TF B5.03

TASK FORCE REPORT

A survey of engineering tools for protective relaying

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Protective relaying is very important as a safeguard of the power system operation. Engineering tools play a significant role in designing and implementing the protective relaying solutions. A survey aimed at better understanding what are the tools used by utilities for facilitating engineering tasks related to protective relaying was conducted. The identified areas of engineering tools of interest are: modelling and simulation, relay setting coordination, relay modelling, relay testing, relay databases, etc. The results of the survey are reported in this paper. For the modelling and simulation, there are lots of software packages for load flow and short circuit studies, while there are fewer for stability and electromagnetic transient studies. Relay setting coordination is a more frequent engineering task than relay modelling. Relay testing is an important and frequent engineering task to assure good performance of relays. Relay databases are not very comprehensive although they are very important in allowing access to and maintenance of ever increasing relay-related information.

Introduction

Task Force B5-03 "*Engineering Tools for Protective Relaying*" started the preparation of a survey in 2001 that was aimed at better understanding of what tools are being used for facilitating engineering tasks related to protective relaying. The tools in this context are any hardware or software solutions used for the mentioned purpose. The solutions may be commercial products or custom-based developments. The following areas of interest are identified: modelling and simulation, relay setting coordination, relay modelling, relay testing, relay databases, other.

This summary focuses on the questionnaire responses received from 16 selected utilities covering 13 countries: Argentina, Belgium, Finland, France, India, Ireland, Portugal, South Africa, Spain, Thailand, The Netherlands, United Kingdom and United States (4 responses). This paper is not aimed at discussing the commercial software or hardware tools used by utilities worldwide. It just gives a general idea about the engineering tools for protective relaying.

Modelling and Simulation

The discussed modelling and simulation tools are related to the following studies: load flow, short circuit, electromagnetic transients, and stability. Since some of the packages provide multiple modelling and simulation functionalities, the section "Combined" is used for the answers related to such solutions.

Load flow study is the backbone of power system analysis and design. It is necessary for planning, operation, economic scheduling, etc. It is also prerequisite for short circuit study, stability study and many other studies [1].

Short circuit study is the analysis of a power system that determines the magnitudes of the currents during a fault. These magnitudes are determined at various points in time after fault inception [2].This type of study is the foundation for fault analysis and relay setting coordination.

Electromagnetic transient study is the analysis of transient behavior of the power system. The transients involve predominantly interactions between the mag-

netic fields of inductances and the electric fields of capacitances in the power system and are referred to as electromagnetic transients. Lightning, switching, short-circuits and resonance conditions can cause power system electromagnetic transients [3].

Stability study is the analysis of the ability of an electric power system, for a given initial operating condition, to regain a state of equilibrium after being subjected to a physical disturbance. Power system stability includes rotor angle stability, voltage stability and frequency stability [4]. The current commercial software packages normally deal with rotor angle and voltage stability.

We give some examples of the used tools based on the survey responses. From the survey, we can see that load flow study is the basis for short circuit study. There are totally 11 different software packages mentioned for both load flow and short circuit studies. Only one utility mentions that it uses different software for load flow and short circuit studies. As for electromagnetic and stability studies, there are fewer choices, three for the electromagnetic studies and four for the transient stability studies respectively.

As referenced in the 16 responses, the considered relaying systems are classified into five categories as shown in Figure 1. We can see that the older relaying system designs (Electromagnetic and Solid State) constitute only 25% of the relaying systems today.

Note: Regarding the relaying systems, "Combined" refers to the relays that use mixed technologies, "Integrated/Coordinated" refers to cases when substation automation products are used.

Regarding the number of users who use the product/tool, frequency of use, and engineering tasks in different studies, the survey results are given in Figures 2, 3 and Table 1 respectively.

Note: Lots of responses did not mention how many users they have. So the N/A is used.

Study	Engineering tasks
Load Flow	Planning, operation, analysis, relay setting purpose, etc.
Short Circuit (SC)	Fault calculation, impedance estimation, SC current contribution, SC study, relay coordination, breaker duty rating, performance, etc.
Electromagnetic transient	EMTP model development, transient analysis, relay testing, system performance evaluation, etc.
Stability	Stability study, planning, dynamics study, relay modelling, relay consideration, evaluation, etc.

Table 1 – Engineering tasks performed by different tools

As for the 'combined' performance software, two software packages are mentioned in the response in this category among a total of 20 software packages in all categories. •••

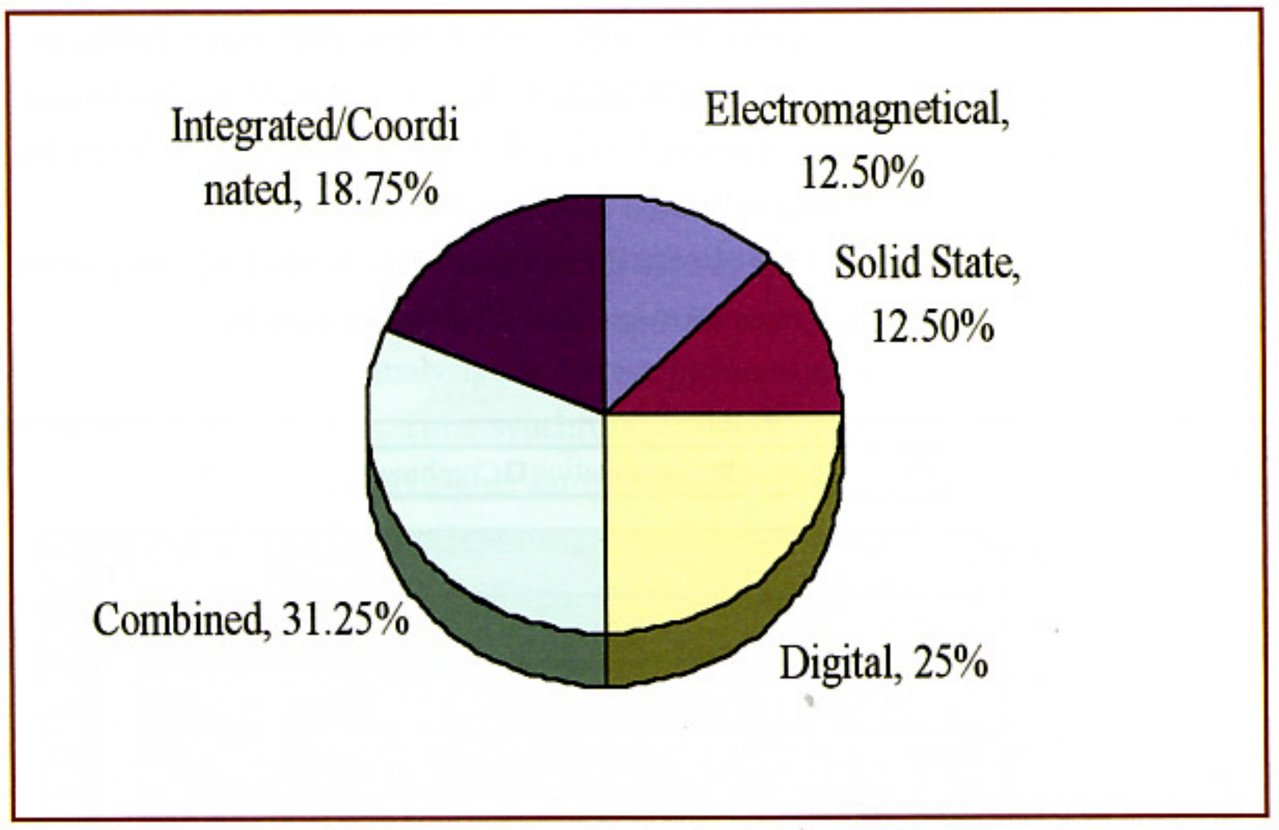

Fig. 1: Relaying systems considered in response

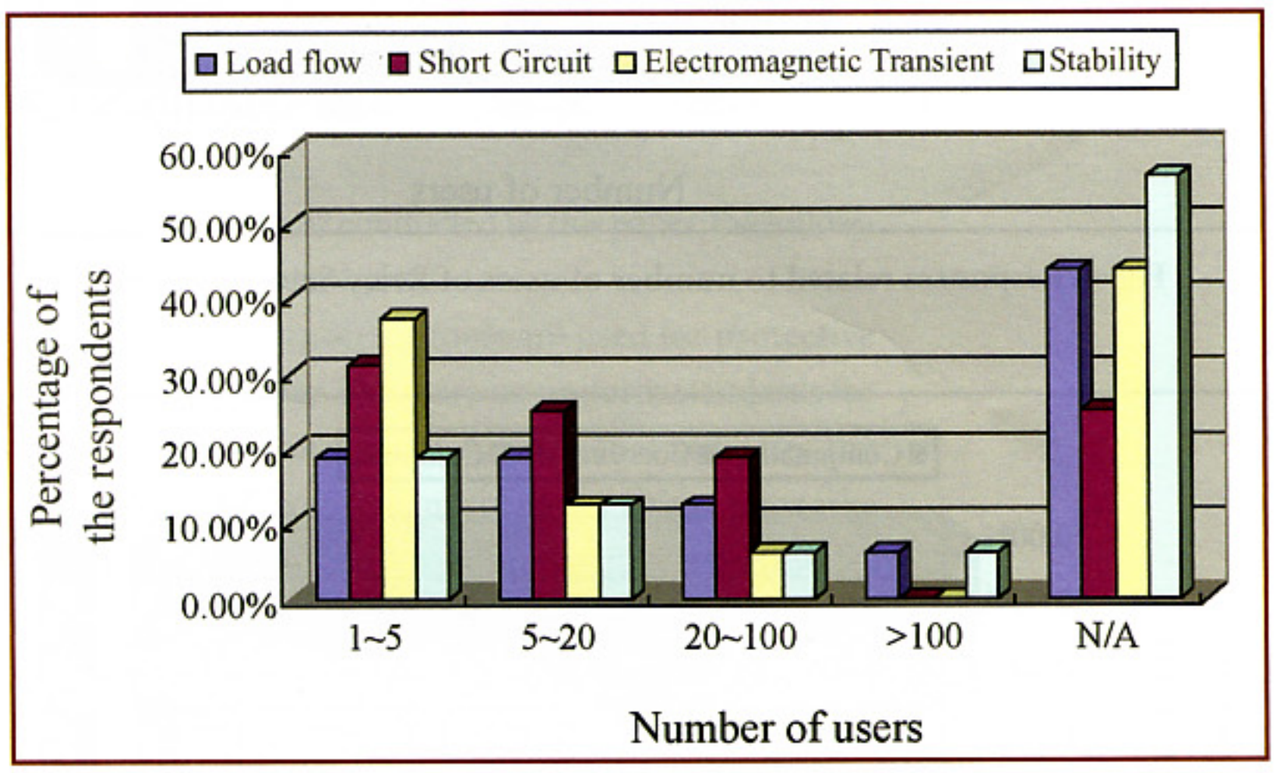

Fig. 2: Responses related to number of users of different studies

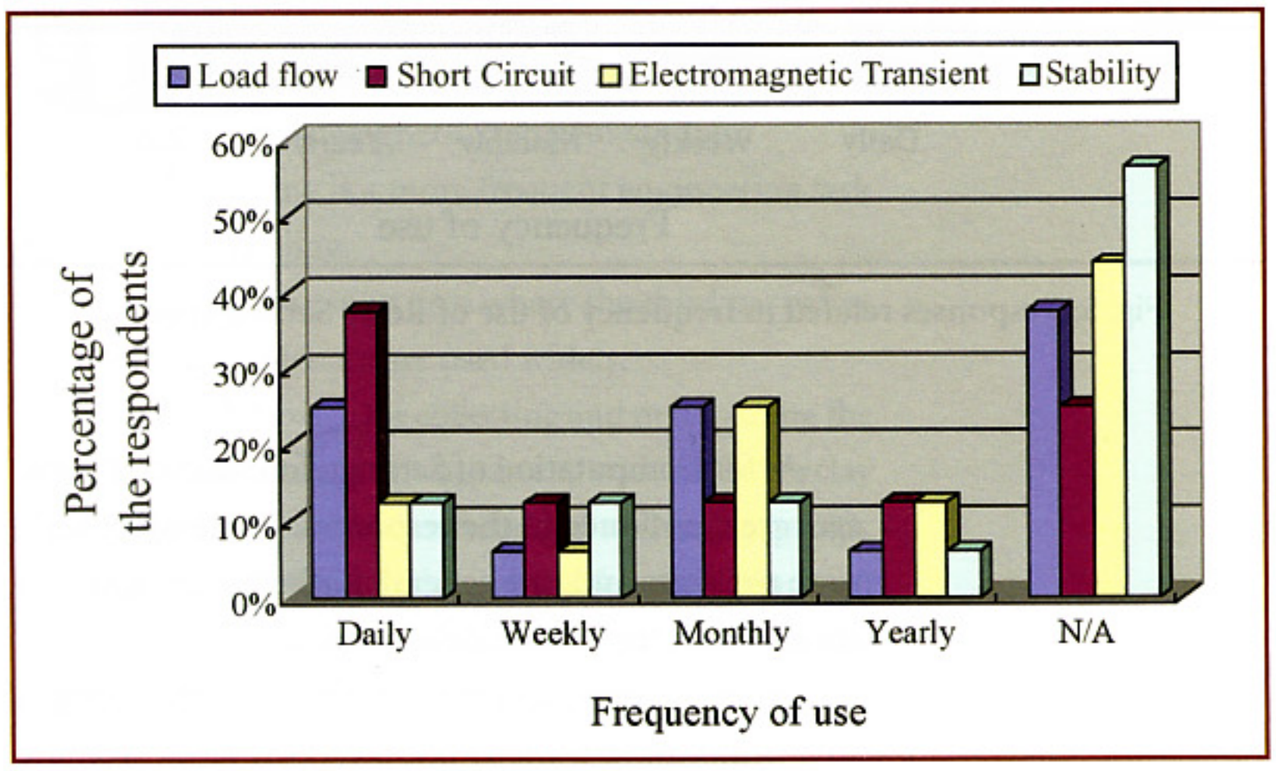

Fig. 3: Responses related to frequency of use of different studies

Relay Setting

Relay setting computation and coordination are very important in determining the selectivity of protection to maximize service continuity and minimize damage to property and personnel. If the setting computation and setting coordination tasks are combined in a given software package, the solution "Combined" is used for answers related to such solutions.

We can see the number of users and frequency of use for relay setting studies in Figures 4 and 5.

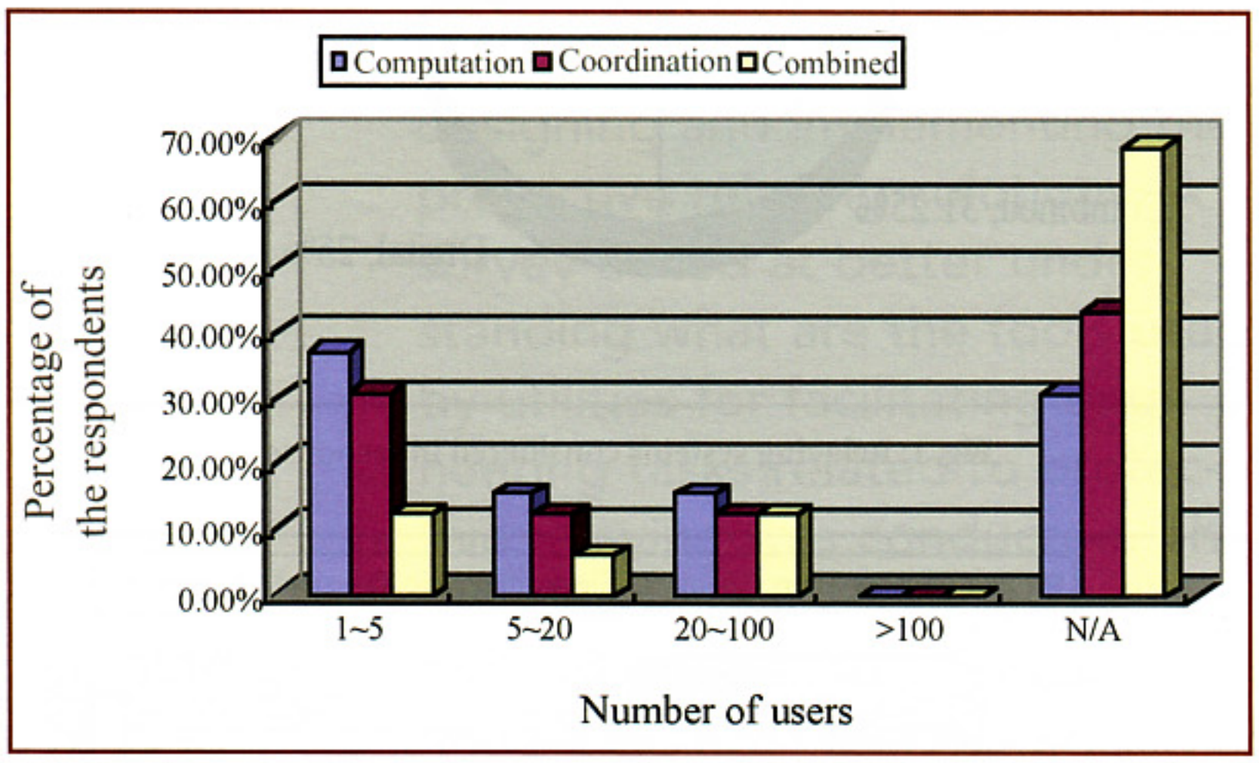

Fig. 4: Responses related to number of users of Relay Setting studies

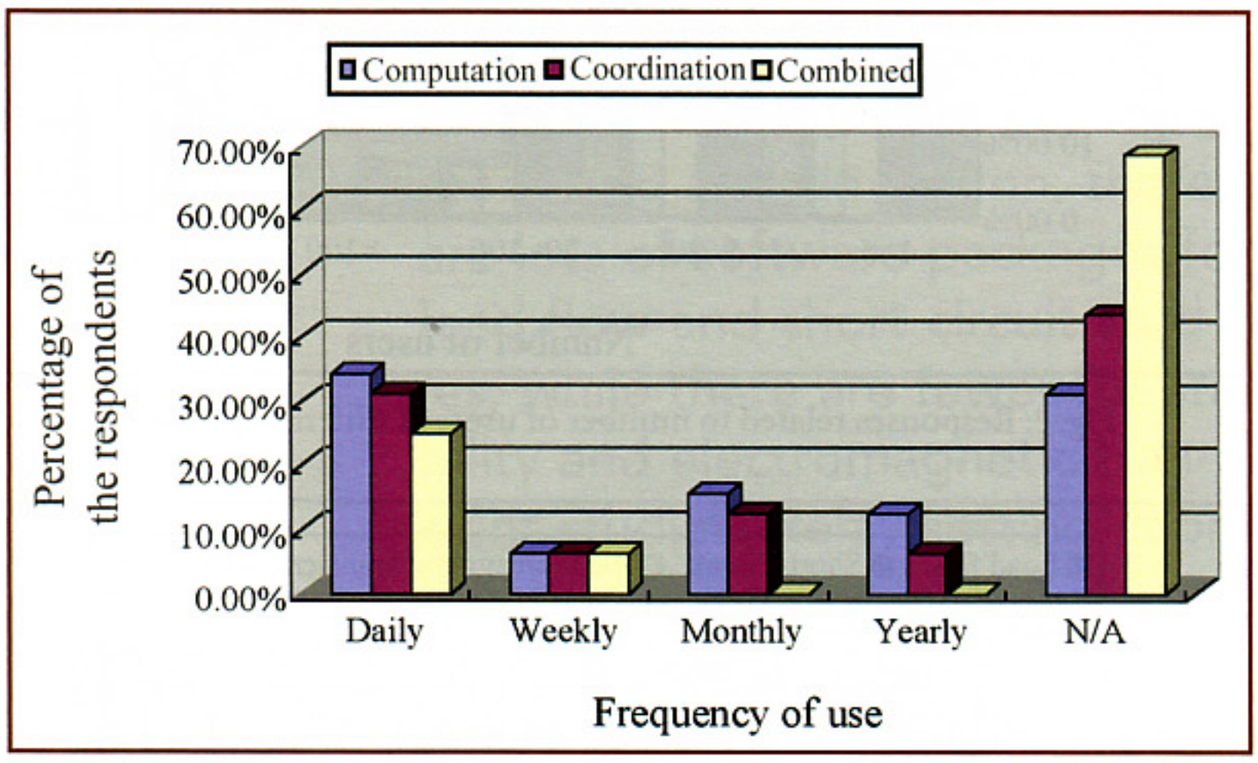

Fig. 5: Responses related to frequency of use of Relay Setting studies

As for Computation of Settings, four software packages are mentioned in the responses. Three office software packages and one general mathematical software are also used for custom developed solutions.

As for Setting Coordination, five software packages are mentioned in survey responses. One office software is also mentioned for custom solutions.

As for the 'Combined' category, two power system software packages are mentioned.

Relay Modelling

The relay models may not yet be used as much today, but it was important to know the extent. A distinction between the models developed using the phasor concept or the transient concept is made clear, even though the solutions that are allowing both approaches have also been mentioned in the section titled "combined".

Phasor-based models use fundamental frequency voltage and current phasors. The limitation of most phasor-based models is their inability to handle time-related dynamics affecting the fundamental frequency phasors. Transient-based models can consider the time-related transient components, such as effects of DC offset, nonlinearities of CT's and CVT's, saturation, inrush, etc.[5].

Based on the survey, relay modelling is not a frequent engineering task compared with load flow and short circuit studies. Only three utilities mentioned that they used phasor-based models. Only two utilities mentioned that they used transient-based models. Only one utility mentioned that they use one power system software package for combined study. For relay modelling studies mentioned by those utilities, they are performed by 1-5 engineers once annually.

Relay Testing

Relay testing is a frequent engineering task and it is conducted on daily or weekly basis based on the survey responses. Please note that here "daily or weekly" means the frequency of the task by a certain group of engineering staff. It should not be considered as the frequency of testing of a single relay.

The typical objectives for relay testing are: relay accuracy and timing check, commissioning, maintenance, fault play back, etc. The traditional testing that uses phasors is still widely used by the respondents. This kind of testing is easy to perform and used by most of respondents for commissioning testing, set point verification, and timing. The number of staff implementing this testing is typically larger than 20.

Transient signal based relay testing is usually a dynamic approach. It plays back the entire pre-fault, fault and post-fault voltages and currents as the inputs for relays. This kind of test is closer to the real fault situation, and is more used nowadays because of the availability of digital simulators. Half of the respondents have

transient-based testing. And the number of users is typically 1-5 by each respondent.

The products used in relay testing are quite different between each respondent. Most of the respondents use third party test sets and software for relay testing. Two respondents use the test sets from relay vendors. The transient-based testing usually requires different hardware and software platform to implement the tests. Only one respondent uses the same product for both kinds of testing.

Relay Databases

Due to the large amount and type of relays that are owned and installed by the utilities, numerous data files need to be built, collected and maintained. The relay databases are very important to access and manage the data. In our survey, the major concerns are the tools used for building and storing engineering drawings, relay settings, relay data sheets, and relay manuals.

Half of the respondents create electronic version of engineering drawings for relay and control connections, relay panel designs, functional and wiring schemes, one-line diagrams, etc. The most common software used are CAD tools, as shown in Table 2.

Most of the respondents have the way of reading and storing relay settings and the used software packages are quite different. Among the respondents, two utilities use manufacturer provided software, six use MS office software, and four use other third party software.

Only three or less respondents have created database for relay data sheets and relay manuals using MS office software. Most of the respondents just keep the documents and CDs delivered by manufacturers.

Product	Vendor
AutoCAD	Autodesk
MicroStation	Bentley
Visio Pro	Microsoft
ELCAD	Aucotec

Table 2–Relay Database – Engineering Drawings

Others

This part of the survey recognizes some other solutions used that are not listed in the previous categories. Two main examples are software packages for relay data entry and analysis of relay recordings.

As for the relay data entry for setting relays and searching the event reports, most respondents use manufactures' software provided by the relay vendors, such as ABB, SEL, GE, SIEMENS, ALSTOM, etc. One respondent uses ASPEN relay database for the tasks.

Almost all the vendors provide software for the analysis of relay recordings within their product, and they are used by the respondents. The typical software tasks are COMTRADE conversion, disturbance analysis, relay performance study, collection and storage of transient recordings. Analysis of relay recordings is very important for post mortem analysis and investigation of new fault analysis algorithms. Time-synchronized data recording with help of GPS, and higher sampling rates are very useful for new fault diagnosis approaches, such as "transient based protection" [6] and synchronized sampling based fault location [7].

Only two respondents indicate applications of some other engineering tools in this survey. One is for incident analysis and the other is for voltage dip and system performance analysis.

Conclusions

From the survey conducted by this paper, the following conclusions are drawn:

◆ Many engineering tools are used for protective relaying tasks today. There are no uniform standards for application of those tools. A guide that indicates the objectives and requirements of each engineering tasks mentioned in this report would be useful for the utilities and vendors.

◆ Most relay vendors develop their own application and analysis software and they are widely used by the utilities.

◆ Regarding modelling and simulation, there are lots of software packages for load flow and short circuit studies, while there are fewer software packages for stability and electromagnetic transient studies.

◆ Relay setting is a more frequent engineering task than relay modelling.

◆ Relay testing is an area where the third party test hardware and software are used widely.

◆ Relay databases for collecting and maintaining the relay information are not used very widely. Only relay settings are collected and maintained well using specific software. A well designed database for collecting and maintaining all of relay related information would be very useful.

The tools for engineering tasks related to protective relaying are showing the new trend with the •••

development of power system and digital relays. For modelling and simulation, the tools should have the capability to generate different scenarios that involve overload and power swings. Those situations are causing relays to misoperate in a system-wide blackout. Relay settings also need to be validated under those situations through relay testing. Relay modelling is very helpful in understanding the overall protection scheme and implementing several application studies before a physical relay is installed in the system. Therefore, development and use of software relay models is encouraged. Transient-based relay testing is a more feasible today with the availability of digital simulators and field data recordings; it should address the need for the accurate relay testing. A well designed relay database is very important when integrated substation automation systems are considered. It helps access and maintain the relay information either at the local level or at system level through the use of communication methods.

The readers are encouraged to read other reports issued earlier by the CIGRE Committee B5 regarding some related issues [8-11].

Acknowledgments

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References

[1] H. Saadat, Power System Analysis, The McGraw-Hill Companies, New York, USA, 1999

[2] B.L. Graves, Short-circuit, coordination, and harmonic studies, *IEEE Industry Applications Magazine*, vol. 7(2), March-April 2001, pp. 14-18

[3] N. Watson, J. Arrillaga, Power systems electromagnetic transients simulation, The Institute of Electrical Engineers, London, UK, 2003

[4] P. Kundur, J. Paserba, V. Ajjarapu, et al., Definition and classification of power system stability IEEE/CIGRE joint task force on stability terms and definitions, *IEEE Transactions on Power Systems*, vol. 19(3), Aug. 2004, pp. 1387-1401

[5] P.G. McLaren, K. Mustaphi, G. Benmouyal, et al., Software models for relays, *IEEE Transactions on Power Delivery*, vol. 16(2) , April 2001, pp. 238 – 245

[6] Z. Q. Bo, F. Jiang, Z. Chen, et al. "Transient based protection for power transmission systems," IEEE PES Winter Meeting, 2000. (3): pp. 1832 –1837

[7] M. Kezunovic, B. Perunicic, and J. Mrkic, "An accurate fault location algorithm using synchronized sampling," *Electric Power Systems Research,* vol. 29, No. 3, pp. 161-169, May 1994.

[8] Task Force B5.05, Extracting Information from data collected by relays and other monitoring devices. Electra, no.215, pp. 24-36, Aug. 2004

[9] Gerhard Ziegler, Protection and substation automation – State of the art and development trends. Electra, no. 206, pp.14-23, Feb. 2003

[10] Working Group 34.06, Maintenance and management of protection systems. Electra, no. 156, pp.137-139, Oct. 1994

[11] Working Group 34.10, Analysis and guidelines for testing numerical protection schemes. Electra, no. 191, pp. 149-160, Aug. 2000.

Appendix

Respondent companies of the survey. ■

Company	Location
EDF	France
Electricity Generating Authority of Tailand (EGAT)	Thailand
Elia	Begium
ESB International	Ireland
Eskom Enterprises	South Africa
GE Multilin	Bilbao, Spain
GE Power Systems	United Kingdom
Helsinki Energy	Finland
Oncor (TXU)	Fort Worth, TX, USA
Pacific Gas and Electric Co.	Oakland, CA, USA
Public Service Electric & Gas Company	Newark, NJ, USA
Reliant Energy HL&P	Houston, TX, USA
REN- Rede Electrica Nacional, S. A.	Portugal
The Tata Power Co, Ltd.	Mumbai, India
TenneT b.v.	The Netherlands
TRANSBA S.A.	Argentina