
- Full automatic operation for disturbance record upload and evaluation
- Export of fault location information to SCADA system, with the intention that the SCADA displays fault locations on its own graphical network overview.
- Integration of additional substations

To fulfil the requirement of full automatic operation and to provide a system, which scales in a better way with system size "intelligent data concentrators" were supplied in the substations. These data concentrators are implemented in software running on normal PCs. The data concentrators in the substations are polling the devices every few minutes and inform the central PDMS server immediately when a new disturbance record has been uploaded.

Experiences of Elektra Basel Land

EBL has now been using the PDMS software for some years. Their technical feedback has been highly appreciated in order to develop new software versions close to customer's needs. It also shows that a smooth integration into different departments in a utility is possible and should be done step-by-step to get highest acceptance and to overcome reservations from personnel.

Experiences with the first system

Most important, the outage time was reduced by up to 40% after PDMS was introduced. Also the number of unsuccessful reclosures initiated by the operator to locate the faulty line segment could be minimized.

The benefit of fault location was dependent on the acceptance and usage by the operators. The acceptance increased with time and with any new integration of a distance protection relay. The accuracy in fault distance was absolutely sufficient. After a fault has occurred travelling by field engineers is most time consuming, the time used by PDMS for uploading and analysis is negligible in comparison.

A positive side effect of PDMS installation was, that the monthly inspection of the protection relays could be extended to a yearly schedule, because basic supervision and data collection can now be done remotely.

The remote parameterization tool is seldom used, only when disturbance record data is not sufficient to analyse the fault in detail. But any time it is used, travelling time is saved. Therefore the protection engineer of EBL can devote his time to new tasks.

Expectations to the second system

The new software extension allows the automatic export of fault results from PDMS to the new SCADA system. Therefore any relevant fault information will be displayed in the graphical network overview and the event list of SCADA. Especially operators with less experience benefit from this integration because they get all relevant information from one system, although different systems are co-operating in the background.

EBL welcomes the fact that local PCs in the substations upload the disturbance records from the devices immediately, which minimizes the risk of data loss and increases the performance. The system performance remains good even when the system is extended to include more relays in further substations.

After completion of the PDMS extension the protection engineer will have remote access from his office to all archived disturbance records stored at a central server. This facilitates an in-depth fault analysis.

Although data concentrators are located in the stations it is possible for the protection engineer to use the device tools from his office. Different user right levels and password protection on application and device level reject unauthorized users from changing parameter settings.

Positive experiences with the first installation leads to the expectation, that more than half of commissioning work for the PDMS system extensions can be done by the customer himself.

Conclusion

The experiences with PDMS show that it is possible to benefit from functions and communication facilities of digital relays not only in the protection department, but also in the operations department.

Step-by-step implementation in function as well as gradual integration of additional protection relays and disturbance recorders is best practice, avoids false expectations and keeps the hurdle of acceptance low.

The extendibility is proven and faster fault restoration is evident. The following extensions are under discussion to further shorten outage time:

- Installation and integration in PDMS of further distance protection relays
- Remote control for some key disconnectors in the power grid
- Because the software is prepared for informing registered users by e-mail, fax of message service to mobile phones, these functions might also be enabled.
- A software component, which provides statistical fault analysis

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